PREFABRICATION OF REINFORCING BARS USING CAD/CAM

Toshio Yamashita,
Yoshimasa Tsuchiya,

The Tokyo Electric Power Company, Incorporated

1-3, Uchisaiwai-cho, 1-chome, Chiyoda-ku
Tokyo 100, Japan

Masahiro Takami,
Isamu Yamamoto,

Shimizu Corporation

13-16, Mita 3-chome, Minato-ku
Tokyo 108, Japan

ABSTRACT

In the construction of large-scale structures such as nuclear power plants, an enormous amount of large-diameter reinforcing bars are used, and generally thousands of drawings are required to fabricate them. The installation and fabrication of heavy reinforcing bars are laborious and dangerous for workers.

To facilitate drawing preparation and fabrication work, a CAD/CAM system and an automatic bar arrangement system were developed. The CAD system produces working drawings and the bar code labels containing bar arrangement data. The automatic bar arrangement system reads the data and arranges straight bars as well as bent bars in a grid shape at the same interval. This system prefabricates 12 m long D38 reinforcing bars and forms a 10-ton/unit.

The application of the two systems is expected to reduce the labor required for drawing preparation to one fifth and the reinforcing bar fabrication to one half. The entire work productivity will increase to twice of the wholly manual. The systems are presently utilized at a nuclear power plant construction site and 30% of all the reinforcing bars required for the construction of the plant is planned to be fabricated by applying the two systems. The systems are expected to contribute to the reduction of construction time and improvement of work safety.

1. Introduction

In case of bar arrangement work for large-scale structures such as nuclear power plants, contrary to ordinary construction work, there are strict regulations regarding bar arrangement and preparation of the drawings for all the structural portions. Consequently, 2,000 to 3,000 drawings have to be prepared and prefabrication methods are often employed at the site to assure quality, safety and smooth progress of

the work. In fact, however, the site fabrication work mostly relies on manual labor. The installation and fabrication of reinforcing bars, especially when large-sized bars are used, are not only toilsome but also dangerous. As the construction of large-scale structures is increasing, the recent shortage of skilled workers and younger generation's tendency to get out of construction only aggravate the problem.

This paper describes the CAD system for reinforcement work which expeditiously produces by simple operation, bar arrangement drawings which satisfy the structural standards for large-scale structures as well as an automatic bar arrangement and prefabrication system which arranges and prefabricates bars in accordance with the bar unit information output from the CAD system.

2. Outline of the Systems

2.1 Outline of the CAD/CAM System

Fig. 1 shows the composition of the CAD/CAM system developed for reinforcement work use. This system, consisting of a personal computer, tablet, plotter, and printer, outputs working drawings for reinforcement work and bar codes for the operation of the automatic bar arrangement system, which will be discussed later. Fig. 2 shows the major process flow of this system. The working drawings are output either through a printer or a plotter. In the case of the plotter, pencil-drawn A1-size drawings are produced. Fig. 3 shows the examples of the CAD outputs.

