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Effects of Construction Elements on Energy Saving and Carbon Reduction

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Abstract

To respond to continuing global warming and rising environmental awareness, owners in the construction industry, a leading industry worldwide, must possess a greater awareness of energy-saving and carbon reduction construction products and their corporate social responsibilities. Construction industry owners are frequently required to focus on profit as the primary goal of projects for corporate sustainability. This study examined the effects on energy saving and carbon reduction efforts on the use of green construction elements in existing construction projects. The analysis results revealed that applying energy-saving and carbon reduction construction elements improves sales prices and rates substantially, even though it raises construction costs. In response to the evolution of green technology and the increase in consumer environmental awareness, future construction projects should increase the application of new energy-saving and carbon reduction construction materials. The results of this study provide a reference to construction industry owners implementing green construction materials.

Keywords: construction industry, green energy, element, energy-saving, and carbon reduction

I. INTRODUCTION

According to the 2019 climate research report by the World Meteorological Organization, carbon emissions from 2015 to 2019 were 20% higher than for 2011 to 2015. The global average temperature from 2015 to 2019 was the highest recorded in human history.

The Katowice Climate Package was completed with most of its articles approved at the 24th Conference of the Parties in Katowice, Poland, in December 2018; the package was to be formally implemented in 2020. All countries, whether developed or developing, are obliged to fulfill the Nationally Determined Contributions and submit a report every five years to limit the temperature increase in the global climate to 1.5–2°C by the end of the 21st century.

This paper discusses the types of energy-saving and carbon reduction materials implemented in construction projects, identified through case research. The effect of the use of these materials on the effectiveness of efforts to save energy and reduce carbon emission was explored. The following topics were investigated:

(1) Comparison of arbors and shrubs, as construction elements, regarding their effectiveness in energy saving and carbon reduction.

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(2) Comparison of heat pump, solar energy, and gas water heaters for their effectiveness in energy saving and carbon reduction, as construction elements
(3) Effectiveness of reclaiming rainwater, as a construction element, in energy saving and carbon reduction

II. LITERATURE REVIEW

The life cycle assessment (LCA) of a building encompasses the life, aging, disease, and death of the building. In addition to daily consumption, LCA considers consumption during the construction process, the environment of the building, and many other factors. Scholars have organized and divided LCA into phases, including construction material production, construction material transportation, construction implementation, daily use, renovation and maintenance, demolition, waste disposal, and recycling and regeneration (Chang, 2002). In Japan, a life cycle of 50 years used to be adopted for office buildings to assess economic factors. Primary planning, design, and construction accounted for 26% of costs; postconstruction operation, maintenance, and renovation accounted for 27%; water and power energy expenditures over 50 years accounted for 21%; and tax, interest, insurance, and other general management expenditures accounted for 26% (Japan Federation of Architects and Building Engineers Associations, 1994). Professor Hsien-Te Lin and some Japanese studies have indicated that the average lifespan of buildings available on the market is 30–40 years. However, the average lifespan of such buildings is determined by the life cycle standard commonly accepted by society, which cannot be used as the basis for building LCA because the average life cycle of buildings gradually increases with the technological advancement in the building industry. The Low Carbon Building Alliance (LCBA) (2020) suggested that International Financial Reporting Standards (IFRS) be adopted to facilitate understanding of building LCA. Since 2005, the IFRS has been applied to property-related forms in over 7000 enterprises in the European Union. IFRS are accounting standards adopted by more than 100 nations. The basic principles of IFRS are market-price-oriented; thus, IFRS can evaluate assets and debts with the fairest possible prices. For fixed-asset value assessment, the use of the component accounting method is recommended. For construction investment financial assessment, assessment of components including building structure, exterior architecture, interior decoration, and building facilities is recommended. Each component has a corresponding life cycle. The method is recommended because it conforms to the norms of building component contracting and construction.

III. RESEARCH METHODOLOGY

This study employed case research and document analysis as follows.

III.1 Case research

The study focused on construction projects proposed by the author's company as the researched cases. The use of commonly employed green construction elements in the projects was analyzed and compared to clarify their effectiveness in environmental protection.

III.2 Document analysis

Data representing market information relevant to the case projects were collected to ensure the accuracy of the study.

III.3 Research procedure

1. Case selection:

   Four case projects by the case company that incorporated green construction elements were selected as research targets.

2. Commonly used green energy construction elements:

   Plants, heat pumps, solar energy, and rainwater, which were the green construction elements employed in the case projects, were compared with conventional construction elements with regard to the following topics:

   2.1 Energy efficiency of the green construction elements:

   The energy efficiency of the selected green construction elements was discussed.

