EVALUATION OF THERMAL DESIGN OF RESIDENTIAL BUILDINGS

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ABSTRACT

A method has been illustrated for evaluating thermal conditions in residential buildings in a given climatic zone. This is based on the calculation of net heat gain averaged over the entire surface area of a building which is correlated with the indoor thermal comfort condition. The detailed procedure with two illustrative examples of lower income group and economically weaker section type houses are discussed in this paper.

INTRODUCTION

Large part of U.P., Delhi, Punjab, Haryana, Bihar, Rajasthan and Madhya Pradesh falls under hot dry climatic zone where maximum daily dry bulb temperature exceeds 40°C and relative humidity is less than 40% during peak summer months of May and June. Representative towns under different climatic categories are given in I.S. 3792-1978 'Guide For Heat Insulation of Non Industrial Buildings'[1]

Indoor thermal conditions can be improved upto a certain extent by judicious selection of building components, orientation, window areas and proper shading of walls and windows. The main problems involved in the thermal design are minimizing the flow of solar heat and reducing wall and roof surface temperatures under summer conditions.

Thermal design of residential buildings is important for providing reasonable thermal conditions without artificial means of cooling both for day and night occupancy due to common practice of sleeping indoors. The overall thermal performance of a building depends upon thermal performance of building components, outside surface finish, orientation and climate conditions[2-5]. To evaluate the indoor thermal conditions of a building taking all these factors into account, a suitable method has been evolved by which building design can be evaluated with respect to thermal comfort in a given climatic zone. In this paper this method which deals with the net heat gain averaged over the entire surface area has been discussed. The ratio of the net heat gain and the building surface area is termed as 'Building Index[6]. The building index has been correlated with actual indoor dry bulb temperature of a room under living conditions. From the dry bulb temperature and predetermined air velocity and relative humidity the indoor thermal comfort conditions can be determined in a given climatic zone.

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This method is illustrated by two illustrative examples of houses for lower income groups and economical weaker sections.

CALCULATION PROCEDURE

The Building Index (B.I.) which will give the indoor air temperature in a building can be calculated by following procedure—

1. Write down the detailed specifications of walls, roof, windows and doors.
2. Determine the total surface area of the building plan including the shaded and unshaded area of walls, windows, doors and intermediate walls.
3. Determine the heat gain factors of walls, roof, windows and doors from the given *tables 1 and 2* for different orientations (Apply correction factors to calculate heat gain factors for other orientation as given in *table 3*).
4. Determine the product of heat gain factor and respective area.
5. Determine the summation of the heat gain of the individual component.
6. Determine the heat gain averaged over surface area of the given building, by dividing the total heat gain by total surface area.
7. Determine the building index (B.I.) by multiplying average heat gain by 2.5.
8. Corresponding to this building index determine the indoor air temperature from *fig. 1.* which for the usual range of relative humidity, and air velocity indicates the comfort conditions indoors.

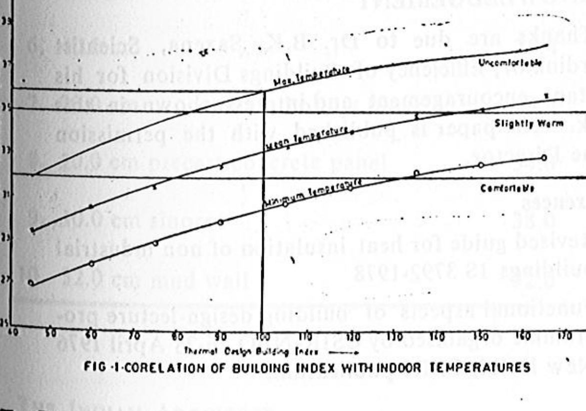

FIG-1-CORELATION OF BUILDING INDEX WITH INDOOR TEMPERATURES

APPLICATION TO LIG AND EWS HOUSES

This method of evaluating thermal performance of houses is illustrated for low income group (LIG) and economically weaker sections (E.W.S.) type houses. These houses are assumed to be situated in hot-dry zone. The plan and specificaion of both type of buildings are given in fig. 2.

