STUDY ON LCC ANALYSIS OF BUILDING ACCORDING TO STRUCTURES – FOCUSING ON MILITARY ESTABLISHMENTS –

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ABSTRACT : Approximately 25% of military establishments became superannuated to unable perform their function, and it influences on the environment by construction wastes and the waste of national budget, as there is no rational and objective standard even though old facilities have been replaced through modernization project. Therefore, it has been searched to introduce industrial building system that can cope with the new building-construction and transference for the improvement of existing military establishments. However, as there is no economical estimation standard for practical use, industrial building-construction is still remaining at the initial stage, and the study is insufficient too.
So. in this study, I would like to develope LCC cost model for rational LCC comparative analysis between industrial construction system (Modular) and existing reinforced concrete structure and cage, and to evaluate economical efficiency through case analysis.

Key words : LCC(Life Cycle Cost), military establishments, industrial construction, economical efficiency evaluation, Lcc cost model

1. INTRODUCTION

1.1 Background and purpose of study

At present, new construction method such as dry construction is intended in Korea, as demands on quality of building increases and construction labor is lacking. Also, demands on eco-friendly construction system that can move and reuse considering of environment and can decrease constructing period is increasing. So, the army has searched system to appropriately cope with the new construction and transference of establishments according to improvement of establishments in functional and social value, improvement of military establishments and change of the number of users etc. The system that can most appropriately cope with military establishments requiring mobility and reuse is industrial construction system. However, domestic introduction is still at the initial stage, and economical evaluation standard and study to practise it is still insufficient.

Like this, it is determined that demand on Modular system would be increase, as the demand on structural change in construction business, eco-friendly and high-efficient building increase.

So, in this study, I would like to develop LCC cost model for the LCC comparative analysis of existing RC structure, STEEL structure and Modular system on military establishments, and to evaluate economical efficiency through case analysis.

1.2. Study range and method

For comparative analysis of LCC targeting military establishments of modular, RC, and steel structure having similar scale, this study developed cost model according to each structure by comparing and analyzing characteristics of methods between existing RC, Steel structure and modular. And by applying the developed cost model to case analysis, LCC was evaluated and analyzed according to each structure, and credibility of cost was confirmed by sensitivity analysis.

2. THEOLOGICAL CONSIDERATION

2.1 Theological consideration of LCC method

2.1.1Definition and necessity of LCC

Life Cycle Cost means the sum of costs generated in each stage of production, use, and disposal in general[*1)]. Therefore, it includes all costs spent for the whole life from planning stage to disposal stage of a building.

Also, as the percentage of maintenance cost is increasing by the development of facility system consisting building and the increase of energy and labor cost, it is unreasonable to make decision by the initial investment cost, and it is required to examine LCC analysis for right decision-making considering of total cost during the life cycle.

2.2 Definition and characteristics of Modular System

Modular system means industrial system that completes construction by processing /assembling Modular Unit of stud-frame type 3D-BOX in the factory, working construction up to 90% according th other process, and moving/assembling it to the field.

As Modular is planned to use after assembling modular during minimum period in the field, after finishing most process such as processing, structure assembling, and panel assembling etc. in the factory, it can be broadly used in school, military camp, emergency establishments, and disaster establishments etc.

2.3 Comparison between Modular, RC structure, STEEL structure method

Table 2-1 compares the characteristics of existing RC structure, steel structure and modular method.

Table 2-1. Comparison of characteristics according to structures

Category	RC structure	STEEL structure	Modular system
Construction period	. Longest construction period	. Shorter than RC structure, but longer than Modular	. Shortest construction period\
Recycle and reuse	. Recycle/reuse is almost impossible	. Main frame can be recycled, but cannot be reused	. Main frame can be recycled Reuse after assembling module (approximately 70%)
Field waste generation	. The most generation of field waste	. Less field waste than RC structure	. The least field waste
Factory production area	. Ready-made construction material	. Parts of frame and ready-made main construction material	. Frame and inner/outer material
Delivery	. Delivery in unit of parts and materials	. Deliver by unit of parts	. Delivery by module unit - limited by road condition
Flat constitution	. Relatively less span, height limit	. Least span and height limit	. Limit of span and floor height by limiting module size
Structural features	. Big burden on load by self weight	. Good for high and long-span structure	. burden of structure weight by using light steel is decreased
Usability	. Excellent thermal resistance, sound proofing	. Weak at noise between floors and vibration	. Security of sound-proofing through separated floor and wall structure
Influence of temperature	. Hard to construct in winter and rainy weather	. Less influenced by temperature	. Least influence of temperature
Uniformity of quality	. Relatively less uniformity of quality	. Relatively high uniformity of quality	. Highest uniformity of quality by factory production of module
Application field	. Less limit of application field	. Less limit of application field	. Construction that same flat side is repeated like school, military camp, boarding house, hotel and office etc.

