Development of Support System in Preparing Placing Drawings for the Improvement of Efficiency of Reinforcing Steel Works

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ABSTRACT: Reinforcing steel works should be carefully controlled by the construction manager considering the severe fluctuation of the price of reinforcing steel bars and for the safety of structure in building constructions. In particular, preparing rebar placing drawings needs more effort and time than before because of the emergence of higher and more complicated buildings. Moreover, the experience of field engineers or foremen (fabricators or detailers) in preparing placing drawings gives rise to the differences in fabricated bar type and quantity of bars used. To address these problems, this study proposed the support system in preparing placing drawings for reinforcing steel works efficiency. In the near future, if this system can be made available on the web, multiple end-users will be able to share the result; the efficiency of rebar supply chain management will also be improved.
Keywords: Reinforcing steel works, Placing drawings, Supply chain management, Reinforcing steel bar

1. Introduction

1.1 Background and Purpose

In reinforcing steel structure construction, reinforcing steel works (RSW) together with form and concrete construction works affect construction safety, durability, and period considerably [1]. RSW can also be a form of basic construction together with form construction in enabling structures to perform their functions properly [2]. RSW accounts for approximately 9.8% of the direct construction cost [3], and many hours of RSW are allocated to the construction site. Therefore, RSW is very important from the perspectives of facilities project cost management and process management [4].

As part of efforts related to reinforcing steel bar (rebar) control, the following studies have been conducted: Study on System Development for the Quality Cost Improvement of RSW [1]; Research on the Rebar Processing Method and Field Management [4], [5] and [6]; Analysis of Rebar Field Processing and Economic Efficiency of Factory Processing [7], and; Study on SCM Application to Rebar Materials [8] and [9].

Note, however, that RSW is based on a series of processing of information such as rebar schedules and preparation of placing drawings after design is completed; hence the need for placing drawing information for rebar materials control and field and construction management. In particular, preparing rebar placing drawings requires more effort and time than before due to the emergence of higher and more complicated buildings. As a result, inefficiency increases in the stage of preparing the placing drawings. Moreover, excessive dependency on the experience of field engineers or foremen in preparing the placing drawings gives rise to the differences in fabricated bar type and quantity of bars used.

To address these problems, this study suggested a system for preparing rebar placing drawings to provide base information through which rebar materials can be controlled via the web at construction sites. The proposed system is expected to enhance RSW efficiency.

1.2 Scope and Methodology

The scope of this study was limited to a series of stages of preparing placing drawings including the preparation of rebar placing drawings and storage of the rebar list in the DB server that may be used in linkage with the external system upon completion of the output design focusing on RSW. For the methodology, this study performed problem analysis through a review of literature related to the analyses of rebar materials and construction companies' rebar procurement systems.

This study also used the 3rd party application concept of auto CAD and suggested a new system for making placing drawings; thus differentiating it from existing studies. The system proposed in this study will enable field engineers and other related experts to use

the system in preparing placing drawings quickly -- which was the focus of the study by Hyeon-Yong Park, et al [2] and [10] -- as an interim output of the project undertaken for the innovative model development of a rebar materials supply chain and procurement system.

