

BUILDING DIGEST

CENTRAL BUILDING RESEARCH INSTITUTE, INDIA



CORRECTION FACTORS FOR THERMAL PERFORMANCE INDEX (for different places, surface colour and orientation)

Introduction

To have comfort conditions inside a building it is necessary to prevent the penetration of solar radiation and minimise the flow of heat into the building. This could be accomplished by the proper choice of building materials. In order to choose the correct combination of building materials from thermal considerations the thermal performance characteristics must be known. In earlier Building Digests* a good deal of data on the thermal performance index (T.P.I.) for flat and sloped roofs and wall sections was presented for Roorkee. The surface absorption coefficient was assumed as 0.7.

The thermal performance index for a particular section depends on many factors, such as place, orientation, surface colour (α) and indoor air temperature. Therefore the data on T.P.I. values presented in earlier digests need corrections for situations other than those covered therein. These correction factors for five different surface absorption coefficients, eight orientations and fourteen major cities of India have been worked out and presented in this digest.

Correction Factors

The rating values (T.P.I.) for unconditioned situations consist of two parts (R_1 and R_2) corresponding to external sol-air temperature and indoor air temperature variations respectively. For a given indoor air temperature profile the values of R_2 mostly depend on the type of interior layer. Though there will be a considerable difference in these values for an uninsulated and insulated internal layer, there will be no significant difference within a given type of material layer. As a rough guide the value of R_2 for uninsulated and insulated interior layers, can be taken as 50 and 75 respectively for all practical purposes. In evolving the above data

a typical indoor air temperature variation has been considered. However, there may be some situations that the indoor air temperatures are much different from those considered here. In such cases, the values of R_2 require modification and suitable correction factors have to be worked out.

The rating part due to external variations, R_1 is obtained by subtracting R_2 from the T.P.I. value. The external variations of an exposed building element will depend on surface colour (α) and the place in general. For wall and sloped roof sections the orientation also plays a role. To account for the variations due to each of these factors, corresponding correction factors are to be applied to the values of R_1 . These have been worked out for different values of R_1 , eight orientations, and fourteen major Indian cities for flat and sloped roof and wall sections.

For conditioned buildings the indoor air temperature is considered to be maintained constant at a temperature of 25°C. Hence the T.P.I. values are due to external variations only. To obtain corrected T.P.I. values for different situations other than those given in the Digest, correction factors for external variations only are to be applied. The correction factors due to place and surface colour for roofs are given in table 1, 2(a) and 2(b). Similar data for walls have been presented in tables 3, 4(a), 4(b), 5(a) and 5(b) and in tables 6, 7(a), 7(b), 8(a) and 8(b) for sloped roofs. The procedure of applying the correction factors is explained below with illustrative examples, for unconditioned buildings.

Correction for surface colour

Example 1

To find out the corrected T.P.I. and classification for a 23 cm brick wall with 1.25 cm plaster on both sides (vide Example I.3 of B.D.** 101) with an

*1. Building Digest 94—"Thermal performance rating and classification of flat roofs in hot dry climates".
2. Building Digest 101—"Thermal performance rating and classification of wall in hot climate".
3. Technical Note "Thermal performance rating and classification of sloped roofs in hot climate".

** B. D. stands for Building Digest.

external whitewash treatment ($\alpha=0.3$), West orientation at Roorkee.

T.P.I. value from B.D. 101 = 93.

$R_2 = 50$

$R_1 = (93 - 50) = 43$.

Correction factor for $\alpha = 0.3$, from table 4(a) = 0.574

Corrected $R_1 = 43 \times 0.574 \approx 25$

Corrected T.P.I. = $25 + 50 = 75$

Correction for orientation

Example 2

For the same wall as in example 1, what will be the corrected T.P.I. for South orientation and $\alpha = 0.7$, at Roorkee?

T.P.I. value from B.D. 101 = 93.

