DEVELOPMENT AND APPLICATION OF CLIMBING ROBOT JACK SYSTEM

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ABSTRACT

Climbing Robot Jack System is a robotized hydraulic jack equipped with a level detector and operating control device that grips and climbs a steel pipe rod. Several sets of jacks are centrally controlled and overall level maintained. This system can be applied to climbing formwork method in bridge pier construction as well as in dismantling temporary steel works used for bridge pier construction. Its applications to scaffolding for vertical shaft in tunnel construction, exterior scaffolding in building construction and in various other fields are considered possible. Excellent results in labor saving, construction time shortening and safety were obtained when this system was applied especially to climbing formwork method.

1. Introduction

Generally, in construction of concrete structure the method of erecting scaffold around the structure and lifting large panel forms with heavy lifting equipment as adopted. However, with this method the erection and dismantling of scaffolds and forms were conducted at high elevation, so as the structure became taller problems in safety and efficiency arose. Later, many construction companies devised a jump up (climbing) method to solve those problems and it is now being applied frequently; but the work of dismantling at high elevation upon completion of a structure could not be avoided, so the problem of safety remained unsolved.

So, a climbing robot jack system (hereafter called climbing system) was developed with the aim to improve construction efficiency through automatic operation and to solve the problem of working at great heights by adding a new lowering function to lifting function of scaffolds and forms.

Outline of this climbing system and its application to bridge pier construction are given in this report.

2. Outline of Climbing System

Concept drawing of the climbing system is shown in Fig.-1. Multiple climbing robot jacks (hereafter called climbing jack) are equipped with micro computer to control each jack and to communicate. Central control board reads the informations received from individual water level sensor and each climbing jack and gives instruction to the climbing jack.

1) Climbing Jack

Exterior view is shown in Photo-1. The climbing jack has a wedge type chock that grasps the steel pipe rod and lifts heavy load by means of hydraulic cylinder. Stroke and pressure of the hydraulic cylinder and chock condition are confirmed and controlled with various sensors and controlling each while communicating with central control board.

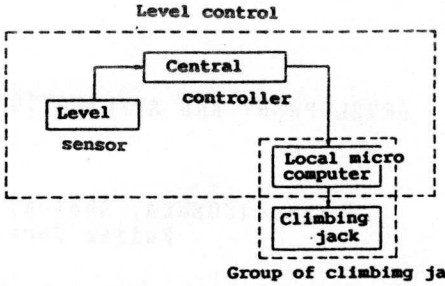

fig-1 Concept of climbing system

2) Central Controller

Fig.-2 shows the exterior view of the central controller. A personal computer is used to control the system. Mode and control rate are established before the system is operated. The composition of the mode and rate of control is climb-descent, automatic-manual, rate of climb (descent), numbers of expansion and contraction of hydraulic cylinder and allowable level tolerance.

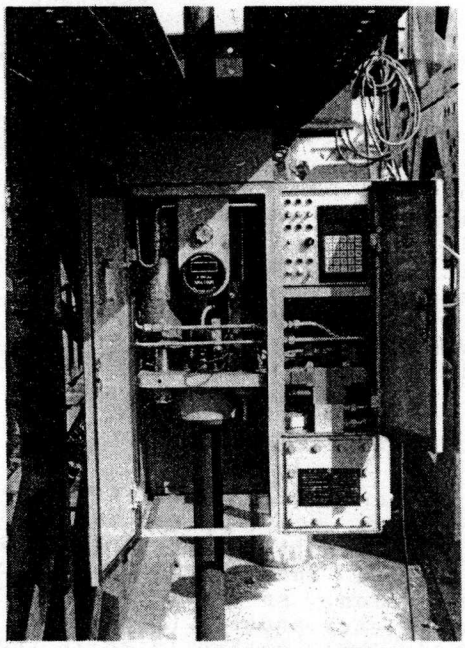

photo-1 Climbing Jack

3) Level Sensor

Level sensors are installed at each climbing jack position and the relative levels are detected with communicating vessel.

3. Example of Application to Climbing Form Construction Method

"F type climbing form construction method" was developed for construction of tall concrete structures, such as bridge pier, tower or cylindrical structure; and the aim was to save labor and improve safety relative to erection of scaffolding and to reduce construction time.

Formwork and scaffolding for one lift are supported with a rigid main steel frame installed around the structure; and this frame is supported and lifted with hydraulic jacks through several steel pipe rods installed at ground level. Fig.-3 shows an outline sketch of this climbing system.

The special feature of this system is the possibility of dismantling temporary plants (formwork and scaffolding) on the ground as the finishing work on the structure proceeds from the top to grade level while lowering the formwork and scaffolding.

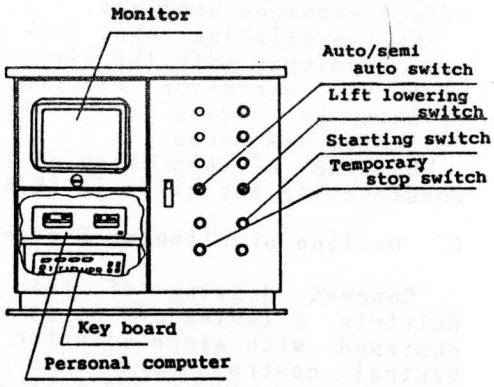

fig-2 central controller

Construction of Nichikodani Section of Kyushu Highway is mentioned below as on example. Photo-2 shows the stage of construction.

