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COMPARSION OF BUILING CODES AND INSULATION IN CHINA AND ICELAND

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ABSTRACT

Heat load calculation for a sample building with and without insulation using Chinese and Icelandic building codes was carried out in this paper. The results shows that the calculated heat load is similar by the two different building codes for the un-insulated building. This confirms that there is agreement between the calculation methods. Heat load decreases by 36.4% when insulation is added to the building envelope. If the thermal insulation property is improved to satisfy the Icelandic standard, which was valid at the time of construction for the sample building, the heat load decreases to 54.8%, which indicates that improving thermal insulation and insulation properties are effective ways to reduce energy consumption.

1. INTRODUCTION

Heat load of a building is dependent on the building's structure, its insulation and its characteristics, volume, and local climate. Following the reference from the China Heating Design Handbook (Tang Huifen,1992), the design heat load per unit area of 46-70 W/m2 in typical residential buildings can be used to estimate the heating load. The method of the building standards has to be followed to obtain the design heat load. Outdoor temperatures affects the indoor temperature through heat conduction in the outer walls, windows and through free and forced infiltration.

1.1 Building heat load

Building heat load consists of following components:

1) Heat loss through building envelope;
2) Heat loss by infiltration;
3) Heat load of inrush air due to opening the doors and windows heat loss;
4) Radiation through building envelope entering room.

In addition, there is other heat load factors, such as illumination, human body heat and other addition heat load factors. These are neglected in the heat load calculation because they are insufficient and unstable.

1.2 Sample building

The sample residential building exemplified in this paper in Tianjin, China is six stories, and contains four flats of three types(A, B and C) on the same floor. A floor layout of the building is shown in Figure 1, and the building area is presented in Table 1.

FIGURE 1: Sample building in Tianjin

TABLE 1: Ares of th building envelope

Type	A (m^2)	B (m^2)	C (m^2)	Total area (m^2)
Roof	913.76	495.76	415.48	1825.00
Floor	913.76	495.76	415.48	1825.00
Outer wall	2537.04	2608.32		5145.36
Inner wall	3520.80	5094.00		8614.80
Windows	418.56	444.48		863.04

2. CALCULATION OF BUILDING HEAT LOAD

The characteristics of the building construction materials need to be identified to evaluate the building parameters, which are given by Emeish (2001) in Table 2.The heat transfer coefficients for door and windows of different materials are given in Table 3.

The following calculations are based on a steady state energy balance by Chinese and Icelandic building codes for the sample building with and without insulation respectively.

TABLE 2: Construction material's properties

Constructions material	Density ρ (kg/m^3)	Thermal conductivity λ (W/(m °C))	Heat capacity C (kJ/(kg °C))
Concrete	2088	1.21	1.08
Brick	1800	0.60	1.80
Plaster	2710	1.00	0.86
Asphalt mix	2000	0.70	-
Roof brick	1400	0.95	1.08
Sand	1450	0.38	0.92
Cement tiles	2145	1.35	0.96

TABLE 3: Overall heat transfer coefficients for door and window

		K(W/(m^2 °C))	structure
Window		2.70	Steel (12mm air layer)
Staris	Wall	1.50	360mm brick
	Door	1.50	Compund insulation
Balcony door (opague part)		1.50	

2.1 Heat loss calculated by the Icelandic codes (un-insulated building)

The total heat transfer coefficient is indispensable to heat load calculations. Heat transfer coefficient, K is a constant that describes the heat transfer between the building and its environment due to conduction, convection and radiation, K_{total} can be calculated according to Equation 1：

$$K_{tatal} = \frac{K_1 A_1 + K_2 A_2 + \ldots}{A_{tatal}} \qquad \text{(W/(m}^2\ \text{°C))} \quad , \tag{1}$$

where K_n =Heat transfer coefficient of different components of building(W/(m^2 °C);

A_n =Surface area of components (m^2);

A_{total} =Total surface area of the building (m^2);

R_n =The thermal resistance of heat transfer for component (m^2 °C/W);

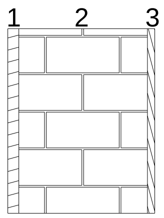
R_o =Total thermal resistance of heat transfer((m^2 °C/W).

