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GUIDE FOR HEAT INSULATION OF NON-INDUSTRIAL BUILDINGS

(First Revision)

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0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 28 December 1978, after the draft finalized by the Functional Requirements in Buildings Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 This standard was first issued in 1966. In view of the experience gained in the country in this field, the Committee responsible for the preparation of this standard felt the necessity for its revision. Some of the significant changes made in this revision are highlighted in **0.2.1**.

0.2.1 The new terms such as thermal performance index and shade factor have been introduced. Recommendations to attain desirable thermal conditions in the buildings have been modified. Figures 2, 3 and 4 have been revised and new sections describing the figures have been introduced. The values of shade factor for various shading devices have been included. Appendix C has been modified to cover the latest building and insulating materials in vogue in the country. Tables 2 and 3 in Appendix D have been deleted.

0.3 General principles of heat transfer have been given in Appendix A, mainly for the purpose of providing some additional information relevant to the recommendations made in this guide.

0.4 In the formulation of this guide the Sectional Committee has also considered the recommendations and practices in vogue in other countries, with regard to heat insulation of buildings wherein no mechanical cooling or heating aids, such as air-conditioning plants, have been used. In major parts of this country, the problem is mainly prevention of undue heat gain of structures during hot-dry and hot-humid periods. This guide lays down recommendations for the reduction of heat flow from outside to inside the building and also gives necessary data required in this connection. It may, however, be noted that thermal insulation applied to minimize heat gain of a structure during the hot season will assist in reducing the heat loss of the same structure in the cold season, though the exact extent may vary.

0.5 This standard is one of a series of Indian Standards on functional requirements of buildings. A list of standards published so far in the series is given on page 40.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This guide is intended to cover heat insulation of non-industrial buildings, such as dwellings, hospitals, schools and office buildings wherein no mechanical cooling or heating aids, such as air-conditioning plants, are used.

2. DEFINITIONS OF TERMS, SYMBOLS AND UNITS OF QUANTITIES USED IN HEAT INSULATION

2.1 Definitions of terms, symbols and units of quantities commonly used in expressing the results of measurements or in calculating the extent of heat flow through building units are given in Table 1.

3. TEMPERATURE-*CUM*-HUMIDITY ZONES IN INDIA

3.1 Keeping in view the fact that for indoor comfort the heat-insulation requirements for buildings in relation to different climatic regions would be different, for the purpose of this guide the country may be divided into zones as detailed under **3.1.1** to **3.1.4**.

3.1.1 *Hot and Arid Zone* — Regions where mean daily maximum dry bulb temperatures of 38°C or higher, and relative humidity of 40 percent or less, prevail during the hottest month of the year and where the altitude is not more than 500 m above mean sea level, may be classified as hot and arid zones. Some representative towns falling under this zone are given in Appendix B.

*Rules for rounding off numerical values (*revised*).

TABLE 1 DEFINITIONS OF TERMS, SYMBOLS AND UNITS OF QUANTITIES USED IN HEAT INSULATION

(*Clause* 2.1)

SL No.	TERM	SYMBOL	DEFINITION	UNIT	EXPLANATION
(1)	(2)	(3)	(4)	(5)	(6)
i)	Thermal transmission or rate of heat flow	q	The quantity of heat flowing in unit time under the conditions prevailing at that time	W	—
ii)	Thermal conductivity	k	The quantity of heat in the 'steady state' conditions flowing in unit time through a unit area of a slab of uniform material of infinite extent and of unit thickness, when unit difference of temperature is established between its faces	W/(mK)	The thermal conductivity is a characteristic property of a material and its value may vary with a number of factors, including density, porosity, moisture content, fibre diameter, pore size, type of gas in the material, mean temperature and outside temperature range
iii)	Thermal resistivity	$\frac{1}{k}$	Thermal resistivity is the reciprocal of thermal conductivity	mK/W	—
iv)	Thermal conductance per unit area	C	The thermal transmission of a single layer structure per unit area divided by the temperature difference between the hot and cold faces	$\frac{W}{m^2K}$	Thermal conductance is a measure of the thermal transmission per unit area through the total thickness of the structure under consideration. Thermal conductivity on the other hand refers to unit thickness of a material. Further, this term applies only to a single layer of material and not to a composite insulation or to a structure made up of several layers, materials of mediums
v)	Thermal resistance	R	Thermal resistance is reciprocal of thermal conductance. For a structure having plane parallel faces, thermal resistance is equal to thickness (L) divided by thermal conductivity (k) as given below: $$R = \frac{L}{k}$$	m^2K/W	The usefulness of this quantity is that when heat passes in succession through two or more components of the building unit the resistance may be added together to get the total resistance of the structure
vi)	Surface coefficient	f	Surface coefficient is thermal transmission by convection, conduction and radiation from unit area of the surface, for unit temperature difference between the surface and the surrounding medium	$W/(m^2K)$	The value of f depends on many factors, such as air or fluid movement in contact with the surface, roughness and emissivity of the surface and upon the temperature and nature of surroundings
vii)	Surface resistance	$\frac{1}{f}$	Surface resistance is the reciprocal of surface coefficient	$\frac{m^2K}{W}$	—
viii)	Total thermal resistance	R_T	The total thermal resistance is the sum of the surface resistances and the thermal resistance of the building unit itself	$\frac{m^2K}{W}$	—
ix)	Thermal transmittance	U	Thermal transmittance is thermal transmission through unit area of the given building unit divided by the temperature difference between the air or other fluid on either side of the building unit in 'steady state' conditions. It is reciprocal of total thermal resistance	$W/(m^2K)$	Thermal transmittance differs from 'Thermal conductance' in so far as temperatures are measured on the two surfaces of material or structure in the latter case and in the surrounding air or other fluid in the former. The conductance is a characteristic of the structure whereas the transmittance depends on conductance and surface coefficients of the structure under the conditions of use
x)	Thermal damping	D	$$D = \frac{(T_o - T_i)}{T_o} \times 100$$ where T_o = outside temperature range T_i = inside temperature range	Percent	Thermal damping or decreased temperature variation is a characteristic dependent on the thermal resistance of the materials used in the structure
xi)	Thermal time constant	T	Ratio of heat stored to thermal transmittance of the structure a) For homogeneous wall or roof, thermal time constant may be calculated from the following formula: $$T = \frac{Q}{U} = \left(\frac{1}{f_o} + \frac{1}{2k}\right) L\rho c$$ where Q = quantity of heat stored U = thermal transmittance f_o = surface coefficient of the outside surface k = thermal conductivity of the material L = thickness of the component ρ = density of the material c = specific heat capacity of the material b) For composite wall or roof, T may be obtained from the formula: $$T = \Sigma \frac{Q}{U} = \left(\frac{1}{f_o} + \frac{L_1}{2k_1}\right)\left(L_1\rho_1c_1\right) + \left(\frac{1}{f_o} + \frac{L_1}{k_1} + \frac{L_2}{2k_2}\right)\left(L_2\rho_2c_2\right) + \left(\frac{1}{f_o} + \frac{L_1}{k_1} + \frac{L_2}{k_2} + \frac{L_3}{2k_3}\right)\left(L_3\rho_3c_3\right)$$	h	—
xii)	Thermal performance index	TPI	$$TPI = (T_{is} - 30) \times 12{\cdot}5$$ where T_{is} = peak inside surface temperature	Percent	A temperature of 8 K has been considered over a base temperature of 30 K. It depends upon the total heat gain through the building section both by steady and periodic part and is a function of outside surface temperature
xiii)	Shade factor	S	$$S = \frac{\text{Instantaneous heat gain through the shading device}}{\text{Instantaneous heat gain through the 3·0 mm plain glass sheet}}$$	Percent	It takes into account the heat gain through glazing both by direct transmission and air to air transfer
xiv)	Time lag	—	It is the time difference between the occurrences of the temperature maximum at the outside and inside when subjected to periodic conditions of heat flow	h	—
xv)	Emissivity	E	It is the rate of the heat emitted by a surface as compared to that of an absolutely black surface under similar conditions. It varies with the temperature of emitting surfaces	—	—

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3.1.2 *Hot and Humid Zone* — Regions where mean daily maximum dry bulb temperatures above 32°C, and relative humidity above 40 percent, prevail during the hottest month of the year and where the altitude is not more than 500 m above mean sea level, may be classified as hot and humid zones. Some representative towns falling under this zone are given in Appendix B.

3.1.3 *Warm and Humid Zone* — Regions where mean daily maximum dry bulb temperatures of 26 to 32°C, and relative humidity of 70 percent or above prevail during the hottest month of the year and where the altitude is not more than 100 m above mean sea level, may be classified as warm and humid zones. Some representative towns falling under this zone are given in Appendix B.

3.1.4 *Cold Zone* — Regions where mean daily minimum dry bulb temperatures of 6°C or less, prevail during the coldest month of the year and where the altitude is more than 1 200 m above mean sea level, may be classified as cold zones. Some representative towns falling under this zone are given in Appendix B.

4. RECOMMENDATION FOR HEAT INSULATION

4.1 Heat Insulation of Roofs and Exposed Walls — To achieve the desirable thermal conditions in the buildings located in the zones described under **3.1.1** to **3.1.4** the maximum values of overall thermal transmittance and thermal performance index (*TPI*) for roofs and exposed walls given in Table 2 may be used. The minimum values for thermal damping and thermal time constant for roofs and exposed walls are also given in Table 2. The relationship between thermal damping and the thermal time constant is given by the limiting curves given in Fig. 1.

