ENERGY CONSUMPTION AND WALL OPENINGS IN COMMERCIAL BUILDINGS

Juan C. Klainsek
Depto. de Construcción y Tecnología Arquitectónicas
E.T.S.Arquitectura-Universidad Politécnica de Madrid
Av. Juan de Herrera, 4 - 28040 Madrid
Spain

ABSTRACT. A proper building design can reduce the amount of operational energy required and windows have an important role in this process, since they allow -if properly designed-, to make use of solar radiation as much and long as possible, and to provide efficient insulation. Due to the fact that non-residential buildings have large glass areas, an office building has been chosen to carry out the analysis.Two different window elements have been considered: a) shape:continuous horizontal window and discontinuous vertical window, both having the same surface; b) type: colorless, bronze colored and reflectant, each of them for insulating glass with different gap thickness, and for single glass. The results of this analysis show the building energy consumptions in summer and winter,to be considered when designing a building.

INTRODUCTION.

An important percentage of the energy produced from processing fossil and fissile fuels is consumed by heating, cooling and illuminating the buildings; this consumption can be considerably reduced if building technology and conditioning techniques complement each other. With regard to this, the choice of both the shape and type of the wall openings is an important decision at the initial design stage of the building. As in non-residential buildings the wall openings influence greatly the lighting, cooling and heating loads, the shape and type of glass areas in an office building have been studied in this paper.

The Weighting Factor Method has been used. This method, which was first introduced by Mitalas and Stephenson, accounts for the important parameters that affect the energy flow of the building. It allows space heat gains at constant space temperature to be determined from a physical description of the building, the ambient weather conditions and internal load profiles. A computer program has been developed

S. Alvarez et al. (eds.), Architecture and Urban Space, 679–684.

to simulate this office building energy needs in a climate region: Madrid.

The purpose of this paper is to study the incidence that certain shapes and types of glass can have on the energy performance of a commercial building.

Base case building.

An office building with 10 floors, located in Madrid: 40m x 26m floor; 37m height, which corresponds to a gross surface per floor of 1036 m^2, useful conditioned of 795 m^2.This building has the most disadvantageous situation, that is, the largest façades face towards the east and west.

The winter season includes the months from November to March, the rest months being included in the summer season.

A constant interior temperature of 20 ºC and RH 50% in winter, 25 ºC and RH 55% in summer is assumed in the calculations; the exterior temperature is variable, so the estimations are carried out hourly.

With regard to the exterior conditions, meteorological variables are generated hourly from reliable meteorological data, and an auxiliary program is used.

The heat transmission coefficients K (U-value) of opaque surfaces are: -horizontal- roof Kr=0.43 W/m^2 K, light color; floor levels above open space Kf=0.66 W/ m^2 K.-Vertical traditional wall composed of seven layers, total thickness 23.5cm, insulating material 4cm, 244.6 kg/m^2 and Kw=0.61 W/m^2 K, and four layer curtain-wall, total thickness 5.3cm, insulating material 5cm thick, 89.6 kg/m^2 and Kw=0.42 W/m^2 K both medium color. Metallic windows with different sorts of glass, which are studied in this paper will be described.

Glass areas will not have any shading devices, except those shadows produced by setback.

Results from the energy consumption calculations are obtained per useful or net surface unit, taking into account that the free height in all floors is 2.80m.

Internal loads are fixed by: occupation 55 pers./floor, equivalent approximately to 14 m^2/pers.; ventilation 2000 m^3/h floor, that is 2.5 $m^3/h\ m^2$; and illumination 7.95 kW/floor or rather 10 W/m^2.

Glass areas.

The glassing used in this paper has the following characteristics: colorless, bronze colored-filtering and reflectant, each of them single 6mm with Kg (U-value) of 5.8 W/m^2 K; insulating 6+6mm, gap of 6mm, Kg=4.0 W/m^2 K; and insulating 6+6mm, gap of 12mm, Kg=3.7 W/m^2 K. Each of this glassing is affected by its corresponding corrective coefficient of the solar gain factor (c.c.), which varies from 0.48, for the reflectant insulating, to 0.94 for the single colorless.

ANALYSIS OF RESULTS.

For the base case building with windows of 1.30m height, all round the building perimeter and using the glassing above, the energy consumptions (e.c.) per conditioned surface in summer and winter are calculated. Later, the glass shapes are transformed from horizontal continuous (h.c.) to vertical discontinuous (v.d.), with the same façade surface than the previous ones and the e.c. are calculated. To carry out the change,the glassing height is 2.10m from floor to lintel

In all the cases considered the traditional wall and curtain-wall have been used.

In the first group, Table 1-Fig. 1, for summer and with traditional wall, the values obtained are analysed. The e.c. per conditioned useful surface unit (kWh/year m^2), are represented on the diagram ordinate axis, as a result of the three different types of glassing (colorless, bronze colored filtering and reflectant), and of their corresponding glassing shape transformations.