$R_2 = 50$

$R_1 = (93 - 50) = 43$.

Correction factor for South orientation from table 5 (a) = 0.530

Corrected $R_1 = 43 \times 0.53 \approx 23$

Corrected T.P.I. = $23 + 50 = 73$.

Correction for place

Example 3

For the same wall as in example 1, what will be the corrected T.P.I. at Jodhpur, with $\alpha = 0.7$ and West orientation?

T.P.I. value from B.D. 101 = 93.

$R_2 = 50$

$R_1 = (93 - 50) = 43$.

Correction factor for Jodhpur from table 3 = 1.098

Corrected $R_1 = 43 \times 1.098 \approx 47$.

Corrected T.P.I. = $47 + 50 = 97$.

Correction for place, colour and orientation

Example 4

What will be the corrected T.P.I. for the same wall as in example 1, with $\alpha = 0.5$ and South orientation at Bombay?

T.P.I. value from B.D. 101 = 93.

$R_2 = 50$.

$R_1 = 93 - 50 = 43$.

Correction factor for Bombay (West, $\alpha = 0.7$) from table 3 = 0.762.

Consequent corrected $R_1 = 43 \times 0.762 \approx 33$.

Now this value of R_1 should be changed for $\alpha = 0.5$, West orientations at Bombay.

For this value of $\alpha = 0.5$ the correction factor from table 4(a) is 0.734.

Hence corrected $R_1 = 33 \times 0.734 \approx 24$.

This value of corrected R_1 should be further changed for the final answer i.e., for South orientation $\alpha = 0.5$, at Bombay.

Correction factor for Bombay (South) from table 5 (a) = 0.344.

Consequent corrected $R_1 = 24 \times 0.344 \approx 8$

Finally corrected T.P.I. for ($\alpha = 0.5$, South, at Bombay) = $8 + 50 = 58$.

The classification can be obtained from table 1 of Digest No. 94 or 101.

Concluding Remarks

By using correction factors presented in this digest the thermal performance index and classification data for any situation for major cities of India can be obtained. This will help the designers making a quick assessment of the relative thermal performance of building sections in tropical climate.

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 103rd in the series. Readers are requested to send to the Institute their experience of adopting the suggestions given in this Digest.

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Table 1
Flat Roofs
Correction Factors for Climate

S.No. Place	Broad Climatic Zone	Correction Factors	
		Unconditioned	Conditioned
1. Roorkee	Hot-dry	1.000	1.000
2. New Delhi	"	1.086	1.076
3. Lucknow	"	1.109	1.096
4. Jodhpur	"	1.209	1.184
5. Ahmedabad	"	1.119	1.105
6. Amritsar	"	1.082	1.075
7. Bhopal	"	1.089	1.079
8. Nagpur	"	1.091	1.080
9. Patna	"	1.051	1.045
10. Hyderabad	"	0.985	0.975
11. Calcutta	Hot-humid	0.950	0.955
12. Madras	"	0.945	0.950
13. Coimbatore	"	0.975	0.970
14. Bombay	"	0.936	0.942

Table 2 (a)
Flat Roofs
Correction Factors for Surface Colour Treatments
(a) Unconditioned

S.No. Place	Broad Climatic Zone	Shaded	Correction Factors			
			White	Light Colour	Dark Colour	Very Dark to Black
			$\alpha=0.3$	$\alpha=0.5$	$\alpha=0.7$	$\alpha=0.9$
1. Roorkee	Hot-dry	0.311	0.467	0.732	1.000	1.267
2. New Delhi	"	0.340	0.524	0.762	1.000	1.235
3. Lucknow	"	0.322	0.526	0.764	1.000	1.240
4. Jodhpur	"	0.345	0.523	0.760	1.000	1.241
5. Ahmedabad	"	0.340	0.522	0.757	1.000	1.222
6. Amritsar	"	0.352	0.531	0.763	1.000	1.231
7. Bhopal	"	0.321	0.532	0.766	1.000	1.233
8. Nagpur	"	0.328	0.517	0.758	1.000	1.242
9. Patna	"	0.304	0.510	0.745	1.000	1.245
10. Hyderabad	"	0.274	0.483	0.742	1.000	1.258
11. Calcutta	Hot-humid	0.267	0.476	0.737	1.000	1.260
12. Madras	"	0.238	0.459	0.726	1.000	1.252
13. Coimbatore	"	0.196	0.471	0.733	1.000	1.260
14. Bombay	"	0.110	0.438	0.718	1.000	1.281

