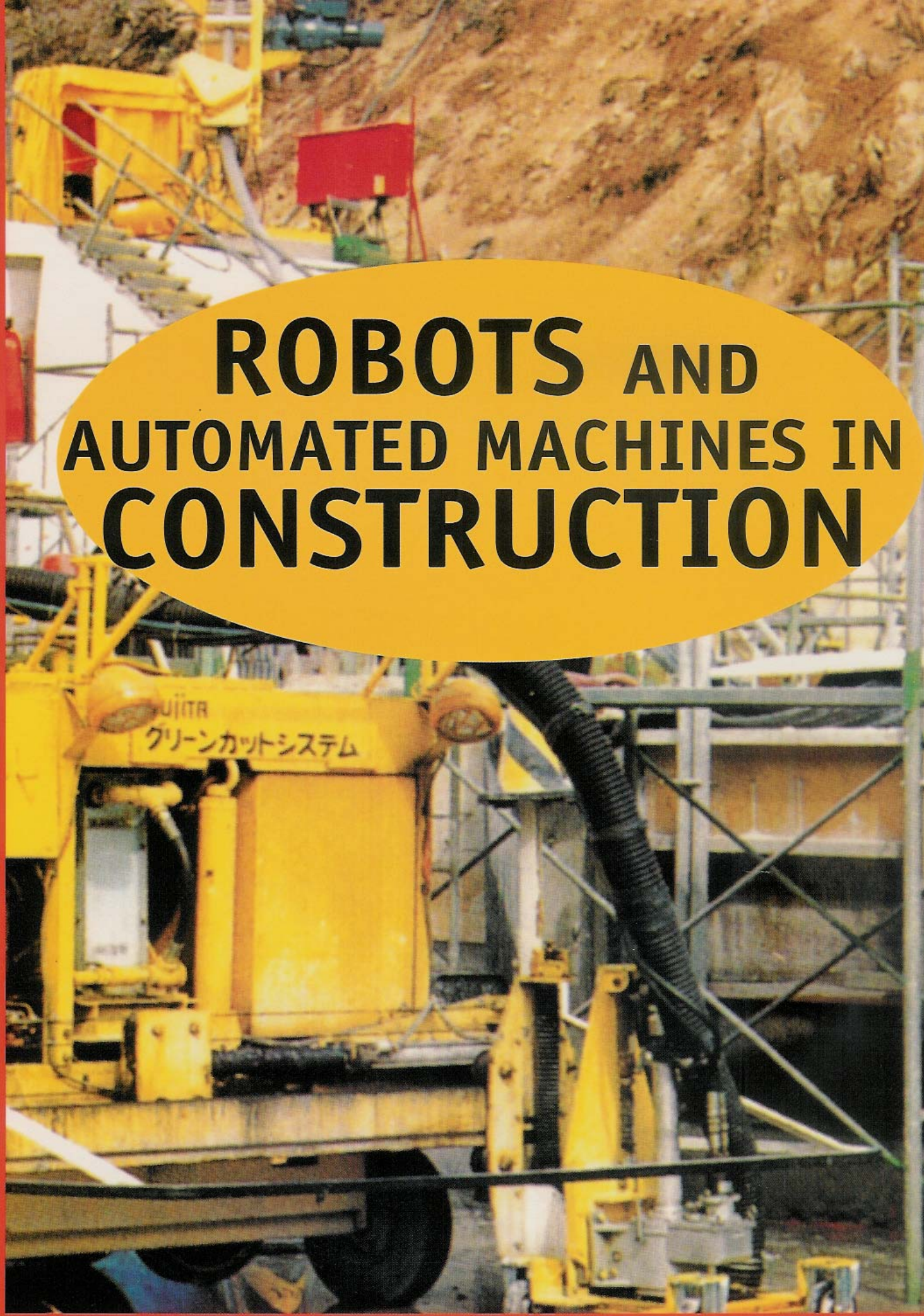

ROBOTS AND AUTOMATED MACHINES IN CONSTRUCTION

Publications Committee
International Association of Automation and Robotics in Construction

IAARC

March 199

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Tel.no.: 04704 - 3556

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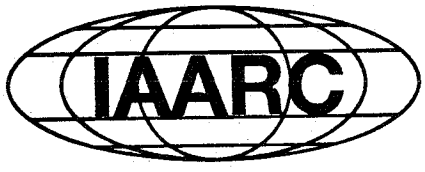


Publications Committee
International Association for Automation and Robotics in Construction

ABSTRACT
This technical catalogue consists of 76 entries, each describes a robot or an automated equipment developed for use in construction. These robots and equipment cover a wide range of construction applications: demolition, navigation-type surveying, excavation and earthmoving, paving, tunnelling, concrete transportation and distribution, concrete-slab screeding and finishing, cranes and autonomous trucks, welding and positioning of structural steel members, fire-resisting and paint spraying, inspection and maintenance, and integrated building construction.

Published by

The International Association for Automation and Robotics in Construction
The IAARC Secretariat
c/o Building Research Establishment Ltd
Watford, WD2 7JR, England, UK
Tel: +44(0)1923 664715, Fax: +44(0)1923 664398
Internet site: //www.iaarc.org

FORWARD

The International Association for Automation and Robotics in Construction (IAARC) is pleased to offer this publication on ***Robots and Automated Machines in Construction*** to its members and construction industry professionals. This edition includes technical characteristics, features, work execution records and usage conditions of 76 robots. The catalogue includes contributions from Japan, Sweden and Germany.

The International Association for Automation and Robotics in Construction (IAARC) was established in 1990 to encourage, facilitate and promote the co-ordination of scientific and technical developments in automation and robotics in construction. IAARC is a non-profit organization, managed by an international board of directors and supported by 6 working committees: strategic planning, membership, publications, finance, awards, newsletter and standards.

The robots included in this catalogue cover a wide range of construction applications: demolition, navigation-type surveying, excavation and earthmoving, paving, tunnelling, concrete transportation and distribution, concrete-slab screeding and finishing, cranes and autonomous trucks, welding and positioning of structural steel members, fire-resisting and paint spraying, inspection and maintenance, and integrated building construction.

The Publications Committee of IAARC would like to acknowledge the support of the organizations and individuals who made contribution to this edition of ***Robots and Automated Machines in Construction*** particularly Japan Robot Association (JARA) for its co-operation, past presidents of IAARC, Professors Y. Hasegawa, R. Tucker, M. Cusack, and Messrs. G. Watson and Y. Miyatake for their leadership, support and commitment to the preparation of this publication. The support of the current president, Professor J. O'Brien, and the members of IAARC board of directors is gratefully acknowledged. Special thanks to Professors S. Obayashi, W. Poppy and T. Bock and Messrs. Y. Komori, P. Ahman and F. Peyret for their direct valuable contributions to the production of this publication.

O. Moselhi, Prof. of Engineering, Concordia University, Montreal, Canada
Editor and Chairman of the Publications Committee.

IAARC BOARD OF DIRECTORS

TABLE OF CONTENTS

Demolition

Demolition unit MiniCut		Official evaluation:
Applicable type of work:	Demolition unit for brick, stone, concrete and other building materials.	Official price:
Classification:		
Purpose of the development:	Manpower saving, time-saving, improvement of work environment, operators safety	Lease and rental:
Level of practical use:	Available on the market	Development company: HOLMHED SYSTEMS AB

Information		
	Company name:	HOLMHED SYSTEMS AB
	Address:	P.O. Box 730, S-931 27 Skellefteå, Sweden
	Phone:	+46 (0)910 884 00
	Fax:	+46 (0)910 885 55

1. Application

Demolition units for brick, stone, concrete and other building materials. The units are designed to be small and compact with great mobility so that they can be transported into confined areas such as blast furnaces and cement kilns. The units can also be used for risky operations such as various construction work in nuclear power plants.

2. Outline

The unit iselectrically driven demolition robots. The principle is simpel and based on a three- part hydraulically driven boom attached to the machine body. The boom is movable horizontally, vertically, sideways and parallel. The construction of the boom makes its movements smooth but with high capacity when requested. It can be turned 245°.

The hydralic braker was developed in cooperation with Atlas Copco and is a small and powerfull braker.

The units are remotely controlled by a portable control panel which enables the operator to work at a safe distance from the machine.

3. Characteristics and effects

① The units are compact with high capacity and power. They can pass through narrow doorways.

② All demolition work is remotely controlled which makes it possible for the operator to manouver the machine within a safe distance from falling debris. The operator is also liberated from sufferings caused by vibrations.

③ Due to the power drive the operator is liberated from health-imparing exhausts such as diesel.

④ Demolition with the specially designed braker is 3-4 times more effective than a conventional hand-held hammer.

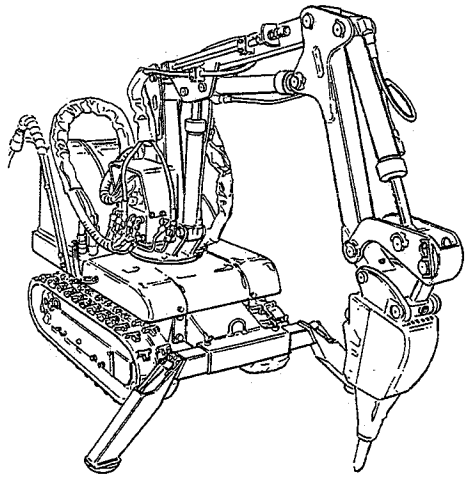


Figure 1. BROKK MiniCut

4. Features of the robotization and automation

Major specifications	BROKK MiniCut
Weight (excl. attachment)	360 kg
Transport length (excl. attachment)	1195 mm
Transport height (lowest)	940 mm
Transport width	600 mm
Operating width (outriggers unfolded)	1040 mm

① The three-part boom is especially designed to whithstand the extreme loads which arise when

operating with the various attachments. Robustly built cylinders have hard chrome-plated piston rods.

A patented machanism allows parallel travel of the boom. The hammer, or other tools, therefore can be applied exactly where you want i - quickly and easily.

② Quick hitch for simple and rapid change of attachments.

③ Underdarriage with geared wheels and caterpillar tracks. Sturdy track sides and hydraulic tensioning ensures reliable steering of tracks and prevents overload fracture. Hydraulically powered caterpillar tracks in steel with guide lugs and sprocket meshing, provide excellent manueverability and mobility even on loose surfaces.

④ The electric output is for MiniCut 4 kW.

⑤ Powered and control cables are located on a swivel boom and therefore can be held clear of the machine.

⑥ All operations are controlled by the control box which can be carried on a belt around the waist or placed on a stand (optional equipment).

5. Work execution record

Country	Type of work
Sweden	Used in almost every heavy demolition work.
Europe	Frequently used for demolition of kilns and furnaces in cement industry and steel plants.
USA	Demolition of skyscrapes in New York.

6. Usage conditions

① The work can be executed by 1-3 men.

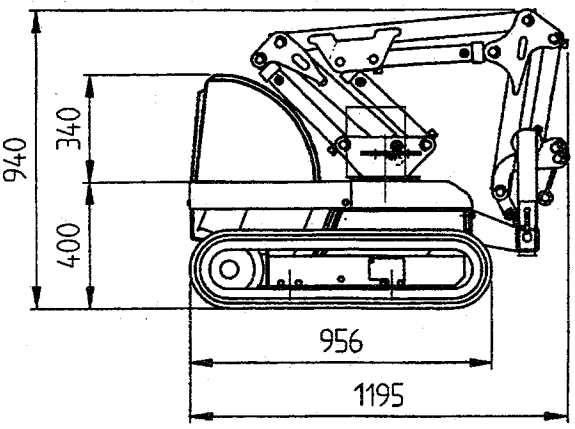


Figure 2. Configuration of BROKK MiniCut.

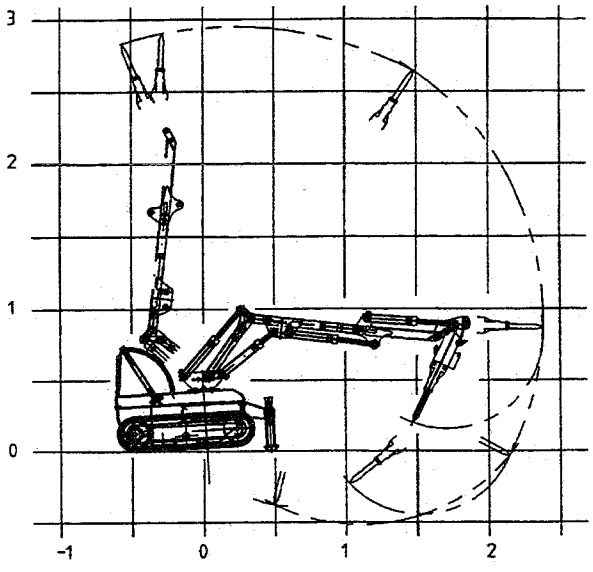


Figure 3. The range of BROKK MiniCut.

Demolition units BROKK BM 110, BM 150		Official evaluation:	
Applicable type of work:	Demolition unit for brick, stone, concrete and other building materials.	Official price:	
Classification:			
Purpose of the development:	Manpower saving, time-saving, improvement of work environment, operators safety	Lease and rental:	
Level of practical use:	Available on the market	Development company:	HOLMHED SYSTEMS AB

Information	Company name:	HOLMHED SYSTEMS AB
	Address:	P.O. Box 730, S-931 27 Skellefteå, Sweden
	Phone:	+46 (0)910 884 00
	Fax:	+46 (0)910 885 55

1. Application

Demolition units for brick, stone, concrete and other building materials. The units are designed to be small and compact with great mobility so that they can be transported into confined areas such as blast furnaces and cement kilns. The units can also be used for risky operations such as various construction work in nuclear power plants.

2. Outline

The units are electrically driven demolition robots. The principle is simpel and based on a three- part hydraulically driven boom attached to the machine body. The boom is movable horizontally, vertically, sideways and parallel. The construction of the boom makes its movements smooth but with high capacity when requested. It can be turned 360°.

The product range includes a number of tools which can be mounted on the robot boom. In addition to the traditional hydraulic hammer there are a number of concrete shearers, breakers and pulverizers for effective and noiseless demolition. The boom can also be provided with telescopic function and be equipped for working in hot environments.

The units are remotely controlled by a portable control panel which enables the operator to work at a safe distance from the machine.

3. Characteristics and effects

① The units are compact with high capacity and power. They can pass through narrow doorways.

② All demolition work is remotely controlled which makes it possible for the operator to manouver the machine within a safe distance from falling debris. The operator is also liberated from sufferings caused by vibrations.

③ Due to the power drive the operator is liberated from health-imparing exhausts such as diesel.

④ Demolition of blast furnaces can be made in half the time compared to conventional methods.

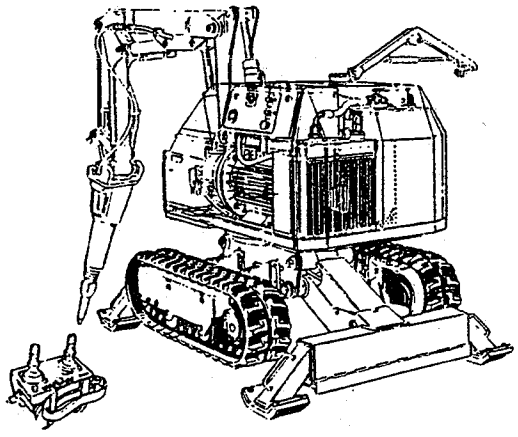


Figure 1. BROKK BM 150

4. Features of the robotization and automation

Major specifications	BM 250E	BM 330
Weight (excl. attachment)	1400 kg	1750 kg
Transport length (excl. attachment)	2340 mm	2340 mm
Transport height	1245/1185 mm	1245/1185 mm
Transport width (outriggers folded/ outriggers retracted)	1530 mm/ 780 mm	1130 mm/ 810 mm
Operating width (outriggers unfolded)	1200 mm	1200 mm

① The three-part boom is especially designed to whithstand the extreme loads which arise when operating with the various attachments. Robustly built cylinders have hard chrome-plated piston rods.

A patented machanism allows parallel travel of the boom. The hammer, or other tools, therefore can be applied exactly where you want i - quickly and easily.

② Quick hitch for simple and rapid change of attachments.

③ Underdarriage with geared wheels and caterpillar tracks. Sturdy track sides and hydraulic tensioning ensures reliable steering of tracks and prevents overload fracture. Hydraulically powered geared wheels and caterpillar tracks in steel with guide lugs and sprocket meshing, provide excellent manueverability and mobility even on loose surfaces.

④ The electric output is for BROKK BM 110 11 kW and for BROKK BM 150 15 kW.

⑤ Powered and control cables are located on a swivel boom and therefore can be held clear of the machine.

⑥ All operations are controlled by the control box which can be carried on a belt around the waist or placed on a stand (optional equipment).

5. Work execution record

Country	Type of work
Sweden	Used in almost every heavy demolition work.
Europe	Frequently used for demolition of kilns and furnaces in cement industry and steel plants.
USA	Demolition of skyscrapes in New York.

6. Usage conditions

① The work can be executed by 1-3 men.

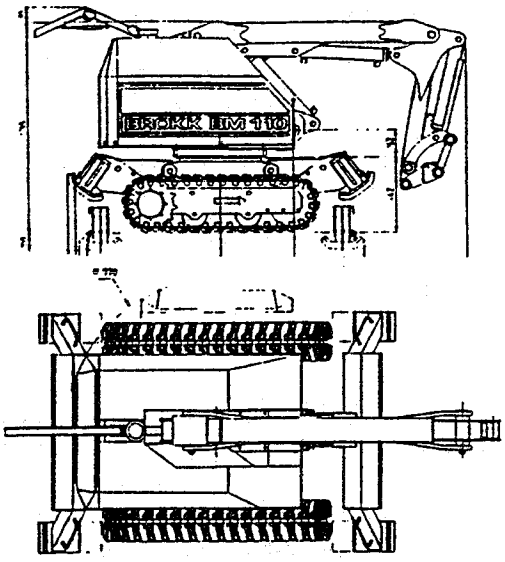


Figure 2. Configuration of BROKK BM 110.

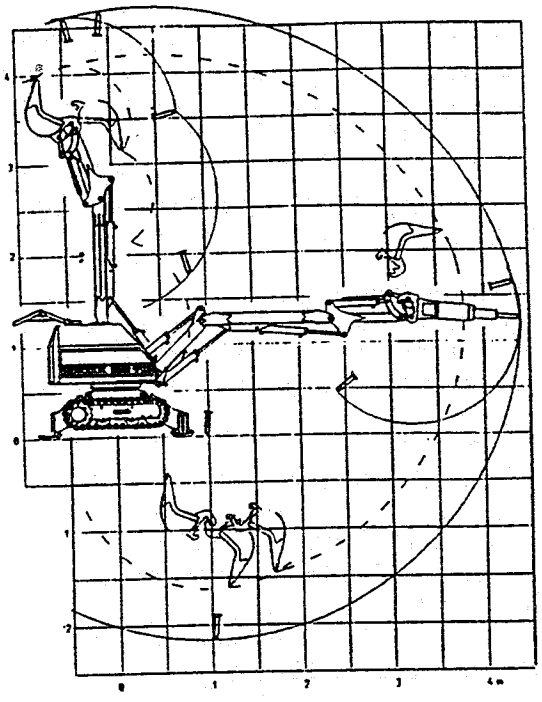


Figure 3. The range of BROKK BM 110

Demolition units BROKK BM 250E, BM 330		Official evaluation:
Applicable type of work:	Demolition unit for brick, stone, concrete and other building materials.	Official price:
Classification:		
Purpose of the development:	Manpower saving, time-saving, improvement of work environment, operators safety	Lease and rental:
Level of practical use:	Available on the market	Development company: HOLMHED SYSTEMS AB

Information		
	Company name:	HOLMHED SYSTEMS AB
	Address:	P.O. Box 730, S-931 27 Skellefteå, Sweden
	Phone:	+46 (0)910 884 00
	Fax:	+46 (0)910 885 55

1. Application

Heavy demolition work for brick, stone, concrete and other building materials. The units are designed to be small and compact with great mobility so that they can be transported into confined areas such as blast furnaces and cement kilns. The units can also be used for risky operations such as various construction work in nuclear power plants.

2. Outline

The units are electrically driven demolition robots. The principle is simpel and based on a three- part hydraulically driven boom attached to the machine body. The boom is movable horizontally, vertically, sideways and parallel. The construction of the boom makes its movements smooth but with high capacity when requested. It can be turned 360°.

The product range includes a number of tools which can be mounted on the robot boom. In addition to the traditional hydraulic hammer there are a number of concrete shearers, breakers and pulverizers for effective and noiseless demolition. The boom can also be provided with telescopic function and be equipped for working in hot environments.

The units are remotely controlled by a portable control panel which enables the operator to work at a safe distance from the machine.

3. Characteristics and effects

① The units are compact with high capacity and power. They can pass through narrow doorways.

② All demolition work is remotely controlled which makes it possible for the operator to manouver the machine within a safe distance from falling debris. The operator is also liberated from sufferings caused by vibrations.

③ Due to the power drive the operator is liberated from health-imparing exhausts such as diesel.

④ Demolition of blast furnaces can be made in half the time compared to conventional methods.

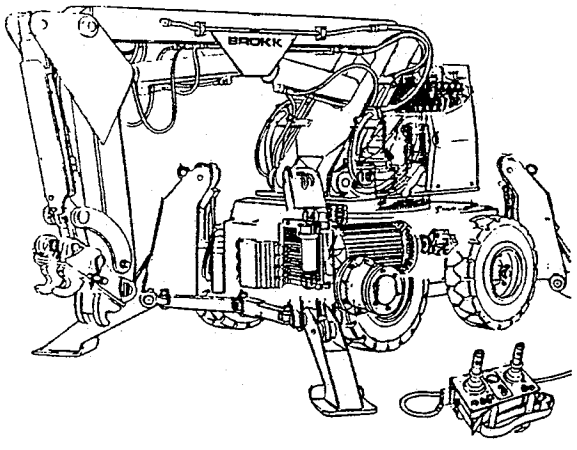


Figure 1. BROKK BM 250E

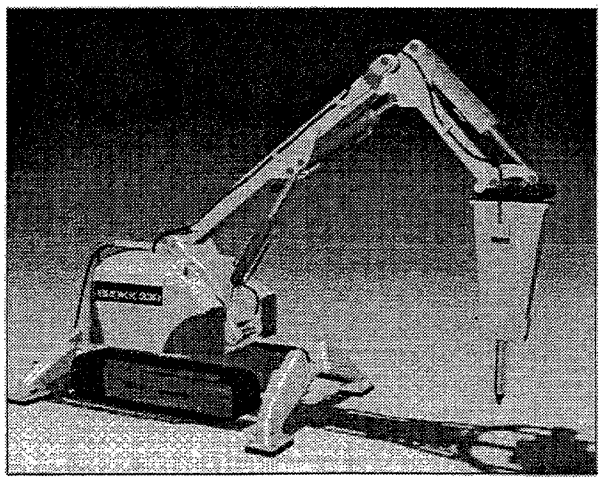


Figure 2. BROKK BM 330

4. Features of the robotization and automation

Major specifications	BM 250E	BM 330
Weight (excl. attachment)	3060 kg	4100 kg
Transport length (excl. attachment)	3600 mm	3920 mm
Transport height (lowest)	1760 mm	1540 mm
Transport width (outriggers folded / outriggers retracted)	1530 mm / 790 mm	2430mm / 1500 mm
Operating width (outriggers unfolded)	2450 mm	2430mm

① The three-part boom is especially designed to whithstand the extreme loads which arise when operating with the various attachments. Robustly built cylinders have hard chrome-plated piston rods. A patented mechanism allows parallel travel of the boom. The hammer, or other tools, therefore can be applied exactly where you want it - quickly and easily.

② Quick hitch for simple and rapid change of attachments.

③ Undercarriage consists of a robust, torsionally rigid closed box construction. The machine body contains the hydraulic oil tank, pump, electric motor and control valves for operation of the wheels and outriggers.

④ The front wheels of the BROOK BM 250E are driven by powerful motors via planetary gearing equipped with passive brakes. The unit is easy to maneuver even in a confined space, the front wheels being individually powered. The rear wheels are freewheeling, making it easy to move the machine over obstacles with the aid of the boom.

The BROKK BM 330 is equipped with caterpillar tracks that are driven hydraucally by powerful hydraulic motors. Strong springs and cylinders filled with grease keep the tracks tensely streched. Tracks can be tilted for easy travel in a circular kiln or furnace. With the tracks removed, the machine can enter through an opening 1500 mm wide or 1920 mm i diameter.

⑤ The output of the electric motor is 22 kW (BM 250E) and 30 kW (BM 330).

⑥ All operations are controlled by the control box which can be carried on a belt around the waist or placed on a stand (optional equipment).

5. Work execution record

Country	Type of work
Sweden	Used in almost every heavy demolition work.
Europe	Frequently used for demolition of kilns and furnaces in cement industry and steel plants.
USA	Demolition of skyscrapes in New York.

6. Usage conditions

① The work can be executed by 1-3 men.

② BROKK BM 250E can be equipped with crawler tracks that provide improved mobility on loose surfaces. They are made of strong and wear-resistant polyurethane. It can also be equipped with a telescopic boom for precision handling.

③ BROKK BM 250E is available with a diesel engine instead of an electric motor, or with combined dieselelectric operation.

④ The product range includes a number of tools which can be mounted on the robot boom such as, hydraulic breakers, crushing jaws, loader buckets, bachhoe buckets and clamshell buckets.

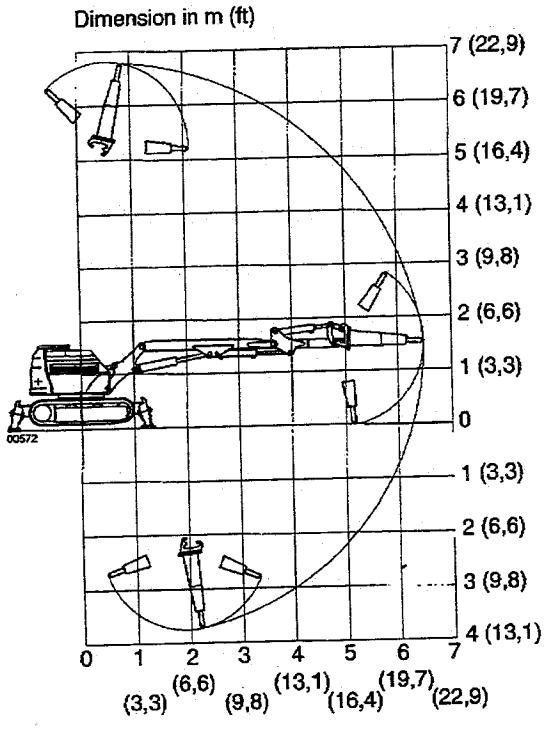


Figure 3. The range of BROKK BM 330

Concrete Hydrodemolition Robot

Applicable type of work: Concrete hydrodemolition	Official price:
Classification: construction	
Purpose of the development: Manpower saving, increasing efficiency, emission reduction	Lease and rental: yes
Level of practical use: State-of-the-art technique	Development company: WOMA Apparatebau GmbH, Germany Aquajet Systems AB, Sweden

Information			
	Company name:	WOMA Apparatebau GmbH	Aquajet Systems AB
	Address:	P.O. Box 141820, D-47208 Duisburg	P.O. Box 46, S-Holsybrunn
	Phone:	+49(0)2065/304-0	+46(0)383-50801
	Fax.:	+49(0)2065/304-200	+46(0)383-50730

1. Application

Self-propelled robot for selectively removing of weakened or damaged concrete with high-pressure water. Used for the rehabilitation of concrete structures, such as bridges, pillars, walls, tunnels and dams, that are affected by salt, acid pollution and by the general wear and tear.

2. Outline

The HVD and HVE robots which are used for horizontal, vertical and overhead work are equipped with a tower assembly kit providing a operating height to 6 m as standard. An innovation is the facility to hydraulically adjust the width of the tracks that allows an increased maneuverability. The power head, also hydraulically driven, can be rotated through 360° and can slide in all directions. Thus, it is ideally suited for situations with limited access. All functions are run and controlled by a computerized closed loop control with a user-friendly display system. If it is once programmed it automatically runs the robot.

3. Characteristics and effects

① The system selectively removes the concrete.
② The sound concrete structure as well as rebars will not be damaged.
③ No vibrations and no additional cracking occurs.
④ The formation of dust will be prevented.
⑤ The affection of operators by vibrations or heavy lifting is avoided.
⑥ The system simultaneously cleans rebars and other metallic sub-parts.

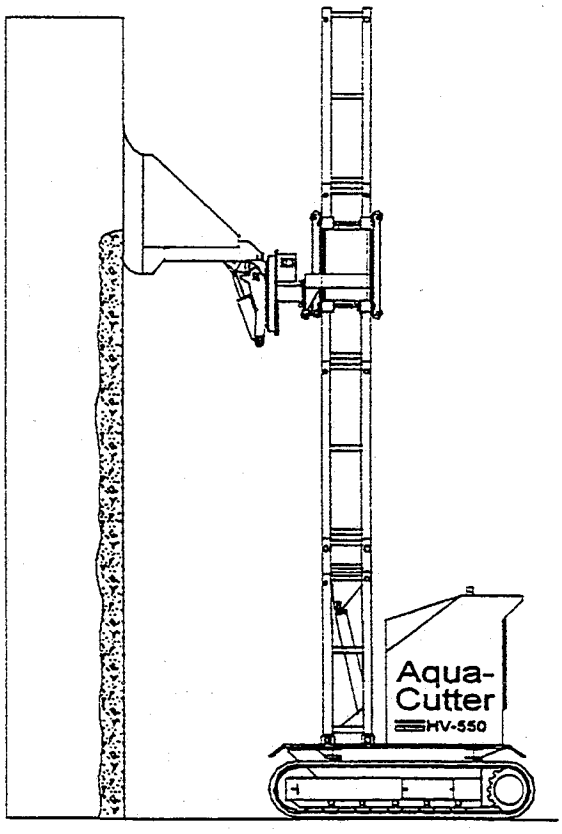


Figure 1. Robot system with assembling kit

4. Features of the robotization and automation

Parameter	Range
Length, min.	2,480 mm
Length, max.	2,730 mm
Width, total	2,000 mm
Width, min.	1,200 mm
Working width range	0 - 2,000 mm
Track width	1,030 - 1,510 mm
Operation height	6,000 mm
Weight	1,800 - 1,900 kg
Drive	Electric motor Diesel engine

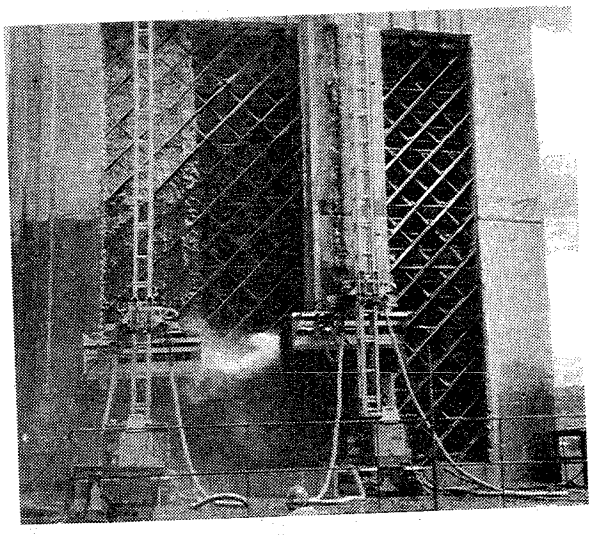


Figure 2. Robot in operation

5. Work execution record

Work performed	Client
Selectively remove concrete and expose steel rebars	Westgate Bridge, Australia
	Niagara Power Proj., Canada
	Great Belt Bridge, Danmark
	Almaraz Nucl. Power Plant, Spain
	Great Straight Bridge, Taiwan
	Thelwall Bridge, Great Britain
	Nak-Dong Bridge, Korea
Efficiency:	5 m^2/h to 40 m^2/h
Removal rate:	0.2 m^3/h to 1.0 m^3/h

6. Operation Conditions

① The track-driven robot is equipped with steel reinforced rubber tracks.
② The robot is adjusted to correct position by a remote-control system that is handled by one operator.
③ The robot can stationary turn and be run on rough surfaces and on suspended ground.
④ The system can load and unload itself on a truck-ramp.
⑤ Typically, the system can be run with operating pressures up to 1,200 bar (120 MPa) and water flow rates up to 200 l/min.

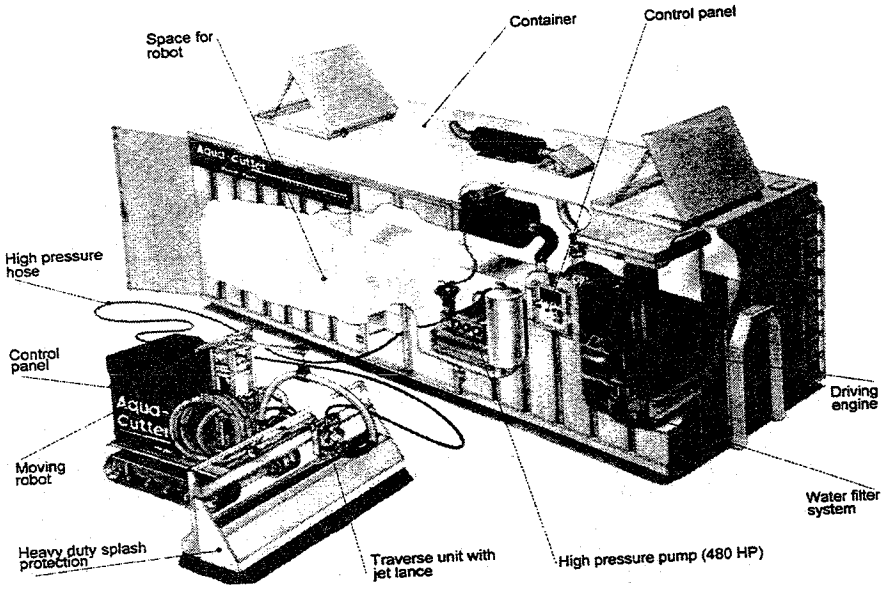


Figure 3. System layout

Aqua Jet H-450 and HV-550 Hydrodemolishing robots		Official evaluation:	
Applicable type of work:	Removal of damaged concrete	Official price:	H-450 676 000 SKR, HV-550 975 000 SKR
Classification:			
Purpose of the development:	Manpower saving, time-saving, improvement of work environment, operators safety	Lease and rental:	Available from Aquajet Systems AB
Level of practical use:	Available on the market	Development company:	AQUAJET SYSTEMS AB

Information		
	Company name:	AQUAJET SYSTEMS AB
	Address:	P.O. Box 46, S-570 15 Holsbybrunn, Sweden
	Phone:	+46 (0)383 508 01
	Fax:	+46 (0)383 507 30
	E-mail:	aquajet@aquajet.se
	Internet:	http://www.aquajet.se

1. Application

Removes damaged concrecte carefully and effectively from horizontal surfaces such as bridges and floors, (H-450). It can also perform on vertical surfaces, such as walls and columns, roofs and ceilings, (HV-550). The H-450 can easily be uppgraded to the more flexible HV-550 model.

2. Outline

The Aqua Cutter removes damaged concrete at the speed of several hydraulic jackhammers. It also works selectivily. A high-pressure jet of water passes across the surface, penetrating into the weak concrete. When the water washes away, it takes the damaged concrete with it but only down to a preset "quality depth". This quality depth is determined by the movement of the water jet and the time the water jet stays in the same place.

The units are computer-controlled with 7 preset programs that can be individually selected. All movement parameters are fully adjustable from the control panels. Unit H-450 is provided with a remote control box complete with 4 meters of cable for manual movement of the unit. All other movement controls are on the unit main control panel. Unit HV-550 is provided with a remote control box with 6 metres of cable from which all important functions are attended to and controlled.

3. Characteristics and effects

(1) Selective removal of damaged concrete to a preset "quality depth".

(2) By using hydrodemolition equipment all manual chipping with mechanical impact hammers are virtually eliminated. Consequently, workers are not subjected to painful and injurious vibrations. There is also a significant decrease in the sound level on the work sites in comparison with the nosie level caused by mechanical impact hammers.

(3) Operating costs including fuel consumption and maintenance are very low. The performance rate is high and continuous, with no down time due to operator fatigue. Demolition work can be done in minimum time with minimum disruption.

(4) The machines are vibration-free. Surroundings and reinforcement remain undamaged and also cleaned from residues and rust.

(5) The control system has been developed to meet the demand for smooth and efficient performance without affecting the overall integrity of the structure. It leaves an uneven surface without risk of additional micro-cracks which is ideal for laying of new concrete.

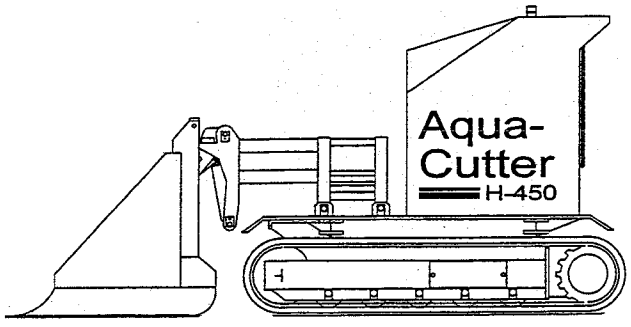


Figure 1. Aqua-Cutter H-450

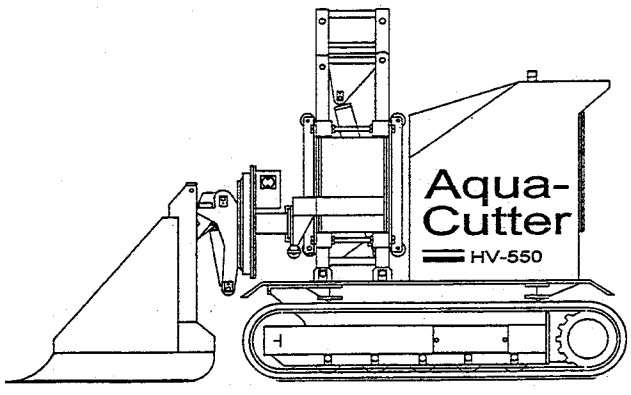


Figure 2. Aqua-Cutter HV-550

4. Features of the robotization and automation

Major specifications:	H-450	HV-550
Length 2370 mm	2400 mm	
Weight 1180 kg	1550 kg	
Min. height 1250 mm	1560 mm	
Width of track	1000 mm	1000 mm
Total width 2000 mm	2000 mm	
Working width range	0-1900 mm	0-1900 mm
Min. width	1250 mm	
Max. working height		5500 mm

(1) Every working functions is automatically controlled from the built-in computer with pre-set programs. It needs no commands duting operations on "Auto" once the appropriate program has been entered (H, HV).

(2) The units are "continous" machines and will continue working as programmed on "Auto" until the operator gives it new commands (H, HV).

(3) Electrohydraulic control system. The hydraulic system is powered by 7,5 kW, 400 V, 32 A. 24 V control system.

(4) Track drive: steel reinforced rubber tracks make the machine very easy to control. The track-carried unit also provides a very solid working position without vibrations. Hydraulic track motors with reduction gear and automatic brakes make the motion smooth and exact (H, HV).

(5) Lateral motion: hydraulically controlled 300 mm sideways moving of the poser head (H, HV).

(6) Power head: covered with tough wear-resistant and replaceable rubber proctection to avoid debris flying around and also as noise insulation for the supersonic waterjet (H, HV).

