UNIT 2 DAYLIGHTING AND CLIMATIC RESPONSIVE PASSIVE DESIGNS

Structure

2.1 INTRODUCTION

You have learnt about energy-conscious building design in the previous unit. Such energy conscious building designs save money through energy reduction after construction when a building begins operation. It has been estimated that many features of solar passive design are very attractive.

In this unit, you will learn more about important aspects of energy conscious designing of buildings like daylighting, climatic responsive designs, active solar systems for heating and cooling of buildings, advantages and disadvantages of solar passive building, building integrated solar PV technologies etc.

Objectives

After studying this unit, you will be able to understand the following

- Concept of daylighting,
- Climatic responsive approach for designing solar passive building,

- Active solar systems for heating and cooling of buildings,
- Advantages and disadvantages of solar passive building, and
- Building integrated solar PV technologies.

2.2 DAYLIGHTING

The ultimate source of daylight is the sun, from which, we also receive a large amount of thermal radiation together with the light. During bright sunshine, the illumination is around 100 klux (100000 lux). Daylighting strongly depends on the externally given conditions and its control is possible by a suitable building design. In our country, which lies in the tropics, daylight may also be accompanied by solar heat. We must, therefore, be cautious to exclude solar heat, whilst admitting daylight.

The eye responds to a very large range of illumination levels extending from 0.1 lux (full moonlit night) to 100000 lux (bright sunshine). For practical situations and various activities, illumination requirements would be different as given in Table 2.1.

Table 2.1 : Requirement of Illumination

Task	Illumination (lux)
Casual seeing	100
Ordinary tasks (e.g. wood machining, general office work)	400
Prolonged tasks (e.g. fine assembly, silk weaving)	900
Exceptionally severe tasks (e.g. watch making)	2000 - 3000

2.2.1 Climate and Light

In high latitude moderate climates, where the sky is typically overcast, the whole of the sky hemisphere acts as a light source. The sky itself has a luminance sufficiently high to provide lighting in normal rooms.

In hot dry climates, sky is usually cloudless and strong direct sunlight is available. The clear sky has the highest luminance near the horizon. The bare, dry, sunlit ground and light coloured walls of other buildings reflect much light, which will be the main source of indoor daylighting. The windows are smaller in these climates, and therefore externally reflected light is used to have adequate daylighting, provided sufficient care is taken to avoid glare.

In warm humid climates, buildings are typically of lightweight construction, with large openings to ensure cross-ventilation and air movement and other shading devices. The sky is bright, could provide sufficient light, but its high luminance would also cause glare. For this reason, view of the sky is screened by shading devices or plants.

In composite climates, wide variations occur in natural lighting between the overcast and clear sky conditions. The approximate reflection factors for various colours are as given in Table 2.2.

Table 2.2 : Reflection Factors for Different Colours

Colour	Reflection Factor (%)
White	80-90
Pale yellow	80
Pale beige, lilac	70
Pale blue, green	70-75
Mustard yellow	35
Medium brown	25
Medium blue, green	20-30
Black	10

The desirable reflection factors for various interior surfaces are given in Table 2.3.

Table 2.3 : Reflection Factors for Interior Surfaces

Surfaces	Reflection Factor (%)
Ceilings	80
End walls in poorly lighted rooms in well lighted rooms	 70 25
Walls containing window (s)	80
Floors	25

A solar building utilizes daylight for interior illumination. Usually, daylighting requires windows that are placed on or near a building's roof, such as skylights. High-level windows and skylights can allow sunlight to reach throughout the building. An effective use of daylighting reduces the need for artificial light substantially.

2.3 CLIMATE RESPONSIVE PASSIVE DESIGNS

The characteristics of each climate differ and accordingly the comfort requirements vary from one climatic zone to another. The proposed building may fall in any of the climatic zones. You have already learnt about different climatic zones in the country. Now, you will learn about their characteristics and design methodology.

2.3.1 Hot and Dry Climatic Zone

The hot and dry zone lies in the western and the central part of India; Jaisalmer, Jodhpur and Sholapur are some of the towns that experience this type of climate. A typical hot and dry region is usually flat with sandy or rocky ground conditions, and sparse vegetation. There are few sources of water on the surface, and the underground water level is also very low. In summer, the maximum ambient temperatures are as high as 40-45ºC during the day, and 20-30ºC at night. In winter, the values are between 5 and 25ºC during the day and 0 to 10ºC at night. The relative humidity is generally very low, ranging from 25 to 40 %.