Table 2 (b)

Flat Roofs
Correction Factors for Surface Colour Treatments
(b) Conditioned

S.No.	Place	Climatic Zone	Correction Factors				
			Shaded	White	Light Colour	Dark Colour	Very Dark to Black
				$\alpha=0.3$	$\alpha=0.5$	$\alpha=0.7$	$\alpha=0.9$
1.	Roorkee	Hot-dry	0.389	0.527	0.762	1.000	1.236
2.	New Delhi	"	0.386	0.575	0.790	1.000	1.213
3.	Lucknow	"	0.391	0.575	0.787	1.000	1.210
4.	Jodhpur	"	0.406	0.569	0.783	1.000	1.219
5.	Ahmedabad	"	0.407	0.572	0.783	1.000	1.201
6.	Amritsar	"	0.422	0.583	0.792	1.000	1.210
7.	Bhopal	"	0.393	0.582	0.793	1.000	1.213
8.	Nagpur	"	0.400	0.567	0.782	1.000	1.215
9.	Patna	"	0.378	0.562	0.780	1.000	1.218
10.	Hyderabad	"	0.359	0.543	0.771	1.000	1.226
11.	Calcutta	Hot-humid	0.354	0.538	0.769	1.000	1.232
12.	Madras	"	0.344	0.522	0.751	1.000	1.221
13.	Coimbatore	"	0.290	0.534	0.765	1.000	1.231
14.	Bombay	"	0.225	0.506	0.754	1.000	1.250

Table 3

Walls
Correction Factors for Climate

S.No.	Place	Climatic Zone	Correction Factors	
			Unconditioned	Conditioned
1.	Roorkee	Hot-dry	1.000	1.000
2.	New Delhi	"	1.062	1.051
3.	Lucknow	"	1.031	1.020
4.	Jodhpur	"	1.098	1.085
5.	Ahmedabad	"	1.052	1.046
6.	Amritsar	"	0.978	0.985
7.	Bhopal	"	1.020	1.018
8.	Nagpur	"	0.986	0.998
9.	Patna	"	0.940	0.971
10.	Hyderabad	"	0.871	0.887
11.	Calcutta	Hot-humid	0.855	0.870
12.	Madras	"	0.795	0.818
13.	Coimbatore	"	0.814	0.834
14.	Bombay	"	0.762	0.788

Table 4 (a)

Walls
Correction Factors for Surface Colour Treatments
(a) Unconditioned

S.No. Place	Climatic Zone	Correction Factors				
		Shaded	White	Light Colour	Dark Colour	Very Dark to Black
			$\alpha=0.3$	$\alpha=0.5$	$\alpha=0.7$	$\alpha=0.9$
1. Roorkee	Hot-dry	0.338	0.574	0.786	1.000	1.210
2. New Delhi	"	0.372	0.590	0.795	1.000	1.209
3. Lucknow	"	0.386	0.588	0.795	1.000	1.210
4. Jodhpur	"	0.406	0.610	0.804	1.000	1.198
5. Ahmedabad	"	0.386	0.601	0.798	1.000	1.202
6. Amritsar	"	0.415	0.604	0.803	1.000	1.196
7. Bhopal	"	0.366	0.598	0.798	1.000	1.201
8. Nagpur	"	0.386	0.574	0.787	1.000	1.214
9. Patna	"	0.352	0.578	0.789	1.000	1.222
10. Hyderabad	"	0.334	0.558	0.779	1.000	1.223
11. Calcutta	Hot-humid	0.318	0.544	0.770	1.000	1.228
12. Madras	"	0.262	0.534	0.760	1.000	1.222
13. Coimbatore	"	0.252	0.525	0.753	1.000	1.240
14. Bombay	"	0.157	0.473	0.734	1.000	1.260