(7) Tilting: hydraulic tilting of the power head for easy nozzle maintenance and easy manual movement of the units (H, HV).

(8) Working positions: hydraulic turning and tilting of the power head for vertical and ceiling demolition, switched in a minute. Two ways of vertical operating: turn the power head 90 and let the unit drive along the wall, or place the unit with the front against the wall and let the power head move on the tower, all controlled by the computer (HV).

(9) The tower sections are hydraulically erected and operated from the remote box (HV).

(10) Supports: 4 adjustable and pivoting jacks for safe and stable vertical ceiling operations. Braces on the tower to absorb the reaction force from the waterjet (HV).

(11) Safety: pressure-tested High Pressure hose line with M36x2 DKO connection, external reinforced protection hose and safety wire on hose line, jacks and braces, emergency stop on the unit (H, HV).

5. Work execution record

Work performed	Object
Opening in a 1400 mm thick wall in the reactor hall, to change the steam generators. Approx. 80 m^3 of concrete, with a reinforcement amount of 500 kg/m^3.	Almaraz Nuclear Power Plant, Spain
Restoration of substructural, vertical renovation of dam-sides inside the dam, removal of approx. 100 000 Sqft of concrete, depth 6-7".	Niagara Power Project, Canada.
Vertical removal of approx. 600 m^3 of concrete.	Great Belt Bridge, Denmark.
Hydrodemolition of curved tunnelceiling 6,5 m from ground, and also the vertical sides. Approx 1000 m^2 of concrete.	Jercico Tunnel, Gothenburg, Sweden.
Bridgedeck renovation approx. 2000 m^2 of concrete.	Samill High Bridge, Seoul, Korea.
Surface preparation of the bridge deck, depth approx. 10-15 mm. Approx. 60 000 m^2 of concrete.	Great Straight Bridge, Taipei, R.O.C.
Restoration of Pile Caps and piles, estimated to approx. 650 m^3 of concrete.	Thelwall Bridge, Manchester, UK.
Renovation of approx. 275-300 m^3 of concrete from different spots.	Nak-Dong Bridge, Pusan, Korea.

6. Usage conditions

(1) The capacity of the high pressure pump is an important factor for reaching efficient and economic hydrodemolition. For optimum performance a pump unit with an approximate capacity of 193 liters/minute (43 gpm) and a working pressure of 900 bar is ideal.

(2) 1 or 2 men are needed in order to execute.

(3) Use of the waterjet technique is restricted to periods when the temperature is above 0C, partly in view of the freezing risk for the concrete and partly for the equipment.

(4) The technique implies that large amounts of rubble must be collected in a suitable manner. This problem, however, can be solved by using large industrial vacuum cleaners.

Conjet Jetframe system for hydrodemolition		Official evaluation:	Tested and evaluated by the National Swedish Road Administration
Applicable type of work:	Removal of damaged concrete	Official price:	Jetframe with Power pac 345 or 540 between 2,3-3 400 000 SKR
Classification:			
Purpose of the development:	Manpower saving, time-saving, improvement of work environment, a nondestructive technique	Lease and rental:	Negotiable
Level of practical use:	Available on the market	Development company:	CONJET AB

Information	Company name:	CONJET AB
	Address:	PO Box 507, S-136 25 Haninge, Sweden
	Phone:	+46 (0)8 741 39 40
	Fax:	+46 (0)8741 39 60

1. Application

Concrete removal in remote areas, confined spaces or where the operation is out of reach. The jetframe is often bolted to a surface, mounted on a skylift or any other carrier. Vertical dam and spillway concrete at water-power plants, bridges and pillars and the bottom side of bridge decks and quays are applications where the jetframe 120 excels.

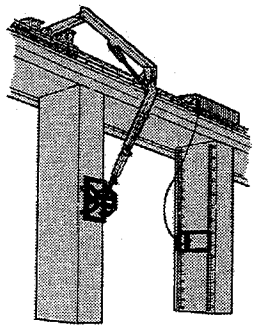


Figure 2. The Conjet Jetframe 120 allows operation in the most difficult areas..

2. Outline

The jetframe 120 has been developed to reach areas which the robot can't reach. The system consists of three parts, the Remote control panel, the Computer Control Unit (CCU 155) and the Jetframe 120. The CCU 155, an electrohydraulic power unit, controls the operation by a microprocessor. The jetframe works in any direction, thanks to limitless positioning horizontally, vertically and from below to handle waterjet pressures over 1000 bar (14.500 psi) at flow rates of up to 300 lpm (78 US Gal/minute). The remote control makes it easy for the operator to control the equipment from a safe position where he can overview the working area.

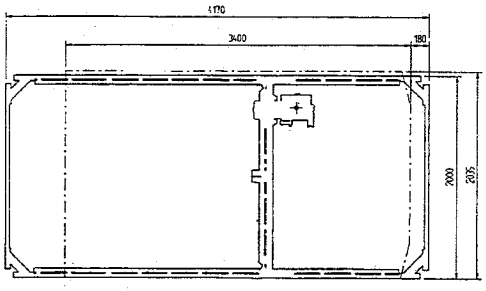


Figure 3. Cover chart for the Conjet Jetframe 120.

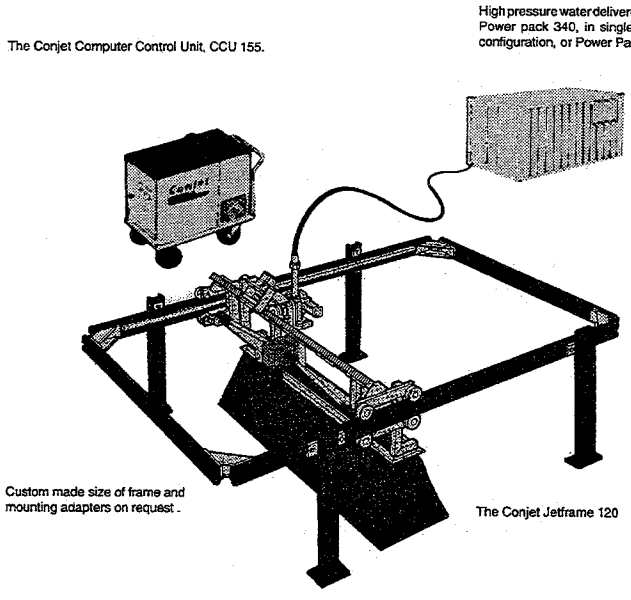


Figure 1. The Conjet Jetframe 120.

3. Characteristics and effects

① Poor concrete is removed selectively only down to a preset quality depth.

② By using hydrodemolition equipment, all manual chipping with mechanical impact hammers is virtually eliminated. Consequently, workers are not subjected to painful and injurious vibrations. There is also a significant decrease in noise level on the work site compared to the level caused by mechanical impact hammers.

③ Up to 50 % better bonding on rough surfaces.

④ Cause no vibrations or microcracks.

⑤ 25-50 times faster than jackhammers.

⑥ Removes concrete under rebars and rust from rebars.

⑦ The CCU 155 is so small that it can be lifted on to a scaffolding and can be positioned up to 50 m away from the Jetframe.

4. Features of the robotization and automation

Major specifications:	Jetframe 120	CCU 155
weight	350 kg	300 kg
length	4170 mm	1400 mm
height	1800 mm	1250 mm
width	2000 mm	700 mm
cutting length	3400 mm	
cutting width	2035 mm	

① The hydraulic system powers all mechanical functions on the Jetframe 120 such as the index of the feedbeam, cradle speed, oscillation motor, and attached cylinder. The hydraulic system is powered by an electric motor. The pump is a gear pump.

② The computer controls the system by four different programs. The programs are made to enable the jetframe to reach different hydrodemolition depths and to take various optional equipment.

③ The operator controls the jetframe from a remote control box. For maximum safety a reactivating timer, which the operator has to reset every two minute, is built into the system.

④ Jetframe 120 is a flexible tool. The size of the lance can easily be changed. Some hydraulic components are mounted on the Jetframe 120 to minimize the number of hoses and cables between CCU 155 and Jetframe 120. Between the control unit and the Jetframe there is only one electrical cord, three hydraulic hoses and the high pressure hose.

5. Work execution record

Work performed	Client
Dubai Dry Dock, U.A.E.	Archirodon
Midskog Waterdam, Sweden	Nordic Construction Co

6. Usage conditions

① The capacity of the high-pressure pump is an important factor for reaching efficient and economic hydrodemolition. Pressure of approximately 1000 bar is used fore normal concrete (30-40MPa). The amount of water increases the productivity proportionally. Common sizes of pumps are between 100-250 liters.

② One man handles the operation, but for safety reasons two men are needed.

③ Use of the waterjet technique is restricted to periods when the temperature is above 0°C, partly in view of the freezing risk for the concrete and partly for the equipment. Below 0°C the equipment is housed in a tent.

④ The technique implies that large amounts of rubble must be collected in a suitable manner. Depending on the cost of labor and type of project, anything from manual removal to large industrial vacuum cleaners is used to remove the rubble.

⑤ The water used must be drinkable since polluted salt water has a negative effect on remaining concrete.

⑥ Since the required amount of water is quite large, fire hydrants are often used for water supply. In remote areas large tank trucks must be used.

Conjet robot 230 for hydrodemolition		Official evaluation:	Tested and evaluated by the National Swedish Road Administration
Applicable type of work:	Removal of damaged concrete	Official price:	Robot system with Power pac 345 between 2,4-3,5 000 000 SKR
Classification:			
Purpose of the development:	Manpower saving, time-saving, improvement of work environment, a nondestructive technique	Lease and rental:	Negotiable
Level of practical use:	Available on the market	Development company:	CONJET AB

Information		
	Company name:	CONJET AB
	Address:	PO Box 507, S-136 25 Haninge, Sweden
	Phone:	+46(0)8 741 39 40
	Fax:	+46(0)8 741 39 60

1. Application

Concrete removal on horizontal surfaces such as bridges, parking decks, sewage plants, dams, industrial floors etc. The unit is small enough to enable easy maneuvers under different conditions.

2. Outline

The threewheel robot is a manipulator for a highpressure waterjet. With its built-in microprocessor the operator can set parameters in manual or automatic mode to control the movements of the waterjet for maximum production. The remote control box provides safe operation for the worker. For safety reasons a reactivating timer, which the operator resets every two minutes, is built into the system.

The hydraulic system is powered by an electric motor. The carrier is equipped with a feedbeam to which a cradle is mounted. The cradle travels back and forth on the feedbeam. The oscillating cassette is an exchangeable tool which is bolted to the cradle. The cassette is the holder for the high-pressure lance. The cassette has two functions: to provide oscillation and an attach angle for the waterjet to work against the concrete surface for maximum production.

3. Characteristics and effects

① Poor concrete is removed selectively down to a preset "quality depth".

② By using hydrodemolition equipment all manual chipping with mechanical impact hammers is virtually eliminated. Consequently, workers are not subjected to painful and injurious vibrations. There is also a significant decrease in noise level on the work site in comparison with the level caused by mechanical impact hammers.

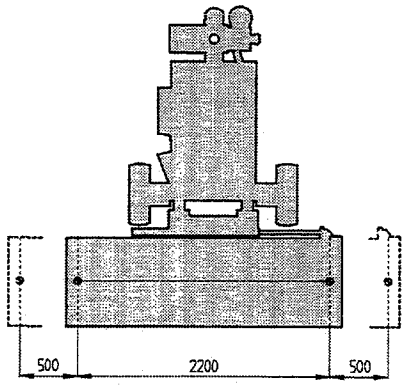


Figure 2. Cover chart for the Conjet robot 230.

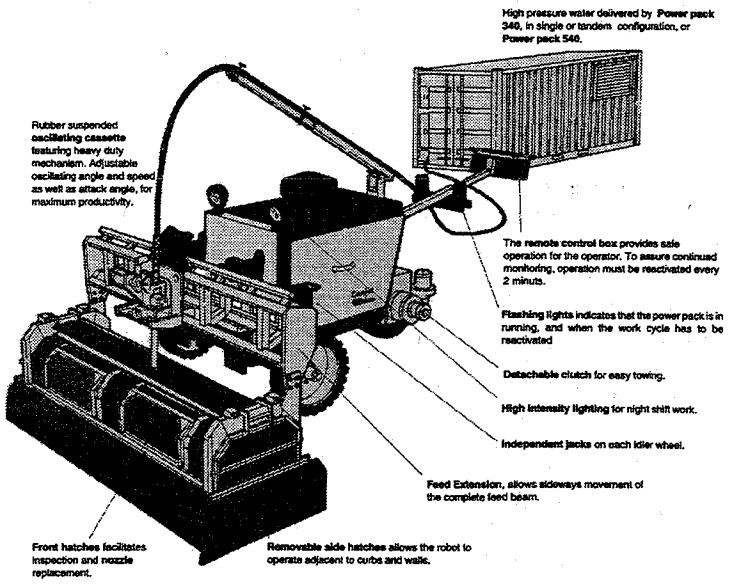


Figure 1. The Conjet robot 230.

③ Up to 50 % better bonding on rough surfaces.

④ Cause no vibrations or microcracks.

⑤ 25-50 times faster than jackhammers.

⑥ Removes concrete under rebars and rust from rebars.

⑦ Thanks to low weight and small dimensions, the robot can even be operated on a scaffolding.

4. Features of the robotization and automation

Major specifications:	Conjet robot 230
weight	1650 kg
length	2800 mm
height	1650 mm
width	2300 mm
cutting width	2200 mm
feedbeam width	2300 mm

① Electro-hydraulic control system. The hydraulic system powers all mechanical functions of the robot such as oscillation, cassette movements, feed beam, the drive wheel and hydraulic jacks. The hydraulic system is powered by an electric motor of 7.5kW, 380V, 50 or 60 Hz. Maximum working pressure is 110 bar (1540 psi.) at 32 l/min (8.5 US gal.) of flow. The robot is powered with 380 V from the Powerpack that is connected to a generator or an electrical outlet.

② The computer, a microprocessor, controls the system by four different programs and the sensors for setting the removal width. The programs are made to enable the robot to reach different depths and to take various optional tools. Custom-made programs are available on request.

③ Feedbeam for horizontal removal. The feedbeam has a cutting width of 2200 mm (87 in.). It is equipped with a heavy-duty protection hood with hatches on both sides for easy access to change nozzle and nozzle nut and to check the results. The oscillating cassette is bolted to the cradle which is mounted on the feedbeam. The cassette holds a 900 mm (35 in.) long lance with an internal diameter of 20 mm (3/4 in.). The feedbeam can be hydraulically adjusted +/-500 mm (20 in.) sideways for easier operation in confined areas and on the edges of a bridge for example.

5. Work execution record

Work performed	Contractor
Niagra falls bridges between Canada and US	Sevensons
Kennedy Art Center in Washington DC	Volker Sterin

6. Usage conditions

① The capacity of the high pressure pump is an important factor for reaching efficient and economic hydrodemolition. Pressure of approximately 1000 bar is used for normal concrete (30-40 MPa). The amount of water increases the production proportionally. Common sizes of pumps are between 100 - 250 liters.

② One man handles the operation, but for safety reasons two men are needed.

③ Use of the waterjet technique is restricted to periods when the temperature is above 0°C, partly in view of the freezing risk for the concrete and partly for the equipment. When the temperature is below 0°C the equipment must be housed in a tent.

④ The technique implies that large amounts of rubble must be collected in a suitable manner. Depending on the cost of labour and the type of project, anything from manual removal to use of large industrial vacuum cleaners is used to remove the rubble.

⑤ The water must be drinkable since polluted salt water will effect the remaining concrete in a negative way.

⑥ Since the amount of water is quite large, fire hydrants are often used as water supply. In remote areas large tank trucks must be used.

Conjet robot 361 for hydrodemolition			Official evaluation:	Tested and evaluated by the National Swedish Road Administration
Applicable type of work:	Removal of damaged concrete		Official price:	Robot system with Power pac 345 or 540 between 2,6-3 800 000 SKR
Classification:				
Purpose of the development:	Manpower saving, time-saving, improvement of work environment, a nondestructive technique		Lease and rental:	Negotiable
Level of practical use:	Available on the market		Development company:	CONJET AB
Information	Company name:	CONJET AB		
	Address:	PO Box 507, S-136 25 Haninge, Sweden		
	Phone:	+46(0)8 741 39 40		
	Fax:	+46(0)8 741 39 60		

1. Application

Concrete removal on walls, ceilings, and horizontal surfaces such as bridges, parking decks, sewage plants, dams, industrial floors etc. Any inclination or distance is controlled by the ultrasonic sensors. The unit is small enough to enable easy maneuvres under different conditions.

2. Outline

The three-wheel robot is a manipulator for a high pressure waterjet. With its built-in microprocessor the operator can set parameters in manual or automatic modes to control the movements of the waterjet to ensure maximum production. The remote control box provides safe operation for the worker. For safety reasons a reactivating timer, which the operator resets every two minutes, is built into the system.

The hydraulic system is powered by an electric motor. Mounted to the chassis the carrier has a turntable which can rotate the feedbeam 360°. The feedbeam is attached to a hydraulic actuator which can be extended 500 mm. On the feedbeam a cradle is mounted which travels back and forth. The oscillating cassette is an exchangeable tool which is bolted to the cradle. The cassette is the holder for the high pressure lance. The cassette has two functions, to provide oscillation and an attack angle for the waterjet against the concrete surface for maximum production.

3. Characteristics and effects

① Poor concrete is removed selectively down to a preset quality depth.

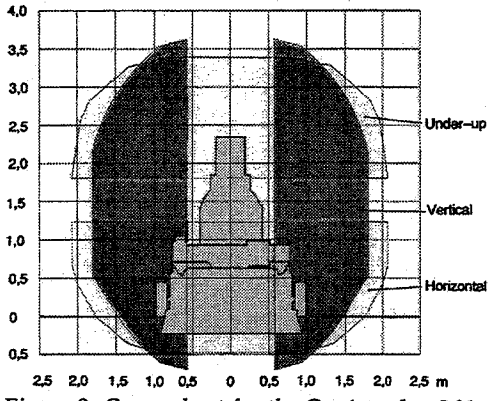


Figure 2. Cover chart for the Conjet robot 361.

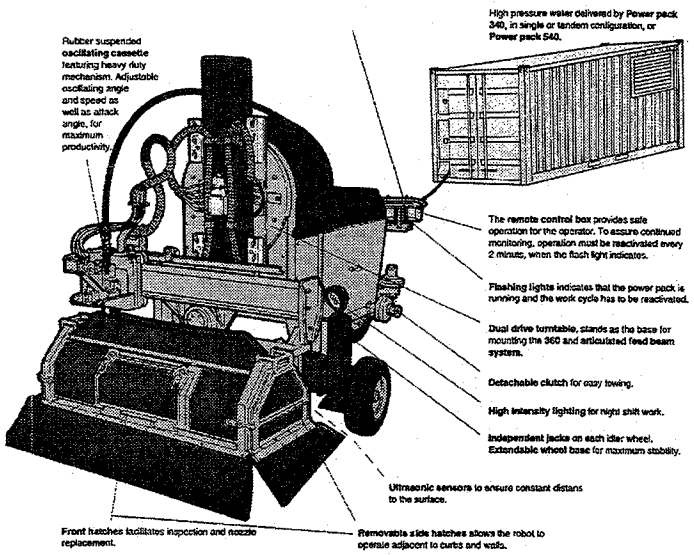


Figure 1. The Conjet robot 361.

② By using hydrodemolition equipment all manual chipping with mechanical impact hammers is virtually eliminated. Consequently, workers are not subjected to painful and injurious vibrations. There is also a significant decrease in the noise level on the work site in comparison with the level caused by mechanical impact hammers.

③ Up to 50 % better bonding on rough surfaces.

④ Cause no vibrations or microcracks.

⑤ 25-50 times faster than jackhammers.

⑥ Removes concrete under rebars and rust from rebars.

⑦ Thanks to low weight and small dimensions, the robot can be operated on a scaffolding.

4. Features of the robotization and automation

Major specifications:	Conjet robot 361
weight	1950 kg
length	3300 mm
width	2000 mm
height	2300 mm
cutting width	1600 mm
feedbeam width	1700 mm

① Electro-hydraulic control system. The hydraulic system powers all mechanical functions of the robot such as oscillation, cassette movements, feed beam, drive wheel and hydraulic jacks. The hydraulic system is powered by an electric motor of 7.5 kW, 380 V, 50 or 60 Hz. Maximum working pressure is 110 bar (1540 psi.) at 32 l/min (8.5 US gal.) of flow. The robot is powered with 380 V from the Powerpack that is connected to a generator or an electrical outlet.

② The computer, a microprocessor, controls the system by eight different programs, with sensors for setting the removal width and ultrasonic sensors that ensure constant distance to the surface. The programs enable the robot to reach different depths and to take various optional tools. Custom-made programs are available on request.

③ Feedbeam for 360 degrees of removal. The feedbeam has a cutting width of 1600 mm (63 in.). It is equipped with a heavy-duty protection hood with hatches on both sides for easy access to change nozzle and nozzle nut and to check the results. The oscillating cassette is bolted to the cradle which is mounted on the feedbeam. The cassette holds a 900 mm (35 in.) long lance with an internal diameter of 20 mm (3/4 in.). The feedbeam can be hydraulically adjusted +/-500 mm (20 in.) sideways for easier operation in confined areas.

5. Work execution record

Work performed	Client
Main water supply from Sierra Nevada - Los Angeles	L.A. water and power
Staples Corner (bridge) London, England	Costain
La Defence (bridge beam) Paris, France	Service European
Seoul Station bridge Seoul, Korea	Standard Engeneering & Construction
Bridge in Berlin	Strate

6. Usage conditions

① The capacity of the high pressure pump is an important factor for reaching efficient and economic hydrodemolition. Pressure of approximately 1000 bar is used for normal concrete (30-40 MPa). The amount of water increases the production proportionally. Common sizes of pumps are between 100-250 litres.

②One man handles the operation, but for safety reasons two men are needed.

③ Use of the waterjet technique is restricted to periods when the temperature is above 0°C, partly in view of the freezing risk for the concrete and partly for the equipment. Below 0°C the equipment must be housed in a tent.

④ The technique implies that large amounts of rubble must be collected in a suitable manner. Depending on the cost of labor and type of project, anything from manual removal to large industrial vacuum cleaners is used to remove the rubble.

⑤ The water must be drinkable since polluted salt water has a negative effect on remaining concrete.

⑥ Since the amount of water is quite large, fire hydrants are often used for water supply. In remote areas large tank trucks must be used.

Water-Jet Concrete Chipping Robot

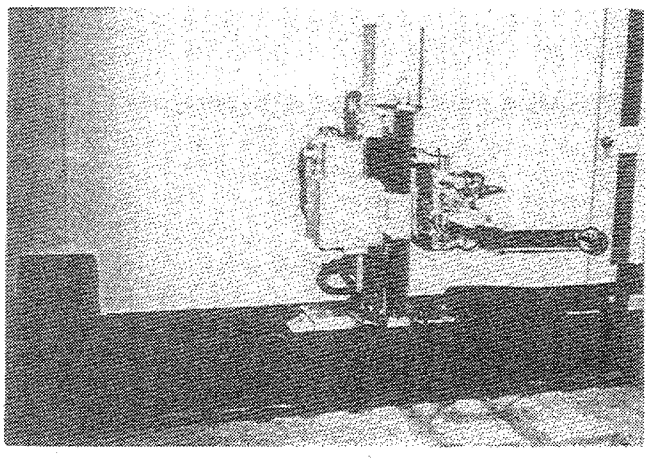
Applicable type of work: Concrete Chipping with water jet	Official price:
Classification:	
Purpose of the development: Manpower saving, Improvement of work environment	Lease and rental:
Level of practical use: Available on the market	Development company: Kumagai Gumi Co,.Ltd
Information Company name: Kumagai Gumi Co,.Ltd Address: 2-1, Tukudo-cho, Shinjuku-ku, Tokyo Phone: 03-3235-8655 Fax: 03-3235-5363 E-mail:	

1. Application

Chipping off deteriorated concrete surface using water jet in repair of concrete structures.

2. Outline

This robot using water jet is intended for, in repair of concrete structures, efficiently chipping off deteriorated concrete surface layer to expose reinforcement bars. When a surface to be removed is specified, it chips off automatically. This is contributes to labor saving in chipping work in hostile environments with vibration, dust, etc. Based on the water jet technology, the chipping reaction is small. So the system can be configured in a compact size.



Phot.1 Chipping robot

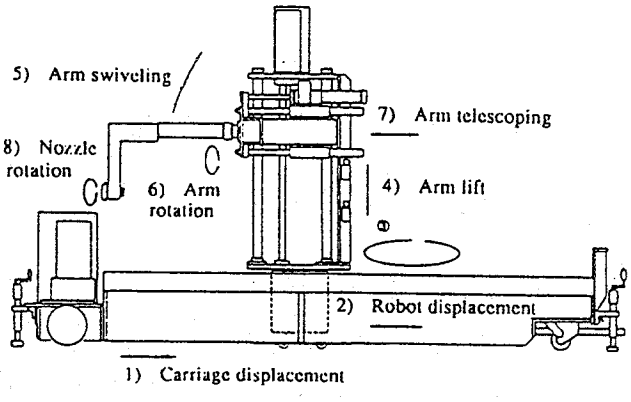


Figure 2. Side Figure Chipping robot

3. Characteristics and effects

① Concrete chipping with water jet, free from vibration and dust.
② Automatic chipping of concrete wall surface, leading to labor saving in hard work.
③ While exposing reinforcement bars, it removes rust on the bars.
④ The robot does not adversely affects influence upon a part of concrete other than the spot to bechipped off. Thus uniform chipping is available

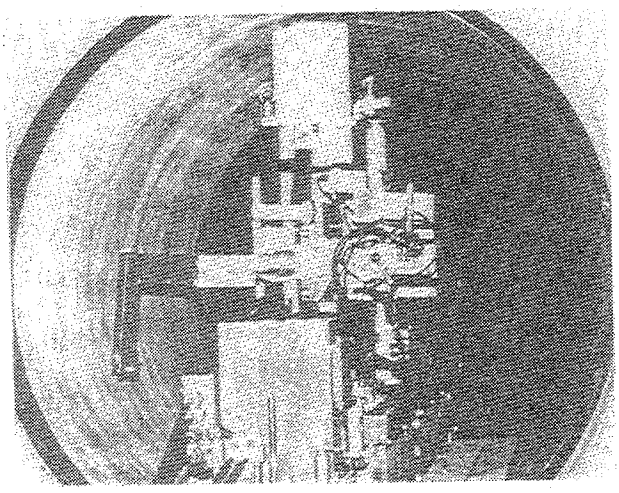


Photo 2. View in a experiment tunnel

4.Features of the robotization and automation

Weight	380 kg	
Length	3060 mm	
width	500 mm	
Action axis	Range	Speed
Carriage displacement	cont.	37 mm/min
Robot displacement	1500mm	max1.0 m/min
Robot rotation	200°	10° /sec
Arm lift	450 mm	400 mm/min
Arm swiveling	150°	max5° /sec
Arm rotation	200°	10° /sec
Arm telescoping	150 mm	400 mm/min
Nozzle rotation	360° cont.	200 rpm

① Dust-proof, drip-proof

② Chipping of circular or rectangular surface of concrete wall.

Chipping practices is done automatically avoiding obstacles.

③ This robot is no more than 500 mm wide and can be disintegrated into seven portions. So it can be carried in a narrow space and displaced there.

5. Work execution record

Work Performed	Client

6.Usage conditions

① The range of equipment can be specifically customized to meet the needs of any subterranean project.

②The work can be executed by 3 men. One operator for jet-pump. One operator for Robot.

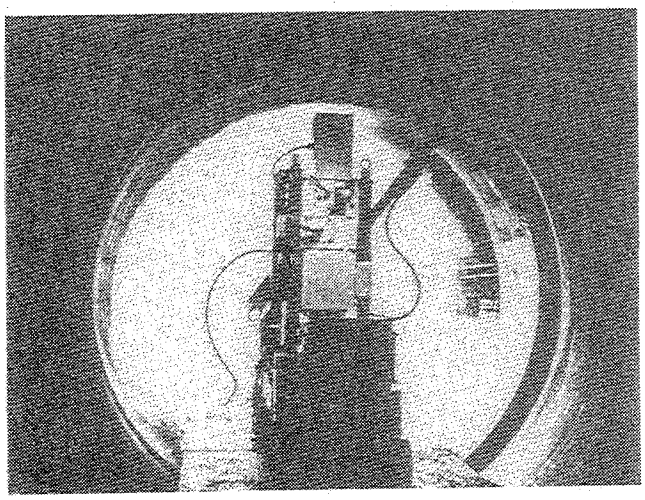


Photo.3 Chipping Condition

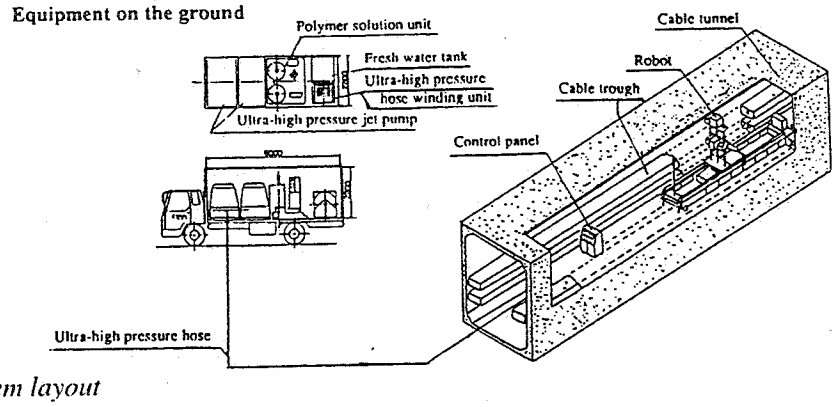


Figure 2. System layout

Surveying

Navigation-type Surveying System
Using Real-time Kinematic GPS

Applicable type of work:	Surveying	Official price:	12 million yen
Classification:	Earth Work Construction Management		
Purpose of the development:	Manpower saving , time-saving , improvement of work environment	Lease and rental:	50,000 yen/day
Level of practical use:	Available on the market	Development company:	Mitsui Construction Co.,Ltd.

Information
Company name: Technical Research Institute , Mitsui Construction Co., Ltd.
Address: 5-1-8,Komaki, Nagareyama-city, Chiba-Prf. 270-01, Japan
Phone: +81(0)471 40 5207
Fax: +81(0)471 40 5218
E-mail

1. Application

Topografic Survey in the earth work as of dam , road , airport , formation of housing site and so on.

2. Outline

GPS survey method is to measure the datum line vector between the datum point and survey point, while each receiver on the two points is receiving the electric wave from the Satellite GPS.

In this system , one receiver is set on the datum point (known coordinates) and the other receiver is set on the moving point as of the car and so on, and travelling to measure the three dimentional coordinates continously .
Measureing interval is more than 1 second , you can grasp the 3-D topography by travelling all around the survey area.

As shown in Fig. 1, the system is formed with GPS rceiver equipment and a GPS antenna at both the moving point (survey point) and the datum point (known coordinates), and a transmitter system. In methods used up to now, the datum point and the moving point were surveyed at the same time, the surveyed data was pooled , and the survey results were obtained after computer-treatment, but for the new system a transmitter system was introduced and the datum point data is sent to the moving point, and with computer-treatment the results can be output in real time. A notebook computer with display screen is used at the moving point.

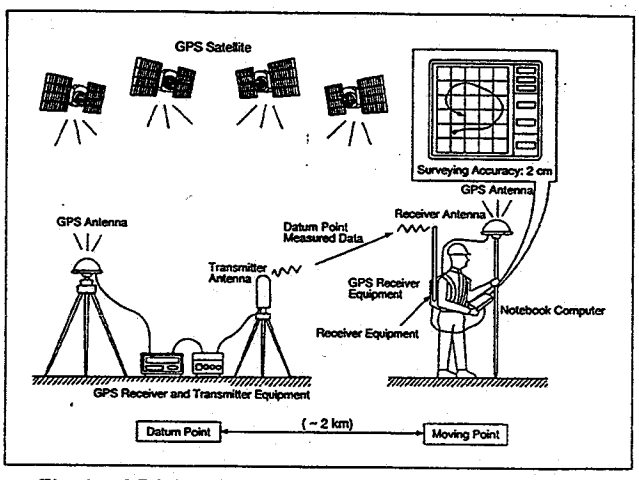


Fig.1 GPS Navigation-Type Surveying System

3. Characteristics and effects

Receiving the electric wave from the satellite GPS , it is not necessary to look through between the datum point and the survey point, being able to measure any point as far as receiving the electric wave . Therefore it takes few hours for one man with GPS to conduct the topographic survey, when it takes few days for more than two men with previous survey method.

In case of measuring interval being 5 seconds , it is possible to measure 720 points in one hour . Survey accuracy is within 1cm in X-Ycoordinates , and within 2 cm in height .

4. Features of the robotization and automation

	Item	Specification
Datum Point	GPS receiver GPS antenna Transmitter Equipment	Trimble 4000SSE Local communication system
Moving Point	GPS receiver GPS antenna Notebook Computer Receiver Equipment	Trimble 4000SSE Local communication system

Photo.1 shows an example that the receiver is set on the car as a Moving Point

Photo.1 example that the receiver is set on the car as a Moving point .

5. Work execution record

Some of the work execution records of Navigation-type Surveying System Using Real-time Kinematic GPS are listed as follows. The clients of these works are private companies.

Work performed	Area	work period
Gorf course in Fukusima Prf.	200ha	Aug. 1993～Dec.1994
Formation of housing site in Ibaragi Prf.	30ha	Mar. 1994～Mar.1995
Gorf course in Tochigi Prf.	200ha	Mar. 1993～Oct.1994
Formation of housing site in Kanagawa Prf.	80ha	Sep. 1993～Feb.1995
Formation of housing site in Hirosima Prf.	10ha	Nov. 1993～May.1995

6. Usage conditions

① The work can be executed by one man .

② This work is not applicable under ground and water condition ,because the electric wave cannot reach the receiver.

Excavation and Earthmoving

Tele-Earthwork System

Applicable type of work: The excavation of earth and loading on dump trucks, transport, and removal of excavated materials	Official price:
Classification:	
Purpose of development: Manpower saving, time-saving, improvement of work environment	Lease and rental
Level of practical use: Available on the market	Development company: FUJITA CORPORATION

Information		
	Company name:	FUJITA CORPORATION
	Address:	6-15,4-Chome Sendagaya, Shibuya-ku, Tokyo 151
	Phone:	81-03-3402-1911
	Fax:	81-03-3404-8477
	E-mail:	chayama@fujita.co.jp

1.Application

- ✧ The earthwork in danger area
- ✧ Restoration construction
- ✧ Garbage processing plant
- ✧ Nucleus pollution area
- ✧ Nucleus processing plant

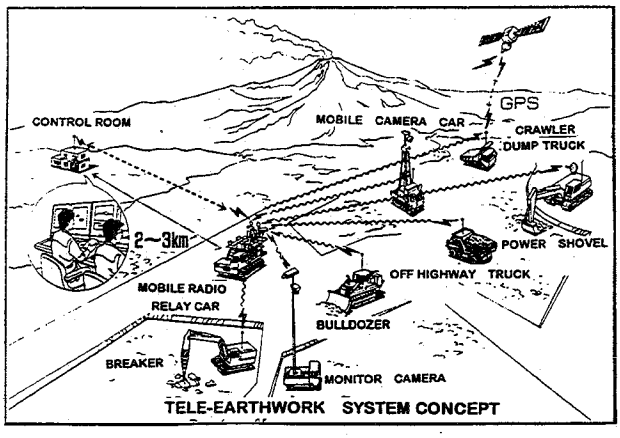


Figure 1.System concept

2.Outline

This is a system which use stereoscopic pictures, computer graphics, and various work monitors in a control room located away from hazardous area to maintain a series of remote operations for the excavation of earth, loading it on to dump trucks, and transport it for disposal.

3.Characteristics and effects

① Radio controlled work can be managed from the control room, which is located about 2.0km from the work site

② The system offers safe and comfortable working circumstances, under which women and aged people work easily.

③ VR technologies allow remote control of radio controlled work that is as efficient as that of manned operation.

④ The system remotely controls vehicles within a radius of 1km from the communication relay car

⑤ The remote survey system makes it possible to control vehicular operation and work progress.

⑥ Bidirectional vehicle control prevents vehicle troubles and ensures stable remote control.

⑦ Global multi-media through communication satellites allows work control to be centralized in the control room.

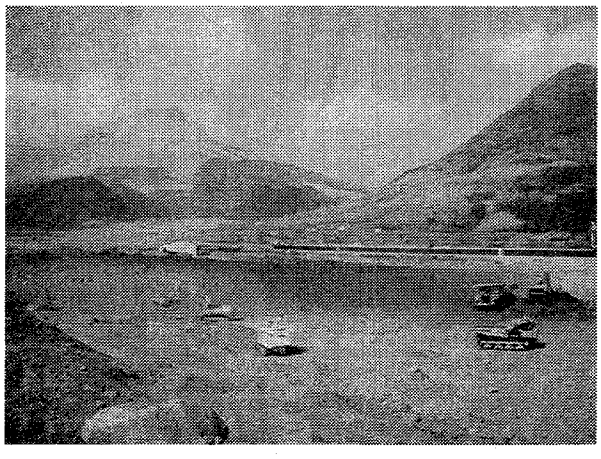


Photo.1.The whole view

Photo.2.The control room

4.Features of the robotization and automation

① Tele-existance system

The remote operation system utilizing stereoscopic image and other virtual reality (VR) technologies allows the operator in the control room to remotely control operations at the site feeling.

② Bidirectional vehicle control system

The bidirectional vehicle control system controls vehicles by bidirectionaly control and vehicle information.

③ Audio video transmission system

The audio video transmission system provides the operator with audio image information required for remote control.

④ Remote survey system

The remote survey system uses a global positioning system(GPS) and an automatic tracking total station (three-dimensional laser positioning machine)

⑤ Vehicular operation and work progress system

These systems output and display the survey information obtained by using the remote survey system through printers and monitoring screens.

⑥ Excavation support system

The survey information obtained through the remote survey system is automatically processed and linked with information on vehicles (posture and inclination) as well as information on the planned excavation profile, before it is provided as stereoscopic visual information for excavation.

5.Work execution record

	1st	2nd	3rd
The quantity	6,500m^3	16,000m^3	125,000m^3
Period	JAN.25,1994 APR.30,1994	JUN.23,1994 AUG.31,1994	OCT.1,1994 MAR.30,1995
Place	Tenjin Motomati, Shimabara Nagasaki Prefecture		
Ordered by	Ministry of Construction		

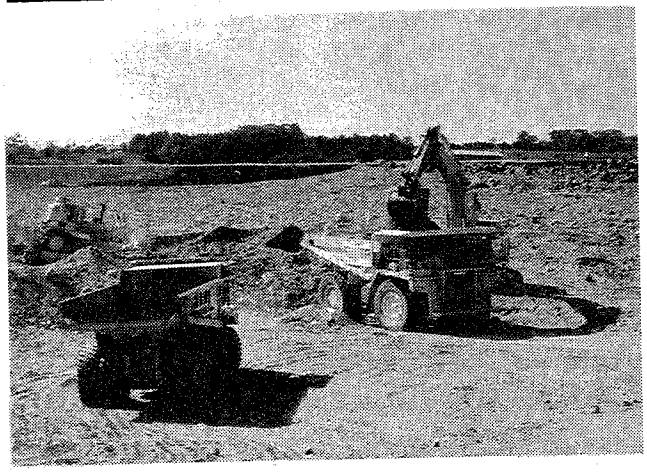


Photo.3.The status of the system being in operation

6.Usage conditions

① A effective arrangement of picture monitors

② A effective arrangement of communication radios

DIGGING WORK ROBOT

Applicable type of work:	Digging work	Official price	
Classification:			
Purpose of development:	improving working environment, skilled-worker saving, and labor saving	Lease and rental:	Available
Level of practical use:	Actual use for construction work at site	Development companies:	TOKYU CONSTRUCTION CO., LTD. TAIKU MACHINERY CO., LTD.

