CSIR-CENTRAL BUILDING RESEARCH INSTITUTE, ROORKEE – 247667 (INDIA)
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BUILDING RESEARCH NOTE

B.R.N. 90

DATA BANK ON THERMAL INSULATING MATERIALS

Heat is a form of energy and always flows from high temperature to low temperature. Heat flow requires temperature gradient. When thermal insulation is kept in between hot temperature and low temperature medium, heat flow is reduced. The reduction of heat flow depends upon type of thermal insulation. Thermal insulation is measured by its thermal property that is known as Thermal conductivity.

Thermal conductivity is the quantity of heat flowing in unit time through a unit area of slab of uniform material of infinite extent and of unit thickness under steady state condition when unit difference of temperature is established between its faces. When number of material is combined, a composite multilayer material is produced. Thermal transmittance through composite material depends upon its overall thermal transmittance (U) value.

Overall thermal transmittance is the heat flow through unit cross sectional area of the given building section in unit time under steady state condition when unit temperature difference between the fluid at one side to fluid at other side is established. It is denoted by U.

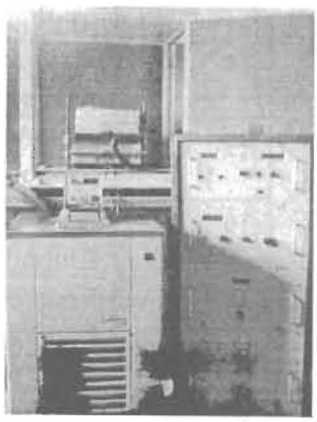
PRINCIPLE OF THERMAL CONDUCTIVITY MEASUREMENT BY GUARDED HOT PLATE APPARATUS

The principle of Guarded hot plate apparatus is that the heat flow through Guarded hot Plate normal to the specimens to isothermal cold plate maintained at lower temperature. The temperature balance between the centre and guard sections of the main heaters which are separated by a small gap is maintained by using the output of the thermocouples to control the power supplied to the Guard heater. The balance conditions can be checked by using the outputs of thermocouples pairs mounted in the surface plates on either side of the plates. In case of measurements at high temperature from 50-300°C two auxiliary plates are used on either side of the specimens to increase the mean temperature. Any difference in the temperature of the central and guard heater is balanced through differential thermocouples by equal guard temperature device. When the temperatures of the guard, central and cold plate become constant steady for about two hours, the desired steady state is reached. The power (Q) consumed in maintaining steady state heat flow and the temperature difference between the hot and cold plate is measured. Thermal conductivity is calculated by the formula:

$$Q = K.A * (\Theta_H - \Theta_c)/d$$

Where, K is Thermal Conductivity (W/mc)
Q is heat flow (W/m^2)
A is area (sq. m)
Θ_H is temperature of hot plate (°C)
Θc is temperature of cold plate (°C)
and d is the thickness of sample (meter)

Thermal Conductivity of single layered homogeneous material is determined by Automatic Guarded Hot Plate Apparatus.Thermal resistance (R) can be computed by dividing the length with thermal conductivity of the material. It is the property which resists heat flow and can be determined by the following equation.



Guarded Hot Plate Apparatus for Thermal Conductivity measurement

$$R = \sum \frac{l_o}{K_o} + \frac{l_1}{K_1} + \frac{l_2}{K_2} + \frac{l_3}{K_3} + \cdots$$

Where, l_o and K_o are thickness and thermal conductivity of the first layer and so on.

Overall thermal transmittance of the material is determined by putting the value of thickness, thermal conductivity and inside and outside surface heat transfer coefficients. It is determined as,

$$U = \left(\frac{1}{\frac{1}{h_i} + \sum \frac{L}{k} + \frac{1}{h_o}} \right) - 1$$

Where, k_1, k_2 ....are thermal conductivity of different materials (layers) and l_1, l_2.....are their thicknesses & h_i and h_o are inside and outside surface heat transfer coefficients respectively.

