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DEVELOPMENT OF REINFORCINGBAR FABRICATING ROBOT

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[ABSTRACT]

When this robot was used to make 1,000 beam reinforcing bars for the B building of the Okawabata River City 21 in Tokyo, it increased production efficiency by 50 percent compared to skilled manual labor.

Usually a team of three rebar workers set stirrup bars around the main reinforcing bars and bind them together with iron wire. However,due to the increase in construction projects and the aging of construction workers, there is now a serious shortage of rebar workers in Japan.

This robot developed by Taisei is 8.5 meters long, 1.7 meters high and 1.5 meters wide and weighs 3.5 tons. It consists of a machine base with rails and a mobile cart carring a bar placement device and an automatic binding device.

Then, this robot has been actively followed in the industry for prefabrication, normalization, standardization of materials and mechanization of actual construction work and, furthermore, the implementation of CAD/CAM in some trades, is basically the same in outline as the development of production technology.

1. Aim of this development

In the present situation when the shortage of skilled workers is being felt more and more seriously, this robot was planned so that skilled workers could be assigned to more complicated tasks, such as panel-zones at the interface between columns and beams, by mechanizing simple repetitious jobs such as the fabrication of beam reinforcing bars. The following three factors were chosen as the basis of development policy before tackling the work:

1 The robot should be easily operable by anyone after simple handling training.

2 The robot should require only one operator.

3 By mechanizing operations, the accuracy of beam reinforcement fabrication should be guaranteed.

This technology was designed specifically to be used for the PC beam reinforcing bars of the Ohkawabata River City 21B Building which is currently under construction at Chuou-ku in Tokyo.
Three types of beam are used in the construction although all are approximately the same in shape, and about 1000 beams in total.
The stirrups for the beams are closed ring stirrups of different design from the conventional hook specification.

2. Fabrication of preassembled reinforcing bar unit

2-1 Conventional operation

In recent years, the construction industry has made widespread use of precast concrete members so as to reduce the number of workers needed and to shorten the site construction period.
The fabrication of reinforcing bars for these various PC members was conventionally done using steel wires of 0.8■ to 0.9■ in diameter and a tool called a hooker, and using a trestle to support the reinforcing bars while jointing work was completed by several reinforcing bar placers.
This work was a repetitious nature that demanded skill to obtain a high fabrication accuracy and it was unpleasant since it involved handling heavy reinforcing bars.

2-2 Scope of automation

Although all the following processes are involved in fabricating PC beams, the robot has been able to autmate steps 4 to 9 :

1 Cutting and bending of main reinforcing bars
2 Cutting and bending ofreinforcig bars for stirrups
3 Placing top main reinforcing bar
4 Marking position of stirrup bars
5 Placing of stirrup bars
6 Binding intersections between main reinforcing bars and stirrup bars

7 Placing of bottom main reinforcing bar inside stirrup bars
8 Binding of hooks at both ends of top and bottom main reinforcing bars
9 Binding of intersections between bottom main reinforcing bars and stirrup bars
10 Lifting and placing into formwork
11 Placing of ready-mixed concrete
12 Curing
13 Stripping of formwork, raising, and installation

3. Description of Mechanizm

3-1 Complete mechanism

In general, the mechanism consists of a base that carries the complete machine, a stirrup holder that draws the stirrup bar into the erection device, a stirrup bar erection device, and two automatic binding machines, upper and lower. There is also a robot carriage that carries the binding wires, manipulator with bindig machines, an upper main reinforcing bar support arm that supports the top main reinforcing bar, a lower main reinforcing bar support arm that supports the bottom main reinforcing bar, and a power supply (refer to Fig-1, Photo-1, Photo-2).