TABLE 2 THERMAL PERFORMANCE STANDARDS

Sl No.	Building Components	Hot Dry and Hot Humid Zones				Warm Humid Zone			
		U, Max	*TPI, Max*	*T, Min*	*D, Min*	*U, Max*	*TPI, Max*	*T, Min*	*D, Min*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		$W/(m^2K)$	percent	h	percent	$W/(m^2K)$	percent	h	percent
1	Roof	2·33	100	20	75	2·33	125	20	75
2	Exposed wall	2·56	125	16	60	2·91	175	16	60

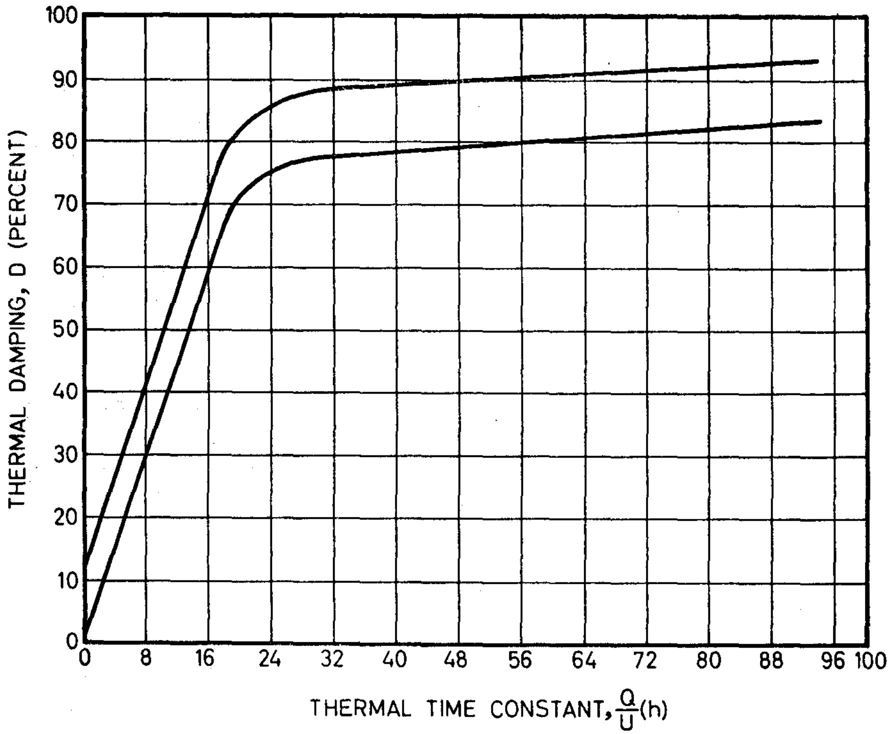


FIG. 1 LIMITING CURVES SHOWING RELATIONSHIP BETWEEN THERMAL TIME CONSTANT IN HOURS AND THERMAL DAMPING IN PERCENT

4.2 Heat insulation is usually not needed for buildings situated in places being not covered under any of the zones mentioned in **3**.

NOTE 1 — Representative towns under this category are Indore, Seoni, Bangalore, Belgaum, Mysore, Pune, Ranchi and Sagar.

NOTE 2 — Marginal cases may be dealt with by users themselves in the light of the principles enumerated in this guide.

4.3 It is recommended that no exposed window located in the zones described under **3.1.1** to **3.1.4** should have a shade factor more than 0·5 and transmittance more than 6·51 W/(m^2K).

5. METHODS OF HEAT INSULATION

5.1 General Methods

5.1.1 *Heat Insulation by Orientation* — The orientation of a building with respect to the sun has a very important bearing on its thermal behaviour.

For optimum orientation there are usually conflicting requirements. Minimum transfer of solar heat is desired during the day in summer, while maximum heat of rooms by solar heat is required during winter.

5.1.2 *Heat Insulation by Shading* — While shading of roof brings down the surface temperature, it is very difficult to achieve this effect in practice, especially when the altitude angle of the sun is quite high during the period of peak heat gain in the afternoons, between 1100 h and 1500 h. Raising the parapet walls can help only when the altitude angle of the sun is low, but the cost may not commensurate with the effect obtained.

5.1.3 *Height of Ceiling* — While the surface temperature of the ceiling does not vary with its height, the intensity of long wave radiation emitted by the ceiling decreases as it travels downwards, but the effect of vertical gradient of radiation intensity is not significant beyond 1 to 1·3 m. Hence, it should be adequate to provide ceiling at a height of about 1 to 1·3 m above the occupants.

5.2 Heat Insulation of Roofs — Heat gain through roofs may be reduced by one or more of the following methods:

a) *Application of Heat Insulating Material* — Heat insulating materials may be applied externally or internally to the roofs. In case of external application, heat insulating material may be laid over the roof but below a waterproof course. In case of internal application, heat insulating material may be fixed by adhesive or otherwise on the underside of roofs from within the rooms. False ceiling of insulating material may be provided below the roof with air gaps in between.

b) Shining and reflecting material may be laid on the top of the roof.

c) Roofs may be flooded with water in the form of sprays or otherwise. Loss due to evaporation may be compensated by make up arrangement.

d) Movable covering of suitable heat insulating material, if practicable, may be considered.

e) White washing of the roof before on-set of each summer.

NOTE — The methods given in (b) and (e) would be fully effective in case the surfaces are kept clean to avoid accumulation of dust.

5.3 Heat Insulation of Exposed Walls — Heat insulation of exposed walls may be achieved by the following ways:

a) The thickness of the wall may be increased;

b) Cavity wall construction may be adopted;

c) The wall may be constructed out of suitable heat insulating material provided structural requirements are met;

d) Heat insulating material (*see* **6**) may be fixed on the inside or outside of the exposed wall. (In the case of external application, overall waterproofing is essential); and

e) Light coloured white wash or distemper may be applied on the exposed side of the wall.

5.4 Heat Insulation of Exposed Windows and Doors — In dealing with heat insulation of exposed windows and doors, suitable methods should be adopted to reduce:

a) incidence of solar heat, and

b) reduction of heat transmission.

5.4.1 *Reduction of Incidence of Solar Heat* — This may be achieved by any one of the following means:

a) External shading, such as louvered shutters, sun breakers and *CHHAJJAS*;

b) Internal shading, such as curtains and venetian blinds; and

c) Use of heat resistant glasses/films.

5.4.2 *Reduction of Heat Transmission* — Where glazed windows and doors are provided reduction of heat transmission may be achieved by providing insulating glass or double glass with air space or by any other suitable means.

6. THERMAL CONDUCTIVITY VALUES

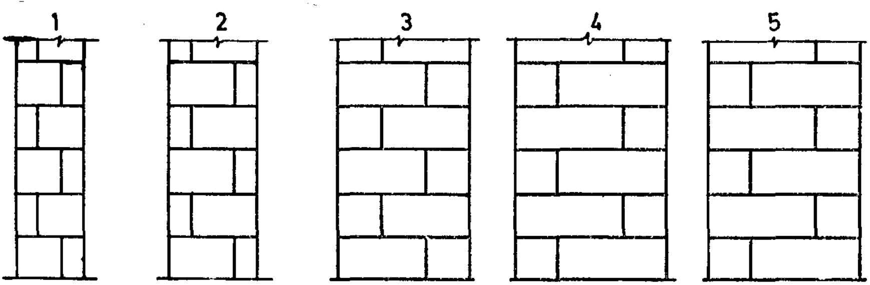
6.1 Typical building and insulating materials and their thermal conductivity values are given in Appendix C. It may, however, be noted that the values are typical and approximate and should be checked with the values declared by the manufacturers, or users should get them tested at one of the recognized testing laboratories.

7. CALCULATION OF OVERALL THERMAL TRANSMITTANCE AND THERMAL TIME CONSTANT

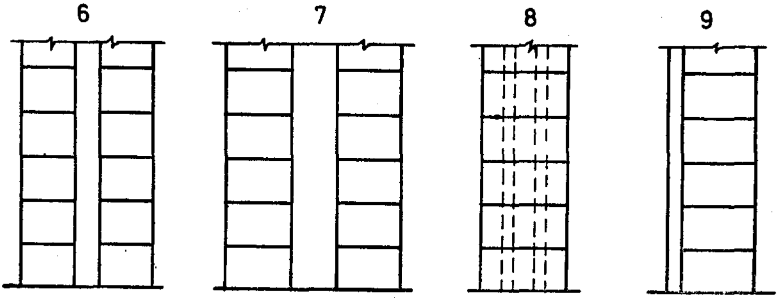
7.1 Examples showing calculations of thermal transmittance and thermal time constant for typical cases are given in Appendix D.

8. VALUES OF THERMAL TRANSMITTANCE; THERMAL DAMPING, THERMAL PERFORMANCE INDEX AND THERMAL TIME CONSTANT FOR TYPICAL BUILDING CONSTRUCTIONS

8.1 Typical building constructions and the values of thermal transmittance, thermal damping, thermal performance index and thermal time constant are given in Tables 3, 4 and 5 read correspondingly with Fig. 2, 3 and 4 for information.