Thermal Conductivity of insulating material determined by Guarded Hot Plate Apparatus

S. No	Type of materials	Density(Kg/m^3)	Thermal conductivity (W/mK)	Specific heat (Kj/Kg K)
(a)	**Insulating materials**			
1	Expanded Polystyrene	16.0	0.038	1.34
2	Expanded Polystyrene	24.0	0.035	1.34
3	Expanded Polystyrene	34.0	0.035	1.34
4	Foam glass	127.0	0.056	0.75
5	Foam glass	160.0	0.055	0.75
6	Foam concrete	320.0	0.070	0.92
7	Foam concrete	400.0	0.084	0.92
8	Foam concrete	704.0	0.149	0.92
9	Cork slab	164.0	0.043	0.96
10	Cork slab	192.0	0.044	0.96
11	Cork slab	304.0	0.055	0.96
12	Rock Wool (Unbounded)	92.0	0.047	0.84
13	Rock Wool (Unbounded)	150.0	0.043	0.84
14	Mineral wool (Unbounded)	73.5	0.030	0.92
15	Glass Wool (Unbounded)	69.0	0.043	0.92
16	Glass Wool (Unbounded)	189.0	0.040	0.92
17	Resin Bonded Mineral wool	48.0	0.042	1.00
18	Resin Bonded Mineral wool	64.0	0.038	1.00
19	Resin Bonded Mineral wool	99.0	0.036	1.00

20	Resin Bonded Glass wool	16.0	0.040	1.00
21	Resin Bonded Glass wool	24.0	0.036	1.00
22	Exfoliated vermiculite (loose)	264.0	0.069	0.88
23	Asbestos Mill Board	1397.0	0.249	0.84
24	Hard Board	979.0	0.279	1.42
25	Straw Board	310.0	0.057	1.30
26	Soft Board	320.0	0.066	1.30
27	Soft Board	249.0	0.047	1.30
28	Siporex	562.0	0.047	
29	Flyash	(i) 2186 (ii) 2480 (iii) 1750	0.067 1.52 1.37	
30	Wall Board	262.0	0.047	1.26
31	Chip Board	432.0	0.067	1.26
32	Chip Board (Perforated)	352.0	0.066	1.26
33	Partical Board	750.0	0.098	1.30
34	Coconut pith Insulation Board	520.0	0.060	1.09
35	Jute Fiber	329.0	0.067	1.09
36	Wood Wool Board (Bonded with-cement)	398.0	0.081	1.13
37	Wood Wool Board (Bonded with-cement)	674.0	0.108	1.13
38	Coir Board	97.0	0.038	1.00
39	Saw Dust	188.0	0.051	1.00
40	Rice Husk	120.0	0.051	1.00
41	Jute felt	291.0	0.042	0.88
42	Asbestos Fiber (loose)	640.0	0.060	0.84
43	Auto Claved aerated Concrete	(i) 490 (ii) 590	(i) 0.133 (ii) 0.171	0.81 0.81
44	Perlite concrete	(i) 550 (ii) 750 (iii) 1000	(i) 0.151 (ii) 0.212 (iii) 0.261	0.92 0.92 0.92
45	EPS Concrete (Thermocrete)	(i) 932 (ii) 800 (iii) 675 (iv) 315	0.231 0.209 0.189 0.131	0.96
46	Polyster Fiber	14.8	0.041	1.00
47	PUF	32.0	0.0242	0.82
48	ISO-Board	32.0	0.028	0.82
49	Styro Foam	35.0	0.027	1.34
50	Gujwool	64.0	0.041	1.00

