BUILDING DIGEST

CENTRAL BUILDING RESEARCH INSTITUTE INDIA

THERMAL DATA OF BUILDING FABRICS AND ITS APPLICATION IN BUILDING DESIGN

Thermal data of building fabrics and components are essentially needed by the manufacturers of building and insulating materials as also by the builders, aircondi-tioning and refrigeration engineers for achieving the design thermal performance and to obtain predetermined cooling load in air conditioning and refrigeration. They have their use also in the construction of cold storages and refrigerated chambers meant for preservation of vagetable, fruits, fish and dairy products.

Thermal parameters

The transfer of heat through building fabrics takes place by all the three processes of conduction, convec-tion and radiation. The amount of heat by conduction depends upon (1) temperature difference, (2) thickness, (3) area and (4) time. The characteristics of a material which determine the rate of this heat transfer is called the thermal conductivity (K value). The value depends upon several factors, such as, density, porosity, moisture content and temperature range to which it is subjected.

The other parameter of importance is the overall heat transfer coefficient (U value), which involves both thermal conduction and surface coefficient of the struc-ture. The surface-coefficient is dependent upon the character of the surface, the velocity of wind passing over it, orientation or position and the temperature difference between the surface and surrounding air. The symbols li and fo are used to denote the inside and outside surface coefficients respectively. If the outside-air is in motion then fo is always greater then li and will increase with the wind velocity. The average value of li for building material surfaces is about 8.05 Kcal/hr°C m² and for out-side wind velocity of 8 km per hour it is 17.08 Kcal/hr°C m². The definition, explanation and units of the different terms are further detailed in Table 1.

A list of thermal conductivity of different indigenous and commonly used heat insulating materials measured in CBRI are given in Table 2. Table 3 gives the U values of different types of walls and roofs, from which it is possible to assess the relative thermal performance of walls and roofs.

From a practical point of view, however, it is im-possible to make individual tests on every possible type of walls or roofs with different thicknesses. The U values can be calculated from a knowledge of K values of different materials, their thickness and surface coefficients.

Calculation of U value for typical cases

Procedure :

(a) Calculate thermal resistance (R) of each uniform material which constitute the building unit.

$R = \frac{L}{K}$ where L = the thickness in cms, K = thermal conductivity Kcal/hr °C m² per cm

(b) Find the total thermal Resistance

$\frac{R}{1} = 1/fo + 1/li + R_1 + R_2 + R_3 + R_4$

1/fo = outside surface resistance

1/li = inside surface resistance

R_1, R_2, R_3, and R_4 are the thermal resistance of different materials.

(c) Then $U = 1/R_T$ Kcal/m² hr °C

Example 1 : To calculate the U value for a 20 cms thick brick wall, with 1.00 cm thick cement plaster on both sides.

1. $K_1 = 81.8$ $K_2 = 69.7$ $K_3 = 81.8$ Kcal/hr°Cm² per cm

   $L_1 = 1.0$ cm $L_2 = 20.0$ cm $L_3 = 1.0$ cm

   $R_1 = \frac{L_1}{K_1} = \frac{1.0}{81.8} = 0\,0122$

   $R_2 = \frac{L_2}{K_2} = \frac{20}{69.7} = 0.2870$

   $R_3 = \frac{L_3}{K_3} = \frac{1.0}{81.8} = 0.0122$

   $1/li = 0.1250$

   $1/fo = 0.0515$

2. $R_T = 1/fo + 1/li + R_1 + R_2 + R_3$

   $= 0.4879$

3. $U = 1/R_T = 1/C4879 = 2.05$ Kcal/hr °Cm²

Fabric Load Calculations for air conditioned Buildings and cold storages.

The procedure given here for computing the fabric load is the equivalent temperature differences (ETD) method. According to this the quantity of heat flow through an area A is

$$H = U.\, t_D.\, A$$

where t_D is called the E. T. D.

The E.T.D. of different structures can be calculated from the design climatic data and the thermal para-meters. Design climatic data for different regions of the country are available from the Climatological Atlas, pub-lished by the C.B.R.I. and some publications of National Buildings Organisation, New Delhi. Example 2 shows the cooling load calculations.