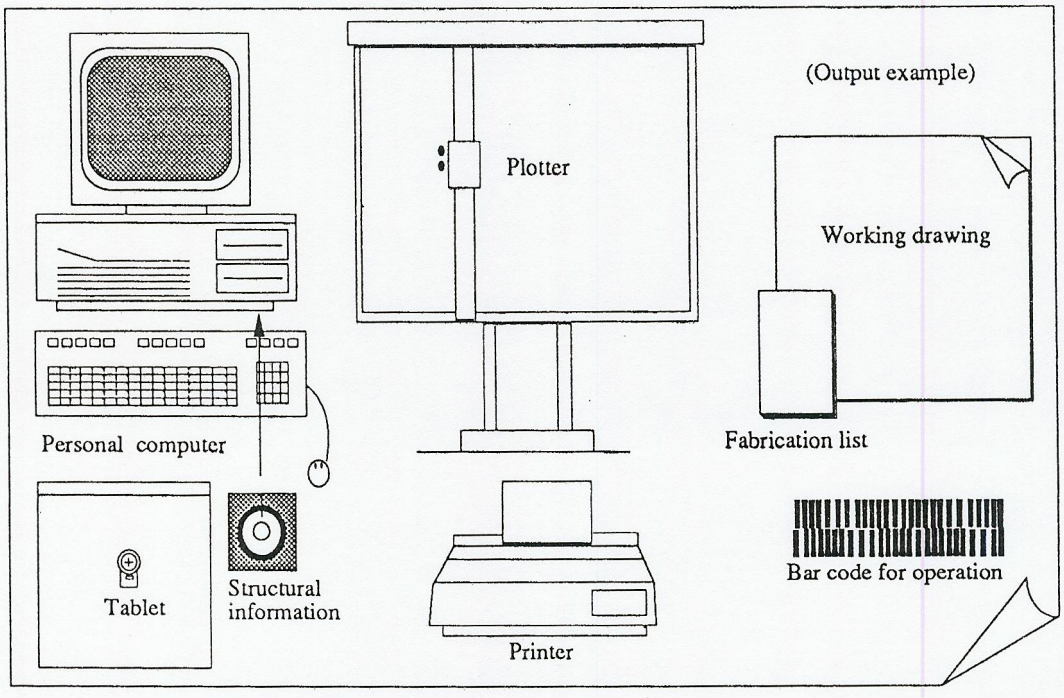

Fig. 1 Composition of the CAD/CAM System for Reinforcement Work

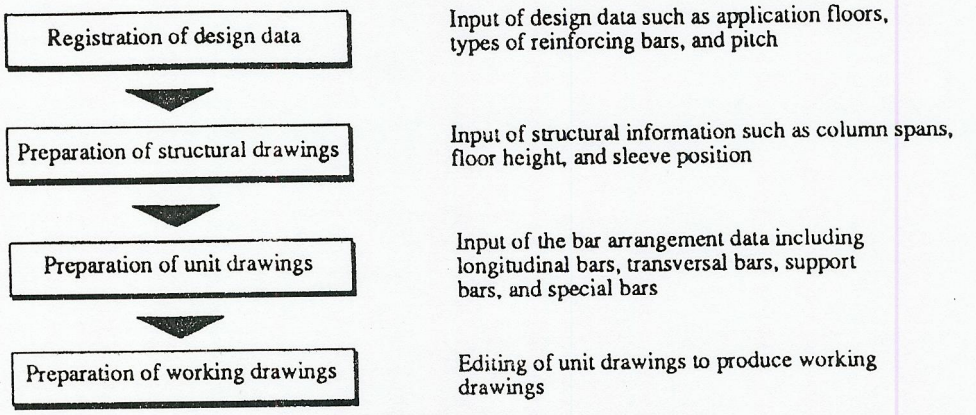

Fig. 2 Major Process Flow

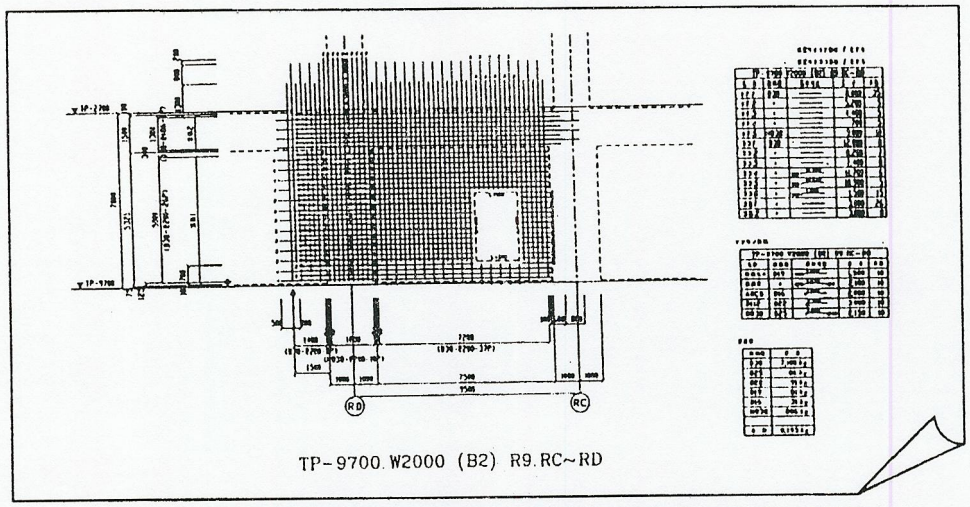

Fig. 3 Examples of Output Drawings from the CAD

The CAD system is usually installed at a field office of a reinforcement work subcontractor. To enable operation by anyone without any particular skill, an interactive system was applied.