The design aims at resisting heat gain by providing shading, reducing exposed area, controlling and scheduling ventilation, and increasing thermal capacity. The presence of "water bodies" is desirable as they can help increase the humidity, thereby leading to lower air temperatures. The ground and surrounding objects emit a lot of heat in the afternoons and evenings. As far as possible, this heat should be avoided by appropriate design.

2.3.2 Warm and Humid Climatic Zone

The warm and humid zone covers the coastal parts of the country. Some cities under this zone are Mumbai, Chennai and Kolkata. Due to high humidity, there is abundant vegetation in these regions. In summer, temperatures can reach as high as 30-35ºC during the day and 25-30ºC at night. In winter, the maximum temperature is between 25 to 30ºC during the day and 20 to 25ºC at night. Although the temperatures are not excessive, the high humidity (about 70-90 %) causes discomfort.

Wind is desirable in this climate, as it can cause sensible cooling of the body. The main design criteria are to reduce heat gain by providing shading, and promote heat loss by maximizing cross ventilation. Dissipation of humidity is also essential to reduce discomfort.

2.3.3 Moderate Climatic Zone

Pune and Bangalore are examples of cities under this climatic zone. Areas having a moderate climate are generally located on hilly or high-plateau regions with fairly abundant vegetation. Being located at relatively higher elevations, these places experience lower temperatures. In summers, the temperature reaches 30-34ºC during the day and 17-24ºC at night. In winter, the maximum temperature is between 27 to 33ºC during the day and 16 to 18ºC at night. The relative humidity is low in winters and summers, varying from 20-55%, and going up to 55-90% during monsoons.

The design criteria in the moderate zone are to reduce heat gain by providing shading, and to promote heat loss by ventilation.

2.3.4 Composite Climatic Zone

The composite zone covers the central part of India. Some example cities are New Delhi, Kanpur and Allahabad. The intensity of solar radiation is very high in summer. The maximum daytime temperature in summers is in the range of 32-43ºC, and night time values are from 27 to 32ºC. In winter, the values are between 10 to 25ºC during the day and 4 to 10ºC at night. The relative humidity is about 20-25% in dry periods and 55-95% in wet periods. The design criteria are more or less the same as for hot and dry climate except that maximizing cross ventilation is desirable in the monsoon period.

2.3.5 Cold and Cloudy Climatic Zone

Generally, the northern part of India experiences this type of climate. Most cold and cloudy regions are situated at high altitudes. Ootacamund, Shimla, Shillong, Srinagar and Mahabaleshwar are examples of places in this climatic zone. The intensity of solar radiation is low in winter, and hence, winters are extremely cold. In summer, the maximum ambient temperature is in the range of 20-30ºC during the day and 17-27ºC at night, making summers quite pleasant. In winter, the values range between 4 and 8ºC during the day and from – 3 to 4ºC at night, making it quite chilly.

This region experiences cold winds in the winter season. Hence, protection from winds is essential in this type of climate. Owing to cold winters, the main criteria for design in the cold and cloudy region aim at resisting heat loss by insulation and infiltration, and promoting heat gain by directly admitting and trapping solar radiation within the living space.

2.3.6 Cold and Sunny Climatic Zone

The cold and sunny type of climate is experienced in Leh (Ladakh). The region is mountainous, has little vegetation, and is considered to be a cold desert. The solar radiation is generally intense. In summer, the temperature reaches 17-24ºC during the day and 4-11ºC at night. In winter, the values range from – 7 to 8ºC during the day and – 14 to 0ºC at night. Winters thus, are extremely cold.

As this region experiences cold desert climatic conditions, the design criteria are to resist heat loss by insulation and controlling infiltration. Simultaneously, heat gain needs to be promoted by admitting and trapping solar radiation within the living space.

2.4 IMPLICATIONS OF CLIMATE ON BUILDING DESIGN

The characteristics of each climate differ and accordingly the comfort requirements vary from one climatic zone to another. Implications of climate on building design and how that can be realized are discussed in Table 2.4.

