DESIGN CRITERIA FOR ENERGY EFFICIENT SHOPPING MALL IN INDIA

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF ARCHITECTURE

By

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JUNE, 2012

CERTIFICATE

Certified that the report entitled **"DESIGN CRITERIA FOR ENERGY EFFICIENT SHOPPING MALL IN INDIA"**, which has been submitted by **Ms. VANDANA SINGH**, for partial fulfilment of the requirement for the award of the degree of **Master of Architecture**, submitted in the Department of Architecture and Planning, Indian Institute of Technology- Roorkee, is her own work done by her under my supervision and guidance. The matter embodied in this dissertation has not been submitted by her for the award of any other degree of this or any other institute.

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CANDIDATES DECLARATION

I hereby certify that this report entitled **"DESIGN CRITERIA FOR ENERGY EFFICIENT SHOPPING MALL IN INDIA"**, which has been submitted in partial fulfilment of the requirement for the award of the degree of **Master of Architecture**, submitted in the Department of Architecture and Planning, Indian Institute of Technology- Roorkee, is an authentic record of my own work carried out during the period from July 2011 to June 2012, under the supervision and guidance of **DR. MAHUA MUKHERJEE ,** Department of Architecture and Planning, Indian Institute of Technology, Roorkee, India.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree of this or any other institute.

Date: 12th June 2012

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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Date: 12th June 2012

Place: Roorkee

Vandana Singh

EXECUTIVE SUMMARY

There has been an increased demand of energy due to the pressing needs of heating and cooling of the buildings in the recent years. But with growing concerns over global warming and climate change, more building owners/managers/designers have decided to "GO GREEN". They have taken measures to reduce the building's energy consumption to help fight the war on climate change. It is estimated that 30 percent of any building's electricity bill is typically represented by the cost of operating lighting systems and around 60 percent by the cost of operating HVAC. The built environment is responsible for up to 40% of total energy use. In India, building sector represents 33% of energy consumption. Energy efficient systems can reduce the power consumption by 50% in existing buildings and 35% in new construction.

PURPOSE

The purpose of this report is to provide certain control strategies and techniques in order to save energy which is used in the malls and shopping complexes. There are countless studies covering energy use in complex buildings in general, but there are only a few published scientific papers on shopping malls. To this date, little statistics have been published on use of energy in shopping malls. The fact that the number of shopping malls are increasing proves the importance of further work. This report provides certain techniques to reduce energy demand in the shopping malls in terms of lighting and HVAC. If energy for lighting is decreased, it will result in a twofold gain since less energy is needed for the removal of surplus heat. After demands have been reduced, new alternative HVAC systems can be designed and adjusted to increase energy efficiency. Hence, the energy efficiency in a shopping mall is the major agenda to save its consumption and to reduce electricity bill.

PROJECT OBJECTIVES

The report is a unique guide that compiles information collected from books, journals, internet and other sources along with the simulation of an existing shopping mall "Gurgaon Central Mall". This has helped in checking the energy consumption before and after the modifications done over it. The report is intended of being aware of the threat generated by climate change, sustainability of energy supplies and rapidly increasingly cost, to explore the methods of providing indoor air quality especially in terms of illumination and space conditioning by maximizing the use of passive energy systems, to identify the optimal energy efficiency through the selection of appropriate materials for glazing to reduce the heat gain and to identify the solutions for the reduction of Lighting and HVAC load.

PROJECT METHODOLOGY

To start with this project, several stages have been identified.

- INTRODUCTION: this stage deals with the coverage on electricity consumption by various sectors of buildings.
- THEORETICAL BACKGROUND: The history of markets in Indian context and the evolution of mall through various stages have been explained at this stage.
- AIM AND OBJECTIVES: Here the goal which needs to be achieved in a limited time frame has been identified by mentioning the scopes and limitations.
- DATA COLLECTION: This section has dealt with the collection of certain information. This is done in two parts: primary and secondary.
- CASE STUDIES: This falls under primary information and deals with the live survey conducted and the interviews by many people. The analysis of case studies has been done on the basis of: physical characteristics, functional performance, demand reduction strategies and energy performance of the building studied.
- LITERATURE REVIEW: This falls under the secondary information and deals with the data has been collected from books, journals, internet and other sources. In this data has been divided into two categories to understand certain things: passive strategies and active strategies. Passive strategies deals with the building form and envelope, daylighting etc. though it has not been covered in detail but has been mentioned to the understanding purpose. In active strategies, artificial lighting and HVAC has been studied in detail.
- LESSONS LEARNT: The lessons from the above mentioned information have been mentioned here.
- MODEL DEVELOPMENT: The model of an existing case has been developed from the simulation tool to check its present energy consumption. This forms the baseline against which the consumption should be reduced.

- ENERGY EFFICIENT STRATEGIES: Certain efficient modifications are done in the models and the best one which reduces the consumption at large scale has been identified.
- ANALYSIS: This stage covers the results drawn out of the simulation method. And checks the heat gain through lights and windows, consumption through HVAC and overall CO_2 production. And then a comparative discussion has been made in the form of graph which clearly shows the reduction.
- CONCLUSION AND RECOMMENDATIONS: After the comparative analysis of the modified cases, conclusions are made and on the basis of literature reviews, case studies and simulations, suggested recommendations are made to make the shopping energy efficient.

PROJECT OUTCOME

In malls, lighting plays a very important role in attracting the customer's attention to sell merchandise which requires adequate thermal and visual comforts. For visual comfort, lighting should be designed properly to help create an appealing effect in the mall. In case of buildings, the usage of light varies with the place of work and the nature of space or building. This report focuses on the shopping mall where the level of illumination varies with different spaces within it. In order to understand lighting strategies, a mall is divided into various levels namely Public areas, Food court, Exterior facades, Retail outlets and Showrooms. The excessive dependence on artificial lighting increases energy consumption. Hence, an understanding on daylighting and sensors is quintessential. Due to certain limitations like unpredictability of the sun, illumination levels change within the space causing color fading effect on the merchandise due to Ultra Violet (UV) rays, daylight alone cannot fulfill illumination requirement within a mall. Daylight harvesting, integrated with artificial lighting and controls is used to overcome this problem. Hence, all sources of lights like daylight, artificial light and a combination of both have been studied and implemented.

HVAC also plays a major role in consuming a substantial amount of electric load in a shopping mall. The use of VAV system along with VFD reduces energy consumption. This report discusses the following strategies for HVAC systems, which are best suited to achieve these goals:

- Working principle of centralized HVAC
- Control loop system of sensors
- Desiccant dehumidification
- Airside economizer
- Thermal storage
- Heat recovery chillers
- Demand controlled ventilation using CO_2 sensor

It is often difficult to estimate the demand savings achieved by HVAC strategies as the building's HVAC electrical load is active and responsive to weather conditions, occupancy and other factors. In order to achieve savings, a simulation model has been developed with two alternatives to check the following factors:

- Heat gain through lights and windows
- Unit energy consumption through HVAC
- CO2 production

The results obtained after modified simulations revealed a significant reduction in annual energy consumption from 526.41MWh down to 388.53MWh when all the controls and energy efficient measures were applied in second case. This has also helped in overall reduction of CO2 and heat gain. Hence, it can be summarized from simulation that though initial costs of energy efficient system is high; it recovers the cost eventually with a low emission of CO2 and hence reduces electricity bills. Finally, a comparative discussion has been made graphically which clearly shows the reduction.

CONCLUSION

The climate of Delhi and NCR has a great variation of temperature in summer and winter season. It goes up to 40°C in summer and below 5 °C in winter. Thus, a mall should be designed according to heat loss and heat gain during both extreme periods so that comfort level is maintained throughout the year. In summer, the cooling demand rises which automatically increases electricity consumption due to increased CO2 emission. In case of passive strategies, an alignment along East-West direction, low U-value of external walls, high VLT value for double glass glazing are some of the strategies to reduce energy consumption. For lighting, the usage of an efficient fixture is a good practice but along with controllers it turns out to be the best practice. For HVAC, demand reduction strategies like thermal storage, VAV systems, centrifugal chillers, maintenance of proper indoor air quality, usage of sensors etc. can reduce energy consumption to a large extent.

Hence, it can be concluded that in a mall, installation of energy efficient fixtures and control devices can reduce the consumption. A similar strategy can be adopted in existing malls to reduce energy consumption. Thus, the overall consumption of energy in malls can be reduced that reduces carbon footprints.

RECOMMENDATION

The information in this report should be dispersed to shopping mall owners and management team so that it reduces the electricity bill and makes people aware of the energy consumption in the mall. The inferences from the simulation and the literature study have helped in making recommendations for an energy efficient shopping mall which have been provided at the end of the report. This information will help to provide a common understanding of control strategies and development procedures to enable these strategies. The report is not an exhaustive list of all strategies. Further research is needed to better understand off peak demand reduction potential and capabilities of these strategies in terms of its feasibility.

BENEFITS OF CASE STUDIES

This report is based primarily on case studies in Delhi and NCR. It is intended to help in understanding the control strategy implementation process. Peak demand reduction and demand response is key part of any mall owner to achieve energy efficiency. The purpose of the case study is to provide a more thorough analysis of cases that might reveal interesting information which exists in practical world. Select city walk, Delhi, Shipra mall and Ghaziabad mall have been selected for the case study as they are significant to this topic. The reason behind its selection is the "popularity of these malls among the people" and hence is the leading malls in Delhi and NCR with certain energy saving measures used in them. Abad Nucleus mall at Kochi has also been studied as it's the only mall in India which has a LEED CS GOLD certification from the Indian Green Building Council.

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CHAPTER 01. INTRODUCTION

1.1. PREAMBLE

The use of energy in buildings has increased in recent years due to the growing demand of energy used for heating and cooling in buildings. According to Loe (2009), "energy efficiency is a prime consideration for all energy efficient professionals with the reasons being a threat from climate change, sustainability of energy supplies, burning of fossil fuels as well as rapidly increasingly costs". Lighting is a major contributor to the energy costs in commercial buildings as illustrated in Figure 1-1 below. (Rogers, 2002)

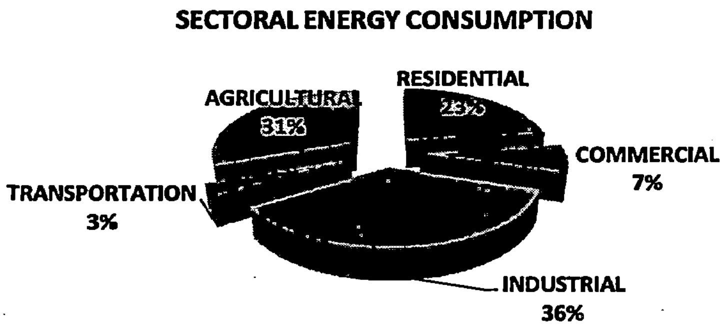


Figure 1-1 TOTAL ENERGY CONSUMPTION BY BUILDING IN 2009

Source: Bureau of Energy Efficiency

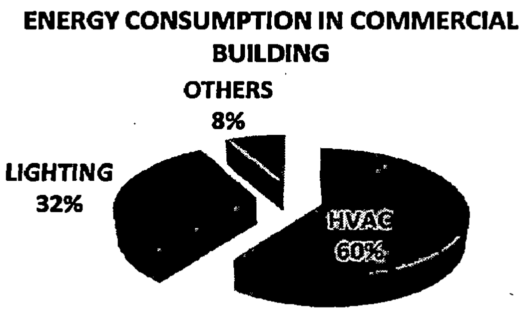
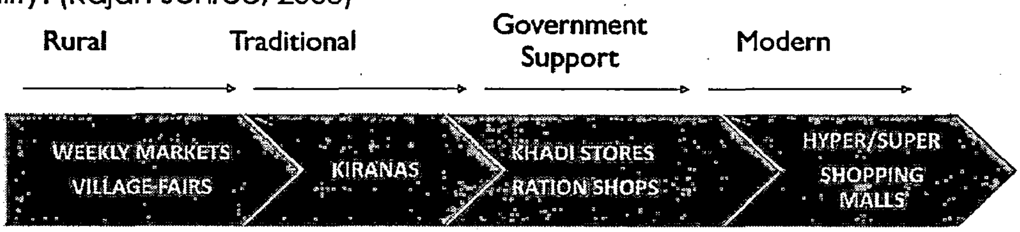


Figure 1-2 COMMERCIAL BUILDING END USE SPLITS

Source: Bureau of Energy Efficiency

The word "mall" depicts various meanings in terms of shopping, entertainment, movies and eating outlets. The meaning of this word is different for different people as it depends upon their activity they perform there. But certainly today, shopping malls have become a part of daily life of all the people living in Metros and big cities. In simple language a shopping mall can be defined as "A shopping mall is a large shopping centre entirely within a roofed structure, controlled by a limited number of entrances. Stores and other services are only accessible via interior corridors". (Stensson, June 2009)

India and its markets has undergone through various stages to come to its existing condition. This change is not only in the way things are sold but also in terms of its overall structure. Today markets and their processes are more flexible in all aspects. The new market places have started to substitute the traditional bazaar – like that of small kirana stores. Be it the chain of supply or the experience to purchase the things, markets and marketers are deriving sustainable competitive edge based on flexibility. (Rajan Johree, 2005)

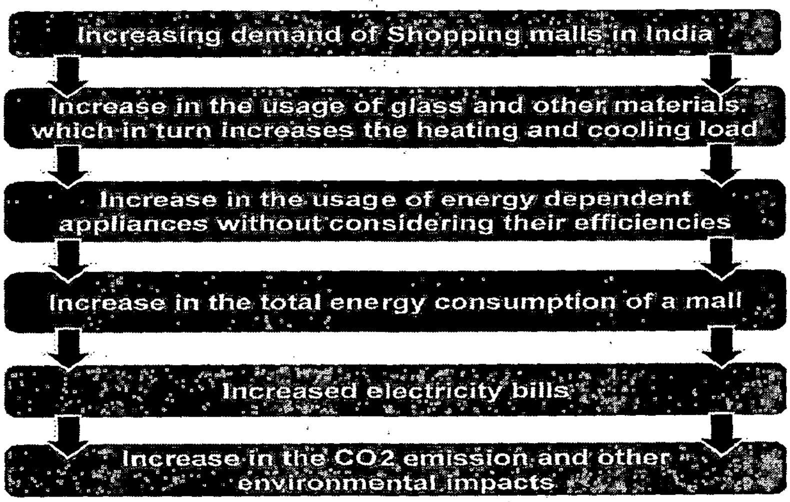


The growth of mall in Delhi and NCR has increased with a vast speed in the last 2 decades. Earlier people had to make choices among various options as they were located at a distance apart but now all things are available under the one roof of a mall which provides a great experience. Mall culture in western countries had been a very old trend and hence it has become the part of their life. But in India it's a new concept, so various factors that govern the success of a mall have to be kept in mind. Aesthetic is the major concern to attract the customers and hence several strategies are made. (kharb, 2007)

Because of the threat from the change in climate, owners and managers of the mall have decided for "GO GREEN". They have taken it upon themselves to reduce the energy consumption of the building and help in saving the change of climate. "The reasons for this may be the threat from climate change from burning fossil fuels or the sustainability of energy supplies or the increasing costs. There are many ways to reduce overall energy consumption in buildings and lighting & HVAC are the major energy consumers. The built environment is responsible for up to 40% of total energy use. In India, building sector represents 33% of energy consumption. (Energy Conservation and Building Code, July 2009) Energy efficient systems can reduce the power consumption by 50% in existing buildings and 35% in new construction. Some 15-30% of total electricity consumption can be reduced by applying green lighting. (Dilouie, 2006)

1.2. PROBLEM IDENTIFICATION

Because of the growing demand of heating and cooling within the building the consumption of energy has increased a lot. And with the reasons being a threat from climate, sustainability of energy supplies and rapidly increasingly cost, efficiency in energy has become the prime goal. As it can be seen in the fig.1, among all the sectors, commercial sector contributes 7% of energy cost. And being a major commercial building, Shopping mall consumes a large amount of energy in space heating, cooling, lighting, lifts, escalators etc. several studies has been done in the field of energy consumption of office buildings but only a few matter has been available on shopping mall. Till this date very few papers have been published on energy efficiency in shopping malls. But as the growth of mall is increasing at faster pace there is a great scope of work in understanding its efficiency. The main reasons are differences between their nature of works, occupancy number and above all the sale value of a mall is completely dependent upon the visual and thermal comfort, which consumes a huge amount of electricity. Hence the first goal for future energy efficiency measures should be to reduce energy demand.
Hence, the energy efficiency in a shopping mall is one of the major agenda to save its consumption and to reduce electricity bill.



1.3. AIM

To formulate guidelines for energy efficient shopping mall in composite climatic region of Delhi and NCR.

1.4. OBJECTIVES

- To explore the methods of providing indoor air quality especially in terms of illumination and space conditioning by maximizing the use of passive energy systems.
- To identify the optimal energy efficiency through the selection of appropriate materials for glazing to reduce the heat gain.
- To identify the solutions for the reduction of Lighting and HVAC load.
- Comparative assessment of an existing and energy efficient strategies of a shopping mall.

1.5. SCOPE

1.5.1. SCOPE

- Understanding the potential of energy efficiency of a shopping mall.
- To understand the strategies of :
  - Lighting
  - HVAC
- Comparative analysis and simulating the model of a shopping mall using literatures, case studies etc.

1.5.2. LIMITATIONS

- As the energy consumption in a mall takes place because of certain other factors also like lifts and escalators, Restaurant kitchen's equipments etc. but the study focus will be only on Lighting and HVAC.
- The application of passive technologies varies from climate to climate and zone to zone. Hence the scope of the research has been restricted to the composite climate zone of Delhi.
- The research will be emphasized mainly on the operational energy of the mall rather than the embodied energy.
- In HVAC, only strategies to be used will be checked and not the mechanical part.
- In case of simulation model, basement parking has been excluded as it consumes comparatively less energy.

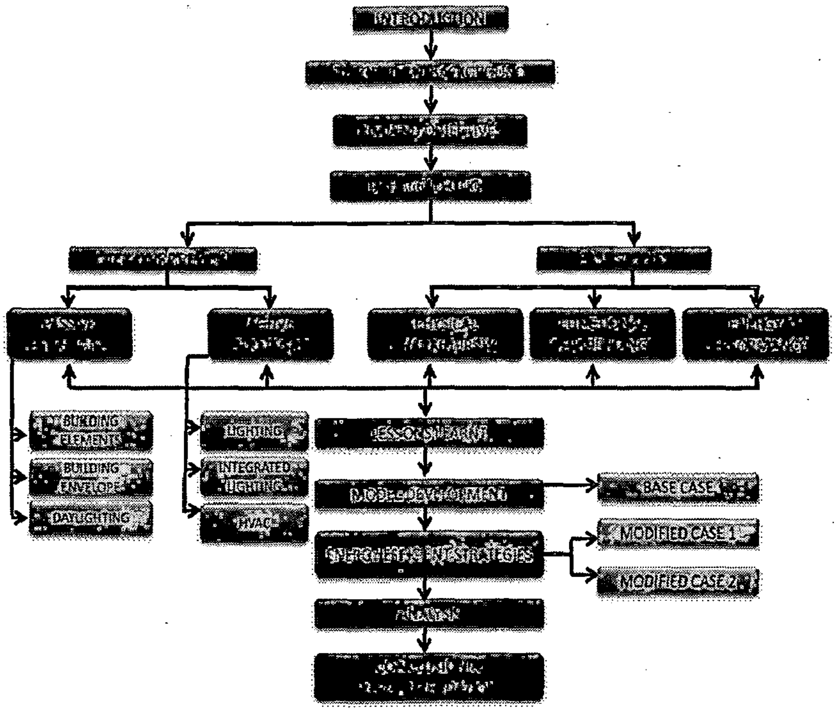
1.6 METHODOLOGY

The study has been conducted to check the efficiency of the shopping mall as it is the major consumer of electricity. To start with this project, several stages have been identified.

- INTRODUCTION: this stage deals with the coverage on electricity consumption by various sectors of buildings.
- THEORETICAL BACKGROUND: The history of markets in Indian context and the evolution of mall through various stages have been explained at this stage.
- AIM AND OBJECTIVES: Here the goal which needs to be achieved in a limited time frame has been identified by mentioning the scopes and limitations.
- DATA COLLECTION: This section has dealt with the collection of certain information. This is done in two parts: primary and secondary.
- CASE STUDIES: This falls under primary information and deals with the live survey conducted and the interviews by many people. The analysis of case studies has been done on the basis of: physical characteristics, functional performance, demand reduction strategies and energy performance of the building studied.
- LITERATURE REVIEW: This falls under the secondary information and deals with the data has been collected from books, journals, internet and other sources.

In this data has been divided into two categories to understand certain things: passive strategies and active strategies. Passive strategies deals with the building form and envelope, daylighting etc. though it has not been covered in detail but has been mentioned to the understanding purpose. In active strategies, artificial lighting and HVAC has been studied in detail and the options available to achieve efficiency in them.

- LESSONS LEARNT: In this, the lessons from the above mentioned information have been taken care of. This helps in making the proper recommendation for the same.
- MODEL DEVELOPMENT: The model of an existing case has been developed from the simulation tool to check its present energy consumption. This forms the baseline against which the consumption should be reduced. Then certain modifications are made in the model through incremental stages and analyzed for its energy performance.
- ENERGY EFFICIENT STRATEGIES: In this, the efficient modifications are done in the models and the best one which reduces the consumption at large scale has been identified.
- ANALYSIS: This stage covers the results drawn out of the simulation method. And checks the heat gain through lights and windows, consumption through HVAC and overall CO_2 production. And then a comparative discussion has been made in the form of graph which clearly shows the reduction.
- CONCLUSION AND RECOMMENDATIONS: After the comparative analysis of the modified cases, conclusions are made and on the basis of literature reviews, case studies and simulations, suggested recommendations are made to make the shopping energy efficient.



1.7. ORGANISATION OF THE DISSERTATION

The report is followed by the references and the list of tables and figures at the end. And each chapter is followed by the summary of that which is provided at the end of the chapters. Chapter 01 explains the importance of the topic, scope, methodology of data collection and analysis. Chapter 02 discusses the literature available on the topic from books, journals, publications, internet etc. there are certain studies which are under process in India and some other countries which is also covered in chapter 02. Standards and specifications available are presented in chapter 03. Significant case studies which are existing and some literature cases are focused in chapter 04. Chapter 05 includes the introduction of study area and the approaches to be followed to make it energy efficient and the development of the base model on the simulation tool. Chapter 06 deals with the implementation of all the studies covered in above chapters having energy efficiency on a simulation model of Gurgaon Central Mall. Chapter 07 gives the conclusions and recommendations. Finally at the end, references and bibliography of the same is provided.

CHAPTER-02. LITERATURE REVIEW

2.1 INTRODUCTION

A shopping mall, as defined, is a large shopping centre entirely within a roofed structure, controlled by a limited number of entrances. Stores and other services are only accessible via interior corridors. (Stensson, June 2009). During collection of energy statistics it has been evident that there are few shopping malls with well thought-out measurement systems (Stensson, June 2009).

Figure 2-2 GURGAON CENTRAL, GURGAON

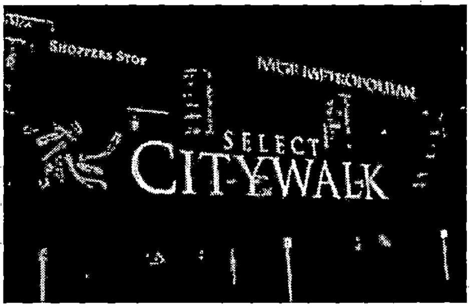


Figure 2-1 SELECT CITYWALK, SAKET

Though many mall's stores provides a best example of advancement in technology. Hence it helps the store owners to understand the value of customer's happiness by providing the best facilities.

2.2 ENERGY EFFICIENT SHOPPING MALL

Shopping malls are an important part of today's quality lifestyle. It is also a fact that shopping malls are one of the major energy consumers among all types of buildings, owing to their huge lighting load, large and fluctuating number of shoppers and long operating hours. This leads to significant demand for air-conditioning and lighting. Therefore, shopping malls are one of the major building types where building energy efficiency improvement is targeted.

As HVAC and lighting are the major contributor for global warming hence their performances are evaluated. Other than the energy consumption of these, certain other parameters like indoor air quality, ventilation, thermal and visual comforts are kept at certain appropriate value to ensure fulfillment to avoid the negotiation in functional performance, and health and comfort in the pursuit for energy efficiency. Hence, an Energy efficient Mall is a symbol of a healthy and performing building. (Unit, 2009)

2.3 SPACE EFFICIENCY STRATEGIES

There are goals which need to be achieved by certain strategies and recommendations to meet the 30% energy use reduction target. (Otto.H.Koenigsberger, 1975)

GOAL 1: Reduce loads on energy-using systems using passive strategies

S.NO	GOALS	GENERAL STRATEGIES	DETAILED STRTATEGIES
1	Reduce internal load	Equipment and Appliances: Reduce both cooling loads and energy use	Use more efficient equipment and appliances
			Use controls to minimize usage and waste
		Lighting: Reduce both cooling loads and energy use	Maximize the benefits of day lighting
			Use skylights and north-facing clerestories to daylight interior zones
			Use efficient electric lighting system
			Use automatic controls to turn lights off when not in use
2	Reduce heat gain through building envelope	Control solar gain to reduce cooling load through windows	Use beneficial building form & orientation
			Minimize windows east & west, max. north and south
			Use glazing with low solar heat gain coefficient (SHGC)
			Use vegetation on South/East/West to control sun heat gain and glare

		Reduce solar gain through opaque surfaces to reduce cooling load	Increase insulation of opaque surfaces
			Increase roof surface reflectance and emittence
			Shade building surfaces as appropriate for surface orientation
		Reduce conductive heat gain and loss through building envelope	Increase insulation on roof, walls. Floor, slabs &doors and decrease U-factor of window
		Reduce air filteration	Provide continuous air barrier
3	Reduce thermal loads	Utilize passive solar designs	Use thermal storage,
			trombe walls
4	Reduce HVAC loads	Reduce heat gain and loss in ductwork	Insulate ductwork
			No ductwork outside the building conditioned space

GOAL 2: Use more efficient Lighting and HVAC systems which have been discussed in the later part of this report.

2.3.1 DAYLIGHTING

Lighting plays a major role in the creating visual comfort, attractive identity, and comfort of a shopping mall. Excessive dependence on artificial lighting increases energy consumption. Hence daylighting in spaces along with sensors are introduced. This system involves allowance of daylighting at the perimeter areas of a building with the help of building form; inner atria, skylights and clerestories. Additional glazing for day lighting will increase the cooling load of HVAC resulting in decreased Solar Heat Gain Coefficient (SHGC), U-value and Visible Light Transmittance (VLT). For high performance glazing, reference parameters stand as U-value <2.27, SHGC < 0.25 and VLT > 0.65. To further increase performance of glass, Low-emissivity glass, glass with a transparent metallic coating on one side, is used as energy efficient glazing. (HVAC Tips for Green Buildings, 2007)

There are two types of daylight harvesting:

- Side Lighting: these glazings are provides at the front façade or the clerestory height to let the daylight enter into the building. But its lighting intensity reduces with the distance. Hence to overcome this problem, fixtures with lighting controls should be provided adjacent to the windows which should be different from the rest to attain the saving in electricity with maximum illumination level.

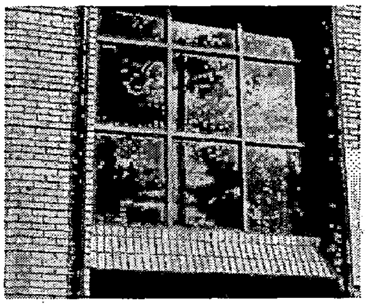


Figure 2-3 VERTICAL GLAZING

Source: Emerson Climate Tech.