2. Status of Rebar Placing Drawings and Materials Procurement System

2.1 Review of Related Literature

The RSW studies conducted recently can be categorized into RSW processing and fabrication and materials procurement. The following studies fall under the rebar processing and fabrication category: Actual Condition Analysis of RSW [5] and [11]; Development of a System for Preparing Rebar Placing Drawings [2], [6] and [10]; Economic Efficiency Analysis of Rebar Processing Costs in Installations Within and Outside the Field [7], and; B2B System Application [9]. In particular, the Measure for Rebar Processing Factory-based RSW Rationalization [4] and [12] expanded the concept of the existing rebar processing factory within the construction site to the concept of outsourcing; thus providing a new turning point in rebar procurement direction. With regard to materials control, various studies have been conducted including Analysis of Major Materials' Features for RFID Technology Application [13], Economic Order Quantity Estimation Considering the Open Yard Size [13], and RFID Technology Applicability Review in RSW [8]. The study of Min-Woo Lee, et al [8] showed the feasibility of RFID application to rebar materials through an RFID experiment. In particular, as suggested in the study of Do-Hyung Gu, et al [14] following the 7 categorization of the materials necessary for construction, additional conditions should be established including the setting of detailed conditions, fusion between RFID and WSN, and RFID tag's unit price decrease in relation to the materials and rebars subject to the intermediate process stage but can be used in the current technical stage. Note, however, that the methods mainly presented as the means of improving RSW have been undertaken focusing on the handling stage and procurement stage. Actually, the study on the interfaced information provision for rebar materials for their processing and procurement after design completion has yet to be conducted. In this context, this study can provide the basis for the research on the system for preparing placing drawings so that the design and construction linkage information of RSW can be offered.

2.2 RSW Process Analysis

The RSW area can be classified into the general construction company area and specialized construction company area. The former can be segmented into the head office executing the construction contract, quantity estimation for budget estimation, and rebar materials ordering and a construction site carrying out construction, supervision, and field management. The latter can be divided into rebar processing and fabrication only and handling of overall structure construction. As carrying out the construction, the specialized construction companies also included the mode wherein the rebar processing factory is located outside the construction site and the mode wherein rebars are processed within the site. Likewise, there is diverse segmentation depending on the contract type and processing type. Figure 1 shows the RSW process, i.e., the work areas and processes of a specialized construction company handling processing and fabrication in detail in addition to the abovementioned work areas.

2.3 Comparison with the Existing System

The existing system of Hyeon-Yong Park re-draws the drawing information by importing into the system the drawing file drawn up using Auto CAD. Note, however, that the proposed system enables users to work in the Auto CAD program directly; although processing is slow due to the 3rd party application of Auto CAD, less of the system capacity is used, and compatibility with DB is enhanced. Table 1 compares the existing system with the proposed system. The system proposed in this paper was designed for an Auto CAD program environment since field engineers are familiar with the program.

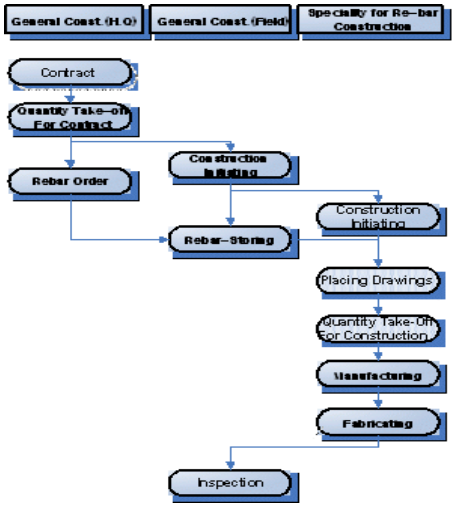


Figure 1. RSW Process [2] and [10]

For this reason, there are many differences in the visually viewed environment even though flows for making drawings look similar. In the proposed system, the algorithm for the major subsidiary materials of the framework structure such as foundation, walls, pillars, beams, and slabs was applied. For other subsidiary materials, the system was designed to enable an end-user to draw up manually and reflect such.

Table 1. Existing System vs. Proposed System

Category	Existing System [2] and [10]	Proposed System
System Type	Independent	Non-independent (operates together with the AUTO CAD program)

Design Drawing Input Type	The drawing information generated and stored during the drawing is re-drawn by the design drawing file imported into the system.	Can perform work in the Auto CAD program
Output Computation Mode	Automatic/Manual preparation through user environment setup + User designation mode	Automatic/Manual preparation through user environment setup + User designation mode
Standard Shape of Placing	The basic standard shape is provided; the system is designed to enable input the bar shape by a user in simplified mode	Provides the practical standard shape that is widely used in the field; the system is designed to enable input the bar shape by a user in simplified mode
Output Data	Placing Drawings, bar list	Placing Drawings, bar list
Saving and Print Mode	Designed for saving to Web DB; confirm and print on the web	Designed for saving to Web DB; confirm and print on the web (print can be performed in the program as well)

