KAWASAKI STEEL TECHNICAL REPORT
No.21 (November 1989)
Civil and Architectural Engineering

Development of Computer Aided Backup System for Bridge Manufacturing

Senji Yamaguchi, Norihisa Kobayashi, Ei-ichi Ohya, Hiroshi Yamamoto

Synopsis :
Kawaden Co., Ltd. has developed an automatic mold lofting, an indispensable process for steel bridge manufacturing, and consequently a computer aided backup system for bridge manufacturing works has been established, which enables the works a continuous operation from design stage to mold lofting process. The know-how which is peculiar to our works, such as bridge fabrication procedure and shrinkage of steel material at welding, has been taken into consideration in the system. The characteristics of this system are as follows: (1) Special shaped end section of the girder which is frequently dealt with is covered. (2) Mutual interference of bridge members can be automatically detected. (3) Output form of mold lofting documents can be easily arranged in accordance with the requests of clients. (4) Man-hour-per-ton necessary for a bridge mold lofting is similar to those calculated by conventional calculation centers in Japan, but can be reduced to nearly 65% of that for manual lofting.

The body can be viewed from the next page.

Development of Computer Aided Backup System for Bridge Manufacturing*


Senji Yamaguchi
General Manager,
Chiba Plant, Bridge &
Steel Structure Dept.,
Kawaden Co., Ltd.


Norihisa Kobayashi
Manager,
Chiba Structural
Design Sec., Bridge
& Steel Structure
Dept., Kawaden Co.,
Ltd.


Ei-ichi Ohya
Chiba Structural
Design Sec., Bridge
& Steel Structure
Dept., Kawaden Co.,
Ltd.


Hiroshi Yamamoto
Chiba Structural
Design Sec., Bridge
& Steel Structure
Dept., Kawaden Co.,
Ltd.

Synopsis:

Kawaden Co., Ltd. has developed an automatic mold lofting, an indispensable process for steel bridge manufacturing, and consequently a computer aided backup system for bridge manufacturing works has been established, which enables the works a continuous operation from design stage to mold lofting process. The know-how which is peculiar to our works, such as bridge fabrication procedure and shrinkage of steel material at welding, has been taken into consideration in the system.

The characteristics of this system are as follows:

(1) Special shaped end section of the girder which is frequently dealt with is covered.
(2) Mutual interference of bridge members can be automatically detected.
(3) Output form of mold lofting documents can be easily arranged in accordance with the requests of clients.
(4) Man-hour-per-ton necessary for a bridge mold lofting is similar to those calculated by conventional calculation centers in Japan, but can be reduced to nearly 65% of that for manual lofting.

1 Introduction

Kawaden Co., Ltd. manufactures steel bridges at its Chiba and Harima Plants. Starting in 1972, the company introduced NC drafting and cutting and drilling machines in the Manufacturing Division at Chiba, while a super-minicomputer and automatic drafting machine were introduced in the Chiba Design Division beginning in 1986, thereby realizing CAD-CAM operation in steel bridge manufacture.

Steel bridge manufacture is, in ordinary cases, divided into the mold lofting and actual production. Mold lofting, in which manual scribing is carried out on a suitable expanse of floor, was widely employed in the past, but the method posed many problems such as the difficulty of obtaining adequate skilled manpower as well as low worker efficiency and frequent errors. As a result, some computation centers and leading bridge makers attempted to automate the mold lofting operation using computers and automatic drafters with several examples of implimentation.[1-3]

Kawaden placed orders for a considerable amount of mold lofting work with computation centers and others, but encountered problems such as the insufficiency of processing capacity, lack of flexibility to cope with short-deadline orders, restrictions in programs, and the need for a large amount of manual work in addition to the computer output. Consequently, it was considered necessary for Kawaden itself to computerize the mold lofting process and develop an integrated processing system covering the design process through mold lofting.

* Originally published in *Kawasaki Steel Giho*, **21**(1989)1, pp. 45-49

Recently Kawaden developed a bridge manufacture backup system for the plate girder and box girder bridges, which are manufactured with comparative frequency, incorporating its own manufacturing information and the function of automatically checking for interference between members. In this report describes the features of the system.

2 Objective of System Development

The main points in the present system development are summarized as follows:

(1) Integrated Processing System Ranging from Bridge Design to Completion of Mold Lofting
Orders for steel bridge manufacture generally comprise two types: (a) orders which include the design work, and (b) orders in which the design calculations and drawings are supplied by the customer. The present system can be applied to either of these two method. In case (a), the present system automatically passes to the mold lofting process such basic data as the cross section shapes of the main girder and cross beams, their positions on the bridge, and the bridge framing in cross-section, all of which should be determined during the design stage, thereby determining the required information for the production process. In case (b), the necessary data is manually input to the mold lofting system and, as with (a), the system then prepares the information required for the production process in a comparatively short period.