- Top Lighting: these are provided on the top of the roof as skylight to let the natural light enter into the building. In case of multistoried buildings, provision of skylight will introduce light only in the upper floors hence it is suggested to provide it in the atrium part. Lighting from above is generally more natural and efficient with a complete uniformity throughout the space. (Technologies, November 2009)

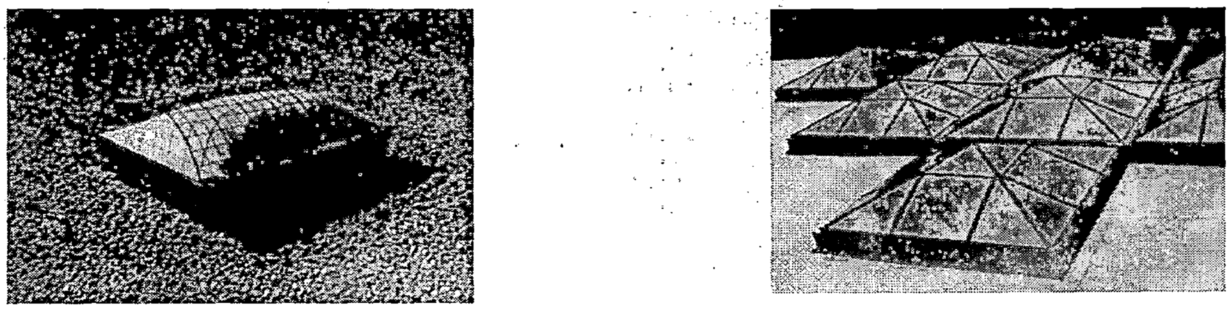


Figure 2-4 TOP LIGHTING

Source: Emerson Climate Technologies

Due to certain limitations like unpredictability of sun, resulting in changing illumination level within the space and the color fading effect on the merchandise caused by of Ultra Violet (UV) rays, daylighting alone cannot fulfill illumination requirement within the mall. Daylight harvesting integrated with artificial lighting and controls shall be used to overcome this problem.

2.4 LIGHTING

In a shopping mall, it is very important to attract the customers to their retail stores. Hence for this, it is very essential to understand the value of creating a unique shopping experience through the effective choice of colour schemes, layouts, displays and of course lighting. In case of mall, it is important to identify the visual tasks, design illumination for them and then work the task lighting into an overall program of lighting design. There are certain measures for an effective and energy efficient lights in a mall: (Energy Conservation and Building Code, July 2009) (National Building Code, 2005) (Unit, 2009)

- **Illumination:** It is the amount of light which is required in a particular space to make the things visible and to create a visual comfort of that space. It varies with the type of building and the type of task to be performed. In case of mall, the areas which are identified are: Public areas, Restaurants, Exterior facades/ landscaped areas, retail stores, showrooms. All these spaces perform differently and hence needs different level of illumination. To achieve energy efficiency, minimum amount of light level, as per standard; should be achieved with the help of energy efficient lamps which suits the task of that particular space. For e.g: Incandescent lamps to be replaced with CFL, T-12 lights to be replaced with T-8/T-5, mercury vapor lamps to be replaced with high pressure sodium lamps/ Light Emitting Diodes (LED) and Tungsten halogen lamps to be replaced with Metal Halide lamps.

Table 2-1 RECOMMENDED VALUE OF ILLUMINANCE Source: NBC,2005

Sl No. (1)	Type of Interior or Activity (2)	Range of Service Illuminance in Lux (3)	Quality Class of Direct Glare Limitation (4)
19	RETAILING		
19.1	Small Shops with Counters	300-500-750	1
19.2	Small Self-Service Shops with Island Displays	300-500-750	1
19.3	Supper Markets, Hyper-Markets		
19.3.1	General	300-500-750	2
19.3.2	Checkout	300-500-750	2
19.3.3	Showroom for large objects, for example, cars, furnitures	300-500-750	1
19.3.4	Shopping precincts and arcades	100-150-200	2

- **Color Rendering Index of lamps**: It helps in assessing colours appearance and skin tones to natural for the people who use the space. Usage of lamps with a CRI of at least 80 is advisable in applications such as specialty retail stores, where the color rendering of merchandise is very important. In the figure below it is evident that lamp with CRI of 90 is showing the best effect as compared to the lamp with CRI of 50.

CRI= 90 CRI=70 CRI=50

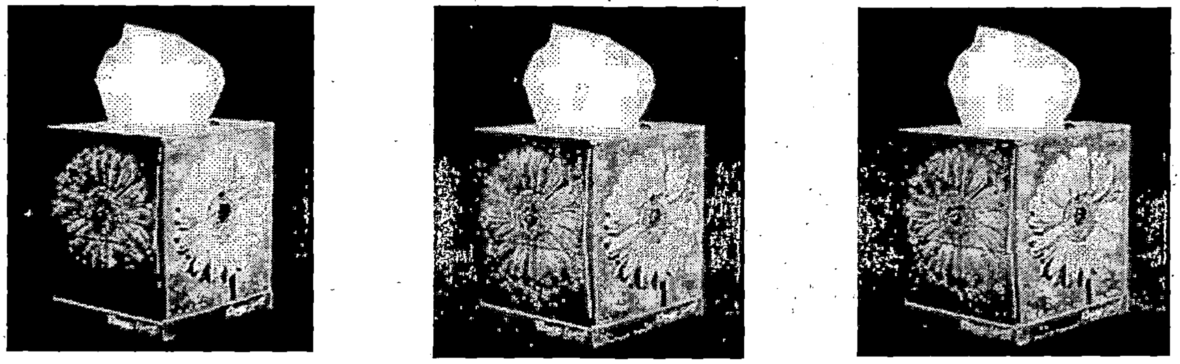


Table 2-2 CRI OF LIGHT SOURCES **Source: NBC, 2005**

Light Source	CRI
Incandescent	100
T8 Linear Fluorescent	75 - 85
Cool White Linear Fluorescent	62
Compact Fluorescent	82
Standard Metal Halide	65
Standard High Pressure Sodium	22
Daylight	100

- **Light Power Allowance (LPA):** As lighting consumes large amount of electricity, hence setting the limit in its usage is required. These limits are defined in terms of the watts-per square meter and are referred as Lighting Power Allowance (LPA). It is calculated by multiplying the Light power density (LPD) in w/ sq.mt. of the space with the Gross Lighted Area (GLA) in sq.mt.

Light Power Allowance (LPA) = Light Power Density (LPD) X Gross Light Area (GLA)

- **Correlated Color Temperature (CCT):** The color appearance of the light emitted by a lamp, when heated to a particular temperature, measured in degrees Kelvin (K) is identified by the help CCT. The CCT rating for a lamp is a general description of "warmth" or "coolness"; E.g. lamps with a CCT below 3200 K are considered "warm", while those with a CCT above 4000 K are considered "cool" in appearance.

Figure 2-5 CCT OF LIGHT SOURCES

Table 2-3 CCT OF LIGHT SOURCES **Source: Philips Lamp Catalog**

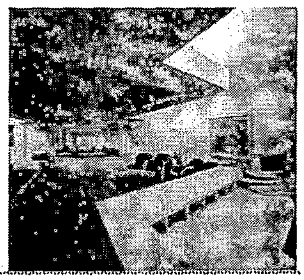
Source	CCT Range
Tungsten Halogen	3000 K – 3200 K
Linear Fluorescent	3000 K – 6500 K
Metal Halide	2900 K – 5200 K
Compact Fluorescent	2700 K – 5000 K

2.4.1 LIGHTING DESIGN CRITERIA

Before installing the lights certain design criterias have to be checked. (Institute, 2005)These are:

- Appearance of space and light fixtures,
- Color appearance,
- Direct glare,
- Horizontal and vertical illuminance,
- Light distribution on surfaces
- Points of interest

2.4.1.1. APPEARANCE OF SPACE AND LIGHT FIXTURES

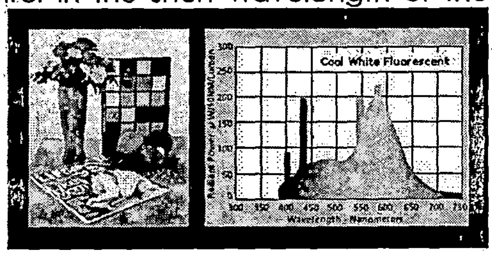


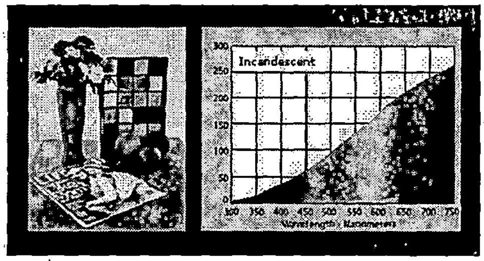
The appropriate positioning of light fixtures according to the placement of furniture can improve the appeal and effect of the space.

2.4.1.2. COLOR APPEARANCE

The spectral composition of a light source affects its skill to provide colors "naturally".

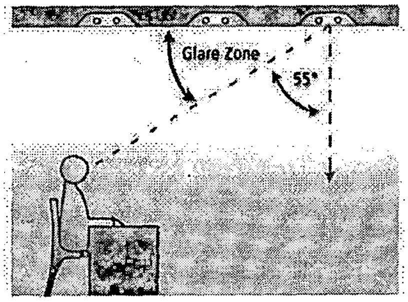
This particular fluorescent lamp has more control in the short wavelength of the visible spectrum (below 450 nm) than the incandescent lamp. Therefore blue colors appear brighter.





The incandescent light source depicted has more control in the longer wavelengths (above 650 nm) of the visible spectrum; therefore red colors appear brighter.

2.4.1.3. DIRECT GLARE

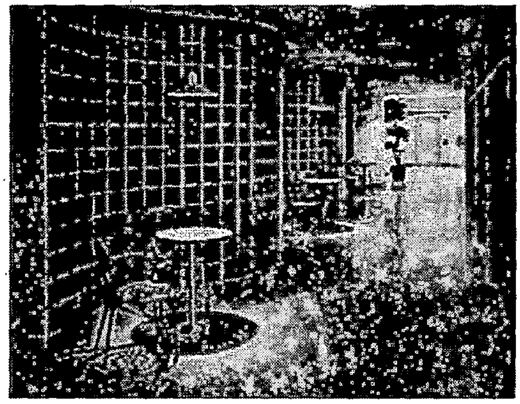


Glaring problem the light fixtures occurs because of its occurrence in glare zone (between 55° and 90° from vertical) as shown in the figure. This problem can be reduced by bounding that intensity at that angle.

2.4.1.4. HORIZONTAL AND VERTICAL ILLUMINANCE

For applications such as retail, lighting at vertical surface is important as the merchandize are placed on racks and mannequins displays the accessories. Hence special attention with the help of lighting effects is produced.

2.4.1.5. POINT OF INTEREST



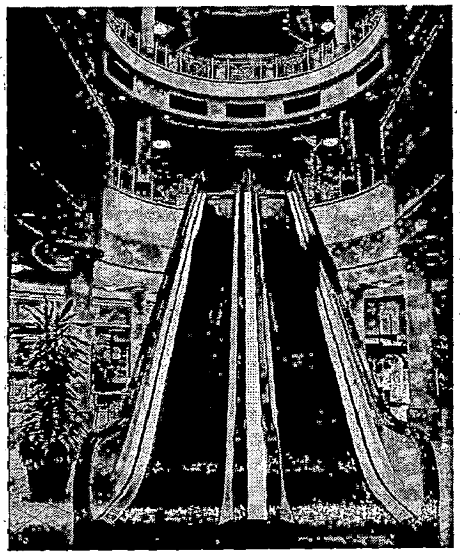
The interest on the object is created using the illumination or color contrasts, moving effect or difference in brightness. In case of malls, it is created with the help of the accent lighting which highlights the object. For general or ambient lighting fluorescent lamps, and accent lights for highlighting only the most important features of a room is a great option.

Using the above mentioned characteristics, the lighting characteristics of different zones in a mall has been identified as shown in the table:

Table 2-4 LIGHTING CHARACTERSTICS OF DIFFERENT ZONES **Source: ECBC, 2009 and NBC, 2005**

ZONES	ILLUMINATION (in LUX)	CRI	LPA (In W/m2)	CCT (in "K" per fixture)
Common spaces	100-200	70	9.688+9.688w/m² for accent lighting	2900-5200K
Shopping precinct and arcades	100-200	70	13.993	3000-4000K
Showrooms & retail stores	300-750	80	20.45+37.675w/m² for accent lighting	4000-6500K
Restaurant & coffee shops	80-200	70	16.145+9.688w/m² for accent lighting	2700-5000K
Restaurant Kitchens	300	70	21.53	4000-6500K

2.4.2 ENERGY EFFICIENT LIGHTING SYSTEM OPTIONS



For the retailers it is very essential to understand the worth of creating a sole shopping experience through the successful choice of color schemes, layouts, displays and of course lighting. The final aspire is to attract shoppers to look at showrooms, market halls and aisles. As lighting is an established means of rapidly lowering energy consumption and can cut costs by between 25 to 50%, certain control features linked with lighting via a centralized smart control board or a dispersed scheme can be used. Specific inclusions in such systems include occupancy detection, dimming, daylight linking and scene setting and optic fiber systems. (Sympholux Lighting Control- Shopping Mall solution guide, 2009)

2.4.2.1 DIMMING AND SCENE CONTROL

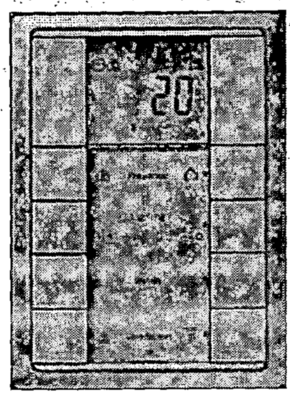


Figure 2-6 PUSH BUTTON WITH TEMPERATURE CONTROL

Dimmers are the perfect method to make architectural lighting along with the formation of strange lighting effects which can be used to manage large numbers or down and display lights. Such a large-scale dimming means will also help in preserving energy and further reduce power bills.

The dimmers use higher stage control switching to make sure of the cooler process and higher dependability. The Scene Controls can also be used to operate quite a few device sequences and set manifold levels or events via one control and are typically used to:

- Make mood lighting and rapidly change in-mall ambience.
- Schedule-switch or dim several lighting areas at a day's start or end.
- Enable/disable occupancy sensors when moving from working to nonworking hours control.

2.4.2.2 DAYLIGHT HARVESTING

Daylight harvesting saves energy by repeatedly monitoring and adjusting non-natural and natural lighting to improve occupants' comfort by eliminating variations in lux levels. Light level sensors are used to decide lighting levels on the basis of the sunlight filtering through windows in exact area. If a dimmer sense a lesser amount of light than optimal artificial brightness in an area, it brightens lights to the preferred intensity value. Similarly, when natural brightness begins to fade outdoors, the lighting control system adjusts the artificial light in small steps.

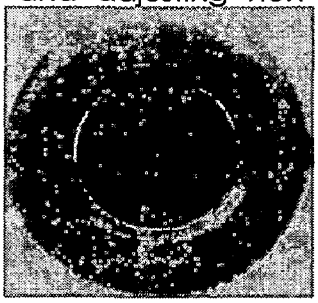


Figure 2-7 LIGHT LEVEL SENSOR

2.4.2.3 OCCUPANCY SENSOR

Occupancy sensors are used to switch the lights off or other loads when people leave an area of a building unattended. Such sensors are often joined with a wall control to offer an option of both physical and mechanical activation/deactivation means. As a result, users occupying an area can by hand control lighting without having to worry about wasting electricity by burning unnecessary lights when the areas are left unoccupied. Other infrequently occupied rooms such as staff and rest rooms can employ occupancy sensors to totally get rid of wall switches in total.

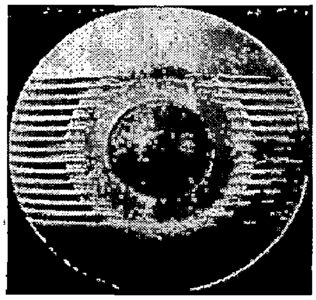


Figure 2-8 DUAL TECHNOLOGY SENSOR

2.4.2.4 OPTICAL SYSTEM

This type of daylight harvesting uses a tubular day lighting device or fiber optic system that provides optically-controlled daylight to modern buildings. The tubular day lighting device is a round tube lined with highly reflective material that leads the light rays through a building, starting from an entrance-point located on its roof to its terminus. Fiber optic day lighting uses fiber optics, together with solar light collectors, to diffuse daylight to spaces commonly hard to daylight. (Technologies, November 2009)

Figure 2-10 TUBULAR DAYLIGHTING DEVICE

Source: Emerson Climate Tech.

Figure 2-9 FIBRE BUNDLE

Source: Emerson Climate Tech.

2.4.3 INTEGRATED DAYLIGHTING AND ARTIFICIAL LIGHTING

To harvest the energy-saving benefits of day lighting, electric lights must be switched off or dimmed. This can be calculated in several ways.

- Sufficient manual switching or dimming to support the user to turn off or dim electric lights
  - An automatic photoelectric device in each day lighted region that either switches off lights during daylight periods or dims lights in quantity to the amount of daylight
  - An automatic photoelectric system that dims or switches off lighting systems all through a building in reply to daylight.
  - An automatic time-of-day control system, preferably with astronomic time functions, that switches or dims lights according to a fixed solar schedule.

2.4.4 LED LIGHTING AS AN ENERGY EFFICIENT METHOD

With the upcoming demand of energy efficient lighting systems and the controls, LED lighting is gaining its own popularity among the mass because of its certain features as mentioned below:

- It consumes a low amount of energy as compared to the other lighting systems and hence it helps in saving the electricity bills.
- The long lasting period of LED lights are 50,000 hours which is much larger than any other kind of lighting systems.
- It can sustain the electricity fluctuations and vibrations as compared to others systems and hence the chances of damage is low.

- The emission of infrared lights and UV radiation is nil and hence contributes in saving the atmosphere from its effects.
- Various colours of lights are possible from LED on light spectrum.

Along with the advantages there are certain disadvantages are also attached with this lighting system, these are as follows:

- The varieties are very limited for the selection of these kinds of lamps and are very hard to find at certain locations like small towns etc as compared to other lamps.
- The expenses of these lamps are high as compared to the conventional ones.
- Though they are available in various colours but the CRI of LED lamps are not as good as compared to the other lamps.

Hence it can be concluded that the initial cost of changing the conventional lamps to LED lamps is very high but within certain period of time this amount can be recovered. And to make it available at every place, people should be made aware of its benefits and effects on atmosphere.

EXAMPLE CASE STUDY

This Lindt Chocolate Shop is located in Albany, New York. It is a 1230 ft2 (114 m2) store which sells Swiss chocolates which are wrapped in shiny foil. General or ambient lighting is provided with the help of parabolic troffers and accent luminaries' are provided at the periphery. In soffits, fluorescent strip lights are provided which brighten the walls, and incandescent track lighting helps in making the package sparkle. This example shows the usage of lighting systems in a retail store as an *energy efficient way to reduce the energy consumption.*

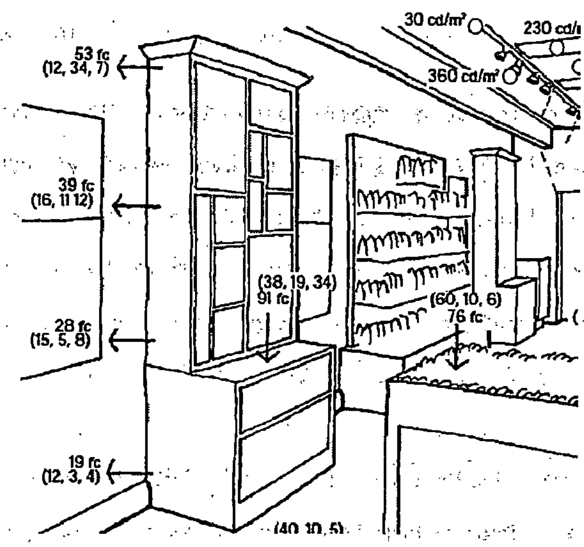


Figure 2-11 LINDT CHOCOLATE SHOP, NEW YORK

2.5 COOLING AND HEATING LOAD

Cooling energy can be reduced by: 1) reducing the cooling load on a building, 2) using passive techniques to meet some or the entire load, and 3) improving the efficiency of cooling equipment and thermal distribution systems. (Blok, 2007)

2.5.1 REDUCING THE COOLING LOAD

Building shape, orientation, building materials and certain other passive factors related to climate affects to a large extent in the reduction of cooling load. Reduction in cooling load includes:

- Orientation of the building along east or west direction to minimize the wall in this direction;
- Using high-reflectivity building materials;
- Provision of insulating materials;
- Provision of fixed or adjustable shading devices
- Usage of glazing materials with solar heat gain and a high visible light transmission factor and low exposure of windows on E-W walls.
- Provision of thermal storage to use it at peak time
- Usage of low electricity consuming equipments i.e. energy efficient equipments to reduce the heat loads.

A drastic amount of energy can be saved by increasing the reflectance power of roofs and walls, and by planting shaded trees. The trees are beneficial both in terms of providing shading and cooling the ambient air.

2.5.2 PASSIVE AND LOW ENERGY COOLING TECHNIQUES

Purely passive cooling techniques require no mechanical energy input, but can often be greatly enhanced through small amounts of energy to power fans or pumps. (HVAC Tips for Green Buildings, 2007)

2.5.2.1 NATURAL AND NIGHT TIME VENTILATION

The mechanical cooling can be reduced to a large extent through natural ventilation by: removal of warm air when the arriving air is cooler than the leaving air, reducing the clear temperature generated by the movement of air which generates the coolness, providing night-time cooling and increasing the acceptable temperature when the occupants have control of operable windows. For natural ventilation, heavy air force and a sufficient number of window openings, to create airflow is necessary. There are certain other design features which help in generating great air force which includes courtyards, atria, wind towers, solar chimneys and operable windows

2.5.2.2 EARTH AIR TUNNEL SYSTEM

Underground earth-pipe cooling provides the cooling of air by letting the exterior air inside the building through an underground air channel. This system is very efficient in the climate which is having a large variation in its temperature. Desiccant dehumidification and cooling involves usage of a hygroscopic chemical (desiccant) that removes humidity from moist air. An amount of around 30 to 50% energy can be reduced for dehumidification of air as compared to the other options of overcooling and reheating.

2.5.3 VAPOUR COMPRESSION CHILLERS

In commercial buildings, chillers are the important device which helps in making chilled water. With the increase in size, COP also increases which helps in understanding its performance under full and part load condition. Higher the COP more efficient it is. Although certain other operations like ventilation, circulating chilled water and operation of a cooling tower requires an extra amount of energy, but this energy can be saved by proper selection of cooling equipment along with efficient auxiliary systems. It generally employs a halocarbon refrigerant in a vapour-compression cycle. (Blok, 2007)

2.5.4 REDUCING THE HEATING LOAD

In the composite climate of Delhi, heating within the building is also very much required during the winter season. Though the heating load is not very large but it still has to be considered. The reduction in heating load includes:

- By lowering the U-value of North side windows, the heat loss can be reduced.
- By reducing the number of windows on North sides, heat loss can be reduced.
- By allowing winter sun to come into the south collector area, the passive solar would get better radically.

- The auxiliary heat source for heat pump unit can be used to supply heating to space.

2.6 HEATING VENTILATION AND AIR CONDITIONING

HVAC systems include filtration and, where required by the climate, humidification and dehumidification as well as heating and cooling.

2.6.1 PRINCIPLES OF ENERGY EFFICIENT HVAC DESIGN

In the simplest HVAC systems, heating or cooling is provided by circulating the air at a sufficient temperature to maintain the preferred room temperature. The speed at which air is spread in this case is normally much superior to that needed for ventilation to take away contaminants. During the cooling season, the air is supplied at the coldest temperature needed in any zone and reheated as needed just before entering other zones. Though the working of centralized AC is different from the packaged unit AC but the principle is same. The working of centralized AC is explained below:

2.6.1.1 WORKING OF CHILLED WATER SYSTEM

In centralized HVAC system, the conditioned space's air is much cooler than that of the other space's which is passed via the cooling coil and is enforced by the supply fan to enter into the zone. Once this cool air enters, the warmer air moves out through the return grille to the duct and then to the AHU. In AHU, 80% of the return air is mixed with the outside air in a mixing chamber and then goes through the filters and then to the cooling coil. The mixed air transfers its heat to the chilled water tubes in the cooling coil, which has fins attached to the tubes to smooth the progress of heat transfer. The cooled supply air leaves the cooling coil and the air cycle repeats.

The frozen water after picking up heat from the mixed air leaves the cooling coil to the chilled water return pipe (CHWR) where it transfers its heat into the refrigeration system. The newly "chilled" water leaves the evaporator and is pumped through the chilled water (CHW) piping into the cooling coil continuously and the water sequence repeats.

The evaporator is a heat exchanger through which the heat from the CHW system is passed to the refrigerant tubes by conduction. The liquid refrigerant in the tubes converts into the vapor removing heat from the water and transmitting the heat to the compressor and then to the condenser. From the condenser this heat is passed to the cooling tower through condenser water pump. Finally, when the outside air is blown across the cooling tower, heat from the water is removed through the process of evaporation.

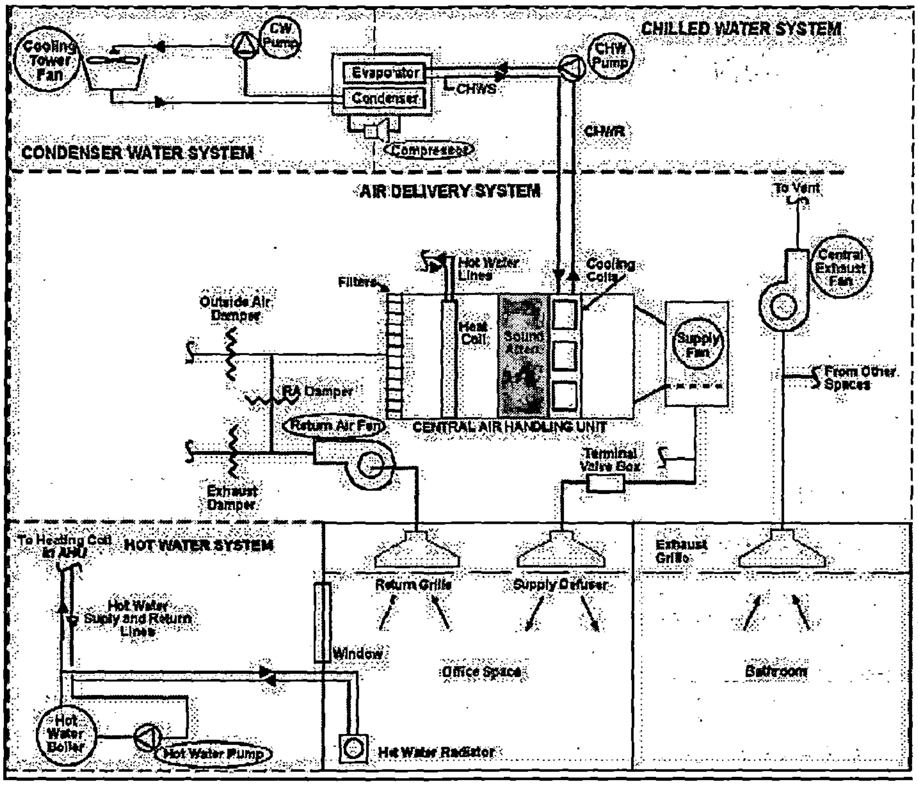


Figure 2-12 WORKING PRINCIPLE OF COOLING CYCLE

Source: Energy Consumption Characteristics of Commercial Building HVAC Systems, 1999

2.6.1.2 AIR HANDLING UNIT

An Air Handling Unit helps in cleaning the air i.e. the impurities from the stale air entering into it, are removed, additives are added and further refined till it reaches up to the comfort level of the occupant. Generally the area of the AHU is approximately 0.3 sq.mt/tonnage + 5 sq.mt. and is provided on each floor of the commercial building.