   2.2 Carbon reduction effectiveness of the green construction elements:

   The effectiveness of the selected green construction elements in carbon reduction was discussed.

3. Cross-comparison analysis:

   Cross-comparison analysis was conducted on the aforementioned data retrieved for the review, focusing on energy saving and carbon reduction.

4. Conclusion:
   A conclusion was drawn according to the results of the comparison to verify the practicality of the green construction elements for energy saving and carbon reduction.

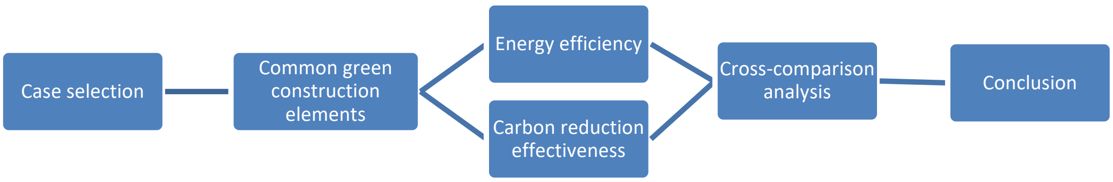

Figure 1. Research procedure

III.4 Research case introduction

The basic background information of the four construction projects used in this study is as follows.

Case A

1. Project name: Ging Sheng
2. Lot size: 972.05 m^2 (294.05 pings)
3. Construction form: Four RC-constructed standalone villas with one underground floor and five aboveground floors for four households

4. Construction completion date: October 2007

Case A Description

1. Green building elements implemented in this project include the following:
    1.1 Vegetation greening on the ground floor
    1.2 Plants on the rooftop deck and balcony
    1.3 The permeable pavement on the garden on the ground floor
    1.4 Rainwater recycling devices
2. The total number of plants in the project: 84 trees, 200 shrubs, and 266 m^2 greening areas.
3. Tiles are mostly used for paving the floor, rooftop deck, and balcony in traditional construction projects.

Case B

1. Project name: Ging Sheng Phase III
2. Lot size: 503.96 m^2 (152.44 pings)
3. Construction form: Four RC-constructed standalone villas with no underground floor and five aboveground floors for four households
4. Construction completion date: March 2009

Case B Description

1. Green building elements implemented in this project include the following:
    1.1 Vegetation greening on the ground floor
    1.2 Plants on the rooftop deck and balcony
    1.3 Rainwater recycling devices
2. The project is in business category 2 for land use zoning with a higher building coverage ratio and smaller land area for each household. Therefore, the greening area on the ground floor is smaller. Green plants are mainly distributed on the balcony and the rooftop deck.
3. The total number of plants in the project: 40 trees, 100 shrubs, and 58 m^2 greening area.
4. Tiles are mostly used to pave the ground floor, rooftop deck, and balcony in traditional construction projects.

Case C

1. Project name: Ging Sheng Phase V
2. Lot size: 527.46 m^2 (159.56 pings)
3. Construction form: Three RC-constructed standalone villas with no underground floor and five aboveground floors for three households
4. Construction completion date: April 2013

Case C Description

1. Green building elements implemented in this project include the following:
    1.1 Vegetation greening around the fence on the ground floor
    1.2 Plants on the rooftop deck and balcony
    1.3 Rainwater recycling devices
2. The ground floor of this project is mainly used as the parking space. Therefore, the greening area on the ground floor is smaller. Green plants are mainly distributed on the balcony and the rooftop deck.
3. The total number of plants in the project: 60 trees, 90 shrubs, and 132 m^2 greening areas.
5. Tiles are mostly used to pave the ground floor, rooftop deck, and balcony in traditional construction projects.

Case D

1. Project name: Ging Sheng Phase VII
2. Lot size: 1871.0 m^2 (565.97 ping)
3. Construction form: 18 RC-constructed standalone villas with no underground floor and three or four aboveground floors for 18 households
4. Construction completion date: October 2017

Case D Description

1. This project provides community-based standalone housing. The main target consumers are assumed to be young first-time buyers. The green building elements implemented in this project include the following:
    1.1 Vegetation greening around the fence on the ground floor
    1.2 Plants on the rooftop deck and balcony
    1.3 Solar water heating and heat pumps
    1.4 Induction heating stove.
2. The open space of the ground floor is used as the driveway and parking space, except for the greening area implemented on the green belt separating households and in corners. Therefore, the greening area on the ground floor is smaller. Green plants are mainly distributed on the balcony and the rooftop deck.
3. The total number of plants in the project: 74 trees, 72 shrubs, and 205 m^2 greening area.

