FACTORY AUTOMATION OF CONCRETE PAVING BLOCK MANUFACTURING FACTORY

S. Suda, T. Yajima

Chlchibu Cement C., Ltd, Japan

O. Kodama, M. Aral

ILB Co., Ltd, Japan

Summary

Concrete paving block factories has adopted a labor-saving system in which operations ranging from concrete mixing, casting and curing to packaging are automated. However, the recent diversified markets require concrete paving block factories to produce a wide variety of products in small quantities. Under such circumstances, the use of conventional equipment to manufacture products of different types is causing a substantial losses, thereby lowering productivity. Along with the construction of a new factory, Saitama Plant of ILB Co.. Ltd, has developed and introduced a factory automation (FA) system with the aim of ensuring efficient production and quality control to permit the production of a wide variety of products and improving the work environment.

1. Introduction

There has been a conspicuous trend toward the improvement of urban environment for the past several years in Japan. This has entailed an increasing demand for diversified paving materials. As a result, a greater diversity of concrete paving blocks has become available. Hundreds of types of products are being produced in a factory each year. The conventional equipment use in the factories has allowed a substantial labor-saving in manufacturing limited product types through completely automated concrete mixing, casting, curing and packaging. However, the manufacturing efficiency and product quality have deteriorated after frequent changes in manufacturing product types. This is not only because mixer cleaning and formwork replacement require a tremendous amount of time but also because a substantial time is required to find the optimum operating condition that ensures a stable quality even after a modification occur in manufacturing product types. In order to improve efficiency in formwork replacement, a block machine that could replace a formwork in five minutes,' was developed several years ago, and most factories are using block machines of this type. However, it is still impossible to find the optimum operating condition quickly only by improving the equipment. Operating methods as well need to be improved.

In order to solve this problem, we have developed a system whereby the optimum operation data of each product type that has been obtained from the past production record, is recorded into the computer, and data on each product type to be manufactured can be accessed during production so that defective products can be avoided from the beginning. In order to save labor, we have also computerized production data process that has increased in volume due to the diversification of products.

Another theme is to improve the work environment. In the concrete

product factories where noise and dust occur, workers have been obliged to work in a tough working condition. On the other hand, other industries are achieving a pleasant work environment through the introduction of FA systems. To improve such an out-of-date working condition is a social mission of concrete manufacturing companies. If this problem is not solved, concrete manufacturing companies will not be able to survive. We have established a control center from which operations can be remote controlled, with the aim of improving the work environment. This report covers the summary of the FA system that was introduced into Saitama plant of ILB Co.

2. Past problems and technological themes for the FA system

Table 1 shows problems, technological themes and remedial measures in order to achieve the following long-lasting themes of concrete paving block factories: (1) to be able to manufacture diversified products, (2) to improve the work environment and (3) to ensure efficient operation. A FA system has been developed so that remedial measures as shown in this table can be taken to solve the technological themes.

With respect to the technological themes marked with an asterisk as shown in this table, since it is not easy to understand how such technological themes are posed by these problems, their specific examples are below.

Theme	Problem	Technological theme	Remedial measure
To be able to manufacture diversified products	① Increased mix proportion	① To simplify the mixing opetation	① Recording of mix proportion into the computer ② Automatic mix proportion are set
	② Increased data and complicated process	② To ensure more efficient data process	③ Computerlized data process
	③ Increased changes in operation procedure (Decrease in operation rate and yield)	*③ To ensure more efficient operation procedure	④ Quicken activation through the use of the past operation data
To improve the work environment	① Noise and dust ② Hot and cold ③ Dangerous ④ Difficult to recruit workers	① To remote-control the operations	① Establishment of a control center ② Automatic quality inspection and making the results displayed in the center ③ Visual inspection by means of a monitor TV
To ensure more efficient opetation	① Many workers are required	① To save labor in material supply	① Automatic material supply
	② Efficiency lowered due to dispersed information	*② To adjust water content of materials more accurately during mixing	② Quality inspection and water adjustment by the casting operators in the center
	③ Unstable quality	*③ To improve the water control method	③ Use of mixer water sensors
		*④ To save labor in quality tests	④ Establishment of automatic testing devices ⑤ Data process by computers
	④ Careless production control	⑤ To save labor in the sampling of production control data	⑥ Automatic sampling of production control data ⑦ Automatic preparatin of daily reports

