RELATION BETWEEN BUILDING ENVELOPE U-VALUE AND BUILDING FORM

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ABSTRACT

This study aims to introduce a methodology which enables to revise the limit values of overall heat transfer coefficient in accordance with the building form from thermal comfort and energy conservation point of view.

In order to prevent excess heat loss, building should be designed as passive heating system. Overall heat transfer coefficient (U-value) of building envelope and building form can be considered as the most important parameters of the passive heating system. Therefore, U-value of building envelope should be determined depending on building form. Building form can be defined basing on the shape factor (the ratio building length to building depth), height and roof type. It is possible to determine a lot of building forms which yields same volume, but different facade area. Therefore, the ratio of building volume to total facade area (V/A) is the best indicator describing the building form. Thus, U-value of building envelope should be determined in accordance with the ratio of V/A.

In this study a methodology which aims to determine the limit values of building envelope U-value in accordance with the ratio of V/A is introduced.

INTRODUCTION

One of the primary functions of a building is to provide the climatic comfort conditions. Provision of the climatic comfort conditions in certain periods of the year can be achieved through mechanical heating and climatisation systems that are being actived by various energy resources. In order to prevent excess heat loss for energy conservation, buildings should be designed as passive heating and climatisation systems. As the most important component of the passive heating and climatisation systems, external walls have to be mentioned. As the building form is one of the most important components with respect to total heat loss of whole building, it has been taken into consideration in detail. In this study building form is represented by the ratio of building volume to total facade area (V/A). The introduced methodology aims to determine the limit values of building envelope overall heat transfer coefficient in accordance with the ratio of V/A and other design parameters affecting indoor climate. As is known the most important design parameters affecting indoor climate and energy consumption in building scale are: orientation , building form and physical properties of building envelope. All of these parameters are related to each other. Therefore, the optimum values of each parameter should be determined depending on the values of each other. In Turkey, the existent building regulation for energy conservation gives the limit values of overall heat transfer coefficient of building envelope (U-value) independently from orientation and building form [1],[2]. This paper introduces a research project to determine the limit U-values in accordance to orientation and building form.

METHODOLOGY

The proposed methodology aims to predict a revision coefficient to be applied to the limit U-values which are determined in accordance with transparency ratio (the ratio of window area to total facade area), type of transparent component and orientation. Thus, the limit U-values will be revised in order to take the effect of building form, which is the one of the most important design parameters affecting total heat loss through the building envelope. The proposed methodology covers the following main steps [3].

1. Calculation of the Limit U-Values for reference V/A ratio

The limit U-values can be calculated depending on the type of transparent component and transparency ratio following the steps given below [4]:

- Selection of the design day
- Predicting the outdoor and indoor design conditions
- Selection of the values of the other design parameters affecting indoor climate
- Calculation of the solar temperatures affecting opaque and transparent surface of the envelope
- Determination of the limit U-values which is calculated basing on the comfort values of inner surface temperatures as follows:

$$U_o = \alpha_i (t_i - t_{oio}) (t_i - t_{eoo}) \quad (1)$$

where U_o is the limit value of overall heat transfer coefficient for opaque components of building envelope providing thermally comfortable indoor environment ($W/m^2{}^\circ C$, $kcal/m^2h^\circ C$) , t_{oio} is the limit value for inner surface temperatures of opaque components, which is determined by thermal comfort requirements (°C), and $t_{eoo}$is the daily average sol-air temperature affecting opaque facade surfaces on the selected design day (°C).

Figure 1.a and 1.b are given as a sample to show the variation of U_o values in accordance to orientation, type of transparent component and transparency ratio.

It is assumed that these calculated limit U-values are valid for reference V/A ratio and reference V/A ratio is defined by the minimum facade area surrounding a certain building volume. Then, the total heat loss through whole building envelope for varies V/A ratios are calculated in order to establish the relationship between U-value and V/A ratio.

