Work Productivity Analysis of High-performance PC Slab Installation

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Abstract: ***Demand is increasing for large, high-rise, and complex buildings, which is leading to advances in the development of high-performance structural systems. In this context, precast concrete (PC) technology has received a large amount of attention owing to its benefits in terms of schedule reduction, high quality, and easy installation. In addition, advanced methodologies that improve the PC performance by the addition of various materials have recently been reported. Research on analyzing the effects of such high-performance PC on the construction process and productivity is very limited. This makes it difficult for decision-makers to apply PC to particular projects. Thus, the aim of this research was to analyze the work productivity of the high-performance PC slab installation process by using a construction simulation tool to resolve critical issues. In this study, a real construction project that adopted PC slab installation work was analyzed, and a sensitivity analysis was performed to confirm the reliability of the analysis results.***

Keywords: High-performance PC Slab, Productivity Analysis, Construction Simulation

I. INTRODUCTION

Recently, demand is increasing for large, high-rise, and complex buildings, which has led to advances in the development of high-performance structural systems. Much research is going into developing practical construction technology for high-strength and high-performance construction materials. In this context, precast concrete (PC) technology has received a large amount of attention owing to its benefits in terms of schedule reduction, high quality, and easy installation [1]. Advanced methodologies that improve the performance of PC by the addition of various materials have recently been reported [2]. However, the application of the PC technique to building construction is unusual. Thus, research on productivity analysis, improvements to the construction process, etc. is very inadequate.

In this study, the work productivity with the application of the PC slab technique was analyzed through a simulation, and a work crew plan to increase work productivity was developed.

II. HALF-PC SLAB WORK PROCESS

The slab construction process is linked to the work processes for the bottom wall, beams, and columns.

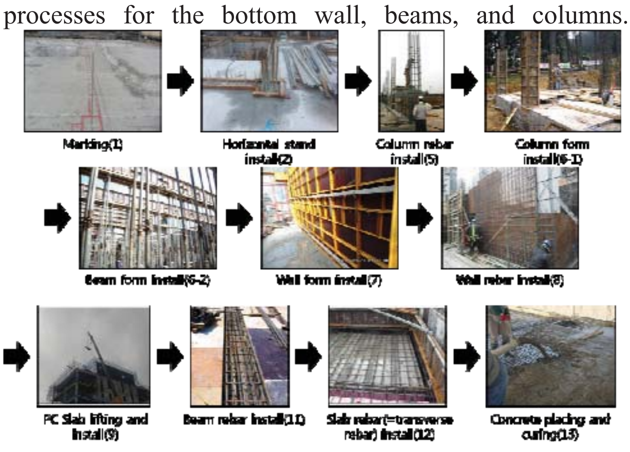

Figure I. Actual Image of PC Slab Installation Process

The detailed procedure for half-PC slab construction of the floor is as follows (refer to Figure I): (i) marking, (ii) horizontal stand installation, (iii) rebar delivery (for columns and walls), (iv) form delivery (for columns, beams, and walls), (v) column rebar installation, (vi) column and beam form installation, (vii) wall form installation, (viii) wall rebar installation, (ix) half-PC slab lifting and installation, (x) rebar lifting (for slab and beams), (xi) beam rebar installation, (xii) slab rebar (= transverse rebar) installation, and (xiii) concrete placement and curing.

III. DATA ACQUISITION FOR WORK PRODUCTIVITY

A. Case installed Half-PC Slab

As a case for gathering data, office building *A* in Gwangju City was selected, because it was adopted a half-PC slab on construction of its fifth floor..

TABLE I
DATA FOR INSTALLING ONE HALF-PC SLAB

Activities	Work Crew	Duration [min/unit]	Equip -ment	Duration [min/unit]	Note
Making and Horizontal Stand Install	Form	60.00	-	-	-
Rebar Deliver	Rebar	3.75	Crane	3.75	8.5 ton
Column Rebar Install	Rebar	60.00	-	-	-
Form Deliver	Foam	11.25	Crane	11.25	
Column Form Install	Foam	60.00	-	-	
Beam Form Install	Foam	45.00	Crane	45.00	
Beam Support Install	Form	15.00	-	-	
Wall Form Install	Form	30.00	-	-	
Wall Rebar Install	Rebar	30.00	-	-	
Half-PC Slab Lifting and Install	Form	90.00	Crane	90.00	
Beam Rebar Deliver	Rebar	11.25	Crane	11.25	26.1 ton
Beam Rebar Install	Rebar	90.00	-	-	24.0 ton
Slab Rebar Install	Rebar	30.00	-	-	2.1 ton
Concrete Placing	Concrete	26.25	Pump Car	26.25	237㎥
Curing	-	-	-	-	13 Day
Form Removal	Form	90.00	-	-	
Total Duration	652.5		187.5		-
	10h 52.5m		3h 7.5m		

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B. Data for analyzing work productivity

Based on the work process as depicted by Figure 1, work activities in Table 1 were identified, and further the case study was conducted for determining work resource (i.e., work crew and equipment) and work duration on each activity. In the office building "***A***," 16 (EA) half-PC slabs were installed on the fifth floor. The research team gathered and analyzed the real data for constructing 16 slabs, and consequently the work activities and work resource and work duration on each activity were identified as shown in Table 1, after case study.

