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Apartment Residential Reinforced Concrete Pre-Construction Stage Cost Reduction Checklist Proposal

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Abstract. In the construction business, the proportion of apartment residential and consequent construction cost are increasing every year. Reduction of construction cost is a very important part of the construction process as it is a factor that can cause matters such as winning or losing, price problems, and suspension of construction, etc. This study aims to supplement the limitations of the existing cost reduction checklist produced 12 years ago for effective cost reduction. This covers the reinforced concrete structure in the pre-construction stage, and supplements the classification system of the existing checklist by updating with data obtained through the survey. The new checklist will be able to prevent unnecessary construction delay and increase in construction cost by systematically classifying cost reduction methods and scope of application.

Keywords: Cost reduction, Apartment residential, Pre-construction, Checklist

1. Introduction

1.1. Purpose of the study

The proportion of apartment residential in the Korean construction industry is increasing every year. According to the data, the proportion of apartment residential among the population housing has increased by 8.49% over the past 10 years as of 2020 and is expected to increase steadily in the future (Statistics Korea, 2020).

Construction cost is a factor that greatly influences the success or failure of a construction project and the problem of the selling price. In particular, the increase in construction cost causes construction interruption and delay. This is one of the frequent problems in construction projects, and more research is needed to reduce construction cost to alleviate this problem in the future (Memon, A.H., 2011).

Therefore, this study intends to focus on apartment residential, which accounts for a large proportion of the housing survey results and shows a steady increase. In addition, we intend to supplement the limitations of the existing checklist by creating a new checklist through this. In the global market, it is already common for construction companies to be involved in business planning and design (Kim, W.Y., 2017). Therefore, the completed cost reduction checklist is applied to the pre-construction stage to reduce construction errors through mutual supplementation between designers and builders.

1.2. Scope and procedure of the study

This study modified the cost reduction and classification system specified in Kyung-seop Lee's "Study on the development of a checklist for cost reduction of apartment residential framework construction through case analysis" However, this study does not distinguish the types of apartment residential according to the type of business. The completed checklist should be applied to the pre-construction stage. The procedure for conducting the study is shown in Figure 1 below.

1) Select previous studies to be used as data for the cost reduction checklist for apartment residential and identify the limitations of the existing checklist through interviews with experts.
2) Analyze the construction methods that can supplement the limitations of previous studies through case studies and questionnaires.
3) Establish a new classification system by modifying and adding the investigated methods.
4) Produce a cost reduction checklist by applying a new method, excluding the parts that are not included in the limit in the existing checklist.