In Table 1 (T1), it is shown that the e.c. differences between h.c. windows and v.d. windows, with the same surface (Δec_1), for the three types of glassing,change from 0.39% to 0.75%. The h.c. ones have always the least e.c.

For h.c. ones and with regard to the single glass, for each type of glassing (Δec_2), the least variation occurs between the reflectant single glass (s.g.) and the reflectant insulating glass (i.g.) with a gap of 6mm (-7.34%); and the greatest variation between the colorless s.g. and the colorless i.g., gap=12mm, (-9.25%).

Still for h.c. ones and with regard to the colorless glass, for bronze colored glass and for each glass constitution -s.g. and i.g., gap=6/12mm-, (Δec_3), the s.g. shows the least variation (-8.54%), and the i.g. gap=6mm the highest (-12.41%).

The colorless and reflectant glass (Δec_4) are analysed in the same way; the least variation corresponds to the i.g. gap=12mm (-14.34%), and the greatest to the s.g. (-15.81%).

Approach to values shown in Tables T2, T3, T4 are made in a similar way.

CONCLUSIONS.

It would be necessary to discuss the different types of fuel, conditioning systems -together with their operation and maintenance-, and ways of using the buildings, so that a technical economic evaluation could be finally carried out. This has not been made in this paper, so the following conclusions are given separately for summer and winter.

With regard to the glass shapes, the vertical discontinuous window has an e.c. greater than the horizontal continuous window, except in winter with curtain-wall and for all kinds of colorless glass studied, when no difference is noticed. Thus, an important factor to take into account is the glass setback in relation to the wall exterior surface. As a result, the differences of the values obtained are not of great significance.

As for the types of glassing and for horizontal continuous windows, the least e.c. in summer, for both traditional wall and curtain-wall (22.76/23.76 kWh/year m^2) is given by the reflectant i.g., gap=12mm.

In winter, with the same sort of walls (16.22/14.83 kWh/year m^2) the lowest e.c. corresponds to the colorless, also i.g., gap=12mm.

Considering the geographical location and the typology of the building studied, and having obtained more significant e.c. in summer, the reflectant insulating glass should be adopted.

NOMENCLATURE.

c.c.: corrective coefficient of solar factor gain. Glassing without blind or shading
e.c.: energy consumption
h.c.: horizontal continuous windows
i.g.: insulating glass
s.g.: single glass
v.d.: vertical discontinuous windows

REFERENCES.

ASHRAE Handbook 1989 Fundamentals. SI Edition. American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta, Georgia.

Bennett, J.R. et al. (1988). "A Study of the Thermal Characteristics and Potential for Energy Conservation at Four London Office Buildings". Building and Environment. Vol. 20, Nº 2, pp. 83-94.

Klainsek, J. (1988). "Energy Saving in Office Building Design and Retrofitting". Energy and Buildings for Temperate Climates. Plea 88. Pergamon Press, pp. 173-178.

McKinley, A.D., and Mitalas, G.P. (1983). "Room Thermal Transfer Functions, Computer Programs to Calculate Z-Transfer Function Coefficients for Rooms". National Research Council of Canada, pp. 1-3.

Selkowitz, S. (1986). "Smart Windows". Glass Magazine. Windows and Daylighting Group, Lawrence Berkeley Laboratory, University of California, pp. 86-91.

Sullivan, D. (1987). "The Influence of Glazing Selection on Commercial Building Energy Performance in Hot and Humid Countries". Lawrence Berkeley Laboratory Report, BS-247.

TABLE 1. Energy Consumptions in Summer-Traditional Wall

Type glass	s.g.			i.g. gap=6mm			i.g. gap=12mm		
	Cont.	Disc.	Δec1	Cont.	Disc.	Δec1	Cont.	Disc.	Δec
Cless	29.28	29.50	+0.75	26.67	26.84	+0.64	26.57	26.74	+0.
Δec2				-8.91			-9.25		
Bron.	26.78	26.94	+0.60	23.36	23.47	+0.47	23.28	23.38	+0.
Δec2				-12.77			-13.07		
Refl.	24.65	24.77	+0.49	22.84	22.94	+0.44	22.76	22.85	+0.
Δec2				-7.34			-7.67		
Δec3	-8.54			-12.41			-12.38		
Δec4	-15.81			-14.36			-14.34		

TABLE 2. Energy Consumptions in Winter-Traditional Wall

Type glass	s.g.			i.g. gap=6mm			i.g. gap=12mm		
	Cont.	Disc.	Δec1	Cont.	Disc.	Δec1	Cont.	Disc.	Δec
Cless	22.48	22.54	+0.27	17.22	17.26	+0.23	16.22	16.26	+0.
Δec2				-23.40			-27.85		
Bron.	23.79	23.85	+0.25	18.85	18.89	+0.21	17.82	17.86	+0.
Δec2				-20.76			-25.09		
Refl.	24.98	25.03	+0.20	19.10	19.14	+0.21	18.06	18.10	+0.
Δec2				-23.54			-27.70		
Δec3	+5.83			+9.47			+9.86		
Δec4	+11.12			+10.92			+11.34		