Example 2 :

It is required to determine the fabric heat gain at 6 p.m. of a room (5×5×3 meters) with 33.7 cm brick walls and 11.25 cm R.C.C.+7.5 cm lime concrete terracing as the roof. It is presumed that all the two surfaces are finished in light colour, exposed to the outside climate and is oriented north, south, east and west. The required computations are shown in the tabular form.

Table A Calculation of fabric heat gain.

S. No	Component	Area (m^2)	U value Kcal/hr °cm²	E.T.D. °C	Heat gain Kcal/hr
1.	Roof	25	2.40	39.0	2340
2.	N wall	15	1.45	13.0	286
3.	E wall	15	1.45	17.0	354
4.	S wall	15	1.45	12.5	275
5.	W wall	15	1.45	13.5	297
					3552

Cooling Load Calculations for cold storages

Example (3) outlines the procedure used for cooling Load Calculations of cold storages as adopted by A.S.H. V.R. Engineers. Tables 4, 5 and 6 give the variation of thermal conductivity with temperature and moisture. The selection of the proper insulating materials for cold storage depends upon their thermal conductivity values moisture resistance and durability at low temperature.

The transmission load of a cold storage is given by

$Q=U\times A\ (\bar{t}s-ti)$.

Q=heat load Kcal/hr

U=Overall heat transmission coefficient Kcal/°C hr m²

$\bar{t}s$ = Design sol air temperature °C

ti = Inside design temperature °C

Example 3 :

Calculate the transmission cooling load for a cold storage of size (6×6×3 m) if the walls are of 22.5 cm brick work and the roof of 11.25 cm R.C.C.+7.5 cm Lime concrete. The insulation used on the walls and roof is 10 cm thermocole.

The design data are

1 Inside air temperature= —1.0 °C

2. Outside air temperature= +37.5 °C

3. Thermal conductivity of Thermocole K= 0.027 Kcal/hr°Cm

4. Taking solar radiation on different horizontal and vertical surface into account, the mean solar air temperatures are—

1. Horizontal surface (roof) = 52.0°C
2. W wall = 42.7°C
3. N wall = 40.5°C
4. S wall = 40.0°C
5. E wall = 42 2°C

Table B : Cooling load for cold storage

S. No.	Sections	Area (m^2)	U value Kcal/ hr°C M²	d (°C)	Heat load Kcal/hr
1.	Roof	36.0	0.30	53.0	552.4
2.	E wall	18.0	0·27	43 7	210.7
3.	W wall	18.0	0.27	43.7	214.1
4.	N wall	18.0	0.27	41.5	203.3
5.	S wall	18.0	0.27	41.0	201.1
					1381.6

Table I.

Definition of terms, symbols used in Heat Transfer

S.No. 1	Term 2	Symbol 3	Definition 4	Unit 5	Explanation 6
1.	Thermal Transmission or rate of heat flow.	q	The quantity of heat flowing in unit time under the conditions prevailing at that time.	K. Cal/hr	—
2.	Thermal conductivity	K	The quantity of heat flowing in steady state through a slab of unit thickness when unit difference of temperature is established between its faces.	$\frac{\text{K. Cal Cm.}}{\text{m}^2\ \text{hr °C}}$	—

1	2	3	4	5
3. Thermal Conductance	G	The heat transmission through a slab of material of unit area divided by the temperature difference between the hot and cold fall.	$\frac{K.\ Cal}{m^2\ hr.^{\circ}C}$	The difference between C and K is that while former is a measure of heat transmission through the total thickness of the structure under consideration later referes to unit thickness.
4. Surface Coefficient	f	Surface coefficient is the heat transmission per unit area from a surface in contact with air due to convection, conduction & radiation divided by the temperature difference between the surface and the air.	$\frac{K.\ Cal}{m^2\ hr.\ ^{\circ}C}$	—
5. Overall thermal transmittance	U	Overall thermal transmittance is thermal teansmittance through the unit area of the given building unit divided by the temperature difference between the air on either side of the building unit	$\frac{K.\ Cal}{m^2\ hr.\ ^{\circ}C}$	U value of a structure involves both thermal conduction and surface coefficient of the structure. For Building Structure U value is related to orientation and exposure.
6. Thermal time constant	T	Ratio of heat stored to heat transmitted.	hr.	T depends upon the heat storage capacity as well as heat transmission characteristics of the structure.