L I G Houses

L.I.G. house consists of two rooms and one kitchen. The specification of walls and roofs are 23 cm brick wall, and 15 cm precast R.C. channel unit roof with 10 cm phuska and 5 cm tiles. The ceiling height is 3 m. The various dimensions of rooms are shown in fig. 2.

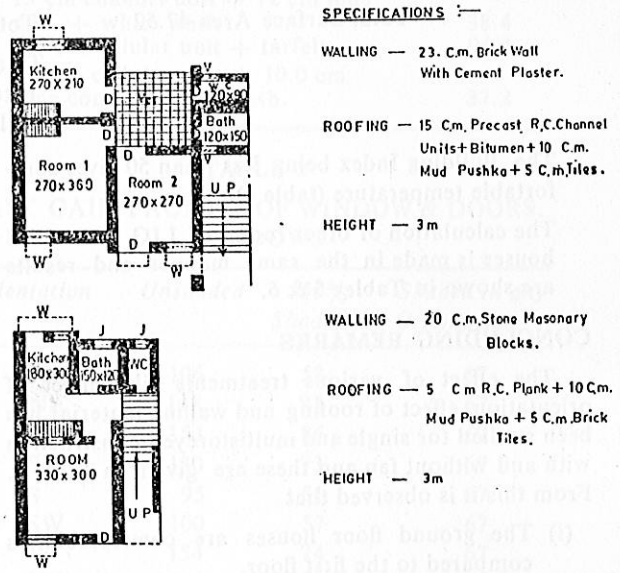

FIG-2 · PLANS OF LIG AND EWS HOUSES WITH SPECIFICATIONS.

E.W.S. Houses

E.W.S. house consists of one room and one kitchen. The specification of walls and roof are 20 cm stone block masonary and 5 cm. R.C. plank roof with 10 cm mud phuska and 5 cm. brick tile. The ceiling height is 3 m. The various dimensions of rooms are as given in fig. 2.

The calculation procedure for 1 room of LIG houses is given below—

ILLUSTRATIVE EXAMPLE

The Procedure of calculation of thermal performance for one room in LIG house is illustrated step by step, so that the users can calculate by seeing this example.

STEPS *Take Room I of LIG house*

Elements with Orientation	*Shading of Exposed Surface*	*Surface Area (m²)*	*Exposed Area (m²)*	*Heat Grain Factor (HGF) (From Table 1 & 2)*	*Heat Gain (Exposed area x H.G.F.)*
Wall (N)	Unshaded	10.8	10 8	40.8x0,45=18.36	188.28
Walls (S)	—	10.8	NIL	—	—
Wall (E)		8.1	NIL		—
Wall (W)	Unshaded	8.1	5.94	40.8	242.35
Door (S)	Shaded		1.8	23.0	41.4
Window (S)	Unshaded	—	2.16	154.0	332.69
Roof	—	9.72	NIL		

Total Surface Area 47.52 Total Heat Gain 814 72 Kcal/hr

$$\frac{\text{Total Heat Gain}}{\text{Total Surface Area}} = \frac{814.72}{47\ 52} = 17.14\ \text{Kcal/hr.m}^2$$

Building Index = 17.14x2.5 = 42.85

The Building Index being less than 50 gives comfortable temperature (table 4).

The calculation of other rooms of LIG and EWS houses is made in the same manner and results are shown in Tables 5 & 6.

CONCLUDING REMARKS

The effect of various treatments like effect of orientation, effect of roofing and walling material has been studied for single and multistoreyed construction with and without fan and these are given in Table 7. From this it is observed that

(i) The ground floor houses are comfortable as compared to the first floor.

(ii) The shading of walls gives quite comfortable conditions inside the building.

(iii) Change of walling materials, from 23 cm brick wall to 20 cm stone masonry blocks does not result in significant change of temperature and comfort conditions remain approximately same in both the cases.

(iv) In multistoreyed residential buildings all the floors except the top floor provide comfortable conditions with fan.

(v) The top floor houses are found to be slightly warm, though within the acceptable limit. These can be made comfortable by providing roof insulation and white wash and treatment.

(vi) The orientation of various rooms does not make significant difference in the thermal conditions because under actual conditions all the walls are not exposed. In many cases either two walls are exposed or one wall is exposed.