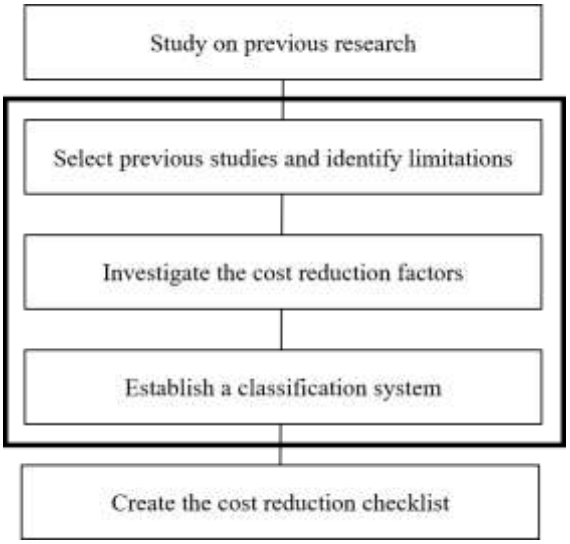


Fig. 1: Research procedure

2. Theoretical study

2.1. Select the previous research

We focused on trends in cost reduction methods that construction companies are dealing with and checklists for apartment residential cost reduction. The previous studies that tried to find effective methods for cost reduction are summarized in Table 1. In addition, Lim Seok-ho, Seol Wook-jae, and Jeong Jun-soo(2020) presented verification and improvement plan on shortening the construction period of a modular apartment residential, and analyzed the factors hindering the shortening of the construction period. In addition, Baek Jeong-hoon(2020) demonstrated the effect of shortening the construction period of a modular building system by comparing and analyzing the conventional method and the modular method. Regarding the cost reduction of apartment residential, Choi Jong-su, Choi Young-jun, and Chae Seong-tae(2009) analyzed in detail the construction cost composition for each construction work of an apartment through total 32 construction improvement case studies to evaluate the cost reduction potential. A Ilmi(2020) developed WBS-based advance checklist to estimate costs for port construction projects by identifying sources that could influence cost reduction in a standardized checklist. Lee Kyung-seop(2010) conducted a study on the development of a cost reduction checklist covering construction work of reinforced concrete structures in apartment residential. It has 662 case data from 85 projects and establishes a systematic classification system. However, since this study was completed 12 years ago, we conducted an interview with an expert in the structural field of K E&C to derive technical limitations. Two limitations were drawn from the interview. First, this study did not specify the steps to apply the cost reduction

checklist. Second, this study did not apply a new technology, that is, a new construction method. Therefore, in this paper, two limitations are supplemented through various methods to complete a cost reduction checklist suitable for the current era.

Table 1. Research and analysis of previous studies

Research title	Researchers	Contents
Analysis of Construction Technology Trends for Nuclear Power Plants Construction with NewConstruction Technology of Overseas Advanced Reactors	Kim Jwa-young and 2 others (2013)	Analysis of new construction methods for shortening the construction period and cost of nuclear power plant construction by reactor type of advanced countries in the world
An Analysis on the Delay Influence Factors of Participants in Construction Project and Its Improvement Measures	Jo Byung-Uk and 2 others (2017)	Analysis of causes of apartment residential construction delay through expert interview
A Study on the Improvement of the Large-scale Apartment Foundation Concrete Pouring Work in South Korea Resource Management using the Queueing Model	Wee Kyung-Soo and 2 others (2021)	Resource leveling through queue model based on case project data Quantitatively analyze the impact on the construction period
A Study of the Development of Apartment's Structural Cost Saving Checklist through the Case Research	Lee Kyeong – Seob and 1 other (2010)	Create a checklist by establishing and analyzing a classification system based on 662 cost reduction cases that occurred in 85 projects

2.2. Cost reduction and pre-construction

Cost reduction in this study can be defined as an activity that can reduce costs based on the initial construction cost while maintaining the functions and performance required by the initial drawings or specifications, or even secure higher quality for the structural part of the apartment residential construction project.

The first limitation of previous studies derived from interviews is that the steps to apply the cost reduction checklist are not specified. This study supplements this

by applying the completed checklist to the pre-con stage. Pre-con is an abbreviation of ‘Pre-Construction’, and the term itself refers to all stages before construction. In practice, it is used as a generic term for project management activities or services performed in the pre-construction stage. In the process of carrying out a construction project, 3 stages of the pre-design stage, the design stage, and the procurement stage, which are stages before the construction stage, are collectively referred to as 'Pre-Construction'. Therefore, this study judges that pre-construction and cost reduction have a close relationship. Accordingly, we intend to bring about a greater effect in reducing construction costs by grafting the completed checklist to the pre-construction stage.

2.3. Construction method theory

The new construction method dealt with in this paper is summarized in 6 items as shown in Table 2 below.

Specifically, the PC method can solve the problem of lack of skilled manpower by minimizing field work and personnel. By reducing the time for on-site manufacturing, it can ultimately bring a great effect in cost reduction. Changing the rebar joint method can have an effect on cost reduction. Rebar joints are prohibited from joining more than half in one place, and places subject to large stress are also excluded. The types of rebar joint methods include overlap joint, weld joint, gas pressure welding, screw joint, slab compression, sleeve filling, and G-Loc splice.