Table II

Thermal Conductivity (K values) of building fabrics at medium temperature

S.No.	Name of the buiding fabrics	Density Kg/m³	Mean temperature	Thermal conductivity Kcal/hr °Cm
1	2	3	4	5
1.	Brick	1820	45.6	0.697
2.	R. C. C (mix 1:2:4 by weight)	2288	42.0	1.36
3.	Cement mortar	1648	45 6	0.818
4.	Reinforced Brick	1920	42.5	0.945
5	Lime concrete	1446	41.0	0.628
6.	Mud phuksha	1922	42.0	0 446
7.	Brick Tile	1892	41 0	0.586
8.	Cement plaster	1762	42.0	0 620
9.	Cinder concrete	1406	43 0	0.590
10.	Cellular concrete	704	42 0	0.162
11.	Foam concrete	704	42.0	0.128
12.	Foam concrete	250	40.8	0.054
13.	Foam concrete	224	42.3	0.044
14.	Window glass	2350	59 5	0.701
15.	A. C. sheet	1520	44.1	0 240
16.	Timber various	720	41.0	0.124
17.	Timber various	480	40.0	0.062

1	2	3	4	5
18.	Gypsum Board (with a layer of Hessian cloth)	939	41.0	0 350
19.	Vermiculite (loose)	264	42.0	0.059
20.	Diotomite brick	675	53.9	0.092
21.	Crushed Dolomite	688	51.2	0.082
22.	Thermo Cole	22	41.0	0.027
23.	Foam glass	160	41.0	0.047
24.	Cork slab	173	41 0	0.037
25.	Thermo fritz	674	52 0	0 093
26.	Foam plastic	24	39 0	0.027
27.	Saw Dust	188	42.0	0.044
28.	Soft Board (wood fibre board)	249	33 0	0.040
29.	Wall board (wood fibre board)	262	37 0	0.046
30.	Chip Board	432	35.0	0.058
31.	Chip Board (perforated)	352	35.0	.057
32.	Particle Board	750	37.2	0 084
33.	Coconut pith insulation board	535	44.0	0.052
34.	Bartex Insulation Board	329	59.6	0 058
35.	Jute felt	291	37.0	0.0ı4
36.	Mineral wool slab	192	43.1	0.035
37.	Glass wool	65	50.1	0.032
38.	LLoyd wool Blanket	283	35.7	0 036
39.	Crown Fibre Glass	32.0	40.1	0.032
40.	LLoydfex	97.2	42.1	0.034

Table III

Overall Heat Transmission Coefficient (U value) for wal's and roofs.

S.No.	Specifications of walls and roofs.	Mean Air Temperature °C	Conductance Kcal/hr °C.m²	U values Kcal/hr °Cm²
1	2	3	4	5
1.	22.5 cm solid brick wall with palster on both sides	37.5	2.92	1.95
2.	33.7 cm solid brick wall with plaster on both sides	39.2	1.92	1.45
3.	2) cm cavity wall (7.5 cm brick+ 5.00 cm air gap+7.5 cm brick)	38.5	2 07	1.60
4.	27.5 cm cavity wall (11 25 cm brick +5.0 cm air gap+11.25 cm brick)	36.5	1.89	1.40
5.	22 5 cm perforated brick wall	38.5	1.95	1.43
6.	10.0 cm Hollow glass brick wall	42.0	4.72	2.41
7.	10 0 cm Foam concrete with plaster	38.0	1.75	1.32
8.	10.8 cm cintered aggregate hollow block with plaster on both sides	34.8	3.23	2.03
9.	7.6 cm cintered aggregate solid block with plaster on both sides	41.7	5.59	2.77
10.	11.25 cm R.C.C +1 25 cm plaster	41.0	13.70	3.24
11.	5.0 cm R.C.+5.00 cm F.C.+3.75 cm R.C.C. with F.C. all over	42.0	1.93	1.46