(2) Range for Processing Shapes of Main Girder and Cross Beams
Recently there has been a trend toward diversification of the details of construction specifications, such as the main girder and cross beam requirements in accordance with requests by the customer. To cope with this situation, the present system makes it possible to carry out automatic processing of not only the basic member shapes, but also special shapes which are processed with comparatively higher frequency, thereby saving labor and enhancing processing speed.

(3) Checking for Interference between Members
When using the member sizes, intersecting lines for connecting member angles, and the layout of bolt holes stipulated in the design of a steel bridge, interference between members occasionally makes assembly work impossible. To prevent this problem, the system checks for any interference between members and, if there is any, automatically eliminates the interference or displays its location, thereby facilitating the necessary redesign work.

(4) Program Modularization
In the system, the stages of design, drafting and mold lofting are made into independent programs, and then these programs are sub-divided into modules. Through this process, even re-calculations accompanying partial changes can be processed in a minimum time by selecting an appropriate program.

3 Outline of Bridge Manufacture Backup System

3.1 Composition of Hardware

The hardware for the system consists of a MELCOM 70/250 system[4] as a computer and DRASTEM 3800C/1225C, which performs the drafting of drawings and template cutting. The hardware composition of the entire system is shown in **Fig. 1**.

3.2 System Composition and Functions

In general, bridge manufacturing work consists of three stages, that is, design mold lofting, and manufacturing. The bridge manufacture backup system is a computerized processing system for mold lofting, and consists of the five subsystems shown in **Fig. 2**. Their functions are described below.

3.2.1 Material calculation subsystem

In this subsystem, the members necessary to be manufactured arranged on the roll plate, which is assumed to be equivalent to the member necessary for manufacture, and the grades of steel, numbers of necessary roll plates, and steel shapes are obtained according to the grades of steels and plate sizes. This subsystem is used in placing orders for roll plates and shapes.

First, members are automatically arranged taking into consideration the performances of the NC drafting and cutting machine and flame planer and the yield of the rolled plate, and then minute corrections are made by interaction with the computer.

3.2.2 Basic coordinates calculation subsystem

Section shapes for the main girders and cross beams, their positions and elevation in the bridge, and the framing of the bridge in cross-section to be determined in the design process constitute the basic data in bridge manufacture. The basic coordinates calculation subsystem takes into consideration manufacture warping at the time of positioning of these members, interpolates the warping using three-dimensional curves, and obtains the required coordinates.

3.2.3 Member calculation subsystem

In this subsystem, the members comprising the bridge are disassembled member by member, the three-dimensional shapes of the respective members are calculated taking into consideration their shrinkage by welding and allowances for cutting, and further, plane development is performed for working on the roll plate, thereby obtaining the external plane coordinates and folding position coordinates. In this system, drilling calculations for bolt holes, manholes, etc., and shaping