To minimize the drawing preparation time, patterned bar arrangement methods were applied and various automatic processing functions such as automatic indication of dimensions and processing of bending lists as well as weight calculation charts were incorporated. To develop its own software for the system, "AutoCad" and "dBASEIIIPlus", the two widely recognized multi-purpose softwares for personal computers and data base use, were used as the base software. Combining the two different types of software made this system not only a line drawing device like a conventional CAD which uses personal computers, but made it a highly sophisticated device. The newly developed system differentiates the lines indicating reinforcing bars from all other lines, and also processes and outputs bending lists and weight calculation sheets.

The bar code labels are output in the form of Code39 based on the reinforcement information specified in the working drawings prepared by the CAD. The reinforcement information includes the data required by

the automatic bar arrangement system, i.e., number of bars, deviation between bars, bar intervals, and bar arrangement starting positions. The bar code labels also indicate the appearance of the unit to be fabricated and the switch setting method for manual operation. The copies of these bar code labels are distributed to the workers before the fabrication work starts.

2.2 Outline of the Automatic Bar Arrangement and Prefabrication System

The automatic bar arrangement and prefabrication system was designed to cope with the handling of long and heavy bars, a laborious work which is a conventional labor consuming task carried out by men. For example, the reinforcing bars used for the construction of a nuclear power plant weigh over 100 kg/bar, requiring 7-8 workers to handle one bar. Not only is it laborious but is also a dangerous work.

The new system has two vehicles, one each moving along the X and Y directions on a steel-frame made support base. The vehicles carry the reinforcing bars and place them one at a time in correct positions. Fig. 4 shows the outline of this system and Table 1 shows its specifications.

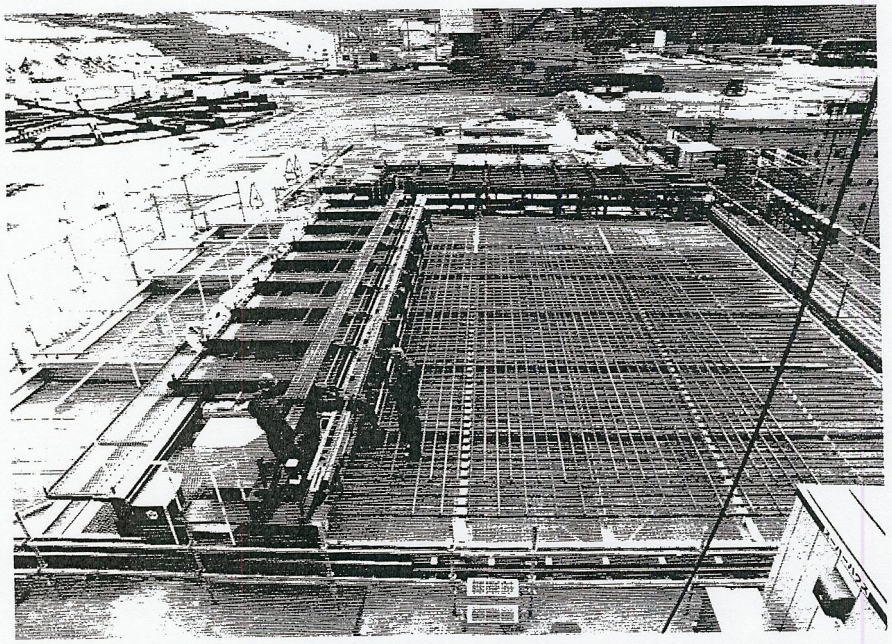

Fig. 4 Outline of the Automatic Bar Arrangement and Prefabrication System

Table 1

. Automatic arrangement of longitudinal and transversal bars
. Automatic arrangement of straight and bent bars
. Bar sizes: D29-D38, 12 m long
. Automatic adjustment according to bar diameters. Staggered arrangement is possible.
. Size of the support base: 18.6 m x 18.2 m

The system, as shown in the figure, consists of three units: two vehicles, one for arranging bars in the longitudinal direction and the other for arranging bars in the transversal direction; and a bar arrangement support base. The bars are arranged in the following manner: First, the longitudinally moving vehicle carrying the bars, moves forward until it reaches the preset position. Then, while moving backwards, it places bars one at a time at a preset interval on the support base. As the transversally moving vehicle places the bars in the same manner, a mesh unit is formed. The bars are then tied manually.