3. System for Preparing Rebar Placing Drawings

3.1 Concept of the Rebar Placing Drawing System

In the system for preparing rebar placing drawings, the drawing designer makes the completed placing drawings and generates a bar list as well as bar tags reflecting the information of the rebar's installation site. The proposed system has a built-in algorithm that automatically prepares the placing drawings through shape information and basic environment setup and lets a user work manually in case of complicated shapes to enhance work utilization. Figure 2 shows in brief the flow of the system for preparing placing drawings.

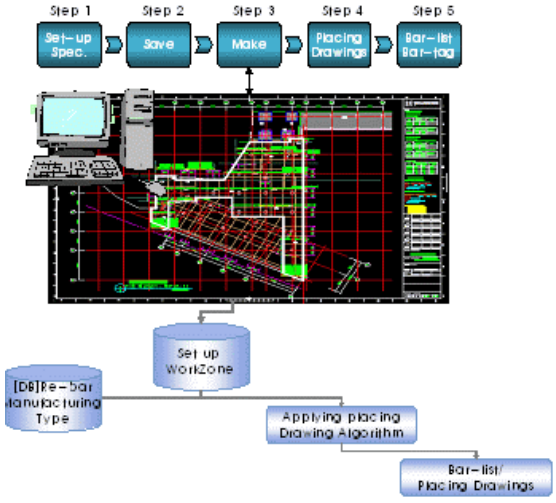


Figure 2. Flow Chart of the System for Preparing Rebar Placing Drawings

3.2 Preparation of Rebar Placing Drawings

This section shows the user environment setup and processing as necessary for processing major subsidiary materials such as foundation, beam, pillar, and slab in building construction. In particular, the characteristic parts are explained in each subsidiary material handling method. With regard to materials such as pillar, beam, and slab including the bar list information in the design stage, the placing drawings and bar list can be generated by matching the list information and rebar placing information in this system.

1) User Environment Setup

The user environment setup is the initial stage of the system. Rebar placing criteria such as the standard hook value by construction and fixation joint length for each subsidiary material are entered; the user environment is designed to make covering or set the rebar placing distance separately because of the difference according to the conditions. Figure 3 shows the window for entering rebar placing criteria and Specs details.

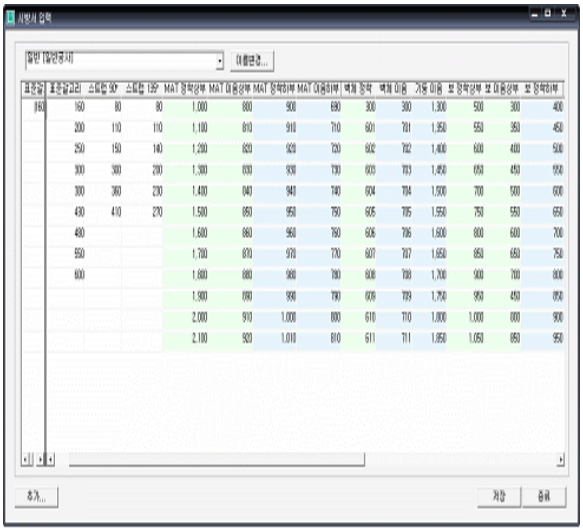


Figure 3. Window for Entering Rebar Placing Criteria and Specs Details

2) Standard Shape of Rebar Placing

For the standard shape of major subsidiary materials' rebar placing, the minimum standard shape used in practice is provided. For other subsidiary materials, a user can input such in the Auto CAD program. Figure 4 shows the standard shapes of the rebar as used in the proposed system.

