Simulation of Heat Gain through Building Envelope for Buildings in Hot Humid Climates.

Tawee Vechaphutti, P.E.
Member ASHRAE

ABSTRACT

A study of heat gain through the building envelop considering the engineers could consider as a guideline to design the appropriate shape of building for energy conservation. In addition, the investigation also considers the method to reduce heat gain by using internal shading devices and thermal insulating materials.

At first an investigation of all factors to be used for calculating heat gain through building envelope are conducted. In order to calculate average heat gain, the building envelop is simulated by varying its shape, fenestration area and orientation of the building to obtain various models. The effects of the variation of configuration factors to the average heat gain are analyzed, and the optimum shape of the building to minimize average heat gain is calculated when materials, fenestration area and orientation are defined. In order to provide guidelines for reduction of that gain through the buildings, the effective shading coefficients of general external shading devices the effective shading coefficients of general external shading devices are calculated and comparisons are made using four thermal insulating materials.

1. INTRODUCTION

Thailand is situated in a hot and humid climate. Heat gain through building envelope depends on many factors such as outdoor weather, solar energy building orientation, size and shape of building. In considering the heat gain, the main factors that have greater influence are the size, shape and orientation of the building.

2. CALCULATION OF HEAT GAIN THROUGH BUILDING ENVELOPE

2.1 In Calculation the heat gain through building envelope, we proceeded by using the yearly solar data (of Bangkok) averaging from 7.00 AM. To 18.00 PM. Heat gain is considered from the followings.

1. Heat conduction through opaque walls and roofs.
2. Heat conduction through glass windows.
3. Solar radiation through glass windows.

The equation used for heat gain calculation through (each side of) building envelope is

$$q = (U_w \times A_w \times TD_{eq}) + (U_f \times A_f \times \Delta T) + (A_f \times SC \times SF) \tag{1}$$

when q = heat gain through building envelope, W (watt)

U_w = thermal transmittance of opaque wall, $W/m^{2o}c$

A_w = opaque wall area, m^2.

TD_{eq} = equivalent temperature difference, ^{o}c

A_f = fenestration area, m^2.

U_f = thermal transmittance of fenestration $W/m^{2o}c$

ΔT = temperature difference between exterior and interior design condition

SC = shading coefficient of fenestration

SF = solar factor W/m^2

The result from solar data,

For wall :   Solar factor (SF) = 130 x correction factor (CF)   (2)
For roof :   Solar factor (SF) = 360 x correction factor (CF)   (3)

Table 1. Solar correction factor for wall. (CF)

SLOPE, degree	NE	E	SE	S	SW	W	NW	N
90	1.08	1.29	1.38	1.43	1.52	1.46	1.18	1.00
80	1.28	1.51	1.63	1.72	1.79	1.70	1.39	1.18

Table 2. Solar correction factor for roof. (CF)

SLOPE, degree	NE	E	SE	S	SW	W	NW	N
30	0.84	0.90	0.96	0.99	1.00	0.95	0.88	0.83
20	0.91	0.95	0.99	1.02	1.02	0.99	0.94	0.91
10	0.96	0.98	1.00	1.02	1.02	1.00	0.98	0.96
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 3. Average equivalent temperature difference (7.00-18.00 hour throughout the year)

Medium colored , Indoor Air Temperature = 25^oc (By using Transfer function Method from ASHRAE Fundamental 1977, 1985)

Construction	Weight kg/m^2	U W/m^2-^{o}c	Equivalent Temperature								Diff.,^{o}c
			NE	E	SE	S	SW	W	NW	N	AVG.
4-in. h.w. concrete block	177	2.72	9	10	10	10	10	10	9	8	9
4-in. clay tile	190	2.37	8	9	10	10	9	9	8	8	9
4-in. common brick	273	2.61	7	8	8	8	8	7	7	7	8