As shown in the figure, each unit has two fans which help in the air movement through it. And each has two or more dampers to allow the required amount of fresh air to get mixed with the return air. This unit typically consists of following subcomponents: Intake louvers, primary damper, air intake filter, heating coils, cooling coils, sprayers, filters, supply fans and this whole is encased in a unit casement. All the above mentioned components help in cleaning the air and conditioning it according to the requirement within the conditioned space. (Butler, March 14, 2002)

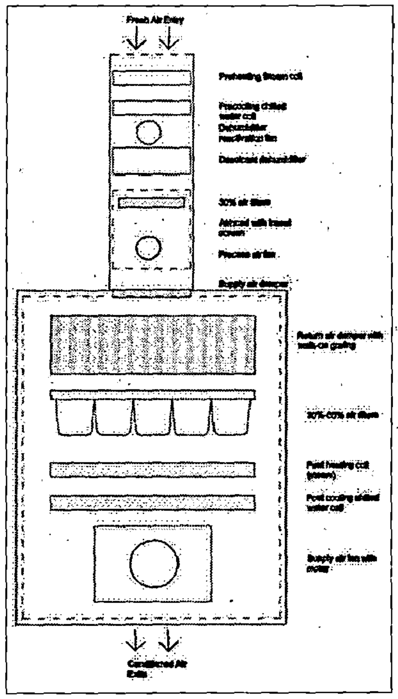


Figure 2-13 AIR HANDLING UNIT, LARGE HVAC SYSTEM

Source: (Butler, March 14, 2002)

2.6.1.3 COOLING TOWER

This is a tower which helps in the removal of waste heat to the environment with the help of cooled air passed across the water from the sides of the tower. It's an internal means to distribute the warm water fed to it over a "fill." "Fill" is a place where heating of air and evaporation takes place. As the water goes down its temperature reduces and comes in contact with air that is passed over it though the sideways. This cooled water is then collected in a basin below which is then pumped back to continue this process to absorb more heat. This heated and moisture containing air which leaves the fill is then allowed to discharge in the atmosphere in such a way that it does not draw back into the tower.

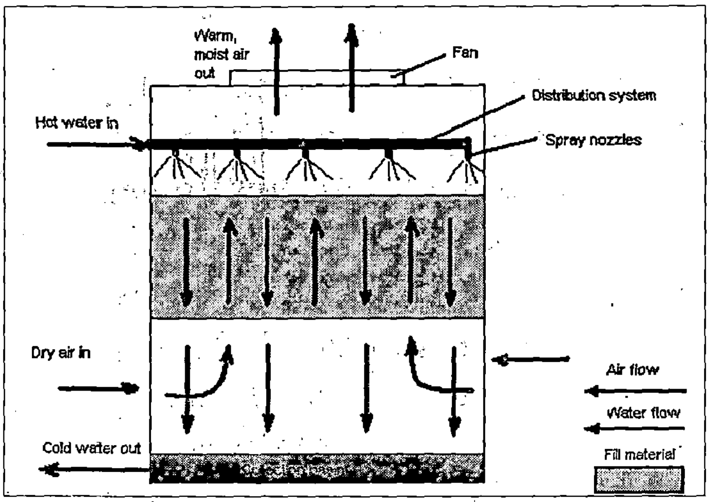


Figure 2-14 COOLING TOWER

2.6.1.4 SENSORS

Sensors are the one which helps in detecting the temperature, humidity, CO_2 etc. inside the space. The entire above mentioned if provided in required quantity helps in making a good indoor air quality.

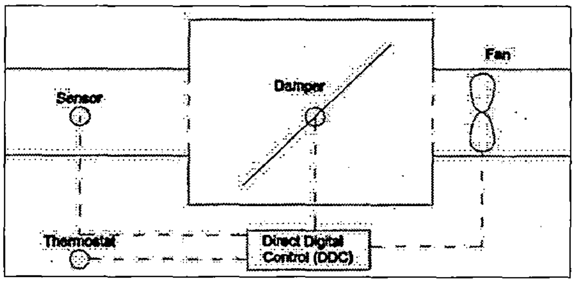


Figure 2-15 WORKING OF SENSOR

Source: (Butler, March 14, 2002)

Through these sensors an electronic impulse is emitted that informs the thermostat about the operation of the system's motors, dampers and other controls. Thermostats are provided in each zone of the building and are visible anywhere. (Butler, March 14, 2002)

The desired value is adjusted on the thermostat. The temperature sensor senses the actual value and sends a signal along the feedback path to the comparison device. The comparison device compares the actual value of temperature to that of the desired value on the controller. Then the difference between the desired value and the measured value is known as the error signal. This error signal is allowed into the controller and then to the actuator as a low voltage signal. The controlled device reacts to the impulse received from the controller and varies the flow of the water. This in turn changes the condition of the space or process to the desired value.

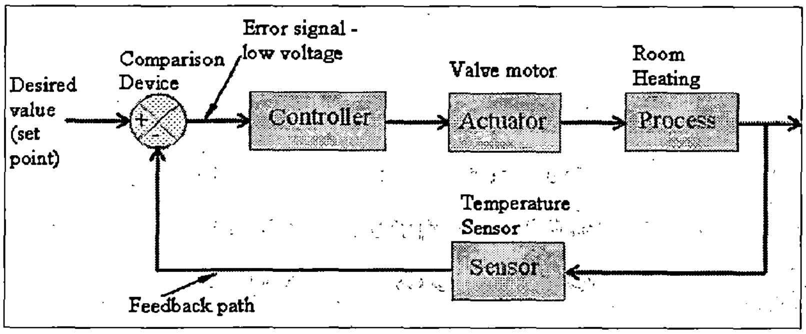


Figure 2-16 CONTROL LOOP DIAGRAM OF SENSORS

2.6.1.5 DESICCANT DEHUMIDIFICATION

Dehumidification in HVAC system can be done by 2 methods: Chillers and Absorbers. In case of chillers, supply air is allowed to cool by mechanical refrigeration below a prescribed dew point and then the water is allowed to fall out of the air. The drier air reheated to the required temperature and humidity. In case of absorbers, water is absorbed from the air with hygroscopic chemicals like desiccant. (Butler, March 14, 2002)

Desiccant is applied in a thin layer on the rotary wheel which is porous and its half part is exposed to the motionless duct through which moist air is allowed to pass and other half is exposed to the hot or dry air stream which removes collected water. High moisture air is passed through the rotary wheel through prefilter by the process fan. When the air is passing through the wheel, moisture in the air adsorbed, and dried air is discharged. The rotor adsorbed moisture is rotated into the reactivation zone before it is saturated. Simultaneously, the reactivation air is drawn from the counter side through the pre-filter and is heated and enters the reactivation zone of the rotor and desorbs the moisture adsorbed in the rotor and then is exhausted to the outside by a reactivation fan. The amount of water removed depends upon the temperature of the regenerating air and also on the humidity and temperature of the supply air, velocity of airstream, type of desiccant and its rotation speed.

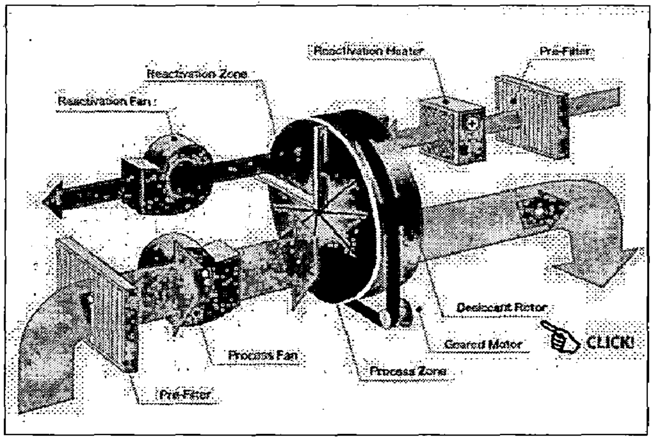


Figure 2-17 DESICCANT DEHUMIDIFICATION

2.6.1.6 AIRSIDE ECONOMIZER

An air-side economizer let the outside air into the building and distributes it to the servers like AHU. But instead of recirculation of the air, it is thrown out. If the outside air is particularly cold, the economizer mixes the return air with the exhaust air so that its temperature and humidity fall within the desired range for the equipment. The air-side economizer is integrated into a central air handling system.

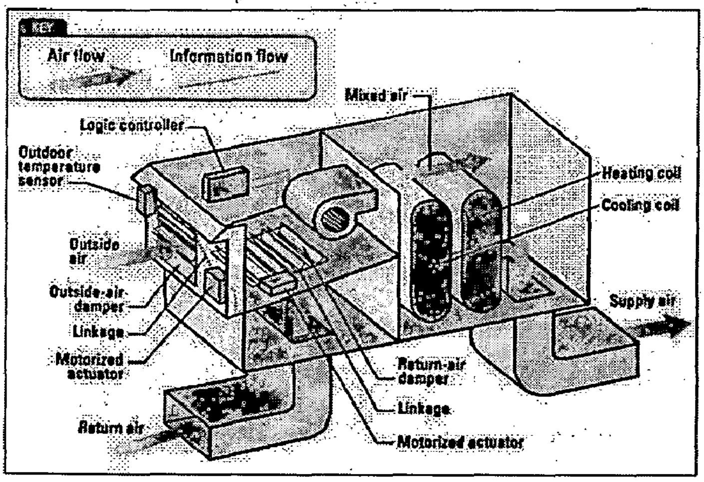


Figure 2-18 AIRSIDE ECONOMIZER

2.6.1.7 HEAT RECOVERY CHILLER

As we know that the water cooled chillers throws the hot air to the atmosphere. Hence all the building heat and compressors heat leaves the building in this manner. But if this hot air is used to heat the building then a huge amount of energy can be saved. The value of rejected heat can be improved by increasing the temperature of water. The procedure for the same is shown in the figure below.

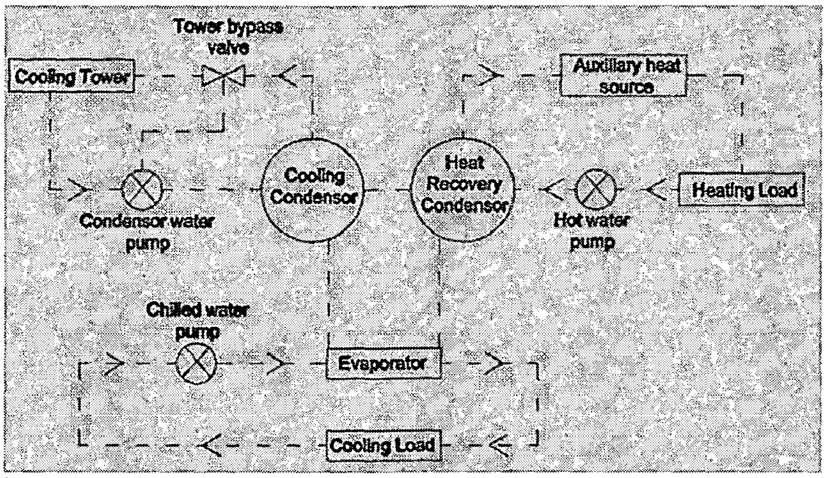


Figure 2-19 HEAT RECOVERY CONDENSOR

2.6.1.8 THERMAL ENERGY STORAGE

This storage system is an option by which off peak electricity is converted into thermal energy which can be used during on peak hours. There are two types of storage systems: hot and cold. Each system contains a large thickly insulated tank which is filled with water, brine or glycol-water solution. Into this solution, two networks of pipes are immersed; one near the bottom of the solution and the other near the top. In case of heat storage, during off peak hours a liquid or gas which has absorbed heat from cheap electricity flows through the bottom and releases its heat into the solution of the tank. Then during on peak hours, a cold medium flows through the top pipes and removes the heat and delivers it to the space in cold weather. This process is reversed in case of cold storage. (Butler, March 14, 2002) The capacity of chilled-water thermal energy storage (TES) system is increased by storing the coldest water possible and by extracting as much heat from the chilled water as practical. Chilled water storage systems use the sensible heat capacity of water (1 Btu per pound per degree Fahrenheit) to store cooling. Ice thermal storage uses the latent heat of fusion of water (144 Btu per pound).

2.6.2 ALTERNATIVE HVAC SYSTEMS

The following paragraphs describe two alternatives to conventional HVAC systems in commercial buildings that together can reduce the HVAC system energy use by 30 to 75%. These savings are in addition to the savings arising from reducing heating and cooling loads. (HVAC Tips for Green Buildings, 2007)

2.6.2.1 DISPLACEMENT VENTILATION

Conventional ventilation relies on unstable mixing to room air with ventilation air. A superior system is 'displacement ventilation' (DV) in which air is introduced at low speed through many diffusers in the floor or along the sides of a room and is warmed by internal heat sources (occupants, lights, plug-in equipment) as it rises to the top of the room, displacing the air already present. The thermodynamic advantage of displacement ventilation is that the supply air temperature is significantly higher for the same comfort conditions (about 18 degree compared with about 13 degree in a conventional mixing ventilation system). It also permits significantly smaller airflow. (Blok, 2007)

Overall, DV can reduce energy use for cooling and ventilation by 30 to 60%, depending on the climate

2.6.2.2 DEMAND CONTROL VENTILATION USING CO_2 SENSORS

Demand-controlled ventilation adjusts the ventilated air to keep level of CO_2 less than or equal to 1000ppm [600ppm + the outdoor air CO_2 concentration] in all spaces with CO_2 sensors. The CO_2 concentration outdoor air can be assumed to be 400ppm, or the CO_2 concentration can be monitored using a CO_2 sensor located near the position of the outdoor air intake. The amount of CO_2 present in the air is a sign of the number of people in the space and, in turn, the requirement of ventilation air is calculated. CO2-based ventilation control does not affect the peak design ventilation capacity required to serve the space as defined in the ventilation rate procedure, but it does allow the ventilation system to modulate in sync with the building's occupancy.

The key components of a CO_2 demand-based ventilation system are CO_2 sensors and a damper with a modulating actuator. The number and location of carbon dioxide sensors for demand-control ventilation can affect the ability to accurately reflect the building or zone occupancy. A minimum of one CO_2 sensor per zone is recommended for systems with greater than 500 cfm of outdoor air. Multiple sensors may be necessary if the ventilation system serves spaces with significantly different occupancy expectations. DCV saves energy by avoiding the heating, cooling, and dehumidification of more ventilation air than is needed. (HVAC Tips for Green Buildings, 2007)

2.6.3 ALTERNATIVE MEANS TO ACHIEVE ENERGY SAVING COMPONENTS

2.6.3.1 HEATING AND COOLING LOAD

- Generally the packaged unit designed to maintain the required dew point for humidity control.
- Usage of Variable Speed Drives (VSD) as an option for reducing the air flow and Fan/Motor energy.
- Equipment shall be designed as per the requirement keeping is mind the internal load result in short-cycled of compressor which in turn result in less dehumidification.
- It determines cooling requirement the sensible and latent load to cool the outdoor air to the room temperature must be added.
- For heating, Outdoor air brought into the space must be heated to room temperature and the heat required added to the building loss.

2.6.3.2 HUMIDIY CONTROL

- Decrease in the sensible load does no decrease proportionately with latent load. Hence increase in space relative humidity under cooling part load conditions.
- Select system with cooling part load performance that minimizes the numbers of hours so that the space Relative Humidity remains above 60%.
- Variable Air Volume needs multiple compressors to reduce the capacity low as possible to meet to minimum cooling requirement. Multiple compressors turn on and off or can be unload to maintain the space air temperature set point.

2.6.3.3 ENERGY RECOVERY

- This system provides the Energy means of dealing with sensible and latent outdoor air cooling loads during summer and reduces the heating of outdoor air in winter.
- Energy Recovery Ventilator (ERV) can be used to recover the exhaust air energy. It conditions the outdoor air before entering the air conditioning unit to which ERV or heat Pump Unit is attached.
- Exhaust Air Energy Recovery (EAER) should be designed as close to balance the outdoor and exhaust airflow as possible.
- Exhaust air from ERV is taken high exhaust duct system or directly from return air stream.
- Equipment efficiency should meet with the cooling requirement / Energy Efficient Ratio for the requirement capacity.
- For heat pump application, heating efficient must exceed the coefficient of performance (COP) for required capacity based on outdoor air.

2.6.3.4 VENTILATION AIR

- For Retails- it should be 16 cfm per persons based on 15 persons per 1000 sq.ft.
- Usage of air economizer to bring the outside cool air for cooling purpose can save energy.
- Usage of motorized outdoor air damper instead of gravity dampers to prevent outdoor air entering in when space is unoccupied.
- Demand control ventilation to be used when the occupancy load is varying or high. The amount of outdoor air can be controlled by using CO2 sensor.
- A controller operates the outdoor air, return air and relief air damper to maintain proper ventilation.

2.6.3.5 CONTROL STRATEGIES

- Time-of-day scheduling is necessary when it is known that which portion of the building will have reduced occupancy.
- Having a setback temperature during the unoccupied period of heating and cooling season.
- Filter differential pressure gauge to monitor the pressure drop across the filters.

2.7 BUILDING ENERGY MANAGEMENT SYSTEM (BEMS)

BEMSs are control systems for individual buildings or groups of buildings that use computers and distributed microprocessors for monitoring, data storage and communication (Levermore, 2000). The BEMS are located at the centre of the building and communicated to certain other parts of the building through various links in such a way that one energy manager alone can manage many buildings. Manually or automatically also several faults can be detected in the building using fault detection software with which certain sensors are connected and which helps in avoiding wastage of energy. With the advanced technologies in sensors and information technology, monitoring at large scale of the building via the Internet has also become possible.

2.8 SUMMARY

The key conclusion of chapter 02 is that reduction in considerable amount of CO_2 emissions from buildings can be achieved using certain advanced technologies for energy efficiency that already exist extensively and that have been fruitfully used. As climatic and economic conditions governs the applicability and feasibility of technologies, hence three criterias can be built-in, which are the advancement of the technology, cost and suitability.

Review shows that planning, design, and building materials have great impact on energy efficiency of building.

- With the appropriate use of green construction materials significant amount of cost and CO_2 emission saving is achieved.
- The operational cost reduction as well as CO_2 emission reduction for certain appliances is achieved using low energy consuming appliances like CFL Lights,
- Building Energy management system is the prime key for the overall reduction of energy consumption as it works on the automatic mode.

CHAPTER 03. STANDARDS AND SPECIFICATIONS

3.1 PERFORMANCE STANDARDS IN TERMS OF ENERGY CONSUMPTION

Building systems' design and operating efficiency are fundamental to the overall energy efficiency of a building. Where appropriate, actions should be taken to retrofit systems and upgrade their efficiency to a suitable standard. The ranges of acceptable performance efficiency for the various systems are as given in Table.

Table 3-1 RECOMMENDED RANGES FOR BUILDING SYSTEM'S ENERGY

Source: ECBC,2009

Systems	*Eligibility Requirements
Air Conditioning	Plant room efficiency < 0.75 kW/RT
Lighting	Lighting power density < 25 W/m²
Mechanical Ventilation	Mechanical Ventilation Power Density < 2.7 W/m²

3.2 ENERGY CONSERVATION BUILDING CODE

3.2.1 GENERAL

It complies with energy consumption norms and standards and to prepare and implement schemes for its efficient use and conservation. ECBC sets the minimum energy efficiency standards for design and construction and also encourages energy efficient design or retrofit of buildings so that it does not constraint the building function, comfort, health or the productivity of occupants. It has been launched in 2007.

3.2.2 LIGHTING

According to ECBC standards, the mandatory requirements for lighting mostly relate to interior and exterior lighting controls. Buildings larger than 500 sq.mt. requires 1 automatic control device. Exterior lighting is usually switched on to correspond to sundown and is switched off again at daybreak by the use of "scheduling control device". Time scheduling of interior is based on occupancy schedules.

Detector circuit ⟶ Controller ⟶ Relay ⟶ Light
(Information) (Processing) (Activates) (Switches)

Table 3-2 SPACE AREA AND LIGHTING CONTROL

Box 7-D: Space Area and Lighting Controls

S.No	Space Area	Coverage Area for each control device
1	Up to 1000 m^2	250 m^2 max.
2	More than 1000 m^2	1000 m^2 max.

In case of lightings of exits, internally illuminated exit signs shall not exceed 5W per face. Efficacy of a lamp is a lumen produced by a lamp/ballast system divided by the total watts of input power.(lm/W)

Table 3-3 INTERIOR LIGHTING POWER

Building Area Type	LPD (W/m^2)	Building Area Type	LPD (W/m^2)
Automotive Facility	9.7	Multifamily Residential	7.5
Convention Center	12.9	Museum	11.8
Dining: Bar Lounge/Leisure	14.0	Office	10.8
Dining: Cafeteria/Fast Food	15.1	Parking Garage	3.2
Dining: Family	17.2	Performing Arts Theater	17.2
Dormitory/Hostel	10.8	Police/Fire Station	10.8
Gymnasium	11.8	Post Office/Town Hall	11.8
Health care-Clinic	10.8	Religious Building	14.0
Hospital/Health Care	12.9	Retail/Mall	16.1
Hotel	10.8	School/University	12.9
Library	14.0	Sports Arena	11.8
Manufacturing Facility	14.0	Transportation	10.8
Motel	10.8	Warehouse	8.6
Motion Picture Theater	12.9	Workshop	15.1

For energy efficient lighting replacement option, the lamp efficacy is the ratio of light output in lumens to power input to lamps in watts. Over the years development in lamp technology has led to improvements in efficacy of lamps.

Table 3-4 LUMIOUS PERFORMANCE CHARACTERSTICS OF LUMINAIRES

Table 3.1 Luminous Performance Characteristics of Commonly Used Luminaires					
Type of Lamp	Lumens / Watt		Color Rendering Index	Typical Application	Typical Life (hours)
	Range	Avg.			
Incandescent	8-18	14	Excellent	Homes, restaurants, general lighting, emergency lighting	1000
Fluorescent Lamps	46-60	50	Good w.r.t. coating	Offices, shops, hospitals, homes	5000
Compact fluorescent lamps (CFL)	40-70	60	Very good	Hotels, shops, homes, offices	8000-10000
High pressure mercury (HPMV)	44-57	50	Fair	General lighting in factories, garages, car parking, flood lighting	5000
Halogen lamps	18-24	20	Excellent	Display, flood lighting, stadium exhibition grounds, construction areas	2000-4000
High pressure sodium (HPSV) SON	67-121	90	Fair	General lighting in factories, ware houses, street lighting	6000-12000
Low pressure sodium (LPSV) SOX	101-175	150	Poor	Roadways, tunnels, canals, street lighting	6000-12000

3.2.3 HVAC

In ECBC, the mandatory requirements for the following HVAC systems are provided:

- Natural ventilation
- Equipment efficiency
- Controls
- Piping and ductwork
- Condensers
- Economizers
- Hydronic systems

Table 3-5 MINIMUM EFFICIENCY

Rated Cooling Capacity		Maximum Power
(kcal/h)	kW	Consumption (kW)
3 000	3.5	1.7
4 500	5.2	2.6
6 000	7.0	3.4
7 500	8.7	4.5
9 000	10.5	5.4

As per the code, cooling equipment shall meet or exceed the minimum efficiency requirements presented in table.

All heating and cooling equipment shall be temperature controlled. Where a unit provides heating and cooling, controls shall be capable of providing a temperature dead band of 3 degree within which the supply of heating and cooling energy to the zone is shut off or reduced to the minimum.

To minimize heat losses, the code requires the piping of the system should be insulated. Code specifies the required R-value for the insulation.

Table 3-6 R-VALUE FOR PIPING INSULATION

Cooling System	
Designed Operating Temperature of Piping	Insulation with Minimum R-value (m^2 K/W)
Below 15°C	0.35
Refrigerant Suction Piping	
Split System	0.35

Ductwork shall be insulated in accordance with the table below.

Table 3-7 R-VALUE FOR DUCT INSULATION

Duct Location	Required Insulation[a] (R-values in m^2 K/W)	
	Supply Ducts	Return Ducts
Exterior	R-1.4	R- 0.6
Ventilated Attic	R-1.4	R- 0.6
Unventilated Attic without Roof Insulation	R-1.4	R- 0.6
Unventilated Attic with Roof Insulation	R- 0.6	No Requirement
Unconditioned Space[b]	R- 0.6	No Requirement
Indirectly Conditioned Space[c]	No Requirement	No Requirement
Buried	R- 0.6	No Requirement

[a]Insulation R-value is measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 24°C (75°F) at the installed thickness

[b]Includes crawlspaces, both ventilated and non-ventilated

[c]Includes return air plenums with or without exposed roofs above.

3.3 NATIONAL BUILDING CODE (NBC)

3.3.1 GENERAL

The National Building Code of India (NBC), is a national instrument providing guidelines for regulating the building construction activities across the country. It serves as a Model Code for adoption by all agencies involved in building construction works is they Public Works Departments, other government construction departments, local bodies or private construction agencies. The Code mainly contains administrative regulations, development control rules and general building requirements; fire safety requirements; stipulations regarding materials, structural design and construction (including safety); and building and plumbing services.

The Code was first published in 1970 at the instance of Planning Commission and then revised in 1983. Thereafter three major amendments were issued, two in 1987 and the third in 1997.

Part 8 has the building services which contains both lighting and HVAC and hence described later.

3.3.2 LIGHTING

According to NBC, it is recommended that the illuminance of all working areas within a building should generally be 150 lux, even though the visual demands of the occupation might be satisfied by lower values. Where work takes place over the whole utilizable area of room, the illumination over that area should be reasonably uniform and it is recommended that the uniformity ratio (minimum illuminance divided by average illuminance levels) should be not less than 0.7 for the working area.

a) For high task brightness Maximum (above 100 cdhn2)

1) Between the visual task 3tol and the adjacent areas like table tops

2) Between the visual task lo to 1 and the remote areas of the room

b) For low and medium task brightness (below 100 cd/m2)

The recommended design sky illuminance values are 6800 lux for cold climate, 8000 lux for composite climate, 9000 lux for warm humid climate, 9000 lux for temperate climate and 10500 for hot-dry climate. For integration with the artificial lighting during daytime working hours an increase of 500 lux in the recommended sky design illuminance for day lighting is suggested.

Sl No.	Type of Interior or Activity	Range of Service Illuminance in Lux	Quality Class of Direct Glare Limitation	Remarks
(1)	(2)	(3)	(4)	(5)
19	RETAILING			
19.1	Small Shops with Counters	300-500-750	1	The service illuminance should be provided on the horizontal plane of the counter. Where wall displays are used, a similar illuminance on the walls is desirable
19.2	Small Self-Service Shops with Island Displays	300-500-750	1	
19.3	Supper Markets, Hyper-Markets			
19.3.1	General	300-500-750	2	
19.3.2	Checkout	300-500-750	2	
19.3.3	Showroom for large objects, for example, cars, furnitures	300-500-750	1	
19.3.4	Shopping precincts and arcades	100-150-200	2	

When sufficient daylight is available inside, suitable photo controls can be employed to switch off the artificial lights and thus prevent the wastage of energy.

