Strategies For Reducing Cooling Load Of Buildings

Tushar Jadhav*

Abstract : *One of the significant parameters in developing smart cities is to understand the mechanism to reduce the air conditioning load of buildings. The present study deals with various options available to reduce the cooling load of buildings. In majority of cases, the traditional way of designing air conditioning for buildings was using rule of thumb such as 100 to 150 square feet per ton of refrigeration. Today buildings are built and operated successfully with air conditioning usage of 600 to 700 square feet per ton of refrigeration. This systematic and scientific approach has resulted in drastic reduction in air conditioning load of buildings, contributing towards huge savings in the overall cost of air conditioning system. The present study addresses key areas for reducing the building cooling load. The outcomes of this study will help the architects, consultants, engineers and building owners to effectively design air conditioning system for buildings.*

Keywords : *Smart cities; Buildings; Air conditioning*

INTRODUCTION

In today's era of low carbon cities, it is important to implement policies, techniques and technologies that will result in energy efficient systems. Though there are several drivers of energy consumption in a commercial building, it is argued that the major consumers of energy are heating, ventilation and air conditioning (HVAC) systems. This highlights the importance of strong measures that need to be incorporated to reduce the energy demand and carbon emissions for HVAC applications. One of the significant parameters in developing smart cities is to understand the mechanism to reduce the air conditioning load of buildings. The present study deals with various options available to reduce the cooling load of buildings..

LITERATURE REVIEW

Dong et al. (2014) investigated the possible reduction of heating and cooling loads in a hypothetical uninsulated rammed earth wall house, located in three different climate zones in Australia. The investigation comprised of simulating the energy load with different building parameters such as glazed area, window type, shading, ventilation and wall thickness. Nazi *et al.* (2015) observed that a standard building can be altered into a low energy office building, by applying heat gain reduction methodologies drawn from heat balance analysis. The authors performed this study on anoffice building located in Malaysia usingdesign builder software.A comparative study of passive methods for reducing cooling load was performed by Venkiteswaran *et al.* (2017). The authors recommended wall insulation as the most suitable cooling reduction method since it had second highest temperature reduction and was also found to be the most cost effective method. Tale (2014) observed that the total annual energy consumption of a residential building in Dubai may be reduced by up to 23.6%, when a building uses passive cooling strategies. Jenkins (2009) highlighted the importance of office internal heat gains in reducing cooling loads in a changing climate. Rijksen (2010) presented general guidelines for the required cooling capacity of an entire office building using thermally activated building systems. The author recommended reducing the peak load by activating the thermal mass of the building, using pipes embedded in the floor. The combination of high reflective roofing sheet and high thermal insulation was found to bemore effective to reduce theannual thermal load (Yuan et al., 2017).

---

*Assistant Professor, National Institute of Construction Management and Research, Pune, India. Email: tjadhav@nicmar.ac.in

McHugh *et al.* (1998) presented a novel daylighting design that utilized beam radiation, thereby avoiding the classic problem of overheating.

METHODOLOGY

The strategies for reducing the cooling load of building are explained in the following section. The emphasis in the subsequent discussion is for Indian climatic conditions.

Building Envelope

The 'U' (overall heat transfer coefficient) values of building construction materials such as glass, walls and roof play a significant role in reducing the cooling load of building. In Indian context, the purpose of Energy Conservation Building Code (ECBC) is to provide minimum requirements for the energy-efficient design and construction of buildings. ECBC was developed by Bureau of Energy Efficiency (BEE) for new commercial buildings in May 2007. ECBC is applicable to buildings or building complexes that have a connected load of 100 kW or greater or a contract demand of 120 kVA or greater and are intended to be used for commercial purposes. ECBC 2017 is one of the first building energy codes to recognize beyond code performance. There are now three levels of energy performance standards in the code. In ascending order of efficiency, these are ECBC, ECBC Plus and Super ECBC. About 22 states in India are in the process of implementation of the code with few states and union territories (Rajasthan, Odisha, Uttarakhand, Punjab, Karnataka, Andhra Pradesh, Telangana and Union Territory of Puducherry) being notified and have adopted the code. The Energy Conservation Building Code (ECBC) classifies Indian climatic zones into five categories viz., Hot and Dry (e.g. Ahmedabad, Jodhpur etc), Warm and Humid (e.g. Mumbai, Chennai etc), Composite (e.g. Nagpur, Jaipur etc), Cold (e.g. Shillong etc) and Temperate (e.g. Bengaluru etc).

