VISUAL REQ CALCULATION TOOL FOR GREEN BUILDING EVALUATION IN TAIWAN

Shen Chang, Bo-Cing Lee, Po-Yen Chen, and I-Chen Wu*

Department of Civil Engineering, National Kaohsiung University of Applied Sciences, Kaohsiung, Taiwan
** Corresponding author (kwu@cc.kuas.edu.tw)*

ABSTRACT：The concept of a "green building" was first introduced to Taiwan in 1999, and began to develop regulations for the design and evaluation of energy-saving buildings. The Ratio of Equivalent Transparency (Req) is a basic index for assessing whether a building is energy-efficient. 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 sunshade. Furthermore, Req is considered particularly applicable due to the ubiquity of terraced houses in Taiwan, given the country's high population density. In this study, the correction factor to include the effect of party walls is added into the formula of Req calculation to prevent distortions to the area calculation of the building envelope. Current practices in Taiwan of manually calculating Req render the results prone to error, and are also time-consuming. To address these issues, 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.

***Keywords**: Req, Green Building, Visualization, Energy Saving, 3D Models*

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. As Wang [1] mentioned, shape is an important consideration in green building design due to its significant impact on energy performance and construction costs. 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) [2]. 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 [3]. 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) [4] as the evaluation system for green buildings. As countries all over the world have dedicated many resources to the development of green buildings [5], 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 [6, 7]. 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. REQ

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

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

The building's envelope includes the external walls and roof. In formula (2), "Awi" indicates the area of the i^{th} external wall in the building and "Ari" indicates the area of the i^{th} 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).

$$Aen = \Sigma Awi + \Sigma Ari + Ab \text{........................} \ (2)$$

$$Ab = 0.3 \times \Sigma Abj \text{......................................} \ (3)$$

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).

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

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.

Table1. Taiwan's Energy Conservation Design of Building Regulation for Residential Building.

Building Type	Energy Saving Standard	Climate Zone	Standard Value
Residential Building	Req	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 Figure 1. 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.

