CENTRAL BUILDING RESEARCH INSTITUTE, ROORKEE-247667 (INDIA)

BUILDING RESEARCH NOTE

B.R.N. 17

THERMAL DESIGN OF BUILDINGS - INFLUENCE OF DESIGN PARAMETERS

Thermal design of buildings is influenced by various parameters, such as building material and fabric specifications, orientation, glass area, insulation, shading, fenestration, ventilation rates and location of rooms. It may not be possible by thermal design alone to create comfortable condition indoors, therefore mechanical devices, such as evaporative coolers, air conditioners may be needed to pull down the thermal loads.

In this context buildings can be categorised into three types : (i) which do not utilise any heating or cooling device and use electrical energy for indoor lights and air motion, (ii) which use heating and cooling devices such as unit air conditioner, evaporative coolers, radiative and convective heaters and (iii) which use air conditioning plant to achieve thermal comfort. Majority of our buildings fall either in first or second category.

This note provides data on thermal performance of buildings under the influence of various design parameters. The suggestions to improve the thermal performance are also made.

Building Index

Thermal environment in a building depends upon the heat flow through fabric, distribution pattern of air, radiation exchange between the various components of an enclosure, and relative humidity. Of all these parameters heat flow contributes the most. It is therefore obvious that thermal behaviour of a building can be judged by the total peak heat flow resulting from individual heat flows. An index known as 'Building Index' has thus been defined as the ratio of total heat gain, averaged over entire surface area of the building envelope, to the acceptable limit of heat gain tor achieving comfortable condition indoors. Acceptable limit of heat gain has been taken as 46.5 W/m^2. Maximum limits of building index for different thermal comfort conditions and the corresponding indoor air temperature with fan are given in table 1. It is clear from the table that a building index upto 50 gives comfortable condition.

Table 1

Limits of Building Index.corresponding to air temperature and comfort conditions

S.No.	Building Index	Indoor air temperature °C	Comfort condition with fan
1.	0-50	32	Comfortable
2.	51-100	32-36	Slightly warm
3.	101-150	36-40	Hot

Thermal Performance of Buildings

Thermal performance of buildings depends on

three factors viz., climate of the place, thermal design, and usage of the building.

Indian Standard code of practice 3792-1978 divides Indian climate in four zones, namely; (i) hot-arid (ii) hot-humid (iii) warm-humid and (iv) cold. It also defines thermal performance standards for wall and roof sections. Data on thermal performance of individual components of fabric, for commonly used specifications have been given in Building Digest Nos 94, 101 and 143. The usage pattern decides the non-structural heat gain.

Effect of various design variables e.g., orientation, exposure of wall and roof, insulation, multistorey construction, white wash, glass area, ventilation rates, water spray on roof and night ventilation on building index was studied. The data on about 50 cases covering above factors were obtained for a typical summer day in hot dry region of the country. General features of building considered are given below.

Walls - 23 cm brick with plaster on both sides.
Roof - 7.5 cm lime concrete over 10 cm RCC slab
Intermediate Floor - 15 cm RCC slab
Window - 3 mm glass
Door - 2.5 cm teak wood
Ventilation - 3 air changes per hour
Aspect Ratio - 1 : 1.5

The data, on building index and comfort conditions for typical cases with different design variables are given in Table 2.

Wherever conditions are not specified in table 2, following features have been assumed :

Glass area - 15% of floor area
Orientation - longer axis of the building along east-west axis.
Exposure - Only one wall.

Influence of Design Factors

The variations in B.I values due to change in orientation can be seen from first four cases. They vary from 85 to 125 and the comfort condition deteriorates as expected. The results indicate that for any building the wall with maximum glass area should face north/south direction. However slight change in orientation is possible depending on the wind direction and site conditions. Cases 5 and 7 give the effect of multistorey construction and B.I. reduces considerably in case of ground floor.

