

# Time Shortening of Structural Framework of High-rise Apartment Housing for the Urgent Project Area: Focused on the Cases of Insufficient Time or Delayed Projects

Jong-Dae Bang<sup>1</sup>, Do-Heun Lee<sup>2</sup>, Young-Soo Chun<sup>3</sup>, Ji-Young Park<sup>4</sup>, Bum-Sik Lee<sup>5</sup> and Myoung-Hoon Jun<sup>6</sup>

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## ABSTRACT

Construction duration is very important as a factor which comprises three axes of construction management with quality and cost in construction project. In general project condition, construction duration is optimized while minimizing construction cost and securing required quality. However, in case of insufficient project time duration or delayed projects, project progress management is different from those of normal projects. These project areas need solutions to complete work within a given completion day. To time shortening the current duration of each typical floor of structural framework in apartment construction is investigated, and a basic time schedule planning for typical floor of structural framework in normal projects is planned. This study proposed 3 ways for time shortening of urgent project or insufficient construction duration project. Also, This study proposed detailed time shortening method and technical solution conditions while time is shortened.

**Keywords:** Urgent Project, Structural Framework, Time Shortening, Time Schedule Planning, Basic Time Schedule Table, Activity, Work Breakdown

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## 1. Introduction

### 1.1 Background and Purpose

Construction duration in a construction project is very important as one of factors constituting three axes of construction management along with quality and cost. In the regular conditions of a project, the construction duration will be established as the optimal period that construction cost could be invested least while securing the required quality. However, due to urgency of a project, a project area that has insufficient a project period or that has a urgent period due to construction delay by unavoidable factors will have different type of construction duration from a project area with regular project conditions. It is necessary to have a plan to complete a project within a given target or to complete the project within the given completion date in these project areas. Therefore it is intended to suggest a plan for

reasonable time shortening that enables a project to be completed within the given target in an urgent project area or in a project area with urgent construction duration.

### 1.2 Scope and Method

The urgent project or delayed project need to time shortening to complete those within the given target. Therefore, this study takes the construction of apartment housing as a subject, and focuses on a project that lacks a project period due to an urgent project or a project that has insufficient construction duration due to construction delay rather than a project with general conditions. In terms of contents, it was limited to suggest the technological method for time shortening through time scheduling for typical floors of structural framework and the technological conditions to be considered upon time shortening. The reason why time shortening of structural framework is selected as scope of this

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1) Senior Research Fellow, Land & Housing Institute (Main author: [jdbang@lh.or.kr](mailto:jdbang@lh.or.kr))

2) Executive Research Fellow, Land & Housing Institute (Corresponding author: [dhlee3@lh.or.kr](mailto:dhlee3@lh.or.kr))

3) Research Fellow, Land & Housing Institute

4) Research Fellow, Land & Housing Institute

5) Research Fellow, Land & Housing Institute

6) Research Fellow, Land & Housing Institute

Table 1. Construction Duration for Each Typical Floor of Domestic Major Construction Companies

Classification	A Company	B Company	C Company	D Company	E Company	F Company	G Company
Construction Duration of Typical Floor (Days)	8	8	9	8	7	6	8

study is that construction duration of structural framework occupies approximately 50% in total construction duration. The part of fluctuation of direct cost and overhead cost that could be affected upon time shortening was excluded. The research methodology are as follows;

Frist, the current construction duration of each typical floor of structural framework of apartment construction in normal project is investigated.

Second, this study analyzed how the specified items of domestic specification related with structural framework affected construction duration of structural framework.

Third, the type of performing works of structural framework, the type of a crew team, the method of division of working zones, the operation plan of skilled workers etc. were clarified through the investigation of literature and a field study.

Fourth, the kind of works by the stages of construction of structural framework of typical floors and the type of composition of a crew team were analyzed, and the activities were divided.

Fifth, the order and the relation of activities, and the working period by activities etc. were specified to make a basic time schedule table<sup>1)</sup> for typical floor in structural framework having general project conditions.

Sixth, CPM (Critical Path Method) technique<sup>2)</sup> was used to make a basic time schedule table.

Seventh, the construction duration for each floor was suggested when performing an urgent project or a project that has insufficient construction duration, and the technological conditions to be solved upon time shortening were suggested.

### 1.3 Literature Review

The result of investigating and analyzing the main studies related to time shortening of structural framework of the existing apartment houses was as follows; “Evaluation of Field Application on the Prediction Method of Early-age Strength of Early Concrete for Construction Work Period Reduction (Lee et al, 2010)”, “A study on the Practical Application of Early Strength Concrete for Reduction of Working Period in Apartment (Jeong et al, 2010)”, “A Study on Field Application of Early Strength Concrete for Construction Work Period Reduction (Kim et al, 2009)” etc. focused on the study of rapid hardening concrete for early stripping of forms. “A Framework System for Reducing the

Construction Duration of the Wall Systems Buildings (Kim et al, 2005)” focused on suggesting an optimum form system for time shortening. “Development of an Effective Time Scheduling Mechanism of the Structural Framework for the High-rise Apartment Housing (Han et al, 2004)” suggests the mechanism of the process of structural framework of apartment and a plan for time shortening. “A Study on 3-Day Cycle Time for Reducing the Duration of Structural Frame Work (Ahn et al, 2007)” takes a high-rise multipurpose building with Rahmen structure as a subject. Besides, “An Assessment of Field Application of Elementary Technology for Reducing Construction Duration in the Apartment Housing Construction (Kim et al, 2007)”, “Structural Plan for Reducing Construction Schedule of Residential Buildings (Kwon et al, 2008)”, “An Analysis on Difficulties and Delay Factors for the Development and Application of Technologies for Reduction of Construction Duration (Jeong et al, 2010) etc. were progressed.