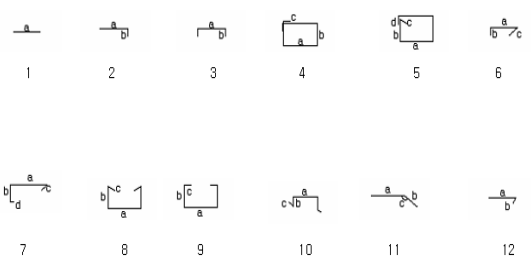


Figure 4. Standard Shape of Rebar Placing

3) Foundation Rebar Placing

In the design drawings of the Auto CAD program, the placing area of the foundation rebar is designated; ditto for the rebar direction on the width and length rebars, anchor on both ends, joints, and fixation (Figure 5 and 6). When there is an opening in the foundation part, it can be selected and designated as a separate area. While anchoring is common on both ends, a construction joint that may be generated in foundation rebar placing can be processed in the system by adding other options such as joint and fixation. In this case, rebar direction can be set as left-right and right-left.

Figure 5. Window for Setting the Foundation Rebar Placing

Figure 6. Window for Rebar Placing Around the Foundation

4) Beam Rebar Placing

For beam rebar placing, the rebar's placing area is selected in the drawings including the sign and size. The inner end, outer end, and central part's upper part/lower part/lateral part are then selected in sequence. Enter the beam sign followed by the covering, pillar distance, main use length, and continuous rebar's placing distance. In case of gaps, the corresponding input values are entered, and the system automatically processes them and makes placing drawings. Figures 7 and 8 show the window for input and window for beam rebar placing, respectively.

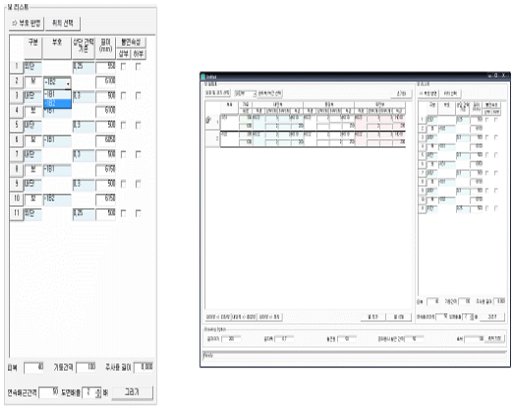


Figure 7. Beam Setup and Rebar Placing

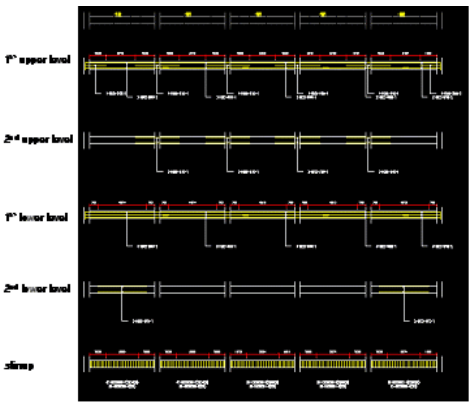


Figure 8. Window for Beam Rebar Placing

5) Slab Rebar Placing

For slab rebar placing, like other subsidiary materials, select the rebar's placing area and enter the sign, type, each part's diameter, and rebar's placing distance (Figure 9 and 10). In the case of slab in particular, select the area by choosing the central line; the system was designed to enable the main row line selection in question to be applied after the distance between beams is entered for the smooth preparation of placing drawings.