3. LCC MODEL

3.1 Initial investment model

Initial investment is a model to calculate the cost generated in the early stage of building and is consisted of costs consumed in the stage before using a building after it is completed.

Initial investment(Level 1) is consisted of sum of Level 2 costs, and each costs of Level 2 is consisted of the sum of Level 3 costs.

Table 3-1. Initial investment category

Level 1	Level 2	Level 3
1. Initial investment	A construction cost	A1 Building work expenses A2 Public works expenses A3 Construction work expenses A4 Electric work expenses A5 Facilities work expenses
	B overhead expenses	B1 Construction indirect cost (General administrative cost, safety control cost, insurance etc.)

3.2 Energy cost model

As air-conditioning energy takes the largest portion in energy consumption of a building, expanded degree day method, to calculate annual energy consumption.

3.3 Repair and replace cost model

In this study, repair and replace cost is not calculated standardized on using till the endurance term of building in structure, and only finishing material is calculated. In calculation of repair and replace rate, standard of repair cycle and repair rate of the Ministry of National Defense is applied. Application items for repair and replace are as <Table 3-2>.

Table 3-2. Object part of repair and replace

Category		Elements	
Part	Elements	Floor	
		Ceiling	
		Wall	Outer wall
			Inner wall
		Roof	
	Windows and doors	Window	
		Door	
	Facilities	Electric facility	
		Mechanical facility	

3.4 Dismantling and disposal cost model

Dismantling and disposal cost model is divided into dismantling cost, disposal cost and old material refund cost. Dismantling cost means the cost required to dismantle building, disposal cost means the cost required to dispose wastes. Old material refund cost means the income obtained by selling old material after dismantling the building. Therefore, dismantling and disposal cost means the cost excluding old material refund cost from dismantling and disposal cost. (refer to <Table 3-3>)

Table 3-3. Items of dismantling and disposal cost

Level 1	Level 2	Level 3
1. Dismantling and disposal cost	A dismantling cost	A1 decorative material A2 RC A3 Steel
	B disposal cost	B1 Loading cost B2 Delivery cost B3 Disposal cost
	C Old material refund cost	C1 Steel refund C2 Iron refund

3.5 Opportunity loss cost model

3.5.1 Opportunity loss cost according to moving and reusing

A. Modular system

The transfer/reuse cost of modular system is divided into dismantling/disposal cost according to transfer and reinstallment cost. Transfer/reuse cost is divided into the case of exchanging final finishing by 100% and the case of exchanging only the finishing of joint part.

Table 3-4. Modular system transfer/reuse cost item

Level 1	Level 2	Level 3
1. Transfer/reuse cost	A dismantling/disposal cost	A1 dismantling cost(decorative material, RC) A2 Disposal cost(loading cost, delivery cost, disposal cost) A3 old material refund cost
	B Reinstallment cost	B1 construction cost B2 general expenses

B. RC, STEEL structure

The opportunity loss cost on transfer/reuse of RC and STEEL structure building is divided into dismantling/disposal cost of existing building, initial investment of new building and residual value cost.

Table 3-5. Opportunity loss cost item according to transfer/reuse of RC . STEEL structure

Level 1	Level 2	Level 3
1. Opportunity loss cost according to transfer/reuse	A Dismantling/disposal cost of existing building	A1 dismantling cost(decorative material, RC, iron) A2 disposal cost(loading cost, delivery cost, disposal cost) A3 Old material refund cost
	B Initial investment cost of new building	B1 Construction cost B2 General expenses
	C residual value cost of new building	C1 residual value = new construction cost × (1-number of year passed × depreciation rate) ※ depreciation rate=1/number of years of building

3.5.2 Opportunity loss cost by shortening construction period

When constructing a building, difference of construction period happens because of characteristics of each structure. By using construction period of each structure, I would like to suggest saved cost estimation model.