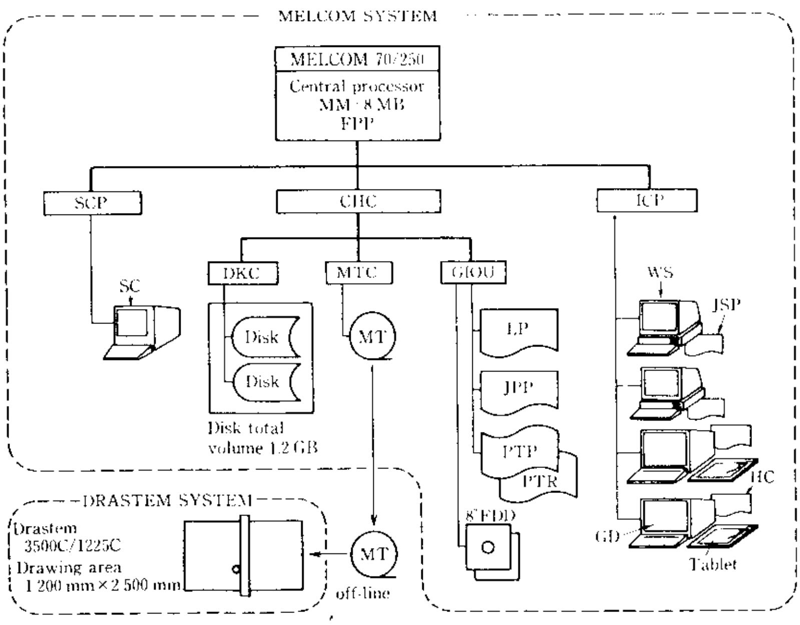

Fig. 1 Composition of hardware

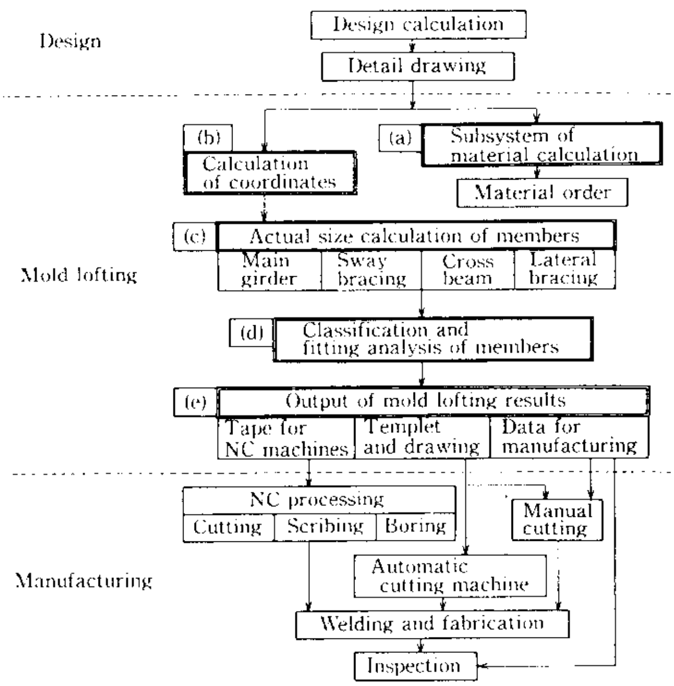

Fig. 2 Bridge munufacturing process

calculations for edge grinding and corner cutting are also performed. Coordinate values and machining information obtained using this subsystem are input to the NC drafting and cutting machine and used for automatic marking-off and cutting of parts.

3.2.4 Member arrangement and classification subsystem

The term "member arrangement calculation" means calculation of the positions and angles at which respective members will be connected. In mold lofting on the floor, this means preparation of a ruler, but in the present system, this arrangement information is sent to the NC machine for automatic scribing. In principle, therefore, the ruler making operation has become unnecessary.

In the classification calculation subsystem, a number of members are classified into groups which can be made up in identical shapes on the basis of the function of the members and working shape information. In addition, members having the same composition and the same assembled size are classified into blocks.

3.2.5 Mold lofting calculation result output subsystem

The results of the model lofting calculation are output by the automatic drafter, printer, etc., in the form of NC machine chart paper and tape, plate joint detail figures, marking-off diagrams, numerical tables, etc.

In the NC output, the member to be output is arbitrarily designated, while in the automatic drafter output, the scale to be used for drafting and the pen or cutter are also designated in addition to the member to be output.

Input/output contents and operations are shown in **Fig. 3**, and an output example is shown in **Fig. 4**.

4 System Features

As features of this system, operations requiring human attention are minimized while those which can be performed automatically by computer are maxi-

