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Relationship of Ceramic Insulation Panel System Development and Verification of LCC

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Abstract

In this study, life cycle cost (LCC) is analyzed according to insulation panel system type using a deterministic LCC analysis method. Through this analysis, it was found that the construction cost in the deterministic LCC analysis for Ceramic panels was low compared to the construction cost for metal and stone panels. Also, the difference in cost between the Ceramic panel and the metal panel was about 2 times. In the area of maintenance cost, it was found to be similar to the previously analyzed construction cost, in which the metal panel has the highest cost due to the high cost of construction and the frequent need for maintenance. In the case of the stone panel, a small difference in cost is shown compared with that of the Ceramic panel, but the cost is higher than the Ceramic panel. Regarding the cost of waste disposal, the Ceramic panel can reduce the cost by at least 1.5 times and up to 2 times compared to other panel systems. Finally, in the analysis of sensitivity according to changes in discount rates, the Ceramic panel and metal panel systems have a similar cost, and the cost of the metal panel is a bit larger than that of other panel systems. Thus, in the subjects used in the analysis, the Ceramic panel system shows the highest economic benefits.

Keywords : life cycle cost, insulation panel system, economic analysis, deterministic analysis

1. Introduction

1.1 Research background and objective

Of total energy consumption in Korea, building structures accounted for about 30%, and of total energy consumption in Seoul Metropolitan city, the construction sector accounted for about 60%. For this reason, it is urgent that efforts be made to achieve energy savings in the area of building structures. With the green growth policy recently promoted by the Korean government, laws and regulations related to energy saving are getting tougher. In addition, interest in green buildings has been on the rise in the public and private sector[1]. To save energy, installing insulation panels at a more affordable price is more important than anything else[2].

However, the insulation system that is currently in wide use is not only expensive but is also poorly maintained, resulting in a short service life. In addition, there are difficulties and dangers inherent to installing insulation panels due to their heavy weight.

For these reasons, this study aims to develop an

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integrated structural insulation panel system in which a structure and internal and external insulation panels are incorporated as one by placing the insulation panels on the internal and external walls of the structure during concrete placement. The panel is a Ceramic-type panel that can secure a heat conductivity of 0.1 W/m.K, achieving simple installation and preventing structural defects on the concrete surface as well as improving heat efficiency. Long-term economic feasibility should be evaluated based on the LCC method in order to perform a comprehensive review from the design phase that includes the performance of the Ceramic panel under development, construction techniques, maintenance and economic feasibility.

Therefore, we developed a new ceramic panel system with effective insulation for the external wall, and performed LCC analysis on the ceramic panel system developed in this study and the existing ones to ultimately suggest an affordable panel system for the external wall.

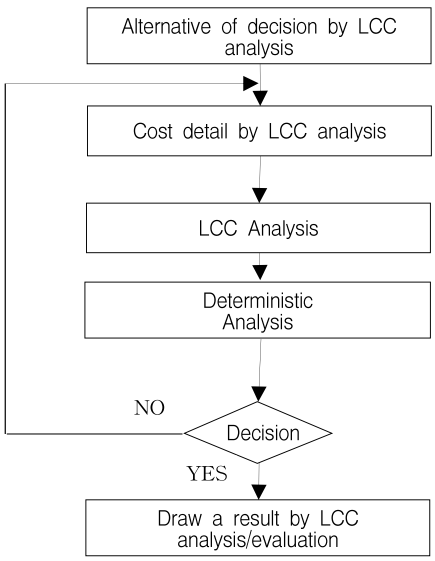


Figure 1. LCC analysis process in this study

1.2 Research scope and method

The deterministic LLC analysis was performed for insulation panels for the external wall to select the optimal panel system for the external wall.

VESOFT was used as the LLC analysis program. The input variables and DB data necessary for the analysis were first researched and then input.

The 45-year basis was used as the period of depreciation for the LCC analysis by referring to the Corporation Tax Law, and Figure 1 indicates the LCC analysis process.

2. Theoretical review

2.1 Definition of LCC

LCC refers to all the expenses spent through the life cycle, including the initial investment cost (construction cost, design cost, supervision cost, compensation expenses, etc.), maintenance cost (inspection and diagnosis cost, management fee, energy cost, repair cost, replacement cost, reinforcement cost, etc.), user expenses, dismantling and disposal cost, residual value and others[3].

