CHAPTER 3

FREE COOLING POTENTIAL

3.1 INTRODUCTION

The possible duration of the free cooling potential is evaluated, utilising the cooling load estimation and hourly weather data for Bangalore city in India, and the appropriate technology for maintaining the comfort conditions within the temperature range of 25 ± 3°C is suggested, in order to reduce the energy requirement of the building considered in the analysis. Bangalore is the capital city of Karnataka state. It is located at 12° 58" North latitude and 77° 34" East longitude. It is at an altitude of 920 meters from the sea level. The city is blessed with a very pleasant climate, compared to other major Indian cities. In summer, the temperature varies between 36°C and 20°C, while in winter it is between 27°C and 14°C, with an average relative humidity of 45 to 80%. The city experiences the south-western monsoon rains in the period between June and September.

3.2 CRITICAL INPUTS FOR COOLING LOAD CALCULATION

Cooling load calculations are carried out to estimate the required capacity of cooling systems, which can maintain the required levels in the conditioned space. To estimate the required cooling capacities, the information regarding the design indoor and outdoor conditions, specifications of the building, and specifications of the conditioned space (such as the occupancy, activity level, various appliances and equipment used,
etc.), and the information regarding the particular applications are required. For comfort applications, the required indoor conditions are fixed by the criterion of thermal comfort, while for industrial or commercial applications, the required indoor conditions are fixed by the particular processes being performed or the products being stored.

The design of the outdoor conditions is chosen, based on the design dry bulb and coincident wet bulb temperatures for the peak summer or winter months for cooling and heating load calculations, respectively.

An accurate evaluation of the heating and cooling loads requires a complete understanding and accounting of the building components that make up the thermal enclosure along with the outdoor / indoor contributions to the load. The load calculation, where the building enclosure has been enhanced with added air tightness strategies, better windows, and additional insulation, will be more sensitive to the manipulation of the inputs.

The method used for calculating the cooling load is based on the CLTD / CLF as suggested by ASHRAE. The cooling load requirement of the building is calculated with the aid of suitable input data and building specifications, such as the building orientation (location, latitude and elevation), internal conditions (indoor temperature and relative humidity), building enclosure (insulation levels of walls, ceilings, and floors, window specification, thermal conductivity of the building material, such as the wall, floor and ceiling, and structural materials, solar heat gain factor, infiltration and ventilation levels, number of occupants, and interior and exterior shading) and internal loads (electronics, lighting and appliances). Being a commercial building the human load is considered only for 11 hours from 8 A.M. to 7 P.M.
Location – Design Conditions

The building location is described by its latitude and elevation. This location describes the values for the outdoor design conditions such as the elevation of the location, latitude, winter heating dry bulb temperatures, summer cooling dry bulb temperatures and relative humidity (RH) information. In the present work, the comfort condition in the room is considered as 28°C, 50% RH for summer and 22°C, 30% RH for winter.

Orientation

The orientation of the building must be considered in the cooling load calculation, due to the changing solar heat gains at various times of the day and the impact of those gains. The orientation of the building can greatly affect the sensible heat gain on the building, depending on the ratio of the windows to opaque walls and the degree of shading from the sun.

Building Components / Enclosure

Building construction, proper details, and materials are critical components of the heating and cooling load calculations. The R-value of the building wall, roof, and foundation construction components can be accurately calculated, using the insulation levels specified, combined with the remainder of the components that make up the construction assembly (i.e. drywall, sheathing, exterior siding materials, structural framing system, roofing materials, etc.). The window performance, described by the U-value, and SHGF and SC, must be known and accurately represented by the data input. Shading - provided by the overhang of leaves, insect screens, and internal blinds or shades will reduce the sensible heat gain. If shading is ignored in the load calculation, the cooling load will be inflated.
The sensible cooling load due to heat gains through the walls, floor and ceiling of a building is calculated, using appropriate Cooling Load Temperature Differences (CLTDs) and U-factors for summer conditions. For ceilings under naturally vented attics or beneath vented flat roofs, the combined U-factor for the roof, and vented space ceiling should be used. The mass of walls is a variable and is important in calculating the energy use, but it is not used because of the averaging technique required to develop the CLTDs. Values assume a dark colour because colour is an unpredictable variable in any building. The daily range (Outdoor temperature swing on a design day) significantly affects the equivalent temperature difference.

Heat transfer through a transparent surface such as a window, includes heat transfer by conduction due to temperature difference across the window, and heat transfer due to solar radiation through the window. The heat transfer through the window by convection is calculated with the CLTD being equal to the temperature difference across the window, and equal to the total area of the window. The SHGF and SC are obtained from ASHRAE tables based on the orientation of the window, location, month of the year, and the type of glass and internal shading device.

Ventilation and infiltration bring the outside air into the conditioned space, impacting the heating and cooling load. The target ventilation and infiltration rate must be accurately represented in the data input for the load calculation. In humid climates, the impact on the latent cooling load added by ventilation / infiltration can be significant.

Most commercial buildings have inoperable windows and are pressurised by the HVAC system to reduce the infiltration of outdoor air. It is generally assumed that a pressurised building prevents infiltration, although infiltration will often occur in the lower third of a building taller than 25 m with an operating, HVAC system, and can occur throughout a building when
the HVAC system is shut off. Generally, building infiltration for larger buildings can be calculated by the crack method.

The outdoor air ventilation load does not have a direct impact on the conditioned space (unless provided via open windows), but it does impose a load on the HVAC equipment. Outdoor air is normally introduced through the HVAC system and adds a load (sensible and latent) to the heating and cooling coils, thus affecting their size and selection. The amount of ventilation depends upon the occupancy and function of each space.