Information	Company name:	TOKYU CONSTRUCTION CO.,LTD.
	Address:	3062-1,Soneshita,Tana,Sagamihara-City,Kanagawa,Japan
	Phone:	0427-63-9533
	Fax:	0427-63-9505

1.Application

This robot is used for remotely controlled digging and loading work in digging work.

2. Outline

Digging work is often carried out manually since this work is necessary on a slope that refuses the entry of a large-sized pile driver or on a site where no room is available over it. Since workers must work severely in dangerous and poor working environments, such as possible ground water discharge, landslide, falling objects, and generation of toxic gases, improvement of such inferior environments has been demanded.

The development of a digging work robot was started in 1989 in order to improve the safety and enhancing the working capability of work in a pit. The robot has been employed up to now to digging work for a vertical pit to reach shield, foundations for piles to restrain landslides, the foundation under a station building, and work in small areas, demonstrating actual results.

This robot is provided with a turning block on the top of the traveling block, that is a crawler, on the fore and aft sides of which cutters for earth and sand cutting work and earth and sand loading buckets (vacuum hoses), and can carry out a series of work from digging to discharging muck by itself. Though its body is light and compact, it can dig even soft rock that conventional small-sized machines have been hard to dig. It eliminates manual finishing work of the dug wall of the pit that has been required in machine digging with a clamshell bucket. The operator can control it remotely from a safe place on the ground surface. This digging work robot has obtained a publicly subscribed technology examination certificate recognized by the Ministry of Construction as a mechanized digging work technology.

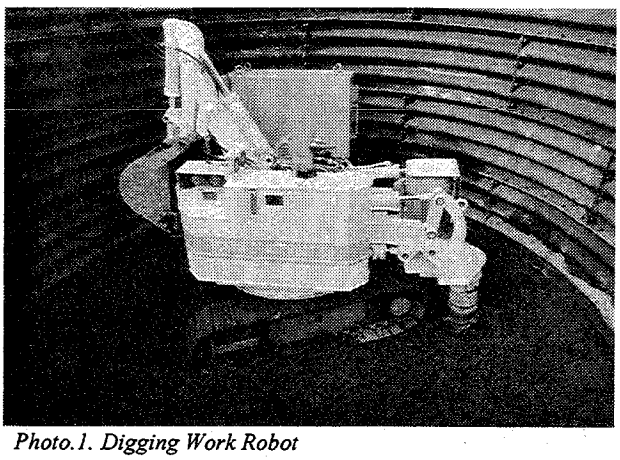


Photo.1. Digging Work Robot

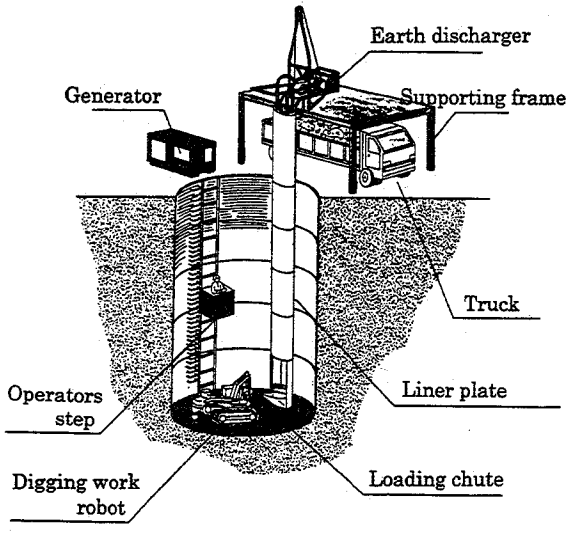


Fig. 1 Outline Sketch

3. Characteristics and effects

(1) The absence of workers on the same plane where the machine is digging eliminates dangers, such as a lack of oxygen, toxic gases, a disaster due to falling objects, and a heavy machine disaster, to improve safety.

(2) Since this system does not dig soft rock out, but scrapes it off with a cutter drum for cutting, this light-weight robot can dig rocks with a one-axis compression strength of about 100 kg/cm2.

(3) Since cutting work by a cutter drum, which does not use compressed air unlike breakers and picks, is less in vibration, noises, and adverse affection to an ambient environment. Its remotely controllable operation eases worker's burden.

(4) This robot is applicable for digging all pits the diameter of which is three meters or above. The free-traveling type digging robot is applicable regardless of the shape of pits, including rectangular pits used for propulsive methods and the like. It can be used also for digging independently of the depth of pits.

(5) The size of the compact body is 1750 mm x 1190 mm. It does not require any special or additional attachments not only in but also around the pit, and can carry out digging work with a space almost similar to that required by conventional methods.

4.Features of robotization and Automation

Digging Block	Cutting type Electric motor	Drum cutter type 5.5kW
Traveling block	Type Traveling speed Ground contact pressure	Crawler 0.2m/s 40kPa
Loading block	Type Bucket capacity	Bucket type 0.025m^3
Controller	Sequence	
Power supply		
Weight	2130kg	

The operation of the digging work robot from digging earth and sand to loading them is controlled on the control panel provided on the body. An instruction signal sent from the remote control box is input to the control panel through a wiring-saving circuit by serial transmission, and outputs control signals to the machine from the panel.

(1) An emergency shutdown switch is provided to stop all functions of the robot if danger should be produced in operating the remote control box. The control circuit is provided with a safety device to prevent erroneous operation.

(2) The use of the wiring-saving system eliminates troublesome multi-core cable and interference in wireless communication.

(3) For digging soil different in property, efficient digging work requires adjustment of the digging speed. This digging feed rate of the digging work robot can be adjusted to that suitable for digging the ground. Adjusting turning speeds in digging and loading work can improve efficiencies.

5. Actual Results

Type of work	Description of work
Station	Tunnel driving work Driving volume: About 100 m^3
Aqueduct	Vertical pit to reach shield Digging diameter: 4.5 m Depth 24 m
Landslide restraining	Landslide restraining pile Digging diameter: 3.0m Depth 20m Number of piles: 28
Station	Foundation piles for station building Digging diameter: 3.5 m Depth: 10m Number of piles: 11
Landslide restraining	Landslide restraining pile Digging diameter: 3.5 m Depth 29.5 m

6. Matters that Require Attention About Use

Discharging soil by vacuum requires appropriate blocking measures.

Unmanned Caisson Method

(Ground-Level Remote Control System For Pneumatic Caisson)

Applicable type of work: Excavation of pneumatic caisson	Official price:
Classification: Execution of works	
Purpose of the development: Improvement of work environment, Manpower saving	Lease and rental:
Level of practical use: Execution in work	Development company: Shiraishi Co. Kajima Corporation

Information
Company name: Machinery Dept. Shiraishi Co.
Address: 1-14 Kanda-Iwamoto-cho, Chiyoda-ku, Tokyo-101, Japan
Phone: +81-3-3253-9121
Fax: +81-3-3253-7427
E-mail:

1.Application

A pneumatic caisson method, which is highly evaluated as a construction method for bridge foundation, start/arrival vertical shaft for shielded tunnel, and other large underground structure, takes advantages of pneumatic pressure to advance excavation while removing groundwater. For this reason, in the works in a great depth there arise bad influences such as high atmospheric pressure in a working chamber. It is the Unmanned Caisson Method that solves this problem, and excavation operation in the working chamber is performed by remote control from an administrative control room on the ground to thereby sweep away the operation under the severe environment and at the same time to improve the excavation efficiency.

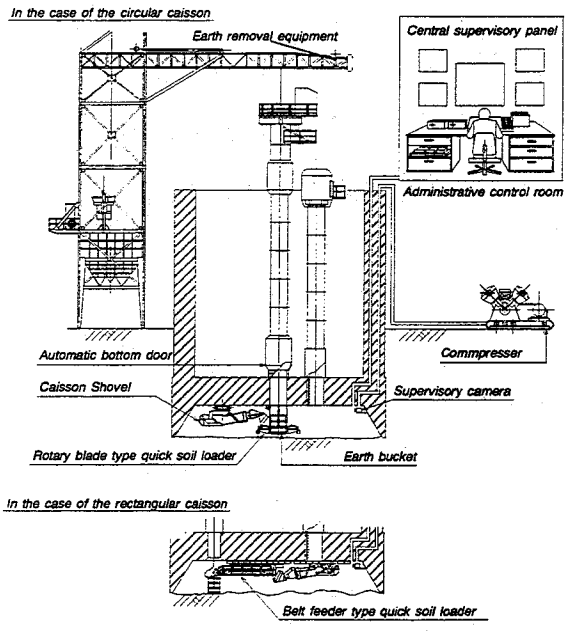


Fig.1 Outline of Construction Method

2.Outline

Since all necessary information for sinking and excavation of the caisson is displayed in the administrative control room, the operator can grasp the state of the sinking and excavation while staying on the ground, and remote control the equipment in the working chamber safely.

The entire system is composed of a remote control and automatic operation system for a Caisson Shovel (Fig.2), an execution supporting system (Figs.3 and 4) for providing with necessary information for the execution in real time, and a Quick Soil Loader (Figs.5 and 6) for increasing the earth removal efficiency for excavated earth.

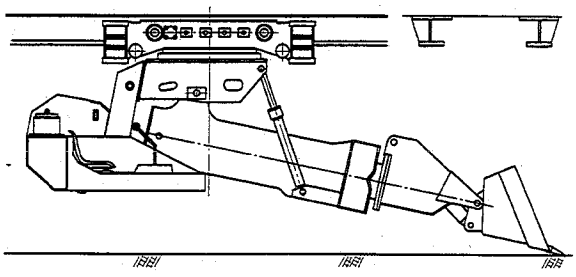


Fig.2 Caisson Shovel

3.Characteristics and effects

①Since sinking and excavation operations can be performed while the operator is staying in the administrative control room at atmospheric pressure, he does not suffer from decompression sickness, nor is any physical injury due to contact, etc. with the working equipment considered to improve the safety.

②Since the administrative control room provides the operator and construction supervisor with necessary information for control of the excavation and sinking in real time, the execution

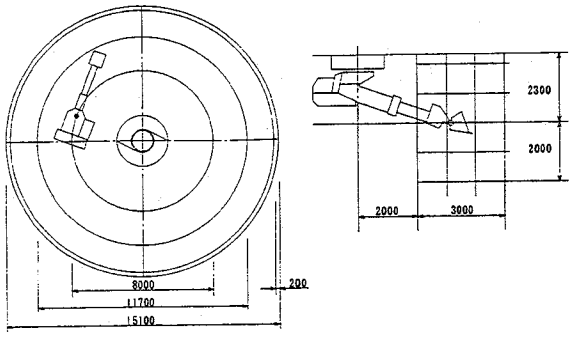


Fig.3 Display of Shovel Operation (Example of Display)

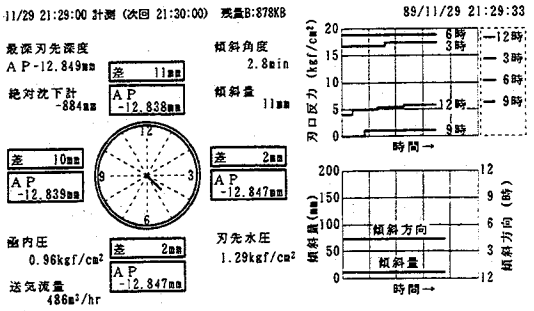


Fig.4 Sinking Control System (Example of Display)

control becomes easier and the sinking precision is improved.

③The excavation equipment in the working chamber can be operated by one operator to enable manpower saving for excavation operation.

④In contrast to the conventional construction method, in which the working hours decrease with an increase in depth, fixed working hours can be secured, and therefore, the excavation efficiency increases in a deep caisson.

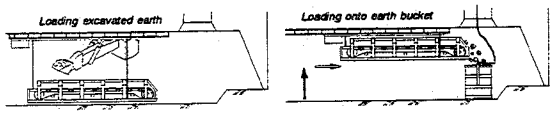


Fig.5 Belt Feeder Type Quick Soil Loader

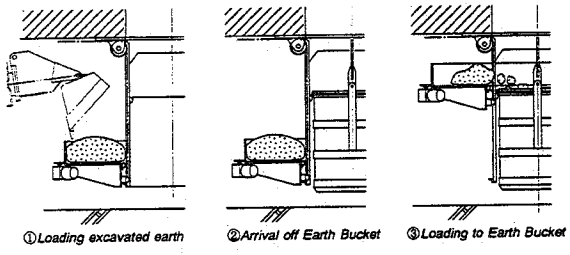


Fig.6 Rotary Blade Type Quick Soil Loader

4.Features of the robotization and automation

Specification of Caisson Shovel

Bucket capacity	$0.12m^3$
Operating radius	4.0m
Drive	Electro-hydraulic drive
Motor	15kw

Specification of Quick Soil Loader

	belt feeder type	rotary blade type
Loading capacity	$1.0m^3$	$1.0m^3$
Dimension	5950L×1470w	2000H×φ2950D
Drive	Motor-driven	Motor-driven

①For remote control for a Caisson Shovel, proportional control using radio operation is adopted.

②The loading operation by the shovel, which is a simple repeated operation, can be automatically performed by computer on the ground.

③All the operations for the Quick Soil Loader can be automatically performed.

④The operation of the shovel is monitored on the ground by means of sensors incorporated in the shovel.

⑤The state of the caisson frame is monitored on the ground by means of sensors installed in the caisson frame.

5.Work execution record

Donor	Application	Number
Tokyo Electric Power Co.,Inc.	Shaft for Shield	4
Japan Highway Public Co.	Bridge foundation	1
Kumamoto City	Shaft for Shield	1

Photo.1 Excavation state by remote control

6.Usage conditions

①For initial excavation, it is desirable to use the conventional construction method together in order to prevent uneven settlement of the caisson.

②The minimum caisson dimensions to which this construction method is applicable are φ8.0 m in outside diameter for a circular one, and 8.0 m×6.5 m for a rectangular one.

ROVO Caisson Method for Automating Excavation, Soil Transfer and Soil Discharging Operations in Pneumatic Caisson

Applicable type of work:	Excavation and excavated soil discharge	Official price:	As per separate price list
Classification:	Work execution		
Purpose of the development:	To improve working environment, develop new technology, and save labor	Lease and rental:	Not available
Level of practical use:	Field tests completed	Development company:	OHMOTOGUMI CO., LTD.
Infomation:	Company name: OHMOTOGUMI CO., LTD. Address: Engineering Div., Technical Development Dept. in Ariake Frontier Building, 3-1-25, Ariake, Koto-ku, Tokyo Phone: 03-5564-2301 Fax: 03-5564-2302		

1. Application

To automate the excavation, soil transfer and soil discharge operations in pneumatic caisson work, thereby eliminating the need for human labor in the working chamber.

2. Outline

This system consists of a ground system for remote-operating excavators in the working chamber and an automatic control system for controlling the excavation, soil transfer and soil discharge operations, the pressure in the working chamber, the excavator operations, and the measuring instruments. The system automates the excavation, soil transfer and soil discharge operations in the working chamber that is under a high temperature, high humidity, and high pressure, thereby freeing the workers from work under high pressures which cause various troubles and improving the efficiency of work execution.

The system also enables pneumatic caisson works to be executed at greater depths underground. It consists of the following equipment and devices.

① Remote-operated overhead traveling excavator or crawler excavator equipped with a 3-D TV camera

② Excavated soil transfer and discharge equipment

③ Automatic pressure control equipment which follows up the change in groundwater level and keeps the pressure inside the working chamber at optimum value

④ Operation contol system which controls the condition of the working chamber and the operations of the excavator and soil transfer equipment

⑤ Measurement and control system for the pneumatic caisson that is being sunk for excavation

⑥ Central control room that controls all the above systems

The arrangement of the system components is shown in Figure 1.

3. Characteristics and effects

① The excavator and soil discharge equipment are remote-operated from the central control room on the ground, making it possible to minimize human labor in the working chamber and free the workers from most of the work under harsh conditions.

② Simple, repetitive operations, such as excavation, soil transfer, and soil discharge can be automated, hence the operator burden can be reduced and the safety of work execution can be increased.

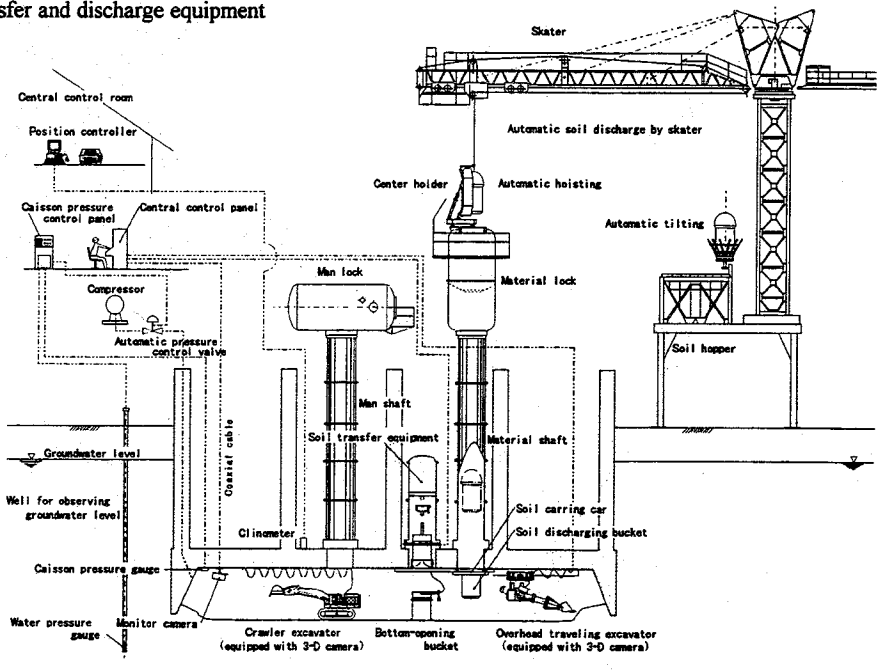


Figure 1. ROVO pneumatic caisson method conceptual diagram

③ The condition of the working chamber and the operations of the excavator and soil transfer equipment are controlled in the central control room. In addition, measurement data obtained while the caisson is sunk for excavation is reflected in the execution of work on a real-time basis. Thus, high-accuracy control of the caisson being sunk can be implemented.

4. Contents of robotization and automation

① The excavator equipped with a 3-D camera is remote-operated from the central control room to perform excavation and soil transfer.

The excavator operator manipulates the machine while observing three-dimensional images displayed on the monitors installed in the central control room. In order to permit the operator to constantly monitor the part being excavated, the 3-D camera mounted on the excavator is computer-controlled to follow up the movement of the boom of the excavator.

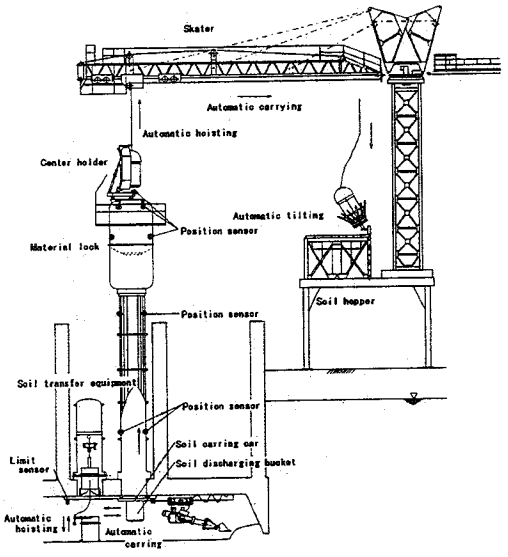


Figure 2. Automated soil discharge operation

The location and position of the excavator are indicated on a graphic display on a real-time basis. Simple, repetitive operations, such as excavation and soil transfer, may be performed automatically under computer control.

② Instead of using two soil buckets which the workers have to manipulate to transfer and discharge excavated soil, new soil transfer equipment with a single bucket which is as efficient as the conventional method has been developed and put to practical use. This equipment can be remote-operated from the central control room. In order to automate the soil discharge operation, the movement of the soil discharge bucket is electrically controlled by sensors installed in the shaft and material lock and on the horizontal jib crane. The automated soil discharge operation is shown in Figure 2.

③ The equipment for automatically controlling the pressure inside the working chamber observes the change in groundwater level in the well as shown in Figure 3 and controls the pressure inside the working chamber to an optimum level.

Thanks to this equipment, it has become possible to execute pneumatic caisson work without the fear of an air blow even at places where the groundwater level fluctuates so much that the air pressure inside the working chamber can hardly be controlled.

④ The measurement & control system automatically measures frictional force at the circumference of the caisson being sunk for excavation, as well as caisson inclination, cutting edge load, groundwater level, etc. and transmits the measurement results to the central control room on a real-time basis.

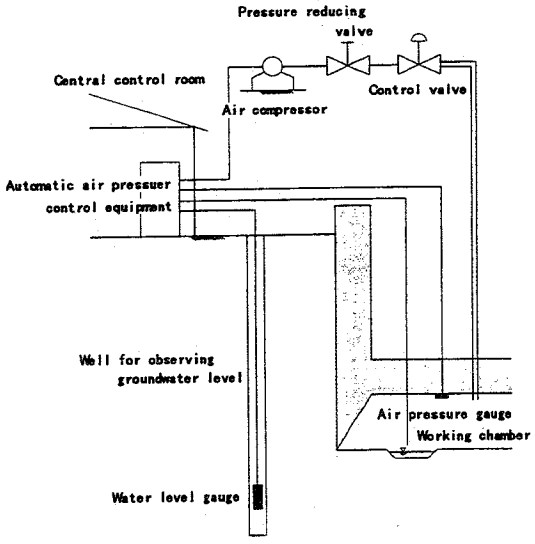


Figure 3. Equipment for automatically controlling air pressure inside the working chamber

5. Work execution record

The ROVO pneumatic caisson system is a total system which automates the soil discharge operation, eliminates the need for human labor in the working chamber, and so on. To date, the ROVO system as a total system has been applied in one pneumatic caisson work. The pneumatic caisson works in which the system was employed to implement an unmanned working chamber are summarized in Table 1.

Table 1. Results of work execution

Period	'90 August ~ '91 July	'90 June ~ '91 July	'91 January ~ '92 February	'93 November ~ '96 October
Customer	Nagano Prefectural Government (Civil Engineering Dept.)	Aichi Prefectural Government (Enterprises Bureau)	Tokyo Metropolitan Government (Sewerage Bureau)	Japan Highway Public Corporation*
Work site	Nagano City, Nagano	Aichi Prefecture	Meguro-ku, Tokyo	Aichi Prefecture
Work contents	14.2 m×9.2 m Oval caisson	32.7 m×23.2 m Rectangular caisson	7.2 m×10.7 m Rectangular caisson	40.1 m×27.1 m Rectangular caisson
Application	Bridge foundation	Pump room	Shield shaft	Bridge foundation

* The ROVO system applied as a total system.

6. Usage conditions

① The minimum cross-sectional area of caisson required for application of the system is about 100 m^2, though it varies according to caisson shape, partition wall position, etc.

② The number of excavators required shall be determined assuming the excavator capacity to be about 150 m^2 per unit.

Ground System for Remote Operation of Overhead Traveling Excavator in Pneumatic Caisson

Applicable type of work: Excavation	Official price: As per separate price list
Classification: Work execution	
Purpose of the development: To improve working environment, develop new technology, and save labor	Lease and rental: Not available
Level of practical use: Used in actual construction works	Development company: OHMOTOGUMI CO., LTD.

Information: Company name: OHMOTOGUMI CO., LTD.
Address: Engineering Div., Technical Development Dept. in Ariake Frontier Building, 3-1-25, Ariake, Koto-ku, Tokyo
Phone: 03-5564-2301
Fax: 03-5564-2302

1. Application

In pneumatic caisson work, to eliminate the human labor for excavation and excavated soil removal under a high pressure in the working chamber by replacing the workers with an overhead traveling excavator which is remote-operated from a control system on the ground.

2. Outline

This system automates the excavation operation in the working chamber of a pneumatic caisson which is under a high temperature, high humidity, and high pressure, thereby freeing the workers from work under high pressures which cause various troubles and improving the efficiency of work execution. It also permits the pneumatic caisson to be sunk deeper in the ground.

The system consists of a remote-controlled overhead traveling excavator which is equipped with a 3-D camera and a remote control system installed in a central control room on the ground for controlling operations of the excavator.

3. Characteristics and effects

① The remote-operated excavator eliminates the need for the workers to enter the working chamber in which the air pressure is high.

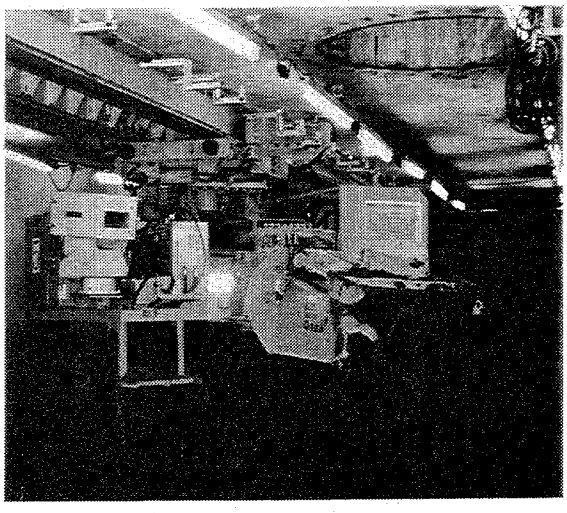


Figure 1. Overhead traveling excavator

Figure 2. Central control room

② Since no workers are in the working chamber, the pneumatic caisson can be sunk to depths more than 40 m below the level of water. (Formerly, the maximum depth to which pneumatic caissons could be sunk was about 40 m below water level.)

③ The 3-D TV camera mounted on the overhead traveling excavator enables the operator in the central control room to remote-operate the excavator as if he were operating it in the working chamber.

④ All information about the excavator and working chamber conditions is graphically displayed on CRTs in the central control room on a real-time basis, allowing the work to be executed properly.

⑤ Since the excavator control system has learning ability, it permits simple, repetitive operations, such as excavation and soil removal, to be performed automatically.

⑥ In addition to the overhead traveling excavator, a crawler excavator can be used to meet particular work requirements.

4. Features of Robotization and Automation

① The overhead traveling excavator having hydraulic motor-driven wheels travels suspended from two rails fixed to the ceiling of the working chamber. It is remote-controlled by a set of cables each with a hydraulic control valve.

② The ground remote operation system consists of a remote operation panel installed in the central control room, a 3-D TV camera mounted on the excavator, monitor cameras set in the caisson, and graphic displays which provide information about the location, position, etc. of the excavator on a real-time basis, so that the excavation and soil removal operations in the working chamber can be remote-controlled from the central control room on the ground.

③ The computer for controlling the excavator processes three-dimensional position information from the excavator and information from various devices. Since the control system has learning ability, such repetitive operations as excavation, excavator relocation, and loading of excavated soil into the discharging bucket, can be automatically performed at the touch of buttons. Fuzzy control employed for controlling automated operations permits operating the machine as smoothly as does the operator.

④ The 3-D TV camera automatically follows up the movement of the excavator boom. Therefore, the operator can always check the condition of excavation on the monitor screen.

⑤ Formerly, inspection personnel had to enter the working chamber to inspect the excavator. The automatic inspection system collects various types of information about the excavator and sends them to the central control room on a real-time basis for computer analysis. Thus, the excavator can be automatically inspected from the central control room on the ground.

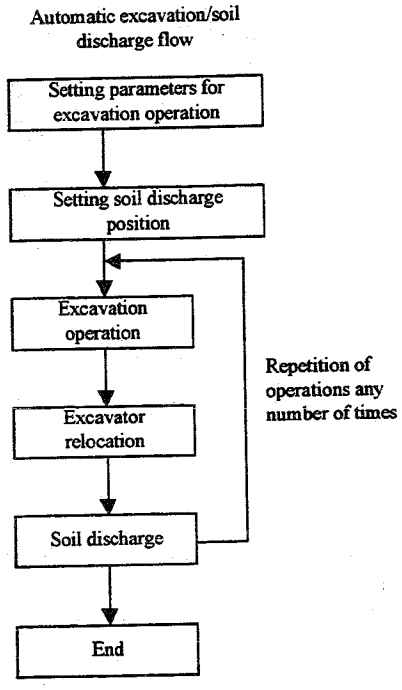


Figure 3. Automatic excavation and soil discharge flow diagram

⑥ In addition to the overhead traveling excavator, a crawler excavator can be used. The crawler excavator having hydraulic control valves is remote-operated by radio. Like the overhead traveling excavator, the crawler excavator is equipped with a 3-D TV camera. Since the crawler excavator has no rails to travel along, it can be freely moved to any place for excavation. Specifications of the two types of excavators are shown in Table 1.

Table 1. Excavator specifications

Type	Overhead traveling excavator		Crawler excavator
Max. excavating radius	4 550 mm	5 250 mm	4 800 mm
Max. excavating depth	3 500 mm	3 900 mm	1 270 mm
Bucket capacity	0.12 m^3	0.25 m^3	0.25 m^3
Motor	15 kW	30 kW	37 kW
Remote operation system	Cable	Cable	Radio

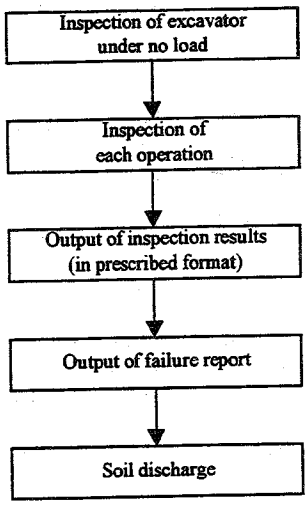


Figure 4. Automatic inspection flow diagram

5. Work execution record

The results of application of the remote-operated overhead traveling excavator and crawler excavator in pneumatic caisson works are summarized in Table 2.

Table 2. Results of work execution

Period	'90 August ~ '91 July	'90 June ~ '91 July	'91 January ~ '92 February	'93 November ~ '96 October
Customer	Nagano Prefectural Government (Civil Engineering Dept.)	Aichi Prefectural Government (Enterprises Bureau)*	Tokyo Metropolitan Government (Sewerage Bureau)	Japan Highway Public Corporation
Work site	Nagano City, Nagano	Aichi Prefecture	Meguro-ku, Tokyo	Aichi Prefecture
Work contents	14.2 m×9.2 m Oval caisson	32.7 m×23.2 m Rectangular caisson	7.2 m×10.7 m Rectangular caisson	40.1 m×27.1 m Rectangular caisson
Application	Bridge foundation	Pump room	Shield shaft	Bridge foundation

* Crawler excavator was used.

6. Usage conditions

① The minimum cross-sectional area of caisson required for application of the system is about 100 m^2, though it varies according to caisson shape, partition wall position, etc.

② The number of excavators required shall be determined assuming the excavator capacity to be about 150 m^2 per unit.

INTEGRATED CONTROL SYSTEM FOR DIAPHRAGM WALL EXCAVATION

Applicable type of work:	Diaphragm wall construction work	Official price:	None
Classification:	Execution management		
Purpose of the development:	Improvement of execution quality and labor saving	Lease and rental:	None
Level of practical use:	Used in actual work	Development company:	Kajima Corporation

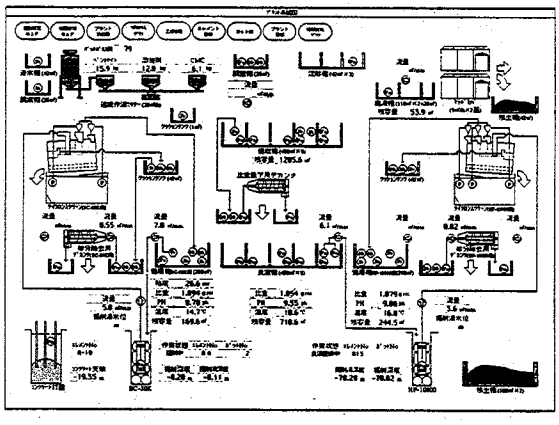
Information
Company name: Kajima Corporation Machine Engineering Center
Responsible section: Execution Technology Dept.
Address: 1045 Kamiwada, Yamato-shi, Kanagawa 242
Phone: 0462-67-0214
Fax: 0462-68-6473

1. Application

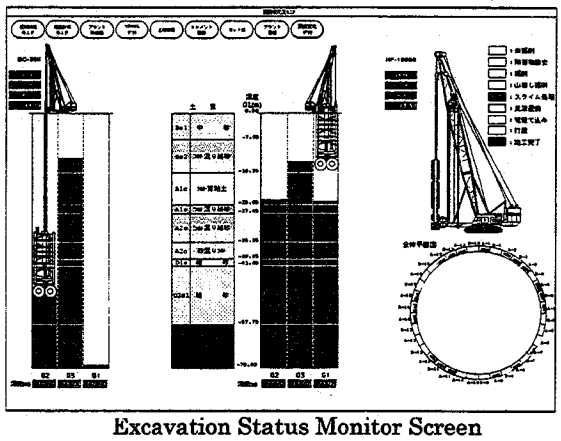
In diaphragm wall construction works, controlling the accuracy of excavated trenches and the properties of stabilizing fluids is important, since these factors will determine the stability of trench walls during excavation. This system is an integrated control system for diaphragm wall excavation, which controls execution information in a centralized manner, primarily based on "accuracy control of excavated trenches" and "stabilizing fluid property control."

2. Outline

In the large-scale constructions of diaphragm walls carried out hitherto, the conventional customary practice of acquiring excavation information, such as the depth and accuracy of the elements under excavation, and plant control information, such as the stabilizing fluid properties, stabilizing fluid remaining quantity, equipment statuses, etc., only used to consist in communication and coordination among the persons in charge. The new system described herein has been designed to allow the control of necessary information in a centralized fashion in offices and the stabilizing fluid control room through a network including the excavators, stabilizing fluid plant, and the offices.



Plant System Diagram Screen



Excavation Status Monitor Screen

3. Features and Effects

① Information concerning the load, discharged mud volume, posture, and accuracy of excavators can be obtained together with depth and boring data.

② To control the transition of stabilizing fluid volumes in different tanks and changes in properties in real time, that information can be checked against changes in the soils along the excavation depth, and changes in the fluid volume over time according to a transition of execution volume can easily be acquired.

③ Since the measured values are represented by visualizing the assignment of elements and different equipment systems, each individual status can be precisely grasped.

④ The data processing implemented by a general-purpose software (Excel) makes it easy to perform postprocessing such as record management.

4. Description of Robotization and Automation

① Measurement Items
This system acquires necessary data from excavators and plant equipment by taking automatic measurements, and transmits it by radio or through coaxial cables to produce a visual display of execution information on the control computer installed in the office building.

Table 1. Table of Measurement Items

Place of Installation	Measurement Item	
Excavator	Location	· Workplace · Depth
	Posture	· Three-dimensional position of bit · Inclination
	Operated status	· Operation of posture-controller, bit load
	Status of excavated trench	· Fluid level · Flow rate
	Description of work	· Excavation, slime treatment, replacement with new fluid
Stabilizing fluid plant	Volume of stabilizing fluid	· Fluid level in each tank · Flow rate
	Operating status	· Operation of each piece of equipment
	Physical properties	· Specific gravity · pH · Viscosity

② Display Functions
Control information, which is divided into different items, is obtained on the personal computers installed in the offices and the stabilizing fluid control room. Moreover, a large display unit is mounted on the excavator to indicate the element and gut No. under execution and the current depth, so that the execution administrator can be kept informed of the control situation.

Table 2. Table of Display Functions

No.	Function	Description
1	Excavation status monitor	· Indicates the workplace of the excavator (element, gut), depth, and working status. · Indicates the changes in the physical properties of the stabilizing fluid, along the depth.
2	Positional measure-ment monitor	· Indicates the posture of the excavator, its variation from the planned line, and the excavation status.
3	Plant system diagram	· Indicates the stabilizing fluid physical properties, and the status of the stabilizing fluid plant. · Controls the properties of stabilizing fluids with the graph describing time-based changes over the whole period.
4	Real-time graph	· Displays graphs of changes in different types of measurement data in a time series.
5	Process control	· Produces a general table of progress statuses of all the elements and guts.
6	Document control	· Creates element reports (progress status), gut reports (measurement value of each excavated trench), and plant reports (measurement values obtained every six minutes).

5. Execution Records

Time: 1996
Client: Tokyo Gas Co., Ltd.
Place: Yokohama-City
Description of work: Excavation 26,000 m^3,
wall thickness 1.5m, depth 68.5 m.

6. Points of Notice for Use

① Prior to setting up this system, the required input items need to be clearly defined in the planning stage, and corresponding sensors have to be installed.

② The interface between the different sensors and the system signals needs to be established.

Automatic excavation system for diaphragm-wall excavator

Application: Diaphragm wall excavation	Official price:
Classification: Construction control	
Purpose of the development: Improvement of quality, easy operation, manpower saving	Lease and rental:
Level of practical use: Available on construction work	Development company: Konoike Construction Co., Ltd.

Information
Company name: Konoike Construction Co., Ltd.
Address: Research Institute of Technology 4-3-55, Dempo, Konohana, Osaka 554 JAPAN
Phone: +81-(0)6-461-0262
Fax: +81-(0)6-468-3659
E-mail: matsuike_ts@konoike.co.jp

1. Application

Positioning and automatic control on diaphragm-wall excavation.

2. Outline

This system is composed of the excavator positioning system and the excavation load control system, and supports the diaphragm-wall excavation by man-machine control. Moreover, the excavator is automatically positioned by a fuzzy controller. Figure 1 shows the system component.

In the development, key concepts below are established.

① Holding excavator displacement within 50mm from designed line.
② Centered control in the operator cabin.
③ Automatic control of excavator adjustment in response to the properties of a layer same as a skilled operator.
④ Stable measuring in all weather.
⑤ Easy handling and simple operation for system and computer.
⑥ Applicable to various specifications of field works.
⑦ Simple component by system units.

The excavator positioning system, composing a main frame, has the measuring equipment (Photo. 1) for the position of the excavator and the guidance equipment of the excavator supported by the excavator inclinometer, the depth meter, the personal computer and the fuzzy controller. Through the functions of these equipment, the excavator can be detected with high accuracy and adjusted by the operation of adjustable guides attached on the side of the excavator.

The excavation load control system, installed in the base machine (crane), automatically controls the downward speed of the excavator (excavation speed) and the interpenetrating force to the earth (excavation load).