2.2 Research trends of deterministic LCC analysis

Before the research was performed, the existing literature on the deterministic LCC analysis was reviewed. The studies recently done by Chung et al.[4], Lee et al.[5], Joe and Lim[6], and Choi et al.[7] all used deterministic LCC analysis. Chung et al.[4] sought to suggest the most economical insulation in terms of energy loss of heating pipe and cost reduction by comparing generally used insulation materials and insulation materials with low thermal conductivity, because heating pipes are known as one of the main factors influencing energy loss. In addition, Lee et al.[5] conducted an LCC analysis comparing the economic feasibility of the existing cooling and heating system and the new cooling and heating system using geo-thermal energy, one of the new renewable energies. Joe and

Lim[6] implemented an economic assessment comparing an existing general window system and a window system with built-in type blinds, and Choi et al.[7] conducted economic evaluation of a rooftop waterproofing method using the LCC analysis to suggest the optimal rooftop waterproofing method.

Table 1. Period of Depreciation of the Structure by Corporate Tax Law

Se-ction	Period of Depreciation and Standard Durable Years (Min-Max)	Structure and Assets
1	5 year (4Yr～6Yr)	Car and Delivery equipment Tool, Equipment part
2	12 year (9Yr～15Yr)	Ship and Air plane
3	20 year (15Yr～25Yr)	Built of brick, Built of block, Built of Concrete, Built of sand, Built of mortar, and Structure
4	40 year (30Yr～50Yr)	Steel frame·Reinforced concrete, Built of stone and Built of Steel frame structure

Table 2. Changes in annual real discount rate(%)

Year	Interest rate of deposits (%)	Inflation(%)		Real discount (%)
		Consumer price index (2005=100)	Inflation rate	
2001	5.4	88.3	4.0	1.4
2002	4.7	90.8	2.8	1.8
2003	4.2	93.9	3.4	0.7
2004	3.8	97.3	3.6	0.1
2005	3.6	100	2.8	0.8
2006	4.4	102.2	2.2	2.2
2007	5.1	104.8	2.5	2.5
2008	5.3	109.6	4.7	0.9
2009	2.5	117.3	2.8	0.3
2010	2.5	120.7	2.9	0.4
Average	4.2		3.2	1.0

3. Basic assumptions for the LCC analysis

3.1 Period of depreciation and discount rate for LCC analysis

General service life of the insulation panel system for the external wall is stipulated similarly to the service period of the depreciation of a concrete structure in Corporate Tax Law Enforcement Regulation Clause 3, Art. 15. As the service period of depreciation of a concrete structure is set between 30 years and 50 years, the period of depreciation was set to be 45 years for the LCC analysis[7].

The real discount rate was set by referring to the official rate and the consumer price index(CPI) based on the statistical data(2001-2010) provided by Bank of Korea and Statistics Korea, and 1.0% was applied as the real discount rate calculated on average by applying the following equations[8,9].

$$I_R = \frac{1+I_n}{1+F} - 1$$

I_R = Real discount rate, I_N = Interest rate of deposits
F = Inflation

3.2 LCC analysis method

The design cost and construction cost were analyzed as the initial cost for the deterministic LCC analysis. A discount rate of 1.0% was applied to the costs occurring for the 45-year service life to convert to present value. The following conversion formula was used for the LCC analysis[10].

$$PW = FW \times \frac{1}{(1+i)^n}$$

(PW=Present Worth, FW=Future Worth, i=Discount Rate, n=Period)

3.3 Repair and replacement cycle

As indicated in Table 3, the repair and replacement cycle of each panel system was set based on the criteria on the long-term maintenance plan for insulation wall panels stipulated in the Housing Law Enforcement Regulation.

Table 3. Maintenance cycle and percent with insulation wall panel types

Panel systems	Items	Repair cycle (Year)	Repair percent (%)	Replac-ement cycle (Year)
Ceramic panel	Ceramic panel	8	15	20
	ㄷ-channel	10	20	30
	L-Clip	10	20	30
	Balt	10	20	30
	Anchor bolt	10	20	30
	Bracket	10	20	30
	Silicon	6	100	-
Metal panel	Stainless panel	10	20	30
	Square pipe	10	10	25
	Fastner	10	20	30
	Silicon	6	100	-
	Filler	6	100	-
Stone panel	Marble panel	25	5	30
	ㄴ-angle	10	20	30
	Regulate valve	10	20	30
	Check pin	10	20	30
	Anchor balt	10	20	30
	Silicon	6	100	-

3.4 Energy cost

The energy cost for each panel system was researched based on the annual energy cost data for an apartment building collected through advice from experts with at least 5 years of practical experience at S Company, which is specialized in facilities. Taking into account that glass wool was used for each system, there seemed to be no significant differences in energy cost, and no analysis was done.