Table 1 gives an indication towards the amount of reduction in building cooling load due to ECBC compliance. The 'U' values specified in Table 1 are for hot and dry, warm and humid and composite Indian climatic zones. Additional information on the prescribed 'U' values is available in ECBC (2017).

The specimen construction material for building envelope of energy efficient building is summarized in *Table 2.*

Energy Recovery Devices

Energy recovery (sensible, latent or both) is important in maintaining acceptable indoor air quality (IAQ) as well as reducing cooling requirement for a particular application. The comparative analysis of various energy recovery devices is available in ASHRAE (2008). Jadhav and Lele (2015, 2016) have investigated the benefits of heat pipe heat exchanger (HPHX) as energy recovery devices in air conditioning systems for Indian climatic zones. *Figure 1* shows the use of HPHX for energy recovery in air conditioning.

A reduction of 5 °C temperature in 1 m^3/s of outdoor air (using energy recovery device) results in saving of 1.7 ton of refrigeration (TR).

Other Techniques

White Roofs

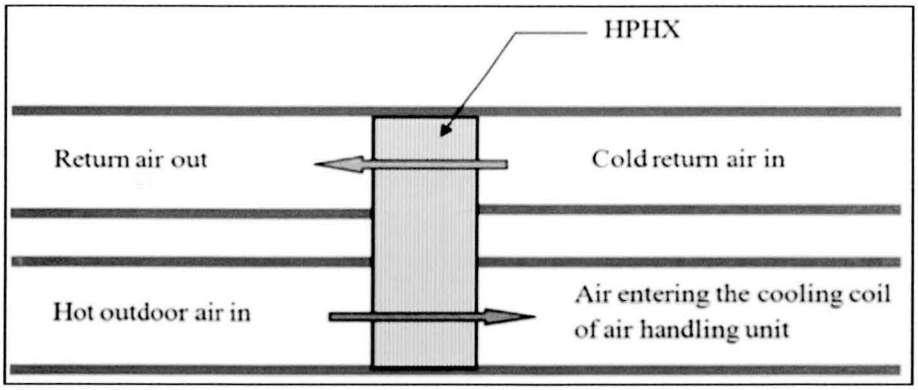
One of the ways to reduce the heat gain through roof is by using high albedo paints with solar reflectance index (SRI) greater than 0.75. Use of such paints

Table 1: Reduction In Building Cooling Load

Category	Non ECBC Compliant Building	ECBC Compliant Building	% Reduction in Cooling Load
U value glass, W/m^2K	7	3.00	57 %
U value roof, W/m^2K	3	0.33	89 %
U value wall, W/m^2K	2	0.63	69 %
SHGC (glass)	0.8	0.27	66 %

Table 2: Building Envelope For Energy Efficient Building

Element	Details
Glass	Double glazing (Manufacturer: Saint Gobain, Colour shade: Misty blue) U – value: 1.8 W/m^{2}K Solar heat gain coefficient (SHGC): 0.25
Roof	150 mm thick RCC slab with insulated and shaded roof (using insulation such as Polyurethane foam, glass wool, mineral wool etc) U value: 0.33 W/m^{2}K
Wall	Cavity wall with insulation such as extruded polystyrene or use of autoclaved aerated concrete (AAC) blocks etc U value: 0.6 W/m^{2}K



Source: Jadhav and Lele, 2015

Figure 1: Energy Recovery Using HPHX

results in reducing the temperature of roof's surface up to 10 °C.

Thermal Adaptation of Occupants

The indoor temperature and relative humidity can be maintained at slightly higher levels than that prescribed in ASHRAE standard 55. This is possible in some situations, especially for comfort air conditioning applications. This methodology can also help to reduce the cooling requirement of buildings.