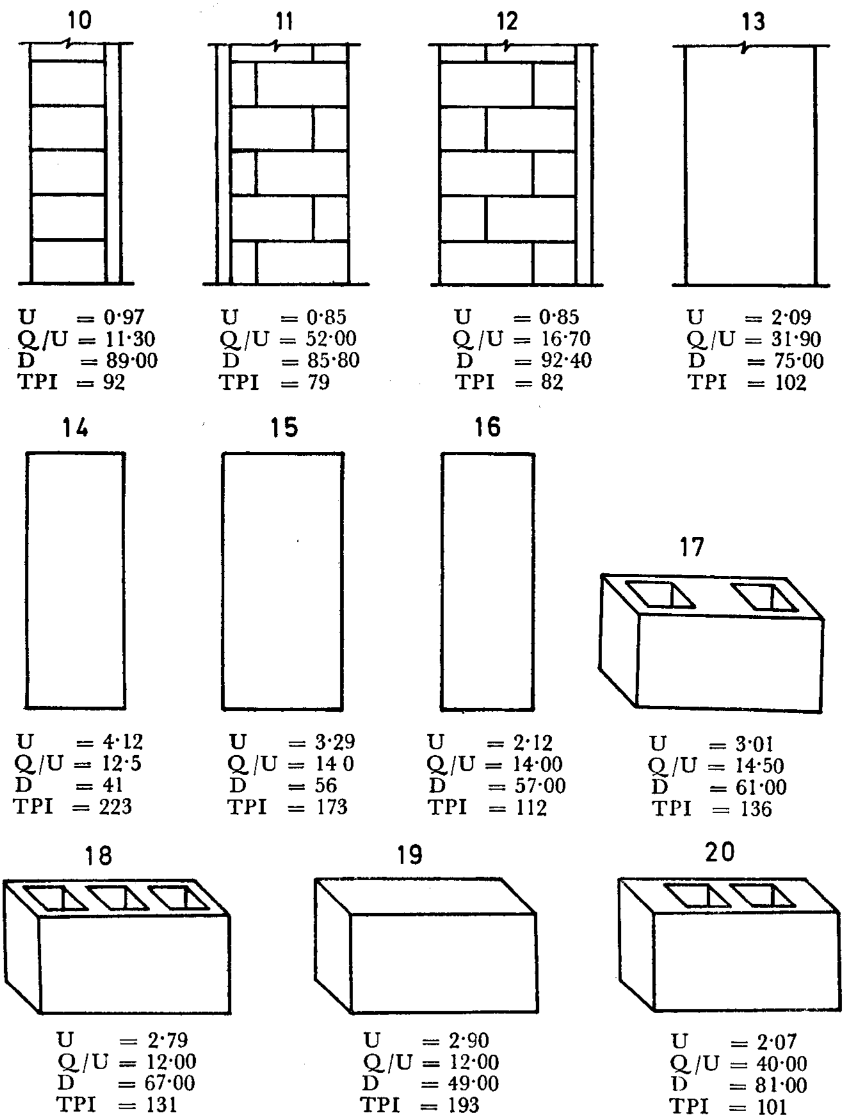
	1	2	3	4	5
U	= 3·00	= 2·28	= 2·13	= 1·65	= 1·35
Q/U	= 7·72	= 17·44	= 21·16	= 41·00	= 67·13
D	= 58·90	= 87·60	= 78·90	= 87·60	= 90·90
TPI	= 164	= 97	= 93	= 64	= 61



	6	7	8	9
U	= 1·80	= 1·55	= 1·69	= 0·97
Q/U	= 18·17	= 30·50	= 41·00	= 43·20
D	= 79·40	= 85·40	= 81·00	= 81·00
TPI	= 109	= 78	= 85	= 95

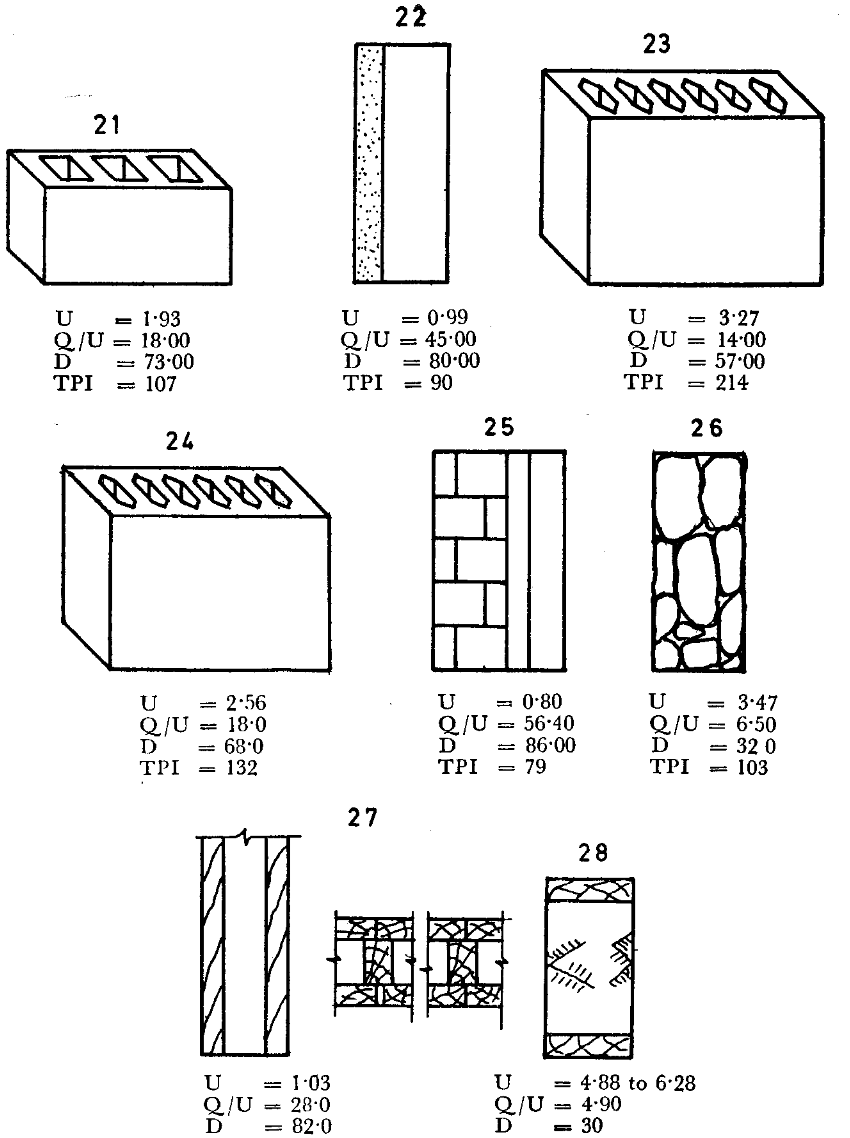
U = Transmittance [W/(m²K)] Q/U = Thermal Time Constant (hours)
D = Damping (percentage) TPI = Thermal Performance Index (percentage)

FIG. 2 THERMAL PERFORMANCE OF WALLS — *Continued*



U = Transmittance [W/(m^{2}K)] Q/U = Thermal Time Constant (hours)
D = Damping (percentage) TPI = Thermal Performance Index (percentage)

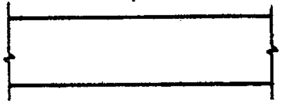
FIG. 2 THERMAL PERFORMANCE OF WALLS — *Continued*



U = Transmittance [W/(m²K)] Q/U = Thermal Time Constant (hours)
D = Damping (percentage) TPI = Thermal Performance Index (percentage)

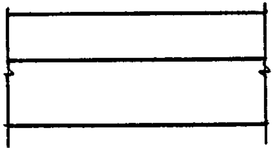
FIG. 2 THERMAL PERFORMANCE OF WALLS

1



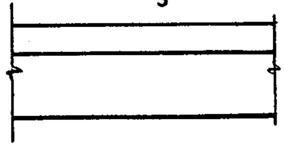
U = 3·59
Q/U = 4·30
D = 30·0
TPI = 184

2



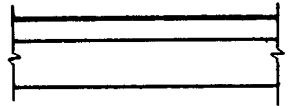
U = 2·78
Q/U = 10·30
D = 71·00
TPI = 131