The bent bars can be longitudinally arranged by modifying the shape of the vehicle and partially modifying the support base so that they conform to the shape of the bent bars. These modifications are controlled by hydraulic units. Figs. 5 and 6 show this mechanism.

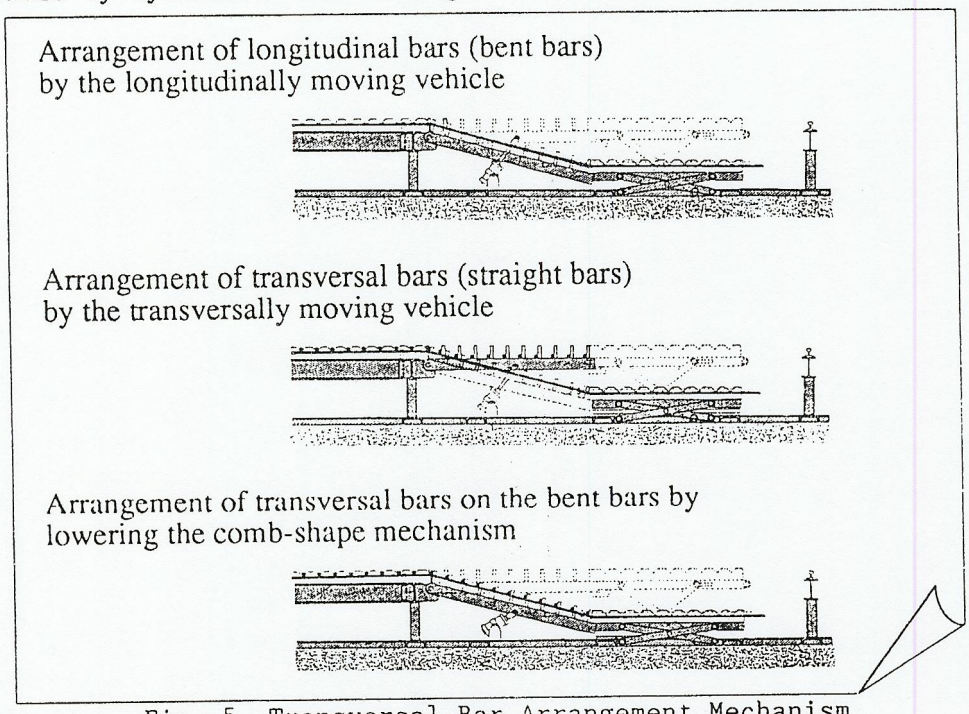

Fig. 5 Transversal Bar Arrangement Mechanism on Bent Longitudinal Bars

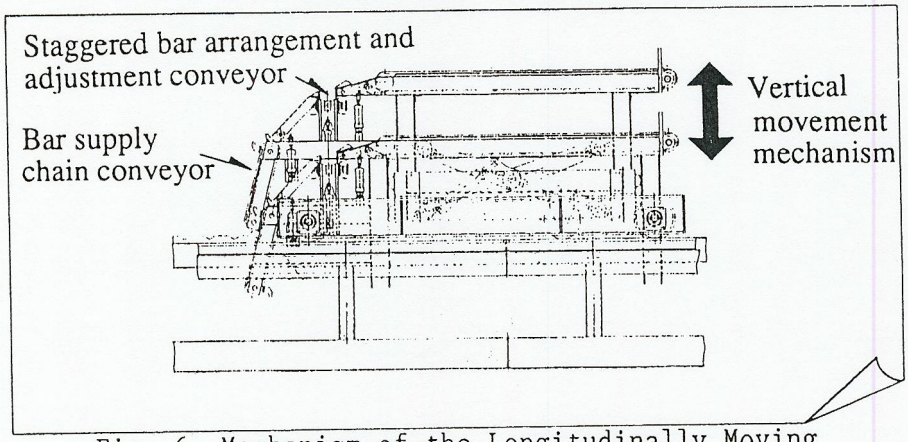

Fig. 6 Mechanism of the Longitudinally Moving Vehicle to Handle Bent Bars

In addition to the above, several bars can be omitted by changing the interval and different types of bars can be arranged. This allows handling of a variety of units and extends the system's scope of application. Fig. 7 shows the types of the units handled by this system.