Reducing Infiltration and Minimizing Duct Leakages

The building cooling load also needs to account for miscellaneous factors such as infiltration and duct leakages. The allowances for these elements can be

Source: Sastry, 2016

Figure 2: White Roofs

reduced by minimizing infiltration and duct leakages, thereby reducing the building cooling load.

Reducing Internal Gains through Lighting And Equipments

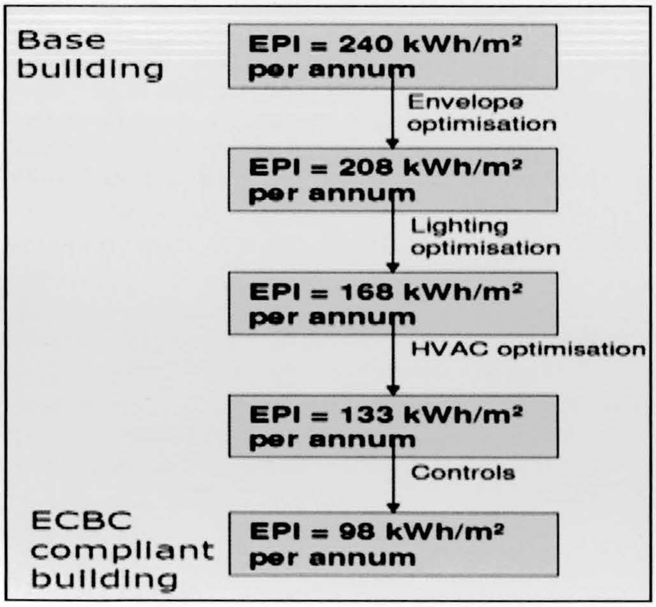
The internal gains in a building can also be reduced by selection of energy efficient lighting systems and other equipments.

CASE STUDY

The various strategies implemented by Infosys (2011) for their building located in Mysore are summarized in *Table 3*. *Table 3* shows a significant reduction of 36 % in the building cooling load due to implementation of various measures as discussed in the preceding section. Sr. No. 1 to 6 in *Table 3* indicates the strategies to reduce building cooling load whereas Sr. No. 7 to 10 are techniques used to reduce the operating cost of the air conditioning system.

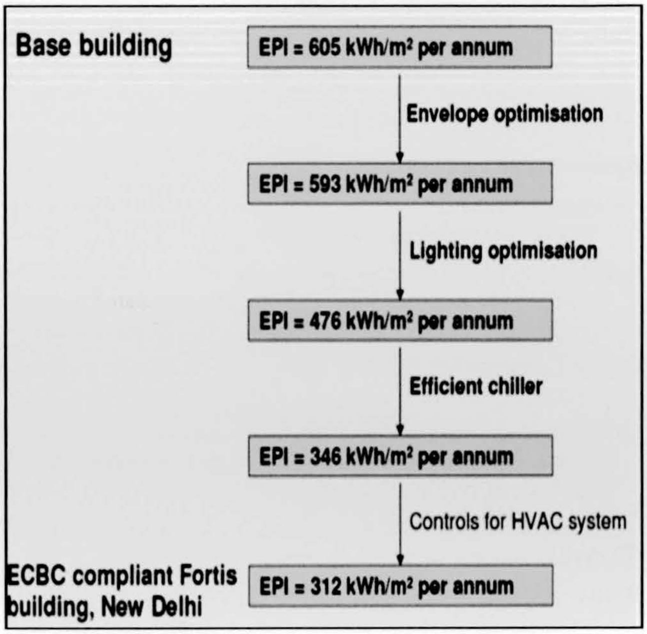
Energy performance index (EPI) is considered to be an important aspect in efficient building design.

The EPI reduction for few projects in India which are ECBC compliant is summarized through *Figure 3* and *4*.