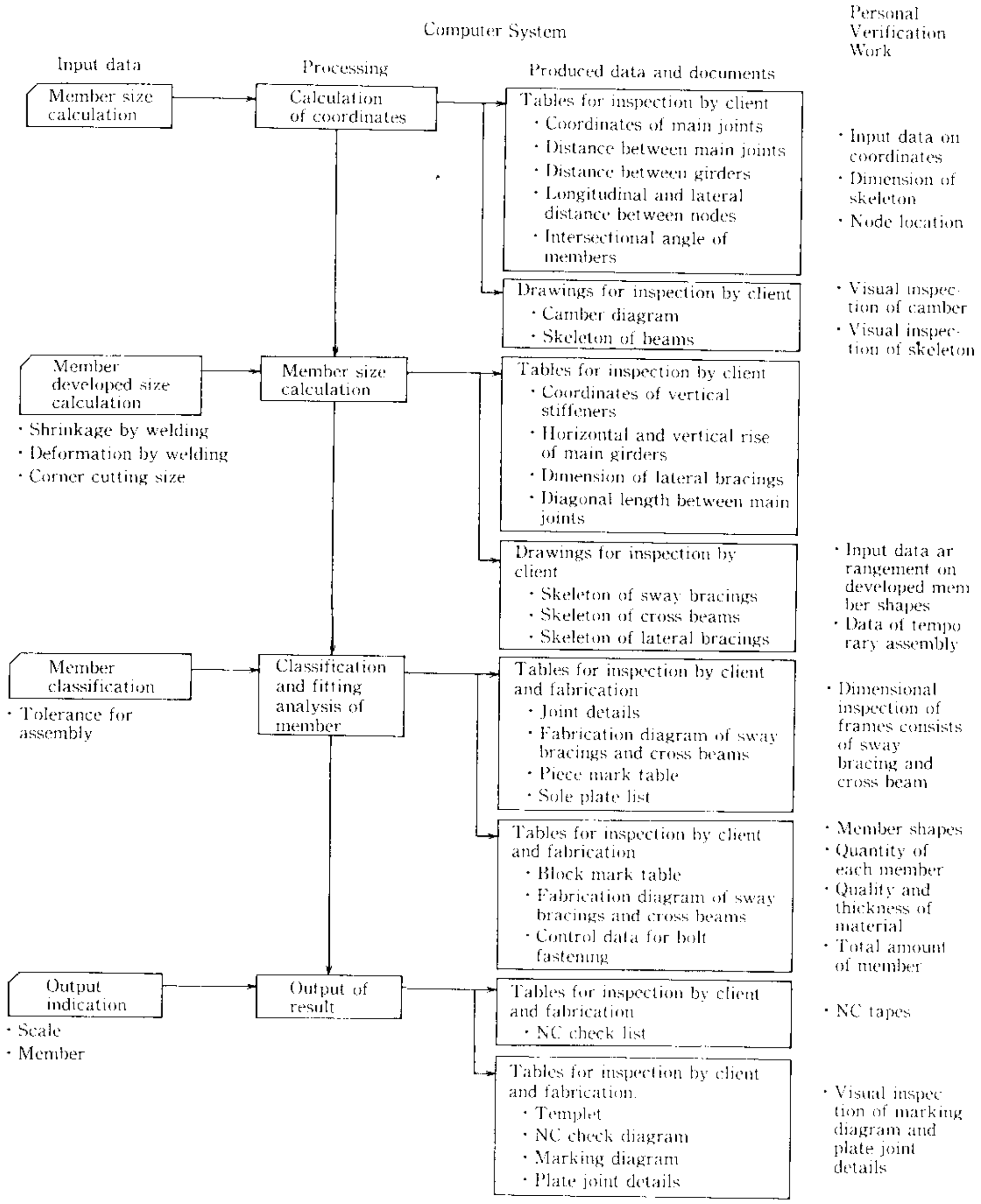

Fig. 3 Input and output processes and their results

mized, minimizing the probability of human error in judgement. A few concrete examples are shown below.

4.1 Variable Cross Section Processing of Girder End Sections

For the girder end sections, various shapes are adopted according to customers' specifications. The present system has made it possible to process the four typical shape types shown in **Fig. 5**. Integrated processing is performed by inputting the shape type and related data, and the individual member is formed.

