CENTRAL BUILDING RESEARCH INSTITUTE, ROORKEE-247667 (INDIA)

BUILDING RESEARCH NOTE

B.R.N. 88

THERMAL PERFORMANCE OF WALL AND ROOF SECTIONS

Introduction

Inddoor thermal conditions upto a certain extent can be improved by a judicious selection of building components,optimum orientation and proper selection of shading devices. The main aspects of the design of thermally comfortable buildings are minimising the flow of solar heat and reducing wall and roof surface temperature under summer conditions. Upto a certain extent indoor thermal environment can be controlled by proper design and planning of building sections in relation to the climatic conditions. In this Building Research Note data on thermal performance of building sections has been provided. This will enable the architect and designer to choose proper section to improve thermal environment in buildings.

Thermal Requirements

The revised code of practice IS-3792-1978 has recommended certain minimum thermal performance requirements for building components in the different climatic zones of country. These are given in Table 1.

Method for the calculation of overall heat transfer coefficient (U) has been illustrated in Appendix. The thermal conductivity of different building materials is given in Table 2.

The values given in Table 1 are the maximum

Table 1
Thermal Performance Standard - Maximum Values

Building Components	Hot — Dry			Hot — Humid			Warm - Humid		
	U-Value		TPI	U-Value		TPI	U-Value		TPI
	K.cal/hm^2°C	[W/m^{2}K]		K.cal/hm^2°C	[W/m^{2}K]		K.cal/hm^2°C	[W/m^{2}K]	
Unconditioned Wall	2.2	2.56	125	2.2	2.56	125	2.5	2.91	175
Exposed Roof	2.0	2.33	100	2.0	2.33	100	2.2	2.56	125

Table 2

Thermal Conductivity (K-Values) of Building Fabrics at Medium Temperature

Sl. No.	Name of the Building Fabrics	Density kg/m^3	Mean Temp. (^{0}C)	Thermal Conductivity KCal/hm ^{0}C	[W/mK]
1.	Brick	1820	45.6	0.697	0.811
2.	R.C.C. (Mix 1 :2 : 4 by weight)	2288	42.0	1.360	1.582
3.	Cement Mortar	1648	45.6	0.818	0.951
4.	Reinforced Brick	1920	42.5	0.945	1.099
5.	Lime Concrete	1446	41.0	0.628	0.730
6.	Mud Phuska	1922	42.0	0.446	0.519
7.	Brick Tile	1892	41.0	0.586	0.681
8.	Cement Plaster	1762	42.0	0.620	0.721
9.	Cinder Concrete	1406	43.0	0.590	0.686
10.	Cellular Concrete	704	42.0	0.162	0.188
11.	Foam Concrete	704	42.0	0.128	0.149
12.	Foam Concrete	250	40.8	0.054	0.063
13.	Windows Glass	2350	59.5	0.701	0.815
14.	A.C. Sheet	1520	44.1	0.240	0.279
15.	Timber Various	720	41.0	0.124	0.144
16.	Gypsum Board (with layer of Hessian Cloth)	939	41.0	0.035	0.040
17.	Vermiculite (loose)	264	42.0	0.059	0.069
18.	Dolomite Brick	675	53.9	0.092	0.107
19.	Crushed Dolomite	688	51.2	0.082	0.095
20.	Thermocole	22	41.0	0.027	0.031
21.	Foam Glass	160	41.0	0.047	0.055
22.	Foam Plastic	24	39.0	0.027	0.031
23.	Saw Dust	188	42.0	0.044	0.051
24.	Soft Board	249	33.0	0.040	0.046
25.	Wall Board	262	37.0	0.046	0.053
26.	Chip Board	432	35.0	0.058	0.067
27.	Chip Board (perforated)	352	35.0	0.057	0.066
28.	Particle Board	750	37.2	0.084	0.098
29.	Coconut Pith Insulation Board	535	44.0	0.052	0.060