Table 3-8 LUMINOUS EFFICIACY, LIFE,CRI & CCT

Sl No.	Light Source	Efficacy lm/W	Average Life h	CRI	CCT K
(1)	(2)	(3)	(4)	(5)	(6)
i)	Incandescent lamps GLS 25 W-1 000 W	8-18	1 000	100	2 800
ii)	Tungsten halogen incandescent lamps Mains-voltage types: 60 W-2 000 W Low-voltage types with reflector have lower wattages	10% higher than comparable GLS lamp	2 000	100	2 800-3 200
iii)	Fluorescent lamps (FTL) a) Standard lamps 38 mm (T12) 20 W-65 W 26 mm (T 8) 18 W-58 W				
	Cool daylight	61	5 000	72	6 500
	Warm white	67	5 000	57	3 500
	b) Tri-Phosper lamps 38 mm (T12) 20 W-65 W 26 mm (T 8) 18 W-58 W	88-104	12 000-18 000	85-95	2 700-6 500
iv)	Compact Fluorescent Lamps (CFL) 5 W-25 W	40-80	8 000	Similar to FTL	
v)	High pressure mercury vapour lamps 80 W-400 W	36-60	5 000	45	4 000
vi)	Blended — Light lamps MLL 100 W-500 W	11-26	5 000	61	3 600
vii)	High Pressure Sodium Vapour Lamps 50 W-1 000 W	69-130	10 000-15 000	23	2 000
viii)	Metal halide lamps 35 W-2 000 W	69-83	10 000	68-92	3 000-5 600

3.3.3 HVAC

According to NBC, Ventilation and air conditioning installation shall aim at controlling and optimizing following factors in the building:

- Air purity and filtration,
- Air movement,
- Dry-bulb temperature,
- Relative humidity,
- Noise and vibration,
- Energy efficiency,

Efficient air filtration prevents fouling of the system and is of special importance in urban areas, where damage is likely to be caused to decorations and fittings by discoloration owing to airborne dust particles. In order to obtain maximum filtration efficiency within the minimum capital and maintenance expenditure, the utmost care should be given to the location of the air intake in relation to the prevailing wind, the position of chimneys and the relative atmospheric dust concentration in the environs of the building; the recommendation for siting of air inlets given in the table.

Table 3-9 COMFORT LEVEL IN BUILDING

Sl No.	Category	Inside Design Conditions	
		Summer	Winter
(1)	(2)	(3)	(4)
i)	Restaurants	DB 23 to 26°C RH 55 to 60%	DB 21 to 23°C RH not less than 40%
ii)	Office buildings	DB 23 to 26°C RH 50 to 60%	DB 21 to 23°C RH not less than 40%
iii)	Radio and television studios	DB 23 to 26°C RH 45 to 55%	DB 21 to 23°C RH 40 to 50%
iv)	Departmental stores	DB 23 to 26°C RH 50 to 60%	DB 21 to 23°C RH not less than 40%
v)	Hotel guest rooms	DB 23 to 26°C RH 50 to 60%	DB 23 to 24°C RH not less than 40%
vi)	Class rooms	DB 23 to 26°C RH 50 to 60%	DB 23 to 24°C RH not less than 40%
vii)	Auditoriums	DB 23 to 26°C RH 50 to 60%	DB 23 to 24°C RH not less than 40%
viii)	Recovery rooms	DB 24 to 26°C RH 45 to 55%	
ix)	Patient rooms	DB 24 to 26°C RH 45 to 55%	
x)	Operation theatres	DB 17 to 27°C RH 45 to 55%	
xi)	Museums and libraries	DB 20 to 22°C RH 40 to 55%	
xii)	Telephone terminal rooms	DB 22 to 26°C RH 40 to 50%	

CHAPTER 04: SIGNIFICANT CASE STUDIES

4.1 INTRODUCTION

The purpose of the case study is to provide a more thorough analysis of a case that might reveal interesting information about the case which is in practical world. It also helps in knowing the implementation of certain researches which has been studied. Select city walk, Delhi and Shipra mall, Ghaziabad have been selected as a live case study as they are significant to the topic. Reason behind its selection is the "popularity of these malls among the people" and hence is the leading malls in Delhi and NCR with certain energy saving measures used in them. Certain abroad cases have also been identified because of the derivation of mall culture in India from abroad where it has been popular since ages. And in energy saving aspect, many construction techniques have been used abroad. These techniques have reduced the energy consumption to certain extent.

The study of the mall has been divided into five categories:

- BUILDING PARTICULARS: It will cover the basic details about the building like site location, architects, area etc.
- PHYSICAL CHARACTERISTICS: This provides the functional information of the building and also shows the plans of the same.
- FUNCTIONAL PERFORMANCE: Here the information about the services like lifts, escalators, HVAC, lighting etc. are provided.
- ENERGY DEMAND REDUCTION STRATEGIES: In this section, various strategies of in terms of energy consumption are provided. It contains passive strategies, lighting and HVAC.
- ENERGY PERFORMANCE: Here the billing of the building and the consumption of electricity in terms of power is mentioned.

4.2 SELECT CITY WALK, SAKET

4.2.1 BUILDING PARTICULARS

SELECT CITYWALK is being situated within India's most wealthy high-end urban & multi-ethnic catchment area of South Delhi. The mall is spread over 6 acres of land. The building is oriented towards the North East.

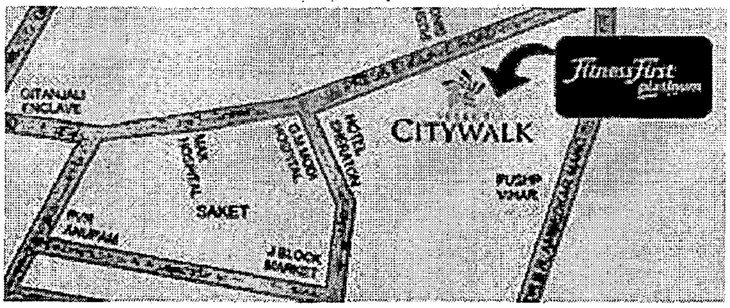


Figure 4-1 LOCATION MAP OF SELECT CITYWALK

Architects: Tevatia Chauhan and Sharma Architects (P) Ltd.

The development of the mall has a front facade of 250 m which is overlooking 100,000 sq. ft of plaza space and the pedestrian walkways extending into 4 acres of green area. There are certain other features like an open-air-theatre, water features and tree canopies; the space is imagined as a space for lively open-air activity.

The main entry to the building has been provided on the front and the two sides of the building with glazing at the upper level. Space frames have been planned at the lower level underneath the curtain glazing, which amplify the visual scale and the aesthetic demand.

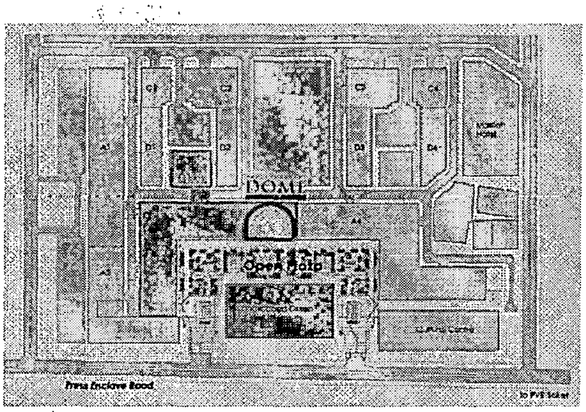


Figure 4-2 SITE PLAN OF SELECT CITYWALK

Granite bands are provided at the lower levels which has helped in making a striking bold impression on the lower shopping level and also relates itself with the mall elevation.

4.2.2 PHYSICAL CHARACTERISTICS

The physical characteristics of the building can again be categorized into:

- Site area: 2,61,360 sq.ft.
- Retail area: 4,00,000 sq ft
- Landscaped area: 1,00,000 sq ft
- Building age: 4 years
- Operating hour: 12 hours (11am to 11pm)

- Setting temperature: 24 degree

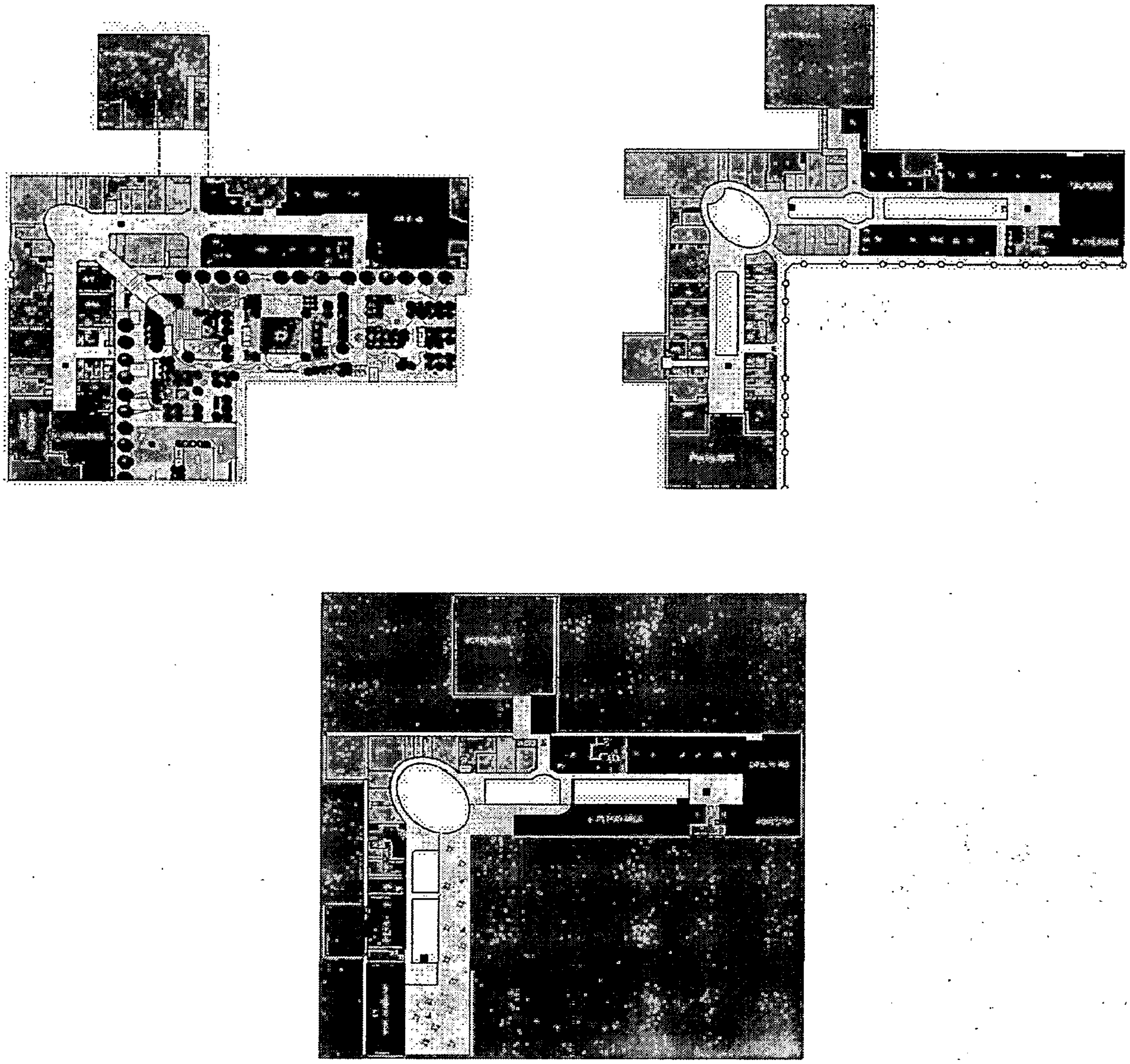


Figure 4-3 FLOOR PLANS OF SELECT CITY WALK, SAKET

Large circular cut-outs are punctuated in the atrium to break its linearity. This mall is a fully leased mall and is India's first earnings rental based model. There are 9 designated zones of shopping.

Figure 4-4 FRONT ELEVATION OF SELECT CITYWALK

4.2.3 FUNCTIONAL PERFORMANCE

The functional performance of this mall can be measured on the basis of the following:

- Building occupancy: 1,00,000 persons
- Design efficiency (%): 60 %
- No. of visitors per average day: 30,000 to 35,000 persons per day
- No. of escalators and lifts: 16 escalators & 8 lifts
- Type of main HVAC:Central air conditioning system
- Type of lighting fixtures commonly used: CFL, Halogen Lamps and cold cathode lamps for signage

4.2.4 ENERGY DEMAND REDUCTION STRATEGIES

- Passive strategies
- Lighting
- HVAC

4.2.4.1 PASSIVE STRATEGIES

- Curtain glazing on north side, a energy saving measure
- Harsh south/south west sun is dealt with by giving a buffer space
- Funneling up atriums to enable better sightlines and visibility of the shops at upper floors.
- Atrium is made up of tensile fabric Ferrari make which has resistant property of UV rays and heat. It can withstand fire for 1 hour.
- On the facades, double glass glazing is provided. 6mm powerful tinted green toughened glass on the outer face and clear toughened glass on the inner face with a 30mm thick dry cladding of granite stone.
- To reduce the heating effect through glass, solar film of 3mm thick is provided which has reduced the heat load by 85%.
- For the purpose of good insulation, light weight concrete blocks are used for the construction.
- STP of 300 cubic meters has been provided to recycle and reuse the water.

- Organic waste convertor is also provided where the waste is first segregated and then is converted into manure or resin liquid which is further used as pesticides and anti turbine

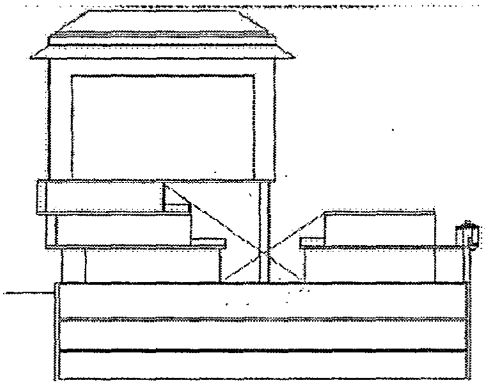


Figure 4-6 SECTION THROUGH OVAL ATRIUM

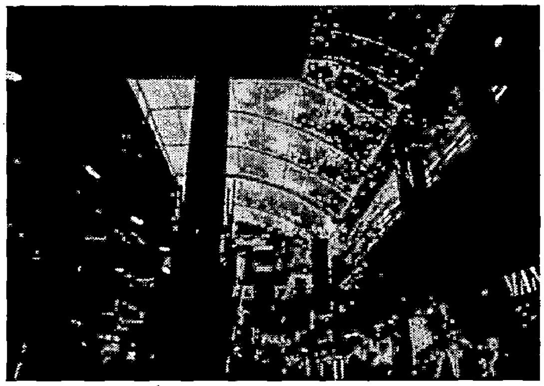


Figure 4-5 ATRIUM

4.2.4.2 LIGHTING

- The lights provided are CFL which are now in the process of replacement with LED as shown in the picture.
- Halogen lamps have been used to highlight the building façade.
- Earlier all signage's were of cold cathode lamps but now they are being replaced with LED

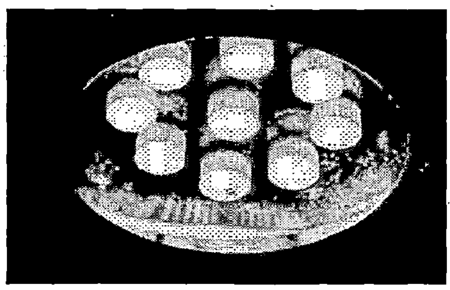


Figure 4-7 REPLACEMENT OF CFL WITH LED

4.2.4.3 HVAC

- For the energy conservation, Building Management System (BMS) is used.
- Standard temperature set within the mall is 24 degree and hence AHU stops working once this temperature is attained.
- 2400 TR of AC plants (600TR X3 and 300TR X2) which again works on auto mode.

- Variable Frequency Drive (VFD) is used for the heating and cooling purpose. In summer, its speed is 50Hz which is 100% and in winter it's been reduced to 32 Hz with the energy saving of 20%.
- The power factor of this system is 99.9 which make it an efficient system.

4.2.5 ENERGY PERFORMANCE

- Peak time for electrical consumption is May-July with the bill of 75,000 units/day.
- And generally the energy consumption is 50000-55000 units/day.
- Electricity used per unit gross floor area is 391-454 kwh/sq.mt./yr

4.2.6 LESSONS LEARNT

- The main power factor for high cooling loads is the solar radiation, which is followed by electrical appliances. The high cooling loads resulting from solar radiation often are because of the ineffective shading systems.
- Monitoring of the whole energy system is very useful to find out if the design of the building and its energy supply worked well.
- To check the performance of the equipment, its power factor should be noted and for its efficiency power factor should be 1.

4.3 SHIPRA MALL, GHAZIABAD

4.3.1 BUILDING PARTICULARS

SHIPRA MALL prides itself in being located at Indrapuram which is having the built up area of 4.5 lakh sq.ft. its architectural style is classical roman style. The building is oriented towards the North East.

Architects: Jaiswal & Associates

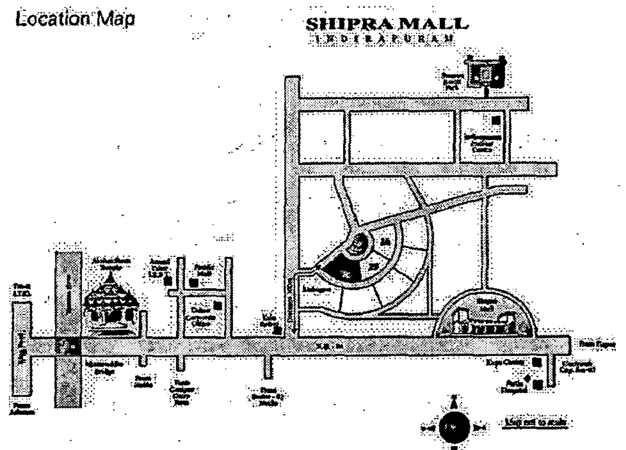
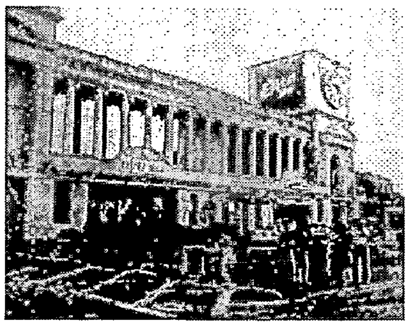


Figure 4-8 LOCATION MAP OF SHIPRA MALL

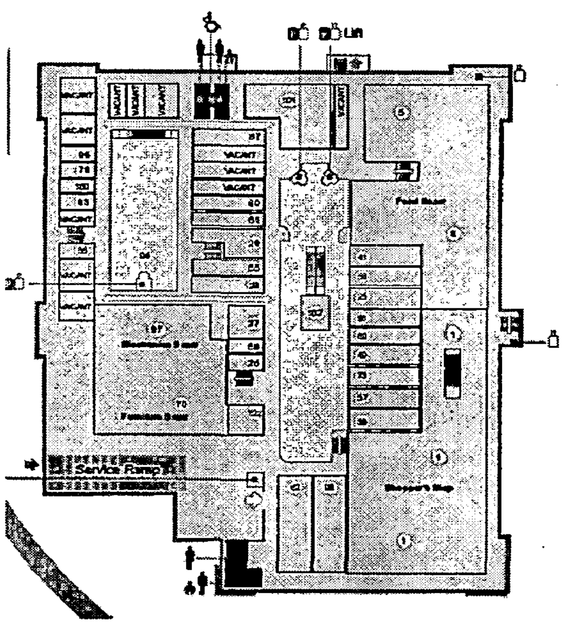


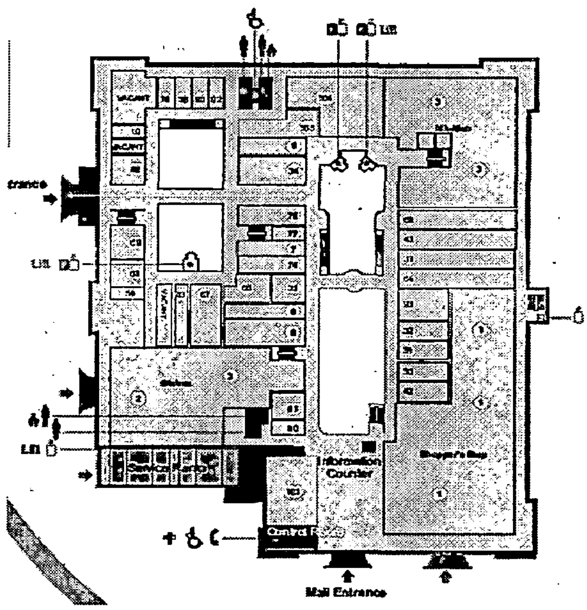
When the real domain developers were developing the village of Gurgaon into the glazed mall at that time a classical building was constructed on the land of Indirapuram. Shipra Mall was a completely unique mall than any other Delhi's glazed mall—it didn't rise vertically up but spread horizontally. Unlike other malls, this mall appears warm white in colour. The main characters of this mall are colonnade and arches which makes it unique than others.

4.3.2 PHYSICAL CHARACTERISTICS

The physical characteristics of the building can again be categorized into:

- Site area: 2,25,560 sq.ft.
- Retail area: 3,60,000 sqft
- Building age: 6 years
- Operating hour: 12 hours (11am to 11pm)
- Setting temperature: 24 degree





It has twin atriums which provide better space and visibility for retailers and free flow for shoppers.

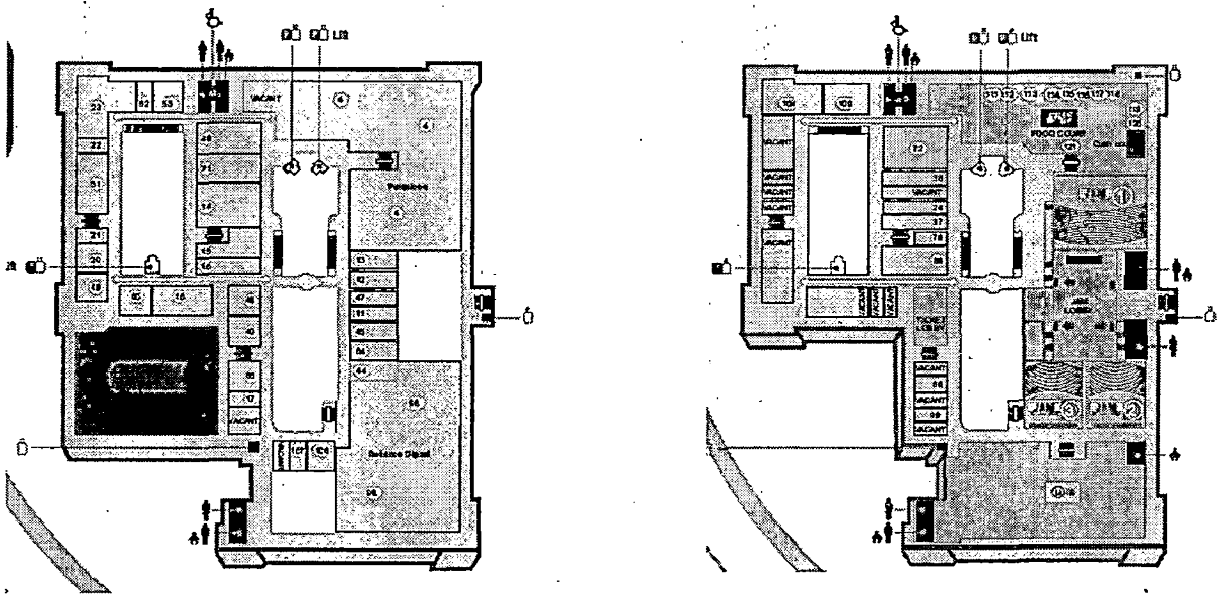


Figure 4-9 FLOOR PLANS OF SHIPRA MALL

This mall is an 80% Leased mall. It is the first and the only international standard retail cum entertainment mall.

4.3.3 FUNCTIONAL PERFORMANCE

The functional performance of this mall can be measured on the basis of the following:

- Building occupancy: 75,000 persons
- Design efficiency (%): 75 %
- No. of visitors per average day: 29,000 to 32,000 persons per day
- No. of escalators and lifts: 12 escalators & 5 lifts
- Type of main HVAC:Central air conditioning system
- Type of lighting fixtures commonly used: Halogen Lamps, flood lights, metal halide lamps, high pressure sodium lamps, LED's and cold cathode lamps for signage

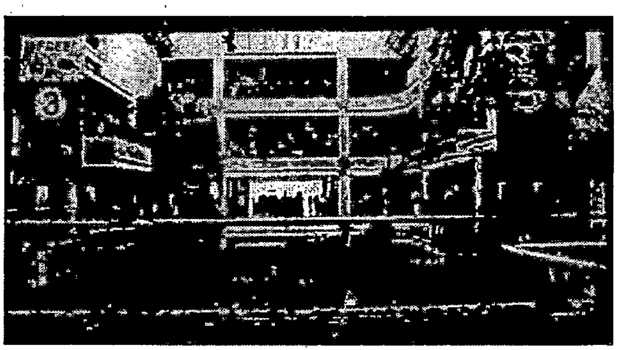


Figure 4-10 VIEW THROUGH CENTRAL ATRIUM

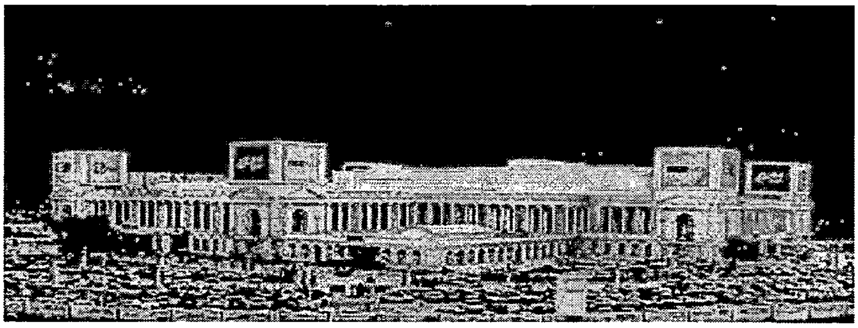


Figure 4-11 VIEW OF SHIPRA MALL

4.3.4 ENERGY DEMAND REDUCTION STRATEGIES

- Passive strategies
- Lighting
- HVAC

4.3.4.1 PASSIVE STRATEGIES

- The walls of the structure reduces heat load by 20 per cent.
- This is a double-layered high performance glass. The glass cuts down the heat radiation by 83%– thereby reducing energy consumption and the related pollution.
- Atrium roof adds to the energy efficiency with a transparent polycarbonate sheet. The polycarbonate panels allow the natural light to filter through but restrict thermal and ultra-violet radiation.
- Because of two atriums and designing of space, 50% of daylight is achieved in almost all the retail shops.
- The shading provided on the outer corridors cuts the harsh south solar radiation.

4.3.4.2 LIGHTING

Lighting has always played an important role in architecture and in mall also it plays a very important role; it fulfills the requirement of both client and designer. Lighting load is 5-7W/sq.ft.

- Halogen lamps have been used to highlight the building façade.
- There are many street lights and two flood lights.

- Corridors have been provided with the false ceiling lighting which contributes to the physical comfort of the people. And the provision of certain lighting control also offers the flexibility and energy management.
- The various lighting fixtures used for the atrium are as follows
  - Downlight Metal Halide lamps
  - There are 14 floodlight luminaires
  - L.E.D fixtures used in shops

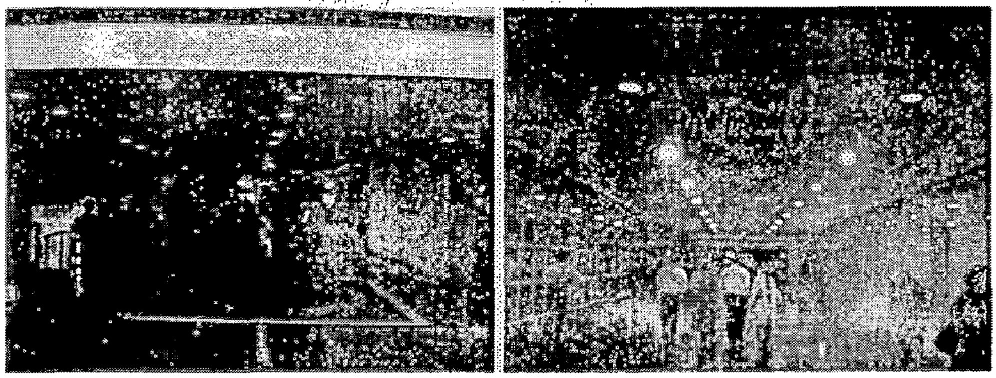


Figure 4-12 LIGHTING AT ENTRY LEVEL

- In the center, a combination of metal halide and high-pressure sodium lamps has been used.
- For the signage's cold cathode lamps in shopping mall shops are used.