IV. SIMULATION RESULT

Based on the work process and the data for implementing each activity (Table 1), simulation model for analyzing work productivity was developed by using a Web-CYCLONE technique. By implementing the simulation model, the work time for installing 16 Half-PC slabs was 169.1 h, and the productivity was 0.0059 cycles/h.

A. Productivity analysis of each resource

Based on the results for simulation, the idle state of the form crew was very low at 0.04%. The crane and rebar crew were 31.39 and 31.98 % of idle, respectively, and the assistance crew was 67.47% idle (refer to Table II). The simulation results could be interpreted as that Form crew on the installation process is the most important resource for determining the work productivity of the work, compared to other resources (i.e., Crane, Rebar Crew, and Assistance Crew), because there is no idle time for the Form Crew while the other resources have idle time. Namely, a low idle percent means (i) a lack of a work crew or equipment and (ii) additional work crew or equipment are needed to improve productivity.

TABLE II
WORK PRODUCTIVITY OF EACH RESOURCE

Node	Name	A i)	B ii)	C iii)	**D iv)**	E v)
28	Form Crew	0.0	1	0.1	**0.04**	0.0
29	Crane	0.5	1	53.1	**31.39**	0.7
30	Rebar Crew	0.5	1	54.1	**31.98**	0.8
31	Assistance Crew	0.7	1	114.1	**67.47**	57.0

i) Average Unit Idle, ii) Max. Idle Units, iii) Times Not Empty [h], iv) % of Idle, v) Average Wait Time [h]

B. Resource Sensitivity Analysis

In order to confirm how each resource affects total work productivity, a sensitivity analysis was performed by changing the number of form crews from one to three, number of cranes from one to two, number of rebar crews from one to three, and number of assistance crews from one to two. Thus, 36 scenarios were derived. The results of the analysis are as follows (refer to Table III and Figure II): (i) The assistance crew did not affect the productivity (compare scenarios 1 and 2), (ii) The crane and Form crew had a large impact on improving the productivity (compare scenarios 1, 7, and 13), (iii) Having two or three rebar crews had a small impact on improving the productivity (compare scenarios 3 and 5).

V. DISCUSSION

Demand is increasing for large, high-rise, and complex buildings, which has led to advances in the development of high-performance structural systems. The results of this study showed that adding a crane and form crew is important to improving productivity. This is believed to reflect the heavy use of a crane in the precast work process.

TABLE III
SENSITIVITY ANALYSIS

Scenario	Form Crew	Crane	Rebar Crew	Assist. Crew	**Productivity**	Cycle Time
1	1	1	1	1	**.0059**	169.1
2	1	1	1	2	**.0059**	169.1
3	1	1	2	1	**.0066**	151.8
5	1	1	3	1	**.0068**	147.2
7	1	2	1	1	**.0068**	146.5
9	1	2	2	1	**.0073**	136.2
11	1	2	3	1	**.0073**	136.2
13	2	1	1	1	**.0065**	153.2
15	2	1	2	1	**.0074**	135.8
17	2	1	3	1	**.0076**	131.2
19	2	2	1	1	**.0078**	127.6
21	2	2	2	1	**.0089**	112.1
23	2	2	3	1	**.0093**	107.6
25	3	1	1	1	**.0067**	150.3
27	3	1	2	1	**.0075**	133
29	3	1	3	1	**.0078**	128.4
31	3	2	1	1	**.0081**	124.1
33	3	2	2	1	**.0095**	105.4
35	3	2	3	1	**.0099**	101

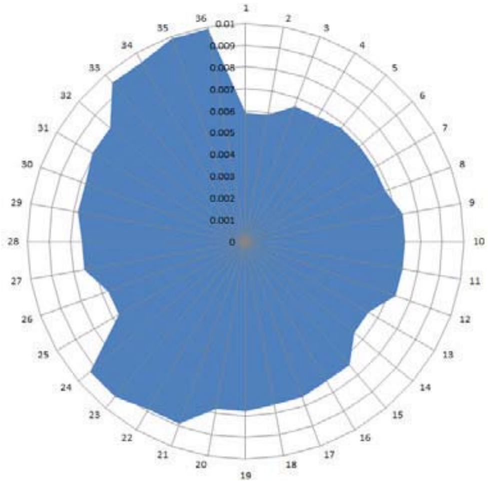

Figure II. Sensitivity Analysis (Productivity in Each Scenario)

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