DEVELOMPMENT OF AUTO-CONVEYING SYSTEM FOR DAM CONCRETE

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In the conventional method of dam construction work, dam concrete is transported from batching plant and then placing work is usually done using bucket moved by cable or jib cranes. This paper reports about the newly developed automatic conveying and transportation system of dam concrete directly from batcher plant to the concrete placing point in a continuous way. The main purpose for this development is to save labor, stabilize the concrete quality and improve the surrounding environment.

Keywords: concrete dam, concrete, transportation, placing, automation, belt conveyor

1. INTRODUCTION

In the conventional method of dam construction, concrete is usually transferred into buckets and transported in stages by cable crane or jib crane to the site. The machine here presented was developed to save labor, achieve consistent quality, and improve the construction environment by forming a consistently high-speed system from batcher plant to concrete placing area. The system automatically and continuously transports and distributes concrete from the place where the concrete is provided to the place where it is cast with its multi-axes rotary arm equipped with a belt conveyor.

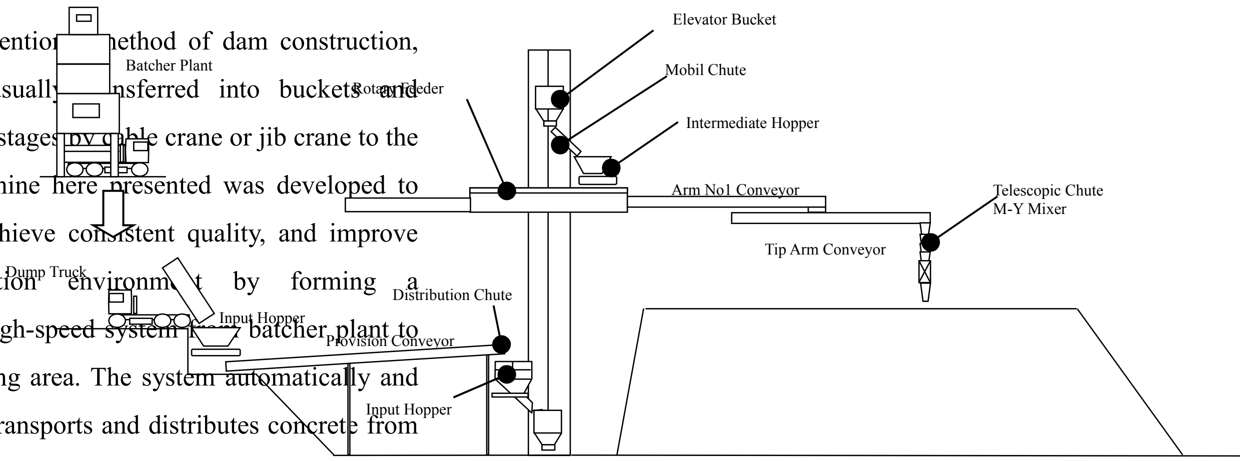


Figure1.Configuration Diagram of Overall Structure

The automated system is composed of three parts, a supply mechanism from concrete plant to the lower part of the tower in the main body of the system; a vertical carrier inside the post from the lower part of the tower to the arm; and an automatic, continuous concrete distributing multi-axes arm in the construction area.

The multi-axes rotary arm at the end has manipulation function and uses an AC servomotor with a built in pulse-encoder. It controls the arm’s 2-axes rotation, operating the AC Servomotor according to changes in command values by comparing, in real time, feedback values from position in the drive shaft and speed detection with command values. It has the same configuration and control method as multi-purpose industrial robots, and may be classified as a super-large industrial robot.