The calculation of opportunity cost by shortening construction period is as <Formula 5-1>.

TSb = Shortened construction period(month) × (general administrative cost on monthly average + interest cost) <Formula 5-1>

As for the cost that can be saved by shortening construction period, there are general administrative cost and interest cost. The cost is calculated by calculating general administrative cost on monthly average by dividing the whole general administrative cost by the total construction period, and by multiplying it to shortened construction period. Interest cost is the cost to pay occurring when using others' capital not own capital. However, in this study, it is not included into cost considering of the speciality of military establishments.

4. LCC ANALYSIS OF MODULAR, RC STRUCTURE, STEEL STRUCTURE

In this study, LCC on the 3 solutions of Modular, RC and Steel shall be compared and analyzed. <Table 4-1> is standard to calculate cost for LCC analysis.

Table 4-1. LCC analysis standard

Category	Standard value	Remarks
Interest rate	5.37%	. Average regular deposit rate for 6 years between 1999~2004 in Korean domestic bank among main economical index that Korea Bank announced . Examination about uncertainty in sensitivity analysis
Inflation rate	2.85%	. Consumer's price increase rate for 6 years between 1999~2004 in Korean domestic bank among main economical index that Korea Bank announced . Examination about uncertainty in sensitivity analysis
Actual discount rate	2.45%	. $i = \frac{1+i'}{1+j} - 1$ (i : Actual discount rate, i' : interest rate, j: Inflation rate)
Service life	50 years	. Corporation tax act enforcement ordinance (revised on Mar. 05, 2004.)
Initial investment	Standardized on specifications	. Divided into construction cost and general cost, and the construction cost is calculated by specifications and the general cost is calculated by the standard of applying general rate application standard of GPA.
Repair/replace cost	Establishments standard repair cycle of national defense ministry, Repair cycle of Japanese construction ministry	. Divided by repair/replace cost generated by damage or replace cycle of material consisting structure . If repair standard of National defence ministry is not exist, Japanese standard shall be applied
Energy cost	Extended degree day method	. Calculate energy cost in life cycle after calculating annual energy cost and energy consumption using program
Dismantling /disposal cost	Standard cost per ton according to appearance Waste disposal cost and delivery cost	. Divided into dismantling cost for dismantling and waste treatment of structure, disposal cost, and old material refund cost that is income by selling system having residual value
Integration of costs	Constant value Present value	. Present value of aperiodic cost: cost occurring once in the n th year $P = F\frac{1}{(1+i)^n}$. Present value of repeated cost: cost occurring equality every year $P = A\frac{(1+i)^n - 1}{i(1+i)^n}$

4.1 Initial investment analysis

<Table 4-2> is comparison of initial investment cost of each structure. Initial investment cost is calculated by the order of STEEL(95%) < Modular (100%) < RC(104%) standardized on modular, and steel structure is analyzed to be most economical.

Table 4-2. Comparison of initial investment cost according to structures

(Unit: won)

Section	Division	Modular	RC	STEEL
		Amount	Amount	Amount
Construction cost	Construction expenses	20,392,503	74,131,737	33,272,887
	Engineering works expenses	5,543,234	10,920,202	6,660,495
	Building expenses	1,356,126,556	1,273,101,458	1,229,029,358
	Electrical work expenses	151,346,163	184,995,186	151,346,163
	Machinery work expenses	222,914,852	264,621,590	222,914,852
	Sub total	1,756,323,308	1,807,770,173	1,688,342,312
General expenses	Construction indirect cost	284,276,284	309,675,813	244,223,933
	Sub total	284,276,284	309,675,813	244,223,933
Sum of initial investment cost		2,040,599,592	2,117,445,986	1,887,447,688

4.2 Energy cost analysis

Table 4-3. Energy cost comparison according to structures

Category	Modular			RC		
	Cooling	Heating	Total	Cooling	Heating	Total
Constant value	352,050,550	340,154,350	692,204,900	350,536,950	324,782,800	675,319,750
Present value	201,709,907	194,893,880	396,603,787	200,842,680	186,086,646	386,929,326

<Table 4-3> is calculation of energy cost during life cycle. Modular system was analyzed to consume more energy cost by approximately 2% than RC structure (in both of constant value and present value).