TABLE 3. Energy Consumptions in Summer-Curtain-Wall

Type glass	s.g.			i.g. gap=6mm			i.g. gap=12mm		
	Cont.	Disc.	Δec1	Cont.	Disc.	Δec1	Cont.	Disc.	Δec
Cless	30.81	30.93	+0.39	28.04	28.13	+0.32	27.95	28.04	+0.
Δec2				-8.99			-9.28		
Bron.	28.05	28.13	+0.28	24.41	24.46	+0.20	24.33	24.38	+0.
Δec2				-12.98			-13.26		
Refl.	25.71	25.77	+0.23	23.84	23.89	+0.21	23.76	23.81	+0.
Δec2				-7.27			-7.58		
Δec3	-8.96			-12.96			-12.95		
Δec4	-16.55			-14.98			-14.99		

TABLE 4. Energy Consumptions in Winter-Curtain-Wall

Type glass	s.g.			i.g. gap=6mm			i.g. gap=12mm		
	Cont.	Disc.	Δec1	Cont.	Disc.	Δec1	Cont.	Disc.	Δec
Cless	20.93	20.93	+0.00	15.79	15.79	+0.00	14.83	14.83	+0.
Δec2				-24.55			-29.14		
Bron.	22.19	22.20	+0.04	17.35	17.36	+0.06	16.35	16.36	+0.
Δec2				-21.81			-26.32		
Refl.	22.36	22.38	+0.09	17.59	17.60	+0.06	16.58	16.59	+0.
Δec2				-21.33			-25.85		
Δec3	+6.02			+9.88			+10.25		
Δec4	+6.83			+11.40			+11.80		

Δec1: betyeen continuous w. and discontinuous w. [%]
Δec2: among continuous w. always with relation to s.g. [%
Δec3: colorless-bronze colored glass [%]
Δec4: colorless-reflectant glass [%]

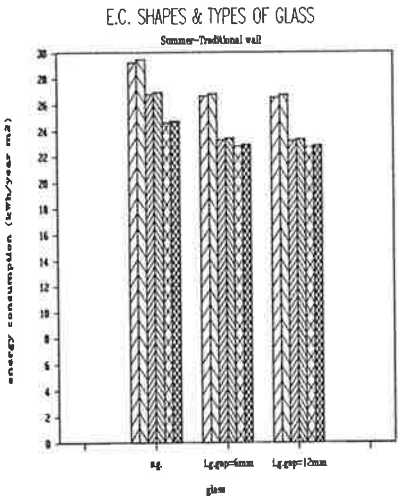

Fig.1

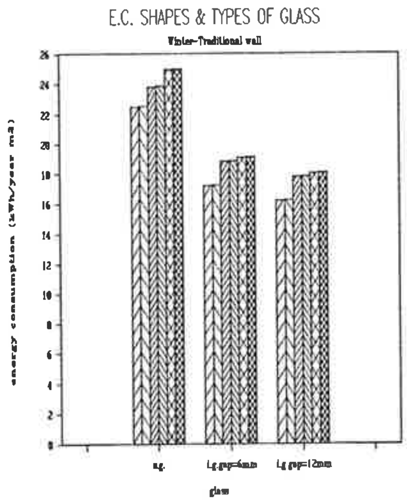

Fig.2

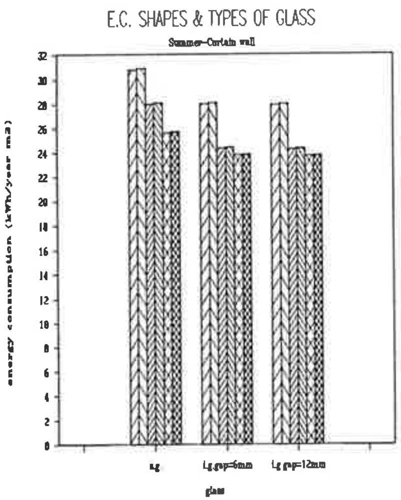

Fig.3

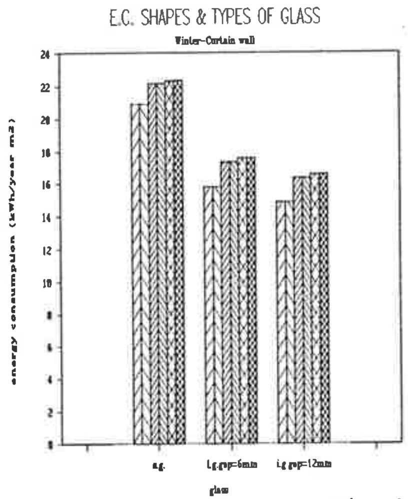

Fig.4

h.c. window; colorless glass
v.d. window; colorless glass
h.c. window; bronze colored glass
v.d. window; bronze colored glass
h.c. window; reflectant glass
v.d. window; reflectant glass