1	2	3	4	5
12.	5.0 cm R.C.C.+5.0 cm F.C.+3.75 cm R.C.C. with bridging of Dense concrete	39.2	2.97	2.12
13.	2.5 cm Thermo cole laminated panel with plywood on both sides	42.5	1.65	1.21
14.	4.0 cm thermocole laminated panel with plywood on both sides	34.8	1.42	1.13
15.	5.0 cm thermocole Laminated Panels with plywood on both sides	43.5	1.16	0.95
16.	2.5 cm silibstos sprayed insulation on G.I. sheet	37.0	1.51	1.18
17.	2.5cm Asbestos sprayed insulation on G.I. sheet	36.4	1.82	1.36
18.	11.25 cm R.C.C.+4½" L.C.	42.0	3.82	2.28
19.	11.25 cm R.C.C.+½"Plaster	41.0	13.70	3.24
20.	1" Asbestos cement board	37.5	5.71	2.87
21.	11.25 cm R.C.C.+7.5 cm M.P.+ 5.0 cm Tile	40.5	2.12	1.70
22.	11.25 cm R.B.+7.5 cm Lime concrete terracing	41 5	2.98	2.11
23.	11.25 cm R.C.C.+2.50 cm Thermo Cole+water proofing (Tar felt)	42.1	1.10	0.86
24.	11.25 cm R.C.C.+10 cm Foam concrete (Density 704 kg/m³) + water proofing	41.2	0.56	0.89
25.	11.25 cm R.C.C.+10 cm Foam concrete (density 224 kg/m³) + water proofing	43.2	0.56	0.39
26.	11.25 cm R.C.C.+5.00 cm Coconut pith+3.7 cm Brick tile	41.2	0.89	0·75
27.	11.25 cm R.C.C.+3.7 cm Coconut pith+3.7 cm B. tile	42.0	1.21	0.91

Table IV

Thermal Conductivity K-values of Insulating Materials at Low Temperatures

S No.	Name of the material	Density Kg/m³	THERMAL CONDUCTIVITIES AT TEMPERATURE (Kcal/hr. m°C)				
			−25°C	−15°C	−5°C	+15°C	+25°C
1.	Thermocole	22.2	0.02480	0.0252	0.0260	0.0265	0.0269
2.	Glass wool	69.0	0.0267	0.0273	0.0280	0.0297	0.0307
3.	Mineral wool	73.5	0.0233	0 0238	0.0243	0.0252	0.0257
4.	Cork slab	164.3	0.3385	0.0344	0.0350	0.0361	0.0367
5.	Foam concrete	224.0	0.04130	0.0419	0 0425	0.0432	0.0441
6.	Foam Glass	127.0	0.0450	0.0456	0 0463	0.0475	0.0480

Table V

Mean values for the change in thermal conductivity of Inorganic building materials with moisture.

S. No.	Group of Materials	Increase in thermal conductivity at moisture content				
		1% by Vol.	5% by Vol.	10% by Vol.	20% by Vol.	25% by Vol.
1.	Burnt Materials (Bricks etc)	37.7	15.4	10.4	6.70	—
2.	Unburnt materials (Sand lime bricks, light weight concrete blocks etc)	23.8	12.7	9.8	7.3	—
3.	Average value according to Cammerer	30	15	10 8	7.7	7.0

Table VI

Effect of moisture on thermal conductivity of organic materials :

S. No.	Density Kg/m³	Increase in thermal conductivity due to moisture by 1% by vol.
1.	300.0	4.2
2.	400.0	3.1
3.	500.0	2.5
4.	600.0	2.1
5.	700.0	1.9
6.	800.0	1.8
7.	900.0	1.6
8.	1000.0	1.25

Table VII

Conversion Factors

1. Thermal conductity—K
   1. B.T.U/hr. °F. ft.² inch to Kcal/hr°Cm² devide by 8
   2. Kcal/hr°C m to Kcal/hr°C m² per cm multiply by 100
2. U value, and conductance
   1. B.T.U/hr°F ft² to Kcal/hr°C m² multiply by 4.88
3. Density

   lbs/cubic foot to Kg/m³ multiply by 16
4. **Heat flow**

   B.T U/hr to Kcal/hr multiply by .252
5. 1 Ton capacity of refrigeration = 12000 B. T. U./hr

There is a demand for short notes summarising available information on selected building topics for the use of Engineers and Architects in India. To meet the need, this Institute is bringing out a series of Building Digests from time to time and the present one is the 52nd in the series. Readers are requested to send to the Institute their experience of adopting the suggestion given in this Digest.

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