Table 1 Past problems and technological themes for the FA system

2.1 Example of operation procedure

The conventional operation procedure is shown in Fig. 1. Since the adjustment of block machine operation patterns and water content of concrete or mortar in the mixer has been carried out by repeating trials based on the survey on causes for defects in casted prototypes, it has required a considerable amount of time to succeed. As a result, the operation rate lowered, and the percentage of defective products has

increased. This has posed a technological theme that is to save labor in operation procedure. To that end, we have reformed the operation procedure as shown in Fig. 2 so that the block machine operation patterns and water adjustment can be set based on the past operation data that can be accessed when necessary.

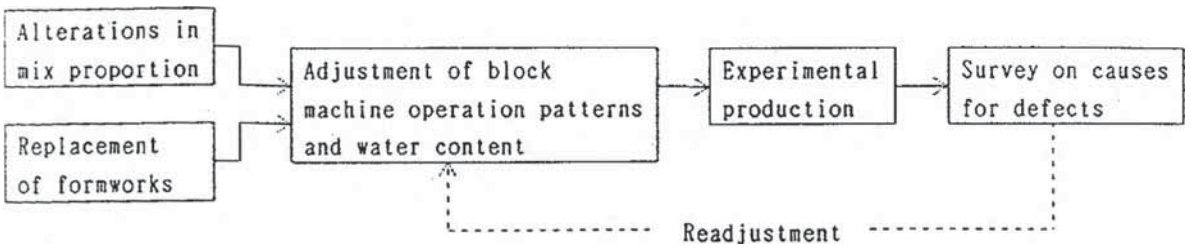

Fig. 1 Past operation procedure

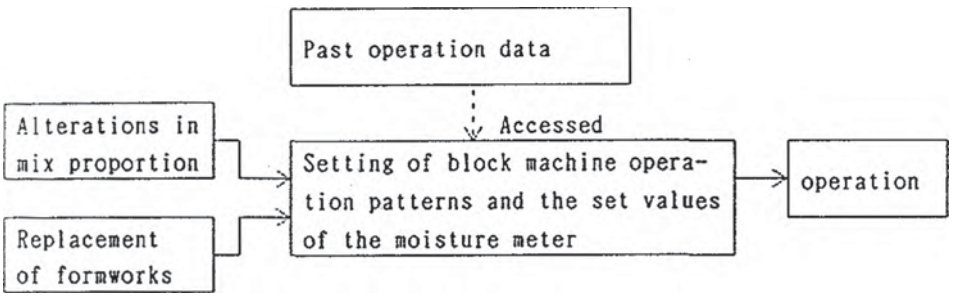

Fig. 2 Operation procedure after the introduction of the FA system

2.2 Example of water adjustment

In the conventional system, water to be added to concrete or mortar during mixing been adjusted jointly by a batcher man in the batcher plant and a casting operator in the casting room. However, since information given from the casting operator to the batcher man has not been quantified, the results of product observation have not been fully reflected in water adjustment, thereby preventing a stable material quality. This has brought up a technological theme that is to ensure more accurate water adjustment during mixing. In order to achieve this theme, we have reformed the water adjustment method as shown in Fig. 4 so that the casting operator can adjust water content based on the quality control data and information on product appearance that are available in the control center and can feed quality information back to the control center.