The effect of glass area under similar conditions is evident from cases 2, 5 and 6. Increase in glass area enhances the heat intake and thereby indoor air temperatures. Therefore minimum glass area should be provided, if other design conditions such as daylight and ventilation permit. Glass area can be increased to accommodate daylight and ventilation but in that case adequate shading should be provided over the glass area. I.S. Code 3792-1978 recommends a shade factor of 0.5 for unconditioned buildings, where shade factor is defined as the ratio of heat transmitted through glass including the shaded part to that through the same area of 3 mm glass when exposed to sun.

Insulation against heat, and evaporative surfaces help in reduction of heat input to the buildings. Light, medium and heavy insulation, white wash and water spray on roof have been considered. As reflected from B.I. values (cases 8 to 14), these treatments improve indoor conditions. B.I. varies from 62 to 100.

Exposure of walls to prevailing solar heat and reduction in thickness of the wall increases the building index from 73 to 87 where as increase in thickness of wall and reduced exposure of solar heat helps in overall improvement in thermal environment indoors.

Reduction in peak cooling load

Heating or cooling of buildings is required to make them thermally comfortable for human living. It is important to assess the reduction in energy requirements using the suggested treatments. The extent of reduction in energy requirement can be assessed with the help of data given in table 2 as explained below.

Example - Let a building have a B.I. value of 80. It is brought to comfortable range (B.I. = 50) by

Table 2

Relative thermal performance of buildings

S.No.	Type of treatment	Building Index	Comfort conditions with fan
	Multistoreyed Construction		
1.	Top floor, unshaded, glass area, 15% of floor area, north orientation.	85	SW
2.	Same as (1) south orientation	87	SW
3.	Same as (1) east orientation	112	H
4.	Same as (1) west orientation	125	H
5.	Same as (2) but glass area shaded	73	SW
6.	Same as (5) but glass area 30% of floor area	85	SW
7.	Same as (5) but ground floor	56	C-SW
	Single storey construction		
8.	Light insulation on roof, glass area shaded	100	H
9.	Same as (8) medium insulation on roof	78	SW
10.	Same as (8) heavy insulation on roof	69	SW
11.	Same as (8) roof white washed	85	SW
12.	Same as (9) roof white washed	62	SW
13.	Water spray on bare roof (RCC)	62	SW
14.	Water spray with gunny bags on bare roof (RCC)	40	C
15.	One wall exposed	73	SW
16.	Two walls exposed	78	SW
17.	Three walls exposed	87	SW
18.	11.5 cm brick wall one wall exposed	79	SW
19.	34.5 cm brick wall one wall exposed	70	SW

H = Hot
SW = Slightly warm
C = Comfortable

using insulation and other treatments. What will be the peak value of saving in energy if building has a surface area of 1000m^2.

Total heat flow (when B.I. is 80) $= \frac{80 \times 46.5}{100}$

$= 37.2\ W/m^2$

Total heat flow (when B.I. is 50) $= \frac{50 \times 46.5}{100}$

$= 23.2\ W/m^2$

The reduction in heat intake =

$= (37.2 - 23.2) \times$ surface area

$= 14 \times 1000$

$= 14\ Kw/m^2$

So to aircondition this building, peak heat load is to be reduced by 14 Kw/m^2.

Concluding Remarks

1. Building index (B.I.) forms a suitable basis for comparing relative thermal performance of buildings with respect to different design parameters. A higher value of B.I. implies the need of mechanical device for cooling while a moderate value of B.I. suggests that a building can be made comfortable by suitable treatment.
2. Treatment of a building to achieve comfortable conditions depends upon the reduction in index required to achieve the desired thermal condition.
3. Suggested treatments to reduce heat intake are : choice of a suitable building fabric, shading of windows, wall & roof, application of insulation which may be light medium or heavy depending on B.I., reduction in glass area, water spray and white wash on roof, enhanced ventilation rates during night and orientation of longer axis of building along east-west axis.
4. Comfortable conditions can be achieved with a fan in ground floor of a multistoreyed building.
5. Reduction required in peak load, thus reduction in peak energy requirements can also be assessed using data given in this Building Research Note.
6. In case large glass area/open area is necessary due to daylight and/or ventilation requirements. Proper shading devices should be installed to reduce heat intake.

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