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A LIFT UP INTELLIGENT CONTROL SYSTEM

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ABSTRACT

The important subject that the construction industry should be accomplished today and in the future is in the rationalization of the construction processes and how to improve the labor-intensiveness of construction sites.

The authors have carried out research on the rationalization of the construction of a structure having a long-span of over 10 m. In the course of this research, we came to the conclusion that by using waffle slabs it is best to adopt large-size precasting in floor size and to use a production process in which such precast members are lifted up.

As hardware technology used in such a construction system we fabricated a prototype device of a Lift Up Intelligent Control System using a new logic, and in lift-up operation experiments we confirmed that it is possible to control the relative position at each point during lift-up and to do synchronized lifting of large-size precast members.

INTRODUCTION

It is pointed out that one reason for the low productivity in the construction industry is the waste of excess labor in construction work. What makes production in the construction industry different from production with factory-line systems is that 1)the location where construction is carried out changes with each work, 2)dimensions vary with each structure, 3)the production is a field job, and 4)the working environment is easily affected by weather and other conditions. Because of this, it is characteristic of construction-industry production that 5)production equipment is temporary, and 6)relative to labor costs, it is difficult to rationalize operations by investing in equipment and mechanizing production processes.

Construction methods in which the steps in production are systematized have been proposed as a means for achieving production rationalization in construction work. In this technique, the production steps in construction work are analyzed and, while taking into account the constraints on each operation, each step of the operation is studied to determine whether it is really necessary (study of whether the step can be eliminated), whether other operations can be incorporated into it (integration study), and whether it can be transposed with another step (study of change of sequence). Finally, the step is simplified with the expectation of making it easier to become skilled at. In this, automation is adopted for the construction step if the work would be difficult without it, and the adoption of automation is rational.

The demand for building space that can flexibly accommodate changes in layout has led us to focus our attention on, and do research in, buildings in which long-span structures have often come to be adopted.

The Lift Up Intelligent Control System described in this report differs f)m the conventional lift-up construction method in the following respects.

(1)It is not necessary, as it is in conventional lift-up systems, to install jacks on column capitals, and the system is capable of self-climbing with the built-in columns.

(2)In floor-size and other large-size structures, the distributed load varies depending on the thickness, and the balance of the structure is disrupted if the same lifting power is applied to each lifting point. Use of a control device for the lift-up made it possible to do synchronized lifting in accordance with the load balance. This makes it possible to lift up, with near horizontal precision, even for a large-size structure whose load distribution is unbalanced.

THE CONSTRUCTION OF A LONG-SPAN STRUCTURE

A Construction System

A waffle slab combines plate and ribs having high flexural and torsion resistance and distributes the load in two directions. Also, except for the concrete portion that bears the tensile stress in the lower part of the member, waffle slabs can be light in weight. This makes the slab advantageous for long-span structures. Moreover, the longer the span in a waffle slab, the lower the construction costs.

In the construction procedure, first, as the half-precast member, the rib portion of the waffle slab is made by multi-layer casting on the ground. Next, with a method that produces no time-dependent deflection and little flexural cracking, by using the unbonded tendons, the ribs of the waffle slab are introduced to a prestress of 10-20 kgf/cm^2 in average axial compression using the post tension method. Then the building structure is built by lifting up the ribs by the Lift Up Intelligent Control System with respect to the built-in columns and by placing the topping concrete.

This building construction system not only rationalizes the construction by large-size precasting in which floor-size slabs are fabricated on the ground, but it can also achieve rationalization of the construction work, including saving labor and the reduction of the construction period. This system is precise the building of long-span structures and promotes the safe of construction work.

Figure 1 shows how construction is done with a Lift Up Intelligent Control System.

Prototype of The Lift Up Intelligent Control Sytem

In a prefabricated construction system, the larger the structure, the greater the effect of construction rationalization. In this case, the larger the size, the greater the massive force, but there is a tradeoff with size and weight from the standpoint of construction work.

In lifting large-size precast members, the following problems occur.

(1)In order to minimize construction stress during the lift-up of a large-size structure, the lifting must be done with the member kept in horizontal balance. This requres synchronized control so that all the lift-up points are kept in balance.