3. Characteristics and effects

① The measuring equipment is characterized by one pair of the measuring tower and the tracer wire are placed separately at right and left side of the trench. The position of the excavator is calculated by a proportional magnification of the horizontal displacements of two tracer wires.
② The differential-transformer transducer automatically tracks to the movement of the tracer wire in the two dimensional range of 100 mm square and measures with the high accuracy. This detector is based on the untouchable magnetic system, so stable measurements are made in all weather without the influence of stains with mud water or other disturbances.
③ The monitor display in the operator cabin projects the processed information, i.e., graphs, instructions, warnings and controlled data at the same time.
④ This system has a fuzzy controller based on the

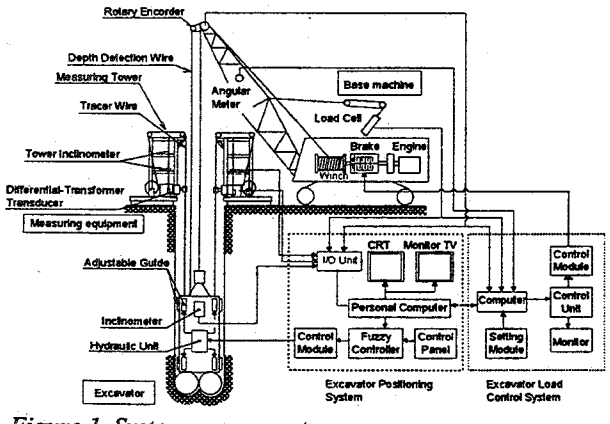


Figure 1. System component

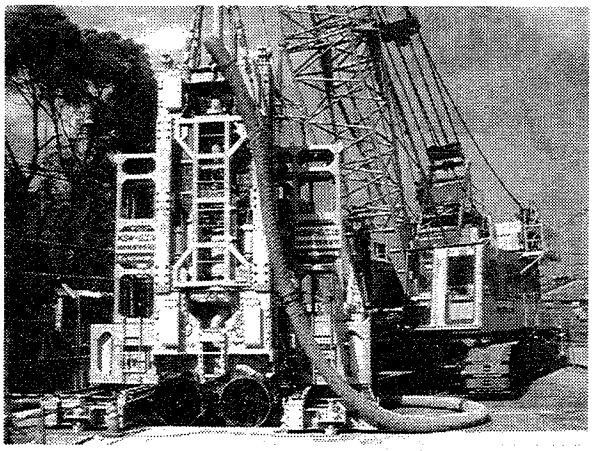


Photo.1. Excavator and excavation control system

relationship between the control condition and the properties of a layer, so that the accuracy by skilled operators or more can be obtained.

⑤ The excavation data is collected by the personal computer with the data processing wireless network.

4. Features of the robotization and automation

① Each tracer wire, as the standards for the measurement, is doubly extended between the top of the measuring tower and the excavator via a sheave attached to the top of the excavator. One end of the tracer wire is connected to the measuring tower as the fixed point at the tower top and the other end is fixed to the wire reel producing constant torque on the base of the tower, so the wire can be pulled with the constant tension and brought synchronously with a up-and-down motion of the excavator. The position of the excavator is computed in the form of two dimensional displacement at the depth of the cutter center point in consideration of the displacements of the tracer wires, and the inclination and depth of the excavator. Moreover, the rotation of excavator is obtained from the horizontal displacements of two tracer wires. These calculated data is denoted on the monitor.

② The excavation data, which is collected by the excavation control equipment from sensors installed in the excavator, the measuring equipment and around the base machine, is projected on the monitor display. The excavation data on the monitor display is useful to give the information of excavator work to a operator. On this system, a skilled operator is capable of controlling the excavator position under 30 mm of indicated displacement. Then, for the excavator of 100 m depth, the operational accuracy of the excavator position is within 30 ~ 50 mm including the measuring error and the over-cutting by the excavator shaking.

③ The fuzzy reasoning method employs the fuzzy singleton-type described with seven labels of the membership functions formed with four units of shape such as ／＼, ／￣＼, ＿／, and ＼＿ on the antecedent part, and with thirteen labels of singleton pole with weight on the consequent part. The fuzzy singleton-type reasoning method can adjust smartly the output signals by tuning the weights of fuzzy control rules, and realize the compact control and the fast execution of fuzzy inference, comparing with a min-max-gravity method, known as Mamdani's fuzzy reasoning method. Moreover, the software for building the rules has the functions of emulation and simulation for fuzzy inference on the basis of the input dada, so the fuzzy rules can be adjusted and changed during the practice of excavation control by the emulation, and optimized in short time. Photo. 2 shows the display for fuzzy rule building

④ The excavation load control system controls the downward speed of the excavator and the interpenetrating force to the earth. The excavation speed is set on the setting panel in the operation cabin, and then, the set speed is maintained through the excavation work, by adjusting the braking force of the multiple disc clutch connected to the drive shaft of a torque converter. Simultaneously, the excavation force is held less than the set value.

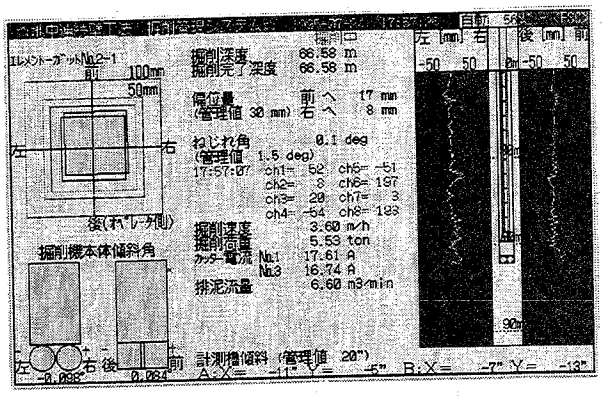


Photo.2. Monitor display of guidance system

5. Work execution record

Field test of the large-scaled diaphragm wall method

Period	1991/10 - 1992/6
Place	Izumiotsu, Osaka JAPAN
Contents	maximum depth: 150m wall thickness: 2.0m

Diaphragm wall for departure pit of shield tunneling

Period	1994/11 - 1995/2
Place	Takaishi, Osaka JAPAN
Contents	maximum depth: 55.7m wall thickness: 1.0m

Diaphragm wall for target pit of shield tunneling

Period	1995/2 - 1995/5
Place	Sakai, Osaka JAPAN
Contents	maximum depth: 60.5m wall thickness: 1.0m

Diaphragm wall for target pit for shield tunneling

Period	1995/4 - 1996/7
Place	Konohana, Osaka JAPAN
Contents	maximum depth: 69.5m wall thickness: 1.0m

As the result of field work with manual and automatic operation, we have taken aim at the accuracy of less than 30 mm as for the displacement from a designed line. In particular, the automatic operation have been verified the performance same as a skilled operator.

6. Usage conditions

① Keeping the inclination of the measuring towers within 20 seconds from the initial position by means of screw jacks through the work.

② Keeping the tracer wires away from slurry supply against disturbance.

EXCAVATION SYSTEM FOR DIAPHRAGM WALL

Applicable type of work	Slurry wall excavation Diaphragm wall excavation	Official price
Classification	Execution Management	
Purpose of the development	Manpower saving, Skilled labor saving Improvement of quality & work condition	Lease and rental
Level of practical use		Development company Obayashi Corporation

Information		
	Company name:	Obayashi Corporation - Machinery Department, Technical Section
	Address:	1-19-9 Tsumi-Dori, Sumida-ku, Tokyo 131, Japan
	Phone:	0081-3-5247-8964
	Fax:	0081-3-5247-8966

1. Application

Automated excavation and slurry management system for the slurry wall excavation

2. Outline

The slurry wall excavation system consists of;

(A) the excavation management system that improves the accuracy of the excavation by means of automated position control and automated operation control of the excavator, and

(B) the quality control system of the slurry that is important for the slurry wall stabilization, excavated soil transportation and separation, and the concrete placement.

This excavation system was developed mainly to cope with recent demands of deeper and wider slurry walls. Further more, this development was targeted to solve shortage of the skilled operators and improve working conditions.

3. Characteristics and effects

(1) By introducing the expert system, the optimum excavation speed control and the pumping volume control can be set automatically. This system can be applied to any ground conditions, including the rocks.

(2) Introduction of the sensors, which stand for hydrostatic pressure at the depth of over 150 meter, improves the accuracy of the excavation.

(3) Accurate and quick data processing by the computer is used for the excavation accuracy control and the operation management.

(4) The excavation data are displayed on the computer CRT monitor and are printed out when necessary. An operator at the console can comprehend accurate excavator condition by obtaining those data.

(5) Wall-building characteristic, viscosity, specific gravity, and pH of the slurry are automatically measured by an automatic measuring apparatus for the quality control. This apparatus contributes the improvement of the slurry quality, manpower saving and cost saving.

4. Features of the robotization and automation

① Several cables were replaced with one multiplex transmission cable for the data and control signal transmission between the excavator and the operator console.

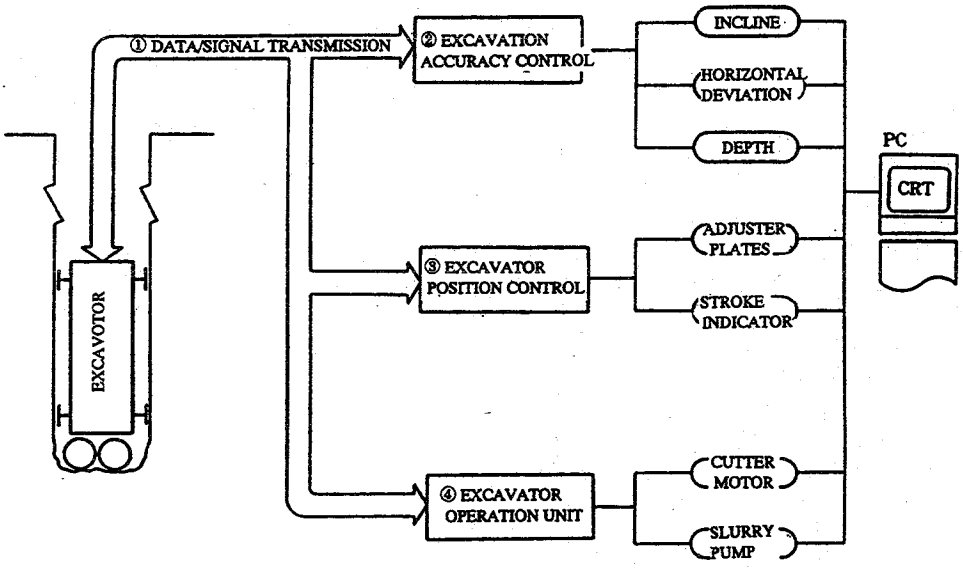


FIG. 1 OPERATION MANAGEMENT SYSTEM FLOW CHART
(HYDROFRAISE EXCAVATION)

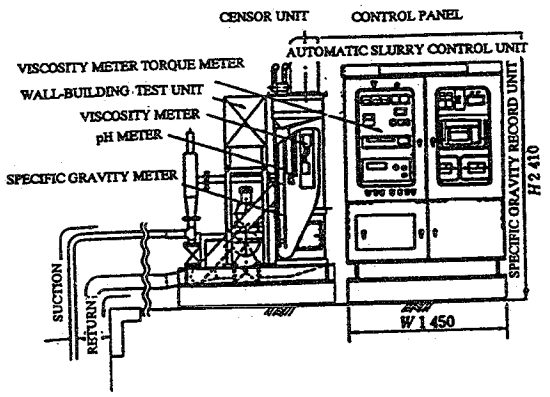


FIG. 2 SLURRY QUALITY MEASURING DEVICE

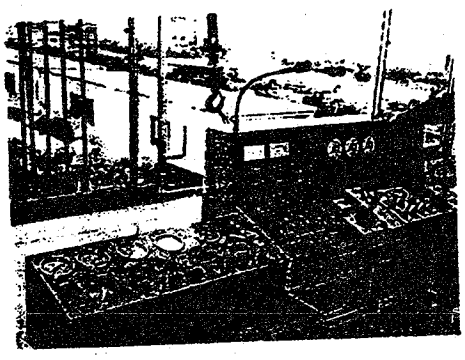


FIG. 4 OPERATOR ROOM

② The excavation accuracy control unit consists of a inclinometer, a horizontal displacement meter, and a depth meter. The unit automatically controls the excavation accuracy based on the data from those meters.

③ The signal from the inclinometer on the excavator is transmitted to the excavator position control unit. This unit automatically adjust the excavator's position by controlling strokes of 6 top and bottom adjuster plates on the excavator.

④ The excavator operation unit consists of cutter motors and a slurry pump. Since the motors and the pump are hydraulically driven, they have good torque response to the ground condition change. Also, in order to cope with deep water depth, a pressure compensated mechanism is applied to the driven parts of the cutter and the pump.

The excavation control is automatically done by above units.

The test of the wall-building characteristic of the slurry uses the capillary suction capacity of the filter paper. The water separated from the slurry rises in capillary and by measuring the speed of the water by laser beam, the wall-building characteristics can be evaluated automatically and in a short time period.

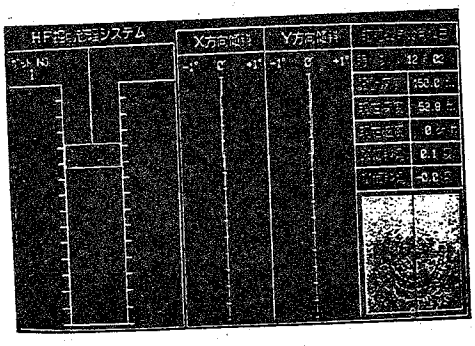


FIG. 3 CRT MANAGEMENT MONITOR

5. Work execution record

Owner	Project Name	Depth × Wall (m)	Area (m²)
Honshu-Sikoku Bridge Authority	Akashi Bridge 1A	76.0×2.2	19,119
Hokkaido Development Agency	Shiratori Bridge No.3 Pier	106×1.5	11,821
Japan Sewer Corp.	Osaka Suminoe Water Extraction Facility	89.0×1.5	23,069

6. Usage condition

① Excavation control system is applied to only Obayashi's hydrofraise excavator, however, the slurry control system can be applied to any excavators.

② With the automatic concrete placing control system, the diaphragm wall construction can be further automated.

High-Accuracy Position Control System for Underground Diaphragm Walls

Applicabele type of work : Underground diaphragm walls	Official price :
Classification : Construction management	
Purpose of the development : Reduced reliance on skilled operators and improved quality	Lease and rental :
Level of practical use : Used at actual construction site	Development Company : Taisei Corporation

Information: Company name : Taisei Corporation
Address : Technical Development No.2 Dept., Fundamental Technology Development Section, Taisei Corporation, Sanken Bldg., Hyakunin-cho 3-25-1, Shinjuku-ku, Tokyo 169
Phone : 011-81-3-5386-7565
Fax : 011-81-3-5386-7578
E-mail : arai@kiku.taisei.co.jp

1. Application

This system gives accurate automatic control over excavations by a lateral multi-axial excavator or vertical multi-axial excavator as used in underground diaphragm wall construction.

2. Outline

The precision of an underground diaphragm wall largely depends on the accuracy of the excavations. Accurate construction thus demands highly accurate construction management during the excavation work. This high-accuracy position control system links the excavator to an accuracy control rack on the ground surface via a position-detecting wire. Measurements of detecting wire displacement are made in units of microns as the excavator moves, allowing the system to detect absolute position, torsion, and inclination of the excavator with high accuracy. The system processes the acquired data in real time and displays the current position of the excavator on a monitor in the operations room. Using this information to control excavator motion, the excavations can be controlled to an accuracy of 50 mm regardless of the depth of the work.

3. Characteristics and effects

(1)Control of excavator position is continuous.
(2)The absolute position of the excavator is detected in real time.
(3)The operator can respond quickly to adjust the posture of the excavator by watching the display.
(4)The position detection system, which is fully automated, does not interfere with other work.
(5)Excavation precision is controllable to a precision of 50 mm regardless of excavation depth. Measurements are possible as deep as 200 m.
(6)Even where the ground or measuring equipment is affected by vibrations, measurements are not affected since there is a correction mechanism with a control point always secured.
(7)Since an outline of the completed trench is displayed on the monitor, ultrasonic trench wall measurements are unnecessary during the work.
(9)The system can be used whatever the thickness of the excavated wall.

4. Features of the robotization and automation

As the excavator moves, a laser displacement gauge in the accuracy control rack measures displacement of the detecting wire, while an inclinometer and depth gauge fitted to the excavator itself give the inclination angle q and depth D of the excavator. The actual position of the excavator is calculated from these data, and indicated in real time on the display along with a cross section of the trench. Figure 1 is a schematic drawing of this high-accuracy position control system.
To ensure the reliability of these measurements, a separate unit for tracking a control point is included in the accuracy control

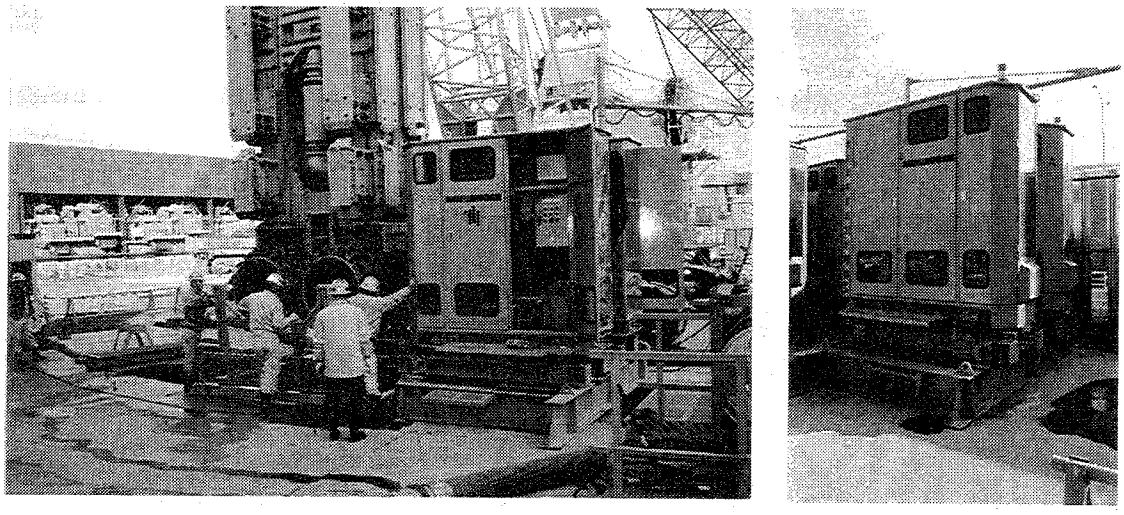


Photo 1. High-Accuracy Position Control System

Table 1. Specifications

	Specifications (separated type; 1 system)
Specifications	
Weight (kgf)	5,000
Dimensions (m)	2.3 L x 3.0 H x 2.0 W
Laser displacement gauge	8 units
Performance	
Laser displacement gauge resolution	1/10,000 mm
Data indication unit	1 mm
Control equipment	
Data processing and control computer: 1 Data display monitor	

rack. Measurements are corrected by synchronizing the behavior of the control point with the excavator displacement measurements. Measurements are subjected to real-time decentralized processing to improve reliability; that is, measurement timing is synchronized among the CPUs, while the average displacement value at each time interval is calculated. This maintains the stability and precision of the measurements. A typical monitor display is shown in Figure 2. The data shown on the screen in Figure 2 are the following:
(1)Lateral displacement
(2)Message
(3)Inclination of excavator body
(4)Excavation hysteresis record
(5)Rate and depth of excavation, displacement of excavator, and torsion angle (in digital form)

Using these data, the excavator can be controlled to an accuracy of better than 50 mm .

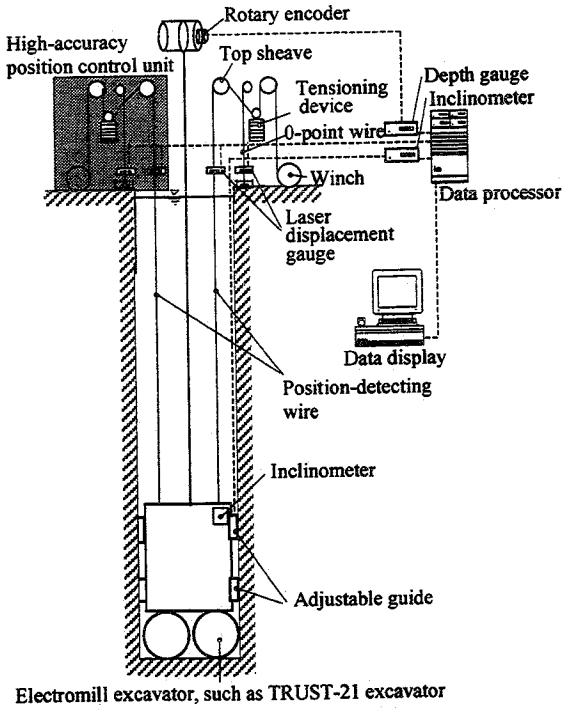


Figure 1. Schematic Drawing of High-Accuracy Position Control System

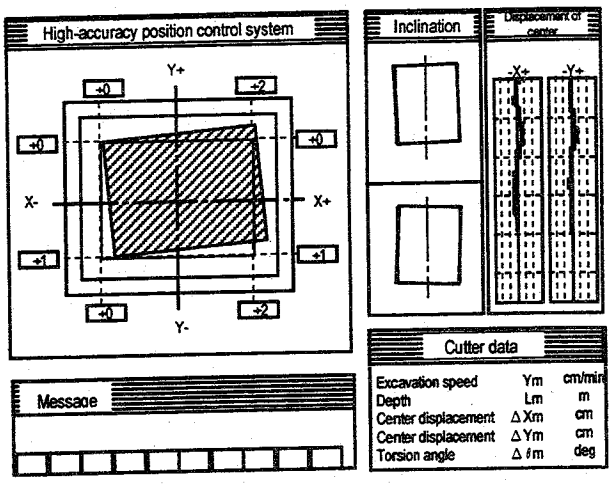


Figure 2. Display

5. Work execution record

Client	Project name	①	②
1.Hokkaido Development Bureau	Hakutyoh Bridge	106 m	1.5 m
2.Tokyo Metropolitan Government	Koto Pumping Station	104 m	2.6 m
3.Metropolitan Expressway Public Corporation	Kawasaki Channel Tunnel	80 m	2.0 m
4.Trans-Tokyo Bay Highway Co., Ltd.	Trans-Tokyo Bay Highway and Kawasaki Artificial Island	119 m	2.8 m
5.Metropolitan Expressway Public Corporation	Nishi-Shinjuku Tunnel	85 m	1.2 m
6.Kawasaki City	Shibukawa Rainfall Storage Conduit	95 m	1.5 m
7.Ministry of Construction	Outer Floodway	129 m	2.1 m
8.Tokyo Metropolitan Government	Wada Yayoi	109 m	1.6 m

①Excavation depth
②Thickness of underground diaphragm wall

6. Usage conditions

(1)This system is applicable to the construction of underground diaphragm walls as well as the RCD method.
(2)All operations involved, except surveying for installation of the rack, are automatic.

Paving

SAKAI ER501F Road Profile Cutter equipped with ACCS (Automatic Cutter Control System)

Applicable type of work:	Road surface profiling	Official price:	
Classification:			
Purpose of the development:	Improvement of the job quality, manpower saving	Lease and rental:	
Level of practical use:	Available on the market	Development company:	SAKAI HEAVY INDUSTRIES, LTD.

Information		
	Company name:	SAKAI HEAVY INDUSTRIES, LTD.
	Address:	1-4-8 Shibadaimon Minato-ku Tokyo Japan
	Phone:	03-3431-9971
	Fax:	03-3436-6212

1. Application

Road surface profiling machine. In accordance with pre-programmed data, the cutting depth adjusts automatically as the vehicle travels forward.

2. Outline

Road profile cutter equipped with ACCS(Automatic Cutter Control System).
The ACCS has two automatic cutting modes :A contour-following mode, and a longitudinal and/or transverse contouring mode. In the contour-following mode, a constant cutting depth with respect to the road surface is maintained.
The longitudinal and/or transverse contouring mode enables the cutting depth to be progressively adjusted with required lateral differential. The cutting depth data is fed to the onboard control system in stages as the vehicle travels forward.

3. Characteristics and effects

① Limits operator fatigue and improves the quality of the finished job.

② Enables the desired cutting depth to be accurately adjusted to conpensate for longitudinal and transverse unevenness in the pavement.

③ The machine runs on rubber tyres, which gives excellent maneuverability.

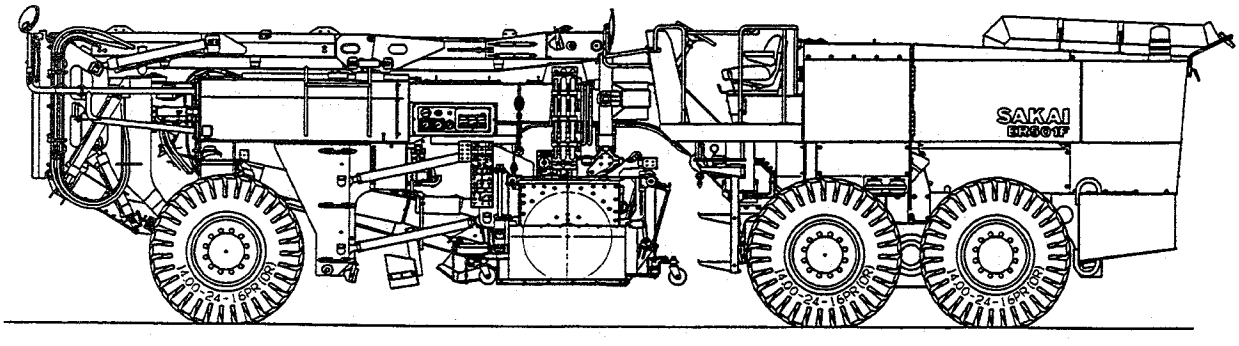


Figure 1. ER501F Road Profile Cutter

4. Features of the robotization and automation

Major specifications	ER501F Road Profile Cutter
Length	10,460 mm
Width	2,470 mm
Height Transport Operating	3,100 mm 3,700 mm
Weight	26,100 kg
Cutting width	2,000 mm
Maximum cutting depth	160 mm

The cutting depth is controlled by electro-hydraulic servo valves, which control hydraulic cylinders. Onboard microprocessors compute data from grade and travel sensors, and then command the servo valves to raise or lower the cutting drum.

5. Work execution record

Country	Type of work
Japan	Used in many road surface profiling job

6. Usage conditions

① The system requires only one operator.

② The grade sensors must have a proper datum plane to follow for automatic cutting depth control.

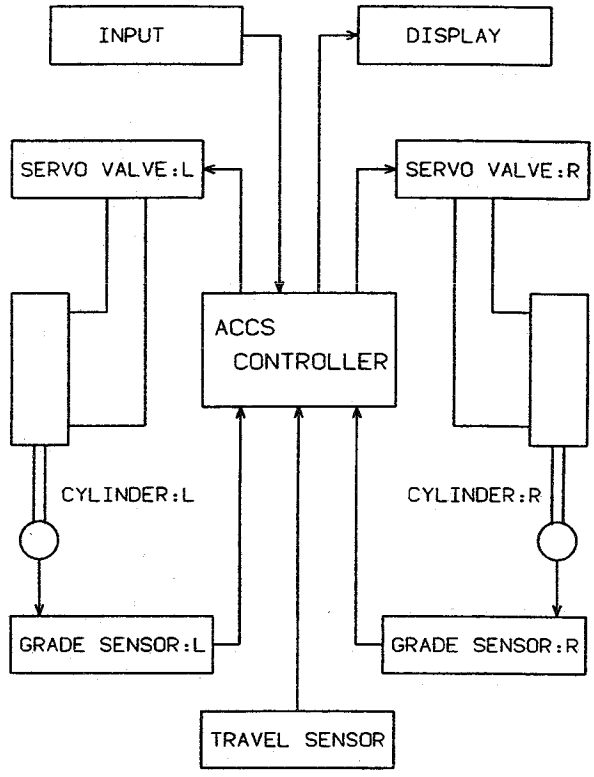


Figure 2. ACCS Block Diagram

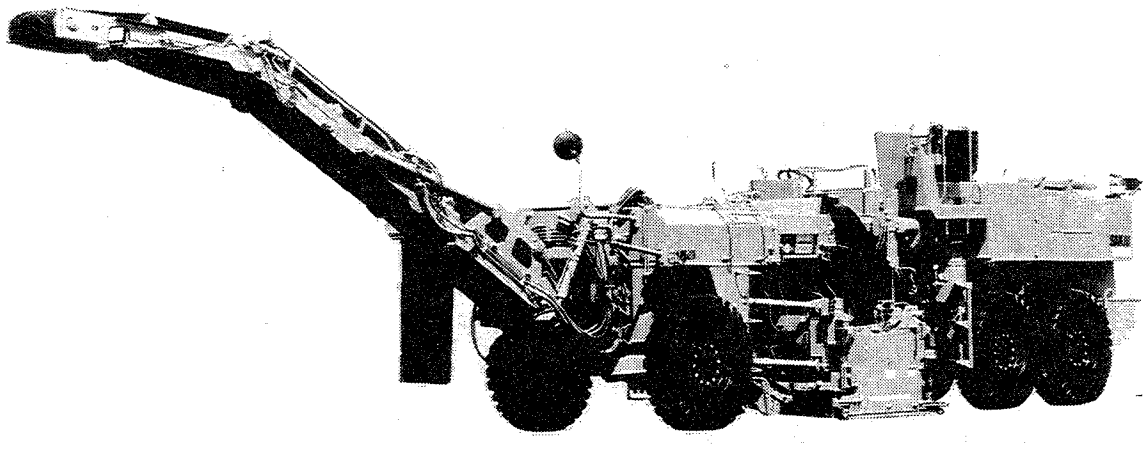


Photo 1. ER501F Road Profile Cutter

RoadRobot - Fully Automatic Road Paver

Applicable type of work:	Asphalt pavement	Official price:	
Classification:	Work	Lease or rental:	
Purpose of development:	Fully automatic road paver Improvement of quality Reduction of costs	Development company:	Joseph Vögele AG
Level of practical use:	Working in practical job		
Information:	Company: Joseph Vögele AG Address: Design Dept. Neckarauer Str. 168-228 D-68146 Mannheim, Germany Phone: +49-621-8105-262 Fax: +49-621-8105-467		

1. Application

Today, road pavers show a high level of automation. On this machinery regulating systems are already provided for conveyance and spreading of the asphalt, for direction of motion and paving speed as well as for surface accuracy of the pavement.

2. Outline

In view of increasingly growing requirements made on quality and in view of increasing costs, automation of only individual functions will not do to satisfy future needs. It is rather necessary to link the entirety of operating functions to form an overall system. The result is a fully automated road paver, in other words a road robot. The newly developed paver „RoadRobot" provides this:

① automated reception of asphalt

② automatic control of asphalt conveyance

③ automatic control of asphalt spreading

④ automatic steering control with mechanical sensor and automatic control of paving speed

⑤ automatically controlled start/stop of all paving functions of the RoadRobot

The paver operator does not have to direct his attention to controlling reception of the asphalt or steering the road paver, i.e. to jobs he usually has to do, but can fully concentrate his skill on the screed for assuring a high paving quality.

3. Characteristics and effects

① Diesel-Electric Drive System

A systematic study of automated pavement construction shows that full automation of a conventional road paver cannot be achieved in an economical way. Only with the development of a road paver with diesel-electric drive system, it was possible to create a basis for automation under economical conditions.

As power source of this new road paver serves a 55 kVA three-phase A.C. generator driven by a diesel engine rated at 61 kW.

The 380 V three-phase output voltage supplied by the synchronous generator has a frequency of 37 or 60 Hz and is made available to the three-phase asynchronous motors operating at constant speed as well as to the system for screed heating. The components such as supply unit, central electronic unit and inverter modules are accomodated in a control cabinet located at the rear of the road paver.

Output voltage of the supply unit is linked to the inverter modules via intermediary circuit. To these inverter modules are connected the variable-speed drive units for traction, conveyors, augers, tamper and vibrators.

Optimum matching of power unit output to the various operating functions of the drives for rotary movements is achieved by frequency converters.

The electrical/digital actuator level created in this way admits to integrate process automation in an economical way, without a need for additional conversion.

The improvements achieved by this drive system in terms of efficiency on the one hand and the better matching of electric drive output for paving functions to demand on the other, permitted to reduce power of the diesel engine by 50 % without a decrease in paving performance.

Especially when it was about designing a low-noise road paver, electric drives proved advantageous. Noise levels at the screed, while paving, could be reduced from formerly 93 dB(A) to 81 dB(A).

Furthermore, the quantity of hydraulic oil which has to be carried along with the paver, could be cut from formerly 380 litres to now 20 litres.

② Reception of Asphalt

Reception of asphalt is a process which is constantly repeated. For the RoadRobot this process has been fully automated.

Sensors located at the front of the driver's cabin pick up the distance to the feed vehicle and measure the height of asphalt on the conveyors. A symbolic display informs the lorry driver about what steps to perform for correct discharge.

A paving start or paving stop is initiated as a function of the quantity of asphalt in the material hopper of the RoadRobot. This ensures that provided a correct handling of the control system for conveyors and augers, a constant head of asphalt in front of the screed is guaranteed, both when starting paving, when paving and when stopping paving.

③ Automatic Steering Control

Steering a road paver precisely along a guide line such as, for example, a curb will very soon make excessive demands on the paver operator due to the monotonous nature of the job on the one hand, and the high degree of concentration required on the other. This risks to produce mistakes in steering. Only automatic steering control allows precise steering along a given reference line.

Automatic steering control used on the RoadRobot is based on mechanical referencing from a guide line such as a curb, for example.The accuracy achieved was +/- 2 mm.

A second type of travel control system which was installed on top of the cabin of the RoadRobot operated according to the principle of a laser-based navigation system. This steering system is applied when no reference or other line is available from which referencing can be carried out.

The laser beam of the laser unit scans, like radar, the area around the RoadRobot, and the laser unit calculates the angle between the RoadRobot and the reflection elements positioned in place.

The more reflexes are identified, the higher will be the accuracy of positioning. The highest possible accuracy achieved with this system was around +/- 20 mm.

4 Features of the robotization and automation

By automation of asphalt reception and steering as well as their integration into the overall system of the RoadRobot, automation of the entire paving process has been completed.

The paver operator very often is a specialist with great skill. While paving, he need no longer concentrate on the paver, but is available for monitoring the functions of the screed.

Robotization of the road paver in an economical way by use of the diesel-electric drive system showed that substantial progress has been made not only as far as automation of operating functions of the road paver is concerned, but also in terms of environment protection by reduction of noise levels and exhaust emission.

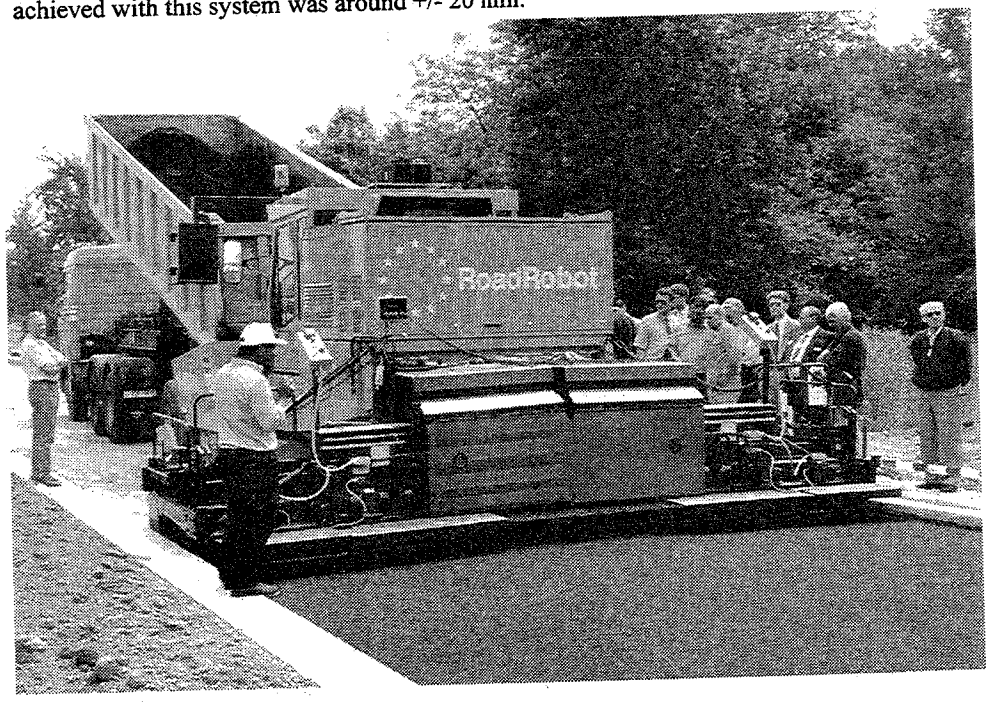
5. Work execution record

Within the scope of a European Research Project entitled ESPRIT, in which partners from 5 European countries participated, the basis of a fully automated road paver (RoadRobot) has been investigated and the result was presented at the German Road Museum at Germersheim on June 28th, 1996, as well as on a job site of the company Teerbau located nearby.

Demonstration of the RoadRobot on site has shown that the fully automated road paver with diesel-electric drive system and also the semi-automated one are developments oriented towards the future.

6. Usage conditions

The RoadRobot is the first road paver worldwide capable of navigating and steering itself. All functions necessary for road pavement construction from asphalt spreading through to levelling, profiling, and compacting are computer controlled.



The fully automatic road paver RoadRobot in operation

Bending asphalt paver

Applicable type of work: Asphalt concrete surfacing on automobile test course runways	Official price: None
Classification: Installation	Offered price: 73.8 million yen
Purpose of development: Labor-saving, improvement of work quality	Lease and rental: Not available
Level of practical use: Available for actual application	Development company: THE NIPPON ROAD CO., LTD

Information Company name: THE NIPPON ROAD CO., LTD TECHNICAL DIVEISION
Address 11-20, TAMAGAWA 2CHOME OTA-KU, TOKYO 146 JAPAN
TEL(813)3739-4854
FAX(813)3759-2250

1. Application

This bending paver, equipped with a mechanism which enables the screed of the asphalt paver to automatically adjust and conform to the designed cross-sectional curved profile of automobile test courses, finishes spreading and smoothing of the road base materials and asphalt concrete mixtures in the paving direction.

2. Outline

① Test courses design outline

The cross-sectional profile of an uphill easement curve of a high-speed circuit increases its curvature gradually from flat to the maximum at its peripheral part, while that of a downhill easement curve shows gradual decrease of the angle to flat. In addition, the cross-sectional profile is generally designed in a two-dimensional or three-dimensional curve depending on the desired design speed. When the bending angle in a design is large (for example, when an angle is greater than 45 degrees), it may be designed as a profile consisting of a curve and straight lines.

② Structure of automation

The mechanism is designed so that the screed spreads and smoothes the material on the surface of the circuit as the work proceeds by gradually and steadily bending itself segmentally. In order to constract a new design profile or duplicate automobile testing course existing on the designed circuit, the machine is provided with a computer storing the motor speed which determines the cross-sectional profile, a control panel which controls the motor speed, and a screed which executes the designed program.

3. Features and Effects

1) The machine is equipped with a computer storing cross-sectional profiles, thus allowing paving of any type of automobile test courses.

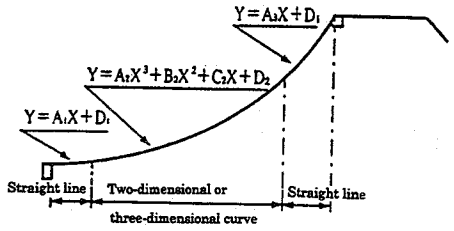


Figure 1 Cross-sectional profile

2) The working width can be freely selected between 2.5 to 5.0 meters.