1) Outline of Temporary Works System

Fig.-4 shows a sectional sketch of the entire temporary plant system for this system.

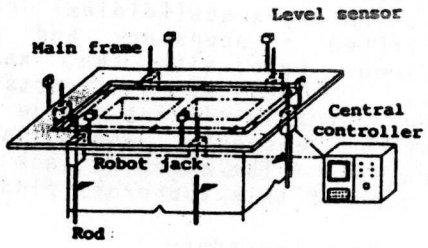

fig-3 Concept of climbing jack system

(1) Exterior Temporary Plant (Formwork-Scaffolding)

Both exterior formwork and scaffolding are fixed to the main steel frame encircling the bridge pier structure to form a construction unit. If the structure is rectangular in section, the form for each of the four surfaces can be made of single panel.

Interior formwork and scaffolding are constructed as a unit with exterior formwowk and scaffolding according to the structural form and shape or as an independent units.

(2) Load Bearing System

Abovementioned main steel frame is supported by climbing jacks on steel pipe rods installed on the ground. Stays extending from the bridge pier structure to the supporting rods at fixed spacing prevent rod buckling.

(3) Lifting Device for Exterior Temporary Unit (Form-Scaffold)

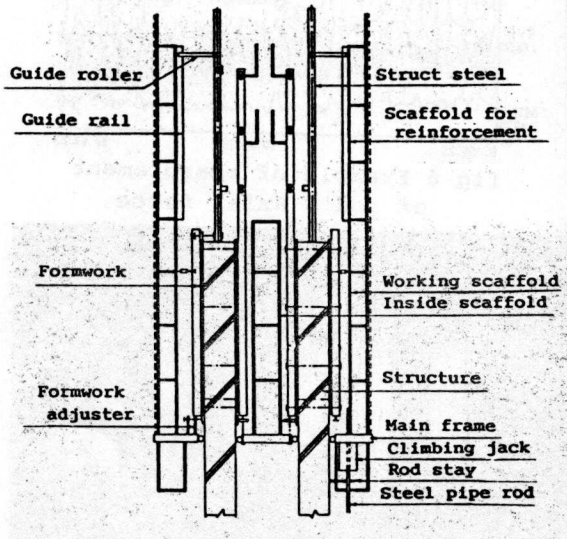

fig-4 Outline of temporary plant system

photo-2 State of construction

Climbing jack is attached to each supporting rod and

abovementioned unit of temporary plant (formwork-scaffolding) can be lifted as necessary and at required rate with the main frame. The most important feature of this lifting device is smooth descent and safe operation. The climbing jack is the core of this temporary plant.

2) Work Procedure

Fig.-5 shows the work procedure. A single normal cycle consists of erection of structural steel and reinforcing steel, loosening formwork, lifting form, tightening form and placing concrete.

Work is conducted on same scaffold and in same posture, so the working condition is good and safe.

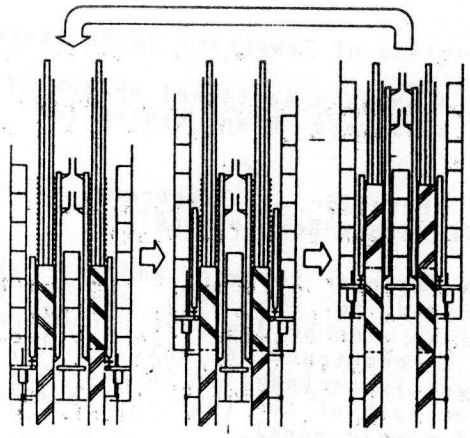

fig-5 Working procedure

3) Control System

o Levelling Control

Normally, each jack during climbing operation will produce different speed due to differences in bearing load. As result, deformation will be produced in the main frame and temporary unit which is not desirable from safety viewpoint.Especially, load will be concentrated on specific supporting rod during lowering operation which is harmful from viewpoint of safety and operation of climbing jack. So, the levels of climbing jacks are controlled by means of communicating vessel.

It was possible to maintain the fluctuation of load on each supporting rod within a fixed range through the use of levelling control in Nichikodani Project. Fig.-6 shows an example of measurement on rod for axial force. It can be seen from this that this construction method can be executed with greater safety.

