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# Study of the Effect of Temperature Differences on the Overall Thermal Transfer Value of buildings

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**Abstract**

This study was conducted to search for the relationship to predict values of Overall Thermal Transfer Value (OTTV) of the building at different time in one day to determine the effects of equivalent temperature difference for opaque walls (TDeq), and temperature difference for glass windows (ΔT) affecting OTTV value: A case study of the sixth floor of Pienvichitr Building, Faculty of Engineering, Khon Kaen University, where the new TDeq and ΔT values obtained from the calculation using the data of the temperature and the solar radiation in Khon Kaen Province. It is based on the reference direction of the building from 06.00 am. - 06.00 pm. The results showed the OTTV value with the highest value was at 02.00 pm., and the minimum was at 06.00 am. The developed parameters used to predict the OTTV with high accuracy compared to the current parameters according to the rules of the Ministerial regulations on building design used. This is approximately 6.8% of the difference, but the OTTV can be taken to improve energy efficiency in the building further.


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*Keywords:* Overall Thermal Transfer Value (OTTV); Equivalent temperature difference (TDeq); Temperature difference (ΔT); Solar radiation; Direction

## 1. Introduction

Since Thailand is a tropical country, electrical energy consumed in the building is most used for indoor air conditioning, and power consumption is not effective. Therefore, energy-saving in air conditioning system is important and it has a significant impact on energy savings in the building. The building

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envelope with a suitable heat transfer will be able to reduce electricity consumption by the air conditioning down [1]. The government has issued Ministerial regulations on building design, andbuilding envelope by selecting a method to reduce the overall thermal transfer value (OTTV) as an important strategy [2]. However, the equivalent temperature difference for opaque walls (TDeq), and the temperature difference for glass windows ($\Delta T$) are used for OTTV calculation, it has not yet been considered by the difference in the climate of the area. It makes the OTTV is not close to the current reality. Therefore this study is proposed to improve the TDeq and $\Delta T$ to be consistent with the climate of Khon Kaen Province, and to find relation to predict the OTTV at different times in one day to determine the impact of TDeq and $\Delta T$ affecting the OTTV in order to take OTTV to improve the energy consumption efficiency in buildings further.

## 2. OTTV Calculation

Heat transfer value is a value that represents a quantity of heat which is caused by the influence of the external atmosphere and the amount of solar radiation transferring into the building. The principles for calculating heat transfer are based on the basic theory of heat transfer which is considered that the heat pass through the envelope of building into the building consisted of 3 parts:

- Heat conduction through opaque walls
- Heat conduction through glass windows
- Solar radiation through glass windows

So when the heat of these three parts to make on average according to the area it would have taken overall heat transfer value. The overall heat transfer value of outside walls on each side ($OTTV_i$) can be calculated by the following equation [3]:

$$OTTV_i = (A_w \times U_w \times TDeq) + (A_f \times U_f \times \Delta T) + (A_f \times SF \times SC) / A_i$$

$$= (1-WWR)(U_w)(TDeq) + (WWR)(U_f)(\Delta T) + (WWR)(SF)(SC)$$

where $OTTV_i$ = overall thermal transfer value ($W/m^2$), $A_w$ = area of opaque walls ($m^2$), $U_w$ = thermal transmittance of opaque wall ($W/m^2\ ^\circ C$), TDeq = equivalent temperature difference ($^\circ C$), $A_f$ = area of fenestration ($m^2$), $U_f$ = thermal transmittance of fenestration ($W/m^2\ ^\circ C$), $\Delta T$ = temperature difference ($^\circ C$), SF = solar factor ($W/m^2$), SC = shading coefficients of fenestration, $A_i$ = total area of opaque walls and fenestration and WWR = window-to-wall ratio.

And OTTV is the average of the total heat transfer of outside walls on each side ($OTTV_i$) is calculated from the following equation:

$$OTTV = \sum (OTTV_i \times A_i) / \sum A_i$$

## 3. Equivalent temperature difference (TDeq)

The equivalent temperature difference between outside and inside the building is a value that includes the absorption of solar radiation through walls. This value is based on period of solar radiation

absorption, solar radiation absorption coefficient, and mass density, including the direction and angle of the wall.