51	Pine needle Board	700.0	0.113	0.82
52	Calcium silicate	9.87	0.193	1.00
53	Ceramic wool (Blanket)	141.1	0.055	1.10
54	LRB Mattress	147.1	0.0697	0.92
55	E-Glass Needle Mat	150.0	0.0337	1.00
56	Expended polyethylene (EPE)	55.0	0.031	0.88
57	Insulflex insulation	91.0	0.038	0.88
58	Siporax (Autoclaved aerated concrete)	(i) 550 (ii) 490 (iii) 590	0.157 0.133 0.171	0.82
59	Expended polystyrene	14.5	0.045	0.88
60	Elastopor	50.0	0.0241	0.96
61	Peripor	51.1	0.028	0.96
62	Marble	2550	2.52	0.84
63	Neopor	19.8	0.0331	1.30
64	Styropor	21.7	0.0321	1.30
65	Ceramic (China mosaic)	2000	1.05	0.84
66	Elastospray	43.8	0.023	1.08
67	Vermiculite Concrete	1230	0.511	0.88
68	NitrileRubber	58.6	0.0395	0.84
69	Expanded Perlite (Loose Perlite)	(i) 65 (ii) 60 (iii) 46.3	0.0434 0.0410 0.0394	0.88
70	Whitewool (Polyster Fiber)	(i) 7.0 (ii) 11.0	0.078 0.064	0.92
71	Vermiculite tile	(i) 1578 (ii) 1254.44	0.356 0.432	0.84
72	Ceramic Fibre	133.3	0.085	0.96
73	Extruded Polystyrene	14.4	0.48	1.00
74	Polyisocyanurate Foam	37.0	0.0477	0.88
(b)	**Building Materials**			
1	Brunt Brick	1820	0.811	0.88
2	Mud Brick	1731	0.750	0.88
3	Dense Conc.	2410	1.74	0.88
4	RCC	2288	1.58	0.88
5	Limestone	2420	1.80	0.84
6	Slate	2750	1.72	0.84
7	Reinforced brick	1920	1.10	0.84
8	Brick Tile	1892	0.798	0.88
9	Lime Conc.	1646	0.730	0.88
10	Mud Phuska	1622	0.519	0.88
11	Cement mortar	1648	0.719	0.92
12	Cement plaster	1762	0.721	0.84
13	Cinder Conc.	1406	0.686	0.84

14	Foam slag Concrete	1320	0.285	0.88
15	Gypsum Plaster	1120	0.512	0.96
16	Cellular Conc.	704	0.188	1.05
17	AC Sheet	1520	0.245	0.84
18	GI Sheet	7520	61.06	0.50
19	Timber	480	0.072	1.68
20	Plywood	640	0.174	1.76
21	Glass	2350	0.814	0.88
22	Alluvial clay (40% sands)	1958	1.211	0.84
23	Sand	2240	1.74	0.84
24	Black cotton clay (Madras)	1899	0.735	0.88
25	Black cotton clay (Indore)	1683	0.606	0.88
26	Timber	720	0.144	1.68
27	Tar felt (2.3 Kg/m^2)		0.479	0.88
28.	Non Ac-Sheet	1201	.0172	0.88

U -value of single layered section

Sr. no	Name of material	Density (Kg/m^3)	Mean temp (°c)	K-Value (W/mK)	Thickness (in cm)	U- Value (W/m^2K)
1.	Alluvial Clay (40% sand)	1958	50°C	1.211	10 20 30 40 50 60	4.17 3.10 2.47 2.05 1.75 1.53
2.	Black Cotton Clay (Indore)	1899	50°C	0.606	10 20 30 40 50 60	3.10 2.05 1.53 1.22 1.01 0.87
3.	Black Cotton Clay (Madras)	1683	50°C	0.735	10 20 30 40 50 60	3.41 2.33 1.76 1.42 1.19 1.02
4.	Burn Brick	1820	50°C	0.811	11.50 23	3.34 2.26
5.	Dense Concrete	2410	50°C	1.74	10	4.66
6.	Lime stone	2420	50°C	1.80	10	4.70
7.	Mud Brick	1731	50°C	0.750	11.50	3.22
8.	Perlite	550	50°C	0.151	5	2.04
9.	Plywood	640	50°C	0.174	0.6 1.0	5.22 4.66

10	Reinforced brick	1920	50°C	1.10	11.50	3.82
11	Vermiculite	1254	50°C	0.432	5	3.66
12	EPS Concrete	315	50°C	0.131	10	1.08
					15	0.76
					20	0.59
					25	0.48
					30	0.40
	-do-	675	50°C	0.189	10	1.45
					15	1.05
					20	0.82
					25	0.67
					30	0.57
	-do-	800	50°C	0.209	10	1.57
					15	1.14
					20	0.89
					25	0.73
					30	0.62
	-do-	932	50°C	0.231	10	1.70
					15	1.24
					20	0.97
					25	0.80
					30	0.68

ROOF SECTION: Basic Materials - 15cm RCC (k=1.26)
U-Value of 15cm RCC =3.62 W/m^{2}K.
Basic composite section - 15cm RCC (k=1.26) + 5cm Mud Phushka (k=0.519) + 5cm Brick tile (k=0.798), U-Value- 2.30 W/m^{2}K.

