OTTV controls – its formulation and relevance – an analysis

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Abstract

Design of energy efficient-buildings is one of the quickest and most cost-effective ways to reduce energy consumption. Potential improvements in energy efficiency exist in all building typologies. But it becomes more of a concern in energy-intensive buildings like air-conditioned office buildings and shopping complexes. The paper aims at understanding the significance of OTTV controls as a means of enhancing energy efficiency. The objectives of using OTTV are discussed. Furthermore, the parameters and component co-efficient used in its formulation are analyzed. The limitations in formulating OTTV standards are discussed. The above is substantiated by taking a base case. Its OTTV for combinations of various building materials is analyzed. Further specific OTTV during extreme climatic conditions (hottest and coolest periods) of the building locations are found. The paper concludes by inferring from the results of the base case study.

1 Importance of energy studies

Our environment and its limited natural resources are a growing concern for all of us. Energy efficiency is now universally recognized as one of the quickest and most cost effective ways to reduce energy related emissions associated with global warming, climate change, acid rain and smog. Improving energy efficiency is a key strategy in making the world’s energy system more economically and environmentally sustainable. Potential improvements in energy efficiency exist in all sectors - in homes, offices, schools, hospitals, factories etc. But it becomes more of a concern in energy intensive buildings like air-conditioned office buildings and shopping complexes. Building Energy Standards (BES) or codes are becoming more and more important in energy efficiency policies [1]. These standards can help raise concern and awareness of building energy conservation, promote energy efficient designs in buildings, encourage the development of energy efficient building products, and form
a basis for assessing building energy performance and developing energy efficiency programmes [2].

2 What is OTTV?

Overall Thermal Transfer Value is a measure of heat gain into the building through the building envelope [3]. Hence it acts as an index for comparing the thermal performance of buildings. The concept of OTTV is based on the assumption that the envelope of a building is completely enclosed. It comprises of two values.

- Envelope Thermal Transfer Value (ETTV)
- Roof Thermal Transfer Value (RTTV)

ETTV is a measure of heat transfer through the walls of the building, while RTTV is a measure of heat transfer through the roof of the building. The total sum of ETTV & RTTV is called as OTTV. It consists of three major components [4].

- Conduction through opaque wall
- Conduction through window glass, and
- Solar radiation through window glass.

The general form of OTTV equation for an external wall is

$$\text{OTTV}_i = \frac{Q_{wc} + Q_{gc} + Q_{sol}}{A_i}$$

Where OTTV$_i$ - Overall Thermal Transfer Value of the external wall (W/m$^2$)

$Q_{wc}$ - Conduction through opaque wall

$Q_{gc}$ - Conduction through window glass

$Q_{sol}$ - Solar radiation through window glass

$A_i$ - Total wall area.

3 Need for OTTV controls

Control of OTTV implies the control of heat transfer through the building envelop. If heat gain is controlled then the load on air conditioner can be reduced, leading to lesser consumption of electricity. Also its formulation would allow authorized persons like architects & designers to be free to innovate and vary important envelope components such as type of glazing, window size, external shading to walls, wall colour, wall type and roof type at the conceptual design stage to meet the maximum OTTV criteria. Hence any measure to improve energy efficiency or to save energy would be considered in planning a building. Hence we need building energy efficiency regulation, which will emphasize the control of OTTV as one of its aspects.

4 Objectives

The main objectives in introducing the OTTV controls are

- To develop and implement energy efficient building design protocols and
the relevant design tools - Hence promote energy conservation
- To establish energy management benchmark and develop best practices system for various building types.
- To suggest ways to improve energy efficiency in buildings.
- To encourage climate-responsive building planning and design.

5 Parameters for OTTV

The parameters used in calculating the thermal transmittance of the construction by OTTV method are
- Building parameters – building materials (U-value), absorbance of exterior treatment, Type of glass used for fenestration.
- Climatic parameters – intensity of solar radiation, climatic factors (air temperature, wind velocity, humidity, precipitation.)
- Local parameters – indoor comfort conditions, type of dressing, acclimatization.

6 An application and study of OTTV

A study of OTTV for a base case plan of an Office building located in Chennai (fig.1) has been done. Parametric analysis was carried out to examine the major parameters of heat gain through building envelope. Fig. 2 shows the general methodology for developing OTTV equations[4,5,6].

Figure 1: Ground Floor plan of Base case study Office Building.
Figure 2: Methodology for formulation OTTV equations
The first step involves using variables in previous OTTV equation. Hence OTTV equations used in Hong Kong was used for a base case plan (fig. 3)

![OTTV Graph](image)

Figure 3: OTTV for the building in Chennai for all the walls for May.

In order to determine the features to be examined, the OTTV for the same building but in a different location was examined.

Table 1: Locational features of Chennai (where the building exists) and Kodaikanal where (the building is assumed to exist).