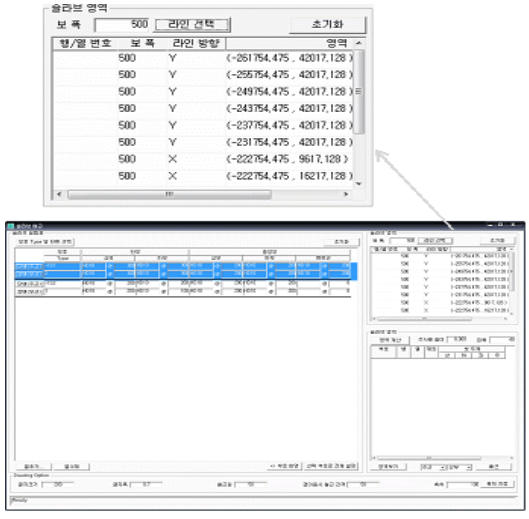


Figure 9. Beam Area Setup and Rebar's Placing Information Input

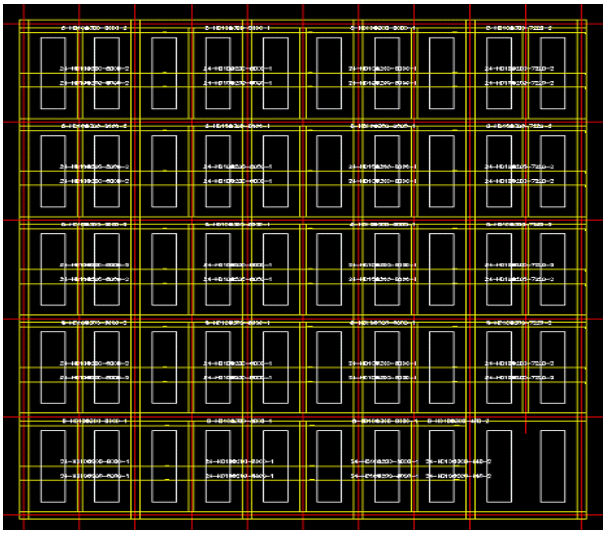
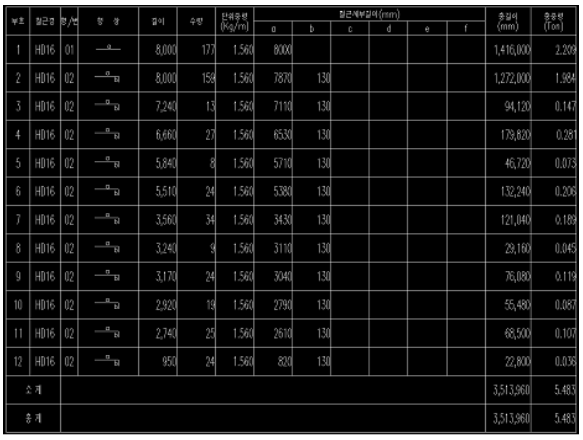


Figure 10. Window for Slab Rebar Placing

6) Window for Output Printing

The outputs of the system for preparing rebar placing drawings as proposed in this study -- the placing drawings and bar list -- are shown in Figures 11 and 12. This system enables the output to be printed or saved in the server in Auto CAD through option setup.



No	철근종	형/번	형 상	길이	수량	단위중량 (Kg/m)	절곡제원길이(mm) a	b	c	d	e	f	총길이 (mm)	중량 (Ton)
1	HD16	01	—a—	8,000	177	1.560	8000						1,416,000	2.209
2	HD16	02	—a—b	8,000	159	1.560	7870	130					1,272,000	1.984
3	HD16	02	—a—b	7,240	13	1.560	7110	130					94,120	0.147
4	HD16	02	—a—b	6,660	27	1.560	6530	130					178,820	0.281
5	HD16	02	—a—b	5,840	8	1.560	5710	130					46,720	0.073
6	HD16	02	—a—b	5,510	24	1.560	5380	130					132,240	0.206
7	HD16	02	—a—b	3,560	34	1.560	3430	130					121,040	0.189
8	HD16	02	—a—b	3,240	9	1.560	3110	130					29,160	0.045
9	HD16	02	—a—b	3,170	24	1.560	3040	130					76,080	0.119
10	HD16	02	—a—b	2,920	19	1.560	2790	130					55,480	0.087
11	HD16	02	—a—b	2,740	25	1.560	2610	130					68,500	0.107
12	HD16	02	—a—b	950	24	1.560	820	130					22,800	0.036
소계													3,513,960	5.483
총계													3,513,960	5.483