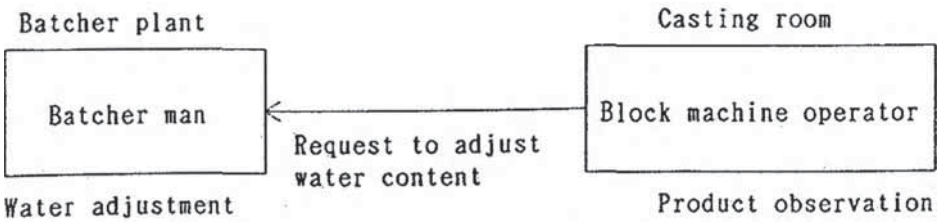

Fig. 3 Conventional water adjusting method

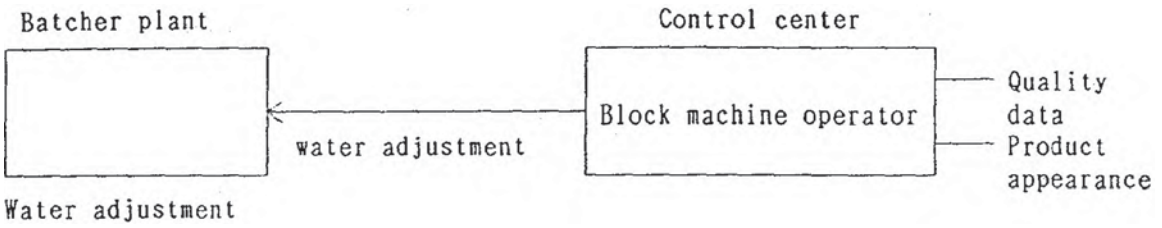

Fig. 4 Water adjusting method after the introduction of the system

2.3 Example of water control

Water control methods before and after the introduction of the FA system are shown in Table 2. Water content has been controlled by weighing the amount of water in the past. Therefore, the measured values need to be modified if surface moisture of aggregates changes. However, noone knew exactly how much it should be modified, and therefore, it was necessary to check the mixing condition visually. The results of such visual inspection differed depending on the inspector. and it was impossible to ensure a stable quality. This has posed a technological theme that is to improve the water control method. To that end, we have adopted an electric-resistance moisture meter. Since this method permits the direct measurement of water content of concrete or mortar during mixing operation, there are advantages as water content can be quantified without being influenced by changes in the surface moisture of aggregates and water content can be set from a distance. As a result, it has become possible to reuse the set values as past operation data, to set water content from the control center and to ensure a stable quality.

Classification	Method	Function	Result
Before the introduction of the FA system	Weighing	· Water weight is modified according to changes in surface moisture · Visual inspection is necessary	· Unstable quality
After the introduction of the FA system	Electric-resistance moisture meter	· It is not affected by surface moisture · Water content can be quantified · Water content can be set from a distance	· Set values can be resued as past operation data · Water content can be set from the control center · Stable quality

Table 2 Water control method before and after the introduction of the FA system

2.4 Labor saving in quality tests

Table 3 shows quality test methods before and after the introduction of the FA system. Before the FA system was introduced, height was measured with a special gauge and filling rate inspected visually. However, there were such problems as measurements were not accurate and changes with the passage of time could not be monitored since tests were not performed frequently, and the feedback of quality data was not satisfactory. In this circumstance, a labor-saving method for quality test has become necessary. To that end, we decided to use various automatic measuring devices to enable the accurate sampling of quality data. It was also made possible to calculate the filling rate automatically from the measured values. As a result, satisfactory data feedback has become possible.

Classification	Test item	Measuring method	Result
Before the introduction of the FA system	Height	· Special gauge	· Inaccurate · Changes with the passage of time cannot be monitored since tests are not performed frequently · Data feedback is not satisfactory
	Filling rate	· Visual inspection	
After the introduction of the FA system	Height	· Automatic height measuring device	· Accurate · Can be fed back
	Filling rate	· Calculated automatically from the measured height and weight	

Table 3 Quality test method before and after the introduction of the FA system

3. Control center

The control center was established for the purpose of serving as the center of FA system and improving the work environment of operators. Operations performed in the batcher plant and casting room are monitored in this center, and all information is concentrated in this center. Three control desks are installed in the room. One is for the batcher plant, and the other two are for the casting room. Inside the room is protected from noise and dust, providing a pleasant work environment as shown in Photo 1. This work environment that is not available in the conventional concrete product factories, has been highly appraised by visitors.



Photo 1 Control center

4. FA system

4.1 Equipment incorporated in the FA system

Equipment incorporated in the FA system is shown in Fig. 5 Among them, the height measuring device, weight measuring device and defective product ejection device were developed along with the FA system. These devices are shown in Photos 2, 3 and 4 respectively. The Defective product ejecting device operates automatically according to the values measured by the height measuring device and the filling rate that is calculated according to data from the weight measuring device. For visual inspection, however, it is operated manually. The batcher plant operation monitor desk and the casting room operation monitor desk are shown in Photos 5 and 6 respectively.