(2)With a large-size structure it is difficult to predetermine the structure's load center of gravity. Because the load on each lift-up point is different, the horizontal balance of the structure is lost if the same lifting power is applied at each point.

A Lift Up Intelligent Control System that lifts up a large-size precast member with massive force has the following characteristics.

(1)The lift-up system is in self-climbing the columns of the building structures as rods.

(2)With a central control unit, synchronized lifting is done in such a way that the lift-up of each point is kept in balance.

(3)Multi-point cylinder units are controlled by a single operator system.

The lift-up system consists of hydraulic jacks for lifting and hydraulic jacks for chucks that hold them in at the top and bottom. The lift-up and chuck jacks consist of multiple hydraulic cylinders which can respond to changes in lift-up load and chuck force, depending on the friction conditions of the column surface.

In lifting the structure, the top chuck system is seated and the lift-up jacks are retracted with the bottom chuck system in an open state. When a lift-up jack reaches the end of its stroke, the bottom chuck sytem is seated, and the top chuck sytem goes into the open state. In this state, the lift-up jacks are extend. Thereafter these steps are repeated.

The central control unit consists of a main box and sub-boxes. The main box ascertains the lift-up level from the standard points by the voltage output singnals of a linear encorder then issues instructions using a microprocessor so as to synchronously control the relative position of each lift-up unit within prescribed values. The sub-box receives instructions from the main box and controls the electromagnetic valve of the pump of each lift-up unit, balancing relative position.

Experimental Mock-Up Test

The Lift Up Intelligent Control System used in the mock-up test has a lift capacity of 6 tons, with a total of four lift-up cylinders. The cylinder stroke is 100 mm, the raising speed is 380 mm/min, and the lowering speed is 190 mm/min. The top and bottom chuck system are each clamped from two directions, and the clamp capacity totals 60 tons in the two directions.

The Lift Up Intelligent Control System is a two-part assembly system attached to the columns corresponding to the rods. It becomes operational when the assembly pins are inserted.

Figure 2 shows the experimental results when the Lift Up Intelligent Control System raises and lowers, with a synchronous width of 30 mm and 50 mm, an approximately 5-ton precast floor slab a lift-up distance of 2.5 m, corresponding to a steel-pipe column filled with concrete.

From the experimental results, the level error from a exact distance of 2.5 m is 7~8 mm, and it was possible to control the lift-up while controlling the clamping force for variations in friction force associated with changes in the shape of the surface of the column.

Figure 3 shows the results when one linear encoder was made to emit simulated voltage output signals of the lift-up level and the Lift Up Intelligent Control System changed to synchronized lifting.

From the experimental results, synchronized control of each lift-up point was possible so as to keep the member in horizontal balance.

The Lift Up Intelligent Control System used in the mock-up test is shown in Photo1.

ANTICIPATED OUTCOMES

The new Lift Up Intelligent Control System can be applied to the synchronized lifting of large-size precast members which have an unbalanced load. This device makes possible the high-precision lifting of large-size precast members, minimizing the construction stress on such members. The application of the Lift Up Intelligent Control System to construction work helps systematize construction processes, minimizes temporary work such as the reinforcing of members during construction, and contributes to the rationalization of the construction processes of a building having a long-span structure.

Application of this system accomplishes the following improvements compared with conventional construction systems.

(1)Figure 4 compares the amount of labor expended on construction work under conventional methods of in-place concrete casting and precast construction. Construction methods that use half-precast concrete can save approximately 45% of the labor needed with conventional construction methods. The greater the level of processing, from raw material to finished product, by using the precasting production processes on the ground work, the less amount of labor expended on the construction work. It is clear that an amount of labor is saved with the precast construction method.

The proposed construction system requires labor for the precasting of long-span slabs on the ground. When the amount of labor for the proposed construction system is considered in the data of Figure 4, taking into account the amount of labor for on-site prefabrication, this construction system can save construction labor by 30% as compared with conventional construction methods.

(2)Figure 5 shows the number of days by which the work schedule is reduced with the precast construction method as compared with conventional construction methods.

In the precast construction method, a 40-50% reduction of the construction period is achieved. Although the proposed construction system involves the work of building-in precast columns and fabricating slabs by on-site prefabrication, compared with conventional construction methods it can reduce the construction period for structural parts of this construction system by 40%, based on the data given in Figure 5.

