

Evaluation of Double Skin Glass Facades in terms of Cost Efficiency with respect to Energy Consumption

Ikbal Cetiner, MSc., Research Assistant¹
Murat Aygun, PhD., Assoc. Prof.²

¹ Istanbul Technical University. I.T.U. Faculty of Architecture. Taskisla. 80191 Taksim. Turkey. Phone: +90 212 293 13 00. Fax: +90 212 251 48 95. E-mail: ikbal@arch.itu.edu.tr

² Istanbul Technical University. I.T.U. Faculty of Architecture. Taskisla. 80191 Taksim. Turkey. Phone: +90 212 293 13 00. Fax: +90 212 251 48 95. E-mail: aygunmur@itu.edu.tr

1. INTRODUCTION

Today as a result of gradual depletion of natural energy sources and rising CO₂ emissions due to excessive fuel consumption, the subjects related to energy demand and environmental consciousness are being considered intensively in facade design. On this account an approach becomes necessary that takes into consideration climatic design, energy efficiency and sustainability concepts. With this approach building facades acquire an intelligent skin. Battle, G. and McCarthy, C. pointed out that the skin can perform the function of balancing between internal and external climate by regulating energy flow, collecting and storing energy, distributing the energy where required (Boyd 1994). Briefly, an intelligent skin should serve to decrease energy consumption and support mechanical systems in achieving optimum comfort conditions. Double skin glass facade is one of the intelligent skins designed for performing these functions by using natural energy resources, i.e. wind and sun.

Double skin glass facades are composed of two glass panes and a cavity inbetween. The width of this cavity ranges between 200-1500 mm. Heat losses are minimum through the facade. Sometimes solar control devices are installed into the cavity to prevent solar gain. Daylight can easily be obtained in deep spaces. Such a facade allows to open windows, even on high buildings, so the ventilation provided by fresh air results in decreasing running cost and energy consumption of the air conditioning system (Evans 1997). Consequently, the amount of energy needed for heating, cooling and lighting can significantly be reduced. Also from the viewpoint of the building owner the investment made for the facade is expected to be economical. For this reason, this paper aims to evaluate double skin glass façade in terms of cost efficiency with respect to energy consumption. In the result of this evaluation where the total life cycle costs of different skin configurations are compared the most efficient configuration can be selected.

2. METHOD

For the evaluation, a simulation is done for the double skin glass façade of an office building assumed to be in Istanbul. The energy consumption for each skin configuration is first computed with WIS and ENER-WIN simulation programs. And then to investigate their cost efficiency Life Cycle Cost (LCC) analysis is used, which is one of the techniques used in evaluating energy conservation investments by taking into account the initial cost, savings in use and change in the monetary value over time. The WIS program has been developed by the teams cooperating in the European research project 'Advanced Windows Information System' (the project WIS), under the coordination of TNO Building and Construction Research, with financial support from the European Commission (DGXII) (Dijk 1996). The ENER-WIN

program (Energy Calculations – Windows version) has been developed by Texas A&M University, with financial support from the DOE (Degelman 1999). In this paper, WIS is used for computing the heat transmission coefficient (U value) and total solar energy transmittance (g value) of skin configurations. These values become the inputs of the ENER-WIN program for estimating their energy loads. After the energy costs are calculated using energy load values obtained by the simulation, the total life cycle costs as the sum of the energy costs and construction costs are calculated. Consequently, the configuration with the lowest total life cycle cost is selected as the most cost efficient alternative.

3. SIMULATION

The simulation is done for a 30 storey office building in Istanbul. It is assumed that building is enclosed on all facades by a double skin glass façade with a 900mm. cavity. The external and internal skin are structural silicone and transparent, respectively. This building is simulated following the steps described below.

3.1. Arranging the Data

The data needed for computing the U and g values of the alternatives are seen on the Table 1. These belong to transparent components, frame and spacer. Clear glass and low emissivity (low-E) glass are selected for the simulation because of their frequent usage in double skin facades. The values related to the glass in this table are provided by a firm producing building glass in Turkey. The others have been selected from the library of the program, which are the standard values stipulated by CEN (European Committee for Standardisation).

