CONCEPT OF OVERALL THERMAL TRANSFER VALUE (OTTV) IN DESIGN OF BUILDING ENVELOPE TO ACHIEVE ENERGY EFFICIENCY

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Abstract
Design of energy efficient buildings is the quickest way to reduce energy consumption. The skin of the building acts as a barrier between the indoor environment and the outdoor environment. The thermal performance of a building depends upon the façade design to a large extent, ranking second to the local climatic characteristics. Potential for energy conservation exists in all building typologies, but it becomes more of a concern in energy intensive buildings such as air-conditioned offices and shopping malls. This paper discusses the significance of the Overall Thermal Transfer Value (OTTV) controls as a means of enhancing energy efficiency of buildings. OTTV is a measure of heat gain into the building through the building envelope. It also acts as an index for comparing the thermal performance of buildings. The objectives and need for OTTV controls are discussed. The parameters used in calculating OTTV and therefore the need to customize OTTV calculations based on the location of the building are analyzed. The paper also discusses the OTTV standards in countries such as Singapore, Malaysia, Jamaica and Thailand. The application and calculation of OTTV for a case study building is demonstrated. The paper discusses the limitations of OTTV standards, its significance and relevance, and concludes that OTTV is one of the means of achieving energy efficiency of air conditioned buildings.

Keywords: Air-Conditioned, Energy Efficiency, Energy Intensive, OTTV, Thermal Performance

1. Introduction

There is a growing concern about energy consumption in buildings and its implications on the environment [1]. Energy efficiency is now universally recognized as one of the quickest and most cost effective ways to reduce energy related emissions associated with global warning, climate change, acid rain and smog. Potential improvements in energy efficiency exists 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 [2].

Building energy standards or codes are becoming more and more important in energy efficiency policies [3]. 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 [4].

2. What is OTTV?

The concept of OTTV originates from the energy conservation standards of ASHRAE Standard 90-75, which was later revised as ASHRAE 90A-1980 [5]. This standard is applicable to mechanically cooled buildings. OTTV is a measure of heat transfer into the building through its envelope [1, 6]. Hence it acts as an index for comparing the thermal performance of buildings, provided the same method is used for calculating OTTV [7]. 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) AND Roof Transfer Value (RTTV). ETTV is a measure of heat transfer through the walls or envelope 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. The calculations for RTTV is relatively simpler as the roof may not have any glazing, except in the case of skylights. Calculations for ETTV consist of three major components [4]:

(a) conduction through opaque wall

(b) conduction through window glass, and

(c) solar radiation through window glass.

The general form of OTTV equation for an external wall is given in equation (1) as follows:

$$OTTV = \frac{Q_{wc} + Q_{gc} + Q_{sol}}{A} \quad (1)$$

Where OTTV = Overall Thermal Transfer Value of the external wall (Watts/Square metre or W/m^2)

Q_{wc} is conduction through opaque wall

Q_{gc} is conduction through window glass

Q_{sol} is solar radiation through window glass

A is total wall area.

1. History of OTTV and OTTV Standards

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) was the first body to propose the OTTV method [5, 8]. It suggested that the limiting OTTV standard for a place would be the function of its latitude. In Asia, Singapore was the first country to develop an OTTV standard in 1979, based on the ASHRAE Standards 90-75 and 90-80A, but with refinements to suit local climate and construction practices [9]. In Hong Kong, the Government has implemented the building energy efficiency regulation in July 1995 [10]. The OTTV method is used as a control measure for building envelope design in commercial buildings and hotels [11]. The philosophy of building codes in Thailand is similar in nature to the Hong Kong Code of OTTV controls, but is applicable only to designated buildings. The Philippines, require that the OTTV of a commercial building must not exceed a statutory limit [12]. Indonesia, Malaysia, Philippines and Thailand have used Singapore as a reference model to develop their building energy standards [5, 13, 14, 15]. They have also made reference to ASHRAE Standard 90 series [16].

At the same time, some countries in Central America, including Jamaica and Ivory Coast, also developed their building energy standards, using OTTV as a part of the requirements [17]. It is believed that OTTV is a simple method suitable for developing countries. A number of countries in the world have adopted mandatory requirements on energy conservation for buildings [5]. A Comparison of the OTTV standards in some countries is given in Table 1.

Table 1: Comparison of OTTV standards in various countries

Sl.	Country	Year	Status	OTTV (Walls)	OTTV (Roof)
1	Singapore 1° 20' N	1979	Mandatory	45W/m^2	45W/m^2
2	Malaysia 3° 7' N	1989	Voluntary	45W/m^2	25W/m^2
3	Thailand 13° 41' N	1992	Mandatory	45W/m^2	25W/m^2
4	Philippines 14° 35' N	1993	Voluntary	48W/m^2	---
5	Jamica 17° 56' N	1992	Mandatory	55.1-67.7W/m^2	20W/m^2
6	Hong Kong 22° 18' N	1995	Mandatory	Tower: 35 W/m^2 Podium: 80 W/m^2	

4. Need for OTTV controls

Control of OTTV implies the control of heat transfer through the building envelop. More the OTTV, more is the heat gain inside the building through its envelope. 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 color, wall type and roof type at the early design stage to meet the OTTV criteria. Hence any measure to improve energy efficiency or to save energy would be considered in the early planning stage of the building. Building energy efficiency regulation must include the concept of OTTV as one of its aspects.