The studies above are considerably distinguished from this study that was intended to suggest a method for time shortening through a basic time schedule plan for typical floors and technological factors to be considered upon time shortening.

## 2. Construction Duration Analysis for Each Floor of Structural Framework and Basic Time Schedule Plan for Typical Floors of Apartment

### 2.1 Construction Duration Analysis of Each Typical Floor for Structural Framework of Domestic Apartment

To investigate the construction duration of each typical floor for structural framework of apartment, persons in charge in the technology department or the construction process management department were interviewed as a subject in domestic major construction companies. The construction duration for each typical floor was analyzed as 8 days to be common as shown in Table 1. The construction duration of 8 days for each typical floor was investigated to be estimated on the basis of data of achievement.

### 2.2 Considerations upon Time Schedule Planning of Structural Framework of Apartment

The construction duration of framework is largely affected by two factors. According to the previous study (Han, Chung-Hee et al, 2004), it was investigated that form remaining period to secure the safety and quality of a structure and an operating plan for skilled workers have influence on a time schedule plan and construction duration of structural framework.

1) The basic time schedule table refers to a time schedule table for one typical floor of structural framework.

2) CPM : Critical Path Method

Table 2. Form Remaining Period (When testing compressive strength)

Member	Compressive Strength of Concrete(Normal Portland Cement)		
	Specialized Specification for Housing Construction	Standard Specification of Concrete	Standard Specification of Architectural Construction
Expanded Foundation, Column, Side of Beam, Side Wall	· More than 50kgf/cm <sup>2</sup> (5N/mm <sup>2</sup> ) after curing more than 24 hours	· More than 5MPa	· 5N/mm <sup>2</sup>
Slab and Bottom of Beam	· design strength × 2/3, but more than 140kgf/cm <sup>2</sup> (14N/mm <sup>2</sup> )	· more than 2/3 of design strength or more than minimum 14MPa	· 100% of design criterion strength. But, first structural calculation upon stripping, More than 12N/mm <sup>2</sup> for minimum strength

### 2.2.1 Specification Conditions for Securing Safety and Quality of a Structure

The form remaining period that is specified in the specification to secure safety and quality of a structure is classified into a case of testing compressive strength of concrete and a case of not doing it. This study took a case of testing it as a subject and the detailed contents are as shown in Table 2.

### 2.2.2 The Operational Method of Skilled Workers

Another important factor in a time schedule plan of structural framework is the operational method of skilled workers. According to the way to operate them, the construction duration of each typical floor and the working period for each activity is varied. When planning a time schedule, it is necessary that their work must not be ceased to improve the efficiency of time schedule and productivity. The cease of their working comes to have bad influence on the construction duration by deteriorating productivity.

According to the previous study (Han et al, 2004), the operational plan of skilled workers that must be considered as top priority in the time schedule plan of structural framework is for the form work comprising approximately 63% of total skilled workers. The next one is the reinforcing bar work followed by concrete work, machinery, electricity and communication work. As a result of investigation it would be most advantageous, if skilled workers of the form work do their jobs circulating 3 blocks or 2 blocks of an apartment to secure the continuity of works. The investigation also shows that reinforcing bar work and concrete work with short construction period and small-scaled manpower investment is most effective and efficient for securing the continuity of works, if skilled workers do their jobs circulating more than 5 blocks of an apartment.

## 2.3 Basic Time Schedule Plan <sup>3)</sup>

The construction duration for each typical floor most commonly in the country is presupposed to be 8 days and the basic time schedule table was made through the analysis of time schedule

3) The basic time schedule plan refers to planning work breakdown, relation, working period etc. for one typical floor of structural framework and to making a time schedule table.

for this. To establish the basic time schedule plan for each typical floor of structural framework, activities were divided after defining the kinds of works, and the relation for each activity was clarified. Besides, the period of each activity was determined and the basic time schedule table was made by considering the operational plan of skilled workers.

### 2.3.1 Breakdown of Activity

The structural framework is largely classified into the form work, reinforcing bar work, concrete work, machinery, electricity and communication work. Table 3 shows the breakdown of works by types into detailed activity.

The activity of the form work is classified into inking line, external wall, internal wall, stairs-core, slab work when considering the order of construction and the working part. The activity of reinforcing bar work is divided into wall works and slab works when considering the order of construction and the working part. The activity of machinery-electricity-communication work is divided into the works of wall and slab considering the order of construction and the working part. The reason of dividing 3 work types of machinery, electricity and communication work into one activity is that the contents of their work differ but even though those are simultaneously done, there is no interception since the start point of work and ending point of those works are similar. The activity of concrete work is classified into placing concrete and curing of concrete. There are activities grouping other cleaning, inspection, and finishing etc.