2.2 Simulation of heat gain through building envelope By Considering the following model.

1. Concrete walls 10 cm. Thick
2. Concrete roof 10 cm. Thick
3. Glass window (cool gray) 6 mm. Thick
4. No external and internal shadings
5. Typical Floor to floor height 3.5 meters

For simulation and analysis (of the heat gain through the model,) only 1 story height (typical) is considered. The heat gain through walls and calculated independently since the heat gain through flat roof is constant and independent of building proportion and orientation of building. The model with varying proportions are listed as in Fig.1
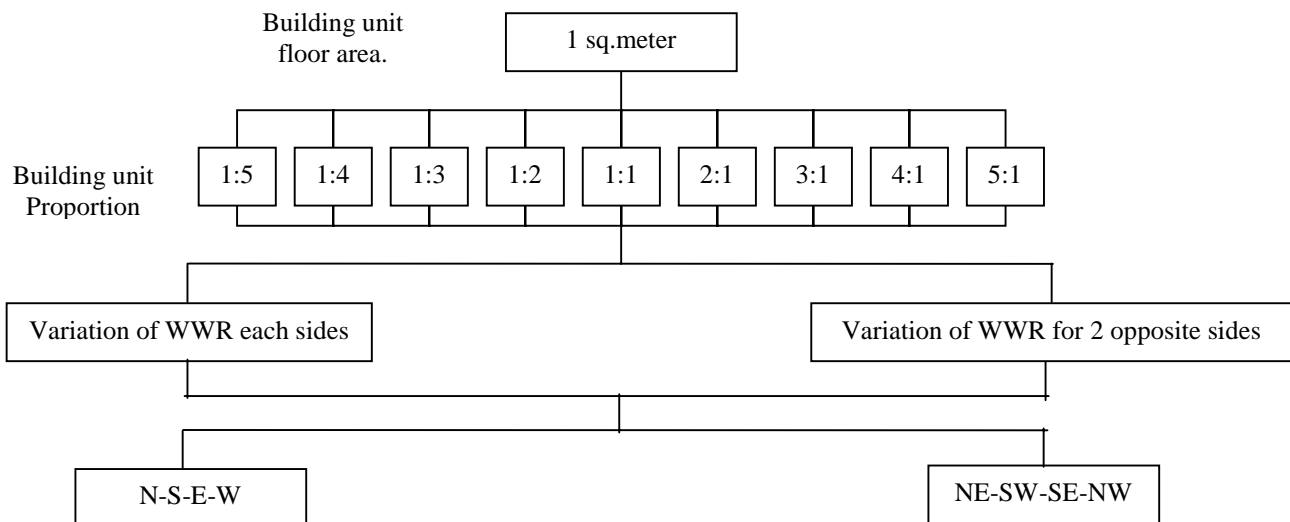

Fig 1. Chart showing variation of building shape for modeling.

As shown in Fig.1., we will get the simulation model of various sizes, shapes, and orientation as well as varying WWR (window-to-wall ratio) defined by:

$$WWR = A_f/A_o \tag{4}$$

where A_f = fenestration area (glass), m^2

A_w = opaque wall area, m^2

A_o = gross area of exterior wall , m^2

= $A_w + A_f$

3. OPTIMUM BUILDING SHAPE FOR MINIMUM HEAT GAIN

From eq. 1, the revised form will be as following

$$q/A_O = (1-WWR) \times U_w \times TD_{eq} + WWR \times U_f \times \Delta T + WWR \times SC \times SF \tag{5}$$

Let $h = (1-WWR) \times U_w \times TD_{eq} + WWR \times U_f \times \Delta T + WWR \times SC \times SF \tag{6}$

Where h = Average heat gain through wall of one unit area (W/m^2)

Let X = Length of wall facing North or South (m.)

Y = Length of wall facing East or West (m.)

and C = Constant value of floor to floor height (m.)

Heat gain through walls could be represented by

$Q = q_N + q_S + q_E + q_W$

$= (h_N + h_S) CX + (h_E + h_W) CY \tag{7}$

Let $A = XY \tag{8}$

Where A = floor area, m^2.