5. Objectives of OTTV

The main objectives in introducing the OTTV controls are

1. To develop and implement energy efficient building design protocols and the relevant design tools -Hence promote energy conservation.

2. To establish energy management benchmark and develop best practices system for various building type.

3. To suggest ways to improve energy efficiency in buildings.

4. To encourage climate-responsive building planning and design.

6. Parameters for calculating OTTV

The three important parameters on which OTTV depends are the architectural design parameters, the climatic parameters and the parameters pertaining to the local inhabitants. These parameters which impact OTTV are shown in Table 2.

Table 2: Parameters affecting OTTV in buildings

Building design Parameters	Climatic Parameters	Local Parameters
• Building Orientation • Walling material • Roofing Material • Envelope color • Type of Glass • Shading of walls • Shading of Windows	• Latitude • Solar Radiation • Air temperature • Wind Speeds • Humidity • Precipitation	• Indoor comfort conditions

For a given location or latitude assuming that the climatic factors and the local parameters such as acclimatization levels do not vary, the interaction of the architectural parameters such as orientation of building, type of glazing on the windows, shading devices etc. and the climatic parameters such as intensity of solar radiation, wind speed etc. are deduced to three main factors on which the OTTV calculation depends.

These three factors are as follows:

i. Indoor and Outdoor Temperature difference: This depends upon the outdoor air temperature and the period over which the air temperature and solar radiation is averaged. Besides, it also depends upon the prefixed indoor temperature for a mechanically cooled building.

ii. The Solar Factor (SF): Solar Factor of a glass wall is the ratio of the total solar energy entering inside through the glazing to the total incident solar energy radiation incident on the surface. Lower SF leads to lower OTTV.

iii. Equivalent Temperature Difference (TDeq): TDeq considers the conduction heat gain and effect of solar radiation of opaque surfaces.

7. OTTV Calculation Method

The method of calculating OTTV can be based on empirical formulas based upon local conditions, or ASHRAE Standard 90A. This paper discusses the equations as given in ASHRAE [16] without any modifications as follows.

$$OTTV_a = \frac{Q_{wc} + Q_{gc} + Q_{sol}}{A_i} \tag{2}$$

$$= \frac{((A_w) \times U \times \Delta T_s) + (A_g \times U \times \Delta T) + (A_g \times I \times \theta)}{A_i}$$

OTTV = OTTV as per ASHRAE.

A_w = area of wall + area of glass in m^2

U = Transmittance value in W/m^2 deg. C.

ΔT_s = $T_s - T_i$

$= (T_o + I x\ a/ f_o) - T_i$.

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.

ΔT = Difference between internal and external air temperature.

θ = solar gain factor of window glass.

Equation (2) involves all the factors that determine the OTTV.

Based on these equations, the OTTV of a case study building is calculated and evaluated.

8. An application and study of OTTV

As a case to study the OTTV of a building, an office building was taken up for study. This office for an IT company is located in Chennai, India. Such building typologies have mushroomed in large numbers with India becoming a major IT hub. Besides, an IT office building is an energy intensive building as it is mechanically cooled (air-conditioned).

Chennai is an important coastal city and is the third largest metropolitan city of India. This city is located at 13.04° N and 80.17° E on the South East coast of India and in the North East corner of Tamil Nadu at an average elevation of 6 mtrs. above MSL. The Bureau of Indian Standards classifies the climate of Chennai as Hot and Humid [18].

The IT Office building measures a total area of 15600sq.mtrs. This three storied building is oriented along the North-South axis. The building façade shows the absence of large curtain walls except for, at the entrance on the East side. The plan and elevations of its four sides are shown in Figure 1.

A brief specification of the envelope façade is given in Table 3.

Table 3 : Specification of façade materials

Sl.	Façade element	Specifications
1	Opaque element (Walls)	0.23 mtrs. Thick brick wall with 1:6 cement mortar and cement plaster on both sides and painted light grey
2	Transparent element (Glazing/ Windows)	Aluminim Framed, Blue tinted glass with double glazing and 6mm space in between- normal exposure

The OTTV for this building was calculated using equation (2) for all the wall surfaces separately. The OTTV was calculated based on the climatic parameters for the hottest time of the year (May) as well as the annual average. The results are as shown in figure 2.

It can be seen that the OTTV of the Southern wall is highest as compared to others, while the OTTV of the Eastern wall is lowest for both data conditions. Besides, the average OTTV of the building is at 99.2 W/m2 . the OTTV of the East and North wall is lower than the average OTTV of the building.

The envelope component contributing to the OTTV as given in equation (1) was analyzed and shown in Figure 3. It is found that the Qsol., which is solar radiation through window glass contributes increase in the OTTV for the West wall. The solar radiation through window is least for the East wall.

