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Basic Research on Applying Temporary Work Engineering at the Design Phase

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***Abstract*—**The application of constructability is increasingly required not only in the construction phase but also in the whole project stage. In particular, the proper application of construction experience and knowledge during the design phase enables the minimization of inefficiencies such as design changes and improvements in constructability during the construction phase. In order to apply knowledge effectively, engineering technology efforts should be implemented with design progress. Among many engineering technologies, engineering for temporary works, including facilities, equipment, and other related construction methods, is important to improve constructability. Therefore, as basic research, this study investigates the applicability of temporary work engineering during the design phase in the building construction industry. As a result, application of temporary work engineering has a greater impact on construction cost reduction and constructability improvement. In contrast to the existing design-bid-build method, the turn-key and CM (construct management) procurement methods currently being implemented in Korea are expected to have a significant impact on the direction of temporary work engineering. To introduce temporary work engineering, expert/professional organization training is first required, and a lack of client awareness should be preferentially improved. The results of this study are expected to be useful as reference material for the development of more effective temporary work engineering tasks and work processes in the future.

***Keywords*—**Temporary work engineering, design phase, constructability, building construction.

I. Introduction

As building construction projects have become more complex and larger in magnitude, efforts for improving constructability should be implemented from the early stages of the project. Most design decisions made during the design phase fairly affect the construction performance of the project [1]. However, the conventional procurement method obstructs construction contractors from providing designers with suggestions and feedback based on construction experience and knowledge for enhancing constructability and project performance [2]. For utilizing construction knowledge in the design process, various methods such as design reviews and value engineering (VE) have been introduced. While these methods can lead to improvements in project performance, there are limitations in introducing constructability information more effectively during the design phase [1].

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In order to use the knowledge effectively, proactive engineering efforts should be implemented with design progress. In particular, construction engineering for temporary works, including facilities, equipment, and other related construction methods, has significant importance for constructability improvement and successful project completion. Despite its importance, most engineering processes for temporary works are now carried out in the construction planning phase. Thus, construction contractors are losing the opportunity to improve constructability of the design and to minimize inefficient work such as design changes and rework during the construction phase. Consequently, construction expertise for proactive engineering should be involved from the early stage of the project for efficient constructability improvements. Therefore, this study aims to investigate the applicability of construction engineering for temporary work in the design phase, especially in the building construction industry. Based on data from questionnaires, this study surveyed effectiveness, possibilities, and responsibilities in accordance with procurement methods and obstacles in applying temporary work engineering.

II. Literature Review

The concept of constructability began in the United Kingdom in the 1960s and initially focused on productivity. Since then, it has developed into an integrated concept of each production phase, including planning, design, and construction, to improve the cost-effectiveness and quality of the construction industry [3], [4]. Table I shows the definitions of the concept of constructability by country. The common concept is to foster efficient decision making by fully reflecting construction knowledge at the design phase.

Many domestic and foreign studies have steadily contributed to improve constructability in construction projects. According to Fischer and Tatum, inefficient works occur because construction knowledge is not delivered to designers properly in construction projects, and the main cause is explained by the lack of explicit and formalized construction knowledge [6]. Pulaski and Horman introduced a conceptual model for organizing constructability information based on appropriate timing and level of detail [1]. Lam et al. investigated a quantitative measure of constructability for common construction systems [7]. Park et al. proposed an information flow-based design process for applying construction knowledge during the design phase [8]. Park and Park suggested the use of building information modeling (BIM) for improving constructability analysis tasks [9]. However, few studies on implementing temporary work engineering at the

design phase to improve constructability have been carried out. Sohn and Kim claimed that techniques for temporary work engineering were necessary to minimize problems such as frequent design changes and to enhance constructability [10]. However, in the field of building construction, further research for applying temporary work engineering at the design phase has not yet been implemented. Thus, in the present study, we conduct basic research on the efficient execution of temporary work engineering tasks in the design process.