2. Calculation of Total Heat Loss Through the Whole Building Envelope

Hourly heat loss per unit area of building envelope composed of opaque and transparent components is calculated by the following formula in order to determine the total heat loss.

$$q = U_o (t_i - t_{eoo}) (1\text{-}TR) + U_w (t_i - t_{eco}) TR \quad (2)$$

where q is the hourly heat loss per unit area of building envelope(W/m^2, $kcal/m^2h$), U_o is the overall heat transfer coefficient of the opaque component(W/m^2 °C, $kcal/m^2h$°C), U_w is the overall heat transfer coefficient of the transparent component(W/m^2 °C, $kcal/m^2h$°C), t_i is the comfort value for indoor air temperature (°C), t_{eoo} is the daily average sol-air temperature for the opaque components(°C), t_{eco} is the daily average sol-air temperature for the transparent components(°C) and TR is the transparency ratio(window area/facade area).

Then, the total heat loss through the whole facade is calculated for the different V/A ratios, which are selected in a systematic order. The total heat loss can be expressed by the following formula

$$Q=(q_1A_1)+(q_2A_2)+...........+(q_nA_n)+(q_çA_t) \qquad (3)$$

where $q_1,q_2,.......q_n$ are the hourly heat losses per unit area of building envelope for differently oriented facades (W/m^2, $kcal/m^2h$); $A_1,A_2,......A_n$ are the facade areas for different orientations of building(m^2) ,q_r is the hourly heat loss per unit area of roof component,(W/m^2, $kcal/m^2h$) , A_r is the ceiling area, m^2

3. Establishing the Relationship between U-value and V/A ratio

The relationship between U-value and V/A ratio can be established by analysing the interrelation between total heat loss and V/A ratio. For the buildings oriented to North, South, East and West. V/A ratios were changed between 1.5 and 5.5 systematically with 0.5 intervals. Heat losses for these buildings were calculated by using equation 2 and 3. Calculations were made for different floor areas. By analysing the results of these calculations the following relations between heat loss and V/A ratio were established [5].

Floor area:	100 m^2	$V/A= 0.0782\ Q^2 - 1.198\ Q +5.572$	(4)
	220 m^2	$V/A= 0.0398\ Q^2 - 0.972\ Q +7.427$	(5)
	300 m^2	$V/A= 0.033\ Q^2 - 0.989\ Q +8.834$	(6)
	400 m^2	$V/A= 0.0253\ Q^2 - 0.943\ Q +10.061$	(7)
	500 m^2	$V/A= 0.0245\ Q^2 - 0.955\ Q +11.284$	(8)

4.Determination of Revision Coefficient for U-Values

By using the equation 4,5,6,7 and 8 replacing Q amount by equations 2 and 3, the relations between V/A ratio and U-value can be established. Then the revision coefficient can be derived to be applied to the U-values which were determined for the reference V/A ratio.

CONCLUSION

In this paper, a methodology which will be used for determination of building envelope U-value depending on the building form which is represented by the V/A ratio, besides the other design parameters affecting indoor climate such as transparent component type and transparency ratio. Thus, it will be possible to revise the limit U-values which is determined independently from building form and it is assumed that they are valid for reference V/A ratio which represents the minimum facade area surrounding the certain building volume.

As a result of the application of the new methodology for different V/A ratios and for different climatic regions of Turkey limit U-values proposed by the existent building regulation for energy conservation will be revised in order to consider the building form.

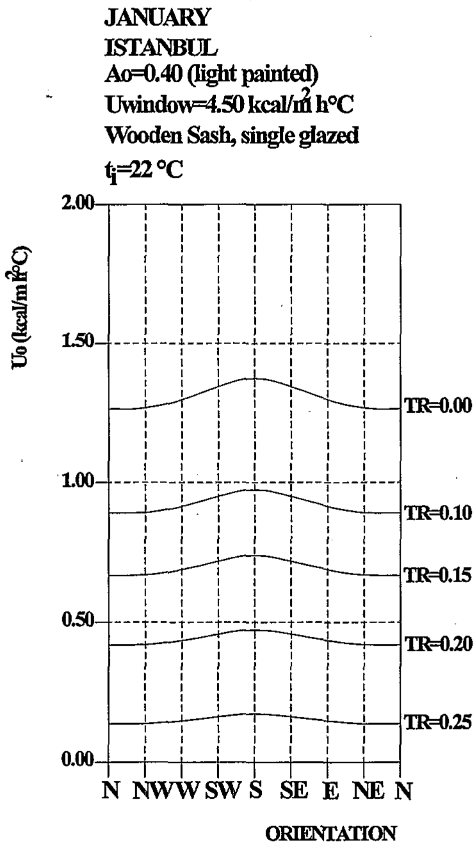

Figure 1 a. Variation of the thermophysical properties of façade element with orientation