The proposed construction system promises to be effective for the rationalization of the construction of long-span structures through the introduction of large-size precasting and automated equipment, and it is expected to contribute to the improvement of the labor-intensiveness of production processes in the construction industry.

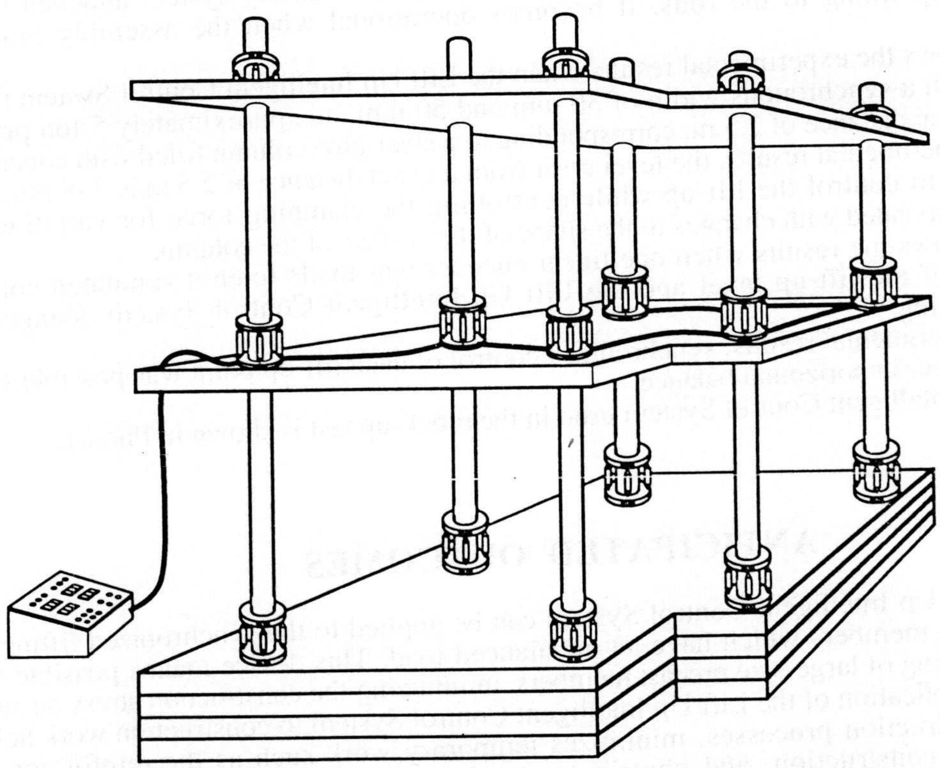

Figure 1 Construction using a Lift Up Intelligent Control System

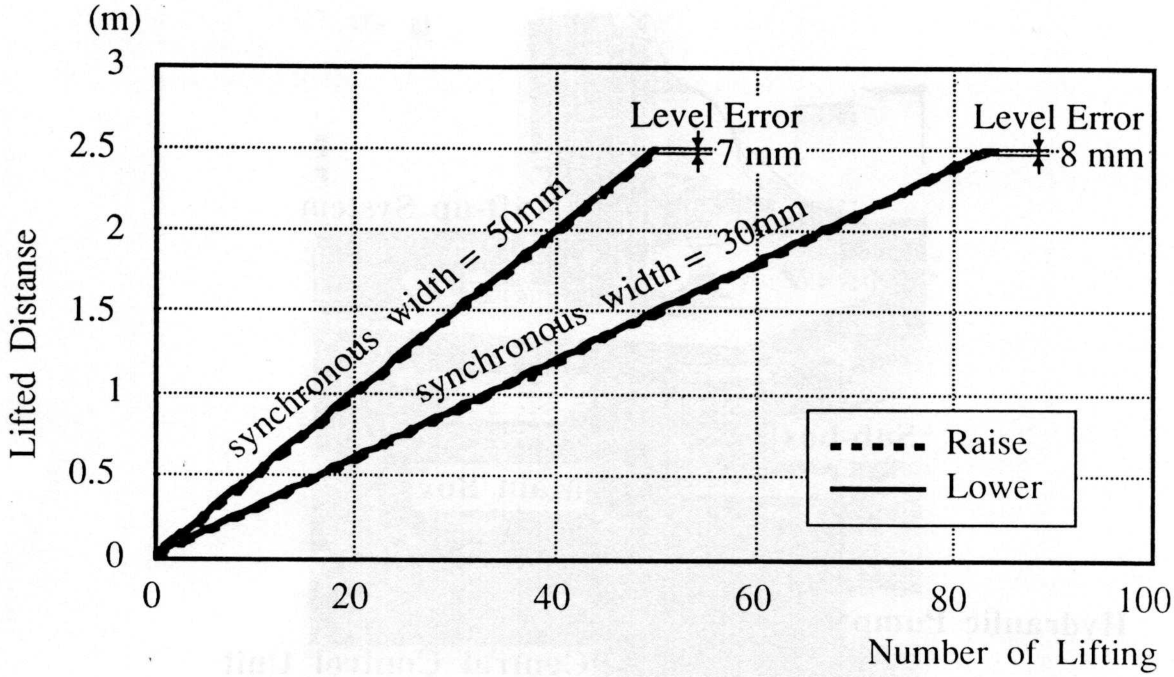

Figure 2 Operation results of a Lift Up Intelligent Control System

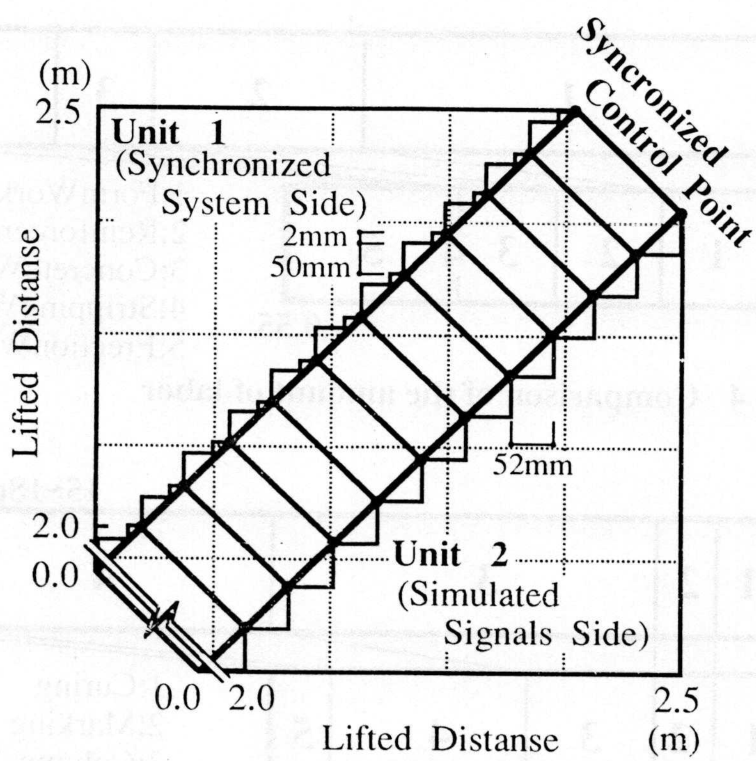

Figure 3 Synchronized lifting (synchronous width = 50mm)