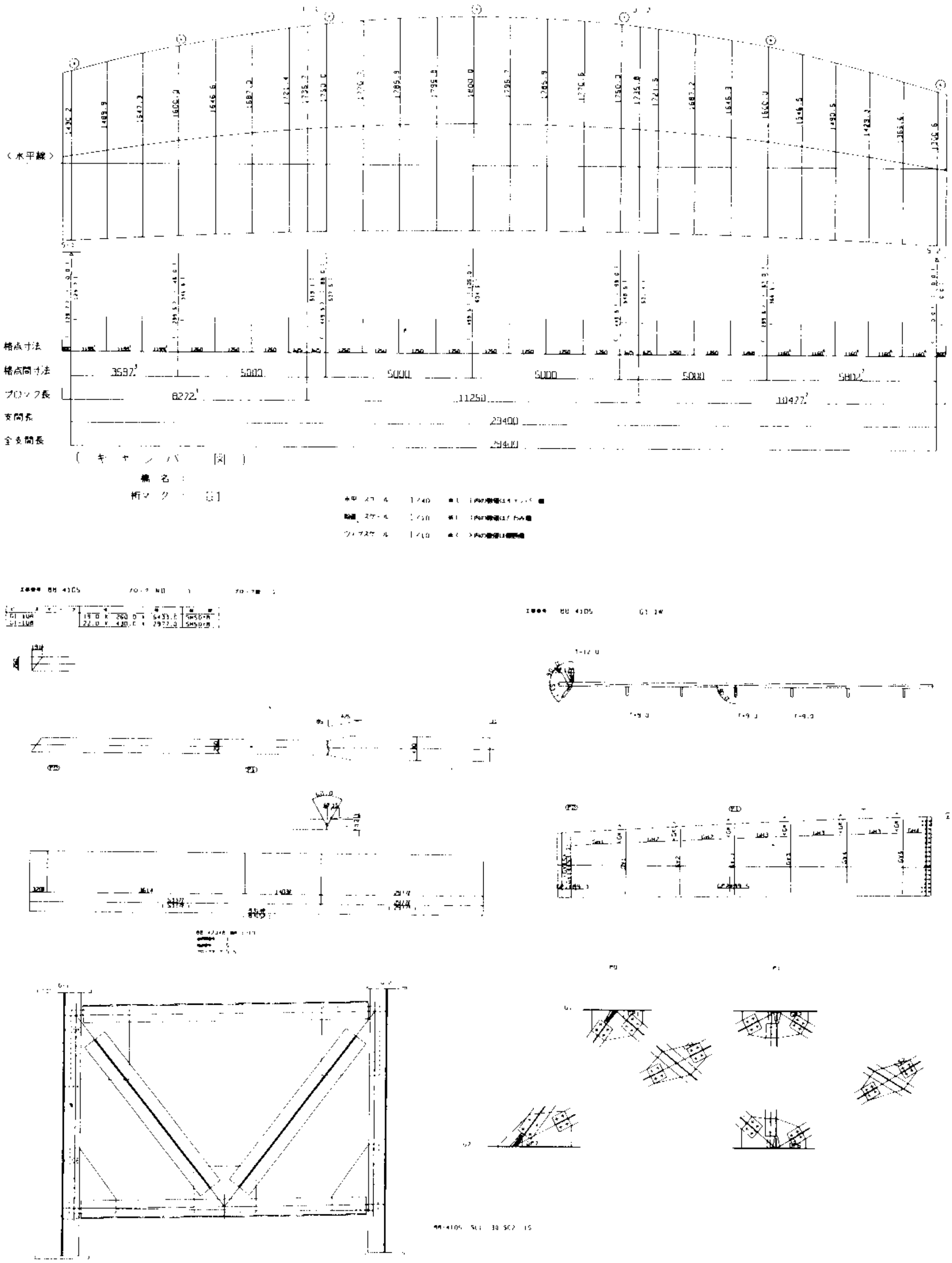

Fig. 4 An example of output of automatic mold lofting

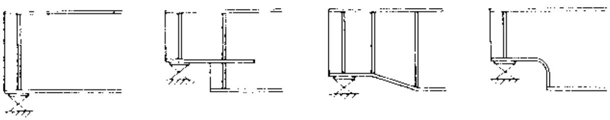

Fig. 5 Girder end section which can be covered by the system

4.2 Processing of Sole Plate

The sole plate must be made into a shape that has different thickness values at its four corners depending upon the angle of intersection of the vertical curve and girder center line of the bridge. The thickness values at the four corners are calculated in the system by inputting the design thickness of the plate center, external dimension and rolled plate thickness, and a check is made to determine whether the thickness of the rolled plate is adequate for the thickness of the sole plate.

4.3 Notch Processing of Sway Bracing Gusset Plate

The sway bracing gusset plate must sometimes be provided with a notch cut to avoid the horizontal stiffener, as shown in **Fig. 6**. Whether this notch was necessary or not was decided by the designer and processing was performed manually in the past, but in the present system, this is automatically determined and, if necessary, a notch shape of appropriate size is output.

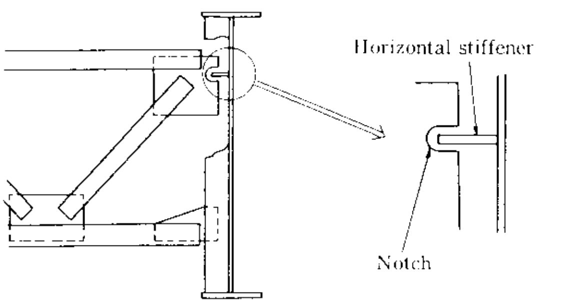

Fig. 6 Gusset plate with automatically drawn notch

4.4 Shape Determination Processing of Horizontal Bracing Gusset Plate

When the horizontal gusset plate interferes with the main girder splice plate, the shape of the former had to be changed manually in the past. The system automatically determines interference and changes the shape of the gusset plate when and as necessary. An example of this automatic process is shown in **Fig. 7**.