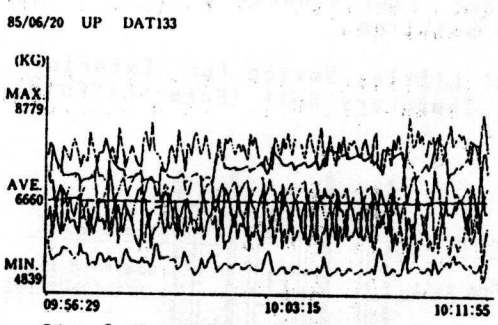

fig-6 Example of measurement of rod's axial force

o Prevention of Erroneous Action

Multiple safety ensuring system is built-in to prevent

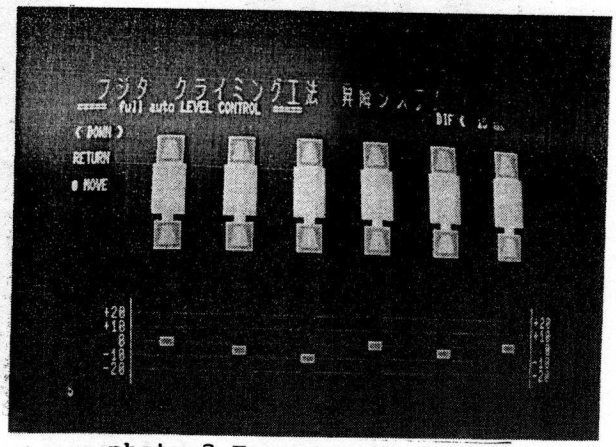

photo-3 Example of central controller monitor

erroneous actions in the system which are caused by improper operation, noise, power failure and other unforeseen troubles.

Operating procedure was simplified for ease of operation. Indicating the system's state of operation in a color monitor also helped in improving operation. Phote-3 shows a picture in a color monitor.

o Alarm System

Melody is automatically played to attract workmen's attention during operation of the system to ensure safety.

4. Application to Other Construction Method

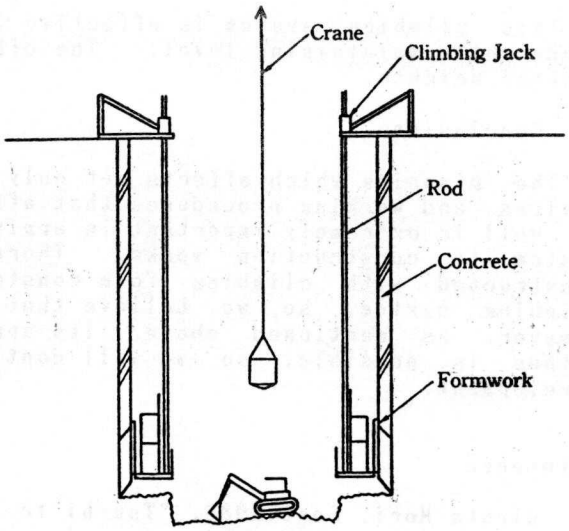

fig-7 Application to vertical shaft

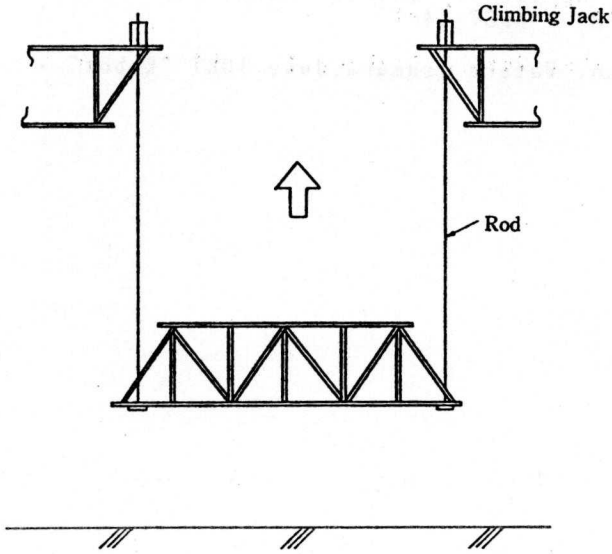

fig-8 Application to lift-up costruction method

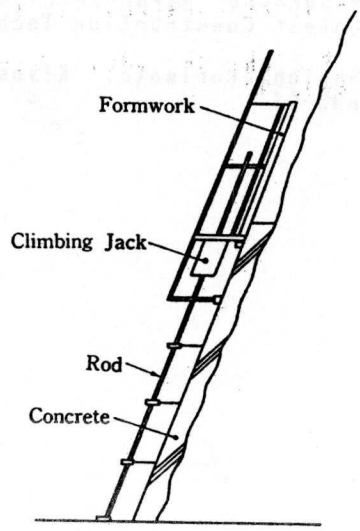

fig-9 application to cnstruction on steep slope

The application of this system is not limited to climbing form construction method only. It can be applied to other construction methods. Fig.-7 to Fig.-9 show examples of other applications.

They are as lifting/lowering scaffold for vertical shaft in tunnel construction, as lifting device in lift-up construction method for raising building roof assembled on the ground, and as lifting/lowering device for form erection scaffolding in placing concrete on steep slope.

This climbing system is effective in lifting and lowering heavy loads while maintaining level. The effect is larger, especially, at greater heights.

5. Conclusion

The planning which affects not only the robots but other temporary devices and working procedures that affect overall construction method as well is extremely important in applying a robot like this climbing system to construction works. There are already 9 bridge piers constructed with climbing form construction method uti-lizing this climbing system, so we believe that this system has taken root. However, as mentioned above, its application to other construction methos is possible, so we will continue our effort for its wider development.

Reference

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