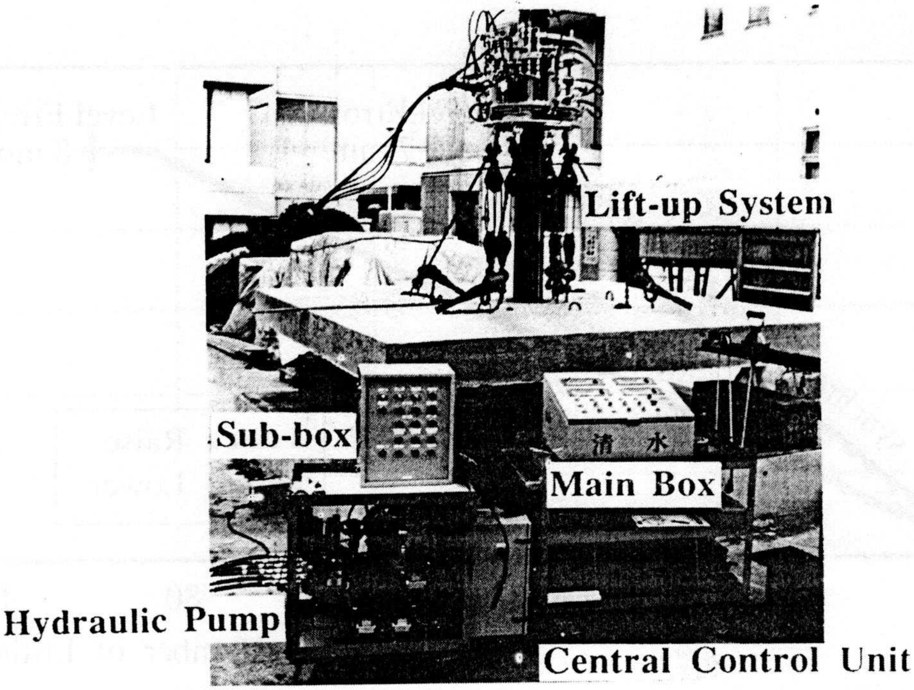

Photo 1 The Lift Up Intelligent Control System used experiment

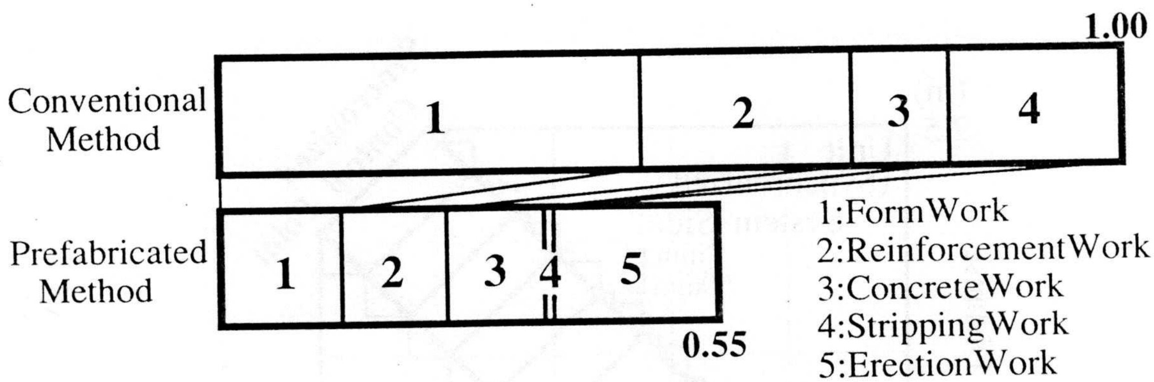

Figure 4 Comparison of the amount of labor

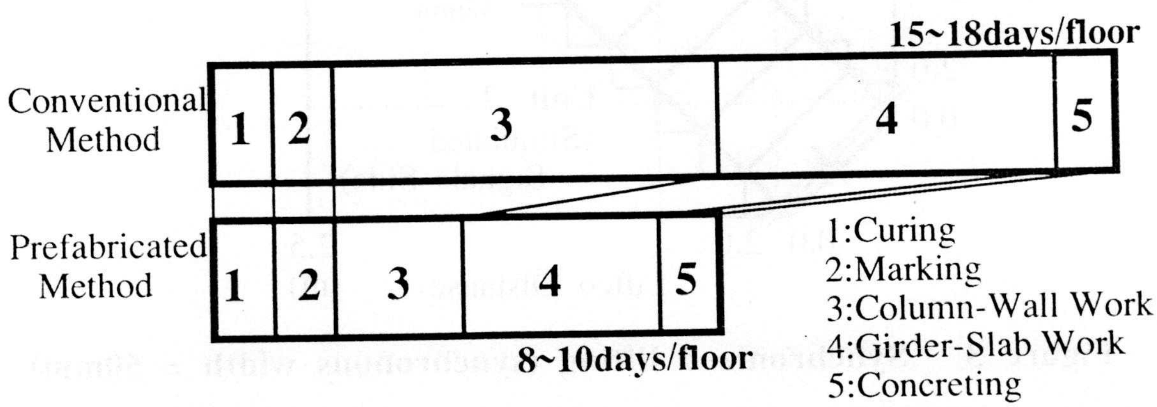

Figure 5 Comparison of the construction period