3.5 Estimation of dismantling and disposal cost

The actual cost of dismantling and disposal could not be estimated, and the approximate cost was applied based on the cost data (from the most recent 5 projects) from T Company specialized in the dismantling and disposal of apartment external wall panels.

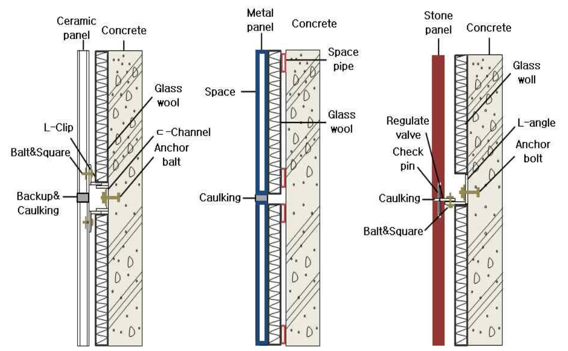
Table 4. Waste disposal of building(Won/m^2)

	Waste	Disposal
Ceramic	70,000	80,000
Metal	100,000	125,000
Stone	81,000	82,000

4. Economic feasibility analysis of the insulation wall panel system

4.1 Composition of the insulation wall panel system

Figure 2 illustrates insulation wall panel types, and Table 5 indicates the thermal conductivity by insulation wall panel type. Extrusion ceramic panels (a) consist of a ceramic panel made of cement and silica sand, filling material, ㄷ–channel, L–clip, anchor bolts, glass wool and external wall. The ceramic panel was inserted after fixing the ㄷ–channel using bolts, and was filled with filling materials in the vacant space to prevent leakage. In addition, glass wool was used for the auxiliary insulation.



(a) Ceramic panel (b) Metal panel (c) Stone panel

Figure 2. Detail of insulation wall panel types

Table 5. Thermal conductivity with insulation wall panel types

Panel system	Material Kinds	Heat Transmission Coefficient W/mK)
Ceramic Panel	Ceramic	0.51
Metal Panel	Stainless	80.00
Stone Panel	Marble	0.67

Metal panels (b) consist of a metal panel made of stainless material, angular pipe, glass wool, and external wall. The angular pipe was fixed using bolts to settle the metal panel, and there were some vacant spaces that could be vented at an external impact.

Stone panels (c) consist of a stone panel made of marble, L-angle, anchor bolts, glass wool and external wall. The stone panel was inserted by fixing the L-angle using bolts. With stone panels, there is the risk of a safety accident due to its heavy weight.

4.2 Deterministic LCC analysis

4.2.1 Initial investment cost

Table 6 and Figure 3 indicates initial investment cost by insulation wall panel type, calculated using the standard per-unit costing method including material of extrusion ceramic panel, metal panel, and stone panel, and labor cost.

The initial investment cost by insulation wall panel system was determined to be KRW105,568/m^2 for the extrusion ceramic panel, KRW185,460/m^2 for the metal panel, and KRW144,445/m^2 for the stone panel. The extrusion ceramic panel is shown to be about KRW 80,000/m^2 less expensive than the metal panel. The metal panel cost was determined to be expensive due to its high material cost and the difficulty of workers in construction.

In addition, the stone panel was shown to be about KRW40,000/m^2 less expensive than the metal panel. The analysis found that the metal panel was most expensive in terms of the initial construction cost, and was less advantageous than other insulation panel types.

4.2.2 Maintenance cost

Table 7 and Figure 4 indicate the maintenance cost by insulation wall panel type. For the extrusion ceramic panel, the cost is shown to be less expensive than that of the metal panel, while the maintenance cost is shown to be much less expensive, at KRW110,000/m^2 less than the metal one. It was determined that this is because the original materials for the ceramic panel are cheaper, and the repairs are significantly simpler than for the metal one.