Table 1 Data for computing U and g values.

ENVIRONMENTAL DATA			
Temperature	Outdoor	10°C	
	Indoor	20°C	
TRANSPARENT SYSTEM			
Pane Type		Clear Glass	Low-E Glass
Thickness		6mm.	6mm.
Emissivity	Outdoor	0.840	0.100
	Indoor	0.840	0.840
Solar reflectance	Outdoor	0.070	0.218
	Indoor	0.070	0.144
Visual reflectance	Outdoor	0.080	0.041
	Indoor	0.080	0.055
Solar Transmittance		0.770	0.574
Visual Transmittance		0.880	0.825
The width of the cavity		900 mm.	
Gas form in the cavity		Air	
Solar Shading Device		Venetian blind	
FRAME and SPACER			
Frame type		Metal with 16 mm. thermal break	
Spacer type		Aluminium spacer	

The data needed to run the ENER-WIN program is composed of weather data and the data for the description of the sample building. Weather variables used by the program are latitude, longitude, standard time meridian and elevation, the monthly average of dry bulb temperatures, dew point temperatures, horizontal solar radiation, wind speed and daily maximum temperatures, and standard deviations of these monthly average values. The other data needed to compute the heat gain/losses resulting from the façade are in Table 2.

Table 2 Data for computing heat gain/losses.

BUILDING PROPERTIES		* WINDOW PROPERTIES	
Building Type	Office	Heat transmission coefficient (U value)	
Building Size	36m x 36m	Total solar energy transmittance (g)	
Number of Floors	30	Emissivity	
Ceiling Height	3.30 m.	Daylight Transmissivity	
Total Facade Area	13896 m ²	* The values related to window properties are the outputs of WIS program.	
Total Floor Area	38880 m ²		
Exterior Shading	No	HVAC SYSTEM	
Surface Exposure	Concrete	Air Conditioning System	Fan coil units
Natural Ventilation	Yes	Heating System	Gas
Seasonal Indicator	Summer	Infiltration Rate	0.4 ach**
	Winter	** ach: Air changes per hour	

3.2. Forming Skin Alternatives

In the forming of the skin alternatives (See Table 3), the following variables are taken into consideration:

- The positions of the clear and low-E glass,
- The positions of single and double glass,
- Whether or not the façade has venetian blinds.

3.3. Computing and Evaluating U and g Values of the Alternatives

The U and g values of the double skin configurations formed according to the type and position of the material and the usage of solar shading device are computed by WIS program. The results in Table 3 reveal that the U and g values of the configurations with the venetian blinds are lower than those without. In the case of using the low-E glass on the external skin, there is a noticeable decrease in the U value. It is also possible to say that the best configuration is formed with the use of the low-E glass both on external and internal skin because of the lowest U and g values.

3.4. Computing and Evaluating Annual Energy Loads of the Alternatives

The monthly heating and cooling loads of the skin configurations are first computed with ENER-WIN program depending on the variation of their U and g values. Then the annual energy consumption per square meter of floor area for the alternatives is calculated. It can easily be seen on Table 3 that the best configuration in terms of energy consumption is formed with the use of the low-E glass both on external and internal skins. It is also possible to say that the position of the low-E glass does not significantly affect annual energy consumption.

3.5. Determining the Construction Costs and Life Cycle Energy Costs of the Alternatives

The unit area of any component forming the skin is multiplied by its cost per unit to determine the construction costs of the alternatives. These components are external glass panel, internal glass panel, cat way, solar shading device, structural frame, opaque panel with heat insulation, sound insulation and fire insulation. The unit costs of the components include the material, production and assembly costs. These values are the average of the unit costs taken from three firms constructing curtain walls in Turkey, The construction costs calculated for all the alternatives are shown in Table 3.

