The Effective & Ineffective Heat Loss by Infiltration --- Field Measurement in a Domitory

Guo Jun, Liu Ming Sheng
Harbin Architectural & Civil Engineering Institute
Harbin, China

1. Introduction

It has been argued for a long time in China if the air leakage could be reduced for saving the energy. Some people said "no", because they considered that the reduction of air leakage would worsen the indoor air quality, as has occured in "sick" buildings in Europe. But our field test shows that as a matter of fact, in some buildings, far from making any benefit for occupants, a large part of air leakage has decreased the room temperature. Obviously these "ineffective" part can be reduced without any harm done. Usually when we talk about the reduction of air leakage, we mean that it consume too much energy and greatly influences the room temperature, but we didn't carefully discuss how to reduce it. If we reduce the air change rate in a room, the fresh air could be felt inadequate. But if we discuss the air leakage in a whole building, we could find that a large quantity of air only flows through the outdoors, staircases, and some cracks or other openings in the building envelopes, consuming a lot of energy but being no use to the occupants, so it may be called ineffective air leakage and should be eliminated without any harmful effect. On the other hand, leaked air which flows through rooms and benefits the occupants may be called effective one and will not be cut. In fact, the energy consumed by effective part is not very much in the practice of Chinese design and maintenance,

A serie of measurements has been made on a four story building to get the correct results.

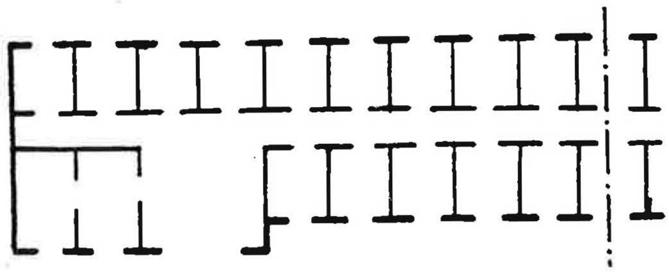

Fig. 1

2. An Overview of the Test

2.1 The measured building

It is a four-story building with the plan shown in Fig. 1, its height, width and length are 13.2, 16 and 92 meters respectively. Two entrance doors are located at opposite sides of the façade. On the top of the staircases two doors lead to the roof. Besides, two windows of 720*620 and 100*50 mm are on the upper wall of the right and left staircases respectively. All the openings (including windows, entrance doors, and balcony doors) makes up 26 % of the exterior walls. The building is located in an urban neighborhood as shown in Fig. 2.

2.2 Determination of air change rate in rooms

The air change rate in rooms is calculated with the measured value of the differential pressure distribution across the exterior envelopes, the air leakage performances, of windows and doors and vents air flow rate in rooms.

Wind directions range

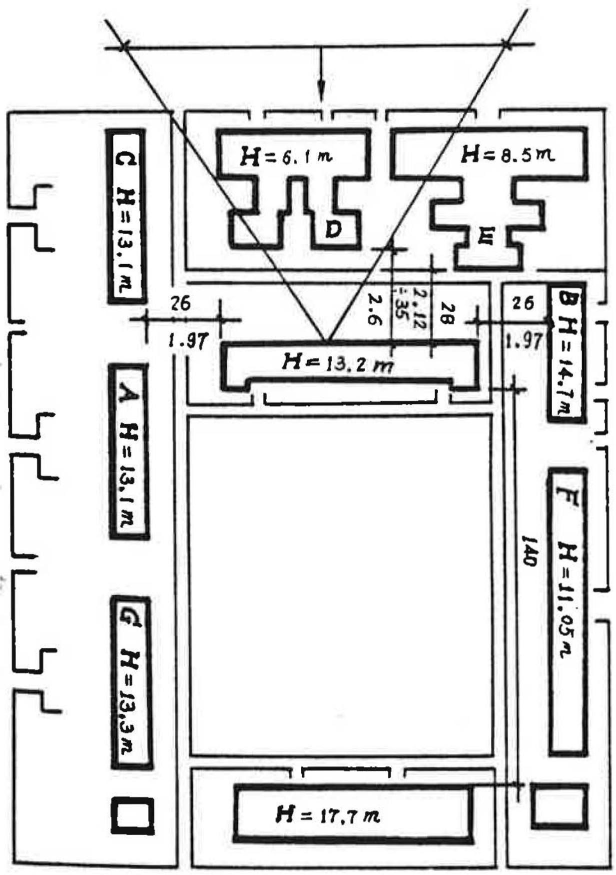

Fig. 2

Twelve test points were arranged along the perimeters on the ground and top stories respectively, and eight points along the vertical center line on façade and back wall. The differential pressure distributions were measured at different weather conditions, and an empirical formula has been regressed. (1)

The leakage performances of windows, doors, and vents were measured with tracer gas in site. (2)

Thus, the air change rate for any rooms, under any weather conditions can be determined on the basis of date mentioned above.

2.3 Leakage through other openings

For determination of air leakage through other openings such as doors etc, where the air speed is relatively high, thermal anemometers were used.

The rooms, corridors and outdoor air temperature were measured with thermocouples and recorded once per hour by an acquisition system. An anemometer (EL MODLE) was set up on the parapet wall to record the wind speed and direction continuously. The heat supply to the building were measured with two calorimeters at the entrance of heating system.