Figure 11. Output Expressed in the AUTO CAD Program

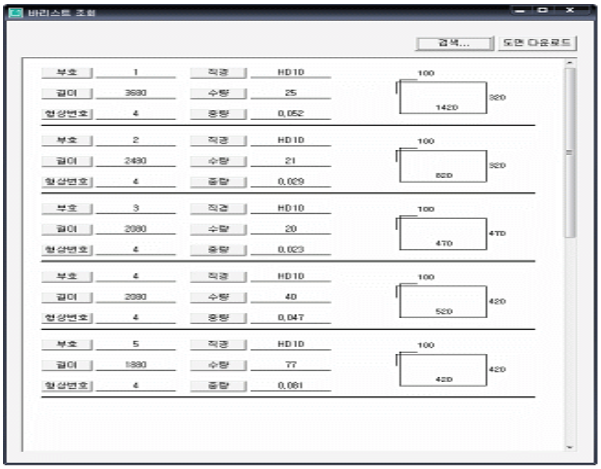


Figure 12. Bar List Saved in the Server Center

4. System Verification

The system proposed in this paper comparatively reviewed the foundation, pillars, and walls in A Construction Company's project. System verification aimed at ensuring completion and drawing matters to be complemented with regard to the subsidiary materials in question of the system. Comparative values such as quantity comparison are simple comparative values, and they are hardly indicative of the excellence of the system because of the differences in various conditions including design criteria. To compare the time spent on preparation by subsidiary material, a comparison was made with experts in field placing drawings preparation.

4.1Field Application and Results

1) Foundation Rebar Placing

The comparison of foundation rebar placing was executed according to the method discussed in Section 3. After working by separately extracting the rebar's placing area selection process, a mode to copy the work in the original drawings was executed, and the test results were then drawn (Figure 13 and Table 2)

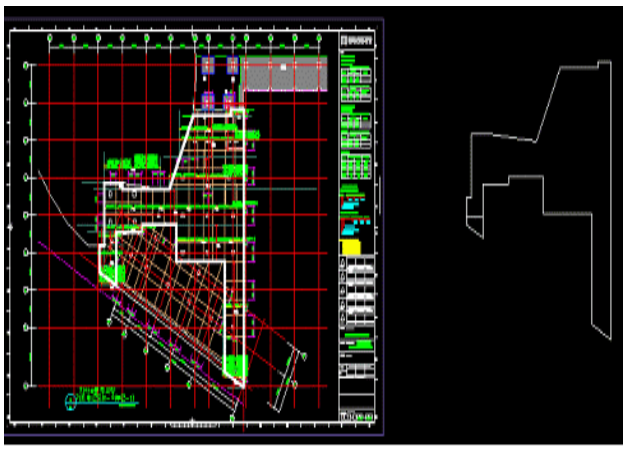


Figure 13. Extraction of Rebar's Placing Section

Table 2. Comparison of Foundation Rebar Placing

Items	A Const. Co.	Proposed System
Time Consumed (skilled labor)	5hr	1hr
Quantities (ton)	20.077	20.525
Reason for Quantity Difference	Difference due to the variable section processing method	

2) Wall Rebar Placing

Similar to the foundation rebar placing, the wall rebar's placing area was separately drawn and copied from the original drawings after rebar placing was completed (Figure 14 and Table 3).

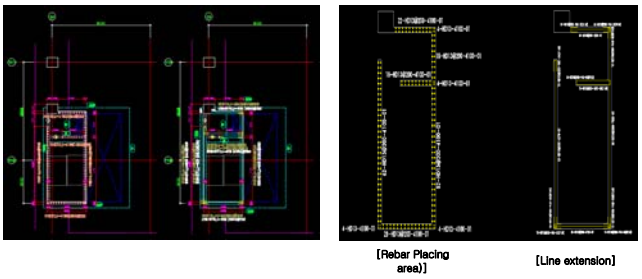


Figure 14. Extraction and Generation of Rebar Placing Section

Table 3. Comparison of Wall Rebar Placing

Items	A Const. Co.	Proposed System
Time Consumed (skilled labor)	40min	25min
Quantities (ton)	1.308	1.301
Reason for Quantity Difference	The situation at the time of design was not reflected.	