3



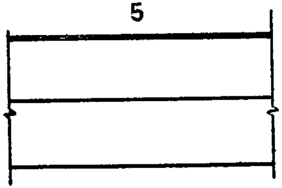
U = 1·08
Q/U = 59·0
D = 88·0
TPI = 70

4



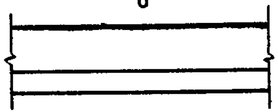
U = 1·08
Q/U = 1·80
D = 84·0
TPI = 64

5



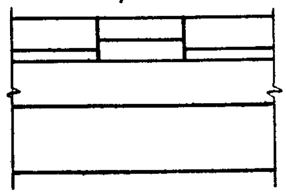
U = 0·62
Q/U = 40·0
D = 83·0
TPI = 61

6



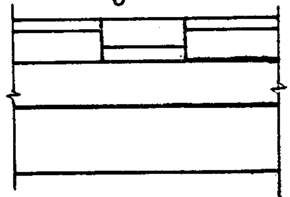
U = 1·09
Q/U = 21·0
D = 78·0
TPI = 72

7



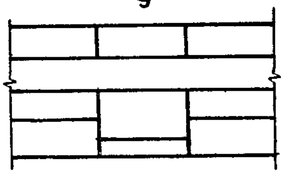
U = 2·07
Q/U = 14·00
D = 85·0
TPI = 90

8



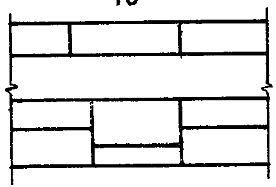
U = 1·76
Q/U = 15·0
D = 85·0
TPI = 80

9



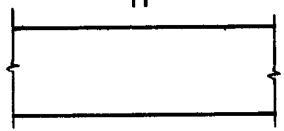
U = 2·31
Q/U = 24·50
D = 87·30
TPI = 84

10



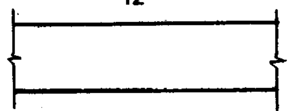
U = 2·01
Q/U = 31·20
D = 91·30
TPI = 84

11

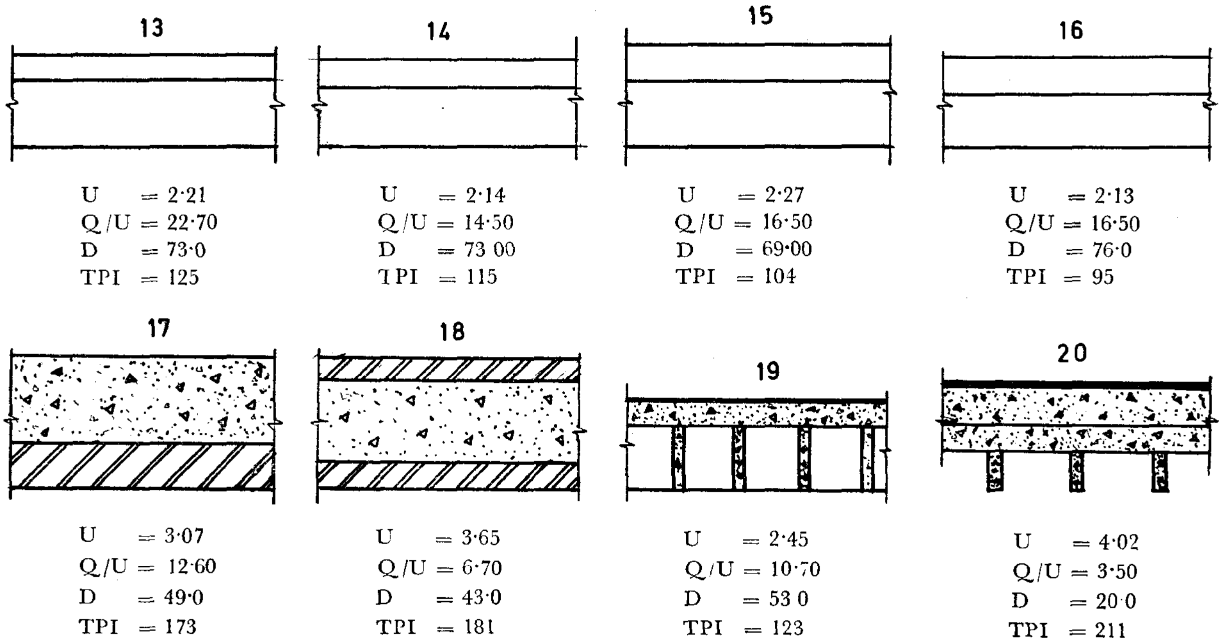


U = 3·15
Q/U = 22·70
D = 75·0
TPI = 125

12



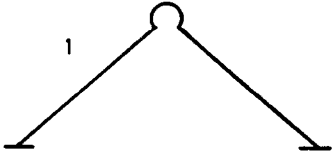
U = 2·99
Q/U = 14·50
D = 73·0
TPI = 115



U = Transmittance [W/(m²K)] Q/U = Thermal Time Constant (hours)
D = Damping (percentage) TPI = Thermal Performance Index (percentage)

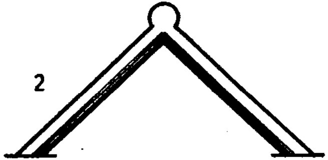
FIG. 3 THERMAL PERFORMANCE OF FLAT ROOFS

1



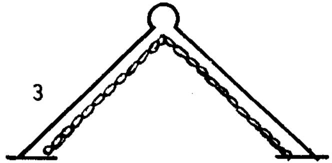
U = 5·47
Q/U = 0·02
D = 12·0
TPI = 186

2



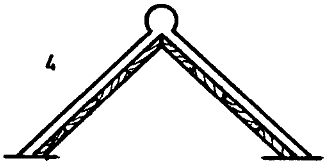
U = 2·44
Q/U = 0·03
D = 39 00
TPI = 111

3



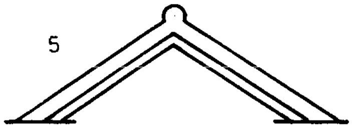
U = 1·40
Q/U = 0·09
D = 18·0
TPI = 80

4



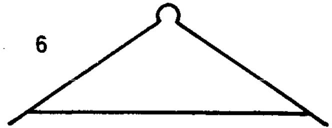
U = 0·65
Q/U = 1·80
D = 17·0
TPI = 75

5



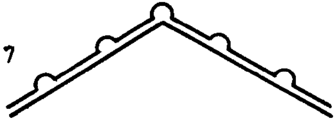
U = 1·22
Q/U = 0·58
D = 21
TPI = 90

6



U = 6·16
Q/U = 0·21
D = 6·0
TPI = 198

7



U = 3·56
Q/U = 7·70
D = 53
TPI = 138

8

U = 3·20
Q/U = 12·2
D = 39·0
TPI = 127

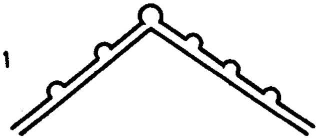
9

U = 2·38
Q/U = 16·0
D = 20
TPI = 116

10

U = 1·69
Q /U = 18·0
D = 26
TPI = 102

11



U = 4·07
Q/U = 6·0
D = 78
TPI = 150

U = Transmittance [W/(m²K)] Q/U = Thermal Time Constant (hours)
D = Damping (percentage) TPI = Thermal Performance Index (percentage)

FIG. 4 THERMAL PERFORMANCE OF SLOPED ROOFS

8.1.1 The thermal performance index (*TPI*) values given in Tables 3, 4 and 5 are for a typical summer design day with a fixed surface absorption coefficient ($\alpha = 0{\cdot}7$). The correction factors may be applied to the *TPI* values for other climatic zones, orientations and surface finish as given in Table 6. Corrected *TPI* values for unconditioned buildings are obtained from the following equation:

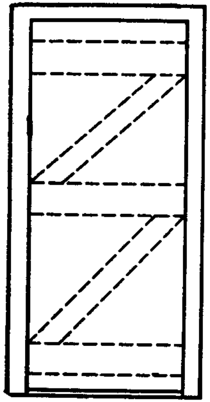
$$\text{Corrected } TPI = (TPI - 50)\, C + 50$$

where C indicates the correction factor as obtained from Table 6.

8.2 Typical values of thermal transmittance for different types of doors and windows are given in Fig. 5.

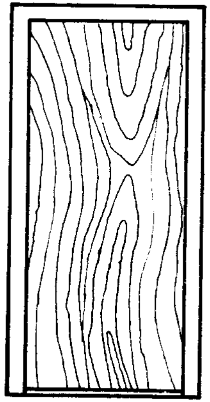
9. VALUES OF SHADE FACTOR

9.1 The values of shade factor for various types of shading devices are given in Table 7.



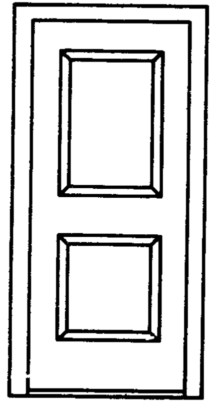
U = 4·83

5A Door Ledged and Braced



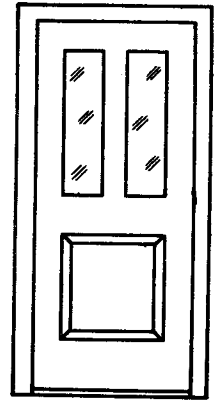
U = 4·83

5B Door Flush Single Hung



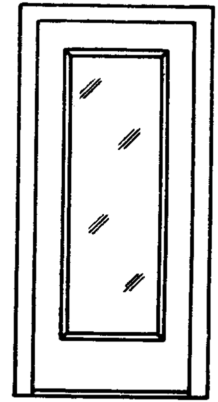
U = 4·83

5C Door Panelled



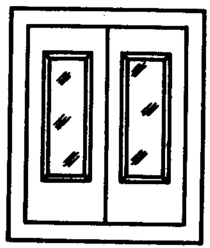
U = 5·18

5D Door Panelled and Glazed



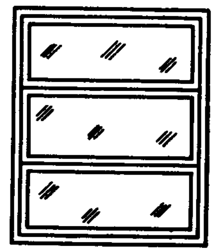
U = 5·68

5E Door Glazed



U = 5·12

5F Window Glazed



U = 5·23

5G Metal Window

U = Overall Thermal Transmittance

FIG. 5 THERMAL TRANSMITTANCE OF DOORS AND WINDOWS

TABLE 3 THERMAL PERFORMANCE OF WALLS

(*Clauses* 8.1 *and* 8.1.1)