The neighborhood of the project lot is free of external pipelines for natural gas. The use of bottled gas is not only hazardous but also causes inconvenience due to the need for constant replacement of empty bottles. Therefore, this project involves the installation of solar water heaters and heat pumps instead of gas heaters. Induction heating stoves are used to replace the conventional built-in gas stoves. The facilities save energy, reduce carbon emissions, and are economical for long-term use.

IV. FINDING AND DISCUSSION

IV.1 Effectiveness of Arbors and Shrubs in Energy Saving and Carbon Reduction

With the 40-year life cycle of a building as the analysis criterion, the carbon reduction effectiveness of the arbors and shrubs employed in the case projects was calculated (Table 1), revealing that arbors are much more effective in carbon reduction than shrubs.

Table 1. Carbon reduction effectiveness of arbors and shrubs

Case name	Adopted item	No.	Amount of carbon reduced in the	Amount of carbon reduced in 40 years (MT)
Case A	Arbor	84	1,008.0	40.32
	Shrub	200	375.0	15.00
Case B	Arbor	40	480.0	19.20
	Shrub	100	187.5	7.50
Case C	Arbor	60	720.0	28.80
	Shrub	90	168.8	6.75
Case D	Arbor	74	888.0	35.50
	Shrub	72	135.0	5.40

IV.2 Effectiveness of Heat Pumps, Solar Energy, and Natural Gas in Energy Saving and Carbon Reduction

With the 40-year life cycle of a building as the analysis criterion, the carbon reduction effect of the heat pumps, solar energy, and gas water heaters employed in the case projects was calculated (Table 2) to reveal that heat pumps are much more effective in carbon reduction than solar energy and natural gas.

Table 2. Carbon reduction effectiveness of heat pumps, solar energy, and gas water heaters

Type of water heater	Fuel	Average annual usage	Total usage in 40 years	Amount of carbon reduced in the 1st year	Amount of carbon reduced in 40 years (MT)
Gas	Liquefied gas (KG)	365	14600	1,160.7	46,428.00
Solar energy	Electricity (˚)	1540	61600	814.7	32,588.00
Heat pump	Electricity(˚)	1423.5	5694	753.0	30,120.00

IV.3 Effectiveness of Rainwater Reclamation for Energy Saving and Carbon Reduction

With the 40-year life cycle of a building as the analysis criterion, the carbon reduction effectiveness of direct current and alternating current power systems was calculated (Table 3), revealing that rainwater reclamation enables substantial carbon reduction.

Table 3 Effectiveness of rainwater reclamation in carbon reduction

Case name	Rainwater reclamation	Unit	Amount	Amount of carbon reduced in the 1st year	Amount of carbon reduced 40 years (MT)
Case A	Yes	M3	136	21.0	0.84
Case B	Yes	M3	31	4.7	0.19
Case C	Yes	M3	67	10.2	0.41
Case D	No	M3	0	0.0	0.00

V. CONCLUSION AND SUGGESTION

V.1 Conclusion

1. Using arbors dramatically increases carbon reduction effectiveness:
   As shown in Table 1, arbors are more effective than shrubs in the areas of energy-saving, carbon reduction, and environmental protection.
2. Using heat pumps markedly increases carbon reduction effectiveness:
   As shown in Table 2, heat pump water heaters are more effective than solar energy and gas water heaters for energy saving, carbon reduction, and environmental protection.
3. Reclaiming rainwater greatly increases carbon reduction effectiveness:
   As shown in Table 3, rainwater reclamation substantially improves energy saving, carbon reduction, and environmental protection.

V.2 Suggestions for future studies:

1. Future studies can employ more diverse energy saving and carbon reduction equipment than those investigated in this study, such as low-emissivity glass, direct current power systems, and smart power-saving systems.
2. In the past, a 40-year LCA was commonly adopted for green building assessment in Taiwan. Therefore, this commonly accepted life cycle standard was also adopted for this research design. Per the trend of increasing the lifespan of buildings and new seismic regulations, particularly relating to the carbon footprint assessment of buildings, high-quality buildings should be selected as the main research targets, and longer life cycle standards should be adopted to meet practical needs. In the United Kingdom, an LCA of 60 years is adopted for houses (Energy Commission of Ministry of Economic Affairs, 2002). In Japan, the Building and Equipment Life Cycle Association mostly simulate value engineering depreciation and amortization plans for over 60 years (BELCA, 2012). Therefore, the LCBA recommends that 60-year life cycles are adopted as the standard period for RC-constructed buildings (LCBA, 2020).

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