Techniques for evaluating TDeq related to the concept of sol-air temperature. The sol-air temperature ($T_e$) is the temperature of external air that would cause the heat to flow into the building through the outer skin of the building. This heat is caused by the radiation of the sun. The heat conduction from the outside air and the reflection of the sky radiation is caused by other environment.

$$T_e = T_o + (\alpha / h_o)I - (\varepsilon / h_o)\, I_r$$

where $T_e$ = sol-air temperature (◦C), $T_o$ = external ambient temperature (◦C), $\alpha$ = solar absorption for surface (0-1), $h_o$ = heat transfer coefficient of outer surface, $\varepsilon$ = emission coefficient for thermal radiation, I = solar radiation on the wall ($W/m^2$) and $I_r$ = thermal radiation from the wall.

Sol-air temperature values will change over time due to the outside temperature and the solar radiation that is changing all the time. Moreover, the solar radiation has also changed according to the direction of the wall facing the sun, thus making the sol-air temperature change according to the direction of the wall for vertical surface area in $I_r = 0$:

$$TDeq = T_e - T_i = (T_o - T_i) + (\alpha / h_o)I - (\varepsilon / h_o)\, I_r$$

From the calculation, Table 1. shows the equivalent temperature difference (TDeq) considered by mass density of wall materials was 1280 $kg/m^3$ and solar absorption for surface ($\alpha$) was 3.

Table 1. Equivalent temperature difference

| | Equivalent temperature difference (◦C) | | | |
|---|---|---|---|---|
| Time | N | S | E | W |
| 06.00 am | 1.5 | 0.7 | 4.2 | 0.7 |
| 07.00 am | 2.8 | 2.1 | 4.3 | 2.1 |
| 08.00 am | 4.5 | 3.4 | 6.2 | 3.4 |
| 09.00 am | 5.8 | 4.8 | 8.3 | 4.8 |
| 10.00 am | 7.6 | 6.3 | 9.3 | 6.3 |
| 11.00 am | 8.9 | 8.0 | 9.7 | 8.0 |
| 12.00 pm | 10.0 | 8.9 | 9.8 | 8.9 |
| 01.00 pm | 10.8 | 9.9 | 10.2 | 10.9 |
| 02.00 pm | 11.2 | 10.5 | 10.5 | 12.0 |
| 03.00 pm | 10.9 | 10.6 | 10.6 | 11.8 |
| 04.00 pm | 10.2 | 9.8 | 9.8 | 10.7 |
| 05.00 pm | 9.3 | 8.9 | 9.6 | 9.6 |
| 06.00 pm | 8.9 | 8.9 | 8.9 | 9.0 |

## 4. Temperature difference (ΔT)

The temperature difference between the temperature of the outside air temperature and the inside air temperature of the air-conditioned area of the building was used to calculate heat conduction through transparent walls.

For any building, ΔT represents the difference in the climate temperature of the location and design internal temperature. The existing Thai standard has been used ΔT = 5◦C. In this study the designing ΔT across the glazing of actual 12 hours periodic variation of outdoor air temperature $T_o(t)$ was determined using ASHRAE method model [4]:

$$T_o(t) = T_{max} - T_r f(t)$$

where $T_o(t)$ = ambient temperature at 1-12 is the hours of the day (◦C), $T_{max}$ = daily maximum outdoor air temperature (◦C), $T_r$ = temperature daily range (◦C) and f(t) = function of the time given by the ASHRAE in tabulated form for t = 1,2,….,12.

A reference 12-h periodic variation of the outdoor air temperature may be defined:

$$T_o^{ref}(t) = T_{max}^{ref} - T_r^{ref} f(t)$$

where $T_{max}^{ref}$ and $Tr^{ref}$ f(t), respectively, are linked together through the maximum temperature and daily range differences:

$$\Delta T_{max} = T_{max[1,2,12h]} - T_{rmax}^{ref}$$

The calculation of temperature difference (ΔT) by 25◦C of room temperature will be shows as in Table 2.