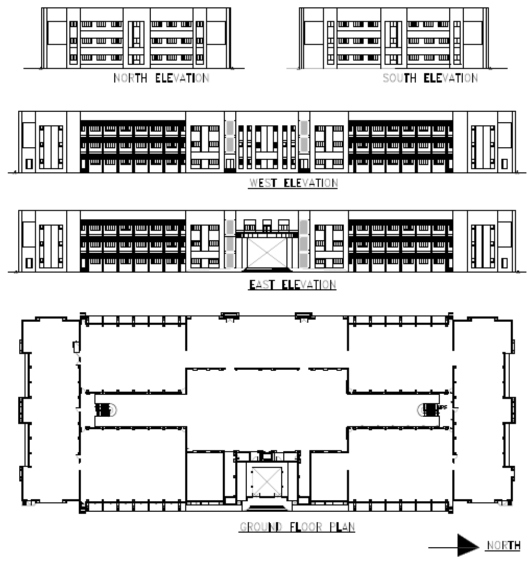

Fig. 1: Plan and Elevations of the case study building

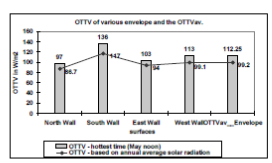

Fig. 2: OTTV of various walls

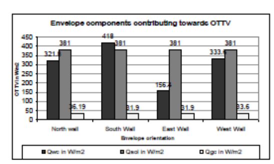

Fig. 3: Envelope component contributing to OTTV

A brief specification of the envelope façade is given in Table 3.

Table 3 : Specification of façade materials

Sl.	Façade element	Specifications
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2	Transparent element (Glazing/ Windows)	Aluminim Framed, Blue tinted glass with double glazing and 6mm space in between- normal exposure

In order to understand the remedial to reduce the OTTV, the specification of the opaque surface was varied for the purpose of research. Varying combinations of walling material were assumed and the OTTV for the same shown in Figure 4. It can be clearly seen that insulation inside reduces the OTTV by almost 50% and can be a very effective way of reducing cooling load, though a fire resistant insulating material has to be chosen.

OTTV for varying type of glass used for windows has also been analyzed. The OTTV of the glazing component is a direct function of the Solar Factor of the glass, which remains same with the type of glass. The Solar Heat Gain Factor (SHGF) for the same type of glass varies with the angle of incidence. All calculations in this paper is based on the average intensity of solar radiation. Therefore, the OTTV will reflect itself as a function of the Shade Factor of Glass though, in reality the SHGF will vary with orientation and time. Figure 5 shows the extent of reduction in OTTV due to variation in the type of glass.

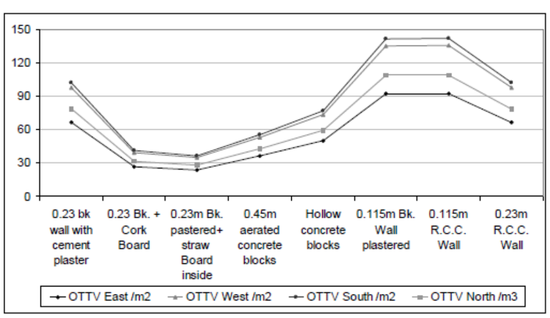

Fig. 4: OTTV for varying walling materials

9. Discussion

OTTV is a measure of the average heat gain through the envelope of a building. There are ways of reducing the heat gain into buildings through appropriate combinations of building materials, glass type and architectural modifications. Such measures will help architects and designers arrive at energy efficient buildings. OTTV is one of the methods to achieve sustainability and resource conservation. Considering that building typologies such as commercial complex and offices are energy intensive and mechanically ventilated, it is for the individual countries to set up bench marking standards for the design of energy efficient building envelope

10. Conclusion

- Certain design modifications can be brought in at an early design stage to ensure reduction of OTTV.
- The OTTV for the time of maximum solar radiation intensity is a good measure for benchmarking. Because, this means the building is designed for minimum solar gain during the worst (hottest condition). But this is relevant only to hot-humid and hot-dry countries which would reduce the load on air conditioners. In cold climates, the benchmark for arriving at OTTV standards must be different as it concerns heating load.
- Options for varying walling material and glazing type for wall orientation where the OTTV is high must be considered at the early design stage. Such preventive measures would reduce the heat gain and therefore the load on the air conditioner.

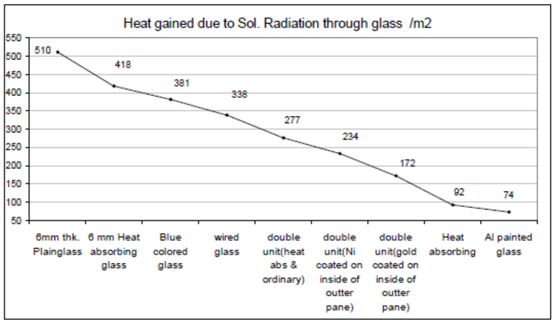

Fig. 5: OTTV of the window area with varying type of glass

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