### 2.3.2 Relation of Each Activity

Activities affect mutual works, and if the mutual relation among activities is summarized, it is as shown in Table 4. First of all, the curing of concrete is the earliest started work among all works. The subsequent activities of concrete curing include inking line, stripping · installing external gang forms, stripping wall forms, stripping forms of stairs · core wall, stripping · assembly of slab forms etc. Since inking line is possible to be implemented on the very next day morning after placing concrete, it has relation with concrete curing as a simultaneous start. Since the

4) FS (Finish to Start), FF (Finish to Finish), SS (Start to Start)

Table 3. Work Breakdown of Typical Floor of Structural Framework

Work Type	Work Breakdown by Work Types(Activity)	Crew Team
Form Work	· Inking line	One team
	· Stripping and Installing external gang form	One team
	· Stripping internal forms	
	· Carrying and assembly of internal wall form	
	· Stripping forms of stairs and core wall	
	· Carrying and assembly of forms for stairs & core	
	· Stripping and assembly of slab forms	
Reinforcing Bar Work	· Carrying and assembly of wall reinforcing bar	One team
	· Carrying and assembly of slab reinforcing bar	
Machinery, Electricity and Communication Work	· Machinery, electricity and communication for walls	One team for each work type
	· Machinery, electricity and communication for slabs	
Concrete Work	· Placing concrete	One team
	· Curing concrete	Directly operated
Others	· Cleaning & Inspection & Finishing	Directly operated

Table 4. Relation of Activity of Structural Framework

Preceding Works	Subsequent Work	Relation <sup>4)</sup>	Time Lag
· Curing of Concrete	· Inking line	SS	0
	· Stripping and installing external gang forms	SS	1
	· Stripping wall forms	SS	1
	· Stripping forms of stairs & core wall	SS	1
	· Stripping and assembly of slab forms	FS	0
· Inking line	· Carrying and assembly of wall reinforcing bar	FS	0
	· Machinery, electricity and communication for walls	FS	0
· Stripping and installing external gang forms	· Carrying and assembly of wall forms	FS	0
· Stripping wall forms	· Carrying and assembly of wall forms	FS	0
· Stripping forms of stairs & core walls	· Carrying and assembly of forms for stairs & core	FS	0
· Stripping and assembly of slab forms	· Carrying and assembly of slab reinforcing bar	FS	0
	· Machinery, electricity and communication for slabs	FS	0
· Carrying and assembly of wall reinforcing bar	· Carrying and assembly of wall forms	FS	0
	· Carrying and assembly of forms for stairs & core	FS	0
	· Machinery, electricity and communication for walls	SS	0
· Machinery, electricity & communication for walls	· Stripping and assembly of slab forms	FS	0
	· Machinery, electricity and communication for slabs	FS	0
· Carrying and assembly of wall forms	· Stripping and assembly of slab forms	FS	0
· Carrying and assembly of forms for stairs & core	· Carrying and assembly of slab reinforcing bar	FS	0
	· Machinery, electricity and communication for slabs	FS	0
· Carrying and assembly of slab reinforcing bar	· Cleaning & Inspection & Finishing	FS	0
	· Machinery, electricity and communication for slab	SS	0
· Machinery, electricity and communication for slabs	· Cleaning & Inspection & Finishing	FF	0
· Cleaning & Inspection & Finishing	· Placing Concrete	FS	0
· Placing Concrete	· Curing of Concrete	FS	0

specification regarding form remaining period on Table 2 must be followed even though stripping · installing external gang forms, stripping wall forms, and stripping forms of stairs · core walls have relation with concrete curing as a simultaneous start, the work is possible only in a day after placing concrete. Due to this, the curing of concrete comes to have one-day lag. Since the carrying · assembly of reinforcing bar for walls is possible only

after completing inking line, the relation of two works have finish to start. With the method above, the relation of other works were established.

### 2.3.3 Working Period by Activities

The working period by activities is as shown in Table 5.

(1) The curing of concrete was set up to be 4 days considering

Table 5. Working Period by Activities

Activity	Working Period(day)
· Curing of Concrete	4
· Inking Line	1
· Carrying and assembly of wall reinforcing bar	1
· Stripping and installing external gang forms	1
· Stripping wall forms	1
· Stripping forms of stairs & core wall	1
· Machinery, electricity and communication of wall	1
· Carrying and assembly of wall forms	2
· Stripping and assembly of slab forms	2
· Carrying and assembly of forms for stairs & core	4
· Carrying and assembly of slab reinforcing bar	1
· Machinery, electricity and communication of slabs	1
· Cleaning & Inspection & Finishing	1
· Placing Concrete	

strength development of concrete.

