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Visual Req calculation tool for green building evaluation in Taiwan

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ABSTRACT

The Ratio of Equivalent Transparency (Req) is a basic index for assessing whether a building is energy-efficient in Taiwan. Req is the ratio of the area of total building envelope and the area of envelope equivalent transparency. Calculation of Req requires not simply the consideration of natural factors such as building location, direction, ambient lighting and sunshine, but also and physical factors such as material, structure, ventilation and sun-shade. Current practices in Taiwan of manually calculating Req render the results prone to error, and are also time-consuming. Therefore, this research developed a visual Req calculation tool based on a 3D environment. This system provides users with various visualization tools to view the status and Req results of the building project. Furthermore, object-oriented modeling and parametric design can shorten the time taken to look-up tables and simplify the process of Req calculation, and also help to reduce computation time and errors.

1. Introduction

In order to cope with projected climate changes brought about by the enhanced greenhouse effect, countries around the world have invested efforts into the development of new energy resources and energy-saving techniques, in addition to the reduction of carbon emission. The concept of a “Green Building” is particularly relevant to these efforts by fully harnessing the available natural resources to reduce pollution, and achieve the aim to create the best environment with the least resources. The greatest opportunities for integrating “green” design strategies occur at the conceptual design stage [1]. The decisions made in the conceptual stage have tremendous impact on building performance in many aspects. For example, by changing design parameters such as shape, orientation, and envelope configuration, a high-quality designed building can consume 40% less energy than a low-quality designed one [2,3]. Therefore, building design must take many different factors into account in order to meet the requirements of a green building. To achieve this purpose, countries worldwide have also started to develop laws to regulate the construction of green buildings. For example, the U.S. Green Building Council (USGBC) is known for the Leadership in Energy & Environmental Design (LEED) [4]. In the UK, the BRE Environmental Assessment Method (BREEAM) has been widely implemented in public building design in order to improve energy efficiency and sustainability of designed buildings [5]. Concurrently in Asia, China's evaluation standard for green buildings is regarded as the policy foundation of resource conservation and environmental protection, and is in constant development. Japan has been using the Comprehensive Assessment System for Building Environment Efficiency (CASBEE) [6] as the evaluation system for green buildings. As countries all over the world have dedicated many resources to the development of green buildings [7], Taiwan has also implemented the Energy Conservation Design of Building Regulation, and passed 598 applications from 2000 to 2011. This Regulation was published with a series of Technical Codes complied with 9 books [8,9]. As long as the designers follow the guidelines of the books, the numerous data tables in them will guide them through the calculations. One of the Energy Conservation Design of Building Regulations in the Taiwan green building evaluation system, the Ratio of Equivalent Transparency (Req), is the evaluation method of energy-saving for residential buildings. It should be noted that the standard value of Req varies with different natural environments in different regions. Until now, Req values have been calculated manually in Taiwan, and this approach not only wastes a lot of time, but also leads to errors being made easily. In order to address these issues, this research developed a visual Req calculation tool which was made using the Visual Basic 2008 computer programming language. This system provides users with various functionalities for viewing the building status and calculating Req values automatically. The main purpose of this system is to help designers estimate whether their building designs have effectively met the standards in Energy Conservation Design of Buildings Regulation.

2. Ratio of equivalent transparency (Req)

2.1. Req definition

Req is predominantly used to evaluate whether the residential building is energy-saving. It is a simplified index of the average

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opening of the building's envelope as shown in formula (1). "Aen" indicates the total area of building's envelope and "Aeq" is indicates the total area of equivalent transparency.

$$Req = Aeq/Aen. \quad (1)$$

The building's envelope includes the external walls and roof. In formula (2), "Awi" indicates the area of the ith external wall in the building and "Ari" indicates the area of the ith roof that has undergone the calculation of horizontal projection. The correction factor "Ab" for the party wall is added into the formula of Req calculation so as to prevent distortion related to area calculation of building's envelope as shown in formula (3).

$$Aen = \Sigma Awi + \Sigma Ari + Ab \quad (2)$$

$$Ab = 0.3 \times \Sigma Abj. \quad (3)$$

The opening of building can be divided into two parts: one is the opening of the external wall (Agi) which includes door and window. Another is the opening of the roof (Agsi). At the same time, we must consider the impact of factors such as sunshine (fk), ventilation (fvi) and sun-shading (Ki) when calculating the ratio of equivalent transparency. The related formula is shown in formula (4).

$$Aeq = \Sigma Agi \times fk \times Ki \times fvi + \Sigma Agsi \times fk \times Ki \times fvi. \quad (4)$$

Req indexes are stipulated for evaluating whether the buildings comply with the Energy Conservation Design of Building Regulation. For Taiwan, the standards are divided into three climate zones (North, Middle and South). They have different levels of standards according to the different weather data and administrative divisions. Although Taiwan is a long and narrow island, the climate in the southern part of the island is quite different from the northern region. Table 1 shows the norm's content.