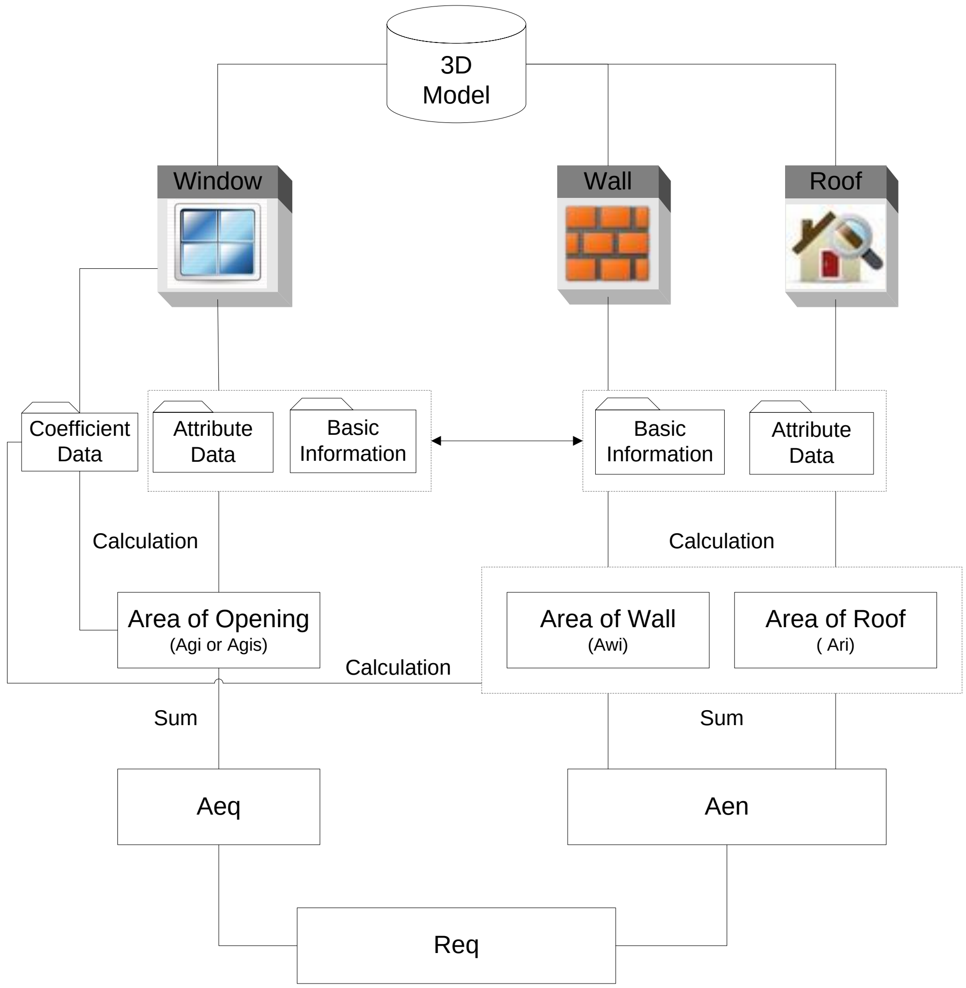


Fig. 1. The concept of the proposed methodology

4. SYSTEM DESIGN AND IMPLEMENTATION

All of the application functions implemented for the visual Req calculation tool were based on Bentley Architecture. The implementation of the visual Req calculation tool was carried out in the Microsoft Visual Basic 2008 environment.

4.1 DATA MODEL

A data model is an abstract model that describes how data is represented and accessed. This research proposed a data model of Req calculation for data definition and storage as shown in Figure 2.

4.2 GRAPHICAL USER INTERFACE

Figure 3 illustrates the main graphical user interface (GUI) of the visual Req calculation tool.

A. **Project**: Users can create a new project and input basic information, such as ID, region, name and project data, via this function. Meanwhile, the system will store these data into the data model we have proposed for Req calculation.

B. **Column**: This function only allows the user to create a column for visualization. Without any other parameters added, it does not affect the results of Req calculation.

C. **Wall**: Users can create the external and internal walls of the building via this system in the 3D environment. It should be noted that the system only can calculate the area of external walls for Req calculation. The internal walls are simply for visualization.

D. **Window**: When this function is clicked, four options for window type will show up, including Ventilation Window, Fixed Window, Sliding Window and Hinged Window. Different window types will cause different effects. Users can choose the window types they need, and create the size and position of windows in the 3D environment.

E. **Door**: Users can choose the door type, either single door or double door, and then input their size and position for Req calculation.

F. **Roof**: We have implemented Flat Roof and Sloping Roof types which are the most popular roof styles in Taiwan, into our system. Users can create roofs for the building using the visualization tool for Req calculation.

G. **Req**: This function will calculate the Req value according the user-provided project information and 3D model of wall, door and roof, created in the system. After this function is clicked, the system will show the results, whether the building project complies with the Energy Conservation Design of Building Regulation.