4.3 Repair/replace cost analysis

Table 4-4. Comparison of repair/replace cost according to structures

(Unit: won)

Category		Modular	RC
Total repair/replace cost	Constant value	1,228,872,421	1,326,645,345
	Present value	617,142,556	681,725,302

As modular and inner/external finishing is same in STEEL structure, the repair/replace cost is calculated same too. In case of constant value, it was analyzed that the repair/replace cost is required less by 8% and 10% in present value.

4.4 Dismantling and disposal cost analysis

As <Table 4-5>, dismantling/disposal cost is saved, as disposal cost decreases as disposal cost decreases because old material refund rate is high, even though dismantling cost of Modular system and Steel structure is required more than RC structure.

Table 4-5. Comparison of dismantling and disposal cost according to structures(Constant value)

(Unit: won)

Category	Modular		RC		STEEL	
	Constant value	Present value	Constant value	Present value	Constant value	Present value
Dismantling cost	246,492,241	73,486,086	128,578,440	38,332,753	200,082,260	59,650,000
Disposal cost	114,034,692	33,996,864	232,046,697	69,179,474	144,345,360	43,033,201
old material refund cost	-98,190,000	-29,273,127	-30,606,750	-9,124,710	-68,107,800	-20,304,800
Total dismantling/disposal cost	262,336,934	78,209,823	330,018,387	98,387,517	276,319,475	82,378,401

4.5 Opportunity loss expenses analysis

Table 4-6. Modular transfer/reuse comparison

(Unit: won)

Category	Final finishing 100% replace	Joint replace
	Amount	Amount
Dismantling/disposal cost according to transfer	122,432,329	62,623,755
Reinstallment cost	666,103,497	378,322,907
Total transfer/reuse cost	788,535,826	440,946,662

<Table 4-6> is transfer/reuse cost and divided into dismantling/disposal cost and reinstallment cost according to the transfer. And it compares two cases of exchanging 100% finishing and exchanging joint part only. Joint part replace saves 56% of whole replace.

4.6 Cost integrative analysis

4.6.1 Cost integration in case of considering mobility

Table 4-7. Dismantling/disposal of existing building and new building

(Unit: won)

Category	Structure	No transfer	10th year trasnsfer	20th year transfer	30th year transfer	40th year transfer
Present value	Modular	3,117,102,674	3,463,254,344	3,388,838,440	3,330,420,513	3,284,561,310
	RC	3,284,488,131	5,024,358,156	4,705,747,375	4,450,803,472	4,133,966,384
	STEEL	2,971,478,108	4,507,293,441	4,201,430,908	4,000,370,454	3,736,817,861
Constant value	Modular	3,117,102,674	3,463,254,344	3,388,838,440	3,330,420,513	3,284,561,310
	RC	3,284,488,131	5,024,358,156	4,705,747,375	4,450,803,472	4,133,966,384
	STEEL	2,971,478,108	4,507,293,441	4,201,430,908	4,000,370,454	3,736,817,861

Cost is compared by classifying into case of dismantling RC and steel-structured new building at the 50th year that modular system's service year ends and case of considering residual value.

In case of considering mobility, LCC of constant value is calculated to consume more cost in the order of RC structure(45%) ＞STEEL structure(33%) ＞Modular standardized on Modular. In case of present value, it was RC structure (45~26%) ＞STEEL structure (30~14%) ＞Modular.

4.6.2 Cost integration in case of considering residual value

As for residual value, the value of building was depreciated by using fixed amount method, and in case that the service life of building ends, the residual value was 0%. In case of considering residual value, LCC of constant value was calculated to consume cost in the order of RC structure (27~-1%) ＞STEEL structure (16~-8%) ＞Modular standardized on modular.

In case of present value, it was in the order of RC structure (39~7%) ＞STEEL structure (25~-2%) ＞Modular.