- (2) The working period of inking line, stripping and installing external gang forms, stripping wall forms, and stripping forms of stairs and core walls was individually set up to be 1 day to manage manpower efficiently.
- (3) Since machinery, electricity and communication for walls are completed within the period between carrying and assembly of wall reinforcing bar and carrying and assembly of wall forms, the working period is within 1 day but it's indicated as one day on the time schedule table.
- (4) Carrying and assembly of wall forms and stripping and assembly of slab forms have the same working period, and they were set up to be 2 days, respectively.
- (5) The working period of form assembly for stairs and core was determined to be 4 days by adding the period of carrying and assembly of wall forms and stripping and assembly of slab forms.
- (6) The working period of carrying and assembly of wall reinforcing bar and carrying and assembly of slab reinforcing bar was decided to be 1 day, respectively.
- (7) Since machinery, electricity and communication for slabs start after forms are assembled and must be completed before placing concrete, the working period is within 1 day but it was indicated as one day on the time schedule table.
- (8) The working period of cleaning, inspection, finishing and placing concrete was determined to be one day to manage manpower efficiently, respectively.

#### 2.3.4 Basic Time Schedule Table of Typical Floors of Structural Framework

The basic time schedule table was made for 8 days of construction duration of each typical floor as shown in Fig. 1 on

basis of partition of activities, analysis of relations by activities, the working period by activities, etc. The operational plan of manpower for form work was designed to circulate 2 blocks of an apartment to secure the continuity of works.

### 3. Time Shortening of Structural Framework at Urgent Apartment Project Areas

In the case of the general conditions of a project, 8-day time schedule was made for each typical floor of structural framework in the previous chapter. In this chapter, 6-day, 4-day, and 3-day time schedule were suggested for each typical floor as a plan for time shortening of structural framework compared to 8-day construction duration to complete a construction of an urgent project area within a given target, and the technological contents to be solved in advance were presented upon time shortening.

#### 3.1 Time Shortening of Typical Floors of Structural Framework (6-day time schedule per each floor)

In this section, 6-day time schedule that 2 days were shortened compared to 8-day time schedule under the general project conditions was suggested as shown in Fig. 2. Besides, when performing 6-day time schedule, the method of time shortening and the technological prior conditions were suggested. The procedure of time schedule plan of 6-day time schedule for time shortening of each floor is the same as 8-day time schedule.

The operational plan of manpower for form work is to make them circulate 2 blocks of an apartment, which secured the continuity of works. When shortening the existing 8-day time schedule into 6-day time schedule, the technological prior conditions for the changes of working period of each activity and time shortening are as shown in Table 6.

Many activities must be improved to perform a project with 6-day time schedule in the technological aspect, and the operational method of skilled workers must be considerably improved as well. First of all, the period of activities on the critical path of 8-day time schedule must be shortened and next, the period of activities on subcritical path must be shortened. If activities on critical path of 8-day time schedule are shortened, and the technological conditions for time shortening, they are as follows;

First, the curing of concrete, in other words, form remaining period of slab forms must be shortened from 4 days to 3 days. It must be considered to use rapid hardening-type concrete, concrete with larger strength than design criterion strength and two sets of slab forms, etc. to shorten the curing period of concrete.

Second, carrying and assembly of slab forms must be shortened from 2 days into 1.5 days. it must be considered to apply a construction method of labor-saving type forms or improve the operational plan of manpower to shorten the form work.

Third, one day for cleaning, inspection, finishing and placing

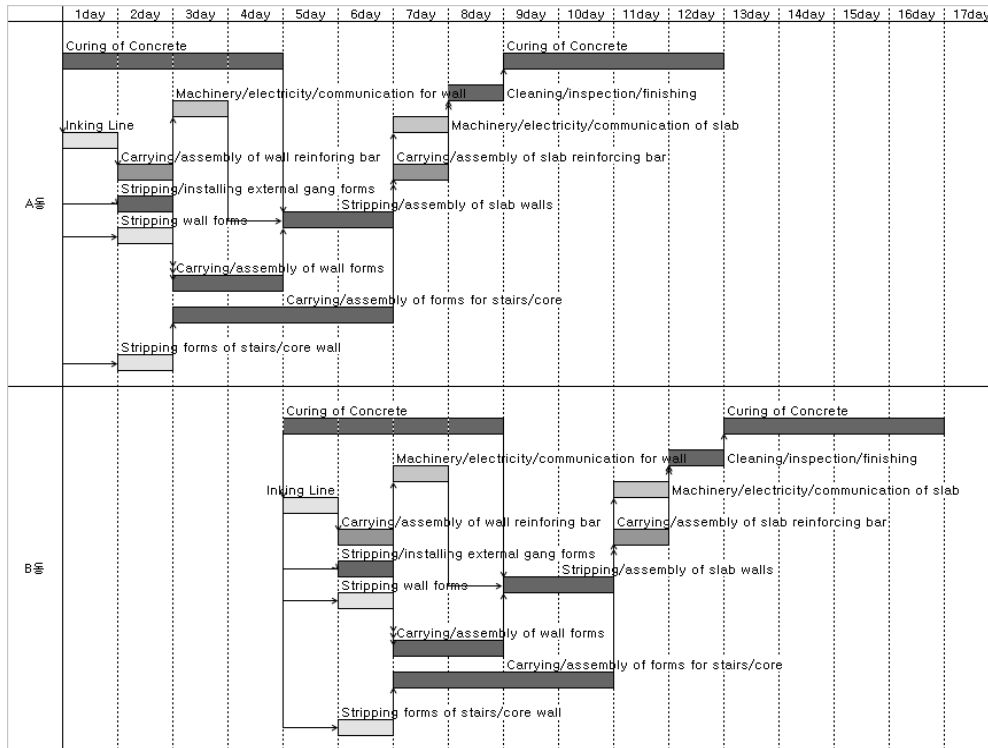


Fig. 1. Basic Time Schedule Table of Existing Structural Framework (8 days)