3) The screed bottom plate is made in one piece in cross-sectional direction, providing smooth cross-sectional profile.

4) All the controlling motors can be controlled simultaneously, requiring only one operator for the machine.

5) No special machine is required, as the controlling computer is contained in the central part of the bending paver, and the control panel is located on the top of the screed.

6) The speed of the worm gear is amplified by the rotary encoder, enabling a more accurate control.

7) A motor speed meeting with the processing speed can be selected, making the vertical gradation smooth.

4. Automated Items

① Procedures for automation

1) Computation of motor speed and file creation: The cross-sectional profiles of automobile test courses differ from each other. Therefore, the bending paver operating position is determined upon completion of the designing, so that the accumulated number of rotations of the motor may be first computed based on the design before the data are stored on a file, using a software product which computes the cross-sectional profile.

2) Conversion and transfer of filed data into

execution data: The data, stored on a file by the software product mentioned above, is converted and transferred to the execution file using a software product to store the data on the control computer (sequential control by a programmable controller).

3) Selection of the data for working position: Select an objective working position (uphill or downhill easement curve, working lane and working layer) among the data stored on the controlling computer.

4) Controlling bending screed: In accordance with the work progress, control the bending screed to fit the cross-sectional profile at the position, by pressing the MOVE switch at a fixed interval.

Model	BAF-ND 50C
Dimensions (m)	L 6.2 x W 2.5 x H 2.6
Weight (kgf)	Total weight: 14,000 Screed weight: 2,000
Rated output (PS/rpm)	97/2,000
Speed:Running speed (km/h)	0 - 4.5
Surfacing speed (m/min.)	0 - 20
Screed width (m)	Max. 5.0
Control device	Programmable controller, Rotary encoder

Table-1 Specifications of the machine

② Operation switches on the control panel and items to be displayed

1. MODE switch
2. MOVE switch
3. Working position selection switch
4. SELECTION switch
5. RESET switch
6. CLEAR switch
7. STEP switch
8. MANUAL switch

2) Items to be displayed:

1. Currently working position
2. Accumulated number of rotations of motors

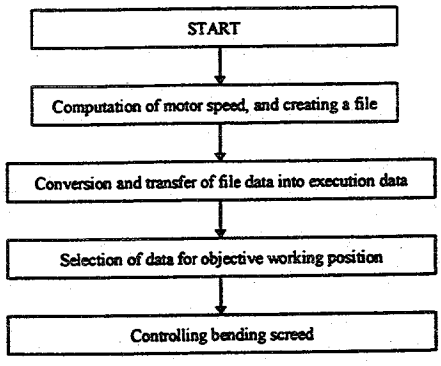


Figure 2 Work flow

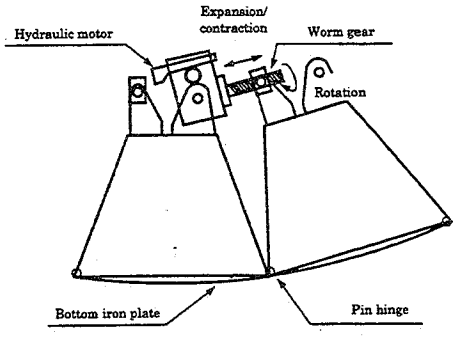


Figure 3 Screed bending mechanism

3. Motor rotation compensation
4. Cross-sectional profile of the Bending screed
5. Compensation for the cross-sectional profile of the bending screed
6. Motor rotation indication lamp

③ Curve changing mechanism of the bending screed

1) The screed is bent in cross-sectional direction by expanding or contracting the clearance between the top parts of the two divided screed's portions.

2) The machine is improved in its expansion and contraction accuracy by amplifying the speed of a small worm gear using a rotary encoder.

5. Applicable works

1) Asphalt surfacing of automobile test course runways

2) Achievements .... Test installation

6. Attentions to be required in using the machine

1) The controlling computer can store the data only for one test course, requiring overwriting the data before starting to work with a new test course.

2) For the computed data, the working position has been decided, and the completed cross-sectional profile may not match to the designed: one if this position is deviated,. Thus coordination with an anchor machine, which supports the bending paver, is also important.

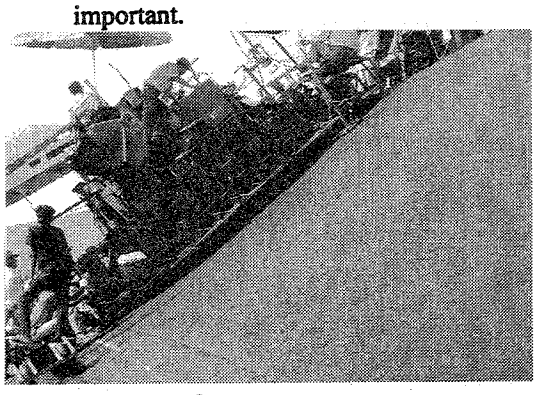


Figure 4 Working scene

Robot Asphalt Finisher

Applicable type of work:	Asphalt pavement	Official price:	48,000,000 Japanese Yen
Classification:	Work	Lease or rental:	
Purpose of the development:	Saving of man-hour and skill Improvement in working environment	Development company:	Nippon Hodo Co., Ltd. Niigata Engineering Co., Ltd.
Level of practical use:	Working in practical job		

Information: Company: Niigata Engineering co., Ltd.
Address: Administration Dept., Transcom Systems Div.
10-1, Kamata Honchou 1-Chome, Ohta-Ku, Tokyo 144, Japan
Phone: ++81-3-3739-3351
Fax: ++81-3-3739-8115
E-mail: webmstr@niigata-eng.co.jp

1. Application

Robot asphalt finisher provides quality pavement, one-man operation and comfortable working environment in asphalt pavement work.

2. Outline

More than 50 years have passed since asphalt finisher was made. However, paving work with asphalt finisher requires difficult controls and adjustment by two or three skillful operator and screedmen.

Robot asphalt finisher has been developed to save labor, and to reduce the level of skill of operator under following concepts.

① Easy to operate in comfortable working environment

② Automate and remotely control to reduce troublesome operations.

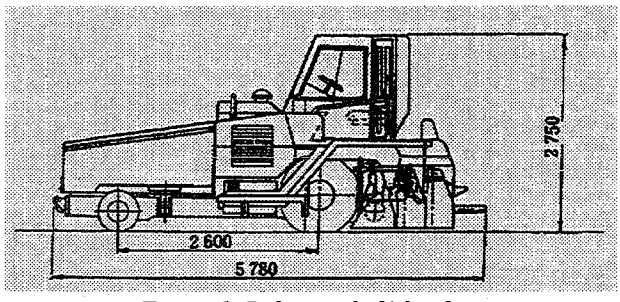


Figure 1. Robot asphalt finisher

3. Characteristics and effects

① Cabin

All controls are concentrated in fully enclosed operator cabin. The cabin glass panes are large to maintain wide operator's view. Video monitor systems are provided to monitor opposite side of operator and blind front area. The cabin is air-conditioned for operator's comfort.

② Paving thickness display system

A paving thickness display and control panel is provided in the cabin. Current thickness at both ends of screed are displayed in digits, and the changes in thickness are shown by graphs. Operator can manage the quantity of asphalt hot-mix by reading the distance paved and paving speed in the display.

③ Ultrasonic grade controller

Operator can adjust paving thickness of both ends of screed automatically by a grade control unit in the cabin. The thickness is shown in digits for more precise control.

Hold mode is incorporated in the system in case a sensor loses its target

④ Ultrasonic feed control system

A uniform feeding over the entire width of the front of the screed lightens the heavy work load of operator, and reduces shoveling, raking and cleaning operations of the paving edges by helpers.

⑤ Powered crown control

The amount of crown is digitally displayed and adjustment of crown is remotely controlled by a switch. This reduces work load of screedman when asphalt finisher is approaching or departing a crossing road.

⑥ Automatic temperature control of screed heater

The screed heater burns LP gas and hot air flows over entire width of screed heating screed plate uniformly. Uniform screed plate temperature is an important factor to good surface texture and paving accuracy.

4. Features of the robotization and automation

① Paving speed control

The movement speed at paving mode is detected by a proximity sensor provided at traction motor. The signal is feedback to traction hydraulic pump and maintains constant paving speed regardless of traction load.

② Paving thickness monitor system

The system is composed of a pair of measuring arm at both sides of screed, two ultrasonic sensors, slope sensor, rotary encoder or proximity sensor for measuring the distance. The on-board computer processes all data from these sensors and displays paving thickness in real time.

③ Ultrasonic grade control system

The system is composed of a grade control panel, remote control units located at both sides, and two ultrasonic sensors. The sensor measures the distance to reference plane and controls pull point of leveling arm. In case the sensor loses its target and the measured distance varies significantly, the movement of pull point stops automatically and buzzer warns the operator.

④ Ultrasonic feed control system

The ultrasonic sensors located at the end of screw spreader detect the amount of asphalt hot-mix, and the controller adjust feeder speed automatically to maintain constant material level.

The system has two control modes. The conveyor runs at minimum speed when feeding of asphalt mixture is not necessary while pavement is in progress. On the contrary, the conveyor stops when feeding is not necessary while the asphalt finisher is not moving.

⑤ Powered crown control

A hydraulic motor is provided at the crown adjusting screw. The motor rotates by a flip of control switch and the amount of crown adjustment is displayed in the control panel.

⑥ Automatic temperature controlled screed heaters

The screed heater starts by pressing "Ignite" button in the control unit. A temperature sensor measures the temperature of the screed plate, and shuts off the heater when the screed plate is heated to preset temperature.

5. Work execution record

Nippon Hodo owns 4 units of robot asphalt finisher and they are working in various job sites.

Paving thickness measuring and display unit, ultrasonic grade controller and ultrasonic feed controller are retrofitted to existing asphalt finishers or equipped to new asphalt finishers as an optional equipment package.

6. Usage conditions

① Conventional grade controller and feed controller can be installed to this robot asphalt finisher.

② Paving thickness display system and ultrasonic grade control system are independent and separate systems although they are interrelated in practical job.

③ Robot asphalt finisher may require helpers or screedman by the job conditions.

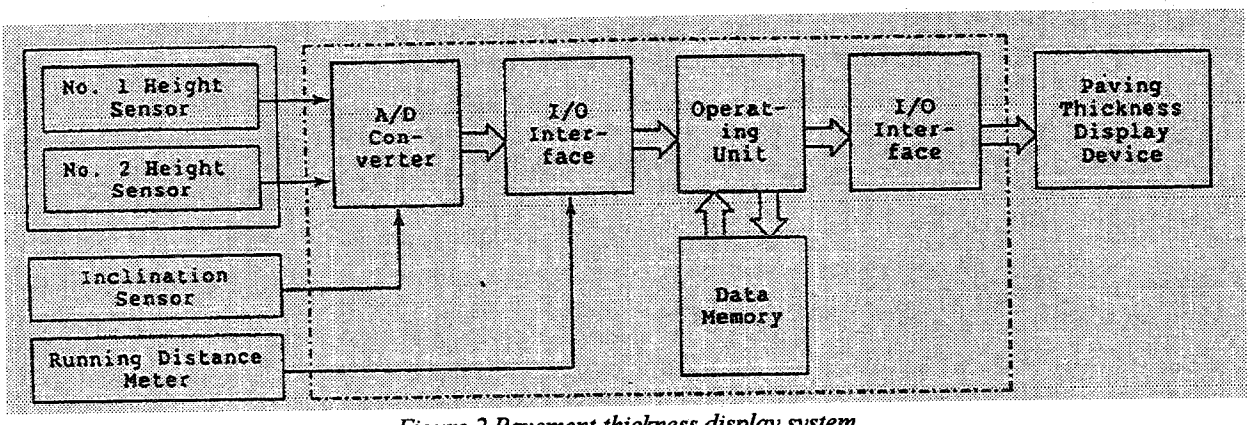


Figure 2 Pavement thickness display system

Table 1 Brief specifications

Gross vehicle weight	11,200 kg	Paving width	2.5 to 4.75 m
Overall length	5,780 mm	Paving thickness	10 to 150 mm
Overall width	2,490 mm	Maximum feeding capacity	240 t/h
Overall height	2,750 mm	Laying material	asphalt hot-mix and base course material
Wheel base	2,600 mm	Traction drive	Hydraulically driven, "No-spin" differential drive, and 4WD or 2WD.
Max. traveling speed	10 km/h		
Working speed	1.5 to 10 m/min		
Engine make and model	Isuzu, 4BD1-T		
Output	61 kW at 2,000 min^{-1}		

Tunnelling

AUTOMATIC OPERATION SYSTEM FOR TUNNEL BORING MACHINE

Applicable type of work	Rock Tunnel Excavation		Official price
Classification	Execution		
Purpose of the development	Skilled labor saving Improvement of quality & work condition		Lease and rental
Level of practical use	Has been applied to the projects		Development company Obayashi Corporation Kawasaki Heavy Industries
Information	Company name:	Obayashi Corporation - Civil Engineering Technical Department Dept. No. 4	
	Address:	2-2-9 Hongo, Bunkyo-ku, Tokyo 113, Japan	
	Phone:	0081-3-5689-9006	
	Fax:	0081-3-5689-9007	

1. Application

Automatic operation system for Tunnel Boring Machine (TBM) mainly focused on the automatic direction control.

2. Outline

It was difficult to control direction of the TBM by a feed back control, because;

1) As the TBM consists of 3 separate bodies (front, middle and rear body), there are many functions of the direction control such as front grippers, direction control jacks, thrust jacks and main grippers.

2) the quality of the rock varies during the tunnel excavation. From data analysis of the past tunnel project and the information from skilled operators, the regularity of the TBM operation was found. Using AI technology, the automatic operation system of the TBM was constructed. Furthermore, by integrating automatic survey system and automatic muck transfer system, full automatic operation system for the TBM was realized.

Hardware system consists of an outside control panel at the central operation room at the surface and an operation panel at the operator room of the TBM. Both are connected by the optical fiber cable for transmitting the TBM control information.

3. Characteristics and effects

① By applying the neural network and the fuzzy theory of the computer, most suitable direction control system of the TBM is achieved.

② In order to decide instruction signals and/or control tools of the neural network, the data from past tunnel projects and the information from skilled operators were used. The automatic operation system surpassed skilled operators in terms of the excavation alignment control and the excavation speed.

③ The learning function of this system capable to select optimum control system for the TBM by collecting several excavation data at different ground (rock) conditions. The automatic operation system can be used at any kind of the ground conditions.

④ Full automatic operation system, with the integrated management system including the automatic muck transfer and a few push button switches, eliminates operators from the tunnel for the TBM operation.

⑤ It solves lack of skilled operators and frees from workers at narrow working spaces.

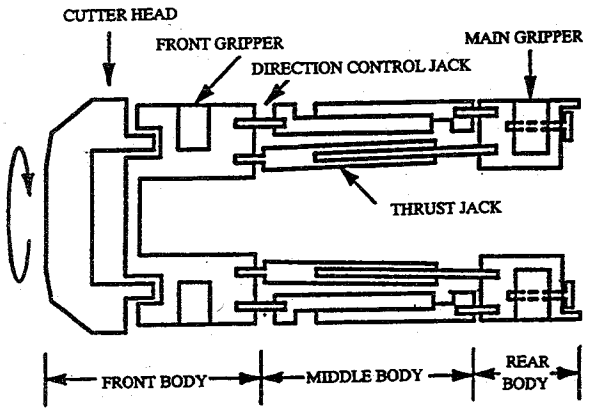


FIG. 1 TBM

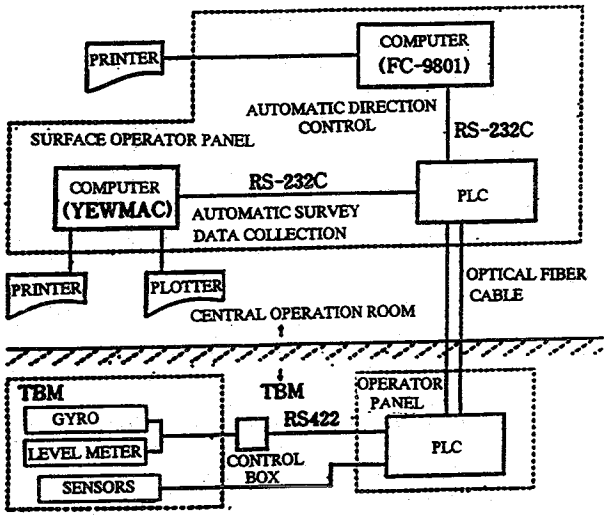


FIG. 2 HARDWARE SETUP

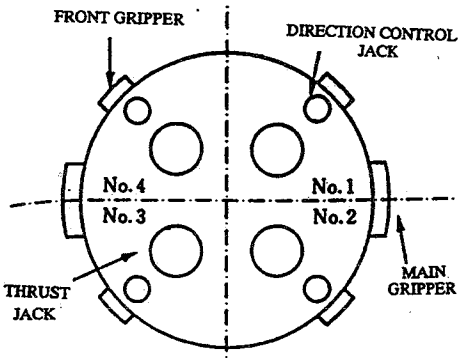


FIG. 3 JACK LOCATION

TABLE 1 EXCAVATION MODE

MODE NO.	FRONT GRIPPER	DIRECTION CONTROL JACK	THRUST JACK W/ FOLLOWING	THRUST JACK W/O FOLLOWING	MAIN GRIPPER
MODE 0	ON	OFF	—	4 ea.	OFF
MODE ±1	ON	ON	—	4 ea.	OFF
MODE ±2	ON	ON	2 ea. × 2 ea.	—	OFF
MODE ±3	ON	ON	—	2 ea.	OFF
MODE ±4	ON	ON	—	2 ea.	ON

① Previous Excavation Mode — 5 Kinds (Table 1)
② Stroke of Direction change — (Stroke at the beginning) − (Stroke at previous excavation)
③ Excavation Result from Previous Excavation — Too much turn, Good, Less turn
④ Current Excavation Mode — 5 kinds (Table 1)

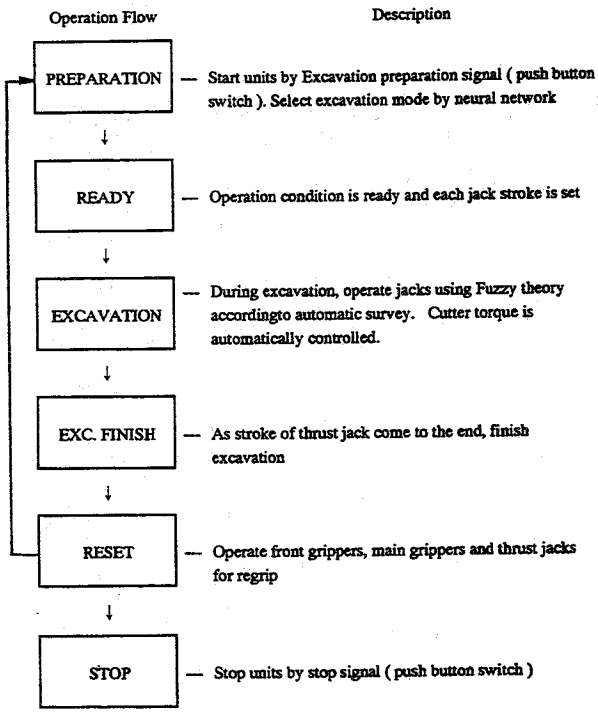


FIG. 4 AUTOMATIC OPERATION FLOW

4. Features of the robotization and automation

① The excavation is started by a signal for " Excavation Preparation " from a operator by pressing a push button switch. The computer for the automatic direction control sends a signal for the selection of the excavation mode and the design values of each jack stroke to a programmable logic controller (PLC).

② The neural network is to select most suitable combination of the control points for the excavation condition. There are 4 kinds of jacks used for the TBM excavation. Table 1. shows the different modes of the excavation in terms of the jack selection and jack numbers. As the mode number is getting bigger, the direction control is getting bigger. A sign of the excavation mode indicates the excavation direction; + for the right and - for the left turn. Inputs to the neural network are previous excavation mode, excavation results, and the stroke of the direction changes. Output is the suitableness of the excavation mode and the most suitable mode is selected for next excavation.

③ Fuzzy theory is used to calculate strokes of the direction control jacks and front grippers in order to match the TBM direction and level to the theoretical one during next excavation.

④ At the beginning of the excavation, the rolling of the front body is automatically corrected. At the reset, the rolling of the rear body is automatically corrected. Since cutter pressure is automatically controlled by controlling the thrust jack pressure, stable excavation is capable.

5. Work execution record

Owner	Location	Description
① Hyougo Pref. Mukogawa No.2 Pipe Shiose-Michiba Section		
Japan Sewer Corporation	Shiose, Nishinomiya City to Michiba, Kobe	Sewage pipe, Dia. 2 m TBM w/ Slurry Muck transfer
② Akita Highway Yuda Tunnel - 1		
Japan Highway Public Corporation - Sendai	Yuda - cho, Iwate Pref.	Pilot Tunnel for Highway Tunnel Dia. 3.5 m

6. Usage condition

Since the data from past tunnel projects are not enough to construct instruction signals of the neural network, the system can not correspond to all kinds of ground conditions. Therefore, in some cases, at the beginning of the project, new instruction signals for the neural network have to be constructed based on the TBM condition.

Automatic Transport System Intended for Long Tunnels, GEO-SHUTTLE

Applicable type of work:	Tunnel driving work		Official price:
Classification:			
Purpose of the development:	Manpower saving, time-saving Improvement of work environment		Lease and rental:
Level of practical use:	Available		Development company: Sato Kogyo Co., Ltd.
Information	Company name:	Sato Kogyo Co., Ltd.	
	Address:	Civil Engineering Dep.	12-20, Nihonbashi-Honcho, 4-chome, Chuo-ku, Tokyo, Japan 103
	Phone:	03-3661-4794	
	Fax:	03-3668-9484	
	E-mail:		

1. Application

This system was developed to allow the automatic operation of the unattended trains used both for segment supply and tunnel spoil removal. The system is remotely controlled by a central control device installed outside the tunnel.

Photo.1. Unattended Trains

2. Outline

With the rapid advancement of tunnel-boring machines, driving operation has recently been carried out with a higher level of speed and efficiently. However, in the case of long tunnels, a rapid transportation system that supports speedy driving is indispensable. It is also important, after carrying out accurate monitoring of a flow of work involved in tunnel driving , from workers' going-in and -out of the tunnel, construction equipment and materials supply, to spoil removal operation, to maintain proper control of the entire work process to achieve the smooth progress of tunnel driving with enhanced safety.

In order to achieve this, and to ensure the safety of workers during the process of rapid transportation, automating tunnel haulage operation and thus minimizing the number of operators and workers inside the tunnel is a viable strategy. A system developed to fulfill these requirements comprises more than one unattended train that travel back and forth inside the tunnel and a train operation control device that continuously monitors on-going operations of the trains to ensure safety.

3. Characteristics and effects

① Unmanned and safety operation of a max. distance of 7 km and five trains (max.) s possible.

a) Proper distance can be maintained between the trains throughout the operation.

b) All trains are mounted with various types of sensors (obstruction detector, obstruction detecting bumper) to ensure safety..

② Material supply that occurs on a irregular basis can be coped with by the operation of the attended train between scheduled unattended train services.

a) To ensure safety operation of the attended train, signals are controlled by continuous monitoring and controlling of the position of each train.

b) The attended train is also kept under control and monitoring. As soon as the attended train is found to be a hindrance to the operation of the unattended train (e.g. disregard of signals, unexpectedly long resident time inside the sections shared by the attended and unattended

trains, etc.), the operation of all the unattended trains will be suspended.

③ Feedback of the analytical results of operational records to the on-going train operation helps improve the safety and efficiency of the tunnel driving work.

a) Mechanical conditions of the trains are grasped from the emergency stop records of all trains to perform precautionary maintenance.

b) Waiting hours consumed in the passing blocks are analyzed. The results will be used in discussing the proper location of subsequent passing blocks and traveling speed levels.

4. Features of the robotization and automation

Major components of the system are given below.

① Central control device

The central control device installed in the central control room located outside the tunnel collects real-time data from various types of devices, based on which, control of automatic train operation is performed. The central control device also outputs operation status data and issues alarm signals.

② Inductive radio system

The inductive radio system allows the central control device to issue instructions to the trains by radio communications. It also allows the trains to transmit operational data to the central control device.

③ Unattended trains

The unattended trains are automatically operated by instructions issued via the inductive radio system from the central control device as well as by data written on ID tags set up along the track. The unattended trains are loaded with safety devices and alarm devices.

④ Attended train

The attended train continuously sends out position data to the central control device via the inductive radio system. According to the data received, the central control device issues signals to control operations of the attended train that is run on an irregular basis.

⑤ ID tags

The ID tags installed along the track carry data necessary for train operations. The ID tags continuously transmit information passing trains.

5. Work execution records

Period	from May 1993 to May 1996
Ordered by	Ministry Construction
Place	Kanagawa Prefecture, Japan
Contents	Project: Doushi Headrace (Hayato section) construction Tunnel length: 5,000 m Excavation diameter: 3,500mm

6. Usage condition

none

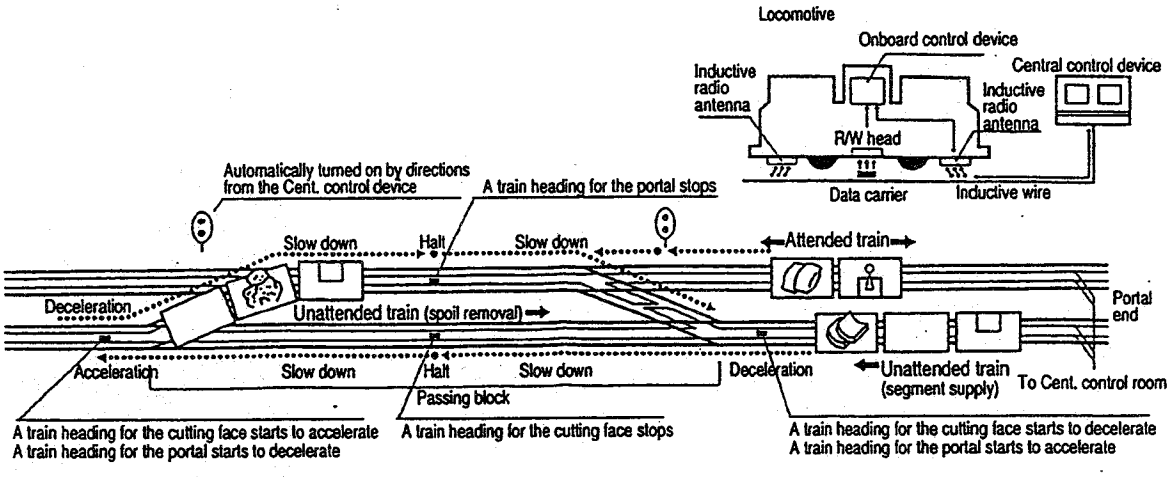


Figure 1. System configuration

Laser ventilation system

Applicable type of work:	Tunnel ventilation	Official price:	Separately given
Classification:	Implementation		
Purpose of the development:	To improve working environment, and save energy	Lease and rental:	None
Level of practical use:	Implementation in real works	Development company:	TOA CORPORATION

Information		
	Company name:	TOA CORPORATION
	Address:	Mechanical & Electrical Department, Central Civil Engineering Bureau Yonban-cho 5, Chiyoda-ku, Tokyo
	Phone:	03-3262-5109
	Fax:	03-3262-9536
	E-mail	

1. Application

To improve working environment in tunnel works by controlling amount of ventilation in accordance with the working condition, utilizing laser beam attenuation.

2. Outline

The system controls air volume in the tunnel, utilizing the characteristic of laser beam being attenuated by dust, by changing the number of revolution of the contrafan according to the degree of attenuation of reflected light.

The system consists of five pieces of equipment, namely a contrafan, an inverter, a controller, a laser head, and a reflector. Red semiconductor laser (10 mW, 670 nm) is used as light source.

As the attenuation degree of laser beam varies according to rock type, attenuation is classified into three levels depending on the site, for each of which the number of controller fan revolution is specified. This makes it possible to obtain air volume suitable for specific working environments.

The laser irradiation distance of 100 m is considered optimum if the target dust concentration of 2.4 mg/m^3 as recommended by the Japan Construction Safety and Health Association (JCSHA) is to be applied.

3. Characteristics and effects

① Air volume is determined by dirt in the working space. While the traditional dust sensors catch dirt in the tunnel as a point, laser beam can catch dirt as a line and is, therefore, more appropriate for representing dirt in working space.

② Air volume is classified into three levels, and the most suited to the working condition can be selected freely and easily. Laser attenuation represented by reflectance of 0 through 99% is divided into three levels, which are used as a basis for determining the appropriate air volume. Operation can be performed only with digital switches, so that it is simpler and easier to understand than in the past.

③ Human senses of sight and smell can be reflected in ventilation. As the controller is set in pairs with the laser head in the tunnel, other factors than dust such as exhaust gas, water vapor and temperature can be taken into consideration in determining the air volume on the site.

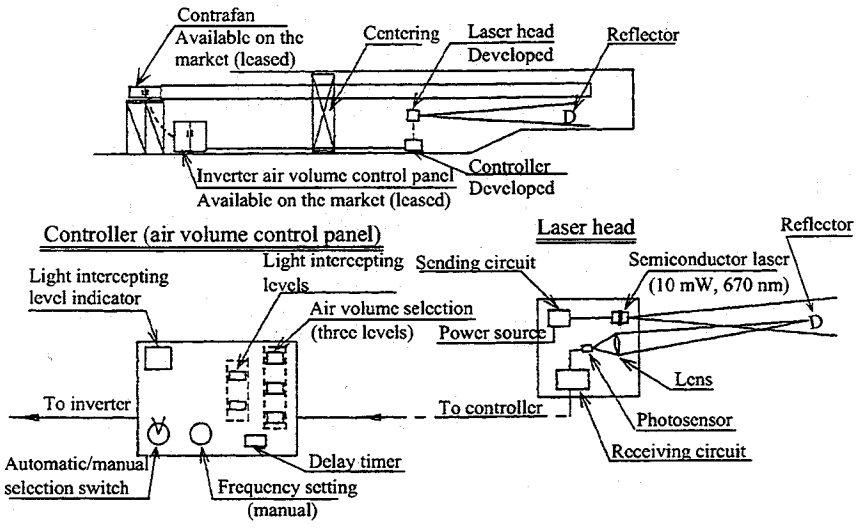


Figure 1. Laser ventilation system.

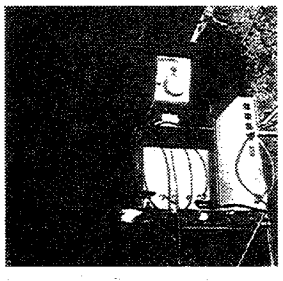


Photo. 1. Laser beam equipment.

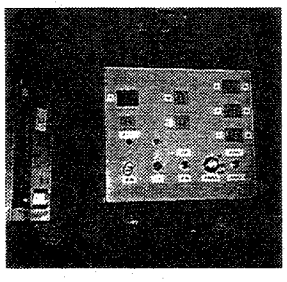


Photo. 2. Controller.

4. Features of the robotization and automation

① Laser Beam Equipment

The laser beam equipment is kept as light as possible by using semiconductor laser, and can respond to changes in power source as Automatic power controller (APC) is built in. Modulation circuit prevents electric lighting and solar light from influencing operation.

Laser beam coming from semiconductor laser is reflected back to the laser head by the reflector. The reflected light is converged by a lens, and then received by a photosensor, and dirt in the tunnel is caught in terms of attenuation of light intercepting level.

This system, equipped with an automatic gain adjuster, chattering prevention feature and hit guarantee feature, smoothly controls air volume sent by the contrafan.

② Rock Type and Laser Beam Attenuation

As for laser beam attenuation characteristics under this system according to the rock type (granite, sandstone or tuff), a joint study with Mr. Y. Yoshida, Assistant Professor of Muroran Institute of Technology, revealed the following points.

At the grain diameter distribution value of $a = 3.5$ (for floating dust in traditional tunnels), similar attenuation is registered for sandstone and tuff, while attenuation is smaller for granite (Figure 2), which shows laser beam attenuation varies according to the rock type.

Studies about attenuation characteristics for exhaust gas revealed that there was little attenuation when the irradiation distance was longer than 40 m.

③ Underground Environment and Changes in Laser Beam Quantity

A study was conducted as to laser beam attenuation in the bottom section in a tunnel where work was actually being done (excavation length: 780 m, top section: 60 m, lining: 300 m from the face).

The appropriate irradiation distance was found to be 100 m on grounds that no laser beam is reflected back when irradiation length is 100 m and dust concentration exceeds some 2 mg/m^3, that the target dust concentration is set at 2.4 mg/m^3, and that the reflector is installed visually.

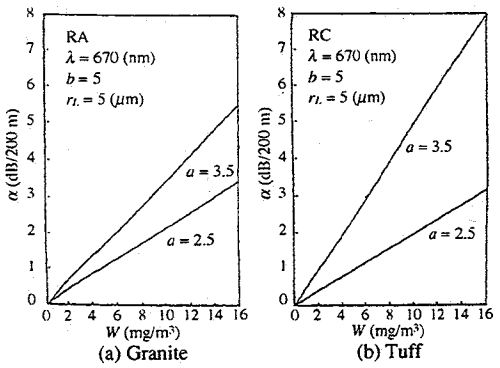


Figure 2. Laser beam attenuation characteristics (theoretically presumed based on experiments).

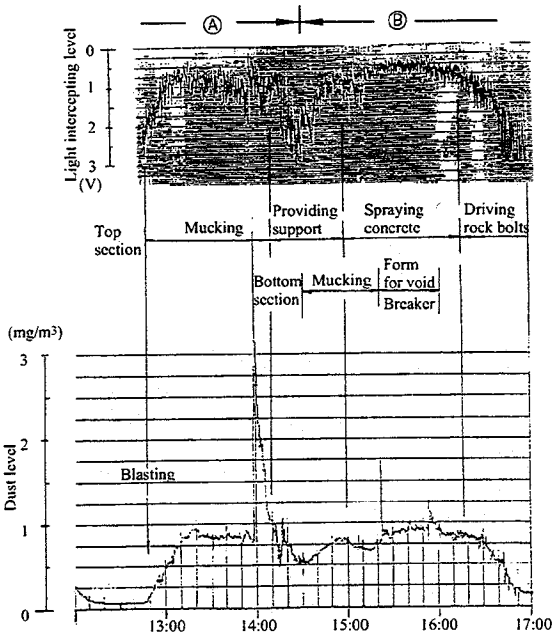


Figure 3. Relation between light intercepting level and dust level.

The relation between laser beam attenuation and dust volume is shown in Figure 3. Attenuation of light intercepting level generally represents dust concentration. Actual dirt in the tunnel (invisibility in space) is, however, better represented by laser beam attenuation. That is, dust levels A and B measured more or less the same, but in reality environment in the tunnel was substantially worse for B where concrete spraying and mucking were done in parallel, which is clearly represented in attenuation of laser beam. The peak dust level does not reflect the general environment in the tunnel as it was reached only in limited parts where mine cars caused a mass of dust to float near the base course.

④ Controller

As laser beam attenuation varies depending on the rock type, irradiation distance, etc., it is most important for the implementation administrator to make appropriate decisions as to ventilation. Accordingly, the controller was installed near the laser head so that appropriate ventilation amount can be selected freely and easily, comparing the light intercepting level with the underground environment.

5. Work execution record

- Ministry of Construction : Construction of a temporary drainage channel in Tomisato Dam (Ehime Prefecture)
  Shiotsu Tunnel construction (Shiga Prefecture)

- Shimane Prefecture: Tsumesaka Tunnel construction

6. Usage conditions

① As for exhaust gas, vapor and temperature for which laser beam is not attenuated, corresponding attenuation should be added according to the site condition in determining air volume.

② As attenuation varies according to the rock type, a constant watch should be kept on attenuation and underground environment suitable to the site condition.

Segment Automatic Carrier System for Shield Works

Applicable type of work: Shield Tunneling Method	Official price: ¥200,000,000~¥1,000,000,000
Classification:	
Purpose of the development: Manpower saving, time-saving, Improvement of work environment	Lease and rental:
Level of practical use: Available on the market	Development company: SHIMIZU CORPORATION

Information	Company name:	SHIMIZU CORPORATION
	Address:	Machinery Technology Department Civil Engineering Division No.2-3, Shibaura 1-chome, Minato-ku, TOKYO JAPAN
	Phone:	(81)3 5441 0556
	Fax:	(81)3 5441 0515

1.Application

The shield works to construct the linear-shaped underground space such as the roads, railroads and life lines.

2.Outline

This system enable the segments to be conveyed from the stock yard on the ground to the erector in the rear of the shield tunneling machine without manual operation.
The system consists of the following components:
1)Battery-operated carriages which are automatically controlled by "central control unit".
2)Automatic segment-stock-rack device
3)Automatic elevator
4)Segment-lifting and transfer device
5)Central control unit and optical communication system

(1)Battery-operated carriages
Battery-operated carriages are primary components of the system and play an important role in conveying the segments from the ground to the segment-lifting device at the rear of the shield machine by way of the shaft. The carriages receive the orders from the central control unit through optical fiber communications system.

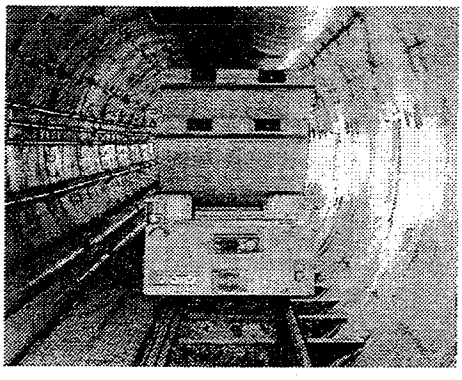


Photo.1. Battery-operated carriages

(2)Automatic segment-stock-rack device
The stucker-crane located between stock-racks goes up, goes down, runs, loads and unloads the specific segment by the order from central control unit.

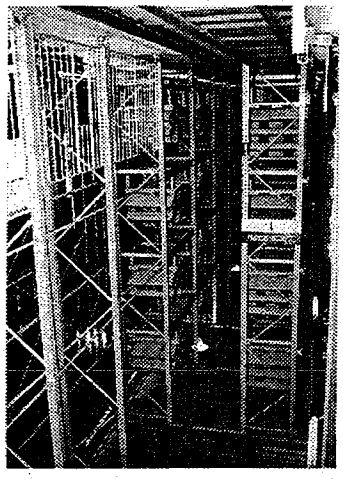


Photo.2. Automatic segment-stock-rack device

(3) Automatic elevator
In this system, the carriages loaded with segments go up and down by the elevator under the efficient operation by the central control unit so that waiting time of the carriages does not occur. Floor of the elevator is equipped with the lock for stopping the carriage wheel for the case of out of control during going up and down. At right position for stop of the elevator , the fixing device is designed to keep the stability for the carriage to go in and out.

(4)Segment-lifting and transfer device
This device has a function to receive the segments from the carriage and hand them to the elevator . It consists of the forklift to receive the segments on the carriage and trolley-hoist to carry the every piece to the erector .Forklift is designed to lift up the segments from the carriage stopped at the specified position due to the signal from the forklift and move the carriage backwards to lift it down to the working range of the trolley hoist. Trolley hoist can grab the segment and rotate within 90 degrees. Those procedures may be performed by the radio control.

