Development of Building Load Prediction Formula for ZEB Realization

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Abstract

Zero Emission Building is a building that emits zero carbon dioxide. Zero Emission Building is must considered energy saving in design phase since building energy saving method is very different by designer then we must survey and arrange about building energy relate elements for detail and objective judgment, before design phase. Therefore in this study, we survey building energy saving elements for targeting building. The saving elements are constituted by Lighting, Cooling, Heating elements and these result used for building design alternative for ZEB. And make design formula by the multiple regression analysis with a table of orthogonal arrays and correlation analysis. Therefore this study suggests process of building energy prediction formula for virtual zero emits carbon dioxide design.

Keywords: ZEB(Zero Emission Building), Load analysis, Design phase, Multiple regression analysis, Multicollinearity

1. Introduction

1.1. Background and goals of the study

Recently, the global warming has damaged all around the world and the CO2 emission, the main cause, control has been expanded. Among others, various countermeasures have been proposed to reduce the CO2 emission from buildings, accounting for 25% of the emission and one method is a development of zero emission building. The Zero Emission Building (ZEB) is a building with no final CO2 emission and has many differences in existing buildings from the aspects of building design, construction and operation compared to simple concepts. Therefore, proper design processes for each planning and developing stages are required for smooth construction of the ZEB by architectures or construction engineers. However, the process and concept establishment are determined by the building purposes and designers and this causes improper evaluation and distribution. There have been studies on eco-friendly and energy-saving buildings but approaches for the carbon neutral are required due to differences in concepts and approaches compared to the ZEB.

Therefore, the study seeks to conclude and propose objective design plans and approaches of the ZEB for the architectures. The study applies statistical methods to conclude such objective concepts and reasonable design plans.

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1.2. Method

Table 1. ZEB Implementation Process

Simulation for the building and unit-based comparison

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Select factors in saving energies and levels

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Make orthogonal array table and simulation

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Multiple regressive analysis and formula

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Calculate contributions for each element technology

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Apply facilities and new and renewable energies

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Find out final design plan

Building provides comfort for human and user stand against to continually changed climate. For these comfort indoor environment, using energy is necessary matter. And building energy is involved a lot of elements by building type and load and site climate. Also these elements are effect to building energy load according to characteristic of building then selection of energy reduction elements and range of application is very important process. But selection of elements is determined by climate, building type, designer and these evaluations are made individually.

Therefore this study analysis building energy consumption for consider complex application of building energy reduction elements. Then classified application level and building energy prediction formula through multiple regression analysis. Energy analysis method is EnergyPlus developed in DOE, and SPSS is used for multiple regression analysis. The deducted regression equation in this process appeared building design method and predicted building energy consumption.

The ZEB realization process of this study is appeared like table 1.

2. Concept and Implementation of the ZEB

2.1. Definition and Implementation Process of ZEB

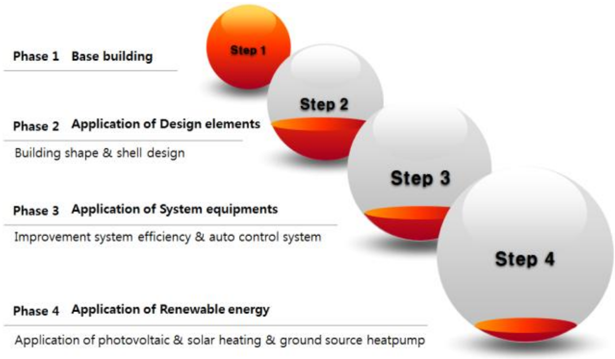

Fig. 1. ZEB Process

The concept of ‘Zero Emission’ was proposed in 1994 by Gunter Pauli (United nation University). This means the process which minimizes waste emission and ultimately makes ‘zero’ wastes. The ZEB in the construction means a building for the purpose of ‘zero’ CO_2 emission for the whole life of the building. This is a difference concept in the ‘Zero Energy Building’ which reduces energy uses in the operation stage and meets energy demands for a year from the energies by the building itself. Therefore, the basic approach of the ZEB is to select energy-saving methods based on load features of the building, select new and renewable energy element technologies, supply energies for the building and minimize CO_2 emission.

As shown in Fig. 1, the planning process or energy-saving concept in the design phase shall be prioritized to save the energies in the buildings. Not only energy-saving, as well as user convenience are determined by the capabilities or concepts of the designer and there needs to perform integrated eco-friendly designs through understanding of multiple application and concepts of elements in saving building energies and eco-friendly concepts of the designer. Therefore, the next chapter mentions elements related to saving building energies.

2.2. Element Technologies to save ZEB energies

As shown in Table 2, ‘the study on energy-saving plans for factory buildings’ in 2011 shows energy-related elements.

Table 2. building energy relation elements

Classification			Energy influenced elements
Design Elements	Building arrangement		Direction, location, site, terrain
	Building shape	Shape	S/V ratio, concentrated ratio, ratio of lateral to longitudinal length
		Size	Level, gross area, floor height
		Zoning	Buffer Zone, space Zoning
	Building shell	Roof	Insulation, heat capacity, roof shape, reflectivity
		Wall	Insulation, position of insulation, heat capacity, reflectivity
		tightness	Infiltration, ventilation
	Opening		Insulation, SHGC, Location, point of the compass, WWR

Table 3. Effective of energy relation elements

Classification	Elements of heating energy	Elements of cooling energy	Elements of lighting energy
Arrangements	Direction to S/SE, wind shielding	Direction to N, Natural ventilation	Direction to S
Shape	Minimized envelope, procure of daylighting, heat storage, buffer zone	Minimized envelope, daylighting block, buffer zone	Daylighting, improvement of indoor reflectance.
Shell	Improvement of insulation, low reflectance	Improvement of insulation, high reflectance.	Maximized WWR, high position window, light shelves, high visual transmittance
Opening	Minimized WWR, strengthen window insulation, high SHGC	Minimized WWR, low SHGC, Shading	

The factors have different impact on cooling, heating and lighting energies depending on application and produces results with different impact on each energy load. Therefore, understanding operational features and selecting proper application levels depending on the features and elements shall be prioritized. Table 3 shows impacts on the building energy loads.