2.1.1 Heat losses through the building envelope

1) Wall heat transfer coefficient

The walls heat transfer coefficient is given in Table 4.

TABLE 4: Outer wall heat transfer coefficient

Outer wall	Construction material	x (m)	λ (W/(m °C))	R (m °C /W)
	1.Concrete	0.03	1.21	0.02
	2.Brick	0.35	0.60	0.58
	3.Plaster	0.02	1.00	0.02
	R_i			0.12
	R_e			0.04
	R_o			0.78

$$K_{wall} = 1/R_o = 1/0.78 = 1.27 \quad \text{(W/(m}^2\,\text{°C))}$$

2) Roof heat transfer coefficient

The construction materials of the roof consists of concrete and roof bricks, concrete covers 80% of the total area and 20% is of roof bricks. Two different heat transfer coefficients need to be calculated. The results are shown in Table 5 and 6.

TABLE 5: Roof heat trandfer coefficient using brick

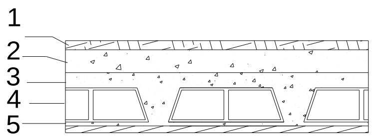
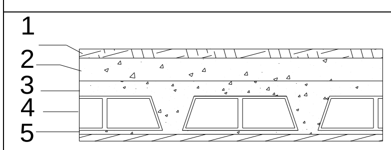
Roof	Construction material	x (m)	λ (W/(m °C))	R (m °C /W)
	1.Asphalt	0.02	0.70	0.03
	2.Concrete	0.05	1.21	0.04
	3.Reinforced concrete	0.06	1.75	0.03
	4.Roof brick	0.18	0.95	0.19
	5.Plaster	0.02	1.00	0.02
	R_i			0.10
	R_e			0.04
	R_o			0.46

TABLE 6: Roof´s heat transfer coefficient without brick

Roof	Construction material	x (m)	λ (W/(m °C))	R (m °C /W)
	1.Asphalt	0.02	0.70	0.03
	2.Concrete	0.05	1.21	0.04
	3.Reinforced concrete	0.24	1.75	0.14
	5.Plaster	0.02	1.00	0.02
	R_i			0.10
	R_e			0.04
	R_o			0.37

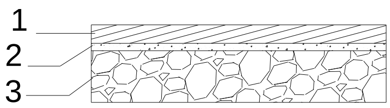
$$K_1 = 1/R_o = 1/0.46 = 2.17 \quad \text{(W/(m}^2\,\text{°C)),} \quad K_2 = 1/R_o = 1/0.37 = 2.70 \quad \text{(W/(m}^2\,\text{°C))}$$

$$K_{roof} = \frac{K_1 A_1 + K_2 A_2}{A_{total}} = 2.28 \ \text{(W/(m}^2\ \text{°C))}$$

3) Floor heat transfer coefficient

Floor heat transfer coefficient is given in Table 7.

TABLE 7: Floor heat transfer coefficient

Floor	Construction material	x (m)	λ (W/(m °C))	R (m °C /W)
	1.Tiles 2.Concrete 3.Sand	0.03 0.01 0.07	1.35 1.21 0.38	0.02 0.01 0.18
	R_i R_e R_o			0.15 0.09 0.45

$$K_{floor} = 1/R_o = 1/0.45 = 2.22 \ \text{(W/(m}^2\ \text{°C))}$$

4) Windows

The type commonly used in Tianjin is single glazing with a K value of 6.40 W/(m^2 °C).

5) Heat loss in the unheated stair area

The stairs of the building are not heated. The equilibrium temperature in the stair area has thus to be calculated. Heat flow from the heated areas of the building into the stair area is equal to the heat lost. Calculation of the stairs temperature is, according to Equation 2, based on energy balance and the area of each component (Table 8).

$$\sum K_i A_i (T_i - T_{stair}) = \sum K_o A_o (T_{stair} - T_o) \qquad (2)$$

Table 8 Stairs heat transfer coefficient

Element	A (m^2)	K (W/(m^2 °C))
Inner wall	333.00	1.21
Outer wall	95.40	1.31
Door in inner wall	36.00	1.50
Window in outer wall	60.00	2.70