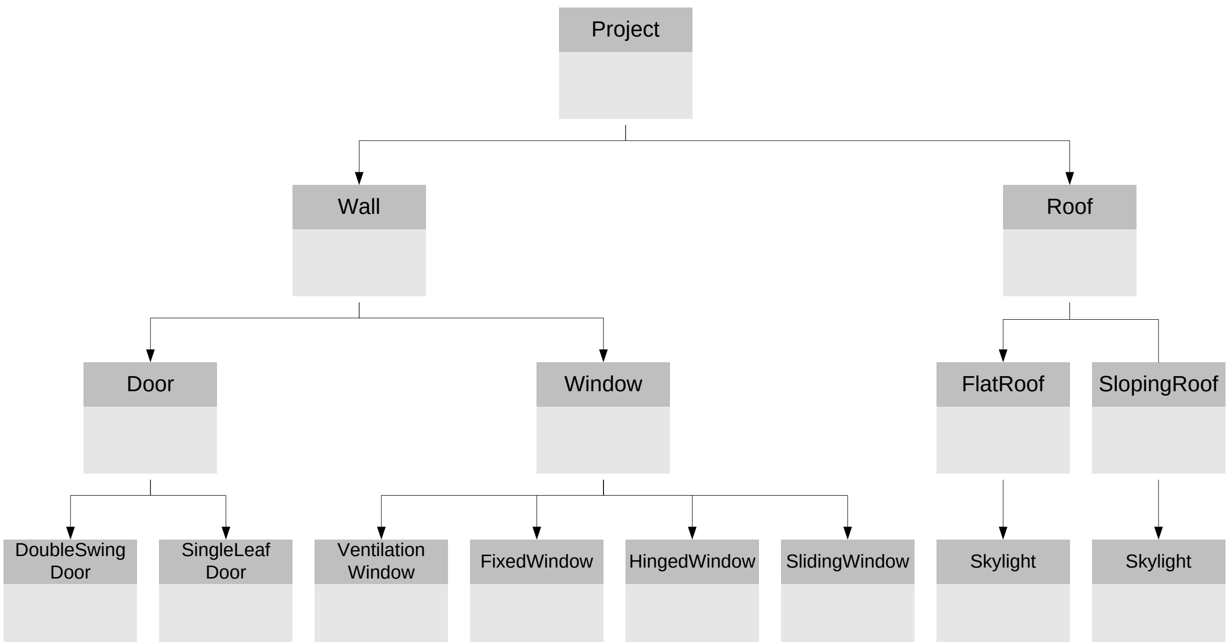


Fig. 2. Data model for Req calculation

Fig. 3. Graphical User Interface

5. DEMONSTRATION

A simple building project was used as an example to test and demonstrate the functionality of the visual Req calculation tool. It is a 3-floor building with flat roof, located in Pingdong City, Taiwan. The building is settled in the south-north direction, and the material is of RC construction. The workflow and steps for 3D model creation and Req calculation are shown as follows.

Initially, the user will start using the visual Req calculation tool and the system will launch Bentley Architecture at same time. The user can open a new building project and set project date via a form, and then save the required data into the database (Figure 4, Step 1). Next, the user can create columns, walls, windows, doors and roofs that they need in the 3D environment (Figure 4, Step 2–6). After finishing all creation processes, they can view the 3D model of the building project to review the design and structure of the building (Figure 4, Step 7). Finally, the system will calculate the Req value and check the results, to determine compliance with the Energy Conservation Design of Building Regulation (Figure 4, Step 8).

6. CONCLUSIONS

Based on the ideas and motivations of this research, this study has focused on the development and design of a visual Req calculation tool, and has obtained preliminary achievements. According to the achievements of this study, the following conclusions can be drawn:

- The development of the tool as the result of this study renders previous calculation approaches obsolete, and helps designers understand the blind points affecting the achieving of energy-saving requirements of the designed buildings, and enables further design modifications to optimize energy-saving effects.
- The possibility of manual operation errors is reduced, and the accuracy of Req calculation is improved through the use of the visualization tool.
- Req calculation is widely used for determining the energy-saving effect of residential buildings, but can also be applied to many other building types and designs. Although the study case presented is a 3-floor building, the Req calculation can be easily conducted for buildings with different floors by modifying the existing program and extending the database, making the calculation tool more flexible.
- The achievement of this study is the development of a tool that can be used by anyone without any occupational restrictions, and simply requires basic computer knowledge and understanding of the related parameter data of the building. The users just need to create a simple 3D model and input the related data into the system for calculation. Using this tool the general public can make accurate energy-saving analyses of their own residences, and contribute evidence of energy-saving improvements for their buildings.

REFERENCES

[1] Wang, W., Rivard, H. and Zmeureanu, R., "Floor Shape Optimization for Green Building Design", *Advanced Engineering Informatics*, Vol. 20 Issue 4, October, 2006, pp. 363-378.

[2] LEED-NC, "Green Building Rating System for New Construction & Major Renovations", Version 2.2, U.S. Green Building Council, 2005.

[3] Curwell, S., Yates, A., Howard, N., Bordass, B. and Doggart, J., "The green building challenge in the UK", *Building Research and Information*, Vol. 27, No. 4-5, July, 1999, pp. 286-293.