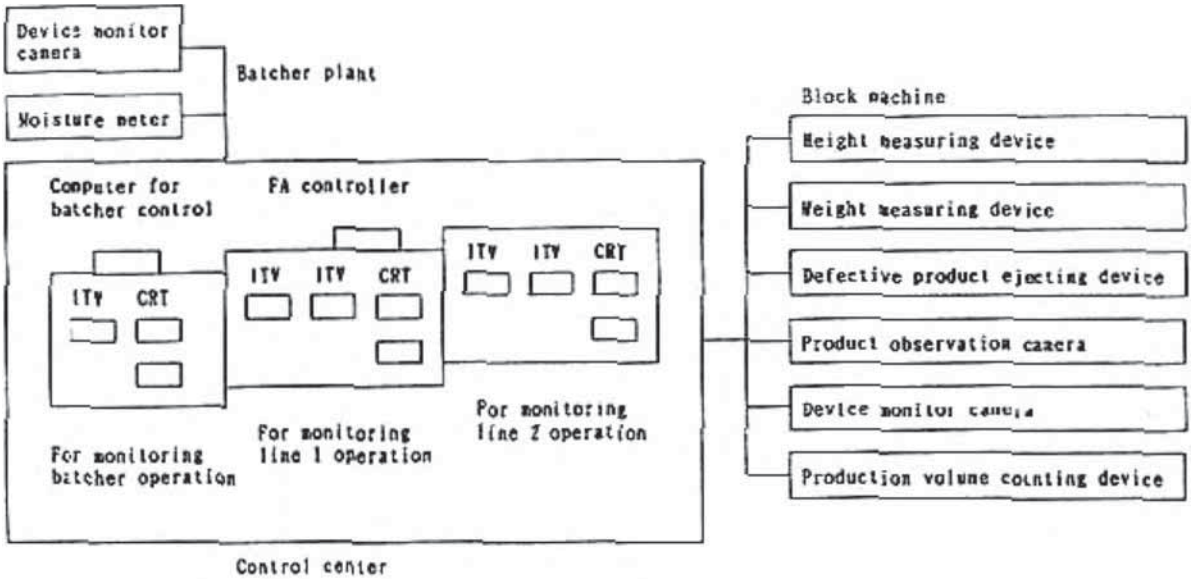

Fig. 5 Equipment incorporated in the FA system

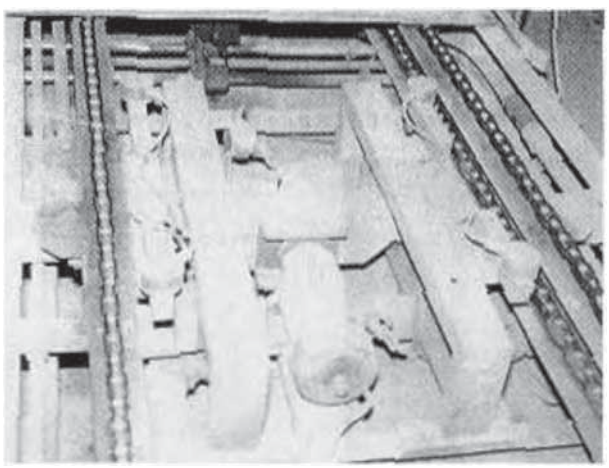

Photo 2 Block weight measuring device

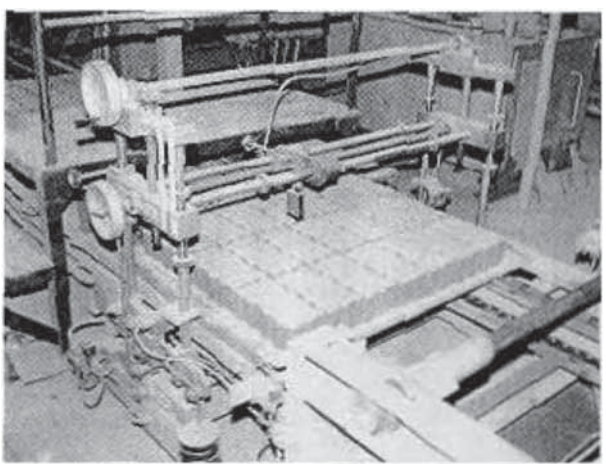

Photo. 3 Block height measuring device

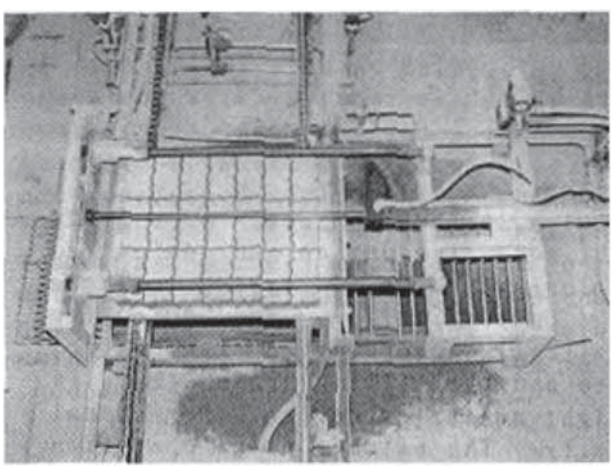

Photo 4 Defective product ejecting device



Photo. 5 Batcher plant operation monitor desk

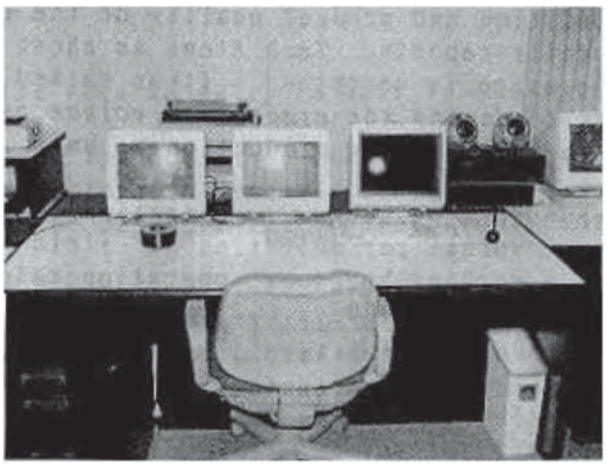

Photo. 6 Block machine operation monitor desk

4.2 Outline of the FA system

An outline of the FA system is shown in the form of a flowsheet in Fig 6.