Table 2. Method theory

Method	Theory	Effect
PC method	A method of prefabricating the members in the factory, transporting them to the site, and then assembling and installing them.	Improves the quality of the construction and reduces the time for on-site manufacturing, which can bring about cost reduction.
CWS top-down method	With the top-down method, the retaining wall is supported through the slab diaphragm effect and the steel column is installed using the PRD method.	There is a reduction effect due to reduction of construction cost and shortening period, and the dismantling process of temporary facilities is unnecessary
Floor demolding deck	It is the same as the existing plywood formwork, but basically the deck comes to the site	This can significantly reduce the period and has the advantage not to have a support and has a bright

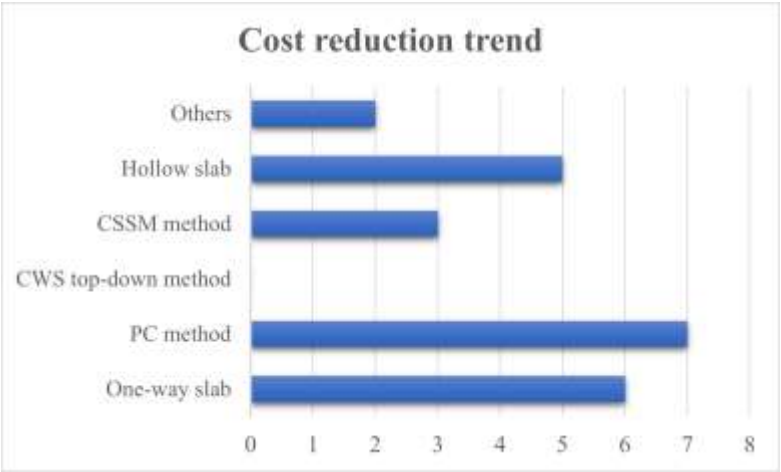
	after reinforcing bars are placed and the lower part is reinforced in a non-pole method.	interior.
LCC method	Refers to the total costs incurred during the entire life cycle of a building, from production to demolition, such as planning, design, construction, operation & maintenance, and disposal.	Appropriate construction methods and materials must be selected by converting the amount that occurs in the overall apartment residential life cycle.
DH-BEAM	This is a girder formwork that acts as a formwork for pouring concrete and is not permanently removed after installation.	Although a formwork is a necessary element in the construction method using concrete, it is desirable to minimize it for manpower and cost reduction, shortening construction period, and improvement of working environment.
Change of rebar joint method	Rebar connection part used in reinforced concrete	Coupler joint corresponding to gas pressure welding joint and mechanical joint are effective in reducing the quantity of reinforcing bars.

3. New construction method for cost reduction and construction error survey

3.1. Cost reduction survey analysis

The survey was carried out with those who have experience in the field of construction and management and supervision. There were 13 subjects, and those in their 30s and 40s accounted for 84.6%, and those with more than 15 years of experience accounted for 61.6%. The survey has two questions: the first is the construction method currently being mobilized for cost reduction, and the second is the factor that increases the cost of construction. The survey results are shown in Figures 2 and 3 below, and the cost reduction trend results are simply expressed as a bar graph. The vertical axis represents construction methods, and the horizontal axis represents the number of respondents. As a result of the first question survey, the

PC method was used a lot in practice at 53.8%, and the one-way slab application accounted for 49.2%, followed by the hollow slab and CWS top-down method. As a result of the second question survey, irregular distribution of labor manpower was cited as the biggest factor increasing the construction cost accounting for 69.2%, and the mismatch between contract terms and actual situation accounted for 61.5%, followed by unfavorable climatic conditions, delay in equipment procurement, and



others.

Fig. 2: Cost reduction trend

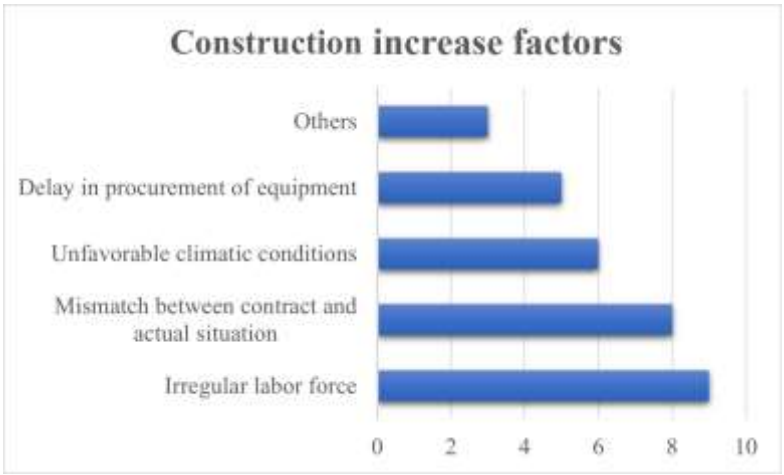
Fig. 3: Construction increase factors

4. How to make a checklist with limitations supplemented

4.1. Establish a new cost reduction classification system

Based on the data obtained through previous interviews, literature review, and survey, the cost reduction classification system for apartment residential that reflects the new construction method was established, as shown in Table 3 (Lee K.S., 2010).