Equation 2 gives $T_{stair} = 8.92$ °C

Heat loss from the stairs is then $Q_s = 5.17$ kW

2.1.2 Building total heat transfer coefficient

On the basis of the above calculation, the total heat transfer coefficient of a building can be summarized as in Table 9

TABLE 9: Total heat transfer coefficient of a building

Element	K (W/(m^2 °C))	A (m^2)	KA (W/°C)
Roof	2.74	1825.00	5000.50
Floor	2.22	1825.00	4051.50
Outer wall	1.29	5145.36	6637.46
Window	6.40	863.04	5523.46
Door	2.30	288.00	662.40
Total			21875.37

2.1.3 Heat loss by infiltration

Infiltration is the leakage of outside air into the house through cracks around the windows and doors, which depends mainly on the tightness of windows and doors, as well as the wind velocity (the pressure difference between the outside and inside of the envelope). The air change method is used here to estimate the volume of flow of infiltration air into the heating area, which is based on the air volume in a space being replaced by outside air a certain times per hour. Chinese building codes recommend 0.5-1.0 air changes per hour for residential buildings. 0.6 is used, in Equation 3:

$$Q_2 = c_p V \rho_d (T_i - T_o) \text{ (kJ/h)} \tag{3}$$

Where c_p =Specific heat of air, 1.0056 kJ/kg;
V =Airflow rate (m^3/h);
ρ_d =Air density when temperature is T_o, 1.32 kg/m^3;

Using air change method to determine V(m^3/h), gives:

$$V = nV_h \text{(m}^3\text{/h)} \tag{4}$$

Where n =Air change rate, 0.6h^{-1};
V_h =Room volume, 32,850 m^3.

From Equation 3 $Q_2 = 210.76$ kW

2.1.4 Heat load of inrush air due to opening the doors and windows

Heat loss of external door is 38.84 kW, So additional heat load of inrush air is calculated :

$$Q_3 = 65N\% \times 38.84 = 151.46 \text{ kW} \tag{5}$$

where: N = the number of stories

2.1.5 Total heat load

Thus, the total heat loss is:

$$Q_{total} = Q_1 + Q_2 + Q_3 + Q_s = 1001.78 \text{ kW}$$

2.2 Heat loss calculated by the Chinese codes (un-insulated building)

2.2.1 Heat losses through the building envelope

As for state heat transfer, the formula has been given as follows:

$$Q_1 = KA(T_i - T_o) \quad \text{(W)} \tag{6}$$

Where Q_1 =Heat loss through building envelope (W);
K =Heat transfer coefficient through building envelope (W/(m^2 °C));
A =Areas of building envelope (m^2);
T_i =Indoor temperature (°C);
T_o =Outdoor temperature (°C).

TABLE 10: Heat transfer coefficient of building envelope

Element	K (W/(m^2 °C))	A (m^2)	K*A (W/°C)
Roof	0.93	1825	1697.25
Floor	0.40	1825	730.00
Outer wall	1.57	5145.36	8078.22
Window	6.40	863.04	5523.46
Stair	1.83	240.00	439.20
Door	4.65	288.00	1339.20

$$Q_1 = \sum K_i A_i (T_i - T_o) = 516.41 \quad \text{(kW)}$$

2.2.2 Infiltration

From Equation 3, $Q_2 = 210.76$ (kW)

2.2.3 Heat load of inrush air

From Equation 5, $Q_3 = 151.46$ kW

2.2.4 Additional heat load

Higher buildings are estimated to have higher heat load than lower. According to the handbook, when the height of building is more than 4m, 2% of the total heat loss should be added for every 1m, but not more 15% of the total. Q_4 is calculated as:

$$Q_4 = (Q_1 + Q_t + Q_3) \times 15\% = 131.79 \text{ (kW)}$$

$$\text{Thus: } Q_{total} = Q_1 + Q_t + Q_3 + Q_4 = 1010.43 \quad \text{(kW)}$$

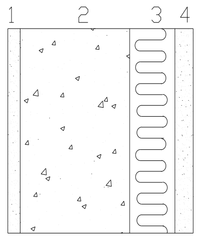
2.4 Building calculation (with insulation), Icelandic codes