SL No.	SPECIFICATION OF WALLS	U-VALUES	THERMAL TIME CONSTANT	DAMPING (*D*)	*TPI*
(1)	(2)	(3)	(4)	(5)	(6)
		W/(m²K)	h	percent	percent
1.	1·25 cm PL* + 11·25 cm brick + 1·25 cm PL	3·00	7·72	58·9	164
2.	1·25 cm PL + 20·00 cm brick + 1·25 cm PL	2·28	17·44	87·6	97
3.	1·25 cm PL + 22·5 cm brick + 1·25 cm PL	2·13	21·16	78·8	93
4.	1·25 cm PL + 33·75 cm brick + 1·25 cm PL	1·65	41·0	87·6	64
5.	1·25 cm PL + 45·0 cm brick + 1·25 cm PL	1·35	67·13	90·9	61
6.	1·25 cm PL + 7·5 cm brick + 5·0 cm air gap + 7·5 cm brick + 1·25 cm PL	1·80	18·17	79·4	109
7.	1·25 cm PL + 11·25 cm brick + 5·0 cm air gap + 11·25 cm brick + 1·25 cm PL	1·55	30·5	85·4	78
8.	22·5 cm cavity brick wall	1·69	41·0	81·0	85
9.	1·25 cm PL + 2·5 cm expanded polystyrene + 11·25 cm brick + 1·25 cm PL	0·97	43·2	81·0	95
10.	1·25 cm PL + 11·25 cm brick + 2·5 cm expanded polystyrene + 1·25 cm PL	0·97	11·3	89·0	92
11.	1·25 cm PL + 2·5 cm expanded polystyrene + 22·5 cm brick + 1·25 cm PL	0·85	52·0	85·80	79
12.	1·25 cm PL + 22·5 cm brick + 2·5 cm expanded polystyrene + 1·25 cm PL	0·85	16·7	92·4	82
13.	1·25 cm PL + 20 cm cin. con† block + 1·25 cm PL	2·09	31·9	75·0	102
14.	10 cm con block	4·12	8·2	41·0	223
15.	15 cm con block	3·29	14	56	173

(*Continued*)

TABLE 3 THERMAL PERFORMANCE OF WALLS — *Contd*

SL No.	SPECIFICATION OF WALLS	U-VALUES	THERMAL TIME CONSTANT	DAMPING (*D*)	*TPI*
(1)	(2)	(3)	(4)	(5)	(6)
		W/(m²K)	h	percent	percent
16.	10 cm cellular con	2·12	14	57	112
17.	20 cm dense con-hollow block (2 holes)	3·01	14·5	61	136
18.	20 cm dense con-hollow block (3 holes)	2·79	12	67	131
19.	10 cm light weight con-block	2·90	12	49	193
20.	20 cm light weight con-block (2 holes)	2·07	40	81	101
21.	20 cm light weight con-block (3 holes)	1·93	18	73	107
22.	1·25 cm PL + 5 cm foam con + 11·25 cm con + 1·25 cm PL	0·99	45	80	90
23.	10 cm hollow pan	3·27	14	57	214
24.	15 cm hollow pan	2·56	18	68	132
25.	1·25 cm PL + 11·4 cm brick wall + 5·08 cm reed board + 3·8 cm cement con plaster	0·80	56·4	86	79
26.	25·4 cm rubble wall + 1·25 cm PL	3·47	6·5	32	103
27.	7·62 × 7·62 cm wooden studs + 3·81 cm wooden boarding with fireproof paint spray on each side	1·03	28·0	82	92
28.	Mud wall based on wooden lacings	4·88 to 6·28	4·9	30	—

*PL = cement plaster

†con = concrete

TABLE 4 THERMAL PERFORMANCE OF FLAT ROOFS

(*Clauses* 8.1 *and* 8.1.1)

SL No.	SPECIFICATION OF ROOF SECTIONS	U-VALUES	THERMAL TIME CONSTANT	DAMPING (*D*)	*TPI*
(1)	(2)	(3) W/(m²K)	(4) h	(5) percent	(6) percent
1.	10 cm RCC	3·59	4·3	30	184
2.	10 cm RCC + 10 cm lime concrete	2·78	10·3	71	131
3.	10 cm RCC + 5 cm foam con + water proofing	1·08	5·9	88	70
4.	5 cm RCC + 2·5 cm expanded polystyrene	1·08	1·8	84	64
5.	5 cm expanded polystyrene + 5 cm RCC + waterproofing	0·62	40·0	83	61
6.	2·5 cm expanded polystyrene + 5 cm RCC	1·09	21·0	78	72
7.	10 cm RCC + 5 cm cin. + 5 cm brick tile	2·07	14·0	81	90
8.	10 cm RCC + 7·5 cm cin. + 5 cm brick tile	1·76	15·0	85	80
9.	11·5 cm RCC + 5 cm Mud *Phuska* + 5 cm brick tile	2·31	24·5	87·3	97
10.	11·5 cm RCC + 7·5 cm Mud *Phuska* + 5 cm brick tile	2·01	31·2	91·3	84
11.	15 cm clay unit	3·15	8·8	52·0	183
12.	13·75 cm clay unit	2·99	7·7	53·0	170
13.	15 cm clay unit + 10 cm lime con	2·21	22·7	75·0	125
14.	13·75 cm clay unit + 10 cm lime con	2·14	14·5	73·0	115
15.	10 cm cellular unit + 8·5 cm lime concrete	2·27	14·0	69·0	104
16.	12·5 cm cord unit + 8·5 cm lime concrete	2·13	16·5	76·0	95
17.	15·4 cm lime con using stone aggregate + 7·6 cm stone slab	3·07	12·6	49	173
18.	8·89 cm concrete using brick aggregate + 2·54 *Kotah* stone slab on each side	3·65	6·7	43	181
19.	5·08 cm lime con using ballast aggregate + 11·4 cm reinforced brick and bitumen wash on top	2·45	10·7	53	123
20.	5·08 cm lime con using brick ballast aggregate + 5·08 cm RCC slab + bitumen wash on top surface	4·02	3·5	20	211

TABLE 5 THERMAL PERFORMANCE OF SLOPED ROOFS

(*Clauses* 8.1 *and* 8.1.1)

SL No.	SPECIFICATION OF (SLOPED) ROOF	U-VALUES	THERMAL TIME CONSTANT	DAMPING (*D*)	*TPI*
(1)	(2)	(3)	(4)	(5)	(6)
		W/(m²K)	h	percent	percent
1.	0·625 cm AC sheet	5·47	0·015	12	186
2.	0·625 cm AC sheet + 2·5 cm air space + insulating board	2·44	0·029	39	111
3.	0·625 cm AC sheet + air space + 5 cm fibre glass + 0·625 hard board	1·40	0·085	18	80
4.	0·625 cm AC sheet + air space + 5 cm sandwich of fibreboard/expanded polystyrene	0·65	1·8	17	75
5.	0·625 cm AC sheet + air space + 2·5 cm sandwich of fibre board/expanded polystyrene	1·22	0·58	21	90
6.	0·3 cm GI sheet	6·16	0·21	6	198
7.	2·5 cm tile + 2·5 cm bamboo reinforcement	3·56	7·7	55	138
8.	5 cm tile + 2·5 cm bamboo reinforcement	3·20	12·0	39	127
9.	2·5 cm thatch roof + 2·5 cm bamboo reinforcement	2·38	16·0	26	116
10.	5 cm thatch roof + 2·5 cm bamboo reinforcement	1·69	18·0	20	102
11.	Mangalore tiles on wooden rafters	4·07	6	78	150

TABLE 6 CORRECTION FACTORS FOR THERMAL PERFORMANCE INDEX (*TPI*)

(*Clause* 8.1.1)

Sl No.	Characteristics	Hot Dry Zone	Hot Humid Zone	Warm Humid Zone
(1)	(2)	(3)	(4)	(5)
1.	Building Component			
	a) Roof	1	0·95	0·92
	b) Wall (W)	1	0·85	0·75
2.	Orientation of Wall			
	a) N	0·45	0·38	0·34
	b) NE	0·70	0·59	0·54
	c) E	0·85	0·72	0·63
	d) SE	0·67	0·57	0·50
	e) S	0·55	0·47	0·42
	f) SW	0·75	0·64	0·57
	g) NW	0·70	0·68	0·60
3.	External Surface Finish			
	a) Roof			
	i) Dark	1·00	0·95	0·92
	ii) Light	0·75	0·71	0·69
	b) Wall			
	i) Dark	1·00	0·85	0·75
	ii) Light	0·78	0·66	0·59
4.	Shading			
	a) Roof	0·32	0·31	0·30
	b) Wall	0·35	0·30	0·26

TABLE 7 THERMAL PERFORMANCE OF DIFFERENT SHADING DEVICES

(*Clause* 9.1)

SL No.	NAME OF THE SHADING DEVICE	TRANSMITTANCE U-VALUE	SHADE FACTOR
(1)	(2)	(3)	(4)
		W/(m²K)	
1.	Plain glass sheet (3·0 mm thick)	5·23	1·00
2.	Plain glass + wire mesh outside	5·00	0·65
3.	Painted glass		
	i) White paint	5·22	0·35
	ii) Yellow paint	5·22	0·37
	iii) Green paint	5·22	0·40
4.	Heat absorbing glass	4·65	0·45
5.	Plain glass sheet + venetian blind inside	3·72	
	i) Light colour		0·35
	ii) Dark colour		0·40
6.	Plain glass sheet + curtain inside	3·14	
	i) Light colour		0·35
	ii) Dark colour		0·40
7.	Plain glass sheet	5·23	
	i) 100 percent shaded		0·14
	ii) 75 percent shaded		0·34
	iii) 60 percent shaded		0·56

APPENDIX A
(*Clause* 0.3)

GENERAL PRINCIPLES OF HEAT TRANSFER

A-1. Heat is a form of energy that is transferred from one side of a building unit to the other due to the existence of temperature difference. The rate of this flow depends on the capacity of component material to transmit the same. This property of the building unit made up of these components is referred to as its thermal transmittance.