<table>
<thead>
<tr>
<th>Locational features</th>
<th>Existing location</th>
<th>Alternative location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Chennai</td>
<td>Kodaikanal</td>
</tr>
<tr>
<td>Latitude</td>
<td>13° 00' N</td>
<td>10° 14' N</td>
</tr>
<tr>
<td>Longitude</td>
<td>80° 11' E</td>
<td>77° 28'</td>
</tr>
<tr>
<td>Altitude</td>
<td>16 Mtrs. Above MSL</td>
<td>2343 Mtrs. Above</td>
</tr>
<tr>
<td>Use</td>
<td>Office</td>
<td>Office</td>
</tr>
<tr>
<td>Type</td>
<td>Air-conditioned</td>
<td>Air-conditioned</td>
</tr>
<tr>
<td>Climate</td>
<td>Warm - humid</td>
<td>Cool upland</td>
</tr>
<tr>
<td>Mean max. temp.</td>
<td>37.2° C</td>
<td>20.4° C</td>
</tr>
</tbody>
</table>

The OTTV for this building in Chennai and Kodaikanal was compared. It was found that the OTTV in Kodaikanal is higher than in Chennai, if the OTTV equations in Hong Kong are used.

This meant that the buildings located in Kodaikanal would gain heat faster than the buildings in Chennai, which is contrary to reality. In fact buildings in Kodaikanal need heaters to heat up their interiors. Hence variables in OTTV had to be re-examined.

The equations as given in ASHRAE [7] without any modifications are as follows.
\[ \text{OTTV}_{a} = \frac{Q_{wc} + Q_{sc} + Q_{sol}}{A_{i}} \]

\[ = \left( A_{w} \times U \times \Delta T_{s} \right) + \left( A_{g} \times U \times \Delta T \right) + \left( A_{g} \times I \times \theta \right) \]

\( \text{OTTV}_{a} \) = OTTV as per ASHRAE.
\( A_{w} \) = area of wall in m\(^2\).
\( U \) = Transmittance value in W/m\(^2\) deg. C.
\( \Delta T_{s} \) = \( T_{s} - T_{i} \)
\( = (T_{o} + I \times a / f_{o}) - T_{i} \).
\( T_{o} \) = Outside air temperature in deg. C.
\( I \) = radiation intensity in W/m\(^2\).
\( a \) = absorbance of the surface.
\( F_{o} \) = Surface conductance outside in W/m\(^2\) deg. C.
\( T_{i} \) = inside air temperature in deg. C.
\( A_{g} \) = Area of glass in m\(^2\).
\( \Delta T \) = Difference between internal and external air temperature.
\( \theta \) = solar gain factor of window glass.

The OTTV using the Hong Kong methodology and \( \text{OTTV}_{a} \) were calculated for the building in Fig. 1 located in Chennai and the result shown in Fig. 4.

![Figure 4: Comparison of OTTV by Hong Kong methodology and \( \text{OTTV}_{a} \)](image)

Variations in both the values are only by a Co-efficient and the values follow the same trend. Upon using \( \text{OTTV}_{a} \) for the same building in different locations, that is, Chennai and Kodaikanal, the following results were obtained. (Fig 5).
Figure 5: OTTV as per the Hong Kong methodology for the same building in Chennai and Kodaikanal.

It indicates that OTTV in Kodaikanal is less than OTTV in Chennai for all the directions, because even though the solar radiation intensity is higher in Kodaikanal than in Chennai, the mean maximum temperature in Kodaikanal is lesser (table 1). Hence it can be concluded that the Equivalent Temperature difference in the OTTV equation of Hong Kong (Tdeq.) considers the climatic data like sol air temperature for Hong Kong alone and cannot be applied to all climate types.

7 Variation of OTTV with parameters

It is important to understand the effect of various parameters on OTTV as it will help us to

- study if new variables will improve the OTTV equation
- determine co-efficients for OTTV equations.

For the same building, OTTV calculations were carried out for the following conditions.

7.1 Varying building orientation

- Longer axis along North – South (Case A)
- Longer axis along North East – South West (Case B)
- Longer axis along North west– South East (Case C)

It is found that for any orientation of the building maximum heat gain is through the West wall. But the best orientation wherein the heat gain would be minimum is when the longer axis of the building is oriented towards South East–North West.

7.2 Varying parts of the year

- The hottest part of the year- May at 2.00 p.m.
- The coolest part of the year- January 7.00 a.m.

It was found that heat gain is at its peak along the Western wall in May making the interiors of the room facing west to be most uncomfortable. Eastern walls gain more heat in the cooler period than in the hotter period.
7.3 Varying building materials

![Graph showing heat gain vs building materials]

Figure 6: Comparison of OTTV for various combinations of building materials for North wall in May.