The calculation of optimum shape of mode oriented in N-S, E-W directions to obtain minimum heat gain is through the use of Lagrange Multipliers having the following equations.

$$X^*/Y^* = R^* = (h_E + h_W)/(h_N + h_S) \tag{9}$$

Where $X^* = \sqrt{A(h_E + h_W)/ (h_N + h_S)} \tag{10}$

$Y^* = \sqrt{A(h_N + h_S)/ (h_E + h_W)} \tag{11}$

$\lambda = C\sqrt{(h_N + h_S)/ (h_E + h_W)/A} \tag{12}$

$Q^* = 2C \sqrt{A(h_N + h_S)(h_E + h_W)} \tag{13}$

And $X^*/Y^* = R^*$ = proportion of building which gives optimum shape for minimum heat gain.

λ = Lagrange Multiplier = Constant.

Similarly for buildings oriented in NE-SW-SE-NW, the same procedure could be used.

Table 4 Average Heat Gain Per Unit Area of Envelope

WWR	HEAT GAIN PER UNIT WALL AREA (W/m^2)							
(%)	h_N	h_S	h_E	h_W	h_{NE}	h_{SW}	H_{SE}	h_{NW}
0	21.76	27.20	27.20	27.20	24.48	27.20	27.20	24.48
20	39.898	51.642	49.266	52.17	43.526	53.226	50.718	45.242
40	58.036	76.084	71.332	77.14	62.572	79.252	74.236	66.004
60	76.174	100.526	93.398	102.11	81.618	105.278	97.754	86.766
80	94.312	124.968	115.464	127.08	100.664	131.304	121.272	107.528
100	112.45	149.41	137.53	152.05	119.71	157.33	144.79	128.29

4. GUIDELINES FOR REDUCTION OF HEAT GAIN THROUGH BUILDINGS

The reduction of heat gain through buildings could be accomplished by:

4.1 Reducing the shading coefficient (SC)

4.2 Using insulation in combination with walls and roofs

The use of external shading could be performed through various methods such as employing horizontal overhangs, vertical fins or combination fins.

Many types of insulation could be selected to use for the insulation of walls and roofs as shown in Table 5

Table 5 Heat gain reduction and annual energy saving through the use of insulation.

Construction	U W/m^2-$^\circ$c	ANNUAL ENERGY SAVING (kW-hrs/m^2)								Average
		NE	E	SE	S	SW	W	NW	N	
10 cm.h.w. concrete block with 2.5 cm. Polyurethane foam	0.91	51.61	57.34	57.34	57.34	57.34	57.34	51.61	45.87	54.47
10 cm.h.w. concrete block with 2.5 cm. Fiberglass	0.84	53.60	59.56	59.56	59.56	59.56	59.56	53.60	47.65	56.58
10 cm.h.w. concrete block with 5 cm. Rockwool	0.51	66.24	73.24	73.24	73.24	73.24	74.86	67.86	59.24	70.15

NOTE: Table 5 shown some example of annual energy saving, in the research all orientation of building are studied.

5. CONCLUSION

Through the analysis of heat gain of the building models having various sizes, shapes and orientation excluding roofs, it could be concluded that:

Heat gain through glass areas facing different directions would be unequal such that the one facing north would have minimum heat gain and the one facing northwest would gain most.

The important factors influenced the heat gain of the building models are window to wall ratio, WWR , and the building proportion, R. The practical R values that could be implemented with reasonable heat gain and requirements of architects and engineers would be in the range 1:1 up to 1:2.

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Tawee Vechaphutti is Associate Professor of Mechanical Engineering Department,
Faculty of Engineering, Chulalongkorn University, Bangkok, 10330,Thailand.
Director of Building Technology and Environment Research Laboratory (BTERL)
BOG.ASHRAE THAILAND CHAPTER,(2000-2001)
Fellow of Professional Engineer (P.E.,) Council of Engineering, Bangkok 10310, Thailand.