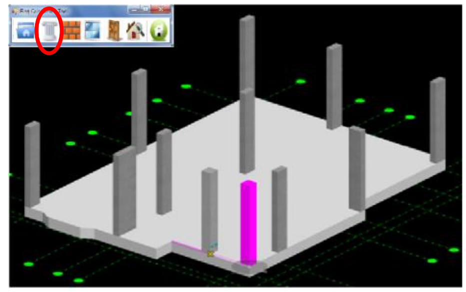
[4] Institute for Building Environment and Energy Conservation (IBEC), "CASBEE for New Construction, *Technical Manual*, 2008, 262 pages.

[5] Janda, K. B. and Busch, J. F. "Worldwide status of energy standards for buildings", *Energy*, Vol. 19, No. 1, 1994, pp. 27-44.

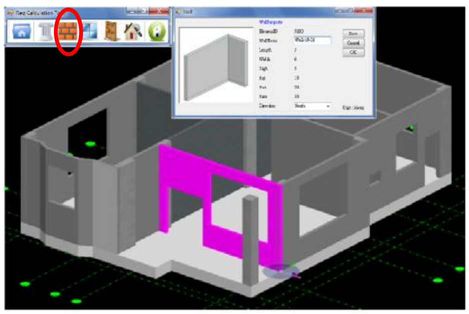
[6] Lin, H.T. and Wang, J.C., "Explanation for Energy Conservation Design of Buildings Regulation in Taiwan", Construction Magazine Publishing Ltd., Taipei, Taiwan, Edition in 1997 and 2002.

[7] Lin, H.T. and Wang, J.C., "The Design Index of Building Energy Conservation and CAD Program BEEP in Taiwan", Proceedings of the Eighth International IBPSA Conference, August 11-14, Eindhoven, Netherlands, 2003.

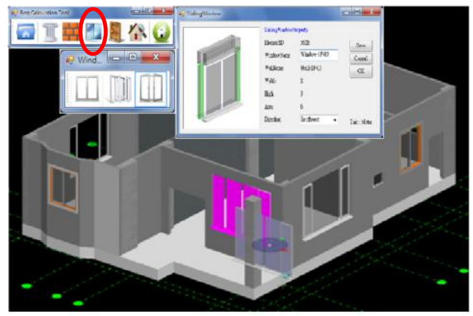
1：Project creation



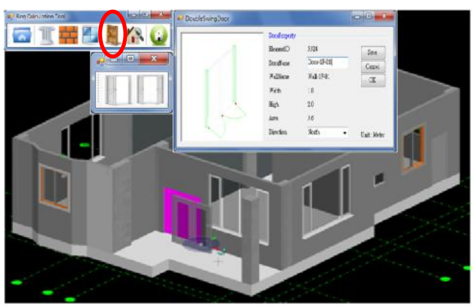
2：Columns creation



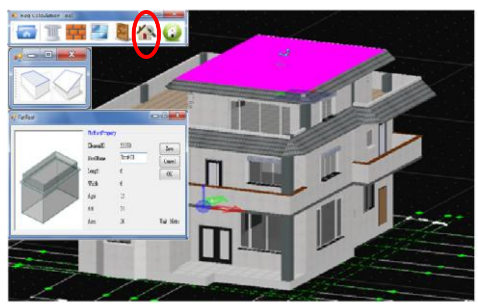
3：Walls creation



4：Windows creation

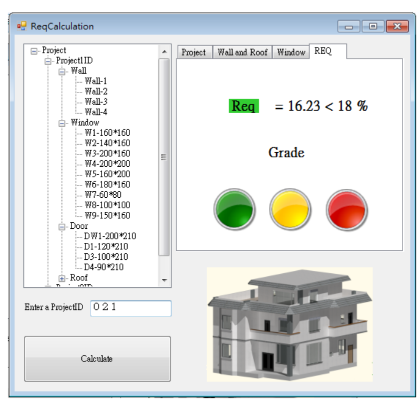


5：Doors creation



6：Roofs creation

7：The 3D building model



8：The results of Req calculation

Fig. 4. A building example for Req calculation