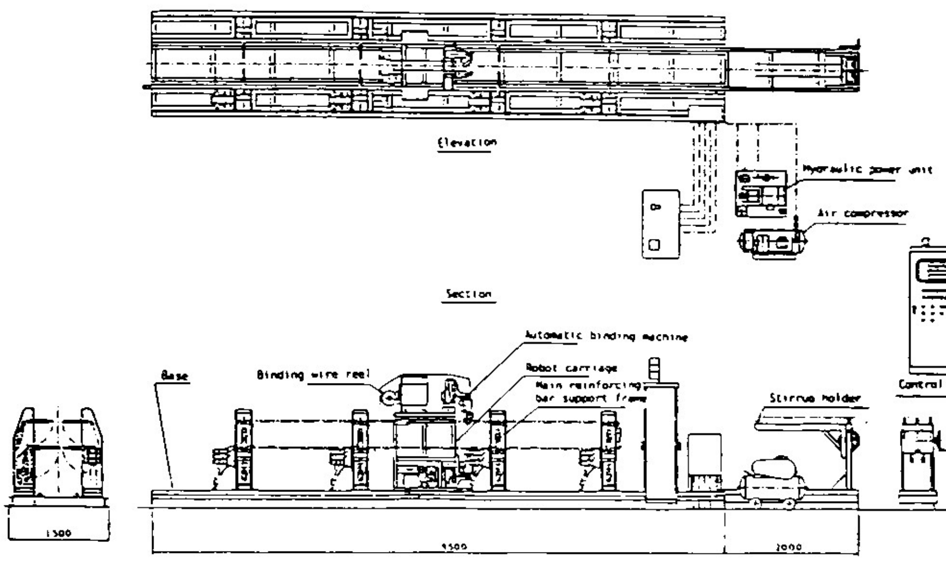

Fig-1 Complete mechanism

Photo-1 General view of reinforcing bar fabricating Robot

Photo-2 Robot carriage

Table-1 show the major specifications.

3-2 Automatic binding machine

There are various methods of binding the reinforcing bars, including the use of wires, resin bands, binding by pressing with steel plates, and welding. With these various binding methods, there many problems to be solved, perticularly in terms of the supply of binding materials, if they are to be incorporated into an automated robot. Binding by welding is not considered suitable as it means heat treatment on bars that will be load bearing.

The method of binding using steel wires was adopted after considering the reliability, ease, and economy of automatically supplying the binding materials (refer to Photo-3).

The main unit consists of a mechanism that feeds a certain length of binding wire from a reel, a mechanical system that guides the binding wires, and a mechanism that twists the steel binding wire. During binding, the guide clips the main bar and the stirrup bar together, feeds a designated length of binding wire through the guide, and cuts it off simultaneously with the twisting operation.

Beam reinforcing bars fabricated using automatic binding machine were tested for durability by applying external bending, torsion, and tension forces, and no deformations nor binding failures were observed.

Table-1 Major specifications

Capacity	Size of corresponding	
	height	300 mm - 500 mm
	length	4,000 mm - 6,000 mm
	width	250 mm - 400 mm
	Minimum pitch of stirrup bar	75 mm
	Corresponding main bar	D19 - D25
	Corresponding stirrup bar	D10 - D16
	Binding time per joint	4 seconds
Power source	Main body drive motor	200V 1.5 kW
	Hydraulic power unit	200V 7.5 kW
	Air compressor	200V 1.5 kW
	Binding machine sliding table	100V 0.2 kW x 2
	Automatic binding machine	100V 0.1 kW x 2
External dimensions	1700 mmH x 8500 mmL x 1500 mmW	
Overall weight	3.5 tons	

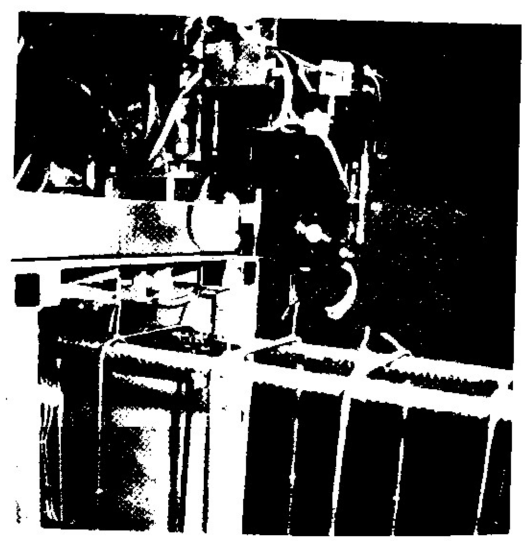

Photo-3 Binding machine

3-3 Operational flow

Select beam specification using selection buttons on control panel.

↓

Place stirrup bar in stirrup holder.

↓

Place main bars in upper and lower main bar support arms. At this point, the lower main bar support arm is above its designated position (refer to Fig-2).