Table 4 (b)

Walls
Correction Factors for Surface Colour Treatments
(b) Conditioned

S.No. Place	Climatic Zone	Correction Factors				
		Shaded	White	Light Colour	Dark Colour	Very Dark to Black
			$\alpha=0.3$	$\alpha=0.5$	$\alpha=0.7$	$\alpha=0.9$
1. Roorkee	Hot-dry	0.411	0.624	0.810	1.000	1.183
2. New Delhi	"	0.443	0.636	0.815	1.000	1.118
3. Lucknow	"	0.460	0.635	0.820	1.000	1.180
4. Jodhpur	"	0.471	0.652	0.824	1.000	1.174
5. Ahmedabad	"	0.458	0.649	0.823	1.000	1.182
6. Amritsar	"	0.486	0.651	0.826	1.000	1.172
7. Bhopal	"	0.441	0.646	0.823	1.000	1.178
8. Nagpur	"	0.462	0.627	0.814	1.000	1.191
9. Patna	"	0.430	0.629	0.815	1.000	1.175
10. Hyderabad	"	0.425	0.618	0.808	1.000	1.190
11. Calcutta	Hot-humid	0.413	0.608	0.803	1.000	1.199
12. Madras	"	0.398	0.604	0.798	1.000	1.194
13. Coimbatore	"	0.358	0.594	0.789	1.000	1.206
14. Bombay	"	0.286	0.553	0.775	1.000	1.222

Table 5 (a)

Walls
Correction Factors for Orientation
(a) Unconditioned

S.No.	Place	Climatic Zone	Correction Factors							
			N	NE	E	SE	S	SW	W	NW
1.	Roorkee	Hot-dry	0.422	0.708	0.858	0.671	0.530	0.733	1.000	0.787
2.	New Delhi	„	0.424	0.715	0.870	0.694	0.540	0.765	1.000	0.815
3.	Lucknow	„	0.459	0.745	0.872	0.719	0.540	0.786	1.000	0.827
4.	Jodhpur	„	0.503	0.700	0.822	0.650	0.496	0.789	1.000	0.904
5.	Ahmedabad	„	0.484	0.697	0.852	0.699	0.513	0.829	1.000	0.855
6.	Amritsar	„	0.482	0.704	0.855	0.728	0.592	0.827	1.000	0.880
7.	Bhopal	„	0.443	0.706	0.870	0.712	0.496	0.816	1.000	0.871
8.	Nagpur	„	0.486	0.707	0.914	0.690	0.563	0.795	1.000	0.856
9.	Patna	„	0.437	0.690	0.842	0.685	0.516	0.795	1.000	0.871
10.	Hyderabad	„	0.475	0.764	0.870	0.603	0.411	0.722	1.000	0.902
11.	Calcutta	Hot-humid	0.439	0.766	0.897	0.668	0.483	0.731	1.000	0.862
12.	Madras	„	0.505	0.784	0.913	0.625	0.471	0.705	1.000	0.886
13.	Coimbatore	„	0.414	0.682	0.836	0.616	0.414	0.760	1.000	0.830
14.	Bombay	„	0.422	0.806	0.952	0.598	0.344	0.644	1.000	0.845

Table 5 (b)