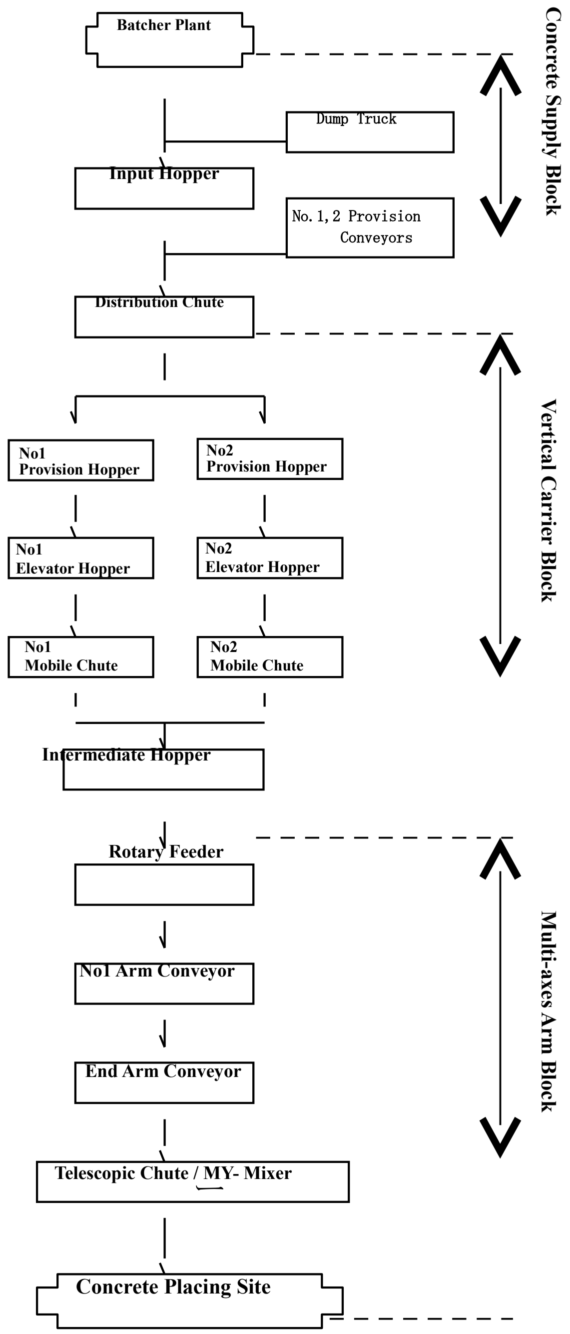


Figure 2. Concrete Distribution Flow-Chart

2. CONFIGURATION AND FUNCTIONAL

PRINCIPLES OF THE SYSTEM

2.1 Input Hopper

The concrete produced in the batcher plant and transported in dump trucks is put into the input hopper. Expelled from the bottom of the input hopper in fixed quantities onto the belt feeder, the concrete is then moved to the provision hopper by the No.1 and No. 2 provision belt conveyors.

According to the type of concrete, automatic adjustments of the aperture of the gate at the end of the fixed quantity feeder, adjusts the quantity of concrete to be provided. It can through this function, transport many kinds of concrete mixes, from mortar to low slump type concrete. The input hopper detects the weight to prevent over filling.

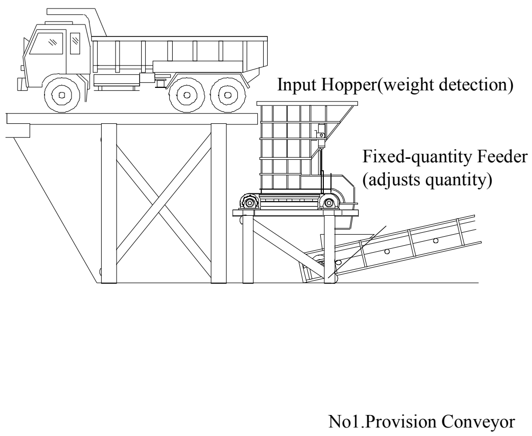


Figure 3. Input Hopper

2.2 *Distribution Chute and Provision Hopper*

The distribution chute at the end of the No2 provision belt divides the concrete into the No1 and No2 Provision Hoppers. Load cells in each of the hoppers detect weight. When one hopper becomes filled with a predetermined quantity, the distribution chute automatically rotates to the other hopper. The provision belt conveyor stops automatically when both hoppers are filled to the predetermined quantity.

Figure 4 shows the Distribution Chute and the Provision Hopper and Figure 5 shows a flowchart of the mechanisms in the Provision Line.