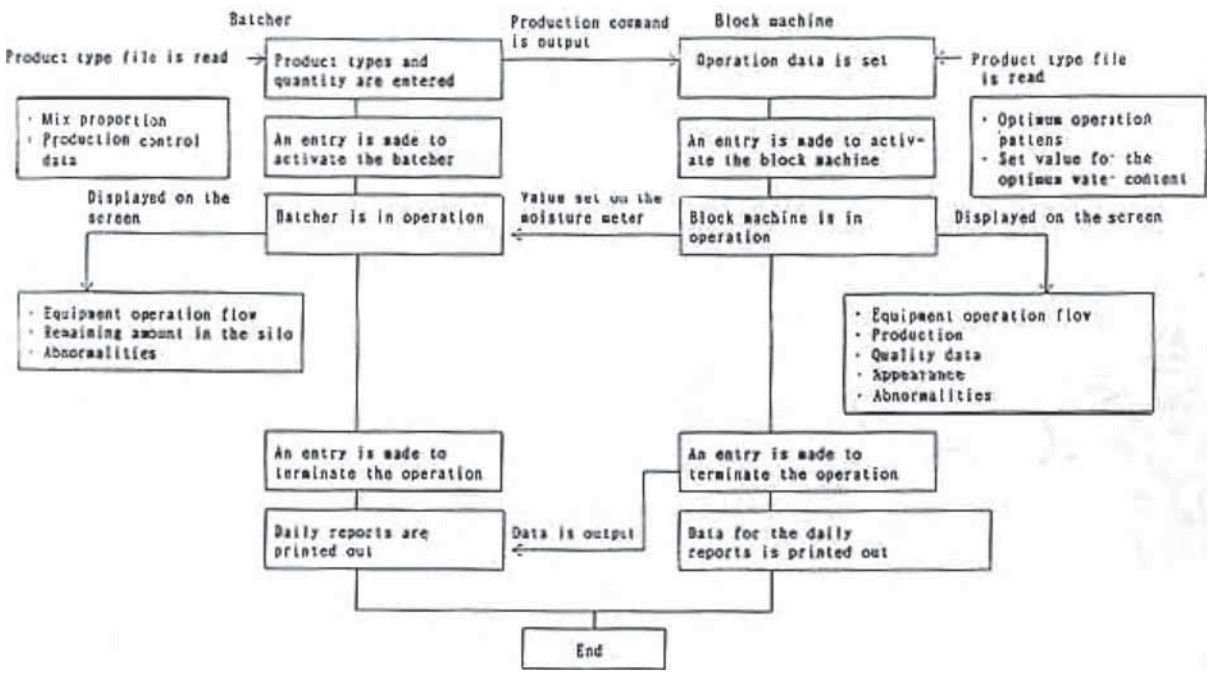

Fig. 6 Outline of the system

The following is the operation procedure.

① An operator in the batcher plant enters the codes of product types to be produced with each block machine and the quantity of the products to be manufactured through the keyboard each day. Data on each product type to be used for mix proportion and production control is read from the product type file. Then, mix proportion are set, and product types and other data related to each block machine is output to the computer used for the block machine.

② These data is received by the computer for the block machine, and the optimum operation pattern and the set value for the optimum water content of concrete that have been recorded, are read from the

respective product type file. Now preparation for production is complete.

③ Operation begins when an entry is made to activate the machine.

④ During operation, the operating condition of equipment and the amount of cement and aggregates remaining in the silo are displayed on the monitor TV for lhe batcher. The operator only monitors the screen.

⑤ The operating condition of the block machine. production volume, quality data such as automatically measured block height and filing, rate and the appearance of blocks are displayed on the monitor TV for the block machine. If the quality is not normal, the operator modifies or correct the block machine operation patterns and values set on the moisture meter while seeing the screen.

⑥ When the production volume reaches the scheduled level, an entry is made to terminate the operation. As a result, data is output from the block machine to the batcher, and daily reports are output. Data for the daily reports is printed out on the block machine side.
The following are screens that are displayed during operation.