(5)Central control unit and optical communication system
Central control unit is placed on the ground and it controls the stock of the segments and operation of the carriage and elevator.

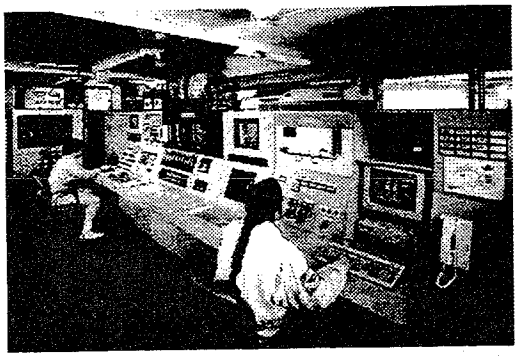


Photo.3. Central control unit

3.Characteristics and effects

① If a storage yard on the surface is not secured and shaft is deep, the segment can be stored inside the shaft. Therefore the amount of surface space required is dramatically reduced.
② The system is effective in reducing the numbers of workers in segment loading and transport.
③ Loading and unloading of the segments is now automated, making the site a safer place.
④ Controlling and monitoring the automated equipment from a central control unit makes the transport process smoother, and contributes to more efficient construction.

4. features of the robotization and automation

The freight load of Battery-operated carriages	3t～10t
The mean to induce Battery-operated carriages	optical communication system
The method to supply segments at the tip of tunnel	by the supply device
The method to stock segments	keep segments to many layer floors each same class and automatically supply

5.Work execution record

Period	1989～1996
Number of work execution	7 (in JAPAN)

6.Usage conditions

Some processes depend upon the man power such as:
① sticking of the waterproofing tapes to the segments
② loading of the segments to the traverser and conveying to the stock-rack
③ inputting of the kind of the segments to be brought in

Stabilator Tunnel Lining Repair System, Hydro-demolisher Jet Rig 2, Robot CSR		Official evaluation:
Applicable type of work:	Restoration of detoriated concrete, lining in circular tunnels.	Official price:
Classification:		
Purpose of the development:	Manpower saving, time-saving, High efficiency, high safety Improvement of work environment	Lease and rental:
Level of practical use:	Available on the market	Development company: STABILATOR AB

Information		
	Company name:	STABILATOR AB
	Address:	Industrivägen 6-8, S-137 37 Västerhaninge, Sweden
	Phone:	+46 (0)8 300 73800
	Fax:	+46 (0)8 500 73805

1. Application

HIgh water pressures demolition of detoriated concrete and restoration of the tunnel support by shotcreting in circular tunnels.

2. Outline

The Stabilator Lining Reapir System is a super efficient equipment for demolition of detoriated tunnel linings, removal of the debris and reinstallation of the tunnel suuport with shotcrete.

The unit consists of a powerful high pressure water jetting pump and nozzle, connected to an individual power pack. The jetting nozzle is controlled by an automatic robot. The debris resulting from the demolition of concrete is removed and collected by a huge vacuum cleaner.

The shotcrete robot is furnished with an automatically controlled oscillating nozzle, which produces a smooth and even sprayed surface. During operation both the water jetting robot, as well as the shotcreting robot, are travelling on a sliding table, resulting in increased coverage area.

The wet shotcrete pump EW 15 R feeds the concrete in a pulsationfree flow, contributing to a superior quality and finish of the concrete lining.

The shotcrete robot CSR is well practicable for shotcreting works in TBM-tunnels generally. All operations are remotely directed from a portable control panel, which enables the operator to choose the most convenient working position.

Each of the equipments is mounted on a separate rail car.

3. Characteristics and effects

① Eliminates all kind of handwork, therefore highest efficiency and safety is achived.

② The removal of the detoriated concrete takes place in a well controlled manner.

③ The vacuum equipment takes charge of the debris in large volumes.

④ The remotely controlled application of shotcrete allows high capacities, while the oscillatory movement

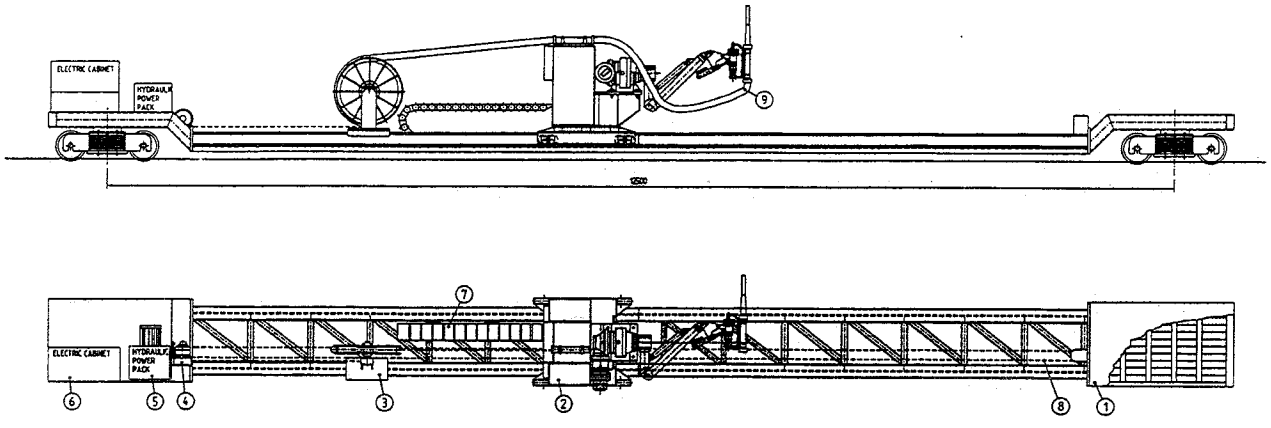


Figure 1. ROBOT CSR

pattern of the nozzle achieves a uniform distribution of shotcrete and an excellent finish of the sprayed surface.

⑤ The automatic travel of the equipments on the sliding tables enables coverage of extensive areas without displacing the entire unit.

4. Features of the robotization and automation

Major specifications	Stabilator Jet Rig 2
Length	14000 mm
Width	1000 mm
Robot travel	9000 mm
Power equipment	11 kW
	High pressure pack
Propellent	2x415 kW diesel
Pump	2x3-piston HP
Water flow	2x187 lit./min.
Water pressure	1000 bar
Meuserment	2x20' container
	Stabilator Robot CSR
Length	14000 mm
Width	1000 mm
Robot travel	9000 mm
Power requirement	11 kW

① Electro-hydraulic operation on/off switchable atuomatic nozzle rotation 360°, movable remote control panel.

② Boom extension 1250 mm, basic boon length according to actual tunnel diameter occasionally.

③ Robot travel: on/off switchable automatic shuttle.

5. Work execution record

Client	Work performed
MTRC Hong Kong	Tunnel lining restoration MTR
Balfour Beatty Ltd.	Breamer Hill, TBM tunnel

6. Usage conditions

① Each part equipment of the system needs only one operator.

② Each part equipment is a complete working tool, useable for individual tasks.

③ Each part equipment is easily adaptable to various tunnel sizes through change of the raobot arm.

④ The range of equipment can be specifically customized to meet the needs of any subterranean project.

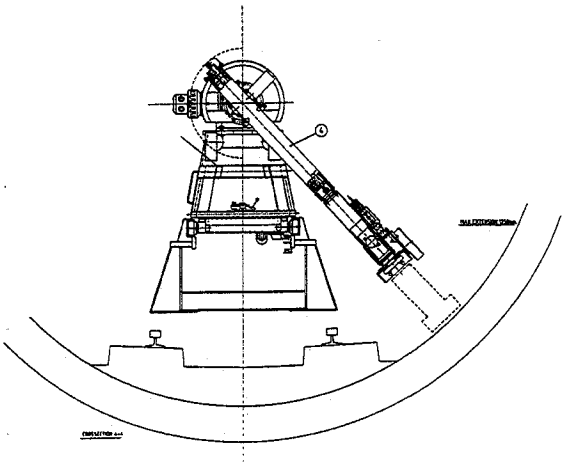


Figure 2. Hydro-demolisher Jet Rig 2.

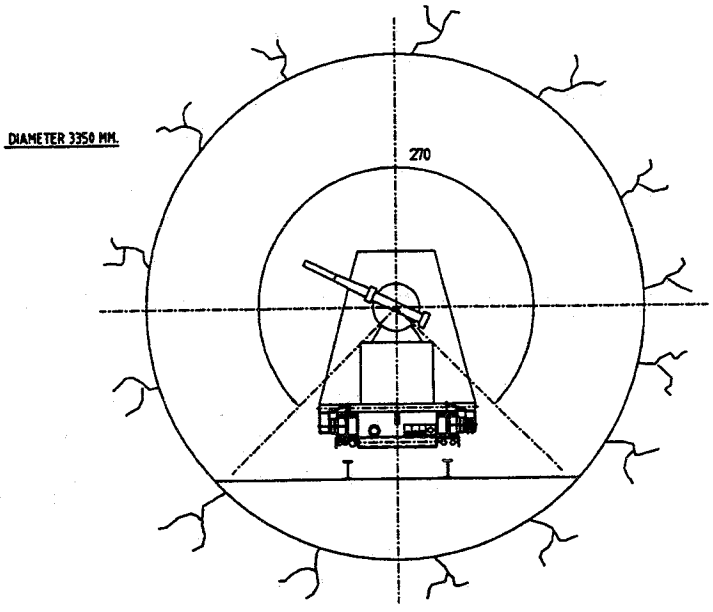


Figure 3. The range of Stabilator Tunnel Lining Repair System

Tunnel Swift Lining Robot

Applicable type of work:	Concrete lining	Official price:	
Classification:	Work execution, maintenance		
Purpose of the development:	Manpower saving, skill saving, improvement of work environment, improvement of productivity, improvement of quality	Lease and rental:	
Level of practical use:	Available on the market	Development company:	Tokyo Electric Power Co., Inc., TEKKEN Corp.
Information	Company name: TEKKEN Corp.		
	Address: Engineering Business Dept., Engineering Div., 5-3, 2-chome, Misaki-cho, Chiyoda-ku, Tokyo, Japan		
	Phone: +81 (0)3 3221 2179		
	Fax: +81 (0)3 3239 1685		

1. Application

Concrete lining for repair work in existing tunnels and for tunnel works.

2. Outline

In the TSL method, the tunnel lining is formed by shotcreting accelerating concrete into the space between the interior form equipped with an endless belt, which is movable along the tunnel periphery.

The TSL robot consists of a movable form equipped with an endless belt, an extending and shortening arm the form, a swivel equipment, a sliding equipment and a hydraulic and electric unit. The entire equipment is mounded on an under-carriage with geared wheels and caterpillar tracks.

The rotation of the extending and shortening arm, the slide at the rotary portion, the belt rotation and the thrust force of the movable form are automatically controlled by computer. The computer controlled TSL robot provides the swift and high-quality lining work, preventing the problems such as the dust and the rebound of shotcrete.

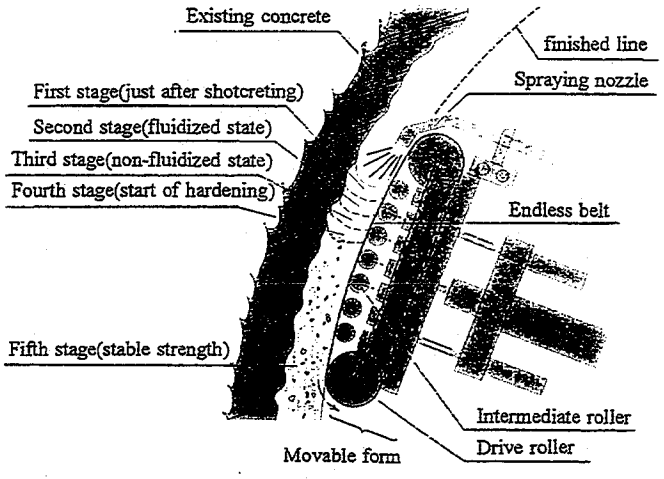


Figure 1. Conceptional illustration of TSL method

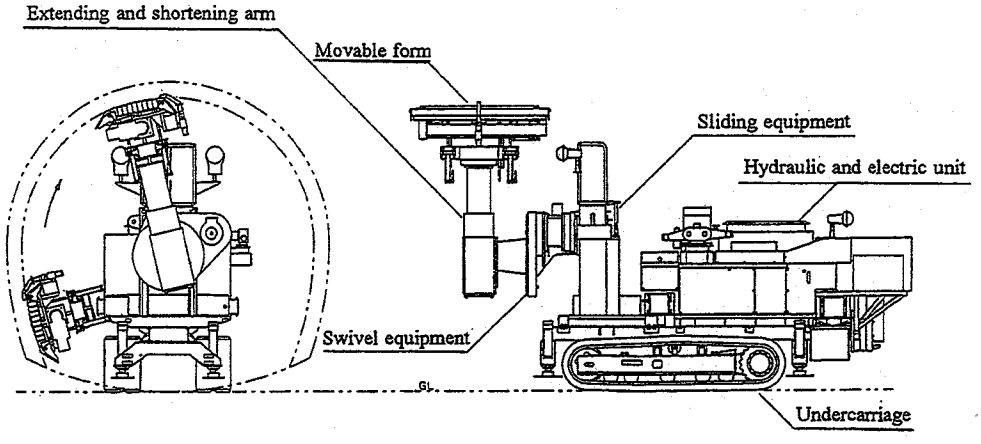


Figure 2. Conceptional illustration of TSL robot

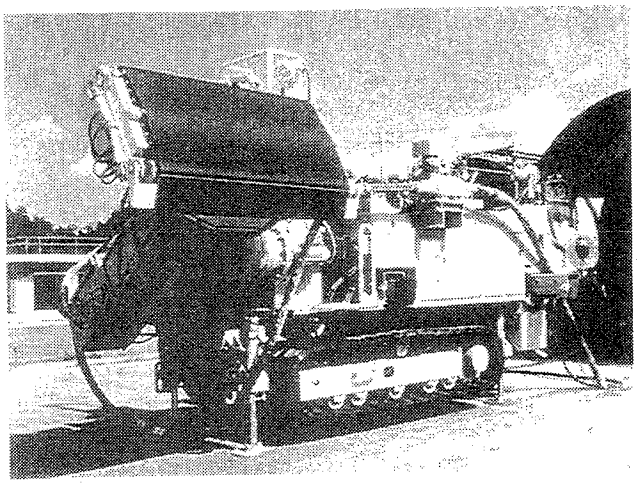


Photo 1. TSL robot

3. Characteristics and effects

① Tunnel lining in various tunnels is executed by the control system, which consists of the extending and shortening arm, the rotary equipment, and the sliding equipment.

② The formation of the high-quality lining is held by automatically controlling the rotation of the extending and shortening arm, the slide of the rotary portion, and the belt rotation and thrust force of the movable form.

③ Lining work is executed by remote control, which makes it for labors to maneuver the machine within a safe distance from the movable form.

④ The dust and the rebound of shotcrete are reduced by the endless belt structure of the movable form and shotcreting in low pressure.

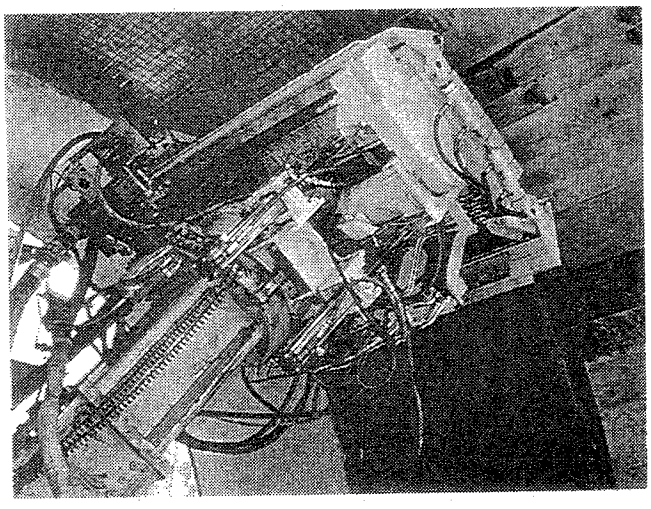


Photo 2. Movable form

4. Features of the robotization and automation

Major specifications:	TSL robot
Weight	10 tf
Size	6400 mm*1600 mm*3150 mm
Required power	AC400V*45kW
Form equipment	Endless belt(1500 mm*700 mm)
Transportation speed	Max. 20 m/min, min. 10 m/min
Applicable cross section	1250 to 2400 mm in radius, horseshoe/hood shape
Lining speed	30 mm/min
Lining thickness	5 to 40 cm
The dust	1 mgf/m ^{3}

① Robot positioning is controlled by measuring distances from the tunnel periphery with ultrasonic sensors attached to the robot body. By this, the robot is positioned with good accuracy and set at quick time.

② Movable form positioning is controlled by measuring the arm length and the stroke of each thrust jack with stroke detectors, and the rotated angle and the rotating speed of the arm with rotation detectors. The rotary motion of the arm coincides with that of the endless belt at the same revolution speed.

5. Work execution record

Period	January, 1994 to March, 1994	
Ordered by	Gunma branch, Tokyo Electric Power Co., Inc.	
Project name	Fuseda Power Station Water Tunnel Repair Works	
Contents	Tunnel cross section	1863 mm in radius, horseshoe shape
	Lining thickness	10 cm
	Total length	68 m

6. Usage conditions

① The TSL robot is operated by a series of system which consists of the system for concrete supply and end form equipments.

② The end form equipment is firmly fixed to withstand thrust force and to hold level, width and space in good accuracy.

③ To surely execute lining work, mix proportion and the amount of accelerator are designed, conducting tests for mixing and pressurized pumping.

Segment Automatic Building Intelligent System "SABIS"

Applicable type of work: Segment assembly	Official price: To be given separately
Classification: Execution of work	
Purpose of the development: Conservation of labor, energy, and improvement of working environment	Lease and rental: None
Level of practical use: Field tests completed	Development company: Hazama Corporation, NKK Corporation

Information
Company name: NKK Corporation
Address: Shield Tunneling Machinery Engineering Sec., Steel Structure and Machinery Engineering Dept. 2-1 Suehiro-cho, Tsurumi-ku, Yokohama 230
Phone: 045-505-7496
Fax : 045-505-7501

1. Application

Automatic transporting and assembling segments for shield tunnelling work.

2. Outline

The automatic segment transporting and supplying system installed in the back end of the shield machine automatically transports the segment to a point immediately before the erector (automatic transporting system). Thereafter, the erector automatically swings and grips the segment. The segment is then raised to the prescribed position, roughly positioned, and adjusted to ensure that the segment is accurately positioned (automatic positioning system). The segment positioned in place is bolted together with the existing segment by a system that automatically supplies the bolts and nuts as well as bolting the segments together.

Accordingly, the system is such that it systematically and automatically transports and bolts the segments together.

The general drawing schematically illustrating the system is given in figure 1.

3. Characteristics and effects

① The segment is gripped by a automatic transporting and assembling system using the conventional screw-in type of grout holes. Therefore, the segment is gripped safely and firmly.

The segments are used intact as RC segments specified in the standards established by the Japan Society of Civil Engineers and Japan Sewage Works Association.

② Positioning is carried out in two stages. The first positioning stage is carried out at a high speed, while the second stage is carried out slowly and accurately. Therefore, the segment is positioned systematically, rapidly, and accurately.

③ The position of edge faces of existing ring is measured. Since the system is provided with a mechanism to correct the direction of end face alignment, the second positioning stage is carried out simply to perform the assembly work rapidly.

④ Since bolts and nuts sufficient for segments of 1 ring are contained in the bolts and nuts-retainers, it can be carried to the prescribed position and fastened together with existing segments without difficulty. Furthermore, since a multiple of fastening units are used to join segments at once, the joining work is carried rapidly.

⑤ Automatic, step-by-step or manual operation modes can be selected freely.

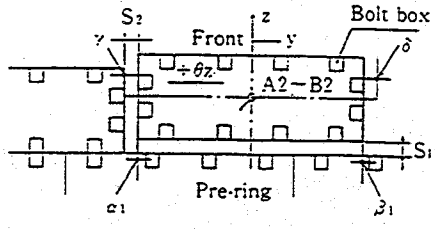


Figure 2. Sensing position and dimensions.

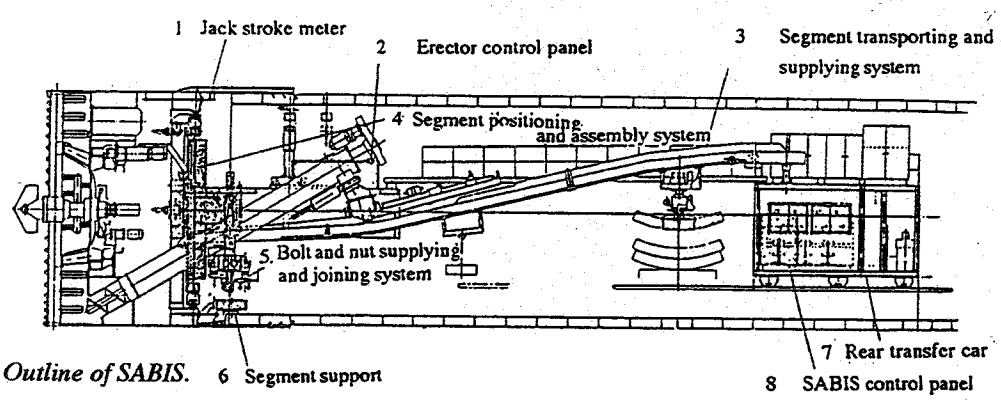


Figure 1. Outline of SABIS.

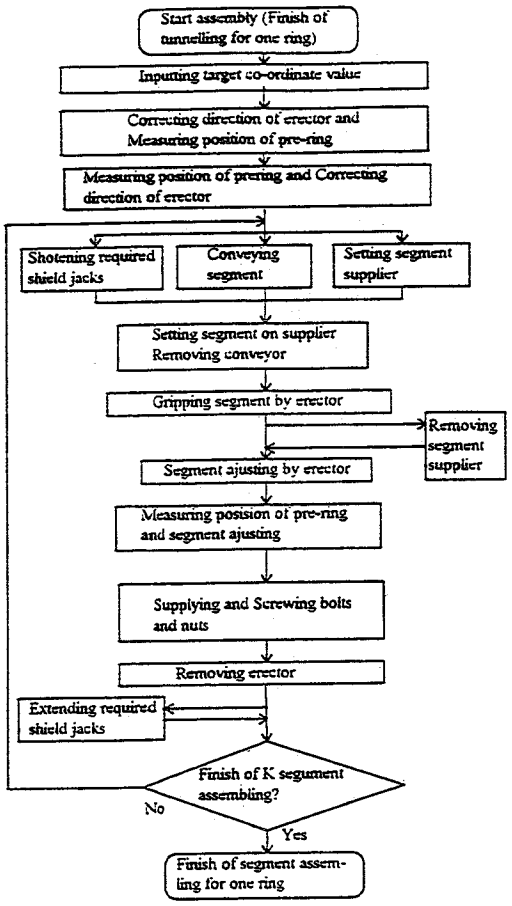


Figure 3. Flow chart of systemcontrol.

4. Features of the robotization and automation

The features of respective systems are given below.

(1) Automatic segment transporting and feeding system

The segment delivered to the site by means of a traveling transfer car is hoisted by utilizing the grout hole, and automatically moved towards the erector. While the segment is moving, it is automatically turned 90°, and the ends of the segment are placed on pads. The segment positioned on the pads is finely adjusted so as to allow the erector to automatically grip the segment.

(2) Automatic positioning of segment

The segment is automatically positioned in steps given below.

① Measurement of end faces: Five hydraulic cylinders with built-in stroke sensors are positioned against the end faces of existing segments. The stroke of hydraulic cylinders are measured. Data thus collected is processed. Pitching and yawing-rings are inched to put the swinging plane of erector in parallel with existing segments.

② Primary positioning (rough positioning): Newly installed segment is positioned in the proximity of assembly inputted beforehand. That is, the segment is moved to a position of about 20mm from the clearance between the existing and new rings, and clearance between the pieces.

③ Secondary positioning (precision positioning): As soon as primary positioning of segment is completed, the erector is swung to a position where the alarm signals of laser sensor γ (or δ) are turned on and swing scanning is stopped. Then the existing measured value of laser sensor α_1, β_1 is read, compared with target value and the positioning of segment in the diametric direction (in the direction of aligning the inner surface) is corrected. The procedures are repeated until the two ends fall within the prescribed accuracy range to complete the work. (See figure 2)

④ Pushing action: As the last step, between ring and ring, piece and tpiece, a segment is moved so that the clearance between existing segment is zeroed out. Then shield jacks are applied against the assembled segment at low pressure to complete the work.

(3) Automatic bolts and nuts feeding and fastening system

The system is made up of four feeding units for storing bolts and nuts, and four fastening units for joining segments. However, in order to reduce the number of units for automatic bolts and nuts and joining segments, the system is so designed that the joining units travel along the erector beam. The respective joining units take out one set of bolts and nuts at a time from the revolving feeding unit attached to the ends of the erector beam, and joins the segments by adjusting the clearances between the rings and pieces.

The series of work just mentioned are illustrated in the form of a flow chart in figure 3.

5. Work execution records

Name of project: Kita-Ueno Community-Tunnel Const.
Planned and designed by: Tokyo Natinal-Road Const. Office, Kanto Regional Const. Bureau, Ministry of Construction
Period of work: March, 1990 to January, 1991
Type of shield: Earth pressure shield
Shield OD: ϕ7,450mm
Segment specifications:
Type: RC flat plate
OD x width x thickness: ϕ7,300mm x 1,000 x 325
Division: 5A + 2B + K
K piece: Inserting type in axial direction
Maximum weight of piece: 2.5 tf
Type of joint: Short bolts (joint box)
Time required for assembly: 10 to 15 minutes per piece
80 to 120 minutes per ring

6. Usage conditions

Earth pressure shield --- Segment ID of more than 5.0m
Slurry pressure shield --- Segment ID of more than 4.5m

Multi-Jointed Arm Erector

Application work: Segments Erection in Shield Tunneling	Official price:
Classifications:	
Purpose of the development: Improvement of work environment Work saving	Lease and rental:
Level of practical use: Available on the market	Development company: KAWASAKI HEAVY INDUSTRIES

Information Company name : KAWASAKI HEAVY INDUSTRIES,LTD Civil Construction Machinery Engineering Dept.
Address : Kobe-kurisutarutawa-21F , 1-3 Higasikawasaki-cho , 1-chome , chuouku , Kobe , Japan
Phone : 078-360-8665
Fax : 078-360-8669

1. Application

A Multi-Jointed Arm Erector has been developed for application of segment erection in the shield tunneling method especially for non-circular section shield tunnel such as three-section shield tunnel.

2. Outline

The three-section shield has to be equiped with three sets of a conventional type erectors and segment transport devices , therefore it takes a lot of workers and cost.

In order to solve this problem ,this inovative Erector which consists of a pair of arms and a rotating ring has been developed.

By installing this new Erector in the center of the three-section shield , it permits the erection of the all type of the segments including the segments for the sub-shields and that it is possible to improve the work environment and create work savings.

3. Characteristics and effects

(1) This new Erector enables four-axis operation (Fig 3.) consisting of multi-jointed arm operation and ring rotation . Thus it achieves many degree of freedom in motion and makes easy to erect the complicate shape of segments at any pose .

(2) For the operation of the erector , either the separate movement by each axis or composite movements by more than two axes can be selected . In case of composite operation , without change of the pose of segments , the movement corresponding to that of joy-stick lever is realized according to the operator's will.

Therefore anyone can soon operate it without special skill at any place with portable wireless control box .

(3) As a pair of arms is equipped with the rotating ring , it is able to support or lift the next segment by the pair of arms during at the pair of arms working for insert of the segment .

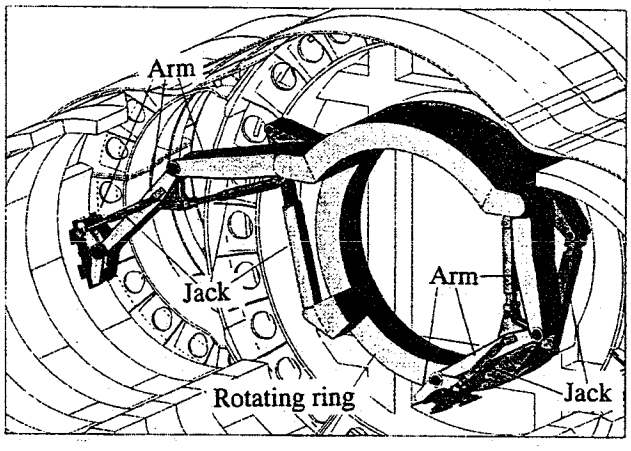


Fig 2. Bird's eye view of Multi-Jointed Arm Erector

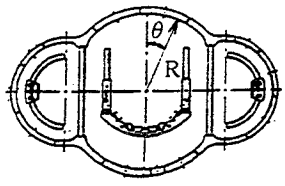
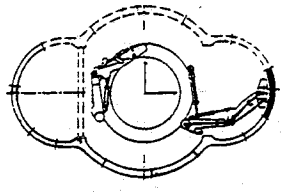
	conventional type	Multi-Jointed Arm Erector
main mechanisim	mono-axis movement by rotating ring and jack (R , θ)	tri-axis arm movement by jacks and rotaiting ring
layout		

Fig 1. Comparison of erector mechanism

4. Features of the robotization and automation

Major specifications	Multi-jointed arm erector
Maximum load	5,290 kg
Ring drum dia.	5,750 mm
Revolution speed	0.5 RPM

The angle (θ) of the arm is changed by the velocity command of the jack for the arm and , at the time of the composite operation the rate of each arm's velocity command are adjusted by the developed automatic control method , so that the horizontal and vertical movement of the arm can be achieved .

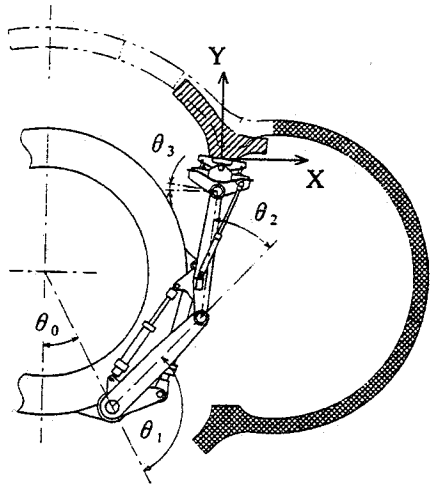


Fig 3. Movement of Multi-Jointed Arm Erector

5. Work execution record

Period (site)	1996.9~
End user	TEITO RAPID TRANSIT AUTHORITY
Client	KUMAGAI. AOKI. JV
Place	Subway Line No7 in Tokyo

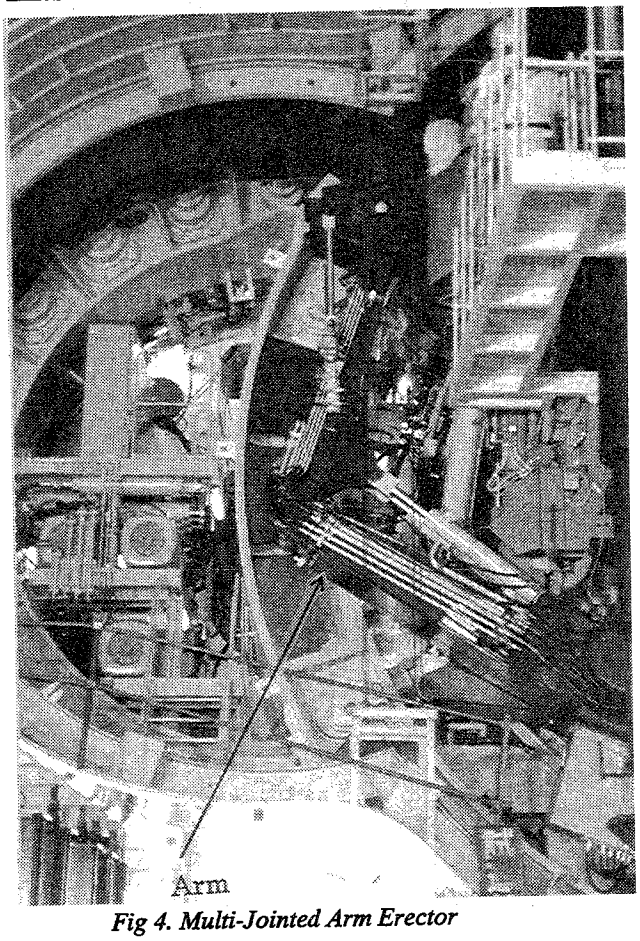


Fig 4. Multi-Jointed Arm Erector

6. Usage conditions

The system needs one operator.

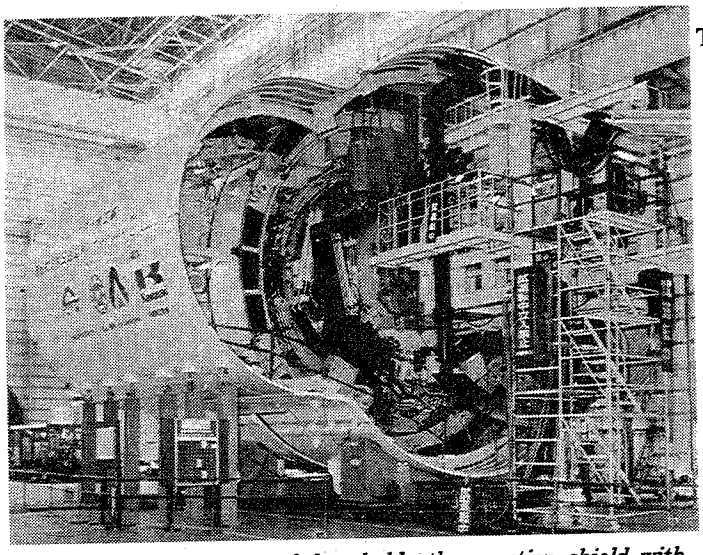


Fig 5. Rear view of detachable three-section shield with Multi-Jointed Arm Erector

Automatic shield direction control system (Fuzzy controlling of deviation and direction deviation amount)	
Applicable type of work: Shield advancing	Official price: Nil
Classification: Execution of works	Lease and rental: Nil
Purpose of the development: Quality improvements, elimination of skilled worker, elimination of manpower	Development company: Maeda Construction Co. Hitachi Construction Machinery Co., Ltd.
Level of practical use: Used in actual tunneling work	

Information: Company name: Hitachi Construction Machinery Co., Ltd.
(Engineering Department, Tunneling Machinery Division)
Address: Nippon Building, 2-6-2, Ohtemachi, Chiyoda-ku, Tokyo 100
Phone: 03-3245-6351 Fax: 03-3246-4921

1. Application

Automatically controlling the shield advancing direction after planning the route of shield driving.

2. Outline

Estimate the machine's deviation amount and direction deviation amount based on the data from the automatic measuring device, the machine's deviation amount and direction deviation amount, and segment conditions, and obtain the modified target line.

Using the fuzzy control, select the jack pattern that decides the moments applied to the machine so that the machine coincides with the target line.

3. Characteristics and effects

(1) The deviation amount and direction deviation amount of the machine and segments are calculated, indicated and stored based on the measured data in the tunnel and the on-line data from the gyroscope and level sensor.

(2) The most adequate jack pattern for the modified target line obtained by estimating the deviation amount and direction deviation amount per ring can be selected, and a series of the jack operation from starting excavation to finishing can be done automatically.

(3) Based on the change of the machine's deviation amount and direction deviation amount from the modified target line, the most appropriate jack pattern can be selected while checking the tail clearances.

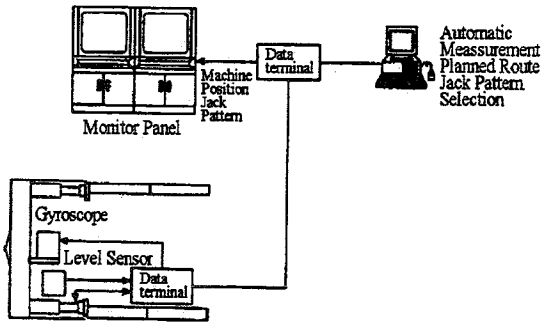


Fig 1. System Configuration

4. Features of the robotization and automation

(1) Based on the data from the automatic measuring device in the tunnel and the kind and assembling procedures of the segments to be assembled, the coordinate positions of the end surfaces of the previously assembled segments and deviations from the planned route are calculated.

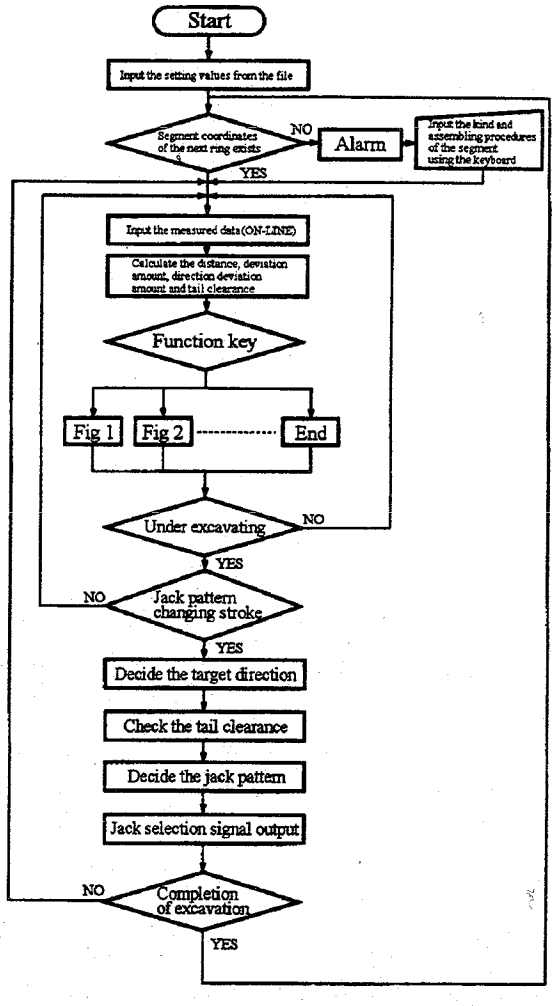


Fig 2. Control System Flow Diagram

(2) Based on the coordinate positions of the end surfaces of the previously assembled segments and the measured data such as the jack strokes, tail clearances and the data from the gyroscope and level sensor, the coordinate positions of the machine and deviations from the planned route are

Table 1. An Example of Fuzzy Rules

Deviation Amount at the Tunnel Face / Variation of Direction Deviation Amount	Small	Medium	Large
Greatly approaches to the modified line	-1	0	0
Slightly approaches to the modified line	0	0	1
No variation	0	1	1
Slightly goes away from the modified line	0	1	1
Greatly goes away from the modified line	1	1	2

-1: Direct to slightly go away from the modified line.
0: Continue the present jack pattern.
1: Direct to slightly approach to the modified line.
2: Direct to greatly approach to the modified line.