The life cycle energy costs are calculated depending on energy consumption, energy unit costs and change in the monetary value over time. In the calculations the life cycle period

assumed for the façade is 30 years. Using discount rate and time, the future energy costs are equated to the present. On Table 3, these values are viewed.

Table 3 WIS and ENER-WIN simulation results for the double skin glass façade alternatives. Single Glass (SG), Double Glass (DG), Clear Glass (CG), Low-E Glass (LEG). Heat Transmission Coefficient (U), Total Solar Energy Transmittance (g). Annual Energy Consumption (AEC). Life Cycle Energy Costs (LCEC), Construction Cost (CC), Total Life Cycle Cost (TLCC).

No	External Skin	Air Gap (mm)	Internal Skin	U (W/m ² K)	g Factor	AEC (kWh/m ²)	LCEC \$ (million)	CC \$ (million)	TLCC \$ (million)
1.1	SG – CG	N0	SG – CG	2.90	0.55	128.27	0.56	2.75	3.31
1.2	SG – CG	YES	SG – CG	2.64	0.22	124.93	0.49	3.47	3.95
2.1	SG – CG	N0	DG – CG	2.21	0.47	107.72	0.47	3.04	3.50
2.2	SG – CG	YES	DG – CG	2.09	0.17	110.03	0.41	3.76	4.17
3.1	SG – CG	N0	DG – LEG	1.93	0.39	98.44	0.38	3.14	3.52
3.2	SG – CG	YES	DG – LEG	1.86	0.14	102.59	0.36	3.86	4.22
4.1	DG – CG	N0	SG – CG	2.20	0.47	107.05	0.46	3.00	3.46
4.2	DG – CG	YES	SG – CG	2.09	0.27	107.26	0.43	3.72	4.15
5.1	DG – LEG	N0	SG – CG	1.82	0.38	94.47	0.37	3.13	3.50
5.2	DG – LEG	YES	SG – CG	2.02	0.25	105.73	0.40	3.85	4.25
6.1	DG – CG	N0	DG – CG	1.86	0.42	95.25	0.39	3.29	3.69
6.2	DG – CG	YES	DG – CG	1.79	0.22	97.10	0.36	4.01	4.37
7.1	DG – CG	N0	DG – LEG	1.70	0.35	90.86	0.34	3.39	3.74
7.2	DG – CG	YES	DG – LEG	1.66	0.18	92.86	0.32	4.11	4.44
8.1	DG – LEG	N0	DG – CG	1.62	0.34	87.99	0.33	3.38	3.71
8.2	DG – LEG	YES	DG – CG	1.76	0.21	96.63	0.35	4.10	4.44
9.1	DG – LEG	N0	DG – LEG	1.50	0.30	84.23	0.30	3.48	3.79
9.2	DG – LEG	YES	DG – LEG	1.61	0.17	91.54	0.32	4.20	4.52

3.6. Calculating and Evaluating the Total Life Cycle Costs of the Alternatives

The total life cycle cost is defined as the sum both of construction cost and the life cycle energy cost that are determined depending on energy loads, energy unit costs and change in the monetary value over time. Maintenance costs are not added to the total cost because there is no available accurate data about the life cycle period of these facades.

As it is clearly seen in Table 3, the construction costs are about 83 - 92% of the total life cycle costs. Using the venetian blind also increases the construction costs by about 15-20%. In addition, the use of low-E glass on both skins instead of clear glass increases the total cost by 2.71 % while it decreases the life cycle energy costs at the rate of 2.65 %.

3.7. Evaluating the Cost Efficiencies of the Alternatives with respect to their Energy Efficiencies

For this evaluation the energy and cost efficiency of all the alternatives are determined by comparing to the alternative with the lowest energy consumption or total life cycle cost. These values are arranged in Figure 1 according to their efficiency percentage. As it is seen the most energy efficient alternative does not have the lowest total life cycle cost. For instance, although the Number 9.1 which is formed with double low-E glass of both skins is

52.29% more energy efficient compared to the Number 1.1 that has the highest energy consumption, it is 17.17% less cost efficient compared to the same alternative. The most cost efficient alternative is the one (Number 1.1) that is formed with single clear glass on both skins. This is, however, the least efficient alternative in terms of energy efficiency. In addition, the cost efficiency of the alternatives with blinds is lower than those without because of an increase in the initial investment cost.