(vii) The glass area should be decided on the basis of daylighting requirement and openable area in accordance with the ventilation requirement. The change of glass area from 15 to 25% make only a difference of 0·5° in the indoor temperature.

ACKNOWLEDGEMENT

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TABLE 1

HEATGAIN FACTORS OF WALL AND ROOF SECTIONS

(Hot Dry Region)

S. No	*WALL SPECIFICATION (Orientation—West)*	*HEAT GAIN FACTORS KCAL/hr° cm²*
1.	34.5 cm brick wall	26
2.	22.5 cm brick wall	40 8
3.	28.0 cm brick cavity wall	31 2
4.	20.0 cm stone block masonary wall	56.8
5.	30.0 cm stone block masonary wall	38.4
6.	40.0 cm ,, ,,	28.4
7.	20.0 cm concrete hollow block	54.4
8.	20.0 cm precast concrete panel	54.0
9.	10.0 cm sinores	38.0
10.	32.0 cm mud wall	32.0

S.No.	*ROOF SPECIFICATIONS*	
1.	10 cm R.B C. with plaster and tarfelt	90.0
2.	11.5 cm R.C.C. with plaster and tarefelt	.81.2
3.	11.5 cm R.B.C.+9.0 cm lime concrete	50.4
4.	11.5 cm R.B.C.+7.5 cm to 10 cm mud phushka + 5.0 cm brick tile	40.0
5.	10.0 cm RCC + 5.9 cm foam concrete + tarfelt	32.4
6.	5.0 cm to 6.0 cm RCC plant + Tarfelt	129.6
7.	5.0 cm to 6 0 cm RCC + 9.0 cm lime concrete	52.8
8.	5.0 cm to 6.0 cm RCC + 7.5 cm Mud phusla + 5.0 cm tile	42.0
9.	,, ,, ,, + white wash	36.4
10.	13 cm channel unit + Tarfelt	124.8
11.	13 cm channel udit + 12 cm lime con. + white wash	38.4
12.	7.5 cm cellular unit + tarfelt	96.4
13.	7.5 cm cellular unit + 10.0 cm lime conc. + white wash.	37.2

TABLE 2

HAET GAIN FACTORS OF WINDOW & DOORS.

WINDOWS

Orientation	*Unshaded*	*50% Shaded*	*Shaded in any Orientation*
N	106	58	67
NE	148	82	67
E	154	86	67
SE	130	73	67
S	95	51	67
SW	100	57	67
W	154	74	67
NW	148	78	67
	Doors		
N	25	—	23
NE	27	—	23
E	27	—	23
SE	26	—	23
S	24	—	23
SW	24	—	23
W	27	—	23
NW	28	—	23

Table 3

CORRECTION FACTORS FOR HEAT GAIN FACTORS
(HOT-DRY ZONE)

S. No.	*Building Component*		*Orientation of Wall*							*External Surface Finish (Roof)*		*Shading*	
	Roof	Wall(W)	N	NE	E	SE	S	SW	NW	Dark	Light	Roof	Wall
	1	1	0.45	0.70	0.85	0.67	0.55	0.75	0.70	1.0	0.78	0.32	0.35

Table 4

RANGE OF BUILDING INDEX AND THERMAL CONDITIONS

S. No.	*Building Index (B.I.)*	*Comfort Conditions*	*Temperature*
1	0.50	Comfortable	⩽30°C
2	51.100	Slightly Warm	⩾30°C⩽34°C
3	101.150	Hot	⩾34°C⩽38°C

Table 5

CALCULATION OF BUILDING INDEX FOR LOW INCOME GROUP HOUSES (L.I.G.)