2.2. Traditional Req calculation method

The workflow of the traditional Req calculation method is shown in Fig. 1. Although its definition is simple, the quoted parameters and the degree of complexity of the calculation processes may easy to cause the errors. The inexperienced planner may easy to quote wrong coefficients from look-up tables and may make several calculation errors, leading to time and cost consuming.

A simple building was used example for describing time-consuming Req calculation in manual. It is one-floor building with flat roof, which was located in Pingtung, Taiwan. The related information as shown in Fig. 2 and calculation process is shown below:

$$\Sigma Aewi = (10 \times 3 \times 2) + (6 \times 3 \times 2) = 96\,M^2$$
$$\Sigma Aeri = (10 \times 6) = 60\,M^2$$
$$Ab = 0$$
$$Aen = \Sigma Awi + \Sigma Ari + Ab = 96\,M^2 + 60\,M^2 + 0 = 156\,M^2$$
$$\Sigma Agi \times fk \times Ki \times fvi = 8.742\,M^2(South) + 5.252\,M^2(West) + 2.288\,M^2(North) + 5.052\,M^2(East) = 21.334\,M^2$$

(Ki = 1, Window fvi = 1, Door fvi = 0.8, South fk = 1.561, North fk = 0.572 and East fk = 1.263, refer to look-up tables in specification which was titled "Design and Technique Directions for Energy Saving of Building on Residence")

$$\Sigma Agsi = 0 (Roof\ with\ no\ window)$$
$$Aeq = \Sigma Agi \times fk \times Ki \times fvi + \Sigma Agsi \times fk \times Ki \times fvi = 21.334\,M^2 + 0 = 21.334\,M^2$$
$$Req = Aeq/Aen = 21.334/156 = 0.1367 = 13.67\%.$$

In formula (1)–(4), Req = 13.67% < South Reqs = 18% (OK).

Table 1
Taiwan's energy conservation design of building regulation for residential building.

Building type	Energy saving standard	Climate zone	Standard value
Residential building	Reqs	North	<13%
		Middle	<15%
		South	<18%

3. Proposed methodology

Building design is a complicated project with numerous elements, including walls, windows, doors and roofs. According to the above-mentioned formula, we can observe that the traditional Req calculation method involves several time-consuming iterations. This research proposes a new methodology for addressing this issue. The concept of the proposed methodology is shown in Fig. 3. Users can create 3D building elements via the visualization tool. The required data including basic project information, geometric attributes, and coefficients will be obtained and stored automatically into a database for Req calculation The proposed methodology can greatly simplify workflow as well as prevent errors during manual calculations. This system not only provides users with a full 3D view of the building project, it is also able to determine whether the requirements of energy-saving are met, and to what extent.

4. System design and implementation

4.1. System framework

As depicted in Fig. 4, all of the application functions implemented for the visual Req calculation tool were based on Bentley Architecture, as well as stored the relevant information into Building Information Model (BIM). The implementation of the visual Req calculation tool was carried out in the Microsoft Visual Basic 2008 environment. The visual Req calculation tool encapsulates complicated Req calculation functions into four modules which are described as follows: (1) Setting Module: this module provides functions to assist the user with configuring the relevant parameters; (2) Modeling Module: this module provides creation functions for user to finish 3D building elements creation; (3) Calculation Module: this module calculates the required value for Req according to input data; (4) Analysis Module: this module is responsible for analyzing the result of the Req calculation. Finally, the system will apply the specific color (red, yellow and green) to visualize the result of Req calculation for the user to easily understand the state of Energy Conservation Design.

4.2. Building information model (BIM)

BIM is the application of modern management techniques and systems during a building's lifecycle from inception onward, including the processes of construction and facility operation. Three-dimensional models serve as communication media between planning and design phases. BIM contains spatial relationships, covers geometry, light analysis, geographic information, quantities and properties of building components. BIM can also help to resolve construction problems, because it can be used during preconstruction, for scheduling and hazard analysis. The National Building Information Model Standard (NBIMS) defines BIM as "a digital representation of physical and functional characteristics of a facility and it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward" [10]. In recent