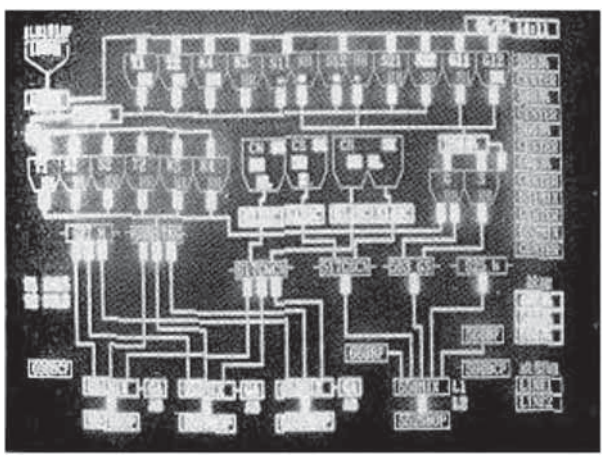

Photo. 7 Batcher plant operation flow

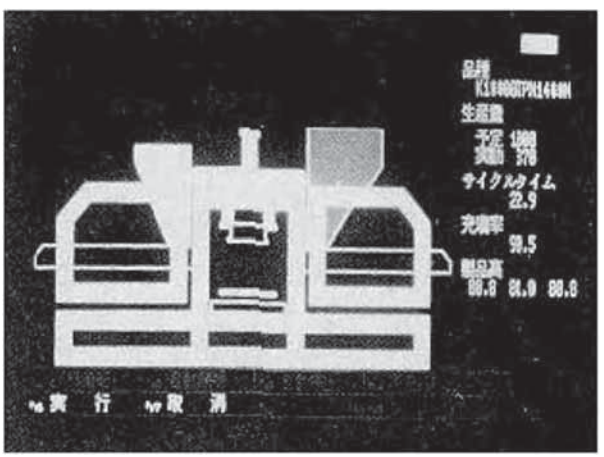

Photo. 8 Block machine operation flow

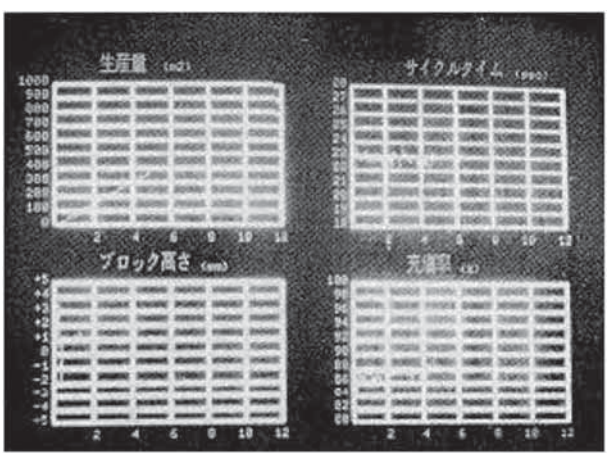

Photo. 9 Production volume and quality graph

4.3 Daily reports

Manufacturing condition and product quality of the respective day are summarized in the daily reports. Such items as shown in Table 4 are printed out. and their usage is described. Items marked with an asterisk are important factors to decide the production volume as are used in the following expression to estimate the production volume.

$$\begin{aligned}\text{Production volume} &= \text{working hours} \times \text{operation rate} \times \text{production volume per unit time} \times \text{yield} \\ &= \text{working hours} \times \text{operation rate} \\ &\quad \times \left(\frac{3600}{\text{cycle time}} \times \text{m}^3 \text{ per cycle} \right) \\ &\quad \times \left(1 - \frac{\text{percentage of defective products}}{100} \right)\end{aligned}$$

These items are also used to control the target productivity by factor.

Itern	Usage
Product type	Receiving and shipping of products
Quantity of products manu-factured	
* Working hours	Productivity analysis
* Opetation rate	
* Production volume per hour	
* Cycle time	Productivity analysis and judgment of when to carry out maintenance
* Percentage of defective products	Productivity analysis and consumption rate control
Block height	Quality control
Filling rate	
Consumption of each raw material	Receiving and shipping of raw materials and consumption rate control

Table 4 Description of daily report

4.4 Data for daily reports

Data for daily reports include such items as shown in Table 5. Operation record is used to locate causes for decrease in the operation rate. Block height and filling rate histograms are used to check for unevenness.

Item	Usage
Opetation record	Analysis of causes for decrease in the opera-tion rate
Block height histogram	Control of unevenness
Filling rate histogram	Control of unevenness

Table 5 Description of data for daily reports

5. Effects of the introduction of the FA system

5.1 Effects on the production of diversified products