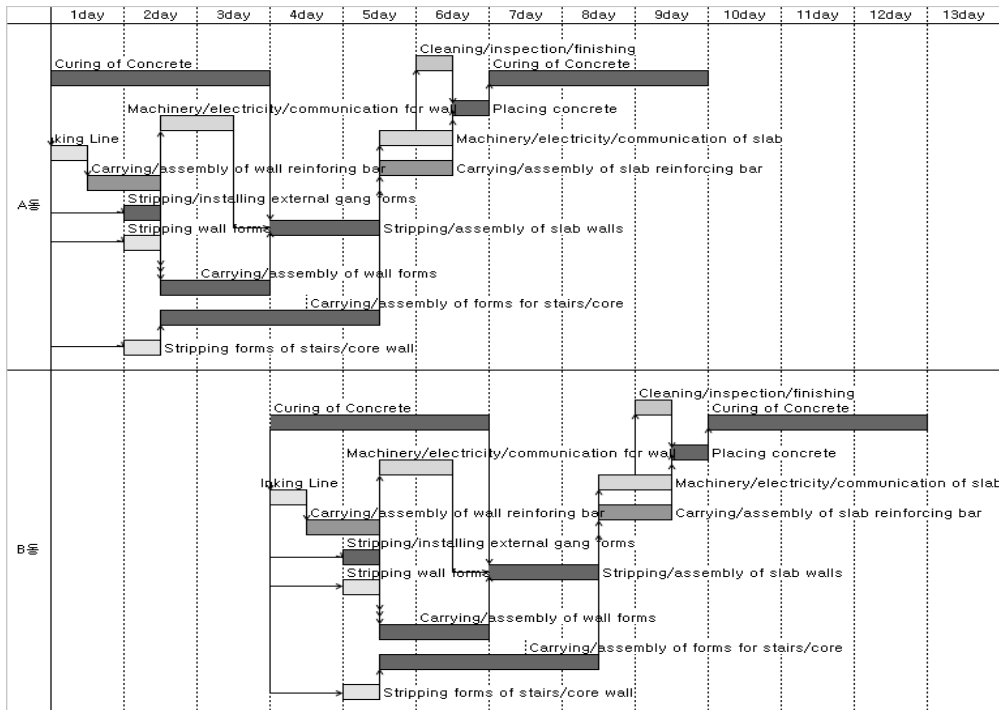


Fig. 2 Basic Time Schedule Table of Time Shortening of Structural Framework (6-day)

concrete must be shortened into 0.5 day. A method to improve the operational plan of manpower and efficiency of placing concrete must be found.

Fourth, one day for cleaning, inspection, finishing and placing

concrete must be shortened into 0.5 day, and it is necessary to construct the close cooperative system between an inspector, a supervisor and a construction company, and to have a plan to improve efficiency of the work for placing concrete.

Table 6. Changes in Working Period and Technological Considerations for 6-day Time Schedule

Activity	8-day time schedule		6-day time schedule	Shortened day	Issues for Prior Settlement
	Critical Path	Period	Period		
Curing of Concrete	◎	4	3	1	Concrete/Form Improvement
Inking Line		1	0.5	0.5	Improvement of Manpower Management
Carrying and assembly of wall reinforcing bar		1	1	0	-
Stripping and installing external gang forms		1	0.5	0.5	
Stripping wall forms		1	0.5	0.5	Improvement of Manpower Management
Stripping forms for stairs · core wall		1	0.5	0.5	Improvement of Manpower Management
Machinery, electricity and communication for walls		1	1	0	-
Carrying and assembly of wall forms		2	1.5	0.5	Improvement of Form/Manpower Management
Stripping and assembly of slab forms	◎	2	1.5	0.5	Improvement of Form/Manpower Management
Carrying and assembly of forms for stairs & core		4	3	1	Improvement of Manpower Management
Carrying and assembly of slab reinforcing bar	◎	1	1	0	-
Machinery, electricity and communication for slabs		1	1	0	-
Cleaning & Inspection & Finishing	◎	0.5	0.5	0.5	Improvement of Manpower Management
Placing Concrete	◎	0.5			Improvement of Construction Method/Manpower Management
Critical Path		8	6	2	

If the working period of activities that are not on critical path of 8-day time schedule is shortened, it is as follows;

First, the working period of inking line, stripping and installing external gang forms, stripping wall forms, and stripping forms of stairs and core wall must be shortened into a half through sufficient manpower investment.

Second, the working period of carrying and assembly of wall forms must be shortened in the same way as stripping · assembly of slab forms.

Third, forms with high productivity must be used or the investment of skilled manpower must be increased to shorten the working period of carrying and assembly of forms for stairs and core from 4-day work into 3-day work.