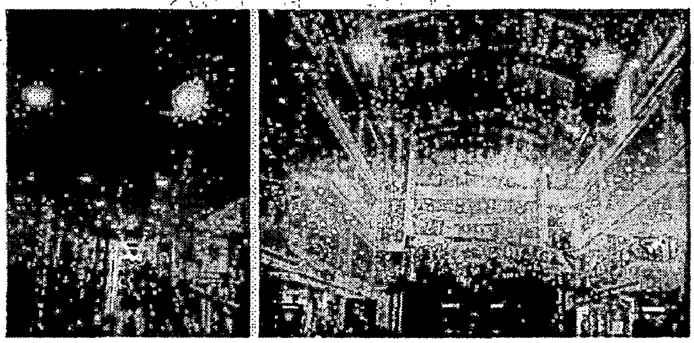


Figure 4-13 INTERIOR LIGHTING OF SHIPRA MALL

4.3.4.3 HVAC

- For the energy conservation, Building Management System (BMS) is used.
- VAM system is used for HVAC which in the recovery of waste heat to regenerate the electricity for running the generator. This system uses diesels and fuel gas hence its usage has reduced a lot.
- In chiller motors, VFD is provided which helps in the reduction of cost of installation.

4.3.5 ENERGY PERFORMANCE

- Peak time for electrical consumption is May-July with the bill of 60,000 units/day.
- And generally the energy consumption is 45000-50000 units/day.
- Electricity used per unit gross area is 231 KWh/sq.mt/yr.

4.3.6 LESSONS LEARNT

- Exposed thermal mass in the wall store heat during the day and release it during the night.
- The main influence factor for high cooling loads is the solar radiation, followed by electrical appliances. The high cooling loads resulting from solar radiation often are because of the ineffective shading systems.

4.4 CASE STUDY: ABAD NUCLEUS MALL, KOCHI

4.4.1 BUILDING PARTICULARS

ABAD NUCLEUS MALL is located in the South end of the Kochi metro along the NH 47 and NH 49 at Maradu. As it lies in the southern entry points which are adjacent to the districts like Allepy and Kottayam, it plays an essential role in the urban development of the Kochi metro towards the south end.

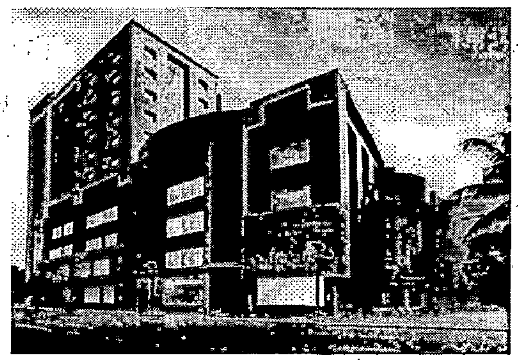


Figure 4-14 VIEW OF ABAD NUCLEUS MALL

Architects: ABAD Architects

This is the first mall of its kind which is an environment friendly green. Other than saving the energy and cooling load it also helps in bringing the nature close to the human by providing green space and natural lighting to the visitors. The energy consultants for this mall was En3 (Engineering, Energy and Environment) who has done ground-breaking work to achieve its LEED CS GOLD certification from the Indian Green Building Council and making it the first mall in Kerala to be certified Green.

4.4.2 PHYSICAL CHARACTERISTICS

The physical characteristics of the building can again be categorized into:

- Built up area: 2,50,000 sq.ft.
- Owner: ABAD Builders
- Green Consultant: En3 Sustainability Solutions
- Building age: 8 months
- Operating hour: 12 hours (11am to 11pm)
- Orientation: North-East

4.4.3 FUNCTIONAL PERFORMANCE

The functional performance of this mall can be measured on the basis of the following:

- Building occupancy: 60,000 persons
- Design efficiency (%): 90 %
- Total Retail Area: 2,30,000 sq.ft.
- No. of visitors per average day: 30,000 to 35,000 persons per day
- No. of escalators and lifts: 8 escalators & 5 lifts
- Type of main HVAC: Central air conditioning system with high COP water cooled chillers
- Type of lighting fixtures commonly used: T-5 and LED fixtures to conserve energy

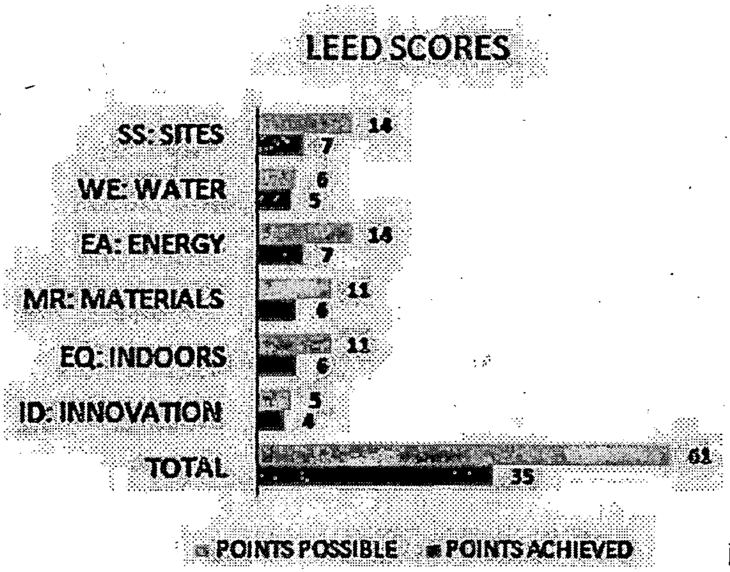


Figure 4-15 LEED SCORE OF THE MALL

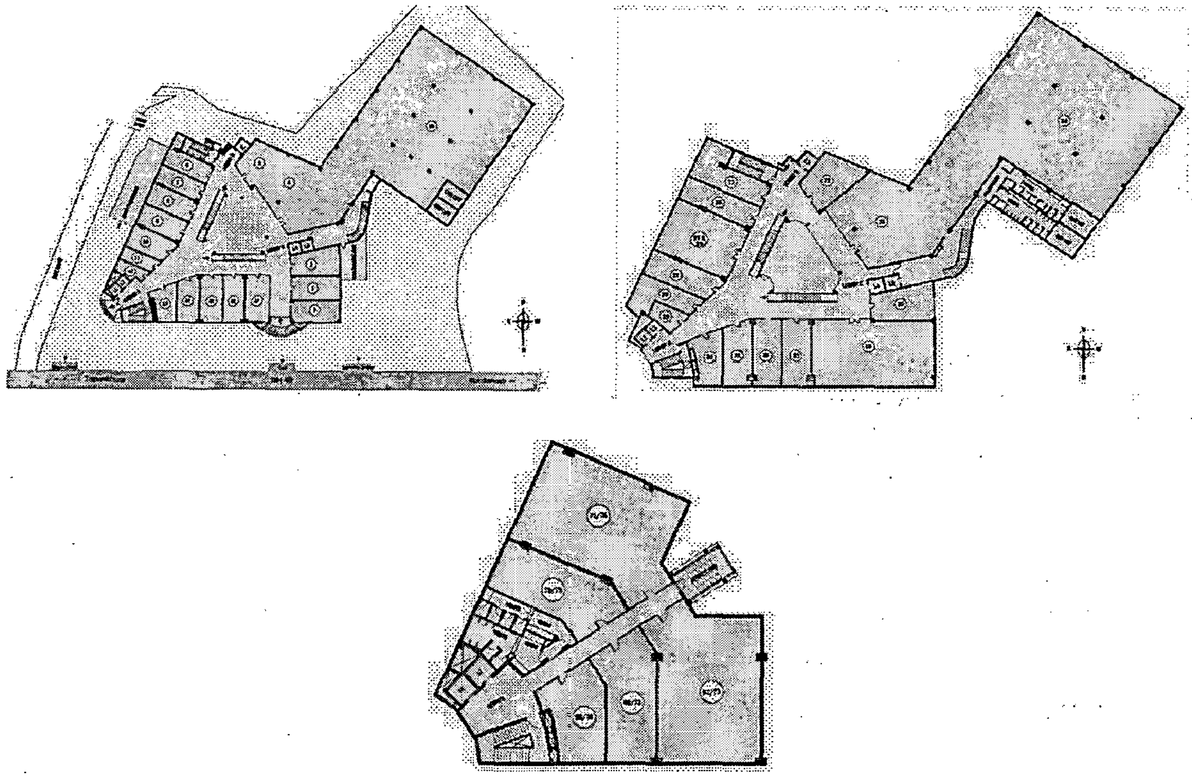


Figure 4-16 FLOOR PLANS OF ABAD NUCLEUS MALL

4.4.4 DEMAND REDUCTION STRATEGIES

- Passive strategies (Site sustainability)
- Lighting
- HVAC

4.4.4.1 PASSIVE STRATEGIES

- Provision of reflective roof and under deck insulation.
- Impressive central atrium with skylight to let the natural light enters into the mall.
- Store facades are provided with toughened glazing with patch fittings.
- To reduce the heating and the cooling load, ACP/ Structural glazing are provided on the exterior facades.
- The glazing is oriented and placed in such a manner that it helps in the saving of energy.
- Site Sustainability features:
  - The location of the mall is an ideal location as it lies close to the public transportation which helps in reducing the pollution from transports.

- Provision of a large open area as the parking of the car on ground are covered which also helps in reducing the local heat island effect.

4.4.4.2 LIGHTING

- The lights provided are T-5, CFL and LEDs which conserves as much amount of energy as possible.

4.4.4.3 HVAC

- Usage of the environmentally friendly refrigerant and the one which has very low ozone depleting and global warming potential.
- Provision of BEMS to keep a check on the functionality of the building systems.
- Before the implementation of this mall, a detailed analysis in terms of the energy and modeling has been done to determine a variety of options for saving energy with analysis of payback period and systems which have been selected based on life cycle cost benefit analysis.
- High Coefficient of Performance (COP) 900 TR water cooled chillers.
- Variable Frequency Drive (VFD) is used for secondary pumps and Air Handling Units (AHUs).
- Central Exhaust system in toilets for ventilation.
- 36 TR of fresh air system through Heat Recovery units to pre-cool fresh air and reduce HVAC loads with proper maintenance of superior air quality.

4.4.5 ENERGY PERFORMANCE

- Reduction in the energy consumption by 30% through these measures.
- By scoring 35 points out of 61, this mall has achieved Gold certification through Indian Green Building Council (IGBC).
- The consumption of water has reduced by over 51.79%.

4.4.6 LESSONS LEARNT

- An intricate metering and monitoring system that is BEMS is necessary to keep a check on the functioning of the mall's equipment so that in any discrepancies suitable measures can be taken to ensure its continuous functioning without disturbing the performance of the mall.

- To enhance the fresh atmosphere within the mall, extra amount of fresh air has to be provided.

4.5 CHADSTONE SHOPPING CENTRE, MELBOURNE, AUSTRALIA

Chadstone mall of Australia opened in 1960 draws its inspiration from suburban malls that were opened in America after world war II. This mall indicates a paradigm shift from the traditional individual storefront districts to the contemporary shopping centre model. With changing times, Chadstone has undergone refinement in design and retail planning. 1983 marked the first augmentation where original enclosure size of this open air mall was doubled for future expansion.

4.5.1 BUILDING PARTICULARS

Chadstone mall is spread around 1.45 million sq. ft. After 1990, the mall has been renamed as New Chadstone due to several renovations and incorporation of new designs focusing on classic and elegant interiors along with column-free, two-level grand skylight dome encompassing three interconnected, glass vaulted roofs.

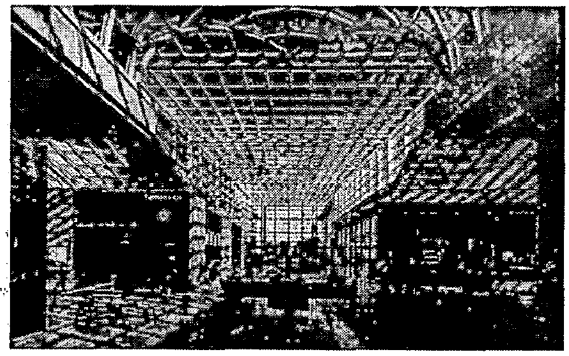


Figure 4-17 DAYLIGHT THROUGH SKYLIGHT

The departmental stores in the mall are well light from natural daylight as the roof is made of sweeping wave of glass as shown in the picture.

Due to its efficient design, Chadstone is the First mall in Australia to be certified a 5-star by the Green Building Council Shopping Centre Design rating system. Fine-spun landscaping along with bronze and stone detailing boasts the beauty and adds a unique architectural individuality to the entrance of the mall.

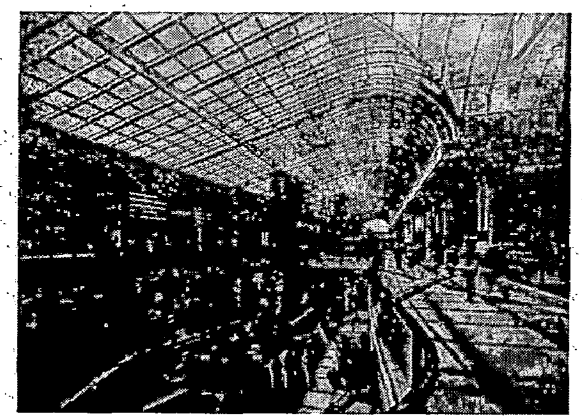


Figure 4-18 VIEW OF THE SKYLIGHT

4.5.2 ENERGY DEMEND REDUCTION STRATEGIES

Several measures are taken to attain energy and water savings which include:

- Use of energy- efficient lighting systems, installation of single air conditioning units for each unit, low flow water fixtures and employing rain sensors all of which have helped to reduce the water usage by 14%.
- Employing Daylight harvesting and proper water utilization due to low water fixtures have reduced the operating cost of mall significantly and it also provides good lighting in the mall.

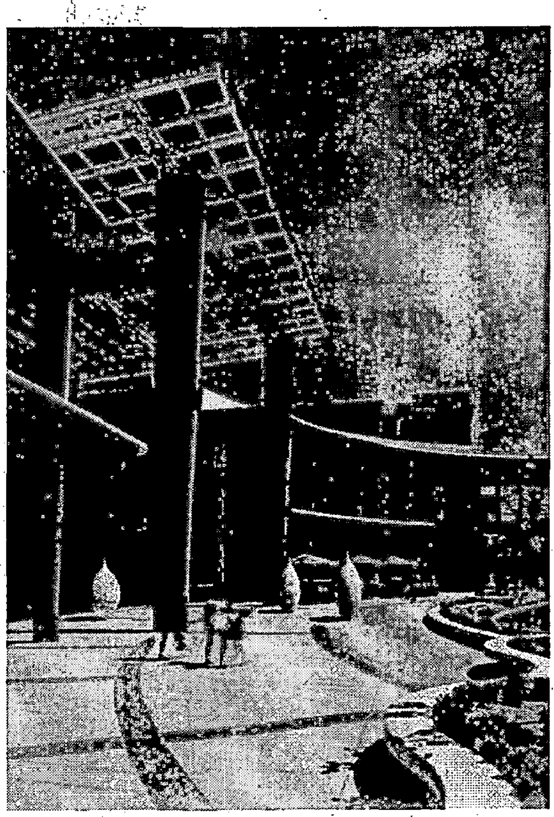


Figure 4-19 EXTERNAL SHADING

- Utilizing highly efficient heating and cooling system along with:
  - Hot layer removal and night purging systems.
  - Variable volume air handling plant
  - High efficiency central plant
- Using Low energy artificial lighting system with:
  - LED lighting throughout the mall
  - Utilizing Daylight and occupancy sensor lighting control
- The Indoor environment quality is maintained by:
  - Employing measures to circulate increased outside air which is delivered to the building and installation of carbon dioxide sensors to increase the outside air quantities further during peak occupancy.
  - Naturally lit mall spaces to enhance the quality of indoor environment and reduce power consumption of artificial lighting.
  - Composite wood products, Carpets and Paints, are selected in such a way that off-gassing is minimized.
- Emissions are minimizes by using:
  - Air conditioning and refrigeration systems that are selected with Zero Ozone Depleting Potential (ODP) refrigerant

- Using insulation products that are not manufactured by processes destroying Ozone layer.
- Reducing sewerage emissions through high efficiency fittings and fixtures

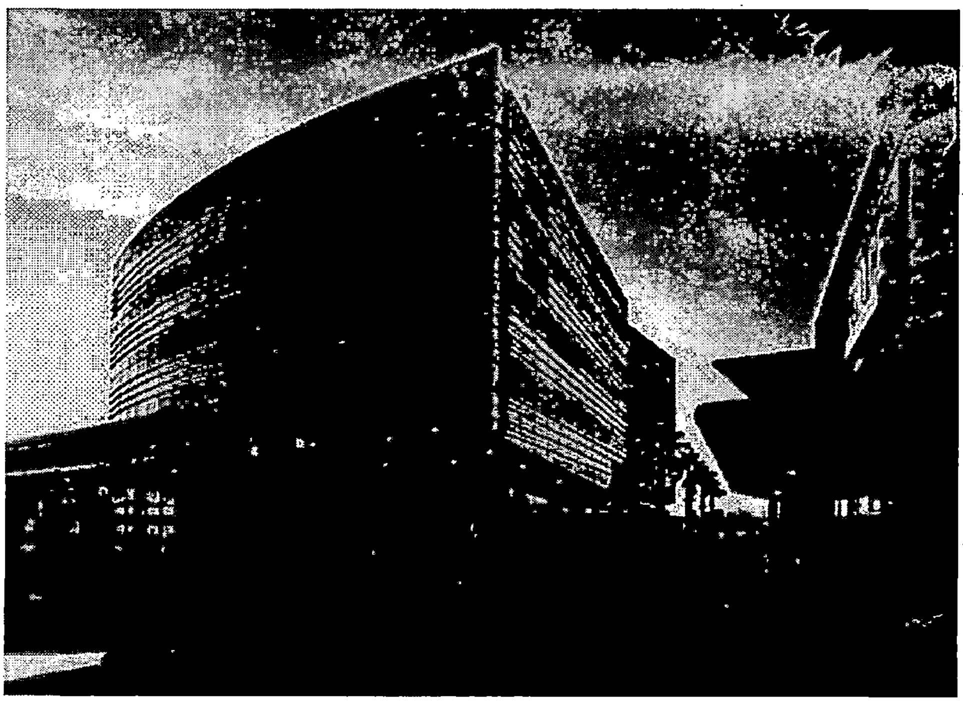
4.5.3 ENERGY PERFORMANCE

61% reduction in greenhouse gas emissions was achieved by using energy efficient measures in this mall which is equal to 3200 tonnes of CO_2/year. Also 63% reduction in water was achieved which saved 13 million liters of water every year.

4.5.4 LESSONS LEARNT

The operation of the building is of high satisfaction.

- To get an optimal daylight utilization sensor controlled shading devices and lighting system are very efficient.
- To get high air quality in the rooms a ventilation system controlled by CO_2 sensors is very useful.
- The main influence factor for high cooling loads is the solar radiation, followed by electrical appliances. The high cooling loads resulting from solar radiation are because of the ineffective shading systems.
- The investment costs for the passive cooling measures are about 50% lower than the investment costs for a chiller.



4.6 SUMMARY

From these case studies following things are observed:

- Shopping malls are very much aware about efficiency within it from very beginning like that of Shipra mall and Abad Nucleus mall. These malls had been designed by considering the efficiency in mind.
- But certain malls like select Citywalk have been designed by considering the aesthetic only. Though the incorporation of efficient fixtures has been going on but it is not that easy as options are many and buildings have inherent limitations.
- Hence the energy auditing of the building is required which helps in identifying the energy use among the various services and then the opportunities to manage them.

This has been explained in the next chapter where "Gurgaon Central Mall" has been taken as the study area to check its energy consumption.

CHAPTER 05. STUDY AREA: GURGAON CENTRAL MALL

5.1 GENERAL

The purpose of this study area is to check the energy auditing of this mall. The audit will produce the data which will help in understanding the energy management and the options available for reducing the energy and increase in its efficiency. The main goal of this auditing is to identify the various options and strategies which will be made on the basis of the results obtained. By applying different options in terms of lightings, HVAC and glazing, the overall energy consumption can be reduced and hence it will reduce the overall CO_2 emission. And by decreasing the CO_2 emission, the building can be made energy efficient. In the following topics, the study area i.e. Gurgaon Central Mall has been studied and its energy performance is checked with its existing services in terms of lighting and HVAC.

5.2 GURGAON CENTRAL MALL, GURGAON

The study of the mall has been divided into five categories:

- Building particulars
- Physical characteristics
- Functional performance
- Energy demand reduction strategies
- Energy performance

5.2.1 BUILDING PARTICULARS

GURGAON CENTRAL MALL is located at Mehrauli- Gurgaon road along the NH 8 at Gurgaon Sector-25 having coordinates 28°28'46"N 77°4'32"E. It is very well connected to metro link. The nearest metro station is MG Road metro station. It's a mall without doors .

Figure 5-1 VIEW OF GURGAON CENTRAL MALL

Architects: Sikka Associates Architects

5.2.2 PHYSICAL CHARACTERISTICS

The physical characteristics of the building can again be categorized into:

- Site area: 65,340 sq.ft.
- Owner: Unitech
- Building age: 6 years
- Operating hour: 12 hours (11am to 11pm)
- Orientation: North-South
- Setting temperature: 23 degree
- Wind speed: 169 kmph

5.2.3 FUNCTIONAL PERFORMANCE

The functional performance of this mall can be measured on the basis of the following:

- Building occupancy: 20,000 persons
- Design efficiency (%): 60%
- Total Retail Area: 1, 02,727 sq.ft.
- No. of visitors per average day: 4,000-5,000 persons per day
- No. of escalators and lifts: 8 escalators & 3 lifts
- Type of main HVAC: Central chilled water system with screw water chiller
- Type of lighting fixtures commonly used: CFL and T-8 fixtures inside the mall. Halogen lamps in exterior façade.

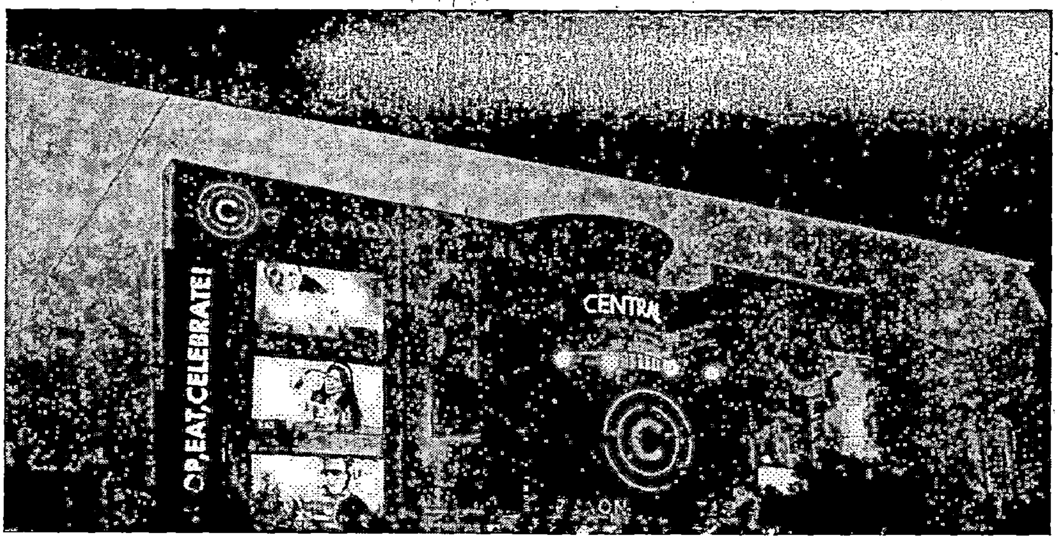


Figure 5-2 FRONT VIEW OF MALL

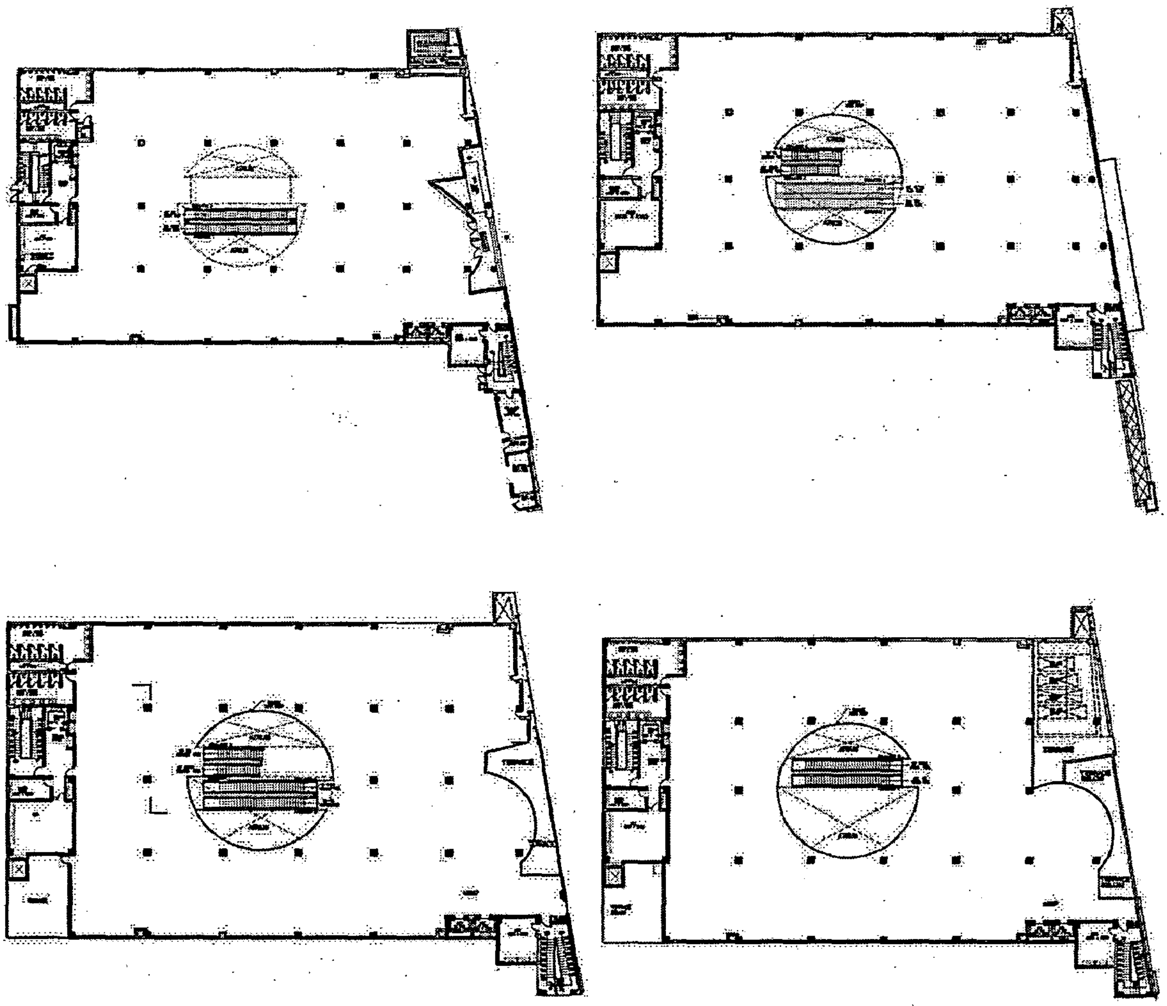


Figure 5-3 FLOOR PLANS OF GURGAON CENTRAL MALL

5.2.4 ENERGY DEMAND REDUCTION STRATEGIES

- Passive strategies
- Lighting
- HVAC

5.2.4.1 PASSIVE STRATEGIES

- Provision of central atrium for maximizing the usage of natural light. But it is not that large enough to allow a large amount of daylight enter into the mall.
- Orientation of the building is improper, as the major façade is along North-South axis.
- Buffer spaces like toilets and staircases are located along North faced which is an inappropriate location.