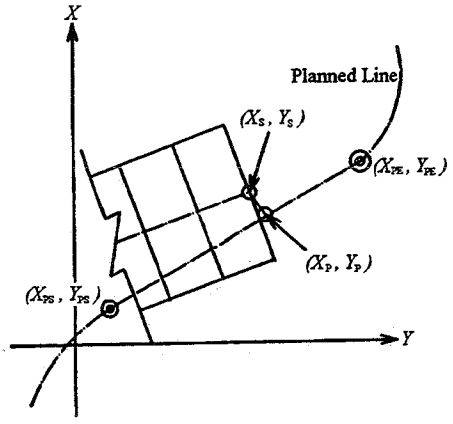


Fig 3. Deviation Amount of Segment End Surface (Horizontal Direction)

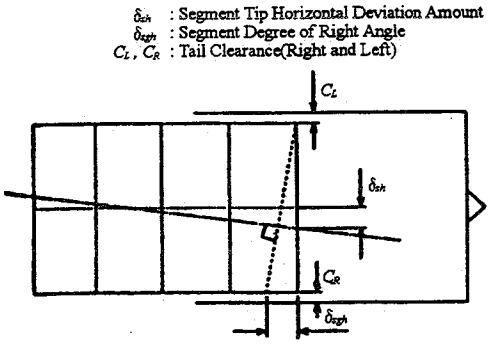


Fig 4. Inputting Measured Data

calculated.

(3) Based on the deviation amount of the shield tip and the direction deviation amount from the last jack pattern check, decide the horizontal and vertical target directions according to each fuzzy rule. Table 1 shows an example of fuzzy rules. The evaluating

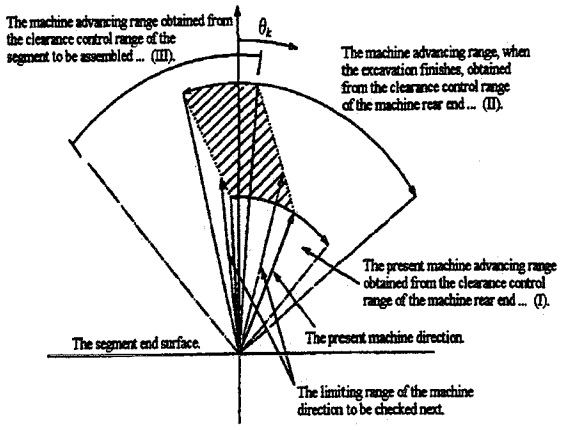


Fig 5. Clearance Control Range and Direction

figures in the table of the deviation amount and direction deviation amount are shown in variable from depending on the conditions.

(4) Calculate the tail clearance based on the calculation data at the end surface of the previously assembled segments. If the tail clearance is within the control range, decide the target direction as stated in (3). If the tail clearance is not within the control range, direct the machine so that it approaches the target direction that considers the clearance. Fig 5 shows an example of the correlation between the clearance control range and the machine advancing range.

(5) The jack pattern of the previously assembled segment is used until the excavation begins. During the excavation the jacks are extended or retracted based on the present jack pattern. Changing the pattern is made independently for horizontal and vertical direction respectively.

5. Work execution record

Time: From December 1993 to April 1994
Project Owner: Kantoh Engineering Office, The Ministry of Construction
Project Name: Azabu Utility Tunnel(Work No. 1)
Place: Higashiazabu 4 chome, Minato-ku, Tokyo
Specifications :Tunnel Length: 918 m
Specifications of Shield: 6.04 m OD DK type Shield

The part of the tunnel where the automatic direction control system was applied: The straight and slightly curved part located on the latter half of the tunnel.

Throughout the above execution, sufficient direction controlling ability for the estimated modified line using the automatic direction control system was confirmed.

6. Usage conditions

(1) In actual using, countermeasures against the data noise and the communication system noise must be considered.

(2) Building up the system construction that considers cooperations with other systems is required.

Shotcrete control system

Applicable type of work:	Concrete spraying in the tunnel (NATM)	Official price:	Separately given
Classification:	Implementation and implementation control		
Purpose of the development:	Quality improvement and productivity increase	Lease and rental:	None
Level of practical use:	Implementation in real works	Development company:	TOA CORPORATION

Information		
	Company name:	TOA CORPORATION
	Address:	Mechanical & Electrical Department, Central Civil Engineering Bureau Yonban-cho 5, Chiyoda-ku, Tokyo
	Phone:	03-3262-5109
	Fax:	03-3262-9536
	E-mail	

1. Application

To automatically add optimum amount of accelerator according to the spraying area and the concrete pumping rate, in concrete spraying works as part of tunneling works (NATM).

2. Outline

This system can be applied to any types of spraying robots, concrete transportation pumps and accelerator supplying equipment, which are components of concrete spraying. It consists of an ultrasonic oscillator (40 kHz), a pulse sensor, a control box and an inverter.

The system identifies the spraying area with the ultrasonic oscillator, and obtains concrete pumping rate with the pulse sensor, and processes these signals in arithmetic operation with the control box. Then it uses the inverter to control the motor of the accelerator supplying equipment so that required accelerator pumping rate can be achieved.

The implementation administrator sets values either through implementation or depending on the machines used.

The system is aimed at automated and labor-saving on-site (implementation) management of concrete spraying works, and at use of an optimum amount of accelerator.

3. Characteristics and effects

① The system can be applied to various types of spraying machines, and an optimum amount of accelerator can be automatically supplied according to the implementation condition as the spraying area (ceiling, shoulder, side wall or bottom half) is identified by the ultrasonic oscillator, and concrete pumping rate is measured based on pulse sensor signals.

② Rebound of shotcrete is reduced and accelerator can be saved because an optimum amount of accelerator is added according to the implementation area. Thus works can be done more economically than by traditional method of supplying a fixed amount.

③ Automated and labor-saving on-site management according to the implementation condition becomes possible.

4. Features of the robotization and automation

① Identify spraying area

In spraying works, as spraying proceeds from the side wall to the ceiling, the spraying nozzle goes upward. Therefore, the distance to the base course as measured by the ultrasonic oscillator attached to the nozzle arm shows where spraying is taking place.

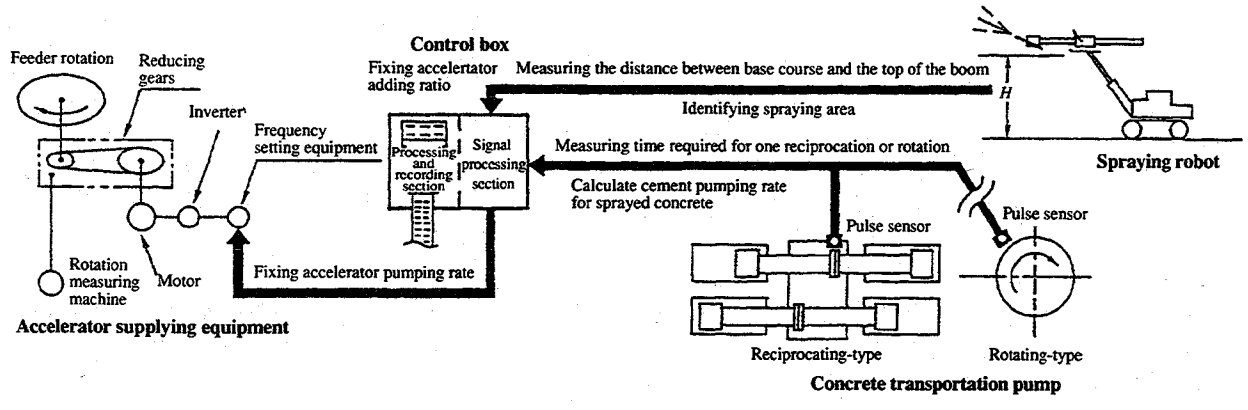


Figure 1. Shotcrete control system overview.

Table 1. Items to be set in the control system.

Category	Items to be set by the implementation administrator	Symbol	Unit
Implementation	Cement content of sprayed concrete	C	kgf/m^3
	Spraying area (1) Start of shoulder	H_1	m
	Spraying area (2) Start of ceiling	H_2	m
	Accelerator addition (1) Ceiling	K_1	%
	Accelerator addition (2) Shoulder	K_2	%
	Accelerator addition (3) Side wall, bottom half	K_3	%
Machine	Maximum number of rotation of feeder	Nm	rpm
	Feeder characteristic	A	–
	Capacity efficiency of concrete transportation pump	V	%
	Net capacity of concrete transportation pump	E	ℓ

② Measure concrete pumping rate

Concrete pumping rate (Q) can be represented by the formula below regardless of the type of the transportation pump.

$$Q = 3600 \times E \times V / S \ (\text{m}^3/\text{hr}) \quad (1)$$

E: Concrete filling ratio (%)
V: Net capacity of transportation pump (m^3)
S: Seconds required for one rotation or reciprocation of pump (seconds)

As the filling ratio (E) depends on the concrete material characteristics and the net capacity (V) depends on the machine used, measurement of intervals (rotation or reciprocation) with the pulse sensor leads to concrete pumping rate (Q).

③ Decide on the accelerator adding ratio, and calculate pumping rate

Once the implementation administrator decides on the accelerator adding ratio (K) according to the spraying area (ceiling, shoulder or side wall), the accelerator pumping rate (q) can be obtained by the following formula.

$$q_i = K_i \times C \times Q / 100 \ (\text{kgf/hr}) \quad (2)$$

i: Spraying area (1 ceiling, 2 shoulder, 3 side wall)
C: Cement content of concrete (kgf/m^3)

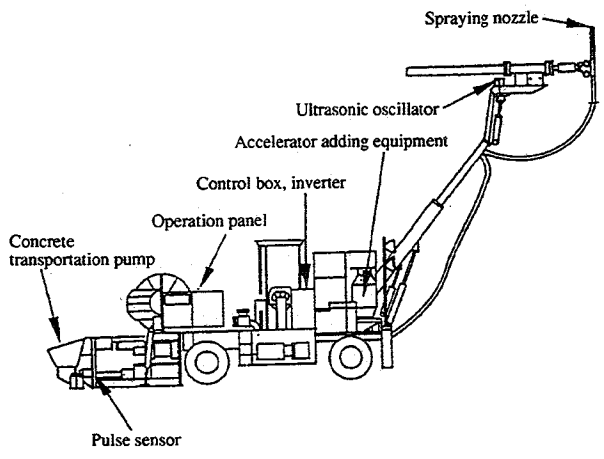


Figure 2. System configuration.

④ Set the feeder characteristic

The feeder characteristic (A) represents the accelerator pumping capability when the accelerator supplying equipment keeps rotating for one hour at 1 rpm, and generally varies according to the type of the equipment. The value is obtained through calibration in which pumping rate is calculated by changing the number of feeder rotation (N) of the equipment actually used.

The accelerator pumping rate (q) can be shown in the following formula, using the feeder characteristic(A).

$$q = A \times N \ (\text{kgf/hr}) \quad (3)$$

⑤ Fix feeder rotation number

The number of feeder rotation should be fixed so that the formula for calculating the accelerator pumping rate required for spraying works (2) may equal that for obtaining the accelerator pumping rate of the accelerator supplying equipment (3). The following formula gives the number of rotation for each spraying area.

$$N_i = K_i \times C \times Q / A / 100 \ (\text{rpm}) \quad (4)$$

Under this system, the operating frequency (ω_2) is determined based on the ratio between maximum feeder rotation number (N_m) and required rotation number (N_i) for the line frequency (ω_1) as shown below. Then required number of rotation is controlled for each spraying area by the inverter.

$$\omega_2 = \omega_1 \times N_i / N_m \ (\text{Hz}) \quad (5)$$

The maximum feeder rotation number (N_m) can be changed by changing moderation ratio of the reducing gears. In view of the on-site implementation, however, it means the maximum ratio of accelerator addition.

5. Work execution record

① Test implementation

• Aliva 280 + Dynamic shooter
Ministry of Construction: Construction of the Aioi Dai-ni Tunnel (Shimane Prefecture)

• Dynamic lorry (2000V)
Japan Highway Public Corporation: Construction of the western part of the Kasaiyama Tunnel Line B (Okayama Prefecture)

② Live implementation

• Dynamic lorry (2000S)
Chiba Prefecture: Toyofusa Dai-ni Tunnel construction

• Dynamic lorry (2000V)
Ministry of Construction: Shiotsu Tunnel construction (Shiga Prefecture)
Shimane Prefecture: Tsumesaka Tunnel construction
Nagano Prefecture: Mikkamachi Tunnel construction

6. Usage conditions

① It is necessary to maintain the quality of sprayed concrete (slump). (An automatic slump adjuster is required.)

② One and the same system is used either for the rotating or the reciprocating spraying machine. But the ROM in the controller is different.

Automatic slump adjusting system

Applicable type of work:	Concrete spraying in the tunnel (NATM)	Official price:	Separately given
Classification:	Implementation and implementation control		
Purpose of the development:	Quality improvement and productivity increase	Lease and rental:	None
Level of practical use:	Implementation in real works	Development company:	TOA CORPORATION

Information	Company name:	TOA CORPORATION
	Address:	Mechanical & Electrical Department, Central Civil Engineering Bureau Yonban-cho 5, Chiyoda-ku, Tokyo
	Phone:	03-3262-5109
	Fax:	03-3262-9536
	E-mail	

1. Application

The system is aimed at conducting stable spraying work regardless of surface moisture of fine aggregate in tunneling (NATM) by constantly mixing and shipping concrete of uniform characteristic (slump in particular) in the batcher plant.

2. Outline

In spraying concrete, there are cases in which no expected concrete characteristic is obtained as a result of changes in the predetermined water-cement ratio (*W/C*) and fine aggregate ratio (*S/a*) owing to changes in surface moisture of fine aggregate during mixing. For example, fine aggregate on the conveyor belt is dry while aggregate in the hopper is wet with the humidity being higher in the lower part of the hopper. Putting additional fine aggregate into the hopper from the aggregate bin also causes surface mixture to change.

This system solves the above problems by utilizing the nature that mixer current after certain amount of time has passed since the start of mixing is the same for concrete having the same characteristic.

At the start of the works, concrete is mixed on a trial basis based on the on-site conditions such as shotcrete material and the type of machines used, and then the mixture is selected which provides appropriate shotcrete . The automatic slump adjusting system relates the deviation from the selected mixture for fine aggregate in terms of surface mixture, and adjust surface mixture so that concrete having slump suitable for spraying can be obtained.

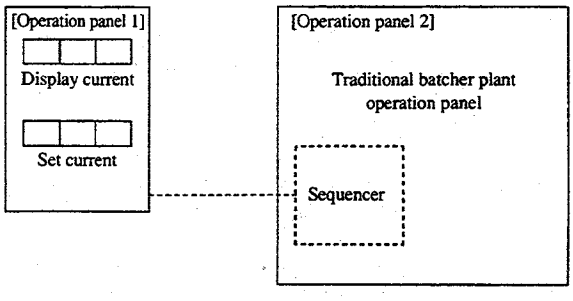


Figure 1. Automatic slump adjusting system components.

3. Characteristics and effects

① As the optimum surface mixture is automatically fixed even during mixing, it becomes unnecessary to control surface mixture each time spraying is carried out. Even when the implementation cycle is shorter, twice-a-day control in the morning and in the afternoon is sufficient to obtain satisfactory concrete.

② Even when fine aggregate having different surface mixture is received depending on the on-site condition (mainly the weather), the surface mixture is automatically adjusted to the optimum value in the mixing process. Thus concrete characteristic remains unchanged, resulting in stable spraying.

③ Stable spraying become possible. Then rebound of shotcrete, and loss of accelerator are decreased, resulting in more economical spraying works.

④ It is necessary to identify the concrete characteristic during trial mixing, and determine based on the mixer current how much adjustment should be made in terms of surface mixture.

4. Features of the robotization and automation

① System components

The system consists of two operation panels, 1 and 2. Operation panel 1 sets the base mixer current, and displays the mixer current at the end of detection time. Operation panel 2 is a traditional panel in the batcher plant equipped with a sequencer which is used to determine based on the mixer current how much adjustment should be made in terms of surface mixture.

② How the automatic slump adjusting system works

The system seeks deviation in mixer current and slump from the base mixer current which provides for optimum slump, by intentionally changing surface mixture in trial mixing, and, based on the data, automatically makes adjustments to surface mixture so that optimum slump can be achieved.

On-site system implementation flow is shown below.

1) Trial mixing is carried out at the batcher plant with an appropriate mix proportion, and with adjustment in surface mixture, using aggregate with a known surface mixture to confirm the expected concrete characteristic and slump.

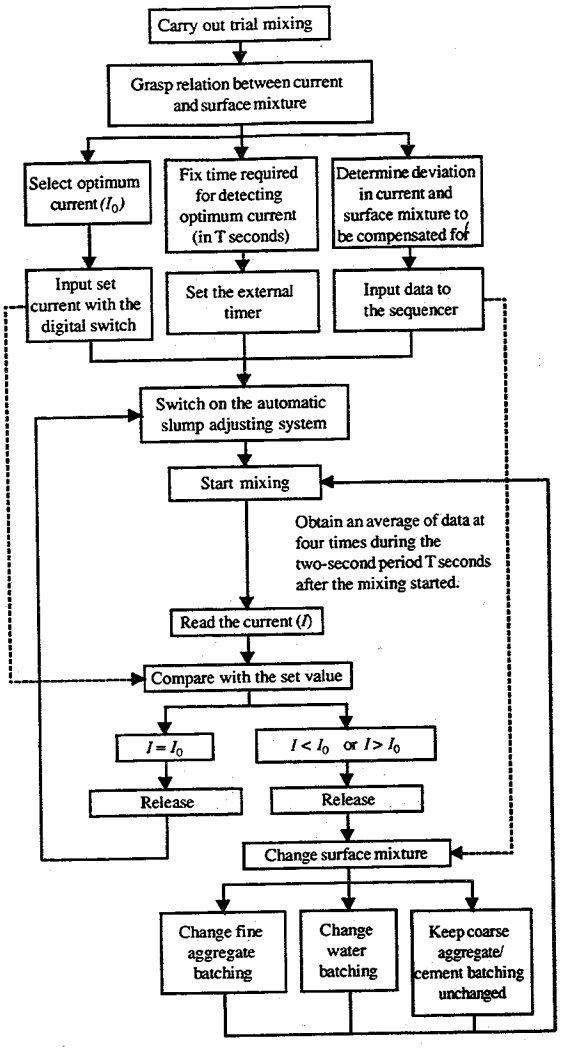


Figure 2. Flow of automatic slump adjusting system implementation.

2) In the above process, the time required for the mixer current to become constant is measured, which is then specified as the detection time and the current which is now constant is specified as the set current. The slump at the time is also recorded as the base value.

3) Then the surface mixture is changed on purpose, and mixing is carried out. The current at the point when the detection time passed, and slump after mixing are recorded. This sequence is repeated an appropriate number of times, and concrete characteristic (deviations in terms of mixer current and slump) according to the varying surface mixture is grasped (Figure 3).

4) The optimum level of surface mixture adjustment in the case of deviation of mixer current from the regular range is obtained from 3) above, which is then input to the sequencer in the operation panel (Table 1).

5. Work execution record

- Construction Ministry: Shiotsu Tunnel construction (Shiga Prefecture)
- Japan Highway Public Corporation: Obatake Tunnel construction (Fukushima Prefecture)

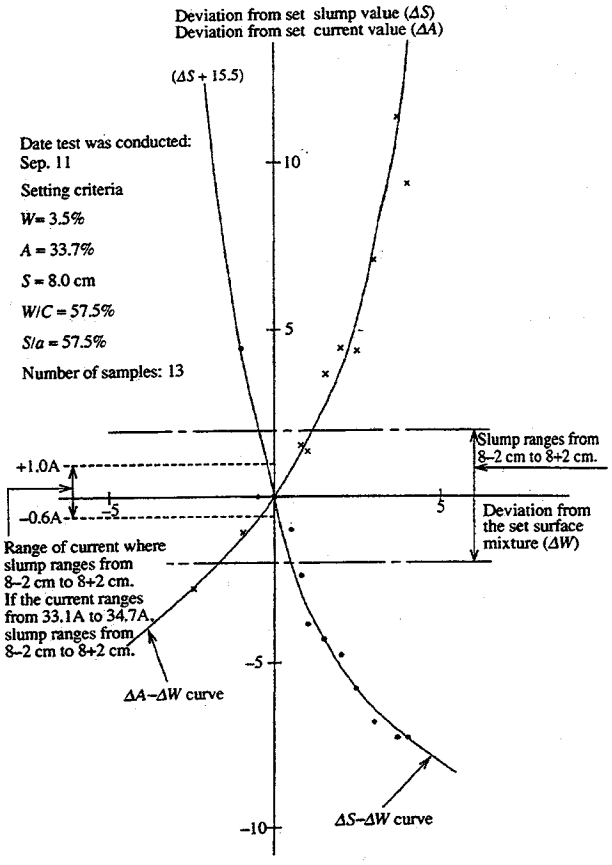


Figure 3. Grasping characteristics with varying surface mixture (Obatake Tunnel).

Table 1. Set values for the automatic slump adjusting system (Obatake Tunnel)

Change in mixer current (I–I_0)	Change in surface mixture (%)
–7.6 or below	+3.2
–5.6 to –7.5	+2.6
–3.6 to –5.5	+2.0
–1.6 to –3.5	+1.4
–1.1 to –1.5	+0.8
–0.6 to –1.0	0
0.5 to –0.5	0
0.6 to 1.0	0
1.1 to 1.5	–0.8
1.6 to 3.5	–1.4
3.6 to 5.5	–2.0
5.6 to 7.5	–2.6
7.6 or above	–3.2

- Shimane Prefecture: Tsumesaka Tunnel construction
  Nagano Prefecture: Mikka-machi Tunnel construction

6. Usage conditions

The set value for the automatic slump adjusting system varies according to the construction works as concrete characteristic is different for different aggregate. Under this system, it is possible to freely set the surface mixture adjustment range. It is most important to define ranges based on the full consideration of concrete characteristics.

Front Monitoring System for mountain tunnel

Applicable type of work: Geological survey	Official price:
Classification: Investigation	
Purpose of the development: Improvement of safety, time-saving	Lease and rental:
Level of practical use: Applied construction sites	Development company: HAZAMA CO.&VIC CO.,LTD.

information Company name: HAZAMA CORPORATION
Address: R&D Center , 515-1 Nishimukai Karima Tsukuba-City, Ibaraki, 305, Japan
Phone: 0298-58-8822
Fax: 0298-58-8839
E-mail:

1.Application

Surveying fault fracture zone and geological boundaries ahead of tunnel face by Rayleigh wave method.

2.Outline

Exciter and vibration detectors are placed on the face using anchor bolts or special attachment. Their equipment are controlled by control unit.

3. Characteristics and effects

① The system is able to predict position and width of fault fracture zones which exist at ahead of the face.

② The system is effective as following situations:
a .The existence of large fault is anticipate along tunnel route.
b .Preliminary geological survey is not sufficient.
c .Execution of pilot boring is difficult.

③ The system can be applied to excavation method by blasting, NATM and TBM.

④ Maximum survey range of the system, which depends on rock mass condition, is 20m ahead of the face.

⑤ The survey by the system dose not disturb excavation work, because of rapid survey (15min/point).

⑥ Elastic wave velocity or modulus of elasticity are estimated from Rayleigh wave velocity.

4.Features of the robotization and automation

The system predict the geological condition ahead of tunnel face by Rayleigh wave velocity generated by exciter. Rayleigh wave velocity decreases with in fault fracture zones or weak rock masses. Their geological conditions are able to predict from layer velocity value of Rayleigh wave.

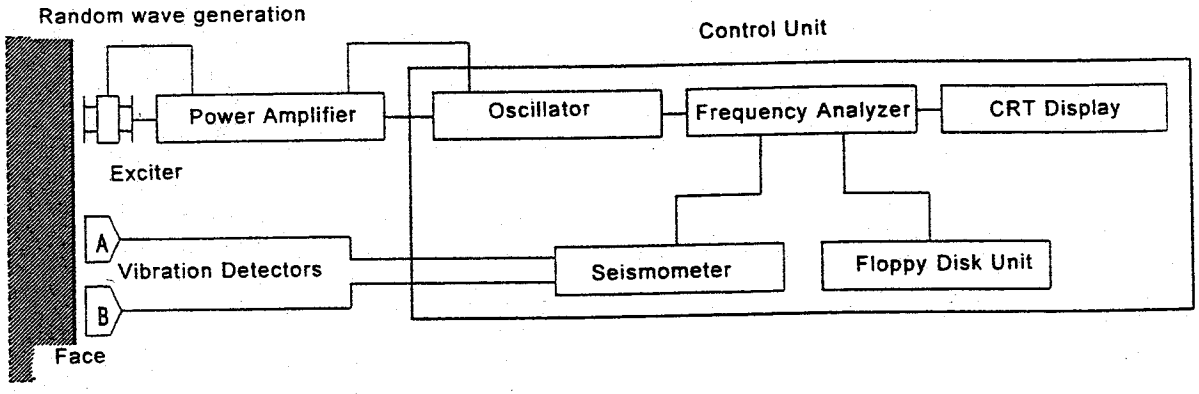


Figure1.Layout of the system

Exciter	Frequency range: 4～10kHz Thrust(Max: kg·G):50 Dimension(mm): 234 ϕ × 304H Weight(kg): 58
Detector	Output impedance: 100 Ω Frequency range: 5～5kHz Sensitivity: 10V/G Power supply: DC± 15V/10mA Dimension(mm): 22 ϕ × 49H Weight(kg): 0.09
Control Unit	Oscillator: 0～10kHz Frequency Analyzer: 0～10kHz Calculator: Depth & Velocity Seismometer: 0～1G CRT Display: 7inches Floppy Disk Unit: 2DD,3.5inches Power supply: AC100～240V 50/60Hz 100VA Dimension(mm):320W×200H×40D Weight(kg): 15
Power Amplifier	Output: 400VA Power supply: AC100～240V 50/60Hz 800VA Dimension(mm):430W×200H×37D Weight(kg): 25

① Exciter can generate various frequency waves, especially, random wave generation enables quick survey.

② There are several kinds of detectors, which correspond to ground conditions. High frequency type detectors are applied for mountain tunnel.

③ Control unit comprises oscillator, frequency analyzer, calculator, seismometer, CRT display and floppy disk unit.

④ Exciter and detectors are can be attached on the cutter face of TBM or drill junbo.

5.Work execution record

Tunneling method	Surveying point	Number of surveying
TBM	Face	11
NATM	Face	3
	Crown	3
Conventional	Face	5

6.Usage conditions

① Surveying difficult in case that rock mass of the face is brittle or cracky.

② Survey outcome is influenced by noise caused by other operation(i.e. blower, drainage facilities and excavation machine)

③ Exciter and detectors must not be place on unstable rock or rough face.

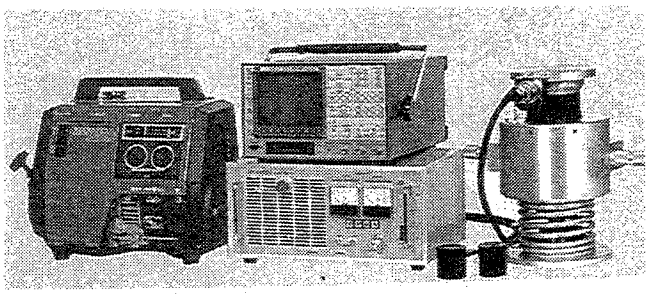


Photo1.Front Monitoring System for mountain tunnel

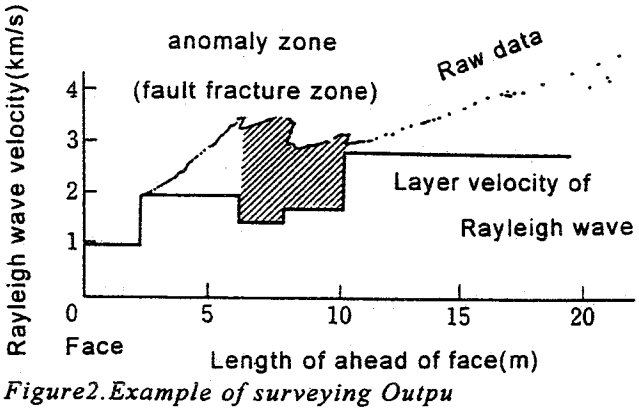


Figure2.Example of surveying Outpu

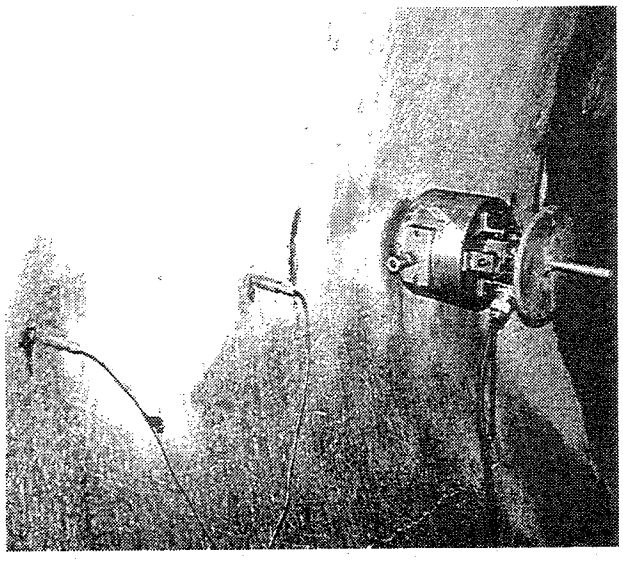


Photo2.Exciter and Detectors placed on the face

Concrete Transportation and Distribution

COMPUTER CONTROLLED MOBILE CONCRETE DISTRIBUTOR

Applicable type of work:	Concrete distribution	Official price:	- Basic price for the mobile concrete distributor
Classification:	Autonomous mobile robot		- Specific features according to the price list of the local representative
Purpose of the labour saving and cost reduction development:	Fast and easy operation, reduction in downtime	Lease and rental:	- yes
Level of practical use:	Used in actual work	Development company:	Putzmeister AG

Information	Company name:	Putzmeister AG	e-mail:	pmw@pmw.de
	Address:	Max-Eyth-Str. 10 D-72631 Aichtal	Internet:	http://www.putzmeister.de
	Phone:	0049-7127-599-0		
	Fax:	0049-7127-599-520		

1. Application

Placing and distribution of concrete in buildings, plants etc.

2. Outline

For economical placing of concrete, truck mounted mobile concrete pumps with placing booms are standard equipment in the building trade. Based on the standard product range the 'Computer Controlled Concrete Distribution Boom' consists in a variety of additional modular features which can be taylored according to the specific customer requirements. These components were designed to improve operation and maintenance of the machines and to increase the efficiency in operating a fleet of vehicles.

3. Features and effects

① Fleet management *PD 2000*

The system will help to optimize the utilization of the vehicles. It ensures the maximum operational availability, the transactions and invoices are accelerated, up to date data are monitored and downtime is minimized.

Multi-resource-scheduling: machinery scheduling, time display etc.

Geographic-information-system: connection of digital land maps, installation of a GPS-receiver in the vehicle, transmission of position coordinates to head office.

Invoicing: of goods, services etc.

Generation of master lists: customer, site, resource, price etc.

② Management systems for maintenance *PARIS*

Optimization in preventive maintenance and inspection to prevent loss of service due to technical causes and to increase the utilization of the fleet.

Maintenance: display of maintenance tasks, monitoring high wearing equipment, workshop and stock management etc.

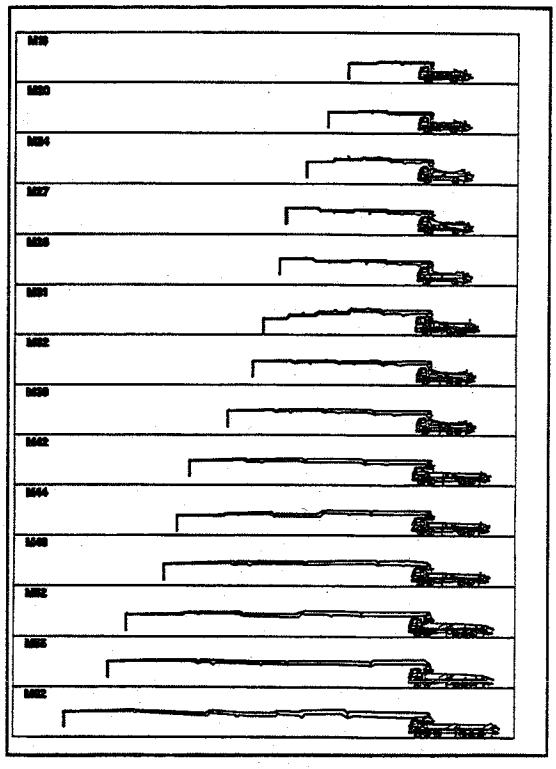


Fig. 1: Standard product range of mobile concrete distributors

Statistical analysis: breakdown rating and cost analysis etc.

③ Automatic stability control *ASC*

The system ensures operation also at difficult worksites were the individual outriggers cannot be folded out completely due to obstacles and other limitations in the workspace (e.g. street).

Locking system: the boom can only move in areas were the stability of the system is ensured taking the individual outrigger positions into account. Other movements generated by the operator are prevented automatically.

④ Automatic mast control *AMC*

The system ensures an easy and, if required, a fully automatic movement of the end hose out of which the concrete emerges. By damping the vibrations of the boom caused by the pumping forces, a smooth movement of the arm structure is achieved.

Servo axis control: position measurement of the piston position, pressure transducers bottom and rod side, cascade servo axis control.

Coordination of the axis: robot control added with specific AMC features such as deflection compensation, coordinate transformation for redundant kinematics, path planning modules with integrated PLC.

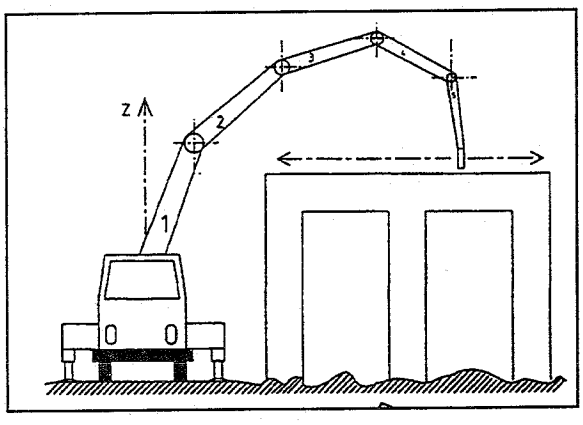


Fig. 2: Coordination of the axis

Operation 'Joystick Control': computer assisted coordinated movement of the axis in carthesian the cylinder coordinates.

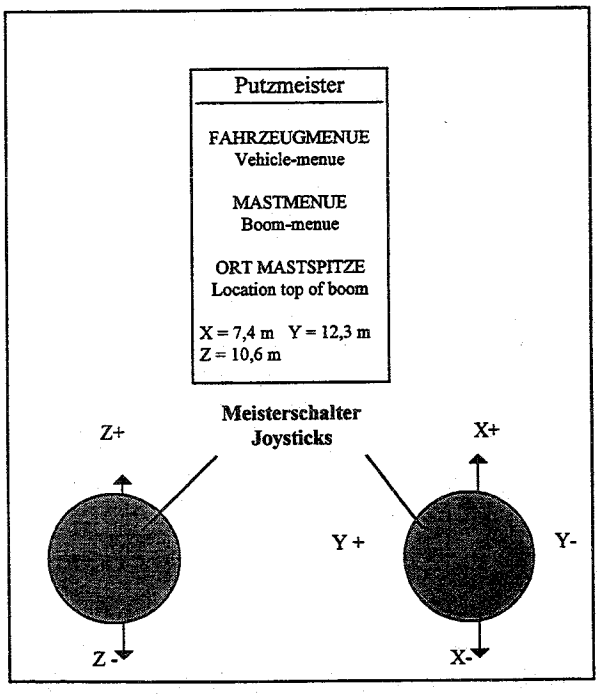


Fig. 3: Joystick control panel

Operation 'Follow me': computer assisted coordinated movement of the end hose. The operator can determine the direction (X, Y coordinates) and the position (Z-coordinates) while pushing the end hose into the required direction and selecting a switch for up and down positions.

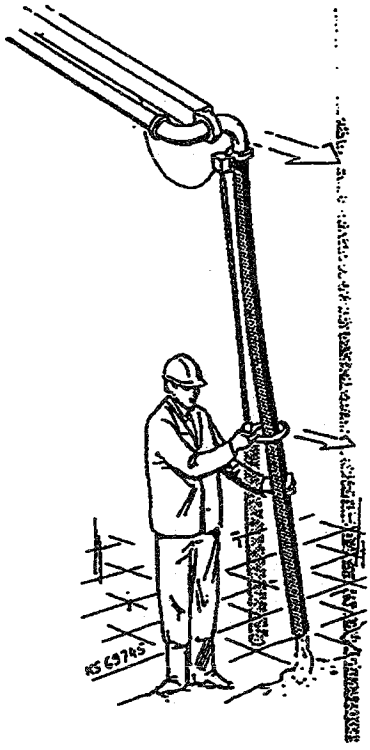


Fig. 4: Operation 'Follow Me'

4. Description of Robotization and Automation

The computer controlled mobile concrete distributor includes features of a manipulator as well as an industrial robot.

A uniform placement of the concrete over the surface by meandering programmes can be achieved in a fully automatic operation supervised by the operator. Difficult movements are possible, e.g. pouring concrete in narrow wooden forms among many other features.

5. Execution Records

The fleet management *PD 2000*, the management system for maintenance and teleservice *PARIS* and the automatic stability control *ASC* are available for nearly the complete product range, the automatic mast control for large booms like M 44. All systems are in practical operation

6. Points of Notice for Use

All movements of the boom are under control of the operator (e.g. acceptance joystick) and in accordance with the usual and accepted safety regulations.

Simplified Distributor "DB ROBO"

Applicable type of work:	Concrete placing work	Official price:	
Classification:	Construction		
Purpose of the development:	Labor saving, improving work environment, upgrading quality	Lease and rental:	
Level of practical use:	Commercialization	Development company:	Takenaka Corporation Sanwa Matoron Co., Ltd.

Information	Company name:	Takenaka Corporation
	Address:	21-1, 8-chome, Ginza, Chuo-ku, Tokyo, 104, Japan Public Relations, General Headquarters
	Phone:	03-3542-7100
	Fax:	03-3545-9083
	E-mail	

1. Application

Concrete placing work

2. Outline

The principal specifications and the outline drawing of the DB ROBO are shown in Table-1 and Fig-1, respectively. The DB ROBO is composed of a concrete distribution section and a traveling section.

The distribution section is equipped with a pipe for concrete placement. The tip of the pipe is of a rubber hose construction, and the hose end is moved up and down by a winch. The distribution section turns horizontally at two places, pipe center and hose end, so that the hose end can be moved through a wide range.

The traveling section has a pair of rails on which to travel, and the distributor section can travel on the rails. By raising the traveling section from the work floor using a center jack, it can be turned in arbitrary directions and the rails can be moved in the traveling direction.