S.No.	*Elements of Building with Orientation*		*Area (m^2)*	*Exposed area (m^2)*	*H G.F. Heat Gain Factors*	*Heat Gain (Kcal/Hr (Exposed area x H.G.F.*	*Total Heat Gain Kcal/Hr (Summation of Col. 4.)*	*Surface Area Summation of Col. 1.)*	*Total Heat Gain Total Surface Area*	*Building Index (B.I.)*
(i)	Wall (N)	U.S.	6.3	6.3	18.36	115.66				
	Wall (S)		6.3							
	(i)	U.S.		2.25	22.44	50.44				22.15x2.5
	(ii)	S		2.25	7.25	17.66	763.64	34.47	22.15	=55.3
	Wall (E)	U.S.	8.1	5.94	34.68	205.99				
	Wall (W)	—	8.1	Nil	—	—				
KITCHEN										
(ii)	Door (S)	S		1.8	23.0	41.4				
(iii)	Window (E)	U.S.	—	2.16	154.0	332.69				
(iv)	Roof		5.67	Nil	Nil	Nil				
(i)	Wall (N)	U.S.	10 8	10.8	18.36	198.28				
	Wall (S)	—	10.8	Nil						
	Wall (E)	—	8.1	Nil						17.14x2.5
	Wall (W)	U.S.	8.1	5.94	40.8	242.35	814.72	47.52	17.14	=42.85
ROOM I										
(ii)	Door (S)	S	—	1.8	23.0	41.4				
(iii)	Window(W)	U.S.	—	2.16	154.0	332.69				
(iv)	Roof		9.72	Nil	Nil	Nil				
(i)	Wall (N)	—	8.1	Nil	Nil	—				
	Wall (S)	S	8.1	8.1	7.85	63.58				18.25x2.5
	Wall (E)	S	8.1	6.3	12.13	76.41	724.39	39.69	18.25	=45.6
	Wall (W)	U.S.	8.1	4.14	40.8	168.91				
ROOM II										
(ii)	Door (E)	S	—	1.8	23.0	41.4				
	Door (W)	S	—	1.8	22.0	41.4				
(iii)	Window(W)	U.S.	—	2.16	154.0	332.69				
(iv)	Roof	—	7.29	Nil	Nil	—				

Table 6

CALCULATION OF BUILDING INDEX (B.I.) FOR ECONOMICALLY WEAKER SECTIONS (E.W.S.)

S. No.	*Elements of Building with Orientation*		*Total area (m²)*	*Exposed area (m²)*	*H.G F. Heat Gain Factors*	*Heat Gain Kcal/Hr (Exposed area x H.G.F.*	*Total Heat Gain Kcal/Hr (Summation of Col. 4.)*	*Surface Area Summation of Col. 1.)*	*Total Heat Gain / Total Surface Area*	*Building Index (B.I.)*
(i)	Wall (N)	U.S.	9.0	9.0	25.56	230.04				
	Wall (S)	U.S.	5.0	0.4	31.24	12.6				
	Wall (E)	U.S.	5.4	2.64	48.28	127.45				
	Wall (W)	—	5.4	Nil	Nil	—	565.53	30.2	18.7	18.7x2.5 =47.5
KITCHEN										
(ii)	Door (E)	U.S.	—	1.80	27.0	48.6				
(iii)	Window (E)	U S.	—	0.96	154.0	147.84				
(iv)	Roof	—	5.4	Nil	Nil	—				
(i)	Wall (N)	U.S.	9.0	9.0	25.56	230.04				
	Wall (S)	S	9.0	9.0	10.93	98.37				
	Wall (E)	—	9.9	Nil	—		879.28	47.7	18.4	18.4x2.5 =46.0
	Wall (W)	U.S.	9.9	6.24	56.8	354.43				
ROOM I										
	Door (W)	U.S.	—	1.8	27.0	48.6				
	Window (W)	U.S.	—	0.9	154	147.84				
	Roof	—	9.9	Nil						

Table 7

EFFECT OF ORIENTATION AND STOREY ON TEMPERATURE INDOORS OF TWO HOUSING SCHEME

Elements	*Orientation*	*LIG Quarters*				*EWS Quarters*			
		Ground Floor		*First Floor*		*Ground Floor*		*First Floor*	
		Heat Gain	*B.I.*	*Heat Gain*	*B.I.*	*Heat Gain*	*B I.*	*Heat Grain*	*B.I.*
ROOM I									
(i)	Longer Walls facing N-S	17.14	42.85	18.4	48.0	18.4	46.0	25 98	64.97
(ii)	Longer Walls facing E-W	17.60	44.0	23.9	59.7	23.9	59.7	30.40	76.00
ROOM II									
(i)	Longer Walls faciug N-S	18.25	45.60	24.42	61.0				
(ii)	Longer Walls facing E-W	21.10	52 57	28.5	71.23				