3. Exprimental Results

3.1 Pressure distribution

On the basis of the experimental results, the following pressure distribution equation has been regressed. (1)

$$PD=DD<1.128-.0214*V^{.4}(D^{1.9}-D+1)-5.842(2H-1.111)>$$

Where :

PD ---- pressure difference (mmH20).
DD ---- density difference between the room and outdoor air (Kg/M^3).
V ---- wind speed over the roof (m/s).
D ---- wind orientation (defined as 1--9 for 8 directions)

3.2 The leakage performances

According to different directions of leaking air and different solar radiations, it was found that the windows at different locations of the building have very different performances in leakage and should be divided into three groups :

(I) Windows at the lower half of the building where infiltration mainly took place and no freezing formed in the gaps;

(II) Windows at upper half of the building with north orientation where exfiltration took main effect but their gaps were frozen tightly;

(III) Windows at upper half of the building with south orientation where air also exfiltreted mainly but their gaps were melted in the daytime and frozen at night.

The experimental results are as following :

For window :

Q	=	2.567+22.678*PD	(I)
Q	=	1.0895+19.454*PD	(II)
Q	=	5.339+55.885*PD	(III)

Where :

Q ----air leakage per unit area (M^3/M^2).
PD----pressure difference (mmH20)

and for door :

LV=7+59.76*PD

Where :

LV----air leakage per unit gap length (M^3/M.h.)

The air change through vents in the rooms is about 24 % of that through windows.

3.3 The air leakage in the building

The experimental data are listed in table 1. The air leakage through the windows is calculated according to their air leakage performances and pressure distributions around the building.

Table 1 : Summary of the air leakage measurements

Time	Infiltration (M^3/h)			Exfiltration (M^3/h)				Gex
	Door	Window	Gin	Opening	Window	Vent	Gex	Gin
14 Feb.								
0:00	11664	5165	16829	12209	2627	1846	16682	0.99
4:00	11046	5462	16508	10320	2857	1887	15064	0.91
8:00	17392	5381	22729	10277	2880	1974	15131	0.66
15 Feb.								
8:00	9976	5435	15411	7270	2794	1975	12039	0.78
12:00	10957	4302	15259	6148	1951	1501	9600	0.63
16:00	9574	4424	13998	13059	1668	1462	16189	1.16
Average	11768	5029	16797	9881	2463	1774	14118	0.84
%	70	30	100	70	17	13	100	

The results show that the infiltration through entrance doors makes up approximately 70 % of the total air leaked in, and rest came in through the windows. The exfiltration through upper openings is about 70 % of the total air leakage. The ineffective air change is considered as the quantity of air which just came in through the doors and went out through upper openings, having not passed through any rooms and so being no use to the occupants. Considering the air exfiltrated through the upper openings wa s a mixture of the fresh air through the entrance doors and the breathed air from the rooms of lower half of the building, the ineffective part took not 70 %, but 53 % of the energy consumed for air change. Fig. 3 shows the air movement distribution in the building.

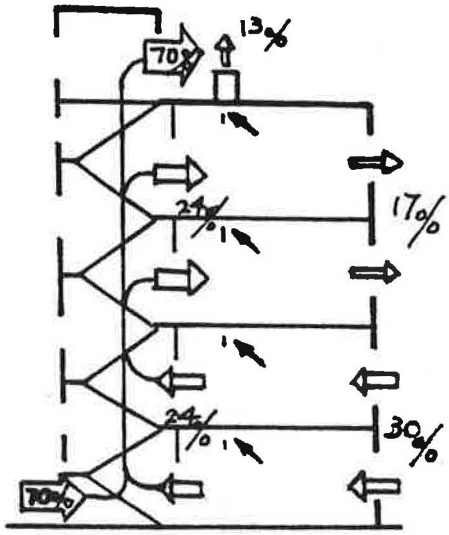

Fig. 3

4. Conclusion

The heat consumption by effective and ineffective air leakage has been calculated for the whole period, table 2 and 3 show the calculated results for January. From the calculated results we can come to the following conclusion :

Table 2. Air leakage calculation (Jan.)

Time	Infilt. (M^3/h)		Exfiltration (M^3/h)			Fresh air		Room air change rate
	Window	Door	Window	Vent	Up.Ho	Room	Corr	
1- 7	5843	11542	2983	2118	12284	8515	8871	0.84
8-14	5662	9972	2664	1999	10971	7970	7664	0.79
15-21	5922	12026	3084	2161	12702	8705	9243	0.86
22-28	5902	12532	3176	2179	13087	8803	9632	0.87

Table 3. Heat consumption by the air leakage

Time	Effective (Kcal/h)				Ineffective		%	Tw
	Q1	Q2	Q3	%	Q4	%		
1- 7	29183	23985	-10976	23.3	37970	21	44.3	-20
8-14	25735	19138	-9922	17.8	27532	14	31.8	-18
15-21	28511	24036	-9136	23.9	43314	23.8	47.7	-21
22-28	28755	25347	-9764	20.2	44471	20.3	40.5	-22

Note : Q1---heat loss of the window leakage; Q2---heat loss of the air which flew in through the entrance doors and then flew in rooms; Q3---heat loss of the air which flew in the staircases from the room; Q4---heat loss of the air leakage through upper openings.

(1) The ineffective air leakage is about half of the total air leakage. It is necessary to put it to an end or at least reduce it to the minimum.

(2) The average fresh air change rate in rooms is about 0.68 1/h. The air quality of the upper half or the building is worse than the lower half.

(3) It is entirely possible and valuable to reduce the energy consumption of air leakage in buildings by eliminating ineffective part without any reduction of comfortableness of occupants.

5. References

(1) Guo Jun, Liu Ming Sheng. The analysis and measurement of pressure distribution for multistory building. Journal of Harbin Architectural & Civil Engineering Institute, 4, 1986.

(2) Liu Ming Sheng. The measurement of the air leakage performance for windows and doors in site. Chinese Heating, Ventilation, and Air Conditioning Annuel Meeting Proceedings, 10, 1986.