Walls
Correction Factors for Orientation
(b) Conditioned

S.No.	Place	Climatic Zone	Correction Factors							
			N	NE	E	SE	S	SW	W	NW
1.	Roorkee	Hot-dry	0.473	0.728	0.722	0.713	0.586	0.756	1.000	0.814
2.	New Delhi	„	0.489	0.745	0.885	0.727	0.590	0.790	1.000	0.834
3.	Lucknow	„	0.524	0.775	0.886	0.750	0.594	0.812	1.000	0.845
4.	Jodhpur	„	0.557	0.732	0.840	0.687	0.550	0.811	1.000	0.913
5.	Ahmedabad	„	0.545	0.734	0.872	0.736	0.570	0.851	1.000	0.874
6.	Amritsar	„	0.544	0.741	0.871	0.760	0.641	0.848	1.000	0.894
7.	Bhopal	„	0.510	0.743	0.886	0.737	0.557	0.812	1.000	0.886
8.	Nagpur	„	0.549	0.744	0.926	0.729	0.617	0.790	1.000	0.875
9.	Patna	„	0.506	0.728	0.861	0.724	0.575	0.819	1.000	0.886
10.	Hyderabad	„	0.546	0.795	0.886	0.491	0.684	0.758	1.000	0.913
11.	Calcutta	Hot-humid	0.517	0.800	0.913	0.715	0.555	0.770	1.000	0.883
12.	Madras	„	0.562	0.810	0.939	0.684	0.539	0.721	1.000	0.912
13.	Coimbatore	„	0.473	0.712	0.851	0.663	0.456	0.795	1.000	0.855
14.	Bombay	„	0.511	0.836	0.961	0.660	0.444	0.699	1.000	0.869

Table 6

Sloped Roofs
Correction Factors for Climate

S.No. Place	Climatic Zone	Correction Factors	
		Unconditioned	Conditioned
1. Roorkee	Hot-dry	1.000	1.000
2. New Delhi	"	1.067	1.060
3. Lucknow	"	1.023	1.021
4. Jodhpur	"	1.121	1.108
5. Ahmedabad	"	1.067	1.060
6. Amritsar	"	1.021	1.019
7. Bhopal	"	1.044	1.040
8. Nagpur	"	1.056	1.050
9. Patna	"	1.016	1.012
10. Hyderabad	"	0.916	0.925
11. Calcutta	Hot-humid	0.909	0.919
12. Madras	"	0.925	0.933
13. Coimbatore	"	0.919	0.927
14. Bombay	"	0.874	0.887

Table 7 (a)

Sloped Roofs
Correction Factors for Surface Colour Treatments
(a) Unconditioned

S.No. Place	Climatic Zone	Correction Factors				
		Shaded	White	Light Colour	Dark Colour	Very Dark to Black
			$\alpha=0.3$	$\alpha=0.5$	$\alpha=0.7$	$\alpha=0.9$
1. Roorkee	Hot-dry	0.284	0.589	0.764	1.000	1.244
2. New Delhi	"	0.316	0.544	0.774	1.000	1.229
3. Lucknow	"	0.318	0.526	0.764	1.000	1.240
4. Jodhpur	"	0.339	0.566	0.784	1.000	1.219
5. Ahmedabad	"	0.314	0.543	0.771	1.000	1.227
6. Amritsar	"	0.342	0.558	0.780	1.000	1.225
7. Bhopal	"	0.306	0.542	0.771	1.000	1.231
8. Nagpur	"	0.308	0.524	0.762	1.000	1.238
9. Patna	"	0.291	0.522	0.761	1.000	1.240
10. Hyderabad	"	0.264	0.511	0.756	1.000	1.246
11. Calcutta	Hot-humid	0.256	0.504	0.753	1.000	1.247
12. Madras	"	0.221	0.498	0.750	1.000	1.238
13. Coimbatore	"	0.190	0.493	0.745	1.000	1.251
14. Bombay	"	0.124	0.467	0.733	1.000	1.276

Table 7 (b)