- Maximum opening should be on North- South facades. But here, the openings/ glazing are along East- West façade.
- For natural lighting, toughened glass is provided in skylight.
- Placement of escalator is in such a manner that one can have a view of all the direction.
- All windows have heat reflecting Single glass in air tight frames with the provision of 3mm solar film layer on the glass of rotunda to reduce the heating effect.
- Exposed roof is insulated with 50mm thick expanded polystyrene.

5.2.4.2 LIGHTING

- Inside the mall, the lightings provided are T-5 lamps and CFL fixtures.
- For decorative poles on the exterior façade, metal halide lamps are used.
- In the central atrium, 16 focus lights with CDM-T of 150w are provided.
- For exterior signage's, halogen lamps are used and for the signage's inside the mall, fluorescent fixtures are used.

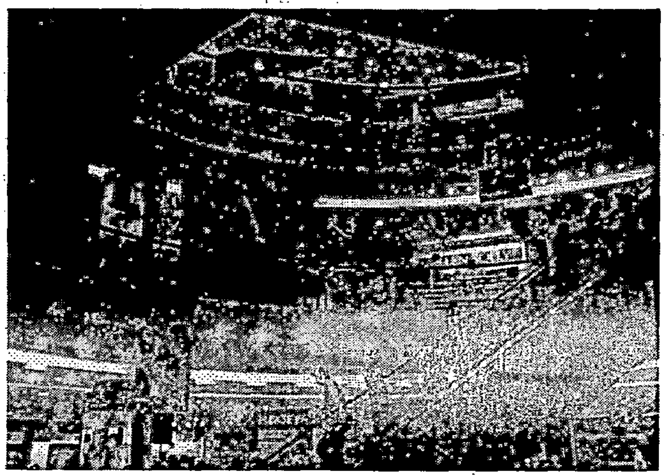
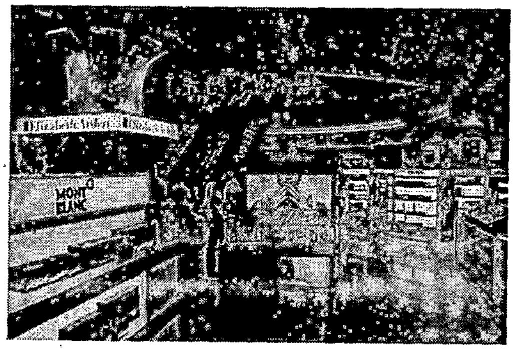


Figure 5-4 LIGHTING IN GURGAON CENTRAL MALL

- On ground floor, approximately 104 recessed lights with CFL fixtures of 26w and 18w are provided. Barista shop has used 13 CFL.
- 442 T-5 fluorescent tubes of 70w are used for cove lighting, display lighting and for signage on ground floor.
- On first floor, 512 T-5 fluorescent tubes of 70w and 104 CFL fixtures are used. Planet M has used 13 CFL.
- On second floor, 485 T-5 fluorescent tubes of 70w and 116 CFL fixtures are used.

- On third floor, 519 T-5 fluorescent tubes of 70w are used. 20 lamps, with 6 fittings in each makes 120 lamps of 35w, are used.
- On fourth floor, 9T-5 fluorescent tubes of 70w and 455 CFL fixtures of 26w are used. 45 fittings of 18w CFL are also used on this floor.
- In all the basements, 36w fluorescent tubes are provided.

5.2.4.3 HVAC



- Usage of highly responsive control system (BMS) to optimize system functioning and energy conservation.
- 3 Water cooled chillers with screw compressors of 150 TR each cooling capacity with the total capacity of 450 TR.
- There are 3 cooling tower of 175 TR capacity along with 4 matching condenser water pumps to increase the pressure of the water.
- 100% fresh air is used for air conditioning.
- Heat recovery Units (HRU) has been installed via which fresh air is introduced through fresh air ducts. The HRU uses the exhaust air of the building to pre-cool the fresh air requirements.
- The recovery is approx. 80%. Hence, the AC load of fresh air reduces by 80% and the total load reduces by approx. 10%.
- For energy saving, Variable frequency drives (VFD) has been used along with the aluminum glass wool to meet the cooling demand.
- In case of basements, axial fans are used to exhaust the air through the shafts.
- The power factor of this system is 96-97 to makes it an efficient system.
- The water requirements of the Cooling Towers are met by passing the Treated Domestic Water through a Water Softening Plant and storing it in an Underground Soft Water Tank. Water from this tank is transferred to an overhead Soft Water Tank of 30,000 Liters located at the terrace level. From this overhead Soft Water Tank water is fed to the Cooling Towers located at the Terrace level by gravity.
- With the provision of above mentioned control system, the AC load of fresh air reduced by 80% and the total load reduced by approx. 10%.

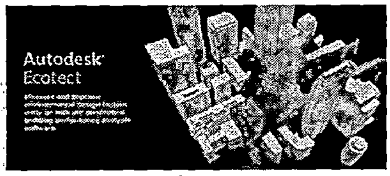
5.2.5 ENERGY PERFORMANCE

- Peak time for electrical consumption is May-July with the bill of 3, 00,000 units/day.
- And generally the energy consumption is 1, 80,000-2, 00,000 units/day.
- Electricity used per unit gross floor area is 195 KWh/sq.mt./yr

5.3 TOOLS AND TECHNIQUES

5.3.1 SIMULATION TOOLS

In order to perform the activity of energy auditing of Gurgaon Central Mall, two softwares have been used: Design Builder simulation and Ecotect software.



5.3.1.1 DESIGN BUILDER

Design builder is an energy modeling software which helps in rapid building modeling. As shown in the figure 5-5 below, certain templates like building activity, construction, openings, lighting and HVAC provides various options for its modeling. This software has been selected because it computes building energy use based on the interaction of the climate, building form, internal gains, and HVAC systems. It provides a range of environmental performance data like energy consumption, CO_2 production, comfort level and HVAC component sizes. Design Builder uses Energy plus dynamic simulation engine to generate performance data. HVAC can be modeled with compact and detailed descriptions which is not available in any other energy software. Hence it provides an easy way to analyze the heating and cooling systems in a detailed manner.

The outputs which are provided by this software is the heating and cooling loads, checks the effects of design alternatives on energy consumption, CO_2 production and broken down energy consumption by fuel and end use. And the final output comes in the form of graphs and tables.

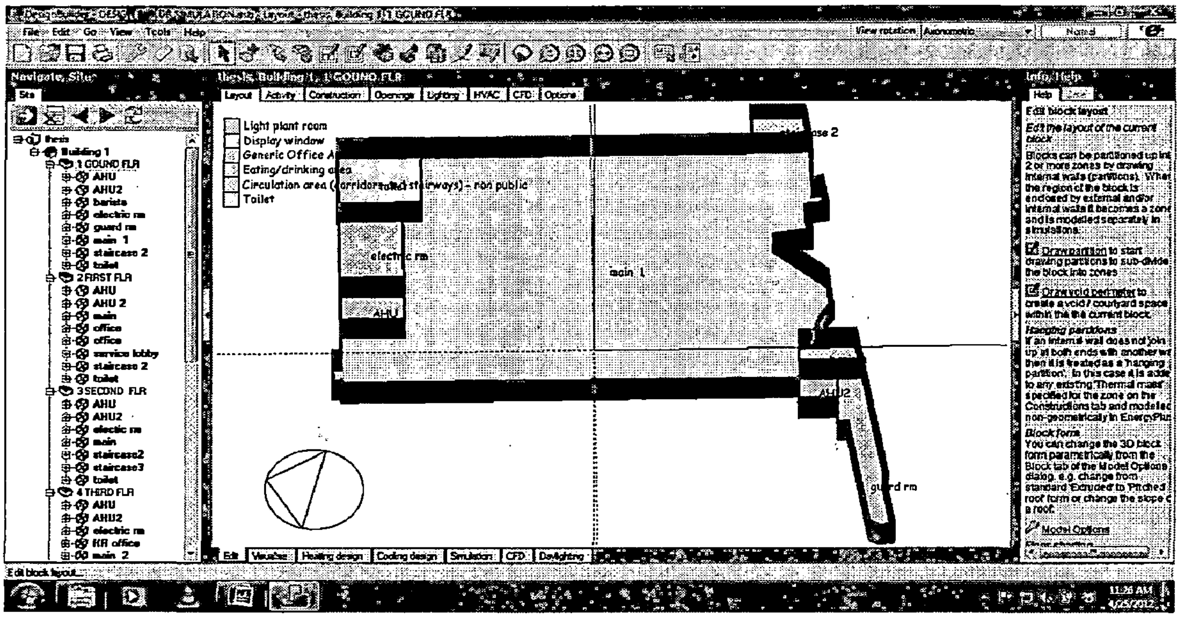


Figure 5-5 INTERFACE OF DESIGN BUILDER

5.3.1.2 ECOTECT SOFTWARE

Ecotect is software which helps the users to visualize very complex simulation data. In ECOTECT, data is presented as gradient color layers on top of 3D building geometry. Models can be rendered in a number of ways. As the data obtained is in the form of gradient color so it helps in analyzing the amount of solar gain within the building more precisely by the change in its glazing materials.

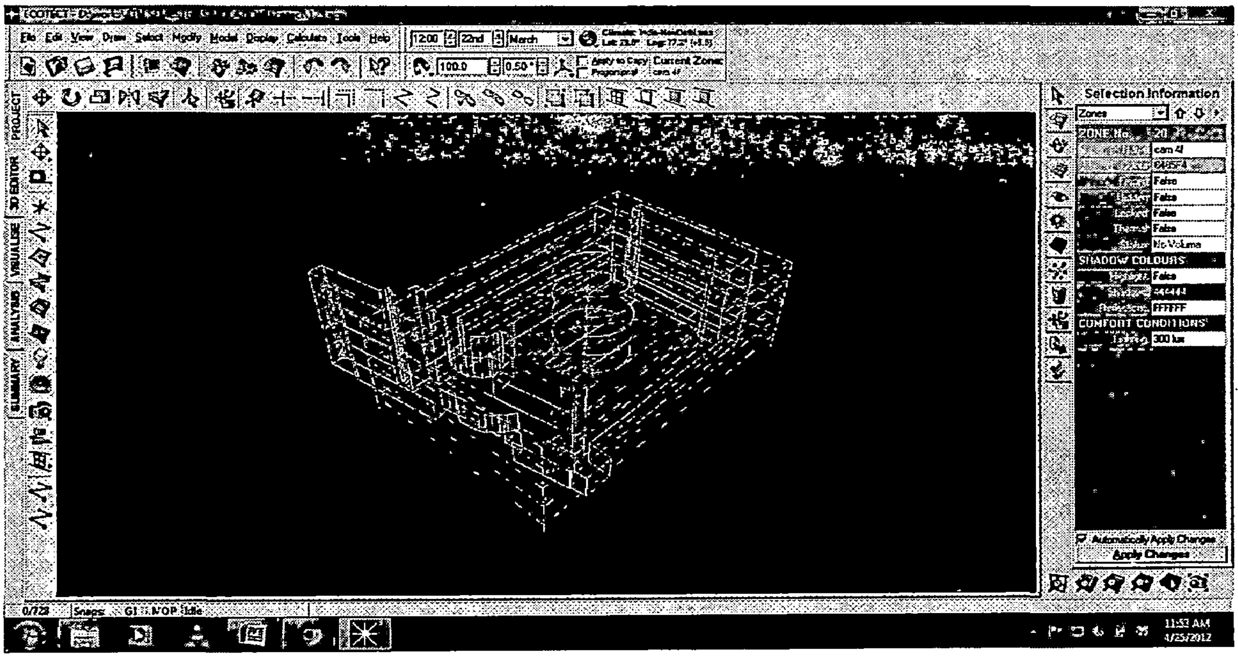


Figure 5-6 INTERFACE OF ECOTECT SOFTWARE

The drawback of this software is that it does not provide the accurate result of the modeling. And for thermal analysis, detailed HVAC is not provided as in case of Design Builder. The output from this software is shading analysis, façade insulation analysis, daylighting and solar gain analysis.

Hence Design Builder has been chosen over Ecotect for detailed analysis of Lighting and HVAC. But the daylighting has been done using Ecotect as it provides the level of lux in the building.

5.3.2 SURVEY & INTERVIEWS

Regarding the performance of the Gurgaon Central Mall, the interviews had been conducted to the operating department people. It has helped in gathering certain information which could not be observed just by looking at the mall like the electricity consumption, peak energy demand, type of chiller and its cooling capacity, general footfall of the mall etc. The working of AHU has been explained by the HVAC operating personnel. This interview session and survey conducted has provided the basic and important information which has been made the base of the research. Certain interviews were also conducted to the visitors of the mall regarding their experience in the mall. This has also helped in understanding the people's reaction and the requirement from their side in terms of visual and thermal comfort.

5.4 ENERGY MODELLING FOR BASE CASE

5.4.1 DEVELOPMENT

Before starting the simulation of the model certain assumptions have been made. These assumptions are:

- Switch from simulation on Ecotect software to Design builders because of the availability of various options.
- As the trial version of Design Builder is used where not more that 50 zones can be simulated hence zones with similar activities are merged together.
- As the software offers limited number of controls for HVAC and Lighting, so the consumption in energy using the available controls has been simulated. But, if the better controls are provided, the result will be much better.

The modeling of the cases has been divided into 3 parts on the basis of their modifications at various stages. These are: Glazing, Lighting and HVAC.

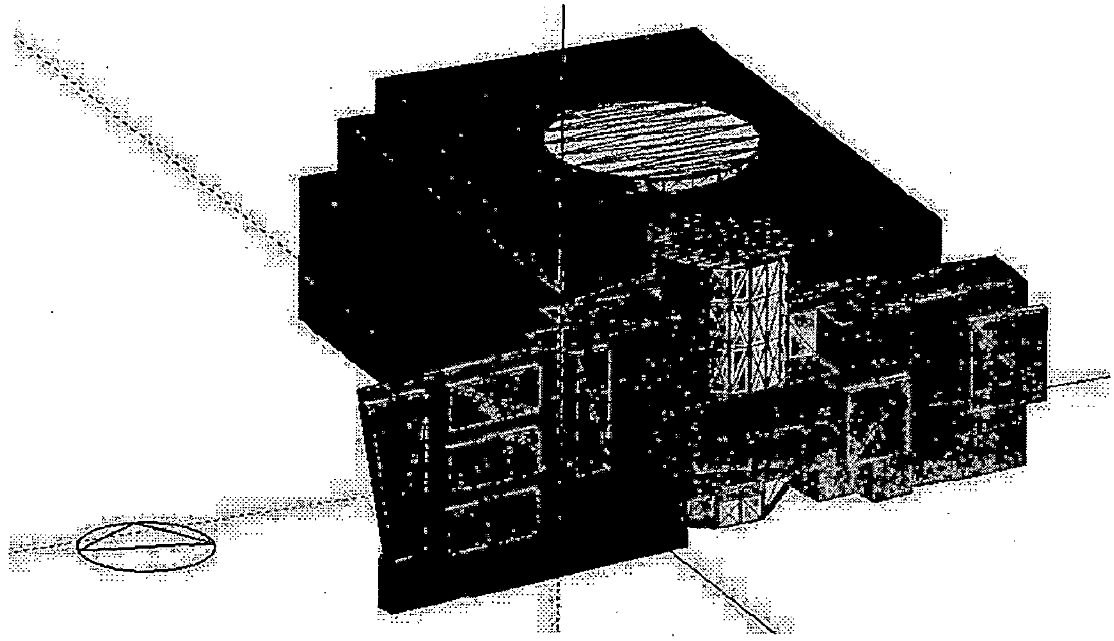


Figure 5-7 SIMULATION MODEL OF GURGAON CENTRAL MALL

5.4.2 ANALYSIS

In base model case, existing materials of the malls like in construction, lighting, HVAC and glazing has been applied.

- GLAZING: the mall has single glazing on the front façade which is 6mm clear glass. This glazing allows most of the natural light and heat into the building. The skylight provided at the top also becomes the mean of daylighting in the mall. The analysis of the daylighting through the glazing has been performed on Ecotect software as shown below.

As it can been be observed from the figures 5-8 to 5-12 that maximum area is getting the daylight which has the VLT of façade glazing as 45 and skylight as 50.

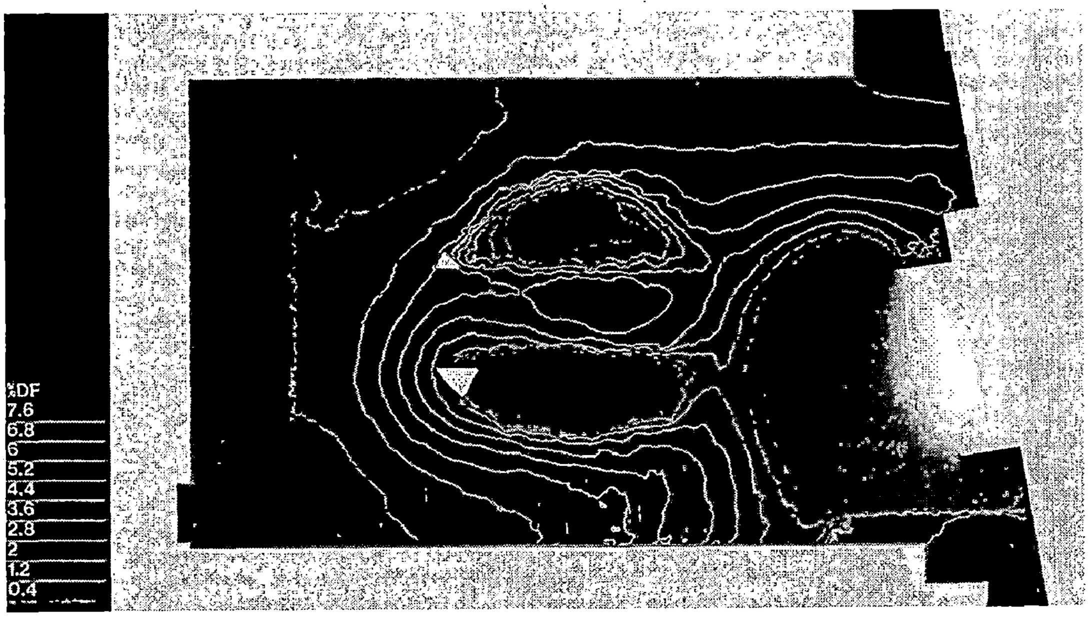


Figure 5-8 ECOTECT SIMULATION OF GROUND FLOOR PLAN

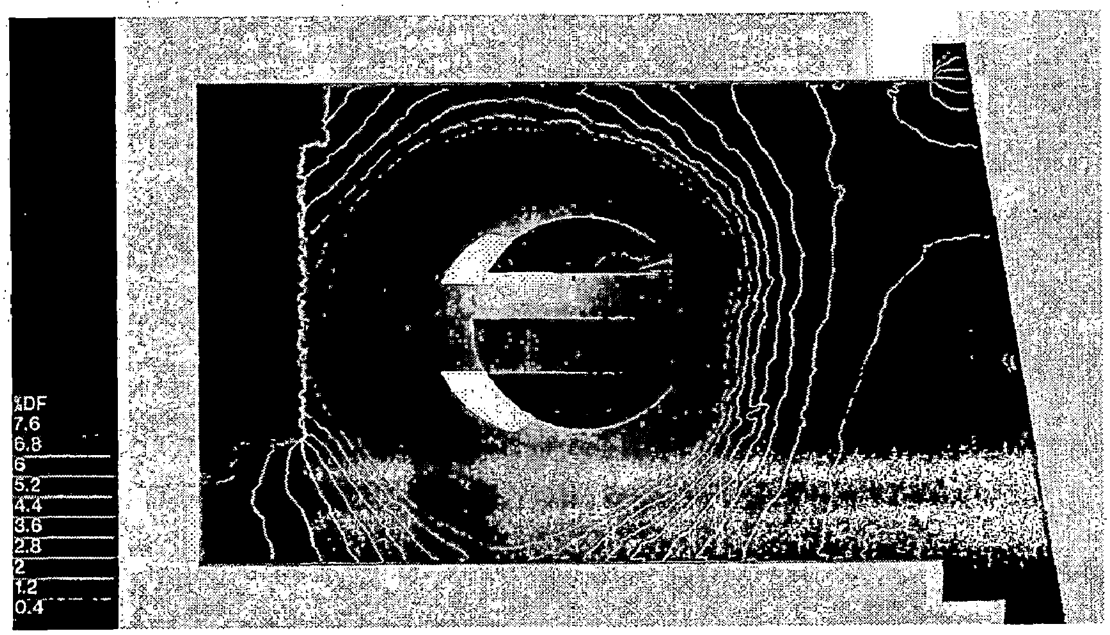


Figure 5-9 ECOTECT SIMULATION OF FIRST FLOOR PLAN

Figure 5-10 ECOTECT SIMULATION OF SECOND FLOOR PLAN

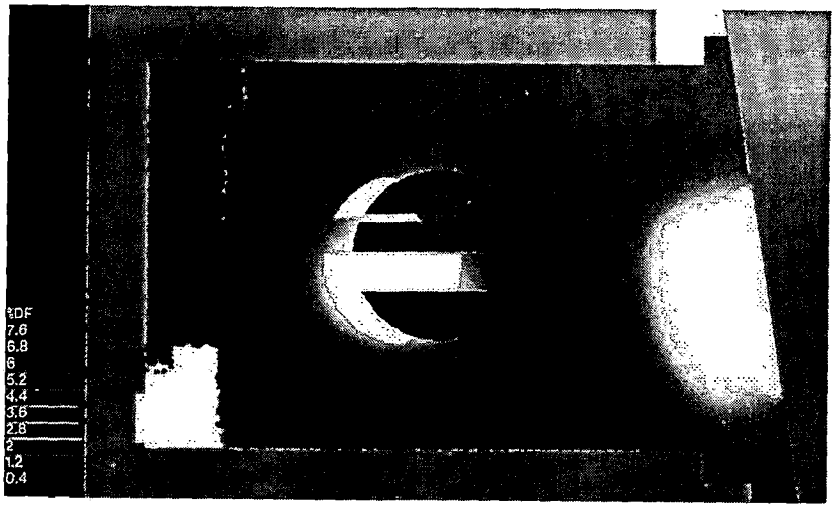


Figure 5-11 ECOTECT SIMULATION OF THIRD FLOOR PLAN

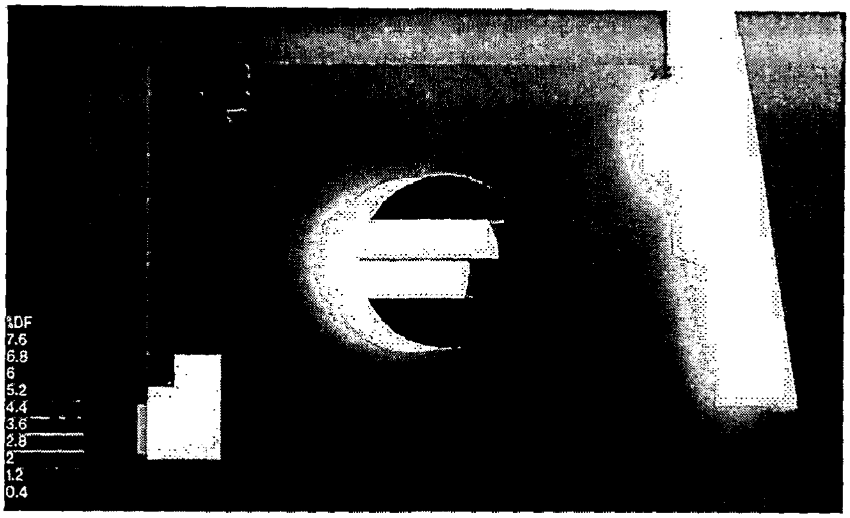


Figure 5-12 ECOTECT SIMULATION OF FOURTH FLOOR PLAN

After importing the Ecotect analysis image on the plan of the mall figure 5-13 is generated. This shows the areas which is getting sufficient daylight.

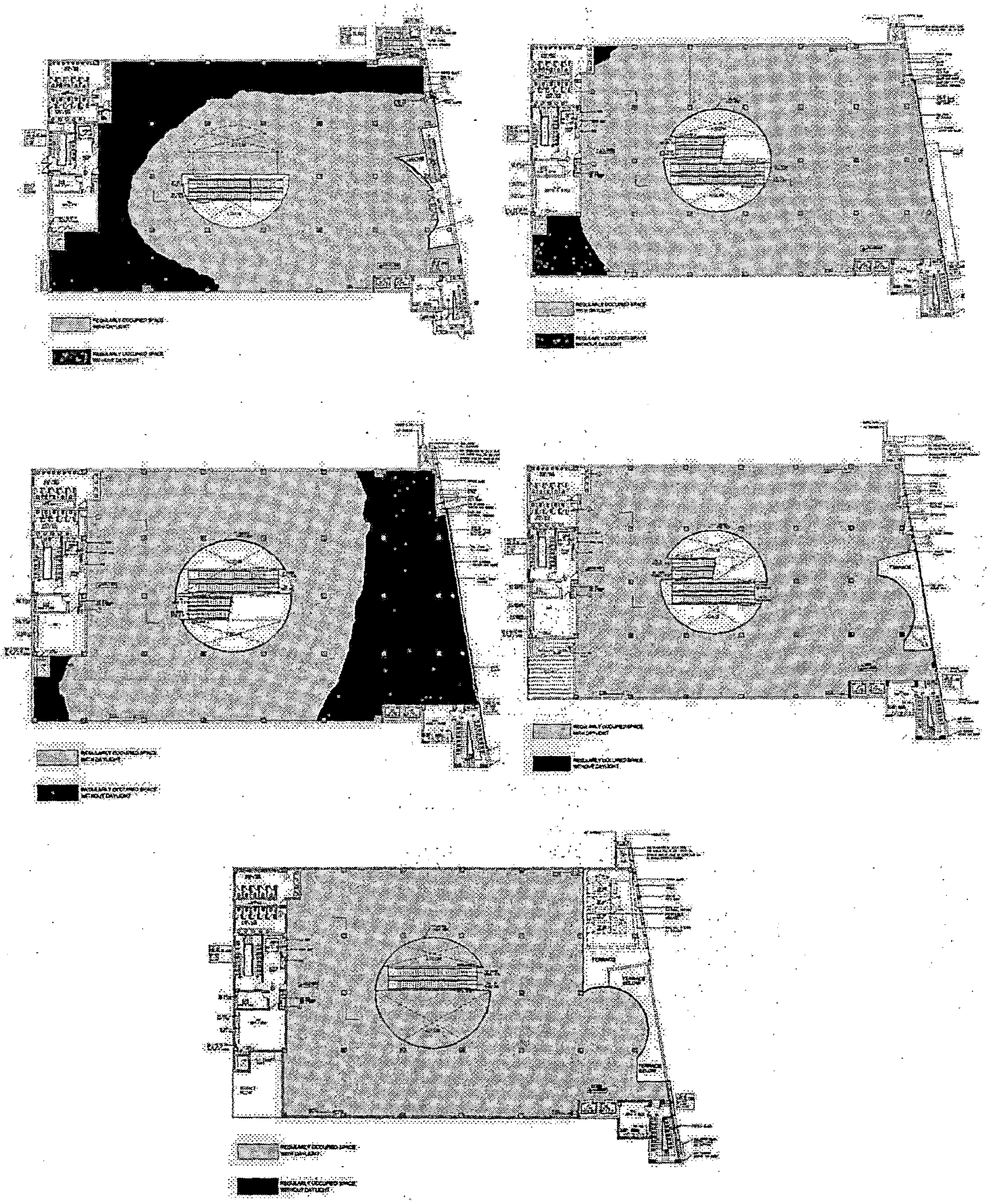


Figure 5-13 DAYLIGHTING LEVEL IN FLOOR PLANS OF GURGAON CENTRAL MALL

Table 5-1 DAYLIGHTING TOTAL TABLE

S.No.	Block	Regularly occupied area	Daylit Area	Non Daylit Area	Percentage Area Daylit
1	Ground floor	1,584	1,053	531	66.5%
2	First Floor	1,560	1,482	78	95.0%
3	Second Floor	1,564	1,078	486	68.9%
4	Third Floor	1,466	1,466	0	100.0%
5	Fourth Floor	1,491	1,491	0	100.0%
	Total	7,665	6,570	1,095	85.7%

Daylight simulation shows that 85.7% of regularly occupied areas are getting daylight levels. Hence the daylight credit is achieved.