This study's classification of cost reduction activities are classified by construction work, character, and area. Classification by construction work was largely divided into formwork work, rebar work, and concrete work. The



construction cost calculation applied the classification criteria (Kang H.W., 2007). Classification by character consists of over-design considering excessive safety factors, technical change due to structural calculation condition change, design change due to design plan change, new construction method according to the development trend of construction technology, and construction error caused by the difference between the design plan and the site. As for the criteria, only characteristics that can be changed in the pre-promotion stage were selected for classification by character (Lee S.H., 2005). Classification by part was largely made based on habitable space and non-residential space, specified as apartments and parking lots. Based on detailed criteria, it can be divided into 7 categories: Foundation, wall, slab, column, beam, staircase, and crossbar. This classification standard was used to increase practitioners' awareness by using the standard used in academia.

New construction methods include PC, CWS, floor demolding deck, rebar pre-assembly, LCC, and DH-BEAM. In the case of construction errors, a new classification by character was added to supplement the limitations of the previously designed classification system. A cost reduction checklist for apartment residential was created by adding some construction errors, new construction method questions, and design changes in the classification system.

Construction errors were included in the classification system to prevent construction delays by providing the grievances experienced by workers at the site before problems occurs, centered on the inconsistency between contract conditions and the site, unfavorable climatic conditions, and delays in equipment procurement.

4.2. Additional checklist items and how to prepare

Cost reduction can be achieved in a variety of ways. Methods include shortening the construction period, reducing material costs, and reducing construction errors. Questions related to shortening the construction period include the PC method, CWS top-down method, floor demolding tech plate, and DH-BEAM. Methods corresponding to material cost reduction include rebar joint method change, slab change, and LCC technique. Construction error questions include labor manpower planning, appropriate contract period and method introduction, meteorological data utilization, and training on the latest equipment.

The construction work corresponding to the added new construction method and construction error include formwork, concrete, and reinforcing bars, and the area are largely divided into apartments and parking lots. In addition, detailed parts were composed of the foundation, wall, slab, column, and beam. The PC method was applied to rebars, concrete work, walls, slabs, columns, and beams. CWS method, floor demolding deck method, rebar assembly method, LCC method, securing and inputting DH-BEAM and planned labor workforce, introducing appropriate contract period and method, utilizing real-time weather data by site

managers, and up-to-date information on equipment drivers and equipment training were also grouped into each corresponding construction work, part, and character.

As for the item preparation method, as described above, the applicable range for the construction method and plan to be applied may be entered. The additional items are arranged in each classification system, and the scope of application of the cost reduction method is expressed. Therefore, it is possible to write checklist items other than the cost reduction method applied in this paper through this writing method. Based on this, a checklist can be prepared with the question of whether the classification corresponding to the detailed characteristics has been applied.

4.3. How to prepare the checklist questions

We allowed cost reduction practitioners who look at the checklist to check all possible ways to reduce costs. Therefore, the question writing method is to write a question asking whether cost reduction is possible according to the written items. For example, regarding the PC construction method, the question was written, “Do you think that the use of the construction method reduces the on-site labor manpower and shortens the construction period?” In this way, it is written to check whether cost reduction can be derived by shortening the period. Questions such as “Have you secured labor force?” and “Can you use foreign workers?” are prepared for construction errors. This is to ensure that there is no missing part in the question.

In the same way, write the questions as in Table 3. In addition to the new construction method, the cost reduction method currently used in the cost reduction checklist through the existing case analysis can be included, as shown in Table 3.

This study investigated the cost reduction trend through literature review, interviews, and surveys. Based on this, a cost reduction checklist was prepared. Previous studies did not explain the checklist creation method in detail, so it was inconvenient to re-create the classification system to add new construction methods and construction errors. However, in this paper, the checklist writing method is specified in detail so that the next generation can apply the cost reduction technique.