30.	Bartex Insulation Board	329	59.6	0.058	0.067
31.	Jute Felt	291	37.0	0.044	0.051
32.	Mineral Wool Slab	192	43.1	0.035	0.040
33.	Crown Fibre Glass	32	40.1	0.032	0.037
34.	G.I. Sheet	7520	50.0	52.000	60.470
35.	Perlite Concrete	671	30.0	0.138	0.160
36.	Perlite Concrete	1785	30.0	0.300	0.348
37.	Needled white wool	64	50.0	0.034	0.040
38.	Plastocrete	1504	50.0	1.023	1.190
39.	Wood wool board	488	30.0	0.046	0.053
40.	Autoclaved aireted concrete	562	30.0	0.147	0.171
41.	Loose Perlite (Powder form)	50	10.0	0.034	0.040
42.	Gujwool	96	50.0	0.033	0.039
43.	Ceiling wool wall panel	110	50.0	0.033	0.038
44.	Crosslinked (XPE) Polyethylene	33	42.0	0.033	0.038
45.	PVC Foam Sheet	600	30.0	0.059	0.068

Table 3

Sl. No.	Peak degree hrs. deg°C above 30°C		T. P. I.		Class	Quality performance
1.		≤6°C		≤75	A	Good
2.	>6°C	≤10°C	>75	≤125	B	Fair
3.	>10°C	≤14°C	>125	≤175	C	Poor
4.	>14°C	≤18°C	>175	≤225	D	Very poor
5.	>18°C		>225		E	Extremely poor

Table 4
Correction Factors

Sl. No.	Design factors		Hot-Dry	Hot-Humid	Warm-Humid
1.	Material	Roof	1.0	0.95	0.92
		Wall	1.0	0.85	0.75
2.	Surface finish				
	Roof	Dark	1.0	1.0	1.0
		Light	0.73	0.74	0.69
	Wall	Dark	1.0	1.0	1.0
		Light	0.79	0.77	0.75
3.	Shade				
		Roof	1.0	1.0	1.0
		Wall	0.31	0.27	0.26

Table 5
Thermal Performance Index and Overall Heat Transmission Value of Walls (Hot-Dry Climate)

Sl. No.	Specifications: Basic	Interior	Exterior	U-Values: K.cal/m² hr°C	(W/m²K)	TPI: Value	Class
	Walls						
1.	7.5 cm brick panel	—	—	3.379	3.930	231	E
2.	7.5 cm brick panel	1.8 cm cement plaster	1.8 cm cement plaster	3.077	3.578	198	D
3.	7.5 cm brick panel	7.5 cm sundried brick + 1.8 cm mud plaster.	"	2.119	2.464	124	B
4.	7.5 cm brick panel	Air space + 7.5 cm sundried brick	"	1.579	1.836	101	B
5.	7.5 cm brick panel	11.5 cm sundried brick + 1.8 cm mud plaster	"	1.857	2.159	102	B
6.	7.5 cm brick panel	Air space + 11.5 cm sundried brick + 1.8 cm mud plaster	"	1.429	1.662	84	B
7.	11.5 cm brick panel	1.8 cm mud plaster	"	2.589	3.011	157	C
8.	11.5 cm brick panel	11.5 cm mud sundried brick + 1.8 cm mud plaster	"	1.688	1.963	85	B
9.	15.0 cm brick panel	1.8 cm mud plaster	"	2.130	2.477	119	B
10.	23.0 cm brick panel	1.8 cm mud plaster	"	1.801	2.094	87	B
11.	15.0 cm cement concrete block	—	—	3.163	3.678	175	C
12.	15.0 cm stone block	1.8 cm lime plaster	—	2.920	3.395	161	C
13.	20.0 cm stone block	1.8 cm lime plaster	—	2.668	3.102	132	C
14.	30.0 cm stone block	1.8 cm lime plaster	—	2.187	2.543	89	B
15.	25.0 cm mud wall	—	—	1.430	1.663	79	B