- Lighting: As the mall is designed for extensive use of natural lighting. But besides that Compact Fluorescent lamps (CFL) and T-8 Fluorescent tubes are used. They provide energy savings as compared to incandescent lamps and T-12 Fluorescent tubes. For the display racks also T-8 lamps are provided.
- HVAC: Because of excessive solar gain from the glazing the need of HVAC arises. In this simulation, screw chillers have been provided with full fresh air intake and part load power coefficient for intake vane damper.

5.4.2.1 HEAT GAIN THROUGH LIGHTS AND WINDOWS

As the glazing provided is single clear glass hence large amount of heat gain from sun occurs. And lighting also has it CCT which also give rise to the temperature within the building. Hence, the heat gain through both the factors has been simulated as shown below. The total heat gain is 1188670 Kwh.

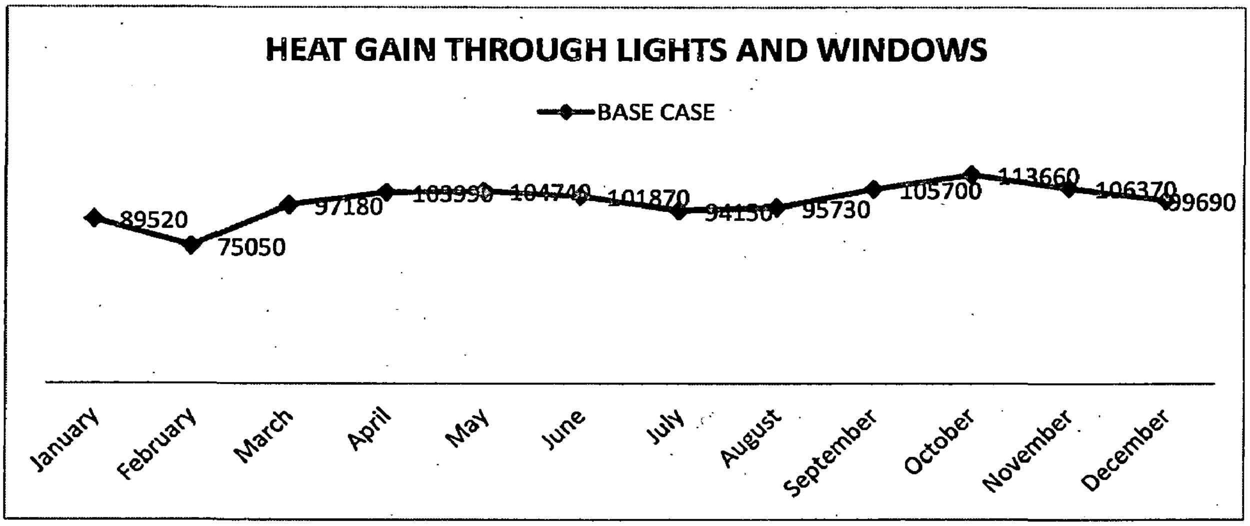


Figure 5-14 HEAT GAIN THROUGH LIGHT AND WINDOWS FOR BASE CASE

5.4.2.2 UNIT ENERGY CONSUMPTION BY HVAC

The use of the mall starts from 11am to night 11pm but the shops get open by 9am for the pre- preparation. The electric consumption of the mall is approximately 1160000 KWh per year.

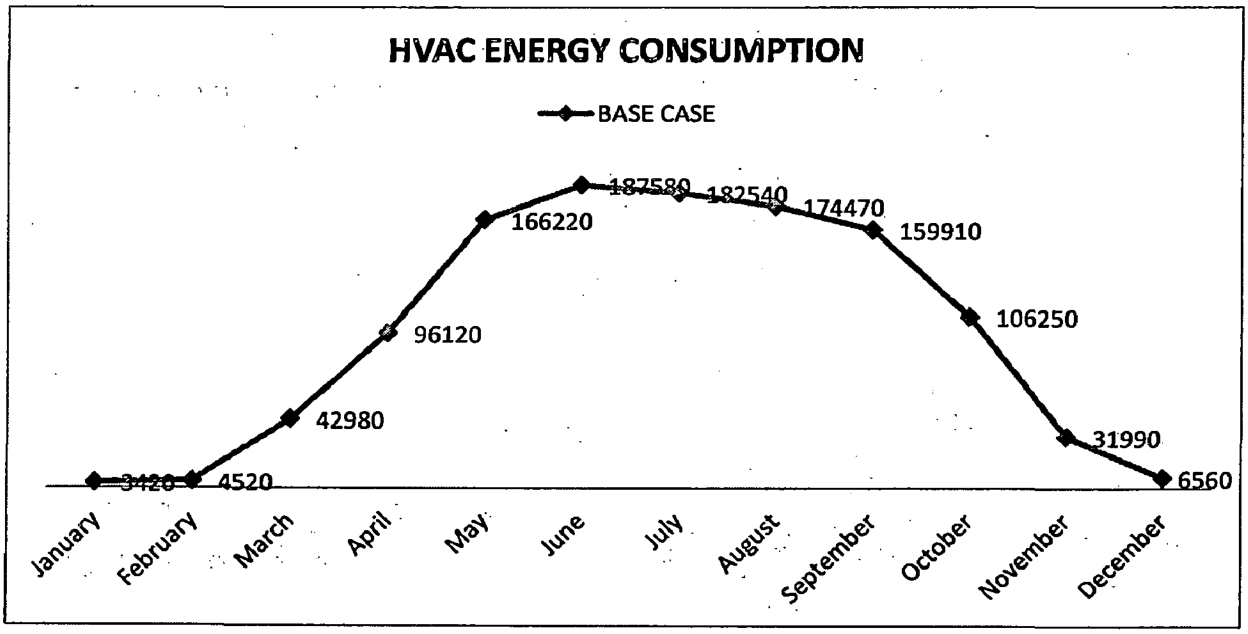


Figure 5-15 UNIT ENERGY CONSUMPTION BY HVAC

5.4.2.3 CO_2 PRODUCTION

The production if electricity emits carbon which raises the level of CO_2. The present energy requirement of the mall according to the simulation -1160000 KWh emits

1400000 kgs of CO_2. The monthly emission of CO_2 has been shown in the figure 5-16 below.

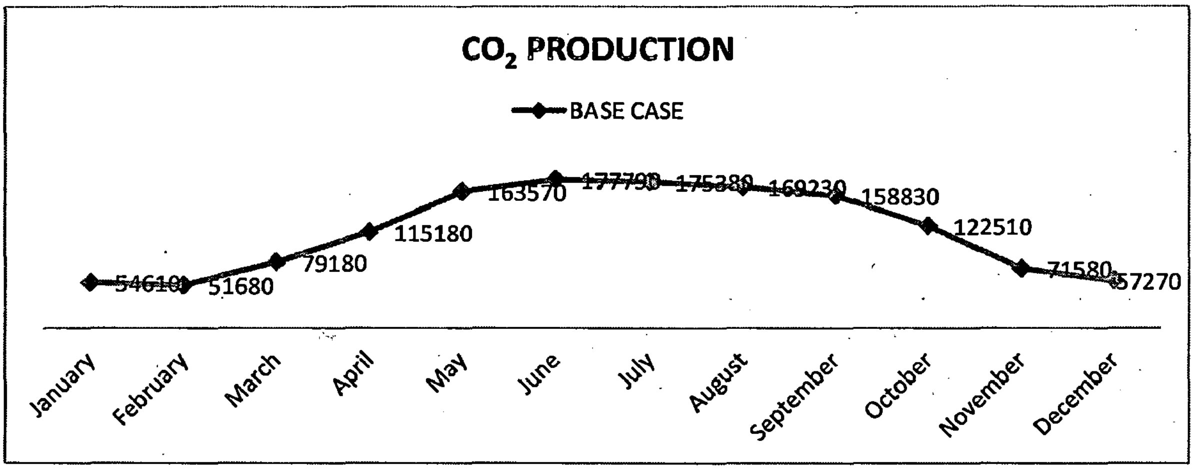


Figure 5-16 MONTHLY CO2 PRODUCTION FOR BASE CASE

5.4.3 DISCUSSION

Commercial buildings are the largest consumers of electricity and shopping mall is one of them. Most of the electricity goes in HVAC, Lighting and other services. In the base case also, following things have been observed:

- Maximum amount of daylight has been achieved within the mall through glazing and skylight.
- As the sale value of mall lies behind the lighting effect, hence maximum amount of artificial lighting has been used without any controls for them hence large consumption of electricity.
- The fixtures used are energy efficient one hence the consumption through artificial and task lighting is comparatively lesser.
- In case of HVAC also, screw chiller which is less effective has been used and hence large consumption of electricity.

5.5 SUMMARY

In the next chapter, certain modifications have been implemented in the model and simulated which shows a vast amount of energy saving within the mall. The modifications are done in stages and then their results are compared against the base model case.

CHAPTER 06. ENERGY EFFICIENT ALTERNATIVES

6.1 STRATEGIC PLANNING

To start with modifications on the model, certain parameters were taken into consideration. First of all the possible passive strategies are incorporated in the case which will be a challenge in design for an architect. This stage will include the orientation, materials application on the walls, roofs and windows. But to achieve more efficiency within the mall certain high technological advancements are considered which includes the functioning of the mall, performance of various lighting fixtures with or without controls and in HVAC, measures like the Coefficient of Performance, thermostat's set point temperature, performance checking using VAV system with or without VFD, amount of air to be recirculated or full fresh air to be used, provision of Heat recovery Unit etc. In case of Coefficient of performance, more the COP is more will be the saving so, the COP has been increased at every stage as can be seen in the models developed. As the use of high SHGC glazing can drastically reduce the size of the mechanical equipment and hence the cooling load which in turn increases the occupants comfort level. Hence, the options with or without high performance glazing is also tested. These tools assess the annual operation of building systems and design alternatives and helps in providing a unique perspective of system performance.

6.2 ANALYSIS THROUGH INCREMENTAL STAGES:

To check the energy saving of the mall, various modifications have been identified which has helped a lot in saving the unit energy consumption. The basic idea behind this incremental stage development is to develop the strategies through various stages and in smaller portions at a time, which allows the software to take advantage of the one which has been learned during development of earlier stages. There are 3 modified cases whose auditing has been done on the software. In the first case, all the passive strategies possible in a mall have been applied and then checked its energy consumption. But to achieve maximum saving in energy consumption certain high level of interventions has been applied in cases 2 and 3 which deal with the advancement in technology.

6.2.1 BASE CASE

Base case has been discussed earlier in the base case model development of chapter 05. This case has single clear 6mm glazing with a VLT of 40-45, CFL and T-8 fluorescent tubes for lighting, screw chiller with full fresh air and part load power coefficient for intake vane damper for HVAC system. Analysis shows a huge consumption of electricity and emission of CO_2.

6.2.2 MODIFIED CASE 1: CHALLENGE IN THE DESIGN

For an architect, it is necessary to design the building keeping in mind the climate and orientation of the building which helps in reducing the energy consumption by the fixtures provided. Some of the basic strategies possible in this mall are in terms of its orientation and material applications on the walls, roofs and windows. In case of material application, the U-value of the walls and roofs are considered which should be low to reduce the consumption, while in case of glazing, the U-value and VLT is considered in which VLT should be high. In case of orientation, the alignment along the East- West direction is considered i.e. longer walls facing North and South and less wall area facing the East and West direction as this direction brings ample amount of heat gain within the building. To further reduce the energy consumption, certain other levels of interventions are introduced as discussed further.

6.2.3 MODIFIED CASE 2: LOW LEVEL OF INTERVENTION

As the energy is consumed a lot by HVAC, hence the screw chiller has been replaced with the centrifugal chiller with the Coefficient of Performance (COP) of 5.5 and having the cooling COP of 2.5 and heating COP of 1.25. Some of the energy efficient systems like Heat Recovery Unit (HRU) and economizer are also provided. The type of airside economizer is return air enthalpy. Instead of using full fresh air, minimum amount of fresh air is used and return air is recirculated within the system. Second largest energy consumer is lighting. Hence the T-8 fluorescent tubes have been replaced with T-5 fluorescent tubes, CFL lamps and metal halide lamps which is a high intensity discharge lamp and saves a considerable amount of energy. These lights along with the controls can achieve much more energy saving than normal replacement of fixtures only. As the change in glass material of glazing can be very much expensive hence in modified case 1 only the lighting's and HVAC's efficiency has been increased.

6.2.4 MODIFIED CASE 3: HIGH LEVEL OF INTERVENTION

In modified case 2, special attention has been given on the glazing as it allows the maximum amount of light in the mall along with the solar gain. Hence, the glazing provided is a double glazing with low emissivity coating on pane 2 with air gap in between the panes. The lighting modifications are same as mentioned above but together with the modification of glazing a significant amount of energy saving can be achieved. In case of HVAC, centrifugal chiller with the COP of 7.6 along with the variable speed Drive (VSD) in the motor reduces the cost of initial energy consumed by the start up of HVAC system. The cooling COP has been increased to 5.8 and heating COP to 2.5. The type of airside economizer is return air temperature. Instead of using full fresh air, minimum amount of fresh air is used and return air is recirculated within the system. The outside air control type is kept fixed and part load coefficient for Variable Speed Motors (VSM) has been provided.

6.3 ENERGY MODELLING FOR MODIFIED CASE 1

6.3.1 DEVELOPMENT

- Orientation: along East- West direction
- Materials on wall (from outer to inner surface): ACP cladding, 15mm plastering, 80 mm extruded polystyrene, 100 mm brickwork, 15 mm plastering.
- Material on roof (from outer to inner surface): 3mm clay tiles, 15mm plastering, 80mm extruded polystyrene, 10mm bitumen layer, 120mm RCC slab, 15mm plastering.
- Glazing: Double glazing with low e-coating on pane 2 and air gap between the panes.

6.3.2 ANALYSIS

The analysis has been done for unit energy consumption, heat gain through windows and lightings and CO_2 production.

6.3.2.1 HEAT GAIN THROUGH LIGHTS AND WINDOWS

As compared to base case, the heat gain through windows and lightings has decreased to 13511.208 KWh hence makes a reduction of 13.65%.

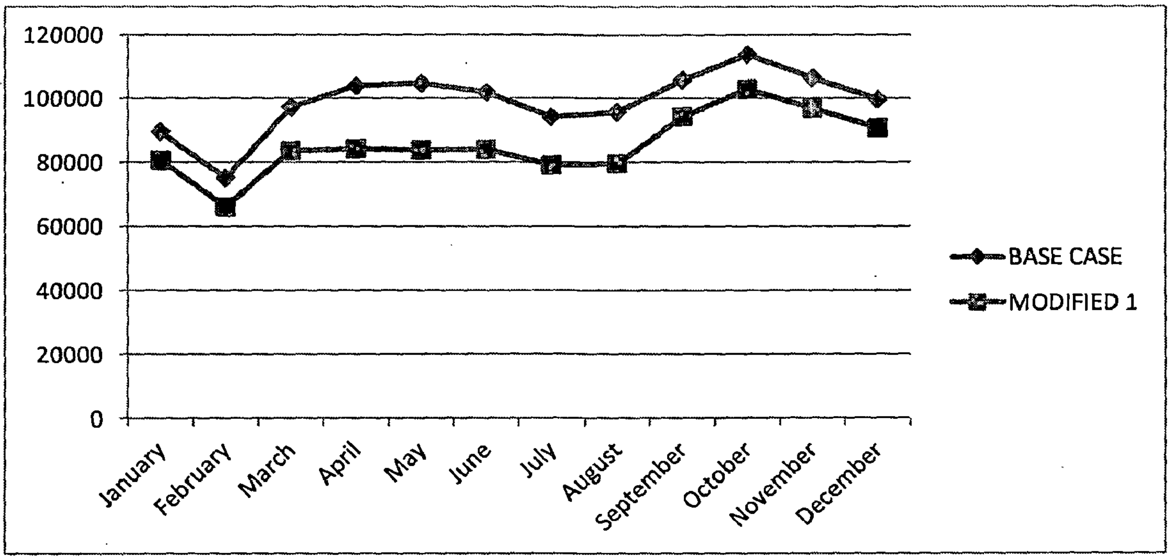


Figure 6-1 HEAT GAIN THROUGH EFFICIENT LIGHTS AND BASE CASE WINDOW

6.3.2.2 UNIT ENERGY CONSUMPTION BY HVAC

As compared to the base case, the electric consumption of the mall has decreased to 35178.658 KWh per year. Hence makes a reduction of 36.312%.

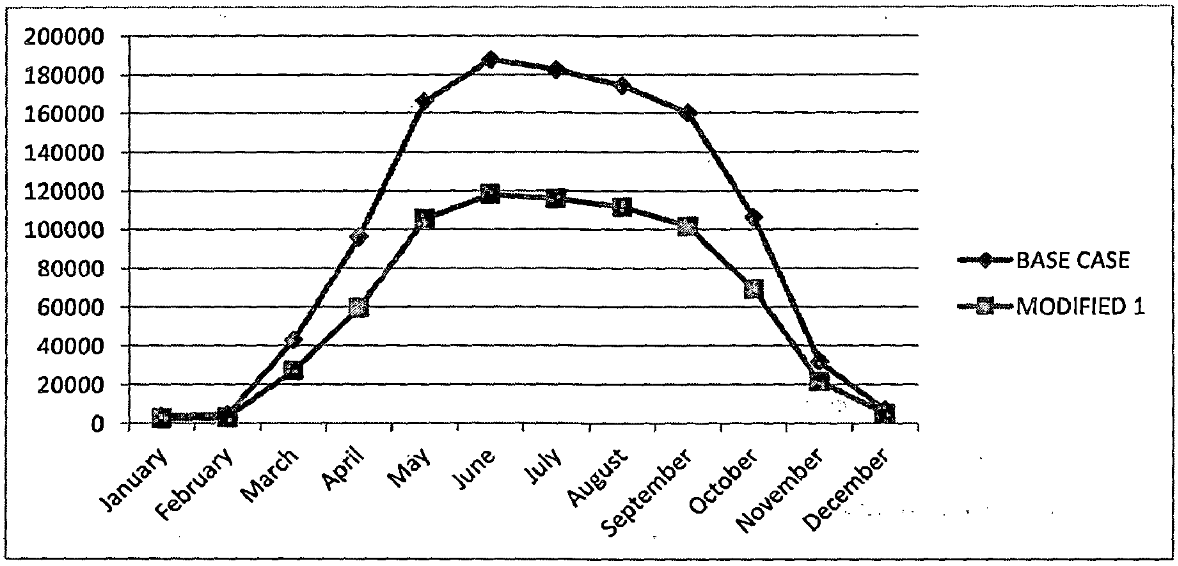


Figure 6-2 UNIT ENERGY CONSUMPTION OF HVAC FOR CASE 1

6.3.2.3 CO2 PRODUCTION

According to the simulation -61701.342 KWh emits 87371.717 kgs of CO2. Hence makes the reduction of 24.94%. The monthly emission of CO2 has been shown in the figure 6-3 below.

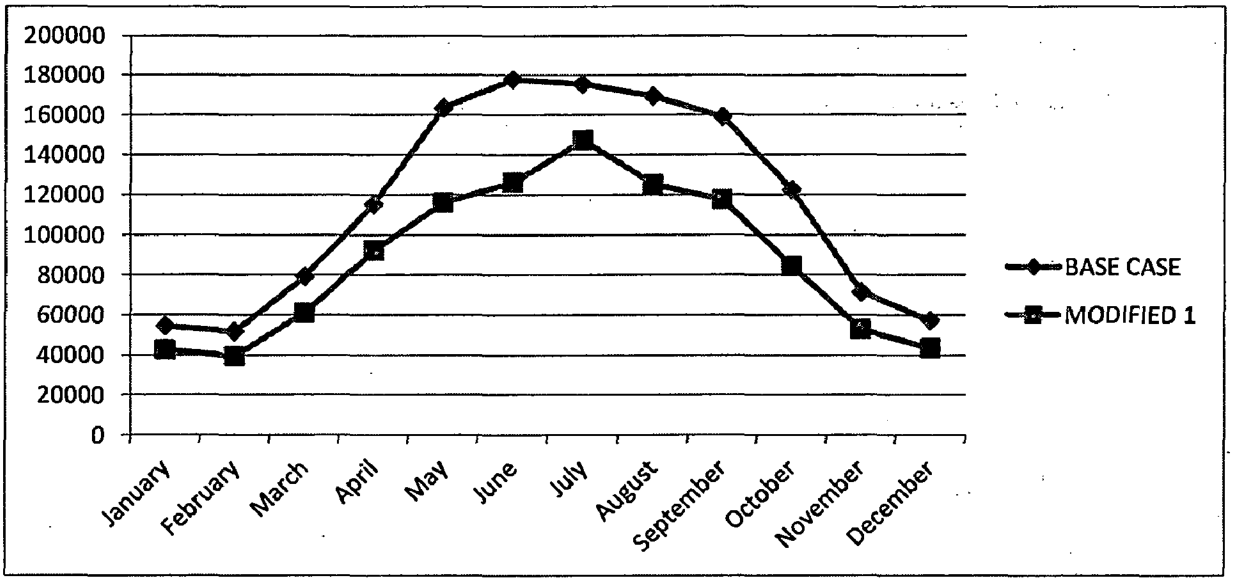


Figure 6-3 MONTHLY CO2 PRODUCTION FOR CASE 1

6.3.3 DISCUSSION

Change in the orientation, construction materials on walls, roofs etc. reduces the energy demand to a large extent but more saving can be achieved using more advanced technologies as explained in further cases.

6.4 ENERGY MODELLING FOR MODIFIED CASE 2

6.4.1 DEVELOPMENT

- Glazing: Single clear 6mm glass
- Lighting: Compact Fluorescent lamps, T-5 fluorescent tubes and metal halide lamps. Lighting controls like daylight dimming controls and photo sensors for exterior.
- HVAC: Centrifugal chillers with COP 5.5, cooling COP 2.5 and heating COP 1.25, Heat Recovery Unit, Airside economizer with return air enthalpy type, recirculation of air and outside air control type as proportional.

6.4.2 ANALYSIS

The analysis has been done for unit energy consumption, heat gain through windows and lightings and CO_2 production.

6.4.2.1 HEAT GAIN THROUGH LIGHTS AND WINDOWS

As compared to base case, the heat gain through windows and lightings has decreased to 89863.819 KWh hence makes a reduction of 9.21%.

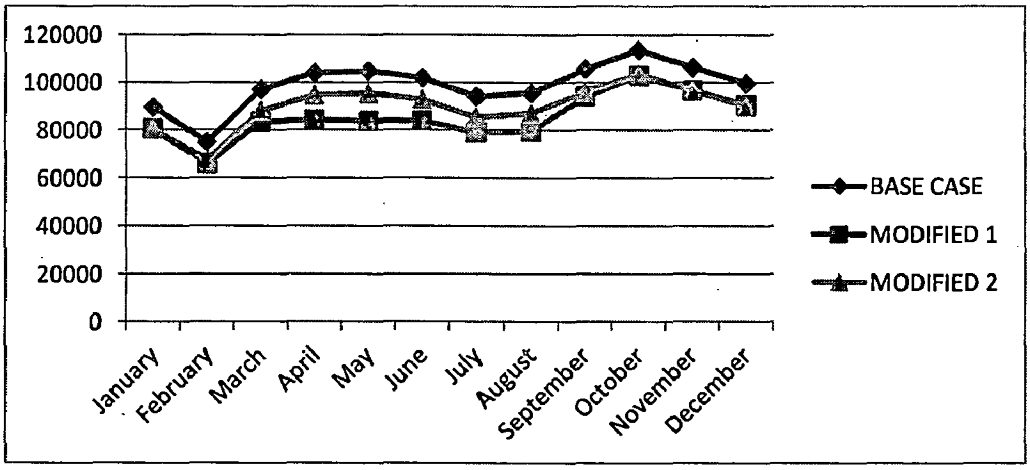


Figure 6-4 HEAT GAIN THROUGH EFFICIENT LIGHTS AND BASE CASE WINDOW

6.4.2.2 UNIT ENERGY CONSUMPTION BY HVAC

As compared to the base case, the electric consumption of the mall has decreased to 53012.44 KWh per year. Hence makes a reduction of 54.71%.

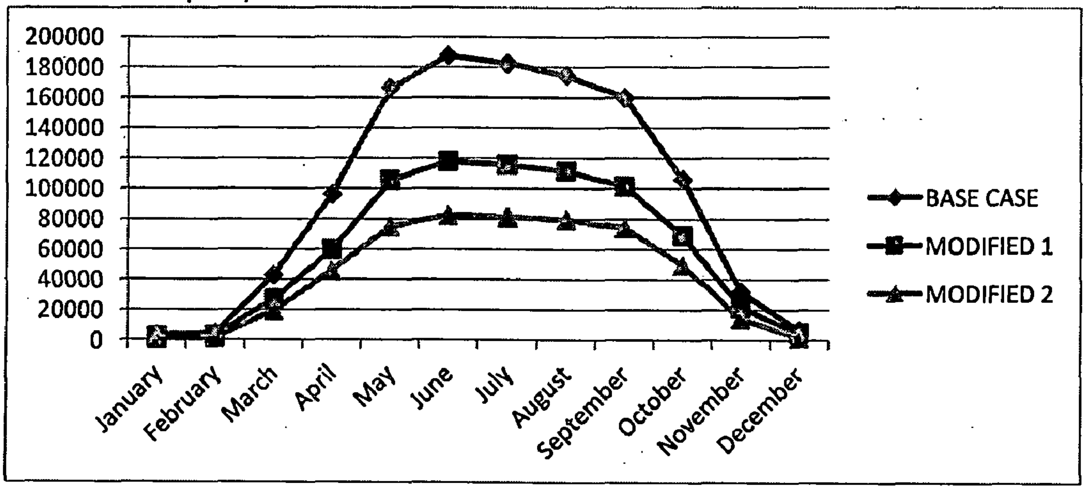
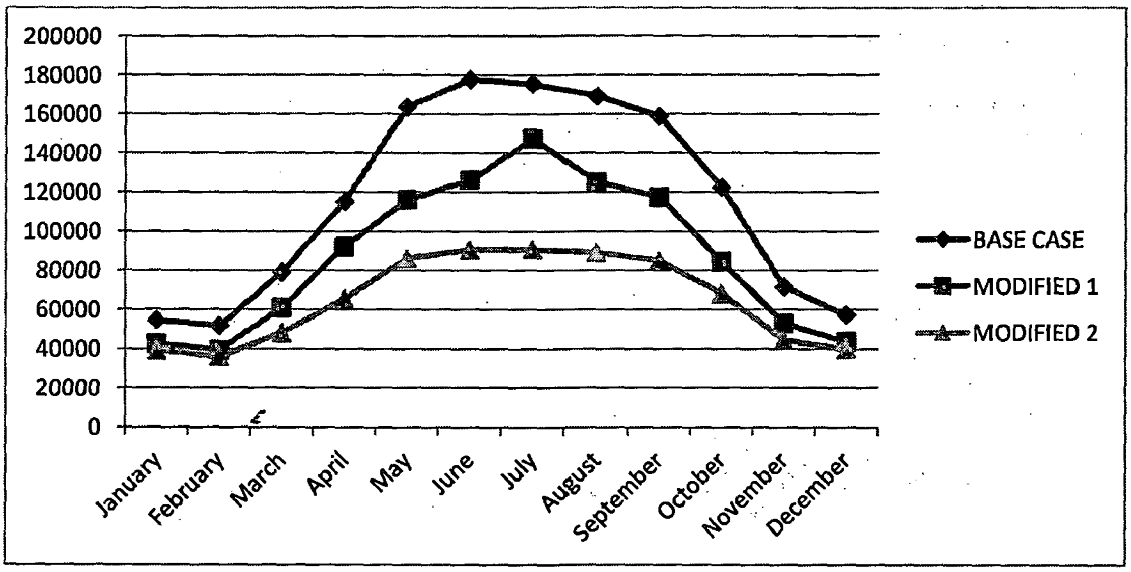


Figure 6-5 UNIT ENERGY CONSUMPTION OF HVAC FOR CASE 2

6.4.2.3 CO2 PRODUCTION

According to the simulation -43867.556 KWh emits 65253.573 kgs of CO_2. Hence makes the reduction of 43.94%. The monthly emission of CO_2 has been shown in the figure 6-6 below.