Source: UNDP, 2011

Figure 3: Centre For Environmental Science And Engineering (CESE) At Indian Institute Of Technology (IIT), Kanpur



Source: UNDP, 2011

Figure 4: Fortis Hospital, New Delhi

Table 3: Reduction In Building Cooling Load

Sr. No.	Description	Chiller Capacity Required (TR)	Annual Energy Consumption (kWhr)	Maximum Electrical Load (kW)
1.	Conventional building envelope	622	32,44,284	1,052
2.	Efficient building envelope	530	30,30,908	968
3.	Efficient lighting design	510	27,13,390	882
4.	Efficient computers	486	23,58,776	778
5.	Variable air volume system for air conditioning	486	20,80,462	754
6.	Heat recovery wheels for air conditioning	400	20,15,430	662
7.	Ultra high efficiency chillers	400	19,92,156	650
8.	Efficient chilled water system design	400	19,60,898	640
9.	High efficient cooling tower	400	19,46,532	632
10.	Lighting controls	400	17,75,706	600

Source: www.greenbuildingcongress.com, 2014

CONCLUSION

The present study addresses several important aspects that can significantly reduce cooling load of buildings. In majority of cases, the traditional way of designing air conditioning for buildings was using rule of thumb such as 100 to 150 square feet per ton of refrigeration. Today buildings are built and operated successfully with air conditioning usage of 600 to 700 square feet per ton of refrigeration. This methodology is extremely necessary in the framework for smart cities especially in India, where the requirements of comfort and process cooling are huge. The outcomes of this study will help the architects, consultants, engineers and building owners to effectively design air conditioning system for buildings.

References

ASHRAE.(2008).Air-to-air energy recovery. *ASHRAE Handbook – HVAC systems and equipment*, 25.16.

Dong, X., Soebarto, V. and Griffith, M. (2014). Strategies for reducing heating and cooling loads of uninsulated rammed earth wall houses. *Energy and Buildings*. Vol. 77, pp. 323-331.

Energy Conservation Building Code. (2017). *Bureau of Energy Efficiency*.

Green building experiences of Infosys (2014). Retrieve from: <http://www.greenbuildingcongress.com/> [Accessed on 2 July 2018]

Guruprakash, Sastry (2016). Infosys: Front-runner in energy efficiency- A Case Study. *Energetica India*. pp. 4-6.

Jadhav, T.S. and Lele, M.M. (2015). Theoretical energy saving analysis of air conditioning system using heat pipe heat exchanger for Indian climatic zones. *Engineering Science and Technology, an International Journal*.Vol. 18, pp. 669–673.

Jadhav, T.S. and Lele, M.M. (2016). Analysis of annual energy savings in air conditioning using different heat pipe heat exchanger configurations integrated with and without evaporative cooling. *Energy*. Vol. 109, pp. 876 – 885.

Jenkins, D .P. (2009). The importance of office internal heat gains in reducing cooling loads in a changing climate. *International Journal of Low-Carbon Technologies*. Vol. 4, No. 3, pp. 134-140.

McHugh, J., Burns, P.J. and Hittle, D.C. (1998). The energy impact of daylighting. *ASHRAE Journal*. Vol. 40, No. 5, p. 31.

Nazi, W.I.W., Wang, Y.D. and Roskilly, T. (2015). Methodologies to reduce cooling load using heat balance analysis: a case study in an office building in a tropical country. *Energy Procedia*, Vol. 75, pp. 1269-1274.

Rijksen, D.O., Wisse, C.J. and Van Schijndel, A.W.M. (2010). Reducing peak requirements for cooling by using thermally activated building systems. *Energy and buildings*. Vol. 42, No. 3, pp. 298-304.

Saswati Chetia, PrashantBhanware, Kira Cusack, Pierre Jaboyedoff, Sameer Maithel(2015). Taleb, H.M. (2014). Using passive cooling strategies to improve thermal performance and reduce energy consumption of residential buildings in UAE buildings. *Frontiers of Architectural Research*. Vol. 3, No. 2, pp. 154-165.

UNDP, GEF. (2011). Energy efficiency improvements in Commercial buildings. pp. 10 - 11.

Venkiteswaran, V. K., Liman, J. and Alkaff, S. A. (2017). Comparative Study of Passive Methods for Reducing Cooling Load. *Energy Procedia*, Vol. 142, pp. 2689-2697.

Yuan, J., Emura, K. and Farnham, C. (2017). Effect of highly reflective roofing sheet on building thermal loads for a school in Osaka. *In MATEC Web of Conferences*. Vol. 119, p. 01056. EDP Sciences.

◆