Table 6
Thermal Performance Index and Overall Heat Transmission of Roof Sections (Hot-Dry Climate)

Sl. No.	Specifications Basic	Interior	Exterior	U-Value K.cal/m^2 hr^{0}C	W/m^{2}K	TPI Value	Class
1.	10 cm R.C.C.	1.5 cm plaster	9.0 cm lime concrete	2.221	2.583	134	C
2.	10 cm R.C.C.	1.5 cm plaster	5.0 cm mud phuska + 5.0 cm brick tile	2.056	2.391	122	B
3.	7.5 cm cement concrete	1.5 cm plaster	9.0 cm lime concrete	2.320	2.698	149	C
4.	11.5 cm brick panel	"	7.5 cm lime concrete	1.977	2.299	132	C
5.	5.0 cm timber	—	15.0 cm mud phuska + gober coating	1.069	1.243	89	B
6.	13.0 cm R.C.C.	1.5 cm plaster	9.0 cm lime concrete	2.11	2.453	121	B
7.	7.5 cm stone	—	12.0 cm mud phuska	1.881	2.187	126	C
8.	3.5 cm brick tile over wood rafter	—	12.0 cm mud phuska	1.327	1.543	121	B
9.	7.5 cm brick tile over wood rafter	—	12.0 mud phuska	1.748	2.033	104	B
10.	15.0 cm brick tile wood rafter	—	1.5 cm cement concrete	2.258	2.626	161	C

Table 7
Thermal Performance Index and Overall Heat Transfer Coefficients of Sloped Roofs

Sl. No.	Basic Elements	Interior Lining Along the Slopes	U-values K.cal/h m^2 ^{0}C	W/m^2 K	TPI	Class
1.	0.640 A.C. sheet	—	4.240	4.931	378	E
2.	—do—	Air space × 2.5 cm fibreglass	0.932	1.084	104	B
3.	0.32 cm G.I. sheet	—	4.760	5.536	425	E
4.	Country tile on bamboo matrix	—	3.422	3.979	322	E
5.	Manglore Tiles	—	4.419	5.139	390	E
6.	7.5 cm compressed straw board	—	0.826	0.961	102	B

prescribed values and should not be exceeded. In earlier building digests (94 and 101) the thermal performance of building sections were evaluated in terms of the parameter 'Thermal Performance Index' (T. P. I.). In case of unconditioned buildings excess of peak inside surface temperature over 30°C has been taken as the criterion and 8°C temperature rise over this base temperature is taken as equivalent to 100 of T. P. I. Suitable criteria for rating and classification was also evolved and has been given in above referred building digests.

Rating Criteria

The basic adopted for rating and board classification (A, B, C, D and E) for unconditioned situations are given in Table 3.

Note

Sections falling under class A are best and are suitable for airconditioned buildings, whereas class B satisfy minimum thermal requirements in unconditioned buildings.

Based on these criteria T. P. I. and U-values have been calculated for few CBRI developed and other wall and roof sections. Thermal performance index and U-value for conventional as well as recently introduced sections of walls, flat and sloped roofs are shown in Table 5, 6 and 7.

Correction Factors

The correction factor (F) for calculating T. P. I. values due to other climatic zones for unconditioned buildings were obtained and are shown in Table 4. The modified T. P. I. value can be obtained from the simple equation.

Corrected T. P. I. = (T. P. I. - 50) × F + 50

Example

Find the corrected T.P.I. values in Hot-Dry and Hot-Humid region for 7.5 cm Brick Panel (Light colour surface finish) with 1.75 cm thick cement plaster on both sides. T.P.I. value from Table 5 is 198 for the wall and correction factors are 0.79 and 0.77 (from Table 4).

(i) Corrected T.P.I.
in Hot-Dry region
(light colours) = (198 - 50) × 0.79 + 50
= 166.92

(ii) Corrected T.P.I.
in Hot-Humid region
(light colour) = (198 - 50) × 0.77 + 50
= 163.96

Similarly the effect of surface finish and shading can be calculated.