**Correction Factors for Surface Colour Treatments
(b) Conditioned**

S.No. Place	Climatic Zone	Correction Factors				
		Shaded	White	Light Colour	Dark Colour	Very Dark to Black
			$\alpha=0.3$	$\alpha=0.5$	$\alpha=0.7$	$\alpha=0.9$
1. Roorkee	Hot-Dry	0.358	0.576	0.768	1.000	1.215
2. New Delhi	„	0.386	0.590	0.796	1.000	1.212
3. Lucknow	„	0.388	0.590	0.794	1.000	1.220
4. Jodhpur	„	0.401	0.605	0.803	1.000	1.188
5. Ahmedabad	„	0.376	0.586	0.792	1.000	1.204
6. Amritsar	„	0.410	0.599	0.804	1.000	1.230
7. Bhopal	„	0.374	0.586	0.792	1.000	1.204
8. Nagpur	„	0.384	0.582	0.800	1.000	1.236
9. Patna	„	0.364	0.570	0.784	1.000	1.220
10. Hyderabad	„	0.347	0.565	0.784	1.000	1.216
11. Calcutta	Hot-Humid	0.340	0.561	0.781	1.000	1.219
12. Madras	„	0.325	0.552	0.776	1.000	1.212
13. Coimbatore	„	0.280	0.548	0.772	1.000	1.221
14. Bombay	„	0.233	0.533	0.766	1.000	1.242

Table 8 (a)

**Sloped Roofs
Correction Factors for Orientation
(a) Unconditioned**

S.No. Place	Climatic Zone	Correction Factors							
		N	NE	E	SE	S	SW	W	NW
1. Roorkee	Hot-Dry	0.799	0.813	0.883	0.916	0.927	0.990	1.000	0.918
2. New Delhi	„	0.846	0.880	0.965	0.914	0.941	0.960	1.000	0.900
3. Lucknow	„	0.870	0.937	0.970	0.960	0.940	0.962	1.000	0.944
4. Jodhpur	„	0.851	0.876	0.909	0.911	0.899	0.967	1.000	0.942
5. Ahmedabad	„	0.886	0.863	0.949	0.922	0.926	0.903	1.000	0.951
6. Amritsar	„	0.874	0.891	0.960	0.962	0.980	0.996	1.000	0.933
7. Bhopal	„	0.884	0.872	0.973	0.943	0.931	0.951	1.000	0.904
8. Nagpur	„	0.898	0.857	0.987	0.896	0.960	0.914	1.000	0.881
9. Patna	„	0.874	0.906	0.955	0.960	0.955	0.983	1.000	0.936
10. Hyderabad	„	0.924	0.936	0.957	0.916	0.898	0.941	1.000	0.966
11. Calcutta	Hot-Humid	0.909	0.922	0.973	0.939	0.937	0.963	1.000	0.955
12. Madras	„	0.974	0.993	0.961	0.920	0.874	0.961	1.000	1.035
13. Coimbatore	„	0.902	0.922	0.935	0.925	0.902	0.949	1.000	0.949
14. Bombay	„	0.931	0.974	0.991	0.957	0.908	0.945	1.000	0.974

Table 8 (b)

Sloped Roofs
Correction Factors for Orientation
(b) Conditioned

SNo	Place	Climatic Zone	Correction Factors							
			N	NE	E	SE	S	SW	W	NW
1.	Roorkee	Hot-Dry	0.817	0.830	0.892	0.921	0.932	0.988	1.000	0.923
2.	New Delhi	„	0.866	0.895	0.975	0.920	0.955	0.946	1.000	0.915
3.	Lucknow	„	0.884	0.945	0.974	0.966	0.946	0.968	1.000	0.952
4.	Jodhpur	„	0.850	0.886	0.916	0.919	0.906	0.968	1.000	0.946
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6.	Amritsar	„	0.887	0.904	0.966	0.967	0.985	0.999	1.000	0.940
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