Insul.Mat.	Thickness (in cms)	R-Value1 (Insul. Mat)	R-Value 2 (RCC)	R-Value 3 (Mud Phus)	R-Value 4 (Brk.Tile)	U-Value (W/m^{2}K)
EPS (K=0.035)	2.5	0.714286	0.119048	0.096339	0.062657	0.870073
	5	1.428571	0.119048	0.096339	0.062657	0.536592
	7.5	2.142857	0.119048	0.096339	0.062657	0.387913
	10	2.857143	0.119048	0.096339	0.062657	0.303750
PUF (K=0.027)	2.5	0.925926	0.119048	0.096339	0.062657	0.734770
	4	1.481481	0.119048	0.096339	0.062657	0.521778
	5	1.851852	0.119048	0.096339	0.062657	0.437274
	6	2.222222	0.119048	0.096339	0.062657	0.376327
	7.5	2.777778	0.119048	0.096339	0.062657	0.311253
	10	3.703704	0.119048	0.096339	0.062657	0.241619
Foam Conc (K=0.070)	2.5	0.357143	0.119048	0.096339	0.062657	1.262329
	5	0.714286	0.119048	0.096339	0.062657	0.870073
	7.5	1.071429	0.119048	0.096339	0.062657	0.663803
	10	1.428571	0.119048	0.096339	0.062657	0.536592
	12.5	1.785714	0.119048	0.096339	0.062657	0.450297
	15	2.142857	0.119048	0.096339	0.062657	0.387913
Fiber Glass (K=0.040)	2.5	0.625	0.119048	0.096339	0.062657	0.943358
	5	1.25	0.119048	0.096339	0.062657	0.593457
	6	1.5	0.119048	0.096339	0.062657	0.516784
	7.5	1.875	0.119048	0.096339	0.062657	0.432892
	10	2.5	0.119048	0.096339	0.062657	0.340710

Styropor (K=0.032)	2.5	0.778816	0.119048	0.096339	0.062657	0.823819
	5	1.557632	0.119048	0.096339	0.062657	0.501838
	6	1.869159	0.119048	0.096339	0.062657	0.433990
	6.5	2.024922	0.119048	0.096339	0.062657	0.406510
	7.5	2.336449	0.119048	0.096339	0.062657	0.360816
	10	3.115265	0.119048	0.096339	0.062657	0.281666
Peripor (K=0.028)	2.5	0.892857	0.119048	0.096339	0.062657	0.753068
	4	1.428571	0.119048	0.096339	0.062657	0.536592
	5	1.785714	0.119048	0.096339	0.062657	0.450297
	5.5	1.964286	0.119048	0.096339	0.062657	0.416783
	6	2.142857	0.119048	0.096339	0.062657	0.387913
	7.5	2.678571	0.119048	0.096339	0.062657	0.321170
	10	3.571429	0.119048	0.096339	0.062657	0.249596
Neopor (K=0.033)	2.5	0.755287	0.119048	0.096339	0.062657	0.840103
	5	1.510574	0.119048	0.096339	0.062657	0.513976
	6	1.812689	0.119048	0.096339	0.062657	0.444893
	6.5	1.963746	0.119048	0.096339	0.062657	0.416877

WALL SECTION : 1.25cm Cement Plaster (k=.721) +11.50cm Brick (k=.811) +1.25cm Cement Plaster + insulating materials.

Note: Without insulating materials, the U-Value of Wall Section is: 3.026 W/m^{2}K

Insulating material	Thickness (cm)	R-Value (Insul.mat)	R-Value1 (C.P)	R-Value 2 (Brick)	U-Value (W/m2K)
Foam Conc (K=0.070)	1	0.142857	0.034674	0.1418	2.099378
	2.5	0.357143	0.034674	0.1418	1.447980
	4	0.571429	0.034674	0.1418	1.105091
	5	0.714286	0.034674	0.1418	0.954417
	7.5	1.071429	0.034674	0.1418	0.711793
	10	1.428571	0.034674	0.1418	0.567522
	12.5	1.785714	0.034674	0.1418	0.471879
	14	2	0.034674	0.1418	0.428546
	15	2.142857	0.034674	0.1418	0.403823
Fiber Glass (K=0.040)	1	0.25	0.034674	0.1418	1.713872
	2.5	0.625	0.034674	0.1418	1.043325
	3	0.75	0.034674	0.1418	0.922957
	5	1.25	0.034674	0.1418	0.631523
	7	1.75	0.034674	0.1418	0.479968
	7.5	1.875	0.034674	0.1418	0.452801
	10	2.5	0.034674	0.1418	0.352924
EPS (K=0.035)	1	0.285714	0.034674	0.1418	1.615017
	2	0.571429	0.034674	0.1418	1.105091
	2.5	0.714286	0.034674	0.1418	0.954417
	7	2	0.034674	0.1418	0.428546
	7.5	2.142857	0.034674	0.1418	0.403823
	10	2.857143	0.034674	0.1418	0.313419
Perlite Conc. (K=0.138)	2	0.144928	0.034674	0.1418	2.090293
	2.5	0.181159	0.034674	0.1418	1.943130
	7.5	0.543478	0.034674	0.1418	1.140313
	8	0.57971	0.034674	0.1418	1.095069
	12.5	0.905797	0.034674	0.1418	0.806926
	20	1.449275	0.034674	0.1418	0.560931