### 3.2 Time Shortening of Typical Floors of Structural Framework (4-day time schedule per floor)

In this section, 4-day time schedule that 4 days were shortened

compared to 8-day time schedule under the general project conditions was suggested as shown in Fig. 3. Besides, when performing 4-day time schedule, a method for time shortening and technological matters calling for prior settlement were presented. The procedure of 4-day time schedule for time shortening per floor is the same as 8-day time schedule. The operational plan of manpower management for form work secured the continuity of work by making them circulate 2 blocks of an apartment. Table 7 shows changes in the working period when shortening it into 4-day time schedule and technological considerations upon time shortening.

If 8-day time schedule were shortened into 4-day time schedule, the division of an activity or the relation of activities are not changed but the working period of activities and the operational plan of manpower come to differ and many technological items must be improved. To shorten 8-day time schedule into 4-day time schedule, the working period of activities on critical path of

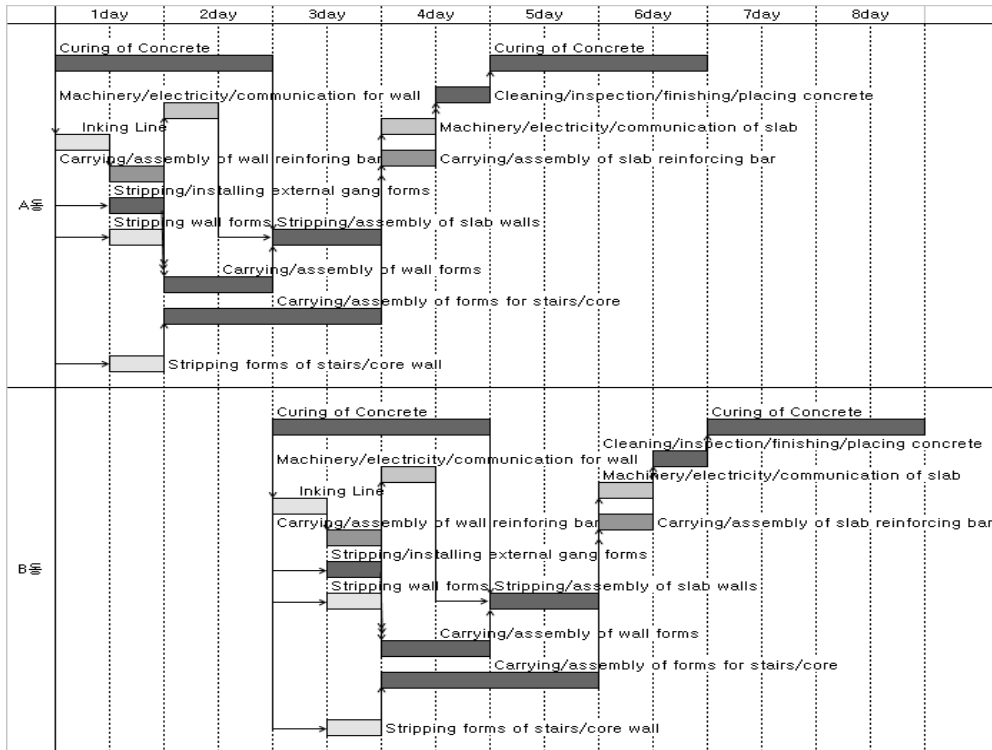


Fig. 3. Basic Time Schedule Table of Time Shortening of Structural Framework (4-day)

Table 7. Changes in Working Period and Technological Considerations for 4-day Time Schedule

Activity	8-day time schedule		4-day time schedule		Shortened day	Issues for Prior Settlement
	Critical Path	Period	Period	Period		
Curing of Concrete	◎	4	2	2	2	Improvement of Concrete/Form
Inking Line		1	0.5	0.5	0.5	Improvement of Manpower Management
Carrying and assembly of wall reinforcing bar		1	0.5	0.5	0.5	Improvement of Construction Method/Manpower Management
Stripping and installing external gang forms		1	0.5	0.5	0.5	Improvement of Manpower Management
Stripping wall forms		1	0.5	0.5	0.5	Improvement of Manpower Management
Stripping forms for stairs & core wall		1	0.5	0.5	0.5	Improvement of Manpower Management
Machinery, electricity and communication for walls		1	0.5	0.5	0.5	Improvement of Manpower Management
Carrying and assembly of wall forms		2	1	1	1	Improvement of Form/Manpower Management
Stripping and assembly of slab forms	◎	2	1	1	1	Improvement of Form/Manpower Management
Carrying and assembly of forms for stairs & core		4	2	2	2	Improvement of Form/Manpower Management
Carrying and assembly of slab reinforcing bar	◎	1	0.5	0.5	0.5	Improvement of Construction Method/Manpower Management
Machinery, electricity and communication for slabs		1	0.5	0.5	0.5	Improvement of Manpower Management
Cleaning & Inspection & Finishing	◎	0.5	0.5	0.5	0.5	Improvement of Construction Method/Manpower Management
Placing Concrete	◎	0.5				
Critical Path		8	4	4	4	



8-day time schedule must be shortened. Next, the working period of activities on subcritical path must be shortened. The followings are technological conditions for shortening the working period on critical path of 8-day time schedule and for time shortening.