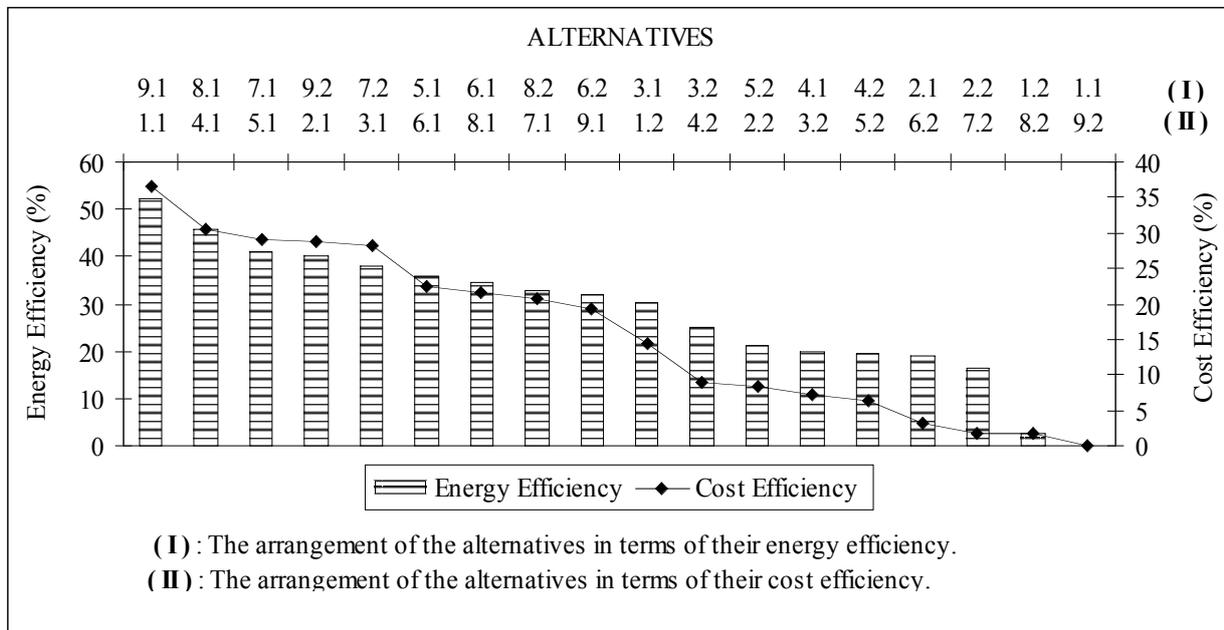


Figure 1 Arranging the alternatives in a row in terms of their energy and cost efficiencies.

4. CONCLUSION

This paper aims to evaluate the double skin facade alternatives formed with different configurations of the skin components in terms of cost efficiency with respect to energy consumption. As a result of this investigation, the configurations formed with double low-E glass are determined as the most energy efficient alternatives, but their total life cycle costs are higher when compared to the configurations formed with single clear glass because of high construction costs. The decision depends on the economic investment from the viewpoint of the building owner and also on conservation of natural energy sources. This subject can be investigated further in future studies. Thus, the determination of the most efficient alternative will be possible.

5. REFERENCES

- Boyd, D. 1994. Intelligent Buildings. University of Central England. Alfred Waller Limited. pp.137.
- Evans, B. May 1997. Through the glass cylinder. *The Architect's Journal*. V:205. No: 19. pp.42-45.
- Van Dijk, D., Goulding, J. October 1996. WIS Reference Manual. TNO Building and Construction Research. Delft. Netherlands.
- Degelman, L.O. (1999). ENER-WIN User's Manual. Texas A&M University. Texas. USA.