Table 2. Temperature difference

| Time | Temperature difference (◦C) |
|---|---|
| 06.00 am | 1.0 |
| 07.00 am | 1.8 |
| 08.00 am | 2.6 |
| 09.00 am | 3.5 |
| 10.00 am | 4.4 |
| 11.00 am | 5.3 |
| 12.00 pm | 6.0 |
| 01.00 pm | 6.5 |
| 02.00 pm | 6.9 |
| 03.00 pm | 7.0 |
| 04.00 pm | 7.0 |
| 05.00 pm | 6.5 |
| 06.00 pm | 6.0 |

## 5. Results of OTTV calculation

According to the OTTV, weather and solar radiation data of Khon Kaen province were used to estimate TDeq and ΔT. The sixth floor of Pienvichitr building was used as the reference location. The total time of measurement employed is 12 hours which is from 06.00 am. to 06.00 pm. Significantly, the area of opaque walls and glass window are taking into account of the direction in N, S, E and W are selected at 116.88, 137.04, 45.72 and 74.52 $m^2$, and 73.92, 53.76, 48.24 and 19.44 $m^2$, respectively. As a result shown in Fig 1., it is found that the highest value of the OTTV was 53.45 $W/m^2$ at 02.00 pm. while the minimum was 37.19 $W/m^2$ at 06.00 am.

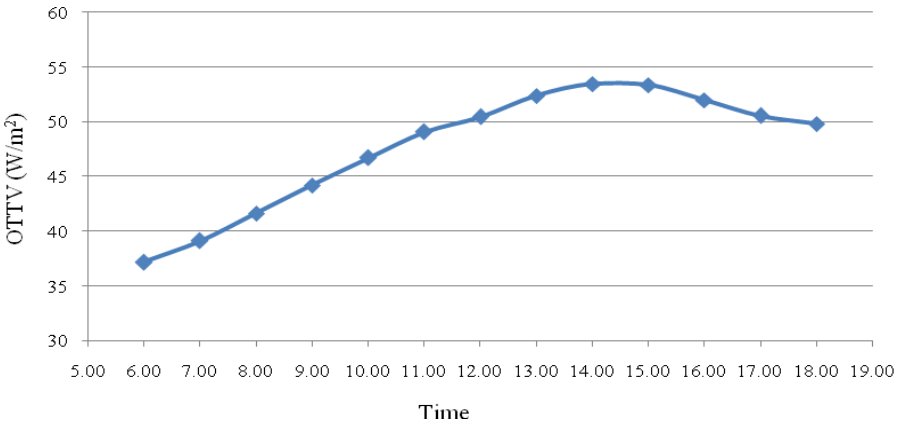


Fig. 1. Results of OTTV calculation

## 6. Relation of TDeq and ΔT on OTTV

In this section present comparison between the current OTTV value calculations and the developed parameters, it is found that those parameters of equivalent temperature difference and temperature difference will be affect OTTV calculation, the average heat transfer through the building different from 51.17 $W/m^2$ to 47.68 $W/m^2$, it is lower than current value approximately 6.8 %.

## 7. Conclusion

The current equivalent temperature difference (TDeq) and temperature difference (ΔT) are average value that the Ministerial regulations on building design used, therefore this study is proposed to develop the TDeq and ΔT to be nearby with the climate of Khon Kaen province, and to determine the OTTV. OTTV calculation is taking into 3 parts of basic theory of heat transfer through opaque walls and glass window. The new parameters were calculated by using data from Khon Kaen Meteorological station. It is based on the reference direction of Pienvichitr building, sixth floor, measured from 06.00 am. -06.00 pm. As a result, it is found that the highest value of the OTTV was 53.45 $W/m^2$ at 02.00 pm. while the

minimum was 37.19 W/m$^2$ at 06.00 am. The new TDeq and ΔT affecting the OTTV, it is different from current OTTV value approximately 6.8 %.

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