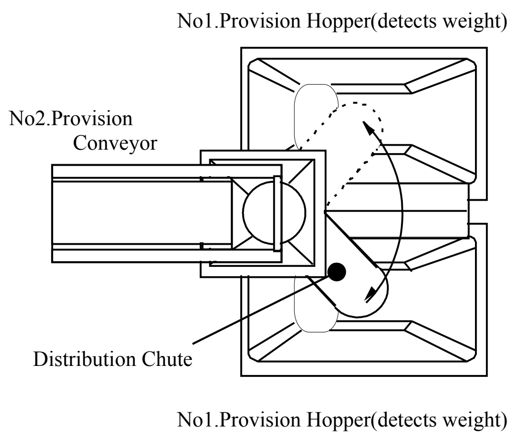


Figure 4. Distribution Chute and Provision Hopper

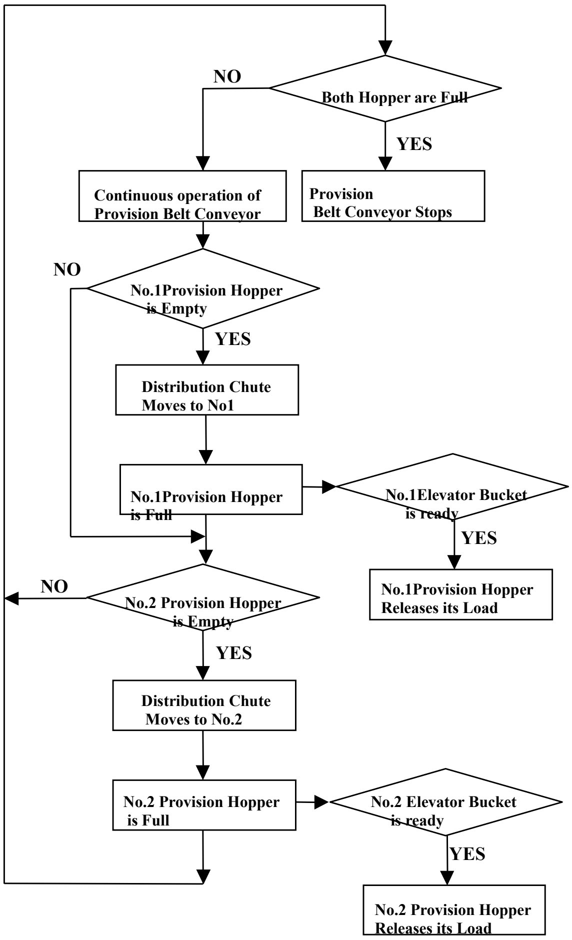


Figure 5. Flow chart of the Provision Line

2.3 Elevator Buckets

The concrete in the provision hopper is discharged by independent operation into the two elevator buckets within the post. The elevator buckets move vertically up and down and in horizontal and vertical directions following a guide rail which has a curvature of 600 R, placed 1,350 mm off-center of the center of the post, stopping at the discharge mouth of the provision hopper. The provision hopper opens and deposits concrete at this point.

The input quantity is controlled by two mechanisms: weight detection by the provision hopper's load cell and the weight detectors in the buckets themselves. When they are filled to the predetermined quantity, the hopper gate closes, and the bucket is raised with gradually increasing speed.

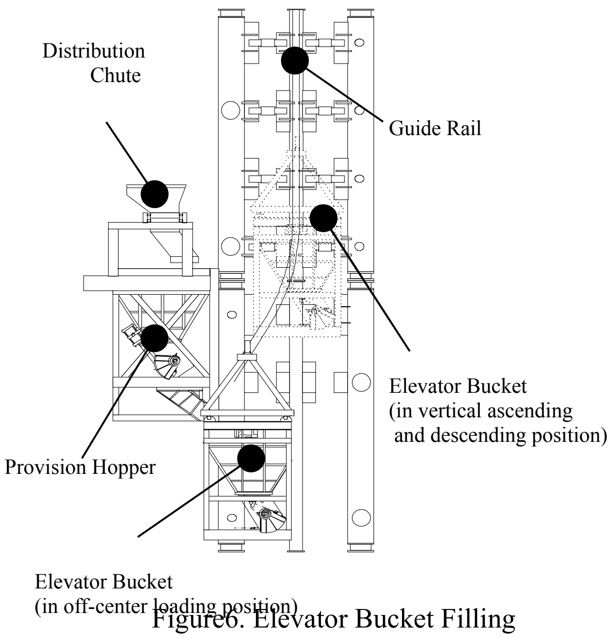


Figure6. Elevator Bucket Filling

2.4. Mobile Chute and Intermediate Hopper

Encoders which have winches and approach switches attached control the buckets loaded with concrete. They are gradually slowed and stopped at the required position.

When the bucket stops, the mobile chute moves, describing an arc from the outside of the post to the bottom of the elevator bucket. When this movement is complete, the gate in the bottom of the elevator bucket opens and concrete is discharged into the intermediate hopper. When the discharge is finished, a discharge completed signal is sent from the load cell which detects weight in the elevator bucket and the bucket gate is closed. The mobile chute retracts and the elevator bucket begins to descend.