As shown in Table 3, element technologies including bound, reflection rates, sunlight acquisition index and window area rates have opposite impact on each other and the statistical methods are applied to determine the level and application for the factors.

3. Statistical approach and expectation result

3.1. Statistical approach method

The study performed the multiple regressive analysis to understand how each design factor and its application affect the building energy load and evaluate understanding and application for the factors.

The multiple regressive analysis is a method to understand the relation between more than 2 independent and dependent variables using mathematical functions and is used to forecast changes of dependent variables against independent variables. The study designates final energy use as the dependent variable and applied elements as independent variables and plans experiment method using the orthogonal table for proper operation of the study and reducing simulations.

The orthogonal table is an experiment method which may systematically form combinations among variables without redundant experiment through variable-level array with rules and may induce the same results as the simulation by performing some experiments.

Table 4. Application of statistical methods process

Base model energy simulation
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Variable application using the orthogonal table and simulation
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Relation with dependent variables through the multicollinearity analysis
↓
Apply final dependent variables and simulation
↓
Find out building energy forecast regressive formula through the multiple regressive analysis

The study selects the formation to collect up to 40 variables through the orthogonal table of L81(340) to apply more variables. The application level consists of 3 levels for application to the orthogonal table.

In addition, the multicollinearity analysis is performed to judge properness for each variable and increase accuracy to the regressive formula prior to applying to the final multiple regressive formula and correlation with designed variables shall be prioritized.

The multicollinearity analysis means strong relations with prediction models (independent variables) against dependent variables and degrades accuracy of the regressive analysis. Therefore, it is used to judge properness of variables and accuracies.

The study design process is shown in Table 4 and the study design applying statistical methods may be configured depending on objective energy contribution for each element and level. Contribution rates and impact on each level may be calculated for design elements through final results from the regressive analysis and this may help configure element levels and select design concepts.

Contribution rate from each design concept for energy loads, ρT, is a percent how much changes in design variable affect the changes in the total energy load and it is considered that the large contribution rates mean more important energy load in the building.

The formulas calculating contributions for each design variable are as follows.

$$\rho_T(\%) = \frac{SS_T'}{SST} \times 100 \quad \text{------------- (eq. 1)}$$

$$SS_T' = SS_T - DF_T \times MSE \quad \text{------------- (eq. 2)}$$

$$MSE = \frac{SS_E}{DF_E} \quad \text{------------- (eq. 3)}$$

ρ_T	: contribution ratio of the clause(%)
SS_T’	: Net changes in the clause
SST	: Total square sum (total fluctuation)
SS_T	: Square sum of the clause
DF_T	: Degree of freedom of the clause
MSE	: Average square of the error
SS_E	: Square sum of the error
DF_E	: DOF of the error

In addition, impacts for each level are evaluated to select the application of the design variables and the level which saves the energy load shall be determined Here, the impact may be calculated as follows.

$$P_{A0} = \frac{Y_1 + Y_2 + Y_3 + \cdots + Y_{27}}{27} - T_m \quad \text{-----------(eq. 4)}$$

$$P_{A1} = \frac{Y_{28} + Y_{29} + Y_{30} + \cdots + Y_{54}}{27} - T_m$$ -----------(eq. 5)

$$P_{A2} = \frac{Y_{55} + Y_{56} + Y_{57} + \cdots + Y_{81}}{27} - T_m$$ -----------(eq. 6)

$$P_{B0} = \frac{(Y_1 + \cdots + Y_9) + (Y_{28} + \cdots + Y_{36}) + (Y_{55} + \cdots + Y_{63})}{27} - T_m$$

-----------(eq. 7)

$P_{Ai, Bi}$: Impact of i-level for each design variable
Y_i : Load calculation for each load from simulation
T_m : The total sum of load calculation from simulations.

3.2. Expectation result

The study evaluates impact on building energy for each design element through statistical approaches above, selects application and levels and finally forms building energy forecast equation.

$$Y = a + A_1X_1 + A_2X_2 + \cdots + A_nX_n$$ ------(eq. 8)

This makes it possible to guess and forecast final energy demand and production, as well as evaluate energy application for new and renewable energies. In addition, existing buildings are linked to variables to easily calculate energy consumption and energy reduction for existing buildings in case of changing variables.

4. Conclusion

The study seeks to develop a forecasting formula to easily calculate energy loads of the building to invigorate distribution of the ZEB. In the process, various design elements related with energy loads of the building were analyzed and it was confirmed to have different fractions and application for different energy loads including heating, cooling and lightings. The study planned experiments using the orthogonal table to propose optimal combination and objectively check figures from the reciprocal action and implemented the multicollinearity analysis to calculate correlation among design factors and contribution rates and impacts for each factor.

Categorizing importance in each design factor from calculating contribution rates may visualize the portions in the concept and the application level for design elements were selected through impact analysis for each level.

Based on the results and application to the subsequent regressive analysis formula, the study compared ZEB model energy consumption compared to the standard model and set up a foundation for future ZEB implementation.

However, the study did not perform researches on the facility system for ZEB implementation and new and renewable energy sources, failing to implement and propose the ZEB system. Therefore, subsequent studies will propose the Zero Emission Building through complex application of the new and renewable energies and energy-saving system based on the study results.

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