Table 6. Construction cost of insulation wall panel types (Won/m^2)

Panel system	Item	Size	Unit	Amount	Cost	Sum
Ceramic panel	Based panel	THK 35	m^2	1.05	28,000	29,400
	ㄷ-Channel	100×50×7.5	kg	10.6	1,300	13,780
	L-Clip	50×50×6	EA	3.2	500	1,600
	Balt	∅10×35	EA	3.2	500	1,600
	Anchor balt	∅12	EA	1.0	320	320
	Bracket	75×75×6	EA	1.0	1,500	1,500
	Metal painting	Anticorrosive paint	kg	10.6	150	1,590
	Metal installation	-	kg	10.6	450	4,770
	Glass woll	600×1200mm	EA	1.0	20,000	20,000
	Panel installation	-	m^2	1.0	18,000	18,000
	Silicon	R-789	m^2	1.0	5,500	5,500
	Equipment costs	-	m^2	1.0	1,000	1,000
	Shipping costs	-	m^2	1.0	1,000	1,000
	Safety control cost	-	%	1.88		1,505
	miscellan-eous cost	-	%	5.0		4,003
	Sum	-	-	-		105,568
Metal panel	Square pipe	0.04×0.04×6m	EA	1.0	15,660	15,660
	Fastener	-	EA	1.0	100,000	100,000
	Panel (material)	-	m^2	1.05	30,000	31,500
	Panel (Fictional)	-	m^2	1.05	12,000	12,600
	Silicon	-	EA	1.0	4,500	4,500
	Filler	15m/m	m	30.0	40	1,200
	Glass wool	600×1200mm	EA	1.0	20,000	20,000
	Sum	-	-	-	-	185,460
Stone panel	Stone panel	-	m^2	1.05	65,000	68,250
	L-Angle	600×600×20	EA	3.2	5,000	16,000
	Balt	∅10×35	EA	3.2	500	1,600
	Anchor balt	∅12	EA	1.0	320	320
	regulate valve	400×400×10	EA	1.0	5,000	5,000
	Check pin	75×75×6	EA	1.0	1,500	1,500
	Glass woll	600×1200mm	EA	1.0	20,000	20,000
	Metal installation	-	kg	10.6	450	4,770
	Panel installation	-	m^2	1.0	18,000	18,000
	Silicon	R-789	m^2	1.0	5,500	5,500
	Equipment costs	-	m^2	1.0	1,000	1,000
	Shipping costs	-	m^2	1.0	1,000	1,000
	Safety control cost	-	%	1.88		1,505
	Sum	-	-	-	-	144,445

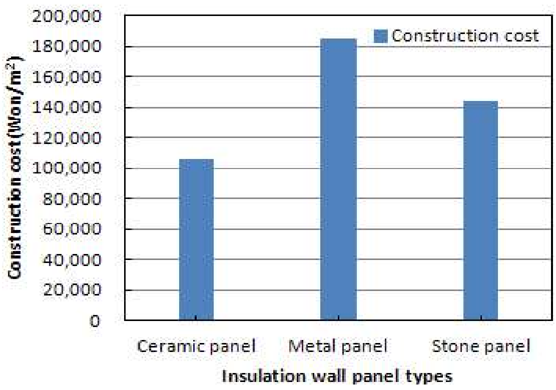


Figure 3. Construction cost of insulation wall panel types (Won/m^2)

Table 7. Maintenance cost of insulation wall panel types (Won/m^2)

Types	Repair cost	Replacement cost	Sum
Ceramic panel	53,802	57,789	111,591
Metal panel	105,522	119,122	224,645
Stone panel	44,136	67,567	111,703

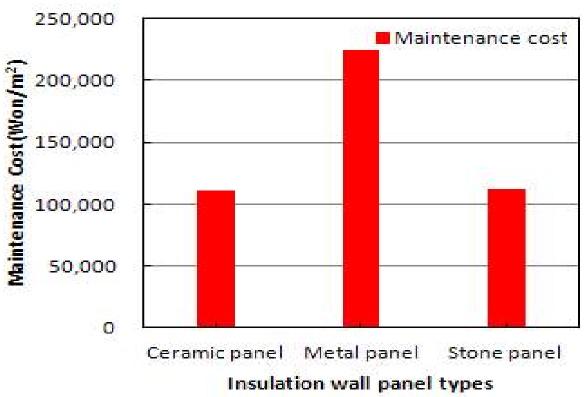


Figure 4. Maintenance cost of insulation wall panel types(Won/m^2)

In addition, for the stone panel, the cost is shown to be similar to that of the extrusion ceramic panel, which was much less expensive than the metal panel. The repair and replacement cost is shown to be significantly different from that of the ceramic panel. In terms of repair cost, the stone panel is cheaper, as the ceramic panel has more repair items than the stone panel. In terms of replacement cost, the stone panel is more expensive, as the subsidiary materials of the stone panel are more expensive than those of the ceramic one.