	25	1.811594	0.034674	0.1418	0.466186
	27.5	1.992754	0.034674	0.1418	0.429880
	28	2.028986	0.034674	0.1418	0.423288
	30	2.173913	0.034674	0.1418	0.398822
Elastopor (K=0.0241)	1	0.414938	0.034674	0.1418	1.336162
	2.5	1.037344	0.034674	0.1418	0.729491
	4	1.659751	0.034674	0.1418	0.501699
	5	2.074689	0.034674	0.1418	0.415254
	7.5	3.112033	0.034674	0.1418	0.290233
Styropor (K=0.032)	1	0.311526	0.034674	0.1418	1.550386
	2.5	0.778816	0.034674	0.1418	0.899046
	3	0.934579	0.034674	0.1418	0.788610
	5	1.557632	0.034674	0.1418	0.528791
	7	2.180685	0.034674	0.1418	0.397747
	7.5	2.336449	0.034674	0.1418	0.374543
	10	3.115265	0.034674	0.1418	0.289961
ISO Board (K=0.028)	1	0.357143	0.034674	0.1418	1.447980
	2	0.714286	0.034674	0.1418	0.954417
	2.5	0.892857	0.034674	0.1418	0.815440
	7	2.5	0.034674	0.1418	0.352924
	7.5	2.678571	0.034674	0.1418	0.332000
	10	3.571429	0.034674	0.1418	0.256088
PUF (K=0.027)	1	0.37037	0.034674	0.1418	1.420768
	2.5	0.925926	0.034674	0.1418	0.794029
	4	1.481481	0.034674	0.1418	0.550978
	5	1.851852	0.034674	0.1418	0.457598
	7.5	2.777778	0.034674	0.1418	0.321414
	10	3.703704	0.034674	0.1418	0.247698
Peripor (K=0.028)	1	0.357143	0.034674	0.1418	1.447980
	2.5	0.892857	0.034674	0.1418	0.815440
	3	1.071429	0.034674	0.1418	0.711793
	5	1.785714	0.034674	0.1418	0.471879
	7	2.5	0.034674	0.1418	0.352924
	7.5	2.678571	0.034674	0.1418	0.332000
	10	3.571429	0.034674	0.1418	0.256088
Neopor (K=0.0331)	1	0.302115	0.034674	0.1418	1.573343
	2	0.60423	0.034674	0.1418	1.066435
	2.5	0.755287	0.034674	0.1418	0.918475
	7	2.114804	0.034674	0.1418	0.408450
	7.5	2.265861	0.034674	0.1418	0.384714
	10	3.021148	0.034674	0.1418	0.298096
Expanded Poly Ethylene (K=0.0310)	1	0.322581	0.034674	0.1418	1.524263
	2	0.645161	0.034674	0.1418	1.021831
	2.5	0.806452	0.034674	0.1418	0.877250
	7	2.258065	0.034674	0.1418	0.385871
	7.5	2.419355	0.034674	0.1418	0.363263
	10	3.225806	0.034674	0.1418	0.280956

Prepared by : Dr. B. M. Suman, *Sr. Technical Officer*
CSIR-Central Building Research Institute
ROORKEE- 247 667, INDIA
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Edited by : Dr. Atul Kumar Agarwal, *Scientist*

Email : director@cbrimail.com & director@cbri.in, Website: www.cbri.org.in/www.cbri.res.in