One of the themes in developing this system was to ensure the efficient production of diversified products. In this system, the optimum set value of the block machine timer and counter and the optimum set value for water content in concrete or mortar are recorded by product type into the computer and can be accessed by entering product type codes. Particularly, if the conventional weight measuring method is used, the set value for water content has to be modified according to changes in the surface moisture of aggregates. Thus, the set value'cannot be reused as the optimum value. Therefore, we have adopted the electric-resistance moisture meter that allows the direct measurement of water content of concrete. As a result, the system can be activated more quickly even after an alteration occurs in manufacturing product types. This has improved the operation rate and yield. According to the past records, the operation rate was 70% and the percentage of defective products was 1% when 100 product types were manufactured in a month using two block machi nes.

Additionally, since it was also made possible to record the mix proportion of concrete or mortar into the computer and to access them using the product type codes, automatic mix proportion setting is possible. thereby preventing errors.

Although data handled at the production site is increasing heavily due to the diversification of products, all such data can be processed by the computer, leading to a substantial reduction in workload at the product ion site.

5.2 Improvement of work environment

Along with the development of this system, the control center was established in order to improve the work environment and permit the remote control of operations. In order to make remote control possible, information such as the operating condition of devices, product quality and production volume must be displayed in the control center. Therefore, it was made possible to monitor the operating condition 'of devices on the monitor TV and the operation flow screen. With respect to the product quality, block height and filling rate that have been obtained from the automatic testing devices, are displayed in the form of a graph on the screen, and the appearance of blocks can be monitored on the monitor TV. Consequently, the remote control of operations from the control center has become possible, and workers at the site can work in a pleasant work env ironment.

5. Conclusion

(1) The development of the FA system has realized a highly efficient production system that can not only cope with diversified products but also improve the operation rate and lower the percentage of defective products.

(2) Remote control of operations from the control center has improved the work environment of the production site remarkably.