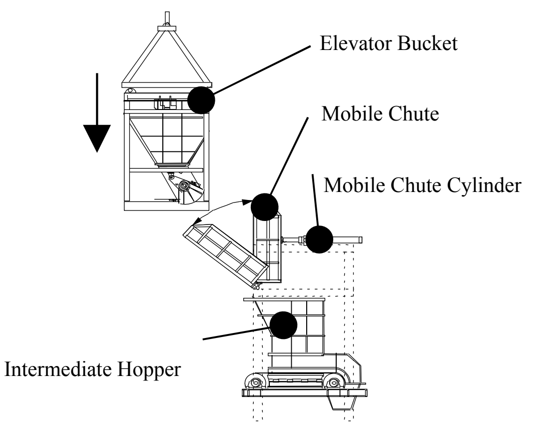
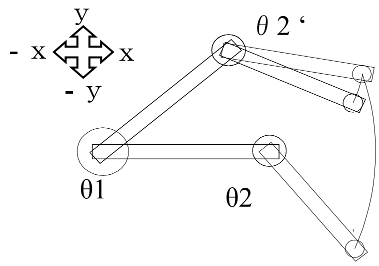


Figure 7. Mobile Chute and Intermediate Hopper

2.5 Rotary Feeder

The concrete discharged in predetermined quantity



by the belt feeder in the bottom of the intermediate hopper moves to the rotary feeder.

The rotary feeder consists of an “outer wall” equipped with a scraper which discharges concrete onto the belt conveyer of Arm No1 and which follows the rotating movement of the arm, and a bottom feeder combined with an “inner wall” which always operates in the same direction in a circular motion.

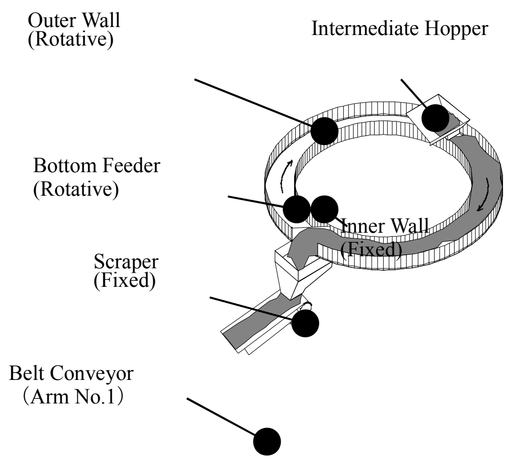


Figure8. Rotary Feeder

2.6 Arm No.1 and Tip Arm

The rotary arm consists of two arms: the Arm No.1

attached to the end of the raising and lowering supporting frame and which can turn 370 degrees (± 185 degrees) around the post, and the tip arm, which revolves 370 degrees around the end of Arm No.1 as its axis. Each arm is equipped with a belt conveyor.

By controlling the bi-axial rotative arms, it is possible to cast in a straight line, providing concrete automatically in a wide range. The arms can be operated in three modes, by manual, semi-automatically, or automatically.

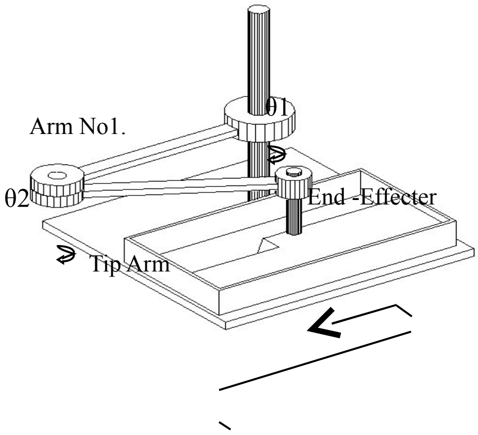


Figure 9. Concept Diagram of Arm Structure

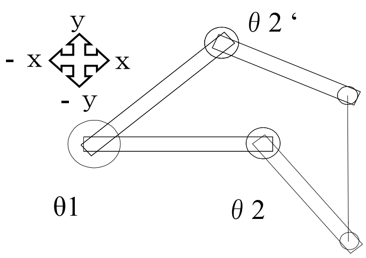
(1) Manual Operation Mode

The manual operation mode operates the axes at Arm No. 1 (θ1) and Tip Arm (θ2) independently. The end-effecter moves following an arc.

Figure 10. Diagram of Operation Track under Manual Operation

(2) Semi-automatic Operation Mode

In the semi-automatic operation mode the effecter can be operated in a straight line in orthogonal axial directions on previously established standard coordinates simply by operating independent levers



to simultaneously operate the axes at θ1 and θ2.