↓

Insert stirrup holder into bar arrangement device in the robot carriage transferring the stirrup bar.

↓

Push automatic operation button on control panel.

↓

Arrange stirrups at the designated pitch, bind points of intersection between stirrups and the top main bar in sequence.

↓

As stirrup bars are placed and bound, the lower main bar support descends until the stirrup bar touches the main bar.

↓

The robot carriage sequentially binds the points of intersection between the bottom main bar and stirrups.

↓

When binding at all places is completed, the robot carriage stops automatically, and informs the operator with a flashing rotating light on the carriage.

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Operator releases the upper main bar support arm manually and removes the completed beam reinforcing unit using a crane, etc.

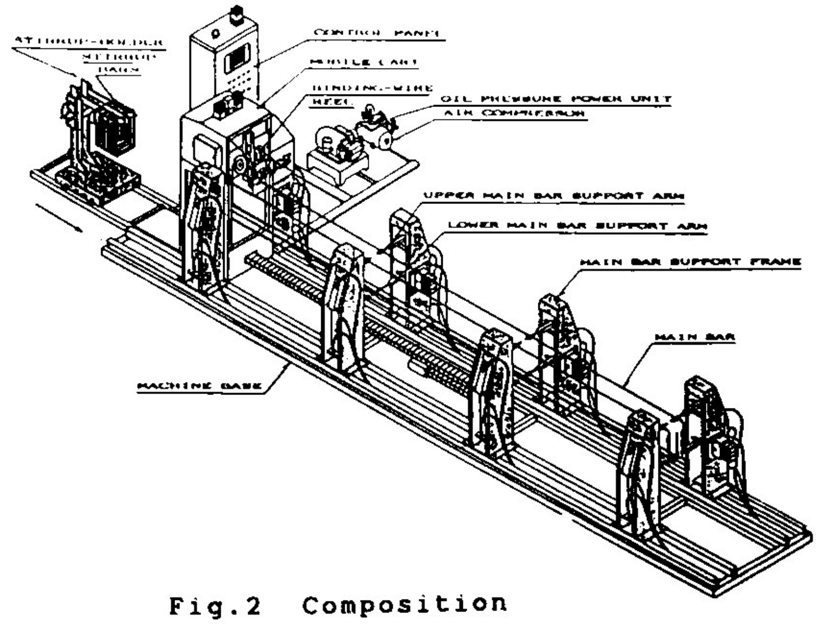

Fig.2 Composition

4. Resultant Labor Saving

Table-2 explains the labor saving effects of introducing the robot. As can be seen from the Table, the results which almost satisfy the initial design criteria were obtained.

Table-2 Comparison of Workforce required for the fabrication cycle

Item \ Type of operation	Conventional manual operation	Robot operation
Number of beams fabricated	1,008	
Workers employed	Reinforcing bar placer 3	Operator 1
Working hours	Actual working hours 7 hours/day	
Required time for erection (1 cycle)	preparation 5 min. / erection 9 min. / moving 6 min. — 20 min./bar	preparation / erection / moving — 31 min./bar
Number fabricated per day	420 min. / 20 min/one = 21 beams/day	420 min. / 31 min/one = 13 beams/day
Total working day	1,008 / 21 beams/day = 48 days	1,008 / 13 beams/day = 77 days
Total number of workers	48 days x 3 = 144 man days	77 days x 1 = 77 man days

5. Conclusion

In the field of manufacturing industry, CAD/CAM systems that link the design and manufacturing processes have been gradually improved as their effects on productivity were verified. An effective policy for this work has been worked out by various research teams centered on MITI and a specific movement toward CIM from the overall viewpoint has been promoted. An example of this is a large scale joint project involving governments, academic groups, and private industry that has been undertaken jointly with North America and Europe under Japan's leadership called the "IMS Joint International Research Programs into an Intelligent Manufacturing System". This program solicited proposals in February of this year and movement toward highly sophisticated production technology for the 21st Century is proceeding through the participation of construction companies. Also, within the construction industry, individual companies have been promoting research and developement on a variety of themes, either jointly or alone, with the aim of revolutionizing production technology.

On site construction work consists of assembling a diverse range of materials using a variety of construction methods and keeping to a tight schedule. Although its form differs from the work of manufacturing industry in many ways, the means by which production technology has moved forward are a valuable lesson for the construction industry.