A-2. Regarding transfer of heat, the simplest system is a homogeneous material which is enclosed between flat parallel hot and cold faces at given temperature. In the steady state condition, the rate of heat flow under given constant temperatures is directly proportional to the area of these faces and inversely proportional to the distance between them. In practice, however, homogeneous materials are rarely met with. Building construction consists of various building units which are formed out of two or more homogeneous materials.

A-3. The combinations of various homogeneous materials actually met with in practice may be defined as building units, whose thermal transmittances are calculated by knowing the thermal conductivity of the individual homogeneous materials and by the thickness of these materials.

A-4. In the design of non-airconditioned dwellings, hospitals, schools and office buildings, it becomes necessary to examine the amount of heat transfer as well as the rate of heat penetration through the building unit and the extent to which the external diurnal range of temperature is damped by the building unit.

A-5. The decreased temperature variation inside the building and time delay, in other words, thermal damping and time lag, are dependent on the thermal properties of the building unit. The thermal damping is mainly due to the overall thermal transmittance of the materials forming the building unit, whereas time lag is mostly dependent upon its heat storage capacity. The combined action of these two properties under a given climatic condition will decide the thermal performance of building section. It has been found that total thermal performance is a function of internal surface temperatures. This temperature depends upon the thermal characteristics of building section and outside climatic data.

APPENDIX B

(*Clauses* 3.1.1, 3.1.2, 3.1.3 *and* 3.1.4)

SOME REPRESENTATIVE TOWNS UNDER HOT AND ARID, HOT AND HUMID, WARM AND HUMID, AND COLD ZONES

Hot and Arid Zone	*Hot and Humid Zone*	*Warm and Humid Zone*	*Cold Zone*
Agra	Ahmadabad	Cochin	Darjeeling
Ajmer	Asansol	Dwarka	Dras
Akola	Bhavanagar	Gauhati	Gulmarg
Aligarh	Bhuj	Puri	Leh
Allahabad	Bombay	Sibsagar	Mussoorie
Ambala	Calcutta	Silichar	Nainital
Bareilly	Calicut	Tezpur	Ootacamund
Bikaner	Cuttack	Trivandrum	Shillong
Gaya	Dohad	Veraval	Simla
Jabalpur	Jamnagar		Skardu
Jaipur	Jamshedpur		Srinagar
Kanpur	Madras		
Khandwa	Madurai		
Kota	Mangalore		
Lucknow	Masulipatam		
Ludhiana	Midnapur		
Nagpur	Nellore		
Neemuch	Patna		
New Delhi	Rajkot		
Roorkee	Ratnagiri		
Sambalpur	Salem		
Sholapur	Surat		
Umaria	Tiruchirapalli		
Varanasi	Vellore		
	Vishakhapatnam		

APPENDIX C

(*Clause* 6.1)

THERMAL PROPERTIES OF BUILDING AND INSULATING MATERIALS AT MEAN TEMPERATURE OF 50°C

SL No.	TYPE OF MATERIAL	DENSITY	THERMAL CONDUCTIVITY*	SPECIFIC HEAT CAPACITY
(1)	(2)	(3) kg/m³	(4) W/(mK)	(5) kJ/(kgK)
a)	*Building Materials*			
1.	Burnt brick	1 820	0·811	0·88
2.	Mud brick	1 731	0·750	0·88
3.	Dense concrete	2 410	1·74	0·88
4.	RCC	2 288	1·58	0·88
5.	Limestone	2 420	1·80	0·84
6.	Slate	2 750	1·72	0·84
7.	Reinforced brick	1 920	1·10	0·84
8.	Brick tile	1 892	0·798	0·88
9.	Lime concrete	1 646	0·730	0·88
10.	Mud *Phuska*	1 622	0·519	0·88
11.	Cement mortar	1 648	0·719	0·92
12.	Cement plaster	1 762	0·721	0·84
13.	Cinder concrete	1 406	0·686	0·84
14.	Foam slag concrete	1 320	0·285	0·88
15.	Gypsum plaster	1 120	0·512	0·96
16.	Cellular concrete	704	0·188	1·05
17.	AC sheet	1 520	0·245	0·84
18.	GI sheet	7 520	61·06	0·50
19.	Timber	480	0·072	1·68
20.	Timber	720	0·144	1·68
21.	Plywood	640	0·174	1·76
22.	Glass	2 350	0·814	0·88
23.	Alluvial clay (40 percent sands)	1 958	1·211	0·84
24.	Sand	2 240	1·74	0·84
25.	Black cotton clay (Madras)	1 899	0 735	0·88
26.	Black cotton clay (Indore)	1 683	0·606	0·88
27.	Tar felt (2·3 kg/m²)	—	0·479	0·88

*The thermal conductivity (k) values have been determined by:

1) Guarded Hot Plate Method, and
2) ASTM Heat Flow Method.

Sl No.	Type of Material	Density	Thermal Conductivity*	Specific Heat Capacity
(1)	(2)	(3)	(4)	(5)
		kg/m³	W/(mK)	kJ/(kgK)
b)	*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 (unbonded)	92·0	0·047	0·84
13.	Rock wool (unbonded)	150·0	0·043	0·84
14.	Mineral wool (unbonded)	73·5	0·030	0·92
15.	Glass wool (unbonded)	69·0	0·043	0·92
16.	Glass wool (unbonded)	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	1 397·0	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.	Wall board	262·0	0·047	1·26
29.	Chip board	432·0	0·067	1·26
30.	Chip board (perforated)	352·0	0 066	1·26
31.	Particle board	750·0	0·098	1·30
32.	Coconut pith insulation board	520·0	0·060	1·09
33.	Jute fibre	329·0	0·067	1·09
34.	Wood wool board (bonded with cement)	398·0	0·081	1·13
35.	Wood wool board (bonded with cement)	674·0	0·108	1·13
36.	Coir board	97·0	0·038	1·00
37.	Saw dust	188·0	0·051	1·00
38.	Rice husk	120·0	0·051	1·00
39.	Jute felt	291·0	0·042	0·88
40.	Asbestos fibre (loose)	640·0	0·060	0·84

*The thermal conductivity (k) values have been determined by:

1) Guarded Hot Plate Method, and
2) ASTM Heat Flow Method.

APPENDIX D

(*Clause* 7.1)

EXAMPLES SHOWING CALCULATION OF THERMAL TRANSMITTANCE AND THERMAL TIME CONSTANT

D-1. CALCULATION OF THERMAL TRANSMITTANCE *U* FOR TYPICAL CASES

D-1.1 Procedure

a) Calculate thermal resistance *R* of each uniform material which constitutes the building unit as follows:

$$R = \frac{L}{k} \text{ [\textit{see} Sl No. (v), Table 1]}$$

where

L = thickness of material in m, and

k = thermal conductivity in $\frac{\text{W}}{\text{mK}}$.

b) Find the total thermal resistance R_T as follows:

$$R_T = \frac{1}{f_o} + \frac{1}{f_i} + R_1 + R_2 + R_3 + \cdots\cdots$$

where

f_o = outside surface conductance (*see* Note),

f_i = inside surface conductance (*see* Note), and

R_1, R_2, R_3 = thermal resistance of different materials.

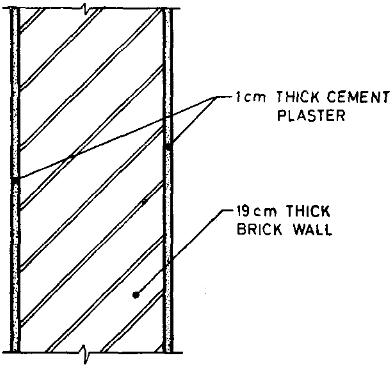
NOTE — The following values of surface heat transfer coefficient and air conductance have been taken for the computation of various parameters:

a) Outside film coefficient at an air velocity of 8·0 km/h (f_o)	19·86 W/(m² K)	
b) Inside film coefficient at still air (f_i)	9·36 W/(m² K)	
c) Enclosed air space conductance [W/(m²K)]	*For* $E = 0·82$	*For* $E = 0·2$
1) Vertical closed air space thickness greater than 2·0 cm at 50°C	6·22	2·72
2) Horizontal air space thickness greater than 2·0 cm at 50°C (heat flow downwards)	6·22	2·04

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

D-1.2 Examples

Example 1 — To find U for 19·00 cm thick brick outside wall provided with 1·00 cm thick cement plaster on both sides.



1) $k_1 = 0{\cdot}721$ W/(mK)

$k_2 = 0{\cdot}811$ W/(mK)

$k_3 = 0{\cdot}721$ W/(mK)

$L_1 = 0{\cdot}01$ m, $L_2 = 0{\cdot}19$ m, $L_3 = 0{\cdot}01$ m

$$R_1 = \frac{L_1}{k_1} = \frac{0{\cdot}01}{0{\cdot}721} = 0{\cdot}013\,9$$

$$R_2 = \frac{L_2}{k_2} = \frac{0{\cdot}19}{0{\cdot}811} = 0{\cdot}234\,3$$

$$R_3 = \frac{L_3}{k_3} = \frac{0{\cdot}01}{0{\cdot}721} = 0{\cdot}013\,9$$

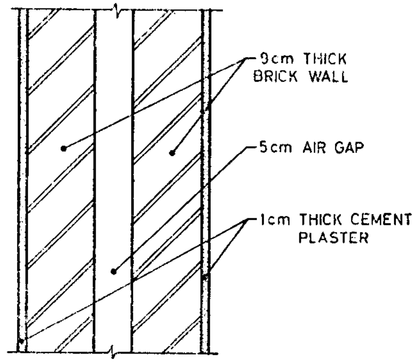
$$\frac{1}{f_i} = \frac{1}{9{\cdot}36} = 0{\cdot}106\,8$$

$$\frac{1}{f_o} = \frac{1}{19{\cdot}86} = 0{\cdot}050\,4$$

2) $$R_T = \frac{1}{f_o} + \frac{1}{f_i} + R_1 + R_2 + R_3 = 0{\cdot}419\,3$$

3) $$U = \frac{1}{R_T} = \frac{1}{0{\cdot}419\,3} = 2{\cdot}385 \text{ W/(m}^2\text{K)}$$

Example 2 — To find U for outside wall of two layers of 9·00 cm brick with 5 cm air gap in between and plastered with 1·00 cm thick cement plaster on both sides.