2.4.1 Heat load of building envelope (Iceland standards UDC 699.86)

1) Wall heat transfer coefficient

The outer wall heat transfer coefficient is given in Table 11

TABLE 11: Outer wall heat transfer coefficient

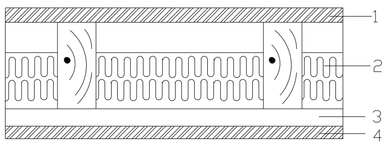
Outer wall	Construction material	x (m)	λ (W/(m °C))	R (m °C /W)
	1.Plaster	0.015	1.20	0.0125
	2.Concrete	0.20	1.70	0.1175
	3. Insulation(Styrofoam)	0.07	0.07	1.75
	4. Plaster	0.02	0.02	0.02
	R_i+ R_e			0.17
	R_o			2.07

$$K_{wall} = 1/R_o = 1/2.07 = 0.48 \text{ (W/(m}^2\text{ °C))}$$

2) Roof heat transfer coefficient

The total heat transfer coefficient of the roof is given in Table 12.

TABLE 12: Roof heat trandfer coefficient

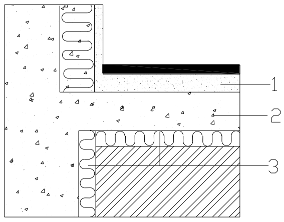
Roof	Construction material	x (m)	λ (W/(m °C))	R (m °C /W)
	1. Wooden panel			0.40
	2. Rockwool	0.12	0.052	2.31
	3. Wood			0.13
	4. Planking	0.02	0.15	0.13
	R_i+ R_e			0.17
	R_o			3.14

$$K_{roof} = 1/R_o = 1/3.14 = 0.32 \text{ (W/(m}^2\text{ °C))}$$

3) Floor heat transfer coefficient

The total heat transfer coefficient of the floor is given in Table 13.

TABLE 13: Floor heat transfer coefficient

Floor	Construction material	x (m)	λ (W/(m °C))	R (m °C /W)
	1.Floor layer	0.04	1.20	0.03
	2.Concrete	0.12	1.70	0.07
	3.Insulation(Styrofoam)	0.03	0.07	0.43
	R_i			0.13
	R_j			0.70
	R_o			2.55

$$K_{floor} = 1/R_o = 1/2.55 = 0.39 \quad \text{(W/(m}^2\ \text{°C))}$$

Heat transfer coefficient of building envelope is summarized in Table 14, accordingly, Heat load of building envelope is calculated.

Table 14: Heat transfer coefficient of building envelope

Element	K (W/(m² °C))	A (m²)	KA (W/°C)
Roof	0.32	1825.00	584.00
Floor	0.39	1825.00	711.75
Outer wall	0.48	5145.36	2469.77
Window	1.30	863.04	1121.95
Stair	0.80	240.00	192.00
Door	2.30	288.00	662.40

$$Q_1 = \sum K_i A_i (T_i - T_o) = 166.51 \quad \text{kW}$$

2.4.2 Infiltration

From Equation 3, $Q_2 = 120.25$ kW

2.4.3 Heat load of inrush air

From Equation 5 , $Q_3 = 65N\% \times 24.3 = 94.77$ kW

2.4.4 Additional heat load due to building height

$Q_4 = 74.95$ kW

2.4.5 Total heat load

The total heat load of building is given as:

$$Q_{total} = Q_1 + Q_t + Q_3 + Q_4 = 456.49 \quad \text{kW}$$

2.5 Building calculation (with insulation), Chinese codes

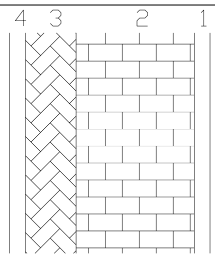
The following calculations are according to China codes and given for comparison.