The system is operable both manually and automatically. As the system transfers the necessary information while reading bar codes, an operator can run the system by just turning on the switch. No special skills are required of an operator even if deformed units are to be made.

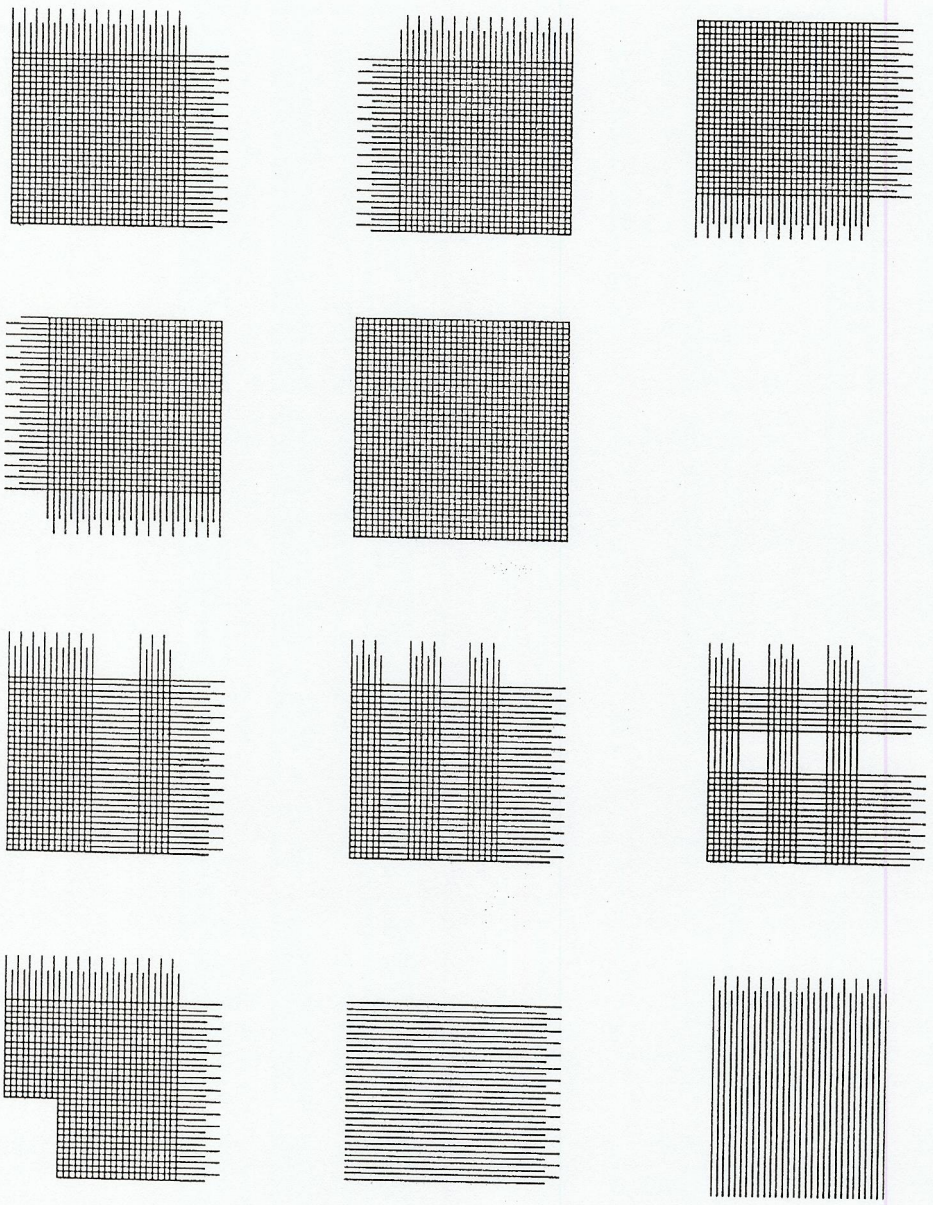

Fig. 7 Possible Types of Bar Arrangement Units

3. Effects of the Systems

By using the CAD system, working drawings can be produced in 2 hours as compared to 10-11 hours per drawing, and the drawing preparation work requires only one fifth of the manpower.