Table 4-8. Dismantling/disposal of existing building, consideration of residual value of new building (present value)

(Unit: won)

	Structure	No transfer	10th year transfer	20th year transfer	30th year transfer	40th year transfer
Present value	Modular	3,117,102,674	3,463,254,344	3,388,838,440	3,330,420,513	3,284,561,310
	RC	3,284,488,131	4,799,716,915	4,354,852,409	3,973,654,781	3,530,563,969
	STEEL	2,971,478,108	4,312,338,515	3,894,245,479	3,580,424,182	3,204,334,838
Constant value	Modular	4,202,560,763	4,643,507,425	4,643,507,425	4,643,507,425	4,643,507,425
	RC	4,449,429,468	5,911,432,047	5,690,695,155	5,267,205,958	4,640,964,456
	STEEL	4,066,750,160	5,410,691,360	5,172,436,893	4,794,947,356	4,278,222,747

4.7 LCC comparative analysis

From the result of analysis in case of dismantling RC and STEEL-structured new building, standardized on Modular, it was analyzed to consume more by approximately 45~26% in RC structure, and approximately 30~14% in steel structure.

As for LCC in case considering of residual value, standardizing on Modular, it was analyzed to consume more by approximately 39~7% in RC structure and approximately 25~-2% in steel structure.

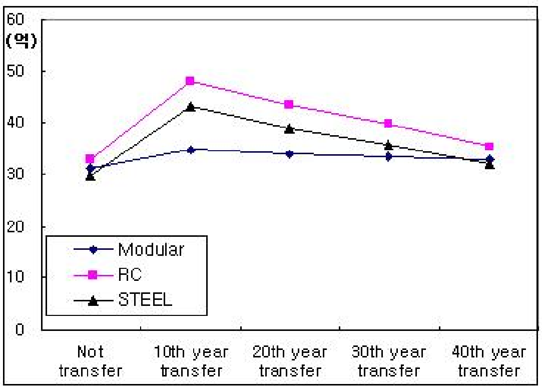

Fig. 4-1. LCC comparison according to structures

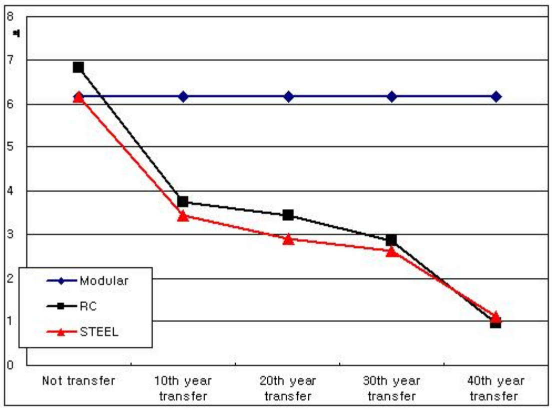

Fig. 4-2. Comparison of repair/replace cost+residual value according to structures

From the result of analysis above, Modular system was found out to be economical regardless of mobility and transfer time, compared to RC structure. And in the comparison with steel structure, it can be economical to reuse using Modular system by 40 years that LCC is calculated to be less and to build newly after 40 years. The reason why LCC of steel structure is calculated less than Modular system after 40 years was analyzed because relatively less repair/replace cost is input than old modular system and because residual value of steel structured new building increases as service life increases.

5. SENSITIVITY ANALYSIS

To analyze how the change in variable value input in LCC analysis step influences on analysis result, real interest rate that can be changed a lot in the future and sensitivity by the change of service life were analyzed. Real interest rate was applied by changing by 1% on the rage of 1.45~5.45% standardizing on 2.45% that was applied to LCC analysis of this study, and service life was analyzed by changing by 10 years on the range of 30~70 years standardized on 50 years. From the result of analysis, it was found out that difference in cost decreases, but the order of LCC consumption has no change, as time goes by.

6. CONCLUSION

1) The case of considering mobility can be divided into two. The cost of dismantling new building is the most economical in Modular, and followed by steel structure(30~-14%) and RC structure (45~26%). And the cost in case of considering residual value was the most economical in modular, and followed by STEEL structure (25~-2%), and RC structure(39~7%).

2) In case of not considering mobility, STEEL structure(95%) was the most economical, and followed by Modular(100%), and RC structure (105%) respectively.

This study result is limited to military establishments, but comparing Modular system to existing RC structure and Steel structure, modular system was found out to be excellent in construction period, mobility and economical efficiency.

If new material and construction method for modular system is developed through constant study in the future and if improvement in principle structure and jointing technique and mass production through automation in production line are done, modular system can be extensively spread.

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