Figure 11. Diagram of Operation Track under Semi-automatic Operation

(3) Automatic Operation Mode

The automatic operation mode is used for distributing concrete into the placing blocks. The end-effecter moves in a straight line along an orthogonal axis on a standard coordinate system as it does in the semi-automatic mode.

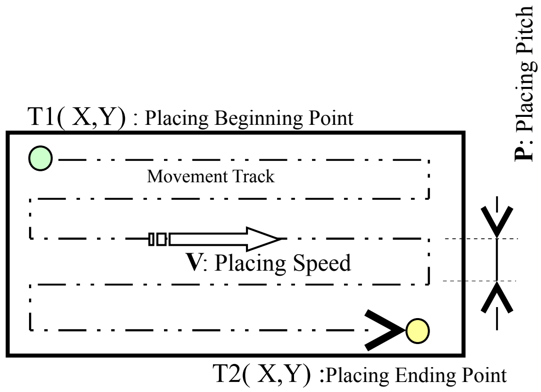


Figure 10. Automatic Placing Track and Customized Parameters

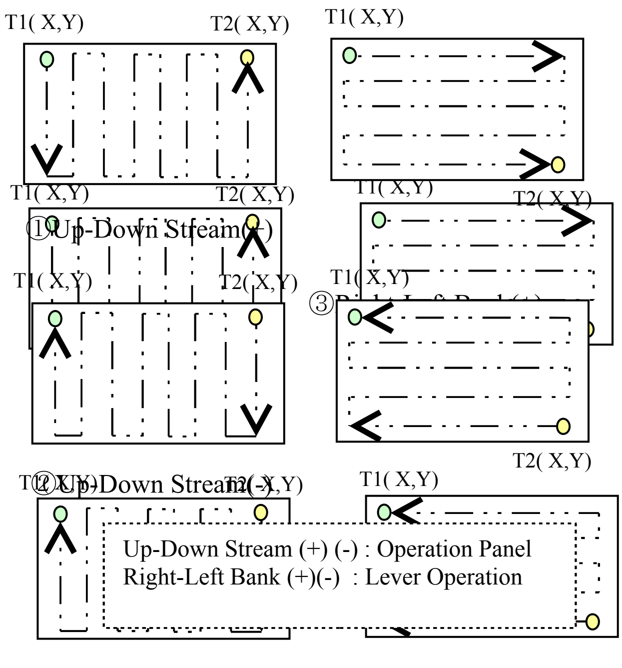


Figure 11. End-Effecter Movement Direction Parameters

上下流、左右岸正負　：操作パネル
　　　　　　　　　　：レバー操作

The automatic placing tracks and the parameters relating to them are shown in Figure 10 and Figure 11.

As a programming method for automatic placing in the semi-automatic or the manual operation mode, move the end-effecter to T1 and T2 in Figure 10 and end the programming of the placing beginning and ending points by pressing the "input" button at each point. After programming is completed, by press in the automatic operation button and then by lowering the operation lever in the movement direction and begin placing concrete operation begin from T1 toward T2 following the illustrated movement track in the direction of the arrows. P (placing pitch) and V (placing speed) are set on the operation panel screen according to the quantity of concrete to be placed. Should a concrete shortage occur during operation, the belt scale on the conveyor will sense it and stop the arm movement. The movement will begin again automatically when the shortage is resolved. The flowchart of arm operation is shown in Figure 12.