Table 2.4 : Climate and Design Strategy to Realize Thermal Comfort

Climate and design strategy	How to realize the thermal comfort
Hot and Dry Region	
1) Resist heat gain	
• Decrease exposed surface area	Orientation and shape of building
• Increase thermal resistance	Insulation of building envelope
• Increase thermal capacity (Time lag)	Massive structure
• Increase buffer spaces	Air locks/ lobbies/balconies/verandahs
• Decrease air exchange rate(ventilation during day-time)	Weather stripping and scheduling air changes
• Increase shading	External surfaces protected by overhangs, fins and trees
• Increase surface reflectivity	Pale colour, glazed china mosaic tiles etc.
2) Promote heat loss	
• Ventilation of appliances	Provide windows/exhausts
• Increase air exchange rate (Ventilation during night-time)	Courtyards/wind towers/ arrangement of openings
• Increase humidity levels	Trees, water ponds, evaporative cooling
Warm and Humid Region	
1) Resist heat gain	
• Decrease exposed surface area	Orientation and shape of building
• Increase thermal resistance	Roof insulation and wall insulation. Reflective surface of roof.

• Increase buffer spaces	Balconies and verandahs
• Increase shading	Walls, glass surfaces protected by overhangs, fins and trees
• Increase surface reflectivity	Pale colour, glazed china mosaic tiles, etc.
2) Promote heat loss	
• Ventilation of appliances	Provide windows/ exhausts
• Increase air exchange rate (Ventilation throughout the day)	Ventilated roof construction. Courtyards, wind towers and arrangement of openings
• Decrease humidity levels	Dehumidifiers/ desiccant cooling
Moderate Region	
1) Resist heat gain	
• Decrease exposed surface area	Orientation and shape of building
• Increase thermal resistance	Roof insulation and east and west wall insulation
• Increase shading	East and west walls, glass surfaces protected by overhangs, fins and trees
• Increase surface reflectivity	Pale colour, glazed china mosaic tiles, etc.
2) Promote heat loss	
• Ventilation of appliances	Provide windows/ exhausts
• Increase air exchange rate (Ventilation)	Courtyards and arrangement of openings
Cold and Cloudy Region (Applies for Cold and Sunny also)	
1) Resist heat loss	
• Decrease exposed surface area	Orientation and shape of building. Use of trees as wind barriers
• Increase thermal resistance	Roof insulation, wall insulation and double glazing
• Increase thermal capacity (Time lag)	Thicker walls
• Increase buffer spaces	Air locks/ Lobbies
• Decrease air exchange rate	Weather stripping
• Increase surface absorptivity	Darker colours
2) Promote heat gain	
• Reduce shading	Walls and glass surfaces
• Utilize heat from appliances	
• Trapping heat	Sun spaces/green houses/Trombe walls etc.
Composite Region	
1) Resist heat gain in summer and Resist heat loss in winter	
• Decrease exposed surface area	Orientation and shape of building. Use of trees as wind barriers
• Increase thermal resistance	Roof insulation and wall insulation
• Increase thermal capacity (Time lag)	Thicker walls
• Increase buffer spaces	Air locks/ Balconies
• Decrease air exchange rate	Weather stripping

• Increase shading	Walls, glass surfaces protected by overhangs, fins and trees
• Increase surface reflectivity	Pale colour, glazed china mosaic tiles, etc.
2) Promote heat loss in summer/monsoon	
• Ventilation of appliances	Provide exhausts
• Increase air exchange rate (Ventilation)	Courtyards/ wind towers/ arrangement of openings
• Increase humidity levels in dry summer	Trees and water ponds for evaporative cooling
• Decrease humidity in monsoon	Dehumidifiers/ desiccant cooling

2.5 ESTIMATED ENERGY SAVING POTENTIAL IN PASSIVE DESIGNS

The estimated energy savings potential of various designs is given in Table 2.5.

Table 2.5 : Estimated Energy Saving Potential in Passive Designs

Solar Passive Design Features	Estimated Energy Saving Potential (%)
Adding insulation in walls	15-20
Adding insulation in roofs	15-18
Adding double glass	5-7
Heating controls by other means	20-30
Controlled ventilation	5-8
Daylight integration	15-20

2.6 ADVANTAGES AND DISADVANTAGES OF SOLAR PASSIVE BUILDINGS

You are now familiar with the concepts of solar passive buildings and in a position to list down various advantages and disadvantages of such designs. Some of the well known advantages and disadvantages are the following:

2.6.1 Advantages of Solar Passive Systems

- Solar passive designs are highly energy efficient
- The building energy needs for lighting, winter heating, and summer cooling are reduced substantially.
- Solar passive designs utilize the solar energy without consuming the conventional energy. Consequently, the energy bills get reduced substantially.
- Solar passive design helps in conserving fossil fuels (coal, oil and gas).
- Day lighting, a component of many passive solar designs, is one of the key cost-effective means of reducing energy usage in buildings.
- A well-designed constructed passive solar building can be as attractive as conventionally designed buildings and still save energy and money.