6-6 MONTHLY CO2 PRODUCTION FOR CASE 2

6.4.3 DISCUSSION

- In case of lighting, implementation of more efficient fixtures along with the controls has reduced the energy consumption and heat gain within the building.
- By changing the chiller from screw to centrifugal, the electricity consumption has reduced to a large level as mentioned above in the analysis. Hence, it can be seen that even increasing the COP reduces the electricity.
- Recirculation of the return air with only 20% outdoor air becomes the economical solution for energy saving.

6.5 ENERGY MODELLING FOR MODIFIED CASE 3

6.5.1 DEVELOPMENT

- Glazing: Double glazing with low e-coating on pane 2 and air gap between the panes.

- Lighting: Compact Fluorescent lamps, T-5 fluorescent tubes and metal halide lamps. Lighting controls like daylight dimming controls and photo sensors for exterior.
- HVAC: Centrifugal chillers with COP 7.6 and VSD, cooling COP 5.8 and heating COP 2.5, Heat Recovery Unit, and Airside economizer with return air temperature type, recirculation of air and outside air control type as fixed.

6.5.2 ANALYSIS

The analysis has been done for unit energy consumption, heat gain through windows and lightings and CO_2 production.

6.5.2.1 HEAT GAIN THROUGH LIGHTS AND WINDOWS

As compared to base case, the heat gain through windows and lightings has decreased to 69310.0067 KWh hence makes a reduction of 29.9%.

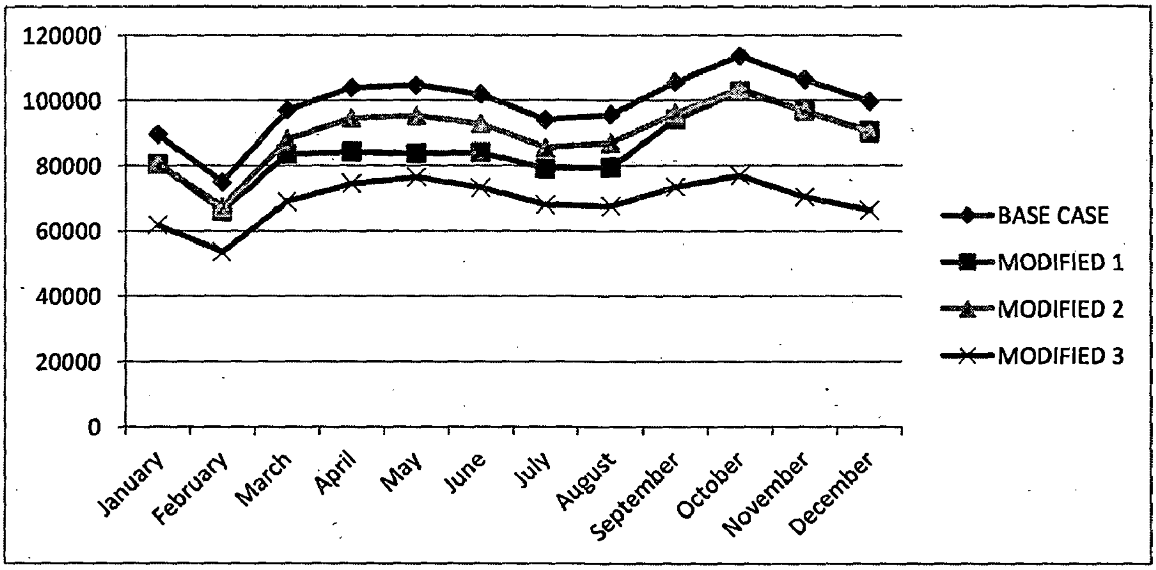


Figure 6-7 HEAT GAIN THROUGH EFFICIENT FIXTURES AND LOW E COATING GLASS

6.5.2.2 UNIT ENERGY CONSUMPTION BY HVAC

As compared to the base case, the electric consumption of the mall has decreased to 32153.6442 KWh per year. Hence makes a reduction of 66.81%.

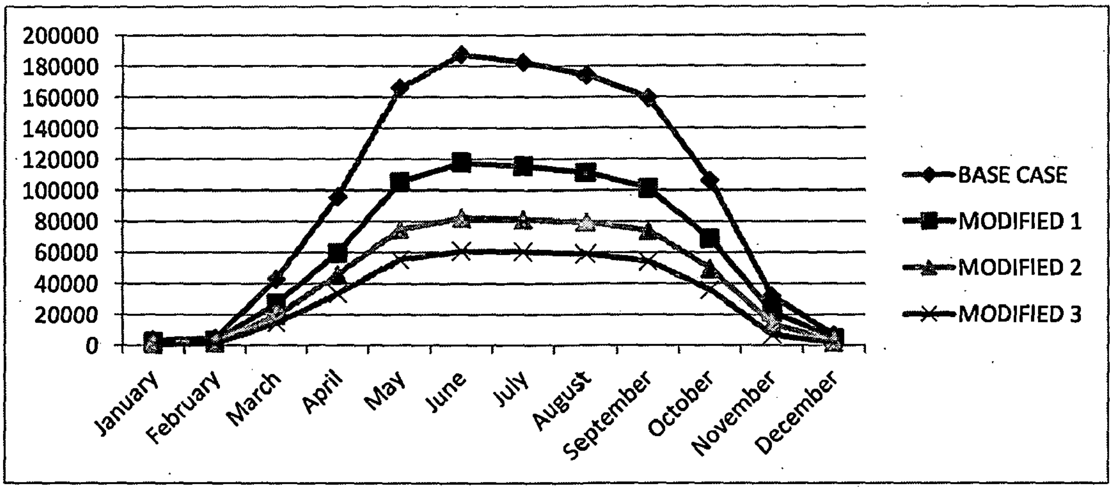


Figure 6-8 UNIT ENERGY CONSUMPTION FOR CASE 3

6.5.2.3 CO_2 PRODUCTION

According to the simulation -32153.6442 KWh emits 57791.635 kgs of CO_2. Hence makes the reduction of 50.35%. The monthly emission of CO_2 has been shown in the figure 6-9 below.

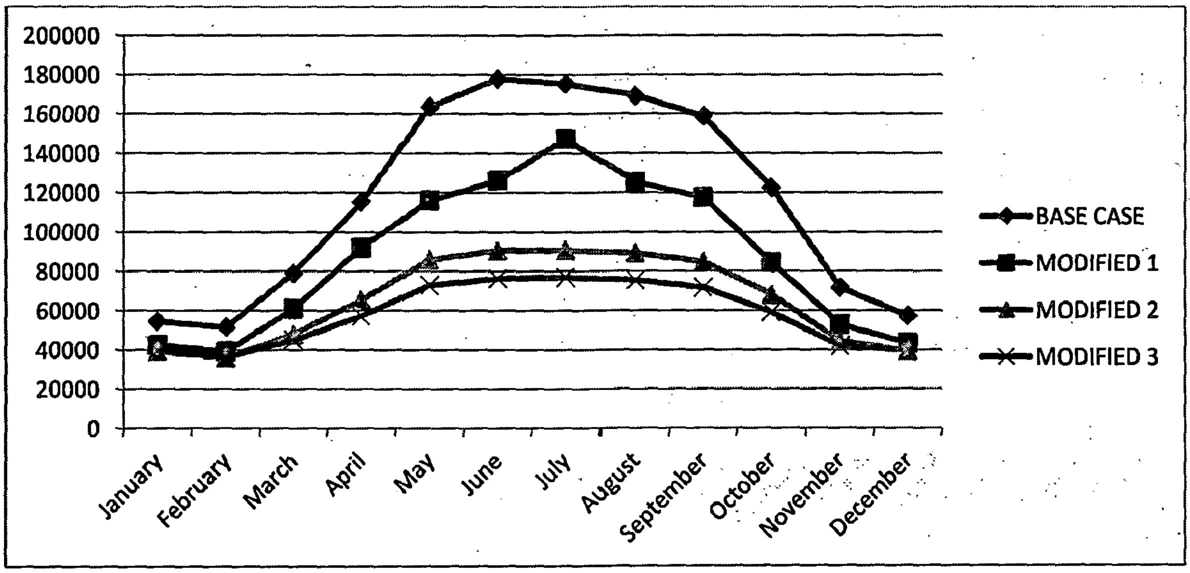


Figure 6-9 MONTHLY CO2 PRODUCTION FOR CASE 3

6.5.3 DISCUSSION

- In case of heat gain through lighting and windows, the usage of low emissivity glass with double glazing has drastically reduced the energy consumption.
- By increasing the chiller's COP along with the VSD, consumption of electricity has again reduced.

- Recirculation of the return air with only 20% outdoor air has always becomes the economical solution for energy saving.

6.6 COMPARITIVE DISCUSSION

After the development of the models with various modifications it can be observed through the graphs that consumption of electricity and energy has reduced a lot in modified case 3 as compare to modified case 1 and case 2.
In figure 6-10 it can be seen clearly that the usage of HVAC controls, Low E Coating glass and lighting controls has very less energy consumption as compared to other cases. The overall reduction is approximately 26.2% as against the other cases.

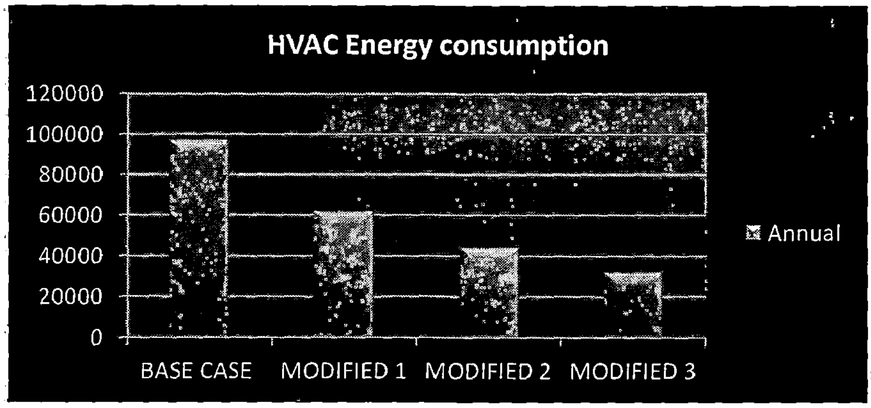


Figure 6-10 COMPARITIVE ANALYSIS OF UNIT ENERGY CONSUMPTION

Similarly in figure 6-11, the usage of lighting controls along with the Low E glass has less heat gain inside the building as compared to the modification with lighting controls only in case 1. This reduction is approximately 22.8% as compared to other cases.

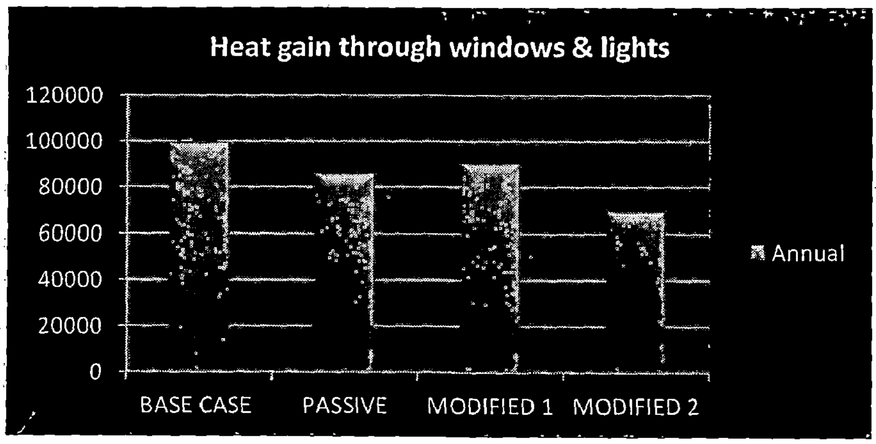


Figure 6-11 COMPARITIVE ANALYSIS OF HEAT GAIN THROUGH LIGHT AND WINDOW

In figure 6-12 also it can be easily observed that reduction in energy reduces the emission of CO_2. The overall reduction has been achieved as 11.43% as compared to the modified case 1 and case 2.

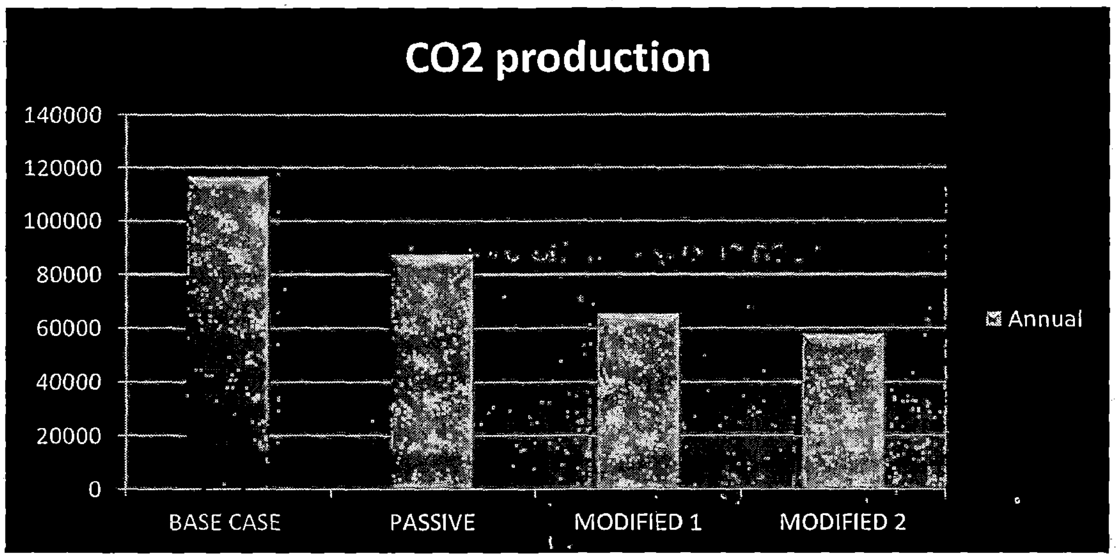


Figure 6-12 COMPARITIVE ANALYSIS OF CO2 PRODUCTION

6. 7SUMMARY

- The results obtained after modified simulations revealed significant reduction in the annual energy consumption from 526410 KWh to 388530 KWh, when all the controls and energy efficient measures are applied in case 2.
- This also has helped in the overall reduction of CO_2 and heat gain.
- Hence it can be summarized that though the initial cost of the efficient systems are high but it recovers it cost in a certain period with low emission of CO_2 and hence reduces the electricity bills.

CHAPTER 07. CONCLUSIONS AND RECOMMENADTIONS

7.1 CONCLUSIONS

The climate of Delhi and NCR has a great diversity of temperature in summer and winter season. It goes up to 40 degrees in summer and below 5 degrees in winter. Thus the mall should be designed according to the heat loss and heat gain during both extreme periods so that the comfort level is maintained throughout the year. In summer the cooling demand rises which automatically increases the electricity consumption and then to the CO_2 emission.

7.1.1 PASSIVE STRATEGIES

- The alignment of the mall in North-South axis as more wall area faces West and South-West direction which receives maximum solar gain. This turn out to be an inefficient feature of the mall.
- The external wall has the cladding of glass and ACP which reduces the U-value of the wall as compared to the simple brick wall with plaster on both sides.
- Single clear glass with Visible Light Transmittance (VLT) of 40-45 has been used which increased the solar gain along with the heat gain in the mall which needs to be high.
- The glazed surfaces and skylight reduces the necessity of artificial lighting as it provides a large amount of natural light to the mall as observed in the Ecotect model.
- The service cores are provided on the North and West sun. Hence they act as a good buffer space in west direction from harsh western sun.
- The energy consumption in base model is high in May-August (summer).
- The solar gain from the single clear glazed surfaces causes the heat gain during summer and heat loss winter.

7.1.2 LIGHTING

- The mall is already using CFL and T-8 fluorescent tubes which are energy efficient and long lasting fixtures. They also helps in improving the indoor air quality and so become an efficient means. But its replacement with more efficient fixtures can reduce further energy. Hence in modified case metal halide lamps and T-5 tubes are used which provide more saving than the previous one.

- The sensors provision again helps in achieving great energy as it gets turned off when daylight falls over it and required amount of illumination is achie' 1 within the space.
- Exterior lighting has been operated manually i.e. it is turned off ma when the sunlight appears. So the placement of photo sensors turi exterior lights off when san rays falls over it.

7.1.3 HVAC

- The present energy consumption of the mall is high during June and July c low in December and January as they have used heat recovery units.
- The chilled water in the HVAC system cools the hot internal air and the h water returns to the chiller to be cooled again. Thus using the same wate again and again in a cycle. This proves to be an efficient feature for HVAC.
- The HVAC system is controlled by the computer but the running time for HVAC system for the day is decided manually. Hence it does not provide proper human comfort to the users.
- The type of HVAC chiller used in base case is screw chiller which consumes a great amount of energy as it's suitable for low tonnage of HVAC. But its replacement with the centrifugal chiller along with the VSD in partial load condition reduces the start up energy required to start the motor.
- The conditioning of full fresh air consumes a lot of energy which is used in the base case. This can be reduced to a large extent by recirculation of the air in HVAC. Hence 80% of the return air is recirculated with proper conditioning. This economizes the system.
- The usage of CO_2 sensors have also been installed in modified case which also saves a significant amount of energy.

Hence it can be concluded that if in one mall installation of energy efficient fixtures and control devices can reduce the consumption, in the similar way, in existing malls, replacement and relighting can reduce the energy consumption. And hence the overall consumption of energy through malls can be reduced and makes the world less of carbon contents.

7.1.4 PAYBACK PERIOD OF MODIFIED CASE 3

As the results from the simulation model shows that the in case of modified case 3, a drastic amount of energy is saved. But the problem which arises is the installation cost of these energy efficient equipments which is quite costly as compared to the conventional ones. Hence an attempt has been made in order to check the payback period of case 3 to show that the investment made before can be recovered fast.

The payback period is calculated by checking the energy saving in units/year as compared base case and then is multiplied with the current tariff rate of electricity in Delhi and NCR. Then, by collecting the investment information of the equipments used, payback period is calculated. It has been calculated in four phases:

- Payback period for using low-e coating glass
- Payback period for using lighting controls and low-e glass
- Payback period for using efficient HVAC systems
- Payback period using all the above mentioned

7.1.4.1 LOW-E COATING GLASS

The energy saved as compared to base case : 76, 560 units/ yr

Using the tariff rate of Rs. 4.3 per unit, annual electricity saving: Rs. 5, 58,888

Estimated cost of the equipment in the mall (Rs. 75/sq.mt.): Rs. 7, 15, 875

Hence, payback period : 1.28 years

7.1.4.2 LIGHTING CONTROLS AND LOW E GLASS

The energy saved as compared to base case : 80,000 units/yr

Using the tariff rate of Rs. 4.3 per unit, annual electricity saving: Rs. 3, 44,000

Estimated cost of the equipment in the mall (Rs. 75/sq.mt.): Rs. 15, 82,245

Hence, payback period : 4.6 years

7.1.4.3 HVAC

The energy saved as compared to base case :	1, 43,290 units/yr
Using the tariff rate of Rs. 4.3 per unit, annual electricity saving:	Rs. 6, 16,147
Estimated cost of the equipment in the mall (Rs. 75/sq.mt.):	Rs. 25, 77,150
Hence, payback period :	4.2 years

7.1.4.4 OVERALL COST BENEFIT (PAYBACK)

Total annual electricity saving:	Rs. 15, 19,035
Total estimated cost of the equipment in the mall:	Rs. 48, 75,270
Hence, payback period :	3.2 years

Hence, it can be seen that though the initial cost is high but the cost can be recovered in 3.2 years which is quite efficient.

7.2 RECOMMENDATIONS

The inferences from the simulation and the literature study helps in the making of recommendations for an energy efficient shopping mall.

7.2.1 PASSIVE STRATEGIES

- An east-west orientation is preferred as northern and southern walls are easier to shade. During summer, South wall gets significant exposure to sun radiation and hence high temperature in S-W.
- As the external window glazing causes the maximum solar gain and it should be reduced by the provision of Low-e glass which is a thin and virtually invisible layer applied on the panes of glass. The infrared rays can be reduced to a large extent and hence glasses with low SHGC and high VLT should be used.
- The outside coating should be applied in such a way so that the mall is protected from the solar heat; one coating should be applied to the outside of the pane. And the inside pane's coating should be applied in such a way that heat loss from the building can be prevented. Low E coating lasts for

around 15 years and hence turns out to be a cheaper option than replacing the windows.

7.2.2 LIGHTING

As the mall is already using CFL and T-8 tubes but for lighting, the mall has been divided into various zones:

1. **ATRIUM:**

- To achieve the maximum daylight within the mall skylight and vertical store front/ vertical glazing shall be provided.
- For top skylight, North and South facing clerestory windows shall be provided which helps in gaining 50% daylight.
- The reflectance of wall and ceiling should be around 50-60% so that maximum heat gain through them can be reduced.
- For ambient lighting, recessed Downlight with CFL shall be used which is being controlled by photo sensors or light level sensors.
- At atrium perimeter decorative lighting of spotlight with metal halide lamps can be installed.
- For roof line glazing, flood light with metal halide lamps can be used.
- All lights are to be controlled by light level sensors.

2. **RETAIL SHOPS AND SHOWROOMS:**

- For ambient lighting, recessed downlights of CFL with light level sensors shall be used.
- For the display of merchandised material, accent fixtures with metal halide lamps.
- For ceiling's recessed lighting, cove lighting with cold cathode lamps.
- For vertical illuminance, wall washers with metal halide lamps.
- In case of store front display windows,
  - Background lighting: T-5 fluorescent tubes/ Phosphor tubes with electronic ballast
  - Ambient lighting: Recessed down light with CFL
  - Track lighting: Series of CFL/ Metal halide lamps
  - Side lighting: Metal halide spot lights
- For counter section, task light with CFL to be used.

- To reduce the light level, time clock switches with alternate luminaires can be used.
- In case of trial rooms, T-5 fluorescent tubes with electronic ballast on sides and top of the mirror in the casement of vanity lamps can be a better option.

3. EXTERIOR FAÇADE:

- For parking lot: metal halide lamps/ sodium lamps (3400k) to be used as they provide a great illuminance level and achieve a large energy saving.
- In the night, the lighting plays a great roll in attracting the customers hence to highlight the mall faced halogen lamps can be used
- As the signage leads to various ways and guides to different areas so LED's can be great option as they consume less power.
- Metal halide lamps for parking garages because of color uniformity and warm temperature. And tubular daylighting system to let the daylight enter.
- All the lights are to be controlled by photo sensors.

4. RESTAURANTS:

- The effect on ceiling plays a great role in case of restaurant. Hence cove lighting should be provided with cold cathode lamps instead of tubes.
- Ambient lighting can be achieved by the means of with CFL as recessed downlights.
- To bring the focus on table, Chandeliers/ Pendant lights with High Intensity Discharge lamps (HID)/ CFL can be used.
- Controllers like dimming and scene controls to be installed with chandelier or pendant lights which helps in creating a marvelous effect within the area.

7.2.3 HVAC

- The HVAC load can be calculated on the basis of:
  - Human load: for 25 people 1 tonnage of AC is required.
  - Volumetric load: for 1500-1800 cu.ft 1 tonnage of AC required
  - Instruments: 4 KW of equipment required 1 tonnage of AC load.
- The space for the chiller plant should be calculated as 0.5 sq.mt/tonnage+10.
- In all the building areas where the usage of outside air for free cooling is required there airside economizer with enthalpy control should be provided.

- The efficiencies of the heating and cooling coils can be increased by the regularly changing the filters.
- The usage of terminal reheat system which is used in base case is of poor energy efficiency. Hence its transformation to variable air volume system in modified case 2 and 3, helps in saving the energy to a large extent. But with high COP more energy saving can be achieved as observed in modified case 3 where COP is 7.6 as compared to the COP of modified case 2 where it is 5.5.
- Most of the energy can be saved by cooling towers. Though less power is consumed in an efficient cooling but they transport cooler water to the chiller(s).
- Provision of a thermal storage system along with the chiller plant provides a great energy saving measure. With this system, chiller equipment runs at off-peak duration and it stores cooled water, which is then used for cooling at the peak duration.
- Variable speed drives helps in controlling the speed of the pump and fan and hence provides the low-cost option to exclusive electric modifications. This is observed in modified case 3 where VSD is used. The performance of this system is good at part load condition for relatively long hours.
- At night, the building can be allowed to b cooled down by the night purging system this will also reduce the cost of the building as it will work at off peak duration.
- By raising the temperature set point on thermostat helps in significant savings. By maintaining the temperature of 21 degree C to 23 degree C and 55 percent relative humidity energy saving can be achieved which will be approximately 13 percent.
- To control the chilled water supply temperature, monitoring of outside air temperature and control on humidity is required.
- The unnecessary working of various equipments leads to wastage of energy hence it is advisable to shutdown redundant auxiliary equipment. The HVAC plants require auxiliary equipment. These equipments should be turned off when they are not in demand. This results in improving the efficiency of the overall system.
- There are many VAV fans which operate at constant speed over the whole operation. Here the flow of fan is controlled by the closing and opening of the

dampers which allows the air to enter into the spaces which in turn leads to the wastage in energy. So, a VFD can be used to vary the speed of the motor.

- As the humidity in composite climate turns out to be more which leads to a great discomfort for occupants. Hence the desiccant dehumidification can be used in that case which removes the excessive water from the air. And then makes the air comfortable for occupants with the less consumption of energy.
- The installation of heat recovery chiller would help in reducing the electricity consumption required for the heating purpose as the heat removed from the chiller is used in the recovery of waste heat.
- CO_2 sensors would also help in sensing the amount of air required within the space as per occupancy in the zone.

7.3 FURTHER STUDIES

Further research is needed to understand the peak demand reduction potential and capabilities of these strategies in terms of its feasibility. There are certain other aspects which need further research like categorization of these strategies according to the mall sizes. There are certain simulation softwares like VISDOE and DIALUX with the help of which more detailed analysis of the same would have been possible. With the help of DIALUX, actual number of luminaires along with the zones illuminance required would have been calculated. And in VISDOE accurate HVAC calculations would have been done. The cooling and heating demand could also have been reduced using the application of various materials for construction. Hence further work needs to be done to establish whether these strategies when applied together prove out to be feasible or not.

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