Name	DB ROBO
External Dimensions (mm)	5050 x 3600 x 1690
Weight	770 kg
Power Source	5.0 KVA (AC200V)
Distribution Pipe & Hose Diameter	4B (ø100 mm)
Rotational Speed	2.8 r.p.m
Hose End Swing Speed	4.4 r.p.m
Hose End Vertical Speed	512 mm/sec
Traveling Speed	15.0 m/min
Jack Elevating Speed	20.0 mm/sec
Turning Speed	1.9 r.p.m

Table-1 Principal Specifications

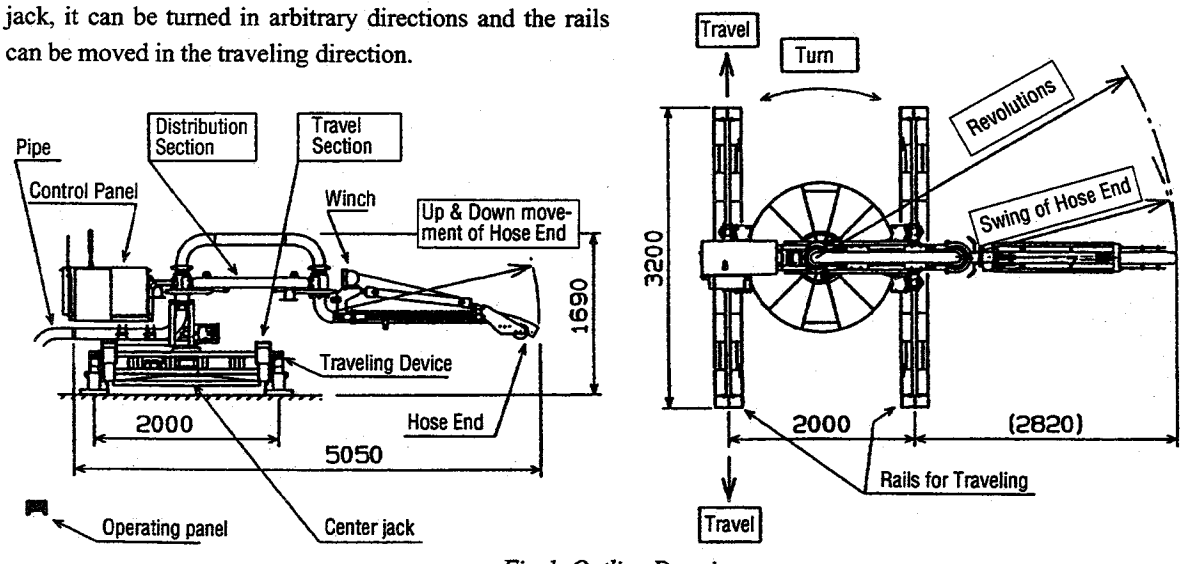


Fig-1 Outline Drawing

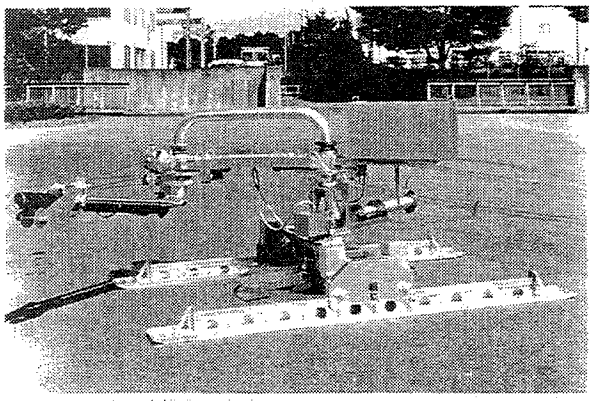


Photo-1 Overall View of DB ROBO

3. Characteristics and effects

①Hose swinging work is mechanized to save labor during concrete placing work, which is heavy labor.
②The robot can be used in any construction site other than large-scale sites.
③The robot can be moved and turned using the rails and jack while placing concrete.
④ Operation is easy due to remote control.

4. Features of the robotization and automation

The hose end is moved vertically using the winch, the upward angle being 10°, downward angle being 30°, and distance moved 1.2 m. The hose end is swung using an electric motor, the right and left swing angle being ±108°. The whole arm is turned ±35° to the right and the left.

The distribution section travels along the rails on driving wheels. When the distribution section reaches the rail end, the rails are raised from the work floor using the center jack. After the rails are moved, they are seated on the floor by contracting the center jack. The rails are turned by contracting the center jack and seating the rails on the floor.

Operation is performed by a remote wireless system incorporating a mode operation (partially automatic) to eliminate troublesome simultaneous manipulation of many levers.

For safety, consideration is given to the safety of workers around the hose end by installing a touch sensor at the hose tip.

Concrete is placed as shown in Fig-2 while performing up and down movement, swinging, and turning the hose end, and repeating replacement of rails laterally over the concrete placement area.

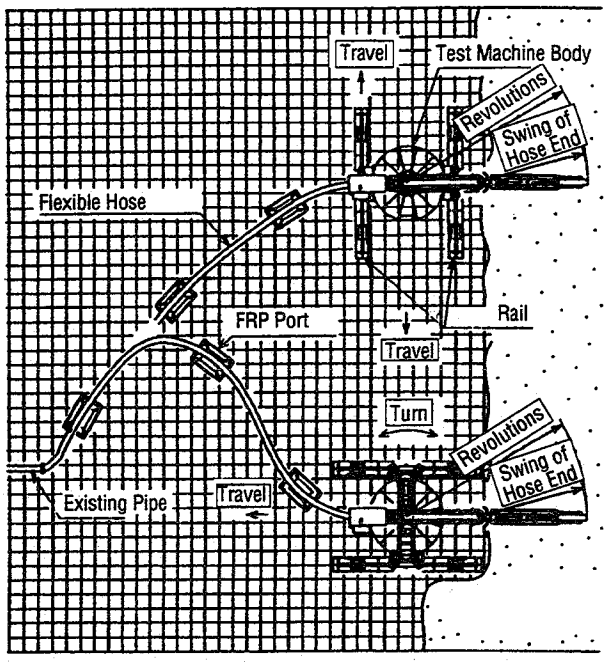


Fig-2 Outline of Work

5. Work execution record

The robot was applied to office building construction work. Work efficiency was 40 m³/hour (200 m²/hour).

6. Usage conditions

①Setting concrete placement sequence and pipe replacement/separation position.
②DB ROBO evacuating place and method, and cleaning method after concrete placement.
③Method of placing DB ROBO on the upper floor. (Usually, the robot is carried by an elevator with the rails removed.)

Automatic Concrete Distribution System with Tower Crane — Applications to Super High-rise R.C.Building

Applicable type of work:	The carriage of concrete in case of high-rise building construction	Official price:
Classification:		
Purpose of the development:	Manpower saving, time-saving, improvement of productivity	Lease and rental:
Level of practical use:	Available on the market	Development company: KONOIKE CONSTRUCTION CO.,LTD

Information

Company name: KONOIKE CONSTRUCTION CO.,LTD
Address: 6-7,3chome zusi,takatuki,osaka,japan
Phone: osaka(0726)-74-0001
Fax: osaka(0726)-76-3327
E-mail

1. Application

This system is used to attempt for the crane operator to do weary reducing, for the work efficiency and the safety to improve when the concrete placing works by Tower crane and the bucket which is used by the RC high-rise building construction.

2. Outline

This system was developed for the bucket to efficient-ize a concrete distribution, for the safety to improve. This system is composed by the control systems such as the crane automatic operation system and the operation watch system and the system of the machines such as the high-speed Tower crane and the concrete supply base and the concrete bucket. These subsystems are integrated and the system is built as one total system.

3. Characteristics and effects

① By using a crane automatic operation system, the crane operator begins a crane automatic operation system with the destination input equipment which was installed in the operation room and without the complicated lever operation, he can carry it to the purpose position. Also, it controls in the acceleration and the deceleration according to the vibration period with hanging wire length, there is not a movement of the hanging load and it is possible to carry at high speed compared with the manual operation.

② The crane operation watch system has the function to stop a crane, emitting a caution so as not for the crane and the hanging load to collide with the obstacles such as the other crane and the building. Besides, it has the function to examine whether it is efficiently operated in recording a use situation and analyzing it, too.

③ The concrete supply base is the machine to replace by moving the concrete which was carried in with the concrete mixer car to the bucket With the guide which was opened like a cone, the set of the bucket is easy and a work member for its purpose isn't needed.

④ The concrete bucket is equipped with the opening and shutting operation function by the battery drive and the worker can operate easily using the radio communication from the placing floor in the opening and shutting.

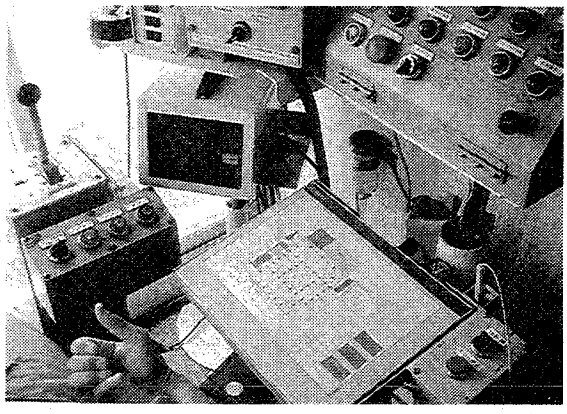


Figure.1.The operation indoor equipment arrangement

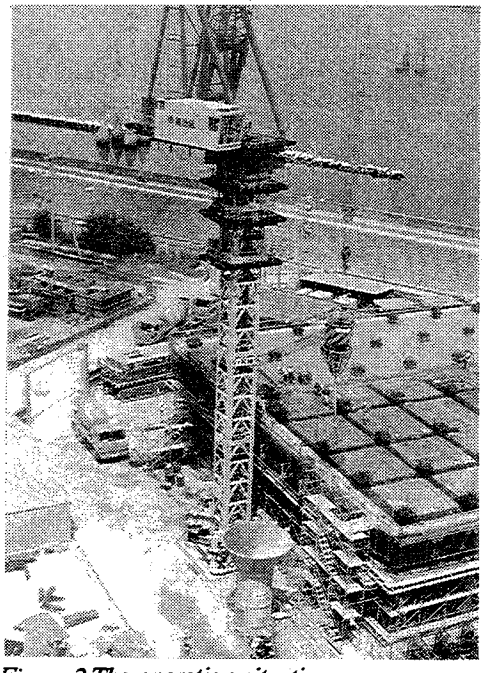


Figure.2.The operation situation

4. Features of the robotization and automation

Major specifications	
The control method	The microcomputer control
The control function	The pitch stop control The load movment prevention control The obstacle avoidance control
The way of operating	The personal tablet input by the monitor screen indication
The indication resolution	20cm
The positioning precision	Hoist ± 2cm Boom Hoist ± 0.1degrees Swing ± 0.45degrees
The position detector	Absolute value-type rotary encoda
The input signal	The crane operation signal 4 points
The output signal	The direction control 6 points The direct stop 1 point The sound caution 1 point The hoist reducer 3 points The speed order,The analog output 3ch
The protection function	The abnormal encoda detection The abnormal CPU watch
The control board size	470 X 570 X 1050 mm
The power supply	AC100V 50/60Hz

① The crane automatic operation system
The system makes the operation of the crane to the specified destination possible only in pen operation without operator's doing complicated lever operation.
② The crane operation watch system
The system is the one which prevents from collision, watching over the running of the crane. Also, to operate a crane efficiently, it records work contents and time for the place automatically and it analyzes a situation.
③ The concrete supply base
It has the guide which was opened like a cone, the set of the bucket is easy and the worker isn't needed.
④ The concrete backet
The electric power of the battery can do opening and shutting work . According to the adoption of the radio communication, there is not danger of the cable cutting by the hanging of the operation line.

5. Work execution record

Period	1987.9 ~ 1989.9
Ordered by	Housinng & Urban Development Corporation
Place	Osaka, japan
Contents	Reinforced concrete structure,31 storys,98.8m

Period	1989.3 ~ 1991.10
Ordered by	Housinng & Urban Development Corporation
Place	Kawaguti,Saitama,japan
Contents	Reinforced concrete structure,25 storys,81.6m

Period	1992.12 ~ 1995.12
Ordered by	Naebo re-development association
Place	Sapporo,Hokkaidou, japan
Contents	Reinforced concrete structure,28 storys,92.25m

Period	1994.5 ~ 1997.10
Ordered by	Housinng & Urban Development Corporation
Place	Nagoya,Aichi,japan
Contents	Reinforced concrete structure,26 storys,95.6m

6. Usage condition

① It be possible for the position detection sensor to install and be Tower crane which it is possible to operate with the outside signal.
② It chooses a concrete supply base from the pit formula and the movement formula according to the site situation.
③ At the time of gale, it isn't possible to use.

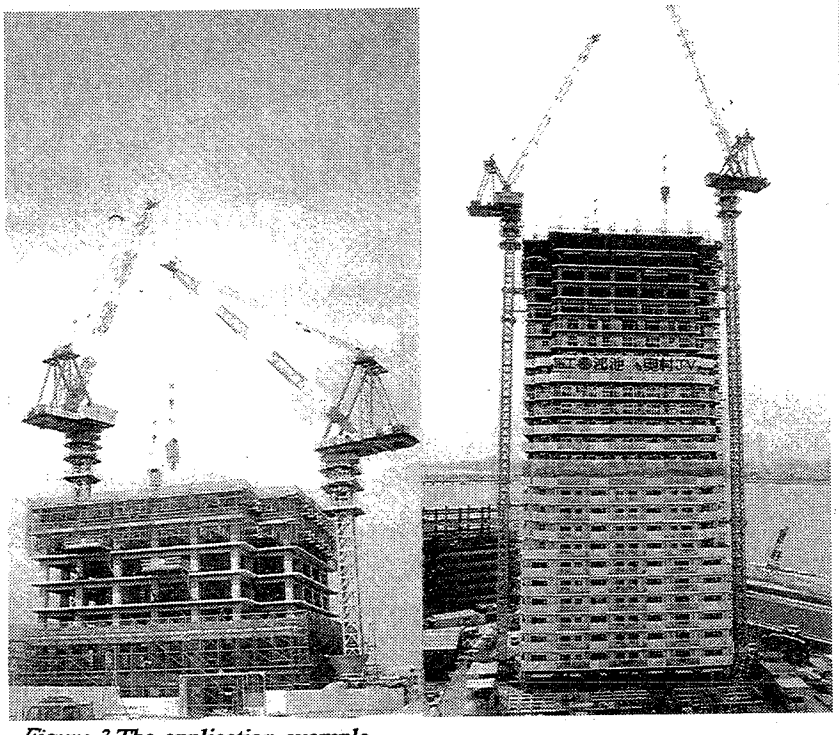
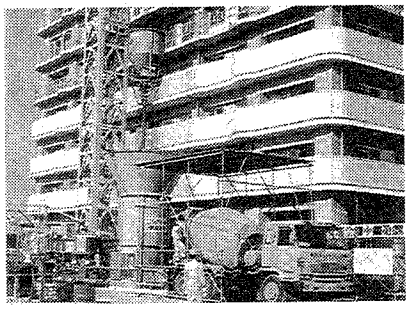
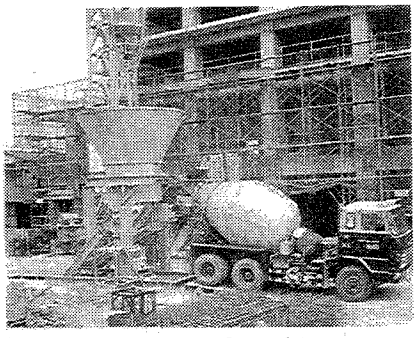


Figure.3.The application example



(The pit formula)



(The movement formula)

Figure.4. concrete supply base

Stabilator shotcreting system, robot 7500 on truck chassis or on rail car		Official evaluation:
Applicable type of work:	Shotcreting in underground excavations	Official price:
Classification:		
Purpose of the development:	Manpower saving, time-saving, improvement of work environment	Lease and rental:
Level of practical use:	Available on the market	Development company: STABILATOR AB

Information		
	Company name:	STABILATOR AB
	Address:	Industrivägen 6-8, S-137 37 Västerhaninge, Sweden
	Phone:	+46 (0)8 500 73800
	Fax:	+46 (0)8 500 73805

1. Application

Shotcreting in underground excavations, from long narrow tunnels to high caverns.

2. Outline

The Stabilator Shotcreting System accelerates tunnel driving, particularly in poor quality rock. Every component unit for measuring, mixing, delivering, spraying, and control forms part of a completely integrated system. The Robot is equipped with an automatically controlled oscillating nozzle, which gives accurate shotcrete application. Its action radius extends up to 12 meters, both horizontally and vertically, and can easily be directed to cover all parts of the tunnel periphery.

Fresh dry-concrete or wet-concrete mix is supplied by the mobile mixing unit, the Trixer. With its built-in proportioning pump, precise volumes of Stabilorapid liquid accelerator can be automatically added to obtain flash set and high early strength.

All shotcreting is remotely steered by a portable control panel, which enables the operator to choose the most effective position from which to work. The robot 7500 features a double-jointed, fully hydraulic boom that, when controlled by joy-sticks, gives the operator very fast response, allowing him to follow every nook and cranny in the rock.

3. Characteristics and effects

① Eliminates the need for long entrance cutting, reduces sealing time and improves worker-efficiency by minimizing risks of rock-fall.

② Tunnel reinforcement can be applied within minutes after blasting, and before mucking out. Securing the face by shotcreting over the muck pile saves valuable tunneling time. And while driving proceeds at the front of the tunnel, the equipment can be used to build up permanent support in previously excavated sections.

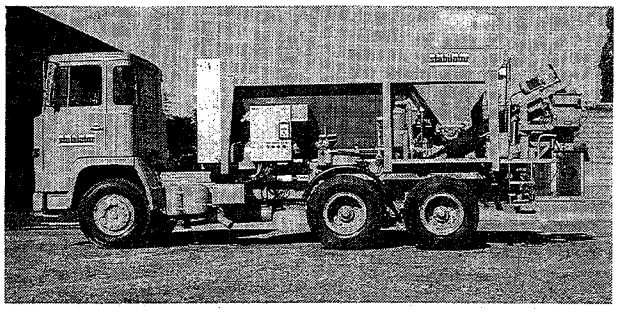


Figure 1. Mobile mixing unit for dry or wet concrete - Trixer B 8400.

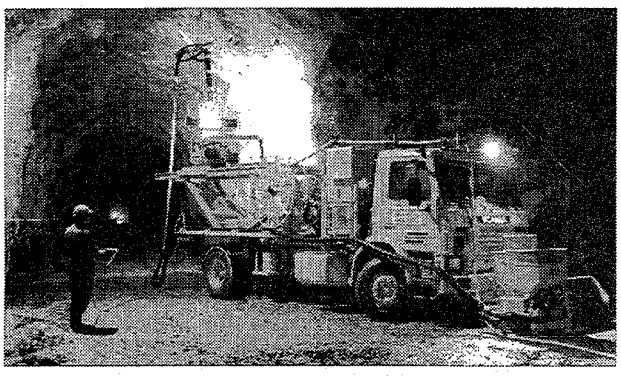


Figure 2. The Stabilator shotcreting system, robot 7500.

③ The result is optimum shotcrete compaction, for higher quality rock support and increased safety. Responsive boom control also leads to less rebound and minimal deviation from contracted thickness.

④ The design of the hydraulic system, in combination with the Stabilator Hydraulic Table, produces an incomparable radius of action. This means that as much as 15 m^3 of concrete can be placed per hour, because the operator is free to focus his attention on the actual shotcreting, instead of having to waste time maneuvering the lift to find the correct shotcreting position.

4. Features of the robotization and automation

Major specifications:	Stabilator robot 7500
Length	6350 mm
Width	1100 mm
Height	1920 mm
Weight	1125 kg

① Electro-hydraulic operation, on/off switchable automatic nozzle rotation 360°, removable remote control panel.

② Boom extension 2000 mm, maximum reach 6.8 m (10.1 m with hydraulic platform and carrier).

③ Hydraulic boom tilt, proportional action on turn and boom raise.

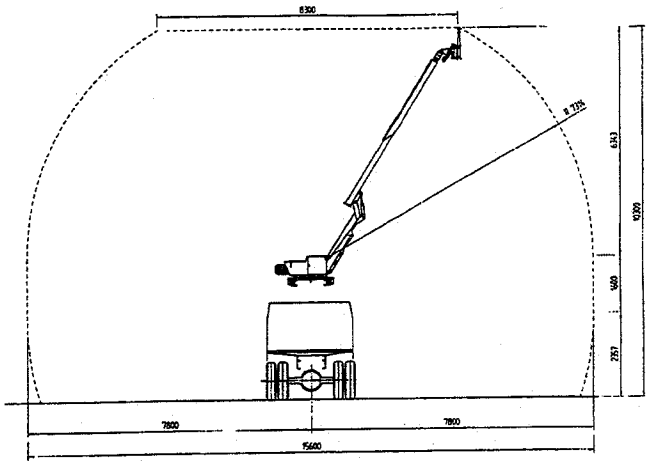


Figure 3. The range of robot 7500.

5. Work execution record

Work performed	Client

6. Usage conditions

① The system needs only two operators, but can also be used as a shuttle service for increased productivity, and even be rail-mounted for long narrow tunnels.

② The range of equipment can be specifically customized to meet the needs of any subterranean project.

③ Hydraulic platform 7500 required - Lifting and sliding device for robot 7500.

④ Mobile shotcrete mixing unit for dry or wet concrete requires Trixer B 8400.

Stabilator shotcreting system, trixer-robot D5000H		Official evaluation:
Applicable type of work:	Shotcreting in underground excavations	Official price:
Classification:		
Purpose of the development:	Manpower saving, time-saving, improvement of work environment	Lease and rental:
Level of practical use:	Available on the market	Development company: STABILATOR AB

Information		
	Company name:	STABILATOR AB
	Address:	Industrivägen 6-8, S-137 37 Västerhaninge, Sweden
	Phone:	+46 (0)8 500 73800
	Fax:	+46 (0)8 500 73805

1. Application

Shotcreting in underground excavations especially for application in mines and medium size tunnels.

2. Outline

The Stabilator Shotcreting System accelerates tunnel-driving, particularly in poor quality rock. The unit consists of trixer, remote controlled robot arm and shotcrete pump EW 15 for wet shotcreting.

The robot arm is equipped with an automatically controlled oscillating nozzle, which gives accurate shotcrete application. Its action radius extends up to 13 meters, both horizontally and vertically, and can easily be directed to cover all parts of the tunnel periphery. The concrete mixing unit, the trixer, consists of separate cement/aggregate bins with a total material volume of 5 m^3. The conveyance and mixing process is effected by augers.

All shotcreting is remotely steered by a portable control panel, which enables the operator to choose the most effective position from which to work. The entire equipment is mounted on an articulated truck.

Equipped with a rotary type shotcrete gun, the trixer-robot D5000H is most suitable also for dry shotcreting.

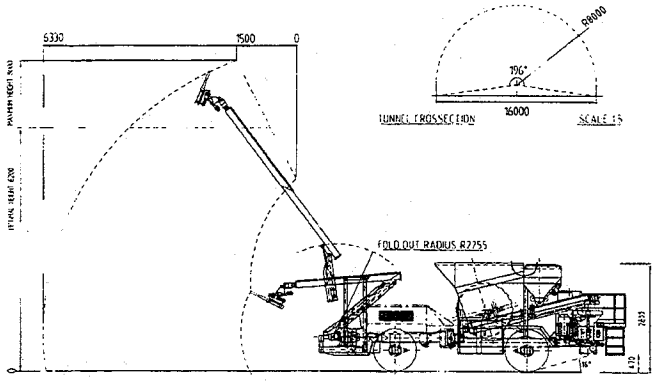


Figure 2. Stabilator shotcreting system, Trixer-robot D5000H.

3. Characteristics and effects

① Eliminates the need for long entrance cutting, reduces sealing time and improves worker-efficiency by minimizing risks of rock-fall.

② Tunnel reinforcement can be applied within minutes after blasting, and before mucking out. Securing the face by shotcreting over the muck pile saves valuable tunneling time. While driving proceeds at the front of the tunnel, the equipment can be used to build up permanent support in previously excavated sections.

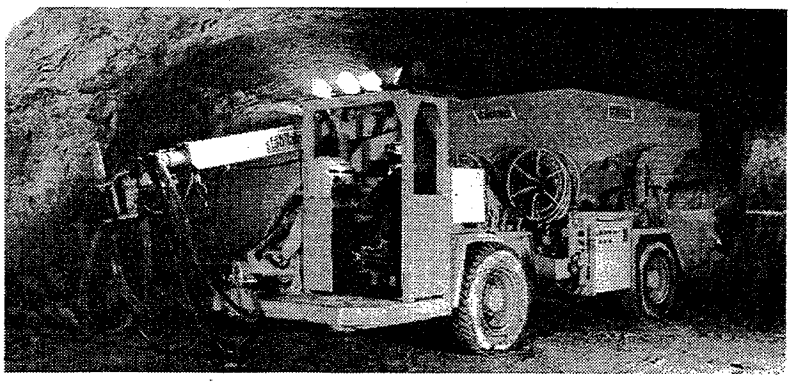


Figure 1. Trixer-robot D5000H.

4. Features of the robotization and automation

Major specifications:	Trixer-robot system D5000H
Length	9000 mm
Width	2300 mm
Height	2650 mm
Weight	9975 kg
	Robot D5000H:
Electro-hydraulic operation	
Automatic nozzle rotation	360°
Portable remote control	
Boom extension	2000 mm
Power requirement	5.5 kW
Working lights	3.0 kW
Maximum reach	7.5 m
	Carrier:
Mine truck PT 100 (or similar)	
Articulated steering	
4 wheel drive	
Exhaust gas scrubber	
Clark 3 speed power shift Engine, Deutz Diesel	
F5L 912 W (57kW)	
	Trixer:
Electro-hydraulic operation	
Cement bin volume	1.5 m^3
Aggregate bin volume	3.5 m^3
Mixing capacity	5-8 m^3/h
Adjustable mixing proportions	
Power requirement	5.5 kW
	Shotcrete machine:
Shotcrete pump EW 15 or rotary shotcrete gun	

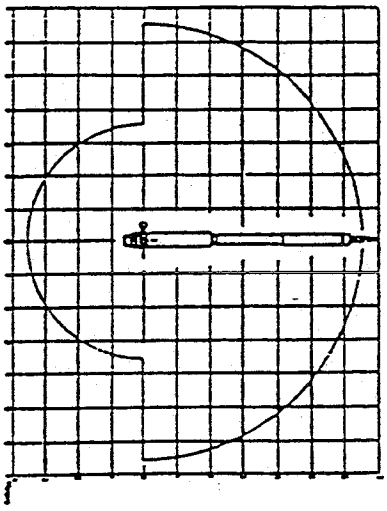


Figure 3. The range of robot D5000H.

5. Work execution record

Work performed	Client

6. Usage conditions

① The system needs only one operator.

② The range of equipment can be specifically customized to meet the needs of any subterranean project.

Dam concrete automatic transfer system

Applicable type of work: Handling work of concrete for dam construction	Official price: Negotiable in detail.
Classification: Dam construction	
Purpose of the development: Skilled labor saving. Improvement of work environment.	Lease and rental: Available for sale of software and hardware.
Level of practical use: Has been Successfully used in several project.	Development company: OBAYASHI CORPORATION

Information
Company name: OBAYASHI CORPORATION—Civil Engineering Technical Department.
Address: 2-2-9, Hongo, Bunkyo-ku, Tokyo 113. Japan.
Phone: 81-(0)3-5689-9013
Fax: 81-(0)3-5689-9010

1. Application

Automatic transfer and handling system of concrete for dam construction project , using cable crane and transfer-car.

2. Outline

Shortage of skilled labor such as operator of cable crane, is one of critical situation in dam construction project site. ' Dam Concrete Automatic Transfer System " as shown in Figure 1, transports concrete , automatically from concrete mixing plant to dump trucks located on concrete placing stage.

Basic policy for development of system are as follows.
(1) Fully automatic system , consist of transfercar, concrete buckets, cable cranes and ground concrete hoppers.
(2) Stability of system. Easy to operate & maintain.
(3) Secure of designed cycle time for concrete placing schedule.
(4) Saving labor.
(5) Improvement of safety workes & environment.

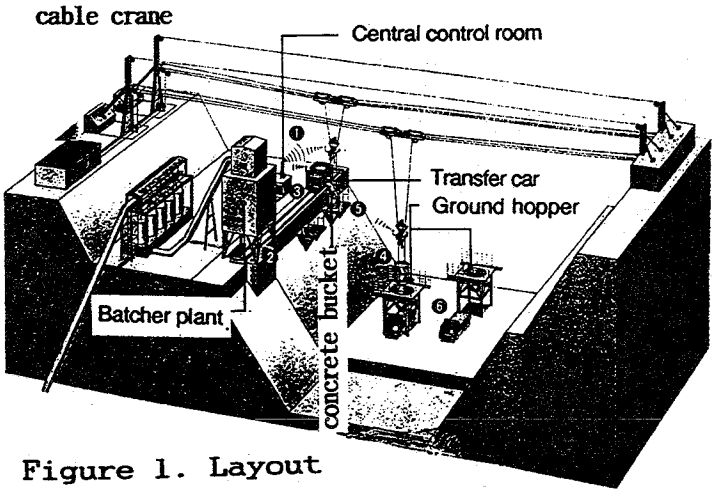


Figure 1. Layout

The component of system showing in Figure 2 consist of host & sub computer, programable controller, sensors of each action progress, software, cable crane & other construction equipments for dam construction site.

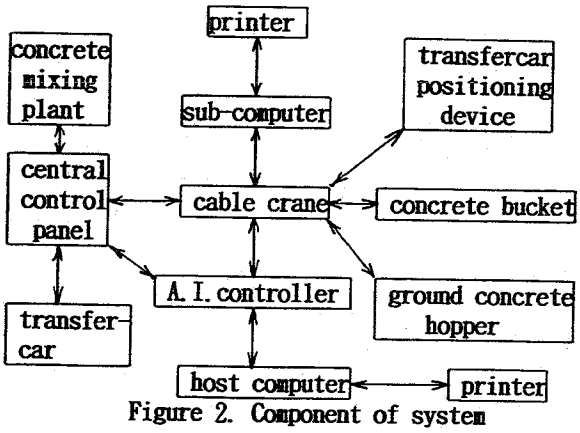


Figure 2. Component of system

3. Characteristics and effects

(1) Smooth movement of concrete handling works between mixing plant & placing stage, constantly placing, saving cycle time and gainning high productivity.
(2) Minimized swing or shaking & high accuracy positioning of concrete bucket at each target point. Excellent in repeat or reproduction of movement produce high stability and trustworthy.
(3) Easy operation system, by just a person incharge in the C.C.R., using central control panel. Displaying all information on C.R.T. (Cathode Ray Tube) screen permits to grasp the situation at site accurately against to occurrence of a trouble in real time.
(4) The system produce safety works , due to non worker is needed for concrete handling works.

(5) Fail safe method of safety devices, such as interlocking system and various kind of sensors are provided to keep safety workes.

4. Features of the robotization and automation

Name of equip.	Capacity	Specifications	Q'ty
Transfer-car	4.5 M³ side dump	driven by Hydraulic motor	1 No.
Cable crane	14.5 tf	both end Stationary type	2 Nos.
Concrete bucket	4.5 M³	Hydraulic driven	2 Nos.
Ground concrete hopper	9.0 M³	Pneumatic driven	2 Nos.
Control devices: • Computer • Programable controller • Sensors: Gyroscope, Optical sensors, Encoder, ···etc.		PC9801 GL60S and others approx. 30Nos.	4 Nos. 8 Nos.

(1) Positioning of concrete bucket is controled on the vertical and horizontal coordinate axis method, and automaticaly operated up to the target point as shown in Figure 3.
(2) Swingless and shakeless control system by ' Forecast control Method " controls handling speed of the load , smoothly for each movement.
(3) Automatic operation device for transfer-car is controled by control signals from C.C.R. to minimize loss times, ex. beginning of travelling to the concrete bucket , priority of two of bucket and dumping of concrete, and
(4) For the movement of bucket discharge gate also controled by wireless signals from C.C.R., through various kind of interlocking systems.
(5) Operation of ground hopper discharging gate is controled by signal from dumptruck driver, as scheduled volume and suitable speed of gate opening.
Grade of concrete and balance volume in the groundhopper also indicated on the control panel.

5. Work execution record

Project name	Period	Ordered by	Place	Type of dam	Volume of concrete
CHI-YA Dam	OCT. 1992 ~ APR. 1996	Okayama prefecture	Niimi city	Gravity type concrete dam (R.C.D. method)	685,000 M³
KUBUSU GAWA Dam	MAR. 1993 ~ JUL. 2001	Toyama prefecture	Bufu dist.	Gravity type concrete dam	472,000 M³
TOMISATO Dam	SEP. 1992 ~ MAR. 1998	Public corp. of Water Resources Development	Ehime pref. Iyo-Mishima city	Gravity type concrete dam	510,000 M³

(1) Easy to manage construction schedule, by using this system.
(2) Constant cycle time even in the dense fog or night time works.
(3) Save man power.
(4) Non human error and non misoperation. ═══ Excellently Safe.

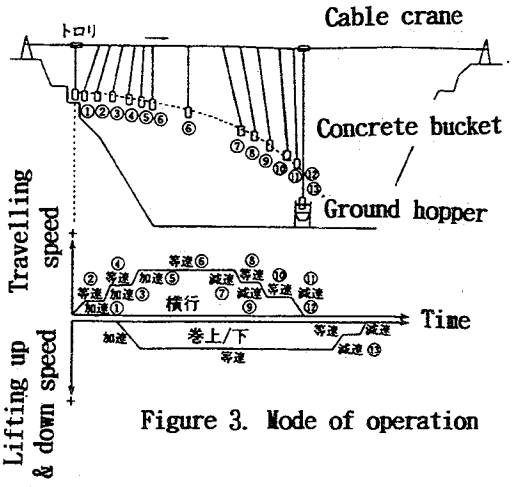


Figure 3. Mode of operation

6. Usage conditions

(1) Controlling method of each device should be used electric signals.
(2) Mode of speed changing for cable crane such as lifting-up & down and main & sub travelling should be continuous type.

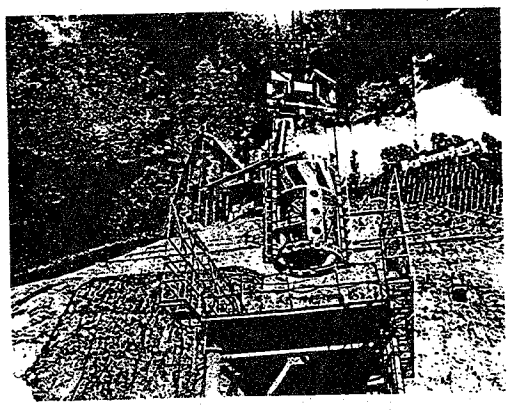


Figure 4. A situation

Automatic concrete transportation system in dam construction works

Applicable type of work: Transportation	Official price: non
Classification: Construction	
Purpose of the development: Rationalization, Improvement of work condition and productivity	Lease and rental: non
Level of practical: Construction in practice	Development company: Nishimatsu Construction Co., Ltd.

Information
Company name: Nishimatsu Construction Co., Ltd.
Address: Technical Research Institute 2570-4, Shimotsuruma, Yamato, Kanagawa 242, JAPAN
Phone: +81-462-75-1135
Fax: +81-462-75-6796
E-mail: GAC00313@niftyserve.or.jp

1.Uses

This automatic system runs the transportation car for a gravity concrete dam.

2.Outline

In casting concrete by using cable-crane or incline facilities, transfer cars for the transportation of concrete are often used between the batch plant and concrete-buckets. However, many laborers such as signal men and drivers are needed in this system. The aim of this system is to develop an automatic operation of transporting and dispensing concrete to buckets.

In this system, a transportation car detects the location of the master cable of the crane. The microcomputer which is loaded into a transfer car automatically calculates the placement of the bucket, the stopping place of the transfer car and the placement of the bucket for pouring concrete, thus, the series is automated.

The structure of a transportation car can prevent vibration of a microcomputer. The power supply uses a deceleration device of closed type, thus preventing damage to the chain by deceleration. *Fig.1* shows the concrete transportation system.

3.The feature and effect in this system

① This automatic system can reduce cost by eliminating the driver and signal man.

② Work safety is improved by detecting obstacles with a sensor.

③ The concrete casting cycle is shortened by using a microcomputer.

4.Features of the robotization and automation

① The travel distance of the transportation car

The fixed tower is a starting point of a *X-Y* coordinate (see *Fig.2*). The distance traveled by the transportation car can be expressed as $\sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2}$ by assuming that the positioning of bucket (X_2, Y_2) is a point of intersection between the batch plant (X_1, Y_1) and the orbit of a bunker.

The positioning of the bucket (X_2, Y_2) can be determined

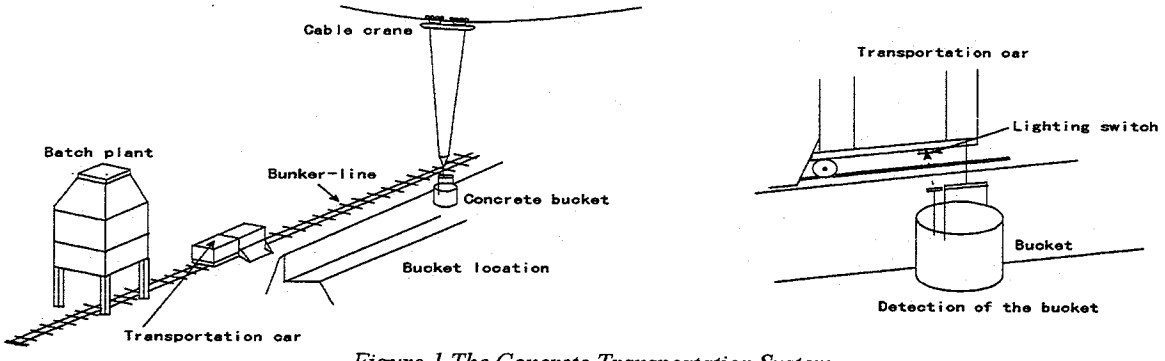


Figure.1 The Concrete Transportation System

from the point of intersection (X_4, Y_4) between the center axis of the crane, the orbit of a bunker $Y = bX + C$ and the location of the traveling tower (X_3, Y_3).

The transportation car must stop before the placement location of the bucket, because it is difficult to set the bucket correctly by swinging.

② Detection of bucket

The transportation car stops at the front of the bucket by using a non-touch sensor (see *Fig.1*).

In order to stop at the front of the bucket, the car has a reflective lighting switch, and the bucket has a reflection board. The car detects the bucket and stops just in front of it.

③ Automatic operation

Fig. 3 shows automatic operation flow diagram.

After stowage of concrete, push the start button

5.Work execution record

Country	Client	Work performed
Japan	The Ministry of Construction	Mano Dam
Japan	The Ministry of Construction	Kirimi Dam

6.Usage conditions

The sensor will not work when covered with concrete. Maintenance and care are required.

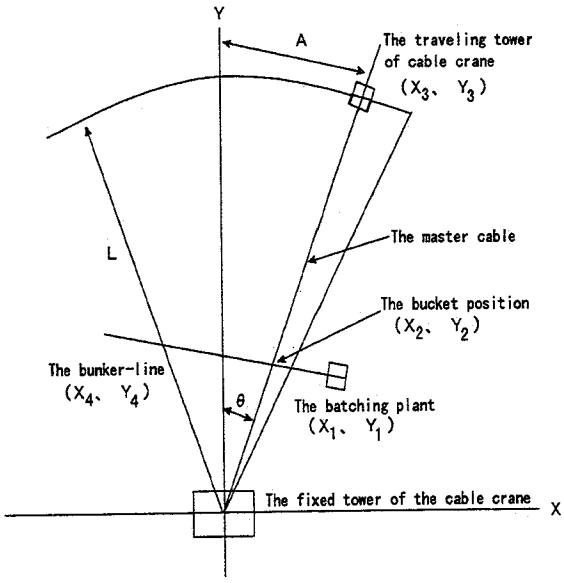


Figure.2 The Bucket Position Detection