Discussions

It can be seen from Table 5 that a layer of mud plaster can be used to reduce T.P.I. and U-values. The results also indicate that it is more effective when used on exterior surface. The thermal performance improves considerably with the increase in thickness of brick wall. It is also observed that cement concrete block and sand stone masonry are inferior to brick wall for the equivalent thicknesses. However, mud walls are better than brick wall. It may be noted from Table 5 that an additional layer of 7.5 cm sundried brick wall and air space in between improves the thermal performance to a great extent. The increase in thickness of sundried brick from 7.5 cm to 11.0 further reduces the T.P.I. values from 101 to 84.

Thermal performance of roof without any insulation treatment does not satisfy the thermal requirements. It can be improved by additional treatment of insulating materials. A treatment of 5.0 cm to 7.5 cm of mud phuska on R.C.C. and R.B.C. improves the thermal peformance considrably as may be seen from Table 6. On the type of insulating materials like foam concrete, thermocole, wood wool board can also be used, 2.5 cm thickness of insulating materials will be sufficient for this purposes.

It can be observed from Table 7, that the thermal performance of sloped roofs can be improved to a great extent by providing air space and insulating materials inside the surface as done in false ceiling.

Concluding Remarks

From the data on thermal performance index and U-values presented in this digest-designers can assess the relative performance of wall and roof sections. It will enable them to make proper choice of materials to obtain better indoor thermal conditions. These values refer to Hot-dry climate. From the correction factors, the thermal performance rating can be calculated for other climatic zones. Similar data for any other material can also be given in referred to this institute.

APPENDIX

Calculation of U-Values

The U-values can be calculated from a knowledge of K-values of different materials, their thickness and surface coefficients. The K-values of different type of materials are given in Table 6. The formula for calculating U-values is :-

$$U = \frac{1}{R_T} = R_0 + R_1 + R_2 + R_j$$

where $R_0 = \frac{1}{f_0}, R_i = \frac{1}{f_1}, R_1 = \frac{L_1}{K_1}, R_2 = \frac{L_2}{K_2}$

Where R_T = Total Resistance offered in the material

f_0 = Outer surface coefficient

f_i = inside surface coefficient

L = Thickness of material

K = Thermal Conductivity

One examples of calculating of U-values for wall and roof are given below :

Example :

To calculate the U-value for a 23 cm thick brick wall, with 1.25 cm thick cement plaster on both sides :

given, K_1 = 0.721 W/mK L_1 = 0.0125 m

K_2 = 0.811 W/mK L_2 = 0.23 m

K_3 = 0.721 W/mK L_3 = 0.0125 m

f_i = 8 W/m^{2}K f_2 = 20 W/m^{2}K

$$R_T = R_i + R_0 + R_1 + R_2 + R_3$$

$$= \frac{1}{f_1} + \frac{1}{f_0} + \frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{L_3}{K_3}$$

$$= \frac{1}{8} + \frac{1}{20} + \frac{0.0125}{0.721} + \frac{0.23}{0.811} + \frac{0.0125}{0.721}$$

$$= 0.494$$

$$U = \frac{1}{R_T} = 2.02 \text{ W/m}^2\text{ K}$$

Roof - To calculate the U-value for a roof with following specification

10 cm RCC + 5 cm MP + 5 cm B.T. + 1.25 cm Cement Pl.

$$R_T = R_i + R_0 + R_1 + R_2 + R_3 + R_4$$

$$= \frac{1}{f_1} + \frac{1}{f_0} + \frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{L_3}{K_3} + \frac{L_4}{K_4}$$

R_T = 0.425, where K_1, ...K_4 are taken from given data on table 2.

$$U = \frac{1}{R_T} = 2.35 \text{ W/m}^2\text{ K}$$

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