First, the curing period of concrete must be shortened from 4 days into 2 days. For this, it could be considered to use super rapid hardening-type concrete that strength development is much faster than the existing one, to use concrete with even larger strength than design criterion strength and to use 2 sets of slab forms.

Second, the working period of stripping · assembly of slab forms must be shortened from 2 days into 1 day but for this, forms with double high productivity than the existing ones must be used or the method of manpower management must be improved.

Third, the working period of carrying · assembly of slab reinforcing bar must be shortened from 1 day into 0.5 day. For this, the skilled manpower must be invested more or the productivity must be raised by applying the construction method of assembling wires for reinforcing bars.

Fourth, the cleaning · inspection · finishing and placing concrete must be shortened from 1 day into 0.5 day. The detailed information for this is the same as the case of 6-day time schedule.

If the working period of activities on critical path of 8-day time

schedule is shortened, it is as follows.

First, the working period of inking line, stripping · installing external gang forms, stripping wall forms, stripping forms of stairs · core wall, and machinery · electricity · communication for slabs must be shortened from 1 day into 0.5 day through sufficient manpower investment.

Second, the working period of carrying · assembly of wall forms must be shortened in the same way as the one of stripping · assembly of slab forms.

Third, to shorten the working period of carrying · assembly of forms for stairs · core, forms with high productivity must be used or the investment of skilled manpower must be increased.

### 3.3 Time Shortening of Typical Floors of Structural Framework (3-day time schedule per floor)

In this section, 3-day time schedule that 5 days were shortened compared to 8-day time schedule with general project conditions was suggested as shown in Fig. 4. Besides, when performing 3-day time schedule, a method for time shortening and technological matters calling for prior settlement were suggested. The procedure of 3-day time schedule plan for time shortening per floor is the same as the one of 8-day time schedule. The operational

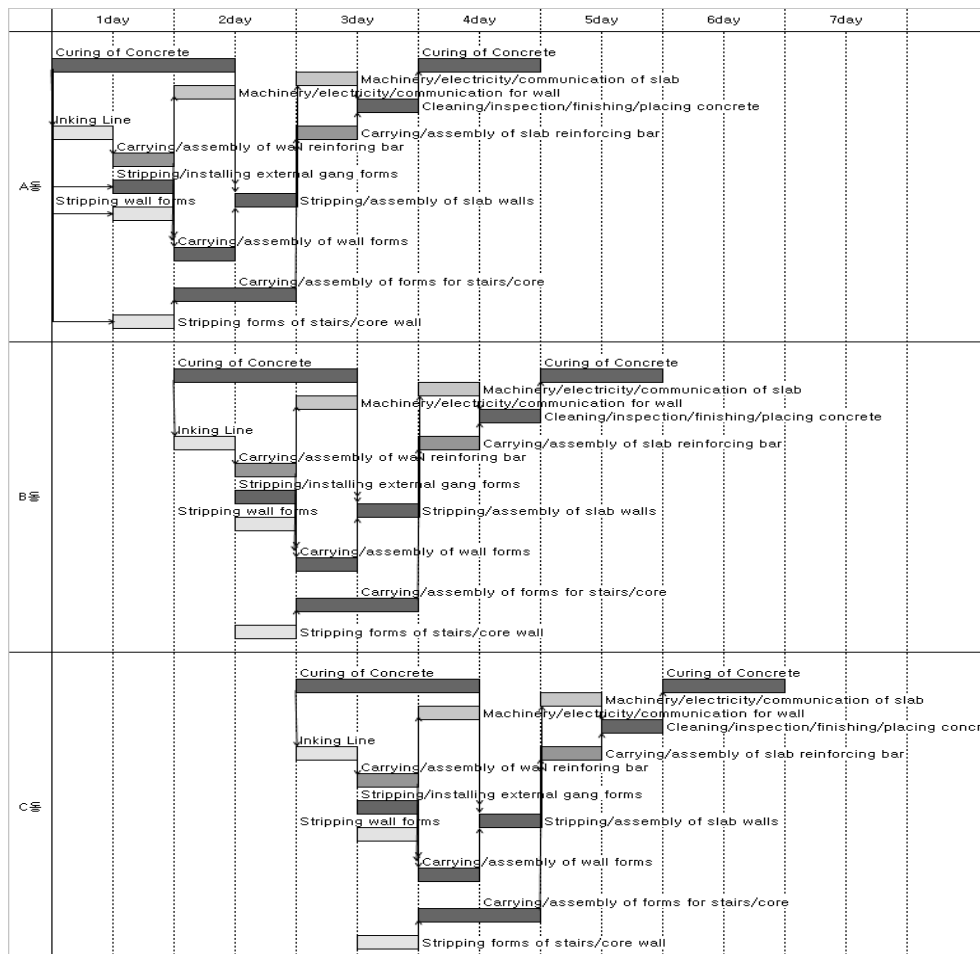


Fig. 4. Basic Time Schedule Table of Time Shortening of Structural Framework (3-day)

Table 8. Changes in Working Period and Technological Considerations for 3-day Time Schedule