1) $k_1 = k_5 = 0{\cdot}721$ W/(mK)

$k_2 = k_4 = 0{\cdot}811$ W/(mK)

$L_1 = 0{\cdot}01$ m, $L_2 = 0{\cdot}09$ m, $L_4 = 0{\cdot}09$ m, $L_5 = 0{\cdot}01$ m

$C_3 = 6{\cdot}22$ W/(m²K) (for emissivity = 0·82)

$$R_1 = \frac{L_1}{k_1} = \frac{0{\cdot}01}{0{\cdot}721} = 0{\cdot}013\,9$$

$$R_2 = \frac{L_2}{k_2} = \frac{0{\cdot}09}{0{\cdot}811} = 0{\cdot}111\,0$$

$$R_3 = \frac{1}{C_3} = \frac{1}{6{\cdot}22} = 0{\cdot}160\,8$$

$$R_4 = \frac{L_4}{k_4} = \frac{0{\cdot}09}{0{\cdot}811} = 0{\cdot}111\,0$$

$$R_5 = \frac{L_5}{k_5} = \frac{0{\cdot}01}{0{\cdot}721} = 0{\cdot}013\,9$$

$$\frac{1}{f_i} = \frac{1}{9{\cdot}36} = 0{\cdot}106\,8$$

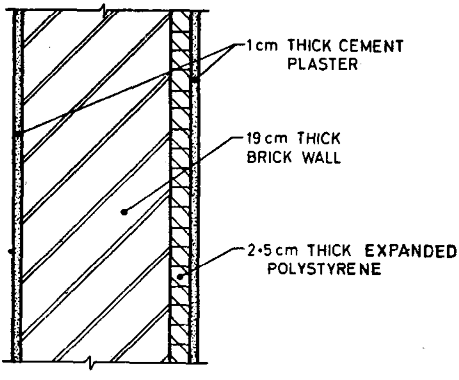
$$\frac{1}{f_o} = \frac{1}{19{\cdot}86} = 0{\cdot}050\,4$$

2) $R_T = 0{\cdot}567\,8$

3) $$U = \frac{1}{R_T} = \frac{1}{0{\cdot}567\,8}$$

$= 1{\cdot}761$ W/(m²K)

Example 3 — To find U for 19·00 cm brick outside wall insulated with 2·50 cm expanded polystyrene and finished on both sides with 1·00 cm cement plaster.



1) $k_1 = k_4 = 0{\cdot}721$ W/(mK)

$k_2 = 0{\cdot}811$ W/(mK)

$k_3 = 0{\cdot}035$ W/(mK)

$L_1 = 0{\cdot}01$ m, $L_2 = 0{\cdot}19$ m, $L_3 = 0{\cdot}025$ m, $L_4 = 0{\cdot}01$ m

$$R_1 = \frac{L_1}{k_1} = \frac{0{\cdot}01}{0{\cdot}721} = 0{\cdot}013\,9$$

$$R_2 = \frac{L_2}{k_2} = \frac{0{\cdot}19}{0{\cdot}811} = 0{\cdot}234\,3$$

$$R_3 = \frac{L_3}{k_3} = \frac{0{\cdot}025}{0{\cdot}035} = 0{\cdot}714\,3$$

$$R_4 = \frac{L_4}{k_4} = \frac{0{\cdot}01}{0{\cdot}721} = 0{\cdot}013\,9$$

$$\frac{1}{f_i} = \frac{1}{9{\cdot}36} = 0{\cdot}106\,8$$

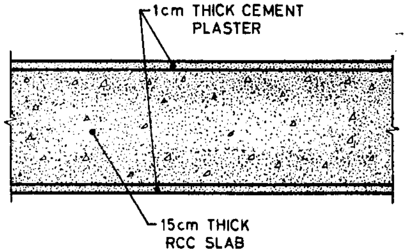
$$\frac{1}{f_o} = \frac{1}{19{\cdot}86} = 0{\cdot}050\,4$$

2) $R_T = 1{\cdot}133\,6$

3) $U = 1/R_T = \dfrac{1}{1{\cdot}133\,6}$

$= 0{\cdot}882$ W/(m²K)

Example 4 — To find U for a 15-cm thick RCC roof slab plastered on both sides with 1 cm thick cement plaster.



1) $k_1 = k_3 = 0{\cdot}721\ \text{W/(mK)}$
$k_2 = 1{\cdot}58\ \text{W/(mK)}$
$L_1 = 0{\cdot}01\ \text{m},\ L_2 = 0{\cdot}15\ \text{m},\ L_3 = 0{\cdot}01\ \text{m}$

$$R_1 = \frac{L_1}{k_1} = \frac{0{\cdot}01}{0{\cdot}721} = 0{\cdot}013\,9$$

$$R_2 = \frac{L_2}{k_2} = \frac{0{\cdot}15}{1{\cdot}58} = 0{\cdot}094\,9$$

$$R_3 = \frac{L_3}{k_3} = \frac{0{\cdot}01}{0{\cdot}721} = 0{\cdot}013\,9$$

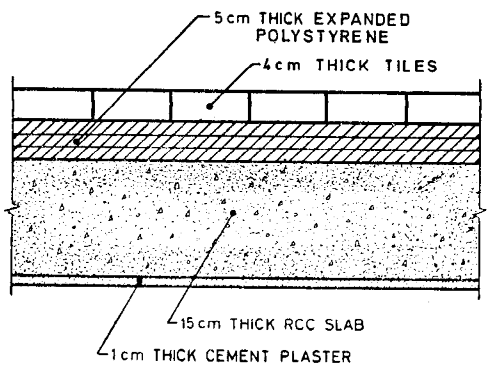
$$\frac{1}{f_i} = \frac{1}{9{\cdot}36} = 0{\cdot}106\,8$$

$$\frac{1}{f_o} = \frac{1}{19{\cdot}86} = 0{\cdot}050\,4$$

2) $R_T = 0{\cdot}279\,9$

3) $U = \frac{1}{R_T} = \frac{1}{0{\cdot}279\,9} = 3{\cdot}573\ \text{W/(m}^2\text{K)}$

Example 5 — To find U for a 15-cm thick RCC roof slab insulated with 5 cm thick expanded polystyrene and finished with 4 cm thick brick tiles on the top and 1 cm thick cement plaster on the bottom.



1) $k_1 = 0{\cdot}798$ W/(mK)
$k_2 = 0{\cdot}035$ W/(mK)
$k_3 = 1{\cdot}58$ W/(mK)
$k_4 = 0{\cdot}721$ W/(mK)
$L_1 = 0{\cdot}04$ m, $L_2 = 0{\cdot}05$ m, $L_3 = 0{\cdot}15$ m, $L_4 = 0{\cdot}01$ m

$$R_1 = \frac{L_1}{k_1} = \frac{0{\cdot}04}{0{\cdot}798} = 0{\cdot}050\,1$$

$$R_2 = \frac{L_2}{k_2} = \frac{0{\cdot}05}{0{\cdot}035} = 1{\cdot}428\,6$$

$$R_3 = \frac{L_3}{k_3} = \frac{0{\cdot}15}{1{\cdot}58} = 0{\cdot}094\,9$$

$$R_4 = \frac{L_4}{k_4} = \frac{0{\cdot}01}{0{\cdot}721} = 0{\cdot}013\,9$$

$$\frac{1}{f_i} = \frac{1}{9{\cdot}36} = 0{\cdot}106\,8$$

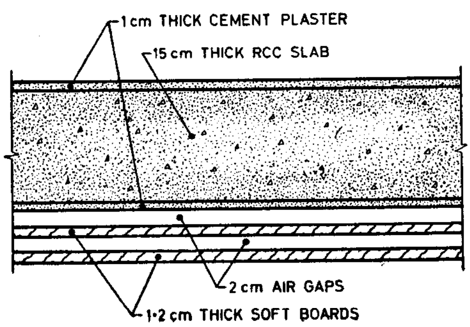
$$\frac{1}{f_o} = \frac{1}{19{\cdot}86} = 0{\cdot}050\,4$$

2) $R_T = 1{\cdot}744\,7$

3) $U = 1/R_T = \frac{1}{1{\cdot}744\,7}$

$= 0{\cdot}573$ W/(m²K)

Example 6 — To find U for a roof of construction as in Example 4 and having a false ceiling made of two layers of 1·2 cm soft board with an air gap of 2 cm.