- Solar passive design reduces greenhouse gases that contribute to global warming because it relies on solar energy, a renewable, nonpolluting resource.

2.6.2 Disadvantages of Solar Passive Systems

- Solar passive designs costs little more than conventional building design but saves money over the long run.
- Any mistake made in the choice of building materials, especially window glass may give adverse results.
- Room and furniture layouts need to be planned carefully to avoid glare on equipment such as computers and televisions.
- Daylighting may come with heat. During the summer or in warm climates, day lighting could actually increase use of energy in a building if proper care is not taken in its designing by adding to the air-conditioning load.

2.7 ACTIVE SOLAR SYSTEMS FOR HEATING PURPOSES

In solar active systems, solar collectors using electric pump are used to convert sun's energy into useful heat for different applications like hot water requirements and space heating. These are larger capacity systems, as compared to thermosyphon based systems. These systems provide flexibility in the installation of solar collectors and the storage tanks without compromising aesthetics of the building. Solar air heaters are also used for space heating applications, especially during daytime.

You have already learned that there are two basic types of solar water heating systems-open loop and closed loop. An open loop system circulates water itself, through the collector. In closed loop systems, the circulating fluid is kept separate from the system used for water supply (Figure 2.1). The closed loop systems are less efficient as the heat exchanger used in the system causes a loss of temperature of water. They are relatively expensive because of the extra cost of the heat exchanger as well as the circulating pump.

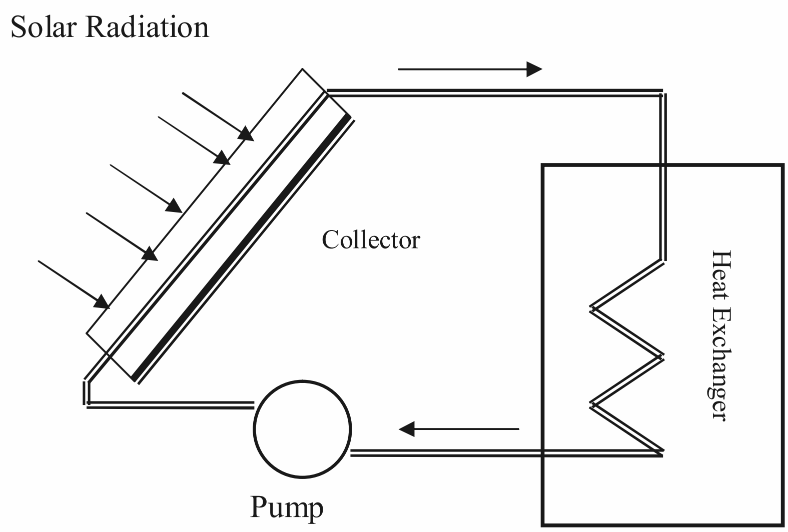

Figure 2.1 : Solar Water Heater with Heat Exchanger

In thermosyphon systems, the water circulates from the collector to the storage tank by natural convection and gravity. As long as the sun is shining, the absorber keeps collecting heat and water continues to be heated in the collector. The heated water rises into the storage tank, placed slightly above the collector level. The cold water in the tank runs into the collector to replace the water discharged into the tank. The circulation stops when solar radiation is less. Thermosyphon systems are simple, relatively inexpensive and require little maintenance and can be used for domestic applications.

SAQ 1

Describe the difference between open and closed loop solar water heating systems.

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2.8 ACTIVE SOLAR SYSTEMS FOR COOLING PURPOSES

In areas where solar radiation insolation is high during large part of the year, heating requirements are easily met but cooling in summer months becomes a difficult task. You are aware about the requirements of increasing demand of energy for meeting thermal comfort conditions on one side and less availability of fossil fuels on the other side. An extensive work has been reported in the literature to utilize renewable energy sources for comfort conditions. Solar energy is the front runner among all the renewable energy sources for meeting comfort conditions inside the building.

The solar cooling systems require a thermodynamics cycle between the solar collector and the building as shown in Figure 2.2.