TABLE I
DEFINITION OF CONSTRUCTABILITY BY COUNTRY

Country	Definition
United Kingdom (CIRIA) [a]	the extent to which the design of the building facilitates ease of construction, subject to the overall requirements for the completed building
United States (CII) [b]	the effective and timely integration of construction knowledge into the conceptual planning, design, construction, and field operations of a project to achieve the overall project objectives in the best possible time and accuracy at the most cost-effective levels
Australia (CIIA) [c]	the integration of construction knowledge in the project delivery process and balancing the various project and environmental constraints to achieve the project goals and building performance at the optimal level

[a]Construction Industry Research and Information Association
[b]Construction Industry Institute (CII), based at The University of Texas at Austin. CII Best Practices: Constructability [5]
[c]Construction Industry Institute, Australia

III. SURVEY RESULTS FOR APPLYING TEMPORARY WORK ENGINEERING DURING THE DESIGN PHASE

Temporary work engineering can be largely divided into equipment operation, temporary building, on-site support facilities, temporary power and water, formwork, and mechanical, electrical, and plumbing (MEP). Temporary work engineering can contribute greatly to the success of a construction project, and it is predicted that the improvement in constructability would be greater due to the minimization of the waste factor and the resulting cost reductions from temporary work performed during the design phase. Therefore, in this study, based on practitioner interviews and the existing literature, we surveyed the effects of engineering works, the current obstacles, and the activities required for efficient activities in the future, and then analyzed questionnaire results using a 5-point scale. In addition, we surveyed the possibility of engineering work according to each project delivery method and the related responsibilities in the case of trouble.

A. Survey Overview

In this study, construction, design, construction management (CM), and engineering companies surveyed primary temporary works to obtain opinions of various subjects. We then conducted questionnaires on 18 construction and CM/ construction inspection company practitioners. Most (about 93%) of the respondents had more than 10 years of working experience, and all respondents agreed that it is necessary to introduce temporary work engineering at the design phase, thereby ensuring the reliability of the results.

B. Effects of Temporary Work Engineering at the Design Phase

Table II shows the effects of temporary work engineering at the design phase. Among the effects, construction cost reduction (4.2 points) and constructability improvement (4.2 points) were the highest, followed by duration reduction (3.9 points) and reduction of design changes and reworks (3.6 points). In addition, improved communication between designer and constructor (3.3 points) and improved design quality (3.1 points) showed low scores of 3.5 or less, but this was analyzed as an effect that can be obtained when performing temporary work engineering at the design phase.

TABLE II
EFFECT OF TEMPORARY WORK ENGINEERING

Effect	Number of responses					Score
	VL	L	M	H	VH	
Construction cost reduction	-	-	1	13	4	4.2
Constructability improvement	-	-	4	7	7	4.2
Duration reduction	-	-	5	10	3	3.9
Reduction of design changes and reworks	-	-	10	5	3	3.6
Improved communication (designer-constructor)	-	3	8	5	2	3.3
Improved design quality	1	1	12	4	-	3.1

Note: VL = Very Low, L = Low, M = Medium, H = High, VH = Very High

C. Possibility of Temporary Work Engineering According to Project Delivery Method

As construction projects become larger and more complicated, various project delivery methods are implemented. These project delivery methods can be divided into the DBB, turn-key, and CM methods. In order to perform efficient temporary work engineering, it is necessary to analyze the possibility of each project delivery method.

According to Fig. 1, 56% of the respondents answered that "Temporary work engineering can be performed in the DBB method" and 28% answered that "It cannot be performed in DBB". In the turn-key method, 100% of the respondents answered that "It can be performed". In the CM method, 67% of respondents answered that "It can be performed" and 22% answered that "It cannot be performed". Based on these results, it was concluded that temporary work engineering can be performed most efficiently in the turn-key and CM methods. In the DBB method, it was concluded that the possibility of temporary work engineering is low due to insufficient laws and institutional strategy as well as insufficient communication between designers and constructors.

D. Task Responsibility According to Project Delivery Method

Based on the existing research literature and consultation results, it was confirmed that the subject of temporary work engineering varies according to each project delivery method. Accordingly, it is necessary to clarify the responsibility for problems that may arise when performing temporary work engineering.

As a result of the survey, the DBB and turn-key methods showed the highest ratios for the construction company; the design company also showed high responsibility because

engineering work was required to improve constructability at the design phase. In the CM method, the CM/construction inspection company showed the highest ratio, and the design company was found to have a low ratio of responsibility. The possibility that the client could become a responsible entity also appeared.

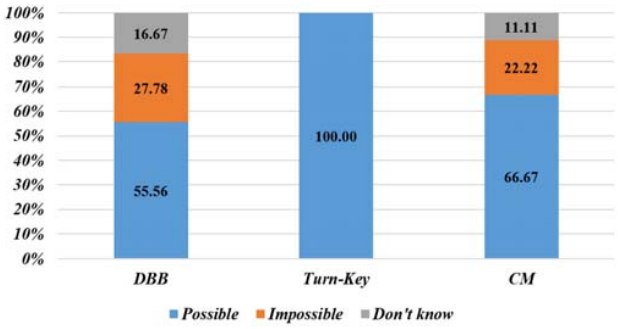

Fig. 1 Possibility of temporary work engineering by project delivery method

TABLE III
RESPONSIBILITY RATIO OF SUBJECTS BY DELIVERY METHOD

Subject	Responsibility ratio by delivery method (%)		
	DBB	Turn-Key	CM
Design co.	30.0	25.6	5.8
Construction co.	48.6	59.7	28.5
Specific construction co.	12.0	8.2	5.1
CM/construction inspection co.	6.7	5.3	52.5
Structural engineering co.	2.7	1.2	1.1
Client	0	0	7.0