1) $k_1 = k_3 = 0{\cdot}721$ W/(mK)

$k_2 = 1{\cdot}58$ W/(mK)

$k_5 = k_7 = 0{\cdot}047$ W/(mK)

$C_4 = C_6 = 6{\cdot}22$ W/(m²K) (for emissivity = 0·82)

$L_1 = 0{\cdot}01$ m, $L_2 = 0{\cdot}15$ m, $L_3 = 0{\cdot}01$ m, $L_5 = 0\ 012$ m,

$L_7 = 0\ 012$ m

$$R_1 = \frac{L_1}{k_1} = \frac{0{\cdot}01}{0{\cdot}721} = 0{\cdot}013\ 9$$

$$R_2 = \frac{L_2}{k_2} = \frac{0{\cdot}15}{1{\cdot}58} = 0{\cdot}094\ 9$$

$$R_3 = \frac{L_3}{k_3} = \frac{0{\cdot}01}{0{\cdot}721} = 0{\cdot}013\ 9$$

$$R_4 = \frac{1}{C_4} = \frac{1}{6{\cdot}22} = 0{\cdot}160\ 8$$

$$R_5 = \frac{L_5}{k_5} = \frac{0{\cdot}012}{0{\cdot}047} = 0{\cdot}255\ 3$$

$$R_6 = \frac{1}{C_6} = \frac{1}{6{\cdot}22} = 0{\cdot}160\ 8$$

$$R_7 = \frac{L_7}{k_7} = \frac{0{\cdot}012}{0{\cdot}047} = 0{\cdot}255\ 3$$

$$\frac{1}{f_i} = \frac{1}{9{\cdot}36} = 0{\cdot}106\ 8$$

$$\frac{1}{f_o} = \frac{1}{19{\cdot}86} = 0{\cdot}050\ 4$$

2) $R_T = 1{\cdot}112\ 1$

3) $U = \frac{1}{R_T} = \frac{1}{1{\cdot}112\ 1}$

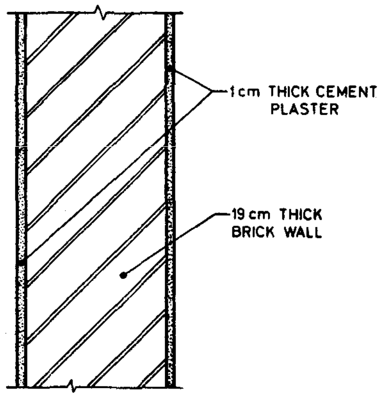
$= 0{\cdot}899$ W/(m²K)

D-2. CALCULATION OF THERMAL TIME CONSTANT FOR TYPICAL CASES

D-2.1 Procedure — Thermal time constant for homogeneous or composite wall or roof may be calculated from the formula given in Table 1, Sl No. (xi).

D-2.2 Examples

Example 1 — To find T for 19-cm thick brick wall provided with 1·00 cm thick cement plaster on both sides.



1) For cement plaster

$L = 0{\cdot}01$ m

$k = 0{\cdot}721$ W/(mK)

$\rho = 1\,648$ kg/m^3

$c = 0{\cdot}84$ kJ/(kgK)

2) For brick

$L = 0{\cdot}19$ m

$k = 0{\cdot}811$ W/(mK)

$\rho = 1\,820$ kg/ m^3

$c = 0{\cdot}88$ kJ/(kgK)

3) For plaster

$$L_1\, \rho_1\, c_1 = 0{\cdot}01 \times 1\,648 \times 0{\cdot}84$$

$$= 13{\cdot}843 \text{ kJ/(m}^2\text{K)}$$

$$= 13\,843 \text{ Ws/(m}^2\text{K)}$$

$$\frac{L_1}{k_1} = \frac{0{\cdot}01}{0{\cdot}721} = 0{\cdot}013\,9 \text{ m}^2\text{K/W}$$

4) For brick

$$L_2 \rho_2 c_2 = 0{\cdot}19 \times 1\,820 \times 0{\cdot}88$$
$$= 304{\cdot}304 \text{ kJ/(m}^2\text{K)}$$
$$= 304\,304 \text{ Ws/m}^2\text{K}$$
$$L_2/k_2 = \frac{0{\cdot}19}{0{\cdot}811} = 0{\cdot}234\,3 \text{ m}^2 \text{ K/W}$$

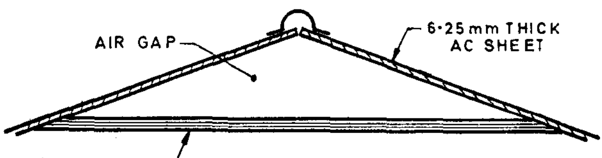
5) $T = \sum \frac{Q}{U}$

$$= \left(\frac{1}{f_o} + \frac{L_1}{2k_1}\right)(L_1 \rho_1 c_1) + \left(\frac{1}{f_o} + \frac{L_1}{k_1} + \frac{L_2}{2k_2}\right)(L_2 \rho_2 c_2) + \left(\frac{1}{f_o} + \frac{L_1}{k_1} + \frac{L_2}{k_2} + \frac{L_3}{2k_3}\right)(L_3 \rho_3 c_3)$$

$$= (0{\cdot}050\,4 + 0{\cdot}006\,95) \times 13\,843 + (0{\cdot}050\,4 + 0{\cdot}013\,9 + 0{\cdot}117\,15) \times 304\,304 + (0{\cdot}050\,4 + 0{\cdot}013\,9 + 0{\cdot}234\,3 + 0{\cdot}006\,95) \times 13\,843$$

$$= 0{\cdot}057\,4 \times 13\,843 + 0{\cdot}181\,5 \times 304\,304 + 0{\cdot}305\,6 \times 13\,843$$
$$= 794{\cdot}59 + 55\,231{\cdot}18 + 4\,230{\cdot}42$$
$$= 60\,256{\cdot}19 \text{ seconds}$$
$$\simeq 17 \text{ hours}$$

Example 2 — To find T for a sloped roof of 6·25 mm AC sheets with an air gap and a false ceiling of softboard 12 mm thick.



1) For AC sheet

$L_1 = 0{\cdot}006\,25$ m

$k_1 = 0{\cdot}245$ W/(mK)

$\rho_1 = 1\,520$ kg/m^3

$c_1 = 0{\cdot}84$ kJ/(kgK)

$$\frac{L_1}{k_1} = \frac{0{\cdot}006\,25}{0{\cdot}245} = 0{\cdot}025\,5$$

$$L_1 \rho_1 c_1 = 0{\cdot}006\,25 \times 1\,520 \times 0{\cdot}84 = 7{\cdot}98 \text{ kJ/(m}^2\text{K)}$$
$$= 7\,980 \text{ Ws/(m}^2\text{K)}$$

2) For air gap

$L_2\,\rho_2\,c_2 = 0$

3) For softboard

$L_3 = 0{\cdot}012$ m

$k_3 = 0{\cdot}047$ W/(mK)

$\rho_3 = 249$ kg/m³

$c_3 = 1{\cdot}30$ kJ/(kgK)

$$\frac{L_3}{k_3} = \frac{0{\cdot}012}{0{\cdot}047} = 0{\cdot}255\,3$$

$L_3\,\rho_3\,c_3 = 0{\cdot}012 \times 249 \times 1{\cdot}3$

$= 3{\cdot}884\,4$ kJ/(m²K)

$= 3\,884{\cdot}4$ Ws/(m²K)

4) $$T = \sum \frac{Q}{U} = \left(\frac{1}{f_o} + \frac{L_1}{2k_1}\right)\left(L_1\,\rho_1\,c_1\right) + \left(\frac{1}{f_o} + \frac{L_1}{k_1} + \frac{L_2}{2\,k_2}\right)\left(L_2\,\rho_2\,c_2\right) + \left(\frac{1}{f_o} + \frac{L_1}{k_1} + \frac{L_2}{k_2} + \frac{L_3}{2k_3}\right)(L_3\,\rho_3\,c_3)$$

$= (\,0{\cdot}050\,4 + 0{\cdot}012\,75\,) \times 7\,980 + 0 + (\,0{\cdot}050\,4 + 0{\cdot}025\,5 + 0 + 0{\cdot}127\,65\,) \times 3\,884{\cdot}4$

$= 0{\cdot}063\,2 \times 7\,980 + 0{\cdot}203\,6 \times 3\,884{\cdot}4$

$= 503{\cdot}94 + 790{\cdot}86$

$= 1\,294{\cdot}8$ seconds

$\simeq 0{\cdot}36$ hours.

INDIAN STANDARDS

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FUNCTIONAL REQUIREMENTS IN BUILDINGS

IS :

1950-1962 Code of practice for sound insulation of non-industrial buildings

2440-1975 Code of practice for daylighting of buildings (*second revision*)

2526-1963 Code of practice for acoustical design of auditoriums and conference halls

3103-1975 Code of practice for industrial ventilation (*first revision*)

3362-1977 Code of practice for natural ventilation of residential buildings (*first revision*)

3483-1965 Code of practice for noise reduction in industrial buildings

3792-1978 Guide for heat insulation of non-industrial buildings (*first revision*)

4954-1968 Recommendations for noise abatement in town planning

4963-1968 Recommendations for buildings and facilities for the physically handicapped

5499-1969 Code of practice for construction of underground air-raid shelters in natural soil

6060-1971 Code of practice for daylighting of factory buildings

6074-1971 Code for functional requirements of hotels, restaurants and other food service establishments

7662 (Part I)-1974 Recommendations for orientation of buildings: Part I Non-industrial buildings

7942-1976 Code of practice for daylighting of educational buildings

8827-1978 Recommendations for basic requirements of school buildings

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2

INDIAN STANDARDS INSTITUTION

Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002

Telephones : 26 60 21, 27 01 31 **Telegrams : Manaksanstha**

Regional Offices:

			Telephone
Western :	Novelty Chambers, Grant Road	BOMBAY 400007	37 97 29
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