3) Pillar Rebar Placing

For the pillar as A Construction Company's characteristic part, two-floor rebar placing drawings were simultaneously drawn and used onsite. For the system proposed in this study, such was drawn up based on 1-floor criteria; hence the absence of total quantity difference. Note, however, that there was a difference in the rebar's placing distance. This was believed to be attributable to the difference between the 2-floor continuous construction and 1-floor continuous construction (Figure 15 and Table 4).

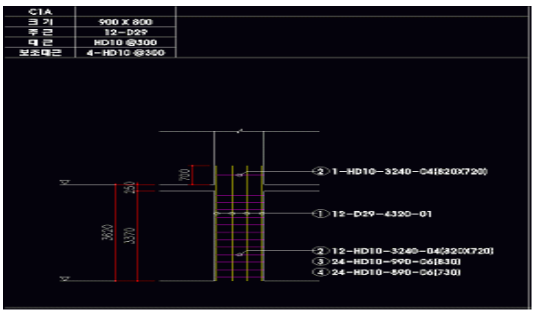


Figure 15. Window for Beam Rebar Placing

Table 4. Comparison of Pillar Rebar Placing

Items	A Const. Co.	Proposed System
Time Consumed (skilled labor)	30min	20min
Quantities (ton)	0.522	0.310
Reason for Quantity Difference	Double joint length not needed based on the 2-floor simultaneous rebar placing	

4.2 Drawing up Matters for Complementation

As a result of application to the field, when the rebar's placing section type is complicated, or a rebar is placed like an iron frame, it is not processed in the system; hence the need for manual processing in the current system. Although shapes can be added so that various shapes can be selected and applied, in addition to the designated rebar's placing shapes, many shapes should be applied when a shape is not constant such as stairs when using the system. Thus, manual work may be more feasible rather than utilizing the system by extracting shapes automatically. In case the rebar's length is complicated, the need to simplify the length by increasing or decreasing it is raised; double joint occurs, however. Nonetheless, as the factor requiring complementation the most, a function for verifying an error caused by the original drawings or worker's mistake -- which requires caution during the work—is needed. In particular, complementation is necessary to reflect the recent trend of the iron frame and rebar being fabricated together.

5. Conclusion and Future Research Direction

In this study, a system was constructed through the 3rd party application of the Auto CAD program. Unlike the existing system proposed by Hyeon-Yong Park [2] and [10], the system proposed in this study is a non-independent system; although system processing is slow, the proposed system has the advantages of increased compatibility with DB and less system capacity used.

As a result of the field applicability test targeting A Construction Company's major construction subsidiary materials using the proposed system, the preparation time was confirmed to have been shortened considerably. If this system is applied to field work, the efficiency of preparation of rebar placing drawings is expected to be enhanced. The biggest goal of the system's field application is to draw matters to be complemented through application to the field and to establish the future research direction for the system based on the suggestions drawn up in this paper. The following summarizes the matters to be complemented as drawn up in this study:

1) Addition of rebar's placing shape
2) Simplification of rebar length
3) Error verification of original drawings and workers
4) Measure for processing the system when both iron frame and rebar are used
5) Linkage with a materials procurement system through the web

In future studies, matters to be complemented as drawn up in this study should be applied to the system; a feasibility analysis as to whether to target major subsidiary materials in the current system or to target overall subsidiary materials including stairs should be conducted as well. In particular, the means of drawing up matters related to basic information for materials procurement and construction management in rebar

construction in linkage with the materials procurement system through the web should be studied.

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