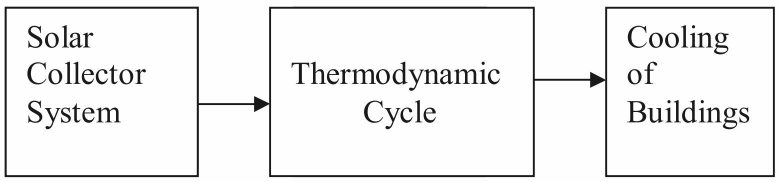

Figure 2.2 : Solar Cooling System

Some of the well known thermodynamic cycles used in solar air conditioning are Vapour-Absorption (V-A), Vapour-Compression (V-C) and Evaporating Cooling (E-C).

Vapour-Compression (V-C) : A V-C refrigeration cycle consists of a compressor, a condenser, an expansion device and an evaporator.

Vapour-Absorption (V-A) : A V-A cycle is identical to a V-C cycle in which the compressor is replaced by an absorber and generator assembly. The absorption cooling systems are used to transfer a heated liquid from the solar collector to run a generator or a boiler activating the refrigeration loop which cools a storage reservoir. The cool air from this reservoir is drawn into the living space for thermal comfort.

Evaporating Cooling (E-C) : It is used in dry regions.

A detailed study of such systems is beyond the scope of this unit.

2.9 BUILDING INTEGRATED SOLAR PHOTOVOLTAIC TECHNOLOGY

You have already learned in detail about solar photovoltaic technology (SPV) in Block 2. It involves the direct conversion of solar radiation into electrical energy. You have also seen that SPV technology is a clean source of energy, produces no noise, smoke, acid rain, water pollutants, carbon dioxide, etc. because it relies on the power of the sun for its fuel. As a result, the environmental impact of activities associated with fossil fuels (coal, oil and gas) such as mining, exploration, production and transportation, and the hazards are eliminated. However, the drawbacks of such systems are their high initial cost and low efficiency, which results in high module area requirements.

SPV can be integrated with almost every possible building structure. The development of PV products for building integration is mainly in the following three areas :

- **Integral roof modules :** Roof integration has been the most popular application. The reason being that SPV modules can collect maximum solar radiation and hence can provide the highest power output.
- **Roofing tiles :** Building integrated SPV modules produced in the same size as building materials like roof tiles or glass and other cladding panels have dual advantage. They can replace these materials efficiently and simultaneously can provide much needed energy.
- **Vertical facades :** Vertical curtain walls can replace traditional cladding materials like glass.

SPV can play following additional multiple roles in the design of solar passive buildings :

- SPV light shelf can shield direct sun while filtering comfortable diffused, indirect light into the interior.
- An opaque SPV module can shade the interior portions of the building from direct sunlight and reduce cooling expenses.
- SPV roof modules can eliminate the need for daytime electric lighting by providing indirect daylight.

SAQ 2

Describe the areas for SPV integration into buildings.

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2.10 LET US SUM UP

A solar passive building utilizes daylight for interior illumination. An effective use of day lighting reduces the need for artificial light substantially.

The various climatic zones and the implications of climate on building design have been discussed in detail.

2.11 KEY WORDS

Daylighting

The use of sunlight to supplement or replace artificial lighting.

Diffuse Radiation

A portion of solar radiation, scattered by water vapor, dust and other particles as it passes through the atmosphere; higher on hazy or overcast days than on clear days.

Direct Radiation

A portion of solar radiation that has traveled a straight path from the sun.

Renewable Energy

Energy resources that constantly renew themselves or that are regarded as practically inexhaustible; include solar, wind, geothermal, hydro and wood.

Renewable Resources

Renewable energy resources are virtually inexhaustible in duration; include biomass, hydro, geothermal, solar, wind, ocean thermal, wave, and tidal.

2.12 ANSWERS TO SAQS

SAQ 1

An open loop system circulates water itself, through the collector. In closed loop systems, the circulating fluid is kept separate from the system used for water supply. The closed loop systems are less efficient as the heat exchanger used in the system causes a loss of temperature of water.

SAQ 2

SPV can be integrated into the buildings by the following three main areas :

(1) **Integral roof modules :** Roof integration has been the most popular application. The reason being that SPV modules can collect maximum solar radiation and hence can provide the highest power output.

(2) **Roofing tiles :** Building integrated SPV modules produced in the same size as building materials like roof tiles or glass and other cladding panels have dual advantage. They can replace these materials efficiently and simultaneously can provide much needed energy.

(3) **Vertical facades :** Vertical curtain walls can replace traditional cladding materials like glass.