It is observed that addition of insulation along the interior of the building helps in reducing the heat gain through the wall. Lesser the U-Value of the composite wall, lesser is the heat gain. More porous the insulating material, lesser is the heat gain because of the presence of more air gaps.

7.4 Varying location

- The building as it exists in Chennai.
- The building if it were to be built with the same technology and building materials in Kodaikanal.

It is seen that the OTTV is less for Kodaikanal for all the directions as compared to Chennai. Hence climatic parameters are extremely important in determining the format for OTTV equations. That is to say, while modifying the OTTV equations for the convenience of applicability by using coefficients, it is important to consider all the climatic aspects.

7.5 Varying the type of glass

Table 2: Description of Glass type

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>SHGF</th>
<th>Heat Gain in W/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain glass 3 mm thick.</td>
<td>1</td>
<td>94.9696</td>
</tr>
<tr>
<td>Plain glass with wire mesh outside</td>
<td>0.65</td>
<td>61.73024</td>
</tr>
<tr>
<td>White painted</td>
<td>0.35</td>
<td>33.23936</td>
</tr>
<tr>
<td>Yellow painted</td>
<td>0.37</td>
<td>35.13875</td>
</tr>
<tr>
<td>Green painted</td>
<td>0.4</td>
<td>37.98784</td>
</tr>
<tr>
<td>Heat absorbent glass</td>
<td>0.45</td>
<td>42.73632</td>
</tr>
<tr>
<td>Plain glass + light color blind</td>
<td>0.35</td>
<td>33.23936</td>
</tr>
<tr>
<td>Plain glass + dark color blind</td>
<td>0.4</td>
<td>37.98784</td>
</tr>
</tbody>
</table>
7.6 Varying the exterior building finish (absorptivity)

- Bright aluminum finish (1).
- Uncolored cement (6).
- Black paint (11).

The more the reflectivity of the surface color the lesser is the heat gain inside the building. A study of OTTV due to varying exterior finishes has been done by comparing the North wall in the month of May for two different office buildings (Building A and B). The results of the study are given below.

<table>
<thead>
<tr>
<th>Status of exterior color</th>
<th>Building</th>
<th>9&quot; Brick wall</th>
<th>4 1/2&quot; Brick wall</th>
<th>OTTV W/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>As per actuals</td>
<td>A</td>
<td>Grey</td>
<td>Grey</td>
<td>64.44</td>
</tr>
<tr>
<td>As per actuals</td>
<td>B</td>
<td>White</td>
<td>Grey</td>
<td>61.65</td>
</tr>
<tr>
<td>Assuming color change</td>
<td>A</td>
<td>White</td>
<td>White</td>
<td>60.69</td>
</tr>
<tr>
<td>Assuming color change</td>
<td>B</td>
<td>White</td>
<td>White</td>
<td>59.68</td>
</tr>
</tbody>
</table>

8 Lessons from the case study

- The study helps us to understand the variables involved in formulating OTTV equations. OTTV equations formulated for a particular location cannot be applied to any other location unless the climate of both places are similar in all respects.
- It is imperative that the OTTV at Kodaikanal is higher than that at Chennai when OTTV equations suitable to Chennai type of climate alone are applied. This is because the Solar Factor at Kodaikanal is higher than that at Chennai, because Kodaikanal is at a higher altitude. But it must also be understood that the OTTV standards at Kodaikanal have to be necessarily higher than that at Chennai because the average mean maximum temperature at Chennai is 37.2°C, while the average mean maximum temperature at Kodaikanal is 20.4°C. Hence buildings at Kodaikanal need to gain heat while buildings in Chennai need to prevent heat gain. Only a thorough understanding of the climatic conditions can help us assign the correct OTTV control standards.
- The OTTV for the hottest and the coolest part of the year has been calculated. This helps us to understand the range of values obtained. Hence this will help us fix an optimum value as OTTV standard.
- OTTV for various building orientations have been found out. This will help us understand the best orientation for buildings in both the locations. Thus one can give clear recommendations for building orientations in order to achieve the appropriate OTTV.

Understanding OTTV for various building finishes and glass types will help us to increase or decrease OTTV as the need may be.
9 Conclusions

OTTV is a way of achieving energy efficiency. Hence the Government must encourage research and development through the co-operation of professionals to formulate Building Energy Standards. Concerned authorities must monitor its implementation. Regular energy audits can be carried out to review if the building continues to be energy efficient and measures taken accordingly. OTTV control formulation will allow architects and designers to be more innovative in using alternative combinations of various building materials. This can be decided at the early design stage. It will also encourage the manufacture of energy efficient building materials.

The use of OTTV controls alone cannot assure us energy efficiency, but energy codes on lighting systems, air conditioning, electrical systems, lifts and escalators etc. must also be formulated to ensure complete efficiency.

References