4.2.3 Dismantling and disposal cost

Table 8 and Figure 5 indicate the dismantling and disposal cost. In terms of dismantling and disposal cost, it was shown as KRW150,000/m^2 for the ceramic panel, KRW225,000/m^2 for the metal panel, and KRW163,000/m^2 for the stone panel. The cost difference between the panel types ranged from about 10% up to 50%.

Table 8. Waste Disposal cost with insulation wall panel types

Section	Waste Disposal cost(Won/m^2)
Ceramic panel	150,000
Metal panel	225,000
Stone panel	163,000

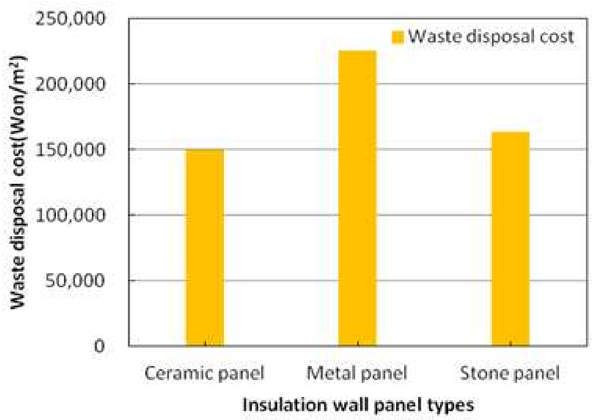


Figure 5. Waste Disposal cost of insulation wall panel types(Won/m^2)

4.2.4 Sensitivity analysis

Figure 6 shows the sensitivity analysis performed by varying the discount rate, which is assumed to change from 1.0% to 3.0% in increments of 0.5% each. Overall, the higher the discount rate, the bigger the change in LCC cost. The changes in LCC cost according to discount rate were shown to be similar in the ceramic and stone panels, while significantly larger in the metal one.

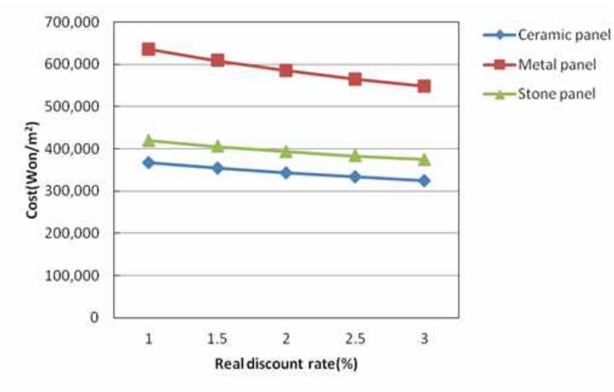


Figure 6. Sensitivity Analysis with Insulation wall panel types

5. Conclusion

In this study, a comparison of the economic feasibility of the existing wall panel systems and the newly developed ceramic wall panel was performed using deterministic LCC analysis and the research findings from the analysis are as follows:

1) In terms of the initial investment cost, the extrusion ceramic panel was cheapest, while the stone and metal panels were more expensive than the ceramic one. The cost of the metal panel was about twice as high as that of the ceramic one.

2) In terms of the maintenance cost, as with the result of the initial investment cost, the metal panel was the highest due to its high initial investment cost and subsidiary materials cost, while the ceramic and stone panels were shown to be about KRW50,000/m^2 and about KRW60,000/m2, respectively, a slight difference, but the ceramic panel was shown to be the cheapest.

3) In terms of the dismantling and disposal cost, the ceramic panel was reduced in cost from about 10% up to 50% compared with other panel types.

4) In the sensitivity analysis, as the discount rate was increased, the changes in the LCC cost of the metal panel were shown to be significantly larger than those for the other panel types, while changes in the LCC cost of the ceramic and stone panels were shown to be similar.

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