**Internal loads**

The internal cooling load due to occupants consists of both sensible and latent heat components. The rate at which the sensible and latent heat transfer takes place depends mainly on the population and activity level of the occupants. Since a portion of the heat transferred by the occupants is in the form of radiation, a Cooling Load Factor (CLF) should be used similar to that used for radiation heat transfer through fenestration. The value of the CLF for occupants depends on the hours after the entry of the occupants into the conditioned space, the total hours spent in the conditioned space, and the type of the building. Values of the CLF have been obtained for different types of buildings and have been tabulated in ASHRAE handbooks. Since the latent heat gain from the occupants is instantaneous, the CLF for the latent heat gain is 1.0.

Lighting adds sensible heat to the conditioned space. Since the heat transferred from the lighting system consists of both radiation and convection, a CLF is used to account for the time lag. The equipment and appliances used in the conditioned space may add both sensible as well as latent loads to the conditioned space. Again, the sensible load may be in the form of radiation and / or convection. The installed wattage and usage factor depend on the type
of the appliance or equipment. The CLF values are available in the form of tables in ASHARE handbooks.

3.3 **HOURLY COOLING LOAD ESTIMATION OF A COMMERCIAL BUILDING**

Figure 3.1 shows the monthly variation of the maximum and minimum dry bulb temperature of a typical day in a month in the year 2011, for Bangalore city. These data will be useful to analyse the feasibility of the free cooling potential, based on the cooling load and the comfort requirement.

![Figure 3.1 Maximum and Minimum dry bulb temperature of a typical day for various months in year 2011](image)

**Figure 3.1 Maximum and Minimum dry bulb temperature of a typical day for various months in year 2011**

In the present investigation, a commercial building of size 40 m × 25 m of 10 floors is considered for air conditioning, and to maintain the comfort temperature level of 25 ± 3°C. The details of the building specifications are given in Table 3.1. The cooling load is estimated for this building for a typical day in every month, utilising the weather data available for this city.
### Table 3.1 Building Specifications

<table>
<thead>
<tr>
<th>Details</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total size of the building (length × breadth × height)</td>
<td>40 m × 25 m × 30.8 m</td>
</tr>
<tr>
<td>No. of floors</td>
<td>10</td>
</tr>
<tr>
<td>Walls</td>
<td>10 cm face brick, heavyweight concrete block</td>
</tr>
<tr>
<td>Ceiling</td>
<td>5 cm heavy weight concrete with 5 cm thick insulation, without suspended ceiling</td>
</tr>
<tr>
<td>Basement floor</td>
<td>17.5 cm high grade basement floor</td>
</tr>
<tr>
<td>Doors</td>
<td>solid wood 5 cm thick</td>
</tr>
<tr>
<td>Windows</td>
<td>double glass, wood or vinyl frame, 3/8 air space</td>
</tr>
<tr>
<td>Shading coefficient (SC)</td>
<td>Double glass (light and clear) with roller type interior shadings</td>
</tr>
<tr>
<td>Cooling load factor (CLF)</td>
<td>glass with interior shading</td>
</tr>
<tr>
<td>Latent infiltration and ventilation losses</td>
<td>Neglected as lower room air humidity resulting from infiltration is acceptable</td>
</tr>
<tr>
<td>Comfort conditions in room</td>
<td>28 °C, 50% RH for summer and 22 °C, 30% RH for winter.</td>
</tr>
</tbody>
</table>

A suitable safety factor is taken into account for uncertainties in the occupants, equipment, external infiltration, other external conditions, etc. This relatively simple method offers reasonably accurate results for most of the buildings. However, it should be noted that the data available in ASHRAE handbooks (e.g. CLTD tables, SHGF tables) have been obtained for a specific set of conditions. Hence, any variation from these conditions introduces some amount of error, though this is generally taken care of by the safety factor (i.e., by selecting a slightly oversized cooling system).
The detailed procedure for calculation of cooling load estimation and the required data considered for cooling load estimation are given in Appendix 1.

Based on the building specifications and other factors, the hourly cooling load requirement of the building for various months is evaluated, considering the weather data available for the Bangalore city. Figure 3.2 shows the cooling load requirement of a commercial building, during various months, in Bangalore city. It is seen from the figure that the cooling is required for 4 months’ duration from February to May with a maximum load of 750 kWh between 5.00 P.M. and 6.00 P.M. in the month of March. During these months, the load requirement is higher between 3.00 P.M. and 6.00 P.M.

**Figure 3.2  Hourly cooling load estimation of a typical day for various months**
3.4 MONTH WISE COOLING LOAD REQUIREMENT

Figure 3.3 is drawn by evaluating the total cooling energy requirement of a day for various months, for the size of the building considered in the present analysis, to design the cool storage system for free cooling applications. It is seen from the figure, that Bangalore city requires a cool storage system with a maximum capacity of 5600 kWh, which will be useful for a period of 4 months from February to May, to store the cool energy during the night hours, and to retrieve this cool energy for daytime requirement.

Figure 3.3 Variation of the total cooling load requirement of a typical day in a month during various months

3.5 TECHNOLOGY RECOMMENDATIONS

The results obtained from the cooling load estimations along with the weather data available are used to make the technology recommendations, in order to utilise the free cooling potential to the maximum extent. Figure 3.4
is drawn to present the number of hours a particular cooling technology can be effectively used per month, to meet the comfort requirement for the city. It is seen from the figure that Bangalore city does not require any mechanical cooling throughout the year. Free cooling without storage is the technology solution to meet the cooling requirement for all the months, with additional cool storage for the period from February to May.

**Figure 3.4 Recommended technology options**