With the automatic bar arrangement and fabrication system, bars can be arranged in about 30 minutes in the case of a 10-ton unit. The overall productivity including tying by manual labor is almost twice the previous level. These work can be carried out by 4 or so workers whereas 7-8 workers were required before.

Since January 1990, two sets of these systems are being used at a nuclear power plant construction site in Niigata prefecture. At this site, a total of 45,000 tons of reinforcing bars has to be installed, and 50% among which will be fabricated by using the prefabrication method. The automatic bar arrangement and prefabrication system is planned to be applied to 60% of the reinforcing bars to be assembled by the prefabrication method. This means that 30% of all the reinforcing bars will be installed by the automatic bar arrangement and prefabrication system. Most of the reinforcing bars to be installed by the automatic bar arrangement and prefabrication system are used for foundation slabs and bearing walls. Fig. 8 compares the scope of the systems and their application efficiency at the site with a conventional method. The application of these systems greatly improved the productivity of the overall reinforcement work from the preparation of working drawings to the fabrication work at the site. In addition, the workers are released from laborious work by conventional methods. Considering these points, these systems are expected to contribute to the reduction in the construction period and improvement in work safety.

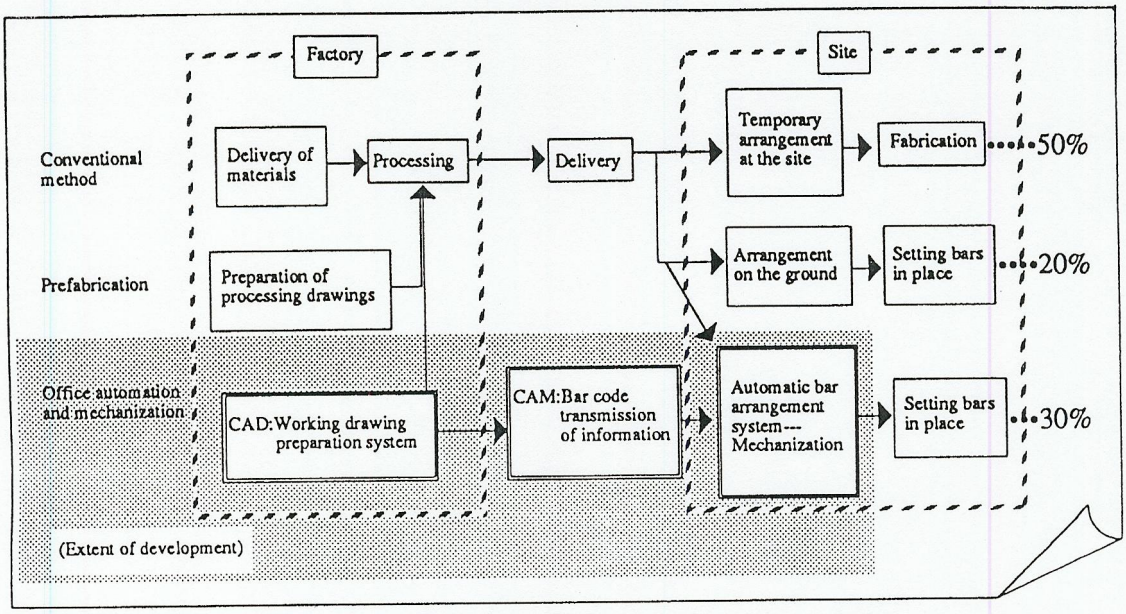

Fig. 8 Extent of the Development and Application Efficiency of the Systems

4. Conclusion

The Japanese construction industry is facing serious problems such as shortage of experienced workers and the disinterest of the young generation in the construction field. The new systems were developed to alleviate these problems by improving the efficiency of the reinforcement work of large-scale structures.

These systems are expected to be applied to other types of structures such as continuous underground walls. At the same time, further efforts are necessary to make the systems more compact so that they can be applied to general structures, and also to improve the performance of the systems by incorporating an automatic tying mechanism.