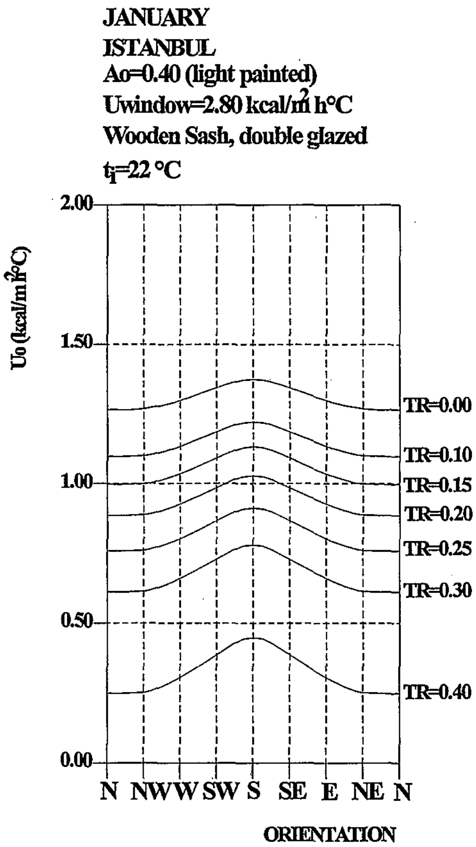

Figure 1 b. Variation of the thermophysical properties of façade element with orientation

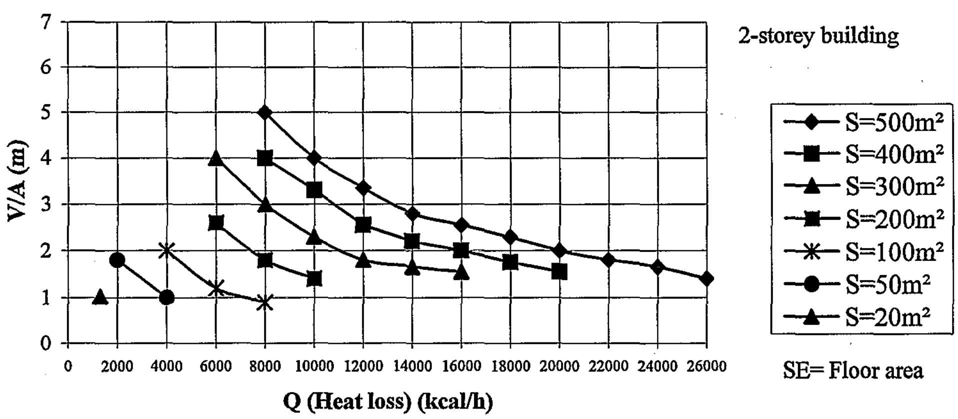

Figure 2. Variation of total heat flow through building envelope in accordance with V/A ratio

REFERENCES

1. Turkey Ministry of Public Works and Housing, *Building Regulations for Energy Conservation*, 1985, Ankara.
2. New Turkish Standard, 1998, *Rules of Heat Insulation in Buildings* (draft standard).
3. Berköz, E., et al., 1995, *Energy Efficient Building and Settlement Design*, Research Project report No:INTAG 201, The Scientific and technical Research Council of Turkey, İstanbul, pp 53-75.
4. Yılmaz, Z., et al., *Determination of U-value Depending on Building Form*, Research Project, İstanbul Technical University, İstanbul (continue)
5. Selamet, S., 1995, *A Model Suggestion for the Analysis of Heat Loss Through the Whole Building Envelope Depending on the Building Form*, Master Thesis, İstanbul Technical University, pp 34-41.