Note: co. = Company

E. Obstacles and Necessary Activities for the Engineering Application

At present, there are many restrictions regarding the execution of temporary work engineering in Korea. For effective temporary work engineering, it is necessary to analyze current obstacles and investigate necessary activities in future studies. Therefore, in this chapter, obstacles to the execution of temporary work engineering are shown in Table IV, and necessary activities for the future are shown in Table V.

TABLE IV
OBSTACLE FACTORS ANALYSIS

Obstacle factor	Number of responses					Score
	VL	L	M	H	VH	
Lack of client awareness				8	10	4.6
Responsibility problem	-	1	2	11	4	4.0
Lack of experts	-	2	3	7	6	3.9
Lack of communication and information exchange	-	-	6	7	5	3.9
Insufficient support program (software)	-	2	6	3	6	3.8
Insufficient laws and institutional strategy	-	5	3	5	5	3.6

Note: VL = Very Low, L = Low, M = Medium, H = High, VH = Very High

According to Table IV, the lack of client awareness (4.6 points) was the biggest obstacle, followed by the problem of responsibility (4.0 points), a lack of experts (3.9 points), and a lack of communication and information exchange (3.9 points). This can be interpreted as the result of a lack of proper conceptualization due to a lack of both professional research on temporary work engineering and training of engineering experts. In order to solve these problems, we surveyed the necessary activities (Table V). All respondents answered that the "Training of experts and professional organization activities (3.9 points)" is needed. Activities to verify the effectiveness of their work and establish monitoring systems also showed a high importance of 3.8 points. In addition, it is necessary to revise current legal/institutional strategies and establish new laws and regulations.

TABLE V
NECESSARY ACTIVITIES ANALYSIS

Activity	Necessary (%)		Average importance
	Yes	No	
Training of experts/professional organization	100	0	3.9
Verify effectiveness of work and establish monitoring system	100	0	3.8
Establish related laws/institutional strategies	94	6	3.8
Establish efficient work process	94	6	3.7
Establish project team member organization system	100	0	3.6
Develop support program (software)	94	6	3.3

IV. CONCLUSION

Currently, as construction projects are becoming larger and more complicated, various techniques such as VE and design reviews are being used to enhance constructability. However, current methods have limitations in introducing constructability information more effectively during the design phase. For the effective use of construction knowledge, proactive engineering efforts are necessary with design progress. This study focused on investigating the applicability of temporary work engineering at the design phase, particularly in the field of building construction, based on data from questionnaires and consultation results. The following conclusions were obtained:

1) The effects that can be obtained from the execution of temporary work engineering at the design phase include a reduction of construction costs, improved constructability, duration reduction, and a reduction in design changes and reworks. If a field expert is able to utilize appropriate construction knowledge in the early stage of design, the constructability of the construction project will be more improved.
2) As a result of investigating the possibility of temporary work engineering according to each project delivery method, it was found that temporary work engineering is more likely to be performed in the turn-key and CM methods than in the DBB method because efficient communication and exchange of information between workers is possible.
3) Since the work performers can change according to the project delivery method, it is necessary to clarify who is responsible for any problems that occur when performing temporary work engineering. In the DBB and turn-key

methods, the construction company showed the highest ratio of responsibility. In CM the method, the CM/construction inspection company showed the highest ratio. In addition, in the CM method, the client showed the possibility of becoming a responsible subject.

4) There are many obstacles, such as a lack of client awareness, a lack of experts, and responsibility problems, in the introduction and execution of temporary work engineering. As a result of investigating the activities necessary to solve these problems, it was found that it is necessary to train experts and professional organizations, to establish effective verification and monitoring systems, and to revise legal/institutional strategies.

Actually, little research has been conducted on temporary work engineering. Further research is acutely required because the application of temporary work engineering at the design phase can provide much greater improvement of overall project constructability. In addition, as project deliveries based on design and build integration are gradually increasing, the necessity and effect of engineering technology will be further increased. Future studies will be continuously carried out to derive specific tasks and establish the work processes of temporary work engineering.

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