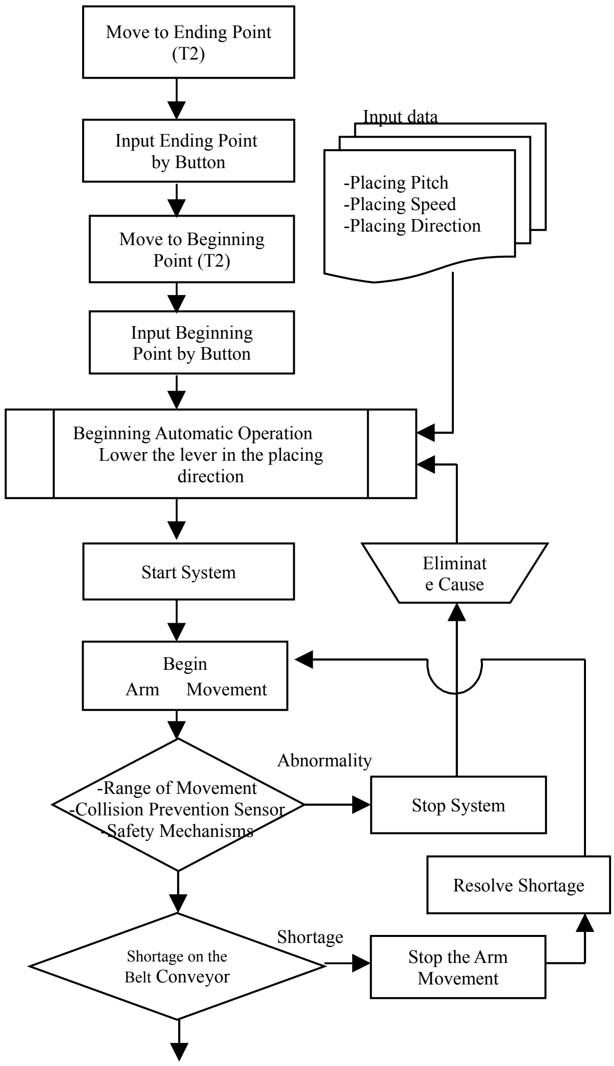


Figure 12. Flow Chart of Arm Operation

2.7 Telescopic Chute

A telescopic chute is attached to the end of the tip arm as an end-effecter. The telescopic chute is provided with a MY-Mixer attached at its middle length and end, which is set in order to prevent the segregation of the concrete. The concrete is placed from the tip arm at the placing site. The vertical chute then becomes, within the climbing steps (L=4m) of the machine, an extending and contracting its telescopic structure to adjust to the needed placing height. It alternates two MY-Mixer with two sections, 15 m or less, of extending and contracting chute to prevent quality reduction due to concrete dropping. This capability was confirmed by concrete quality tests at actual placing sites. Fracture of the aggregate was also not found.

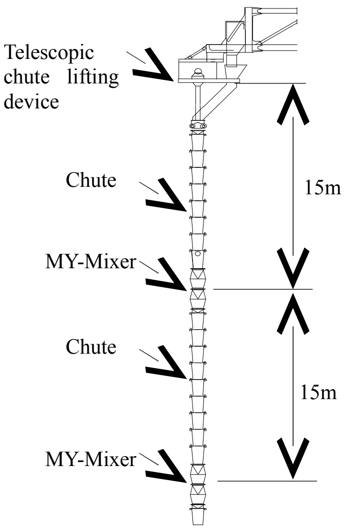


Figure 13. Telescopic Chute

2.9 Remote Access

Set values and functions of operational conditions and malfunction locations are displayed in real time on the ground control board at the lower part of the tower. This function is connected by RS-422 cable to the office on site where a similar monitoring is carried out.

Control settings can also be manipulated from the office, which may be accessed remotely from the outside. When software problems occur the manufacturer can immediately access the inside of the on-site control panel online through public telephone lines, observe the operation conditions, search for the place malfunction occurred, correct the program, and devise a system whose set values may be revised.

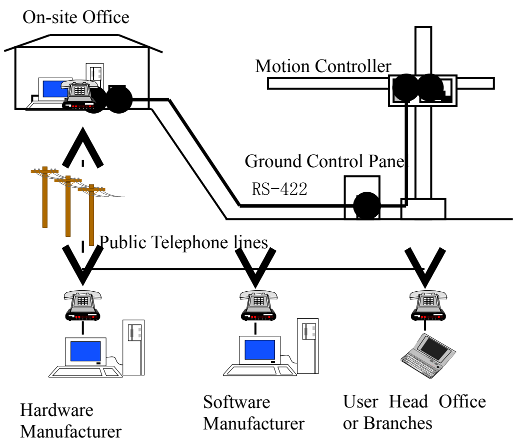


Figure 14. Outline of Remote Access System

3. CONCLUSIONS AND FUTURE DEVELOPMENT

3.1 Conclusion

The system provided a good transport capability that shortened concrete placing operations, reduced concrete provision line personnel, and the burden on the operator who alone operates the system. Safe concrete placing independent of the operator’s level of skill became possible in the narrow parts of the training walls, as well, in the automatic and semi-automatic modes, and without using any auxiliary equipment.

3.2 Future Development

The present system has a crane function in addition to the concrete distribution function. We would like, however, to develop a system having better cost performance by installing a laitance scraper on the arm end (end-effecter) and adding functions that can be used in many ways as it can be done with a multipurpose industrial robot.

Photo 1. Overview of the Whole System

Acknowledgments

We would like to express our gratitude to everyone involved in the development and operation of this system for their great guidance and cooperation.