Table 3. Prepare a checklist for additional items

Work	by Part		by Characteristic		Checklist
	Part	Detail part	Characteristic	Detailed characteristics	
R/C	A	W/S/C/B	New construction method	PC method	Is it possible to reduce on-site labor manpower and shorten the construction period by using the new construction method and the PC method?

R	P	W/S	New construction method	CWS Top-down method	Is the CWS top-down method applicable to determining the start time of the above-ground structure when excavating?
R	P	S	New construction method	Floor demolding deck	Is it possible to shorten the construction period by using the demolding deck plate method?
F/R/C	A/P	F/W/S/C/B	New construction method	LCC method	Has an analysis of LCC or a cost-benefit analysis been done?
C	P	F	New construction method	DH-BEAM	Is it possible to reduce on-site formwork production time by using DH-BEAM instead of conventional beams?
R	A/P	B	New construction method	Change of rebar joint method	Are the reinforcing bar is jointed by a coupler joint and a gas pressure welding joint? In the case of parking lot, are the rebar anchorage and joint length applied by examining the detailed formula for each member?
R/C	A/P	F/W/S/C/B	Construction error	Labor manpower plan	Have you secured labor force? Can you use foreign workers?
F/R/C	A/P	F/W/S/C/B	Construction error	Introduction of appropriate contract period and method	Are there any discrepancies between the terms of the contract and the site?
-	-	-	Construction error	Use of weather data	Do field managers have real-time weather data?
R/C	A/P	W/S/C/B	Construction error	Training on The latest equipment	Has the latest equipment training been provided to equipment operators?
R	A	S	Design change	Slab change (Apply one-way slab)	Did you reduce the quantity of reinforcing bars by changing the slab

					(Apply one-way slab)?
R	A	S	Design change	Calculation condition change	Did you analyze the wall in detail considering the slab effect?
R	A	W	Overdesign	Reinforcement reduction	Have you designed detailed reinforcement by subdividing the member names of the walls? In the case of inter-floor displacement and total displacement, are the structural wall weights designed to a satisfactory minimum level? Are unnecessary wall end reinforcements applied? Are structural walls unnecessary for bearing capacity designed as non-bearing walls?
F/R/C	P	W	Design change	Floor height change	Is the parking lot designed with the minimum floor height required for the building plan?

5. Conclusion

In this study, the limitations of the existing checklist were investigated through interviews with practitioners. The checklist items were composed according to the newly revised and added classification system.

The conclusion is as follows. There are two limitations derived from the existing checklist. The first is that the exact steps for cost reduction are not presented, and the second is that the new method is not applied. To compensate for these limitations, the scope of the checklist was limited to apply to the pre-construction stage that is most effective for cost reduction. In addition, a literature review related to the new construction method and a questionnaire survey was conducted with 13 experts. As a result of the investigation, it was possible to find the trend of construction methods that can reduce the cost of apartment residential, and the problems that occur in the construction stage that the practitioners directly experience were investigated. Based on this, improvement measures were sought, and a new cost reduction classification system was constructed. The standards are divided by construction work, character, and part. Classification by construction work was largely divided into formwork work, rebar work, and concrete work. The

construction cost calculation applied the classification criteria (Kang H.W., 2007). Classification by character consist of over-design considering excessive safety factors, technical change by structural calculation condition change, design change by design plan change, new construction method according to the development trend of construction technology, and construction error caused by the difference between the design plan and the site. Only the characteristics that can be changed in the previous stage were selected (Lee S.H., 2005). Classification by part consists of largely habitable space and non-residential space and specified as apartments and parking lots. Detailed basis can be classified into 7 categories of foundation, wall, slab, column, beam, staircase, and other rebar arrangement. Based on this, we could create a cost reduction checklist, as shown in Table 3, by entering the classification items for additional items. The use of cost reduction data presented in this study is expected to contribute to the stabilization of parcel prices and to be utilized as data for reasonable commercialization plans for consumers. In addition, this checklist will prevent unnecessary construction delay and increase in construction cost by systematically classifying the cost reduction method and scope of application.

6. Acknowledgements

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