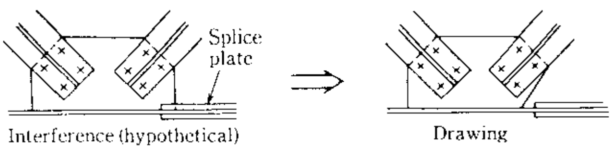

Fig. 7 An example of automatic adjustment of joint design
(When a gusset plate for lateral bracing interferes with splice plates in original design, this system automatically adjusts shape of the gusset plate and gives a drawing without any interference.)

5 Effect of System Development

5.1 Company-Owned System

Automatic mold lofting systems are employed by some computation centers as mentioned earlier. In the past, Kawaden placed a considerable volume of orders with outside computation centers, but with the development of the company-owned system, the following benefits are now expected:

(1) Since the functions of the NC machinery can be used to the maximum limit, the company can now improve its automatic model lofting system independently and is now in a position to easily achieve automation of bridge manufacture.
(2) Processing is executed by the company's own computerized system, giving the company the flexibility to rapidly cope with imminent delivery dates or sudden design changes during processing.
(3) The output format of reference materials for inspection by the customer can be easily changed, when and as necessary.
(4) The bridge manufacturing sequence peculiar to the company's factory and know-how, such as methods for coping with shrinkage due to welding and allowances for cutting, can be incorporated into the system, upgrading the quality of the company's products.

5.2 Operation Example

The K-Bridge as an example was recently processed by the system, and a comparison was made between the system, conventional method of mold lofting on the floor, and processing commissioned with an outside computation center. The K-Bridge is a 114-m-long 3-span continuous non-composite plate-girder road-bridge (with four main girders) weighing 207 t. The result of the comparison is shown in **Table 1**.

The system required nearly the same processing man-hours as if commissioned with an outside computation center, but showed a remarkable reduction when compared with model lofting on the floor. The system prevented, however, problems in the manufacturing

Table 1 Man-hour-per-ton comparison as to mold lofting for K Bridge between this system and others

	Mold lofting on the floor	Calculation Service Center*1	This system
Man-hour/ton*1	100	37	35

*1 Expected values which consist of automatic mold lofting and residual manual works.

stage, because the interference checking function of the system was effective. In addition, this system seems to have contributed to higher efficiency during the manufacturing stage, because it permitted easy readout of output documents.

6 Conclusions

The authors have constructed a steel bridge manufacture backup system which incorporates manufacturing information available at Kawaden Co., Ltd. factories and the girder accessories processing process. The main functions of this system are enumerated below.

(1) Integrated processing is possible in bridge manufacture ranging from design to completion of mold lofting.

(2) At the end sections of main girders and cross beams, not only the basic member shapes, but also those with special shapes which are in comparatively frequent use, can now be processed automatically.

(3) The system has an automatic checking function for determining whether the rolled plate thickness is adequate for the sole plate.

(4) A notch shape of a suitable size can be output for the sway bracing gusset plate, so as to avoid interference with the horizontal stiffener.

(5) When interference of the horizontal bracing gusset plate with the main-girder splice plate occurs, the shape of the former can be automatically changed to avoid this problem.

(6) The number of mold lofting man-hours with the system are nearly equal to those required by outside computation centers, but a reduction as great as 35% can be expected in comparison with actual mold lofting on the floor.

Because every bridge is unique, bridge manufacturing is a typical multiple small-lot production task. The system which the authors have developed cannot be said to be an automatic mold lofting system able to cope with all bridge members, and areas requiring human attention still remain. The authors therefore intend to coutinue with the improvement of supplementary member functions in the mold lofting process and the development of subsystems permitting processing of accessories such as handrails and expansion joints.

Finally, the authors would like to express their deep appreciation to the staff of Kawasaki System Development Co., Ltd. and other staff members who have cooperated in the course of the system development, and also to all other persons concerned.

References

1) Mold Lofting System Kaihatsu-kai (Development Group): *Bridge Engineering*, **17**(1981)10, 8
2) ADAMS Kenkyu-kai (Study Group): *Bridge Engineering*, 17(1981)10, 8
3) T. Kamei, E. Hayashi, Y. Ôtsuka, S. Ogawa, M. Yamanaka, T. Sakurai: *KHI Technical Review*, **96**(1987), 101
4) Mitsubishi Electric Co., Ltd.: MELCOM70 Series VOS System Control Manual