Activity	8-day time schedule		3-day time schedule	Shortened day	Issues for Prior Settlement
	Critical Path	Period	Period		
Curing of Concrete	◎	4	1.5	2.5	Improvement Concrete/Form
Inking Line		1	0.5	0.5	Improvement of Manpower Management
Carrying and assembly of wall reinforcing bar		1	0.5	0.5	Improvement of Construction Method/Manpower Management
Stripping and installing external gang forms		1	0.5	0.5	Improvement of Manpower Management
Stripping wall forms		1	0.5	0.5	Improvement of Manpower Management
Stripping forms for stairs and core wall		1	0.5	0.5	Improvement of Manpower Management
Machinery, electricity and communication for walls		1	0.5	0.5	Improvement of Manpower Management
Carrying and assembly of wall forms		2	0.5	1.5	Improvement of Form/Manpower Management
Stripping and assembly of slab forms	◎	2	0.5	1.5	Improvement of Form/Manpower Management
Carrying and assembly of forms for stairs & core		4	1	3	Improvement of Form/Manpower Management
Carrying and assembly of slab reinforcing bar	◎	1	0.5	0.5	Improvement of Construction Method/Manpower Management
Machinery, electricity and communication for slabs		1	0.5	0.5	Improvement of Manpower Management
Cleaning & Inspection & Finishing	◎	0.5	0.5	0.5	Improvement of Manpower Management
Placing Concrete	◎	0.5			Improvement of Construction Method/Manpower Management
Critical Path		8	3	5	

plan of manpower for form work secured the continuity of work by making them circulate 3 blocks of an apartment. Table 8 shows changes in the working period when shortening 8-day time schedule into 3-day one and technological considerations upon time shortening. To shorten the curing period of concrete of 8-day time schedule, the working period of activities on critical path of 8-day time schedule must be shortened. Next, the working period of activities on subcritical path must be shortened. The followings shows the suggestion of technological conditions for shortening the working period of activities on critical path of 8-day time schedule and for time shortening.

First, the curing period of concrete must be shortened from 4 days into 1.5 days. For this, it could be considered for a method to use rapid hardening concrete or concrete with higher strength than design criterion strength while using super rapid hardening-type concrete, concrete with much higher strength than design criterion strength and 2 sets of slab forms.

Second, the working period of stripping and assembly of slab forms must be shortened from 2 days into 0.5 day. For this, the construction method of labor-saving type forms with much higher productivity than the existing construction method must be used or the more manpower must be invested.

Third, since the working period of carrying and assembly of slab reinforcing bar must be completed in 0.5 day, the productivity must be increased by investing more skilled manpower or applying the construction method of prior assembly of reinforcing bars etc.

Fourth, the cleaning, inspection, finishing and placing concrete must be shortened from 1 day into 0.5 day. For this, the detailed contents are the same as the case of 6-day time schedule.

The working period of activities other than ones on critical path of 8-day time schedule must be shortened as well.

First, the working period of inking line, stripping and installing gang forms for external wall, stripping forms of stairs and core wall, machinery, electricity and communication for walls and machinery, electricity and communication for slabs must be shortened from 1 day to 0.5 day through the improvement of the method of manpower management.

Second, the working period of carrying and assembly of wall forms must be shortened in the same way as carrying and assembly of slab forms.

Third, to shorten the working period of carrying and assembly of forms for stairs and core, forms with high productivity must be used or the investment of skilled manpower must be increased.

## 4. Conclusions

This study is aimed at suggesting a plan for time shortening that enables a project to be completed within a given target at an urgent project district or a project district with an urgent construction duration. It is investigated for the basic time schedule for typical floors of apartment structural framework by domestic construction companies to be commonly progressed with 8-day time schedule. This study suggests a method of time schedule that can shorten 8-day time schedule into 6-day, 4-day, and 3-day time schedule, and technological solutions for fulfilling this. The following shows technological solutions for time shortening of those 3 types.

1. Activities on critical path must be shortened for time shortening of structural framework, and the curing of concrete that affects the construction duration most among activities on critical path must be shortened. For this, it was analyzed that methods including using rapid hardening concrete or using concrete with higher strength than design criterion strength and using two sets of forms etc. must be considered.
2. To shorten the working period of form work that consumes manpower most and affects construction duration a lot in the structural framework, it was analyzed that the construction method with higher productivity than the existing one must be used or the operational plan of manpower must be improved.
3. It was analyzed that the construction method of assembling wires for reinforcing bar must be used or the productivity must be improved through the improvement of the operational plan of manpower.
4. To shorten the work of cleaning and inspection, finishing and placing concrete, it was analyzed that the mutual cooperative system must be constructed between an inspector, a supervisor and a constructor, and the efficiency of placing concrete must be increased.

The results of this study will be used as a method for time shortening of structural framework in the urgent project or delayed project. But, To utilize the plan for time shortening suggested in this study at an actual project, concrete methods among technological items suggested in this study must be selected. The method to select must be progressed through a general review including site conditions, quality, and construction cost etc.

Due to the limit of time and cost, this study was limited to suggest a plan for time shortening and technological factors that

must be settled in advance upon time shortening. To shorten the construction duration at an urgent project district or at a district with an urgent construction duration with minimum cost in the future, it is thought that it would be necessary for more concrete data regarding the fluctuation of direct cost and overhead cost according to time shortening.

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