2.5.1 Heat load of building envelope

1) Wall heat transfer coefficient

The wall total transfer coefficient is given in Table 15

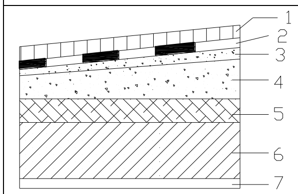
Table 15: Outer wall heat transfer coefficient

Outer wall	Construction material	x (m)	λ (W/(m °C))	α	R (m °C /W)
	1.lime mortar	0.02	0.81	1.00	0.03
	2.Brick	0.36	1.21	1.00	0.30
	3.Insulation (XPS)	0.04	0.03	1.10	1.21
	4.Tile	0.02	1.35	1.00	0.02
	R_i				0.12
	R_e				0.04
	R_o				1.72

$$K_{wall} = 1/R_o = 1/1.72 = 0.58 \quad (\text{W/(m}^2\ ^\circ\text{C))}$$

2) Roof heat transfer coefficient

Table 16: Roof´s heat trandfer coefficient

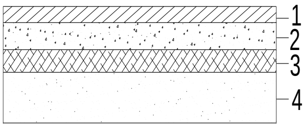
Roof	Construction material	x (m)	λ (W/(m °C))	α	R (m °C /W)
	1.Cement mortar	0.04	0.93	1.00	0.04
	2.Water-proof material	0.01	0.17	1.00	0.06
	3. Cement mortar	0.02	0.93	1.00	0.02
	4. Plaster	0.07	0.29	1.50	0.16
	5.Insulation (XPS)	0.06	0.04	1.30	1.54
	6.Reinforced concrete	0.11	1.74	1.00	0.06
	7.Plaster	0.02	0.81	1.00	0.03
	R_i				0.12
	R_e				0.04
	R_o				2.07

$$K_{roof} = 1/R_o = 1/2.07 = 0.48 \quad (\text{W/(m}^2\ ^\circ\text{C))}$$

3) Floor heat transfer coefficient

The total heat transfer coefficient of the floor is given in Table 17.

TABLE 17: Floor heat transfer coefficient

Floor	Construction material	x (m)	λ (W/(m °C))	α	R (m °C /W)
	1.Tile	0.03	1.35	1.00	0.02
	2.Concrete	0.10	1.74	1.00	0.06
	3. Insulation (EPS)	0.06	0.04	1.50	1.00
	4. Lime & soil mixture	0.15	0.29	1.50	0.35
	R_i				0.12
	R_o				1.55

$K_{floor} = 1/R_o = 1/1.55 = 0.65$ (W/(m^2 °C))

The heat transfer coefficient of the building envelope is summarized in Table 18, accordingly, heat load of the building envelope is calculated.

Table 18: Heat transfer coefficient of building envelope

Type	K (W/(m^2 °C))	A (m^2)	KA (W/°C)
Roof	0.48	1825.00	876.00
Floor	0.65	1825.00	1186.30
Outer wall	0.58	5145.36	2984.30
Window	2.70	863.04	2330.21
Stair	1.50	240.00	360.0
Door	2.91	288.00	838.10

$$Q_1 = \sum K_i A_i (T_i - T_o) = 343571.70W = 343.57 \text{ kW}$$

2.5.2 Infiltration

From Equation 3, $Q_2 = 120.25$ (kW)

2.5.3 Heat load of inrush air

From Equation 5 , $Q_3 = 65N\% \times 24.3 = 94.77$ kW

2.5.4 Additional heat load due to building height

$Q_4 = 83.77$ kW

2.5.5 Total heat load

The total heat load of building is given as:

$Q_{total} = Q_1 + Q_t + Q_3 + Q_4 = 642.37$ kW

3 .CONCLUSIONS

Table 19 shows the comparision of building calculation with and without insulation by China and Iceland codes.

TABLE 19: Comparision of heat load calculation for sample building

Heat load for sample building (kW)	Without insulation		With insulation	
	China codes	Iceland codes	China codes	Iceland codes
	1010.43	1001.78	642.37	456.49

Thermal insulation is one of the most effective energy-conservation measures in buildings. According to comparison of heat load calculations, the following conclusions for a sample building in Tianjin are obtained.

1) Heat load is calculated by Icelandic and Chinese building codes, and the results are similar.
2) The results of heat load calculations indicate that thermal insulation is an effective way to reduce energy consumption. Heat load decreases 36.4% when insulation is added to the building envelope.
3) When the thermal insulation property is improved to Icelandic standard, the heat load decreases to 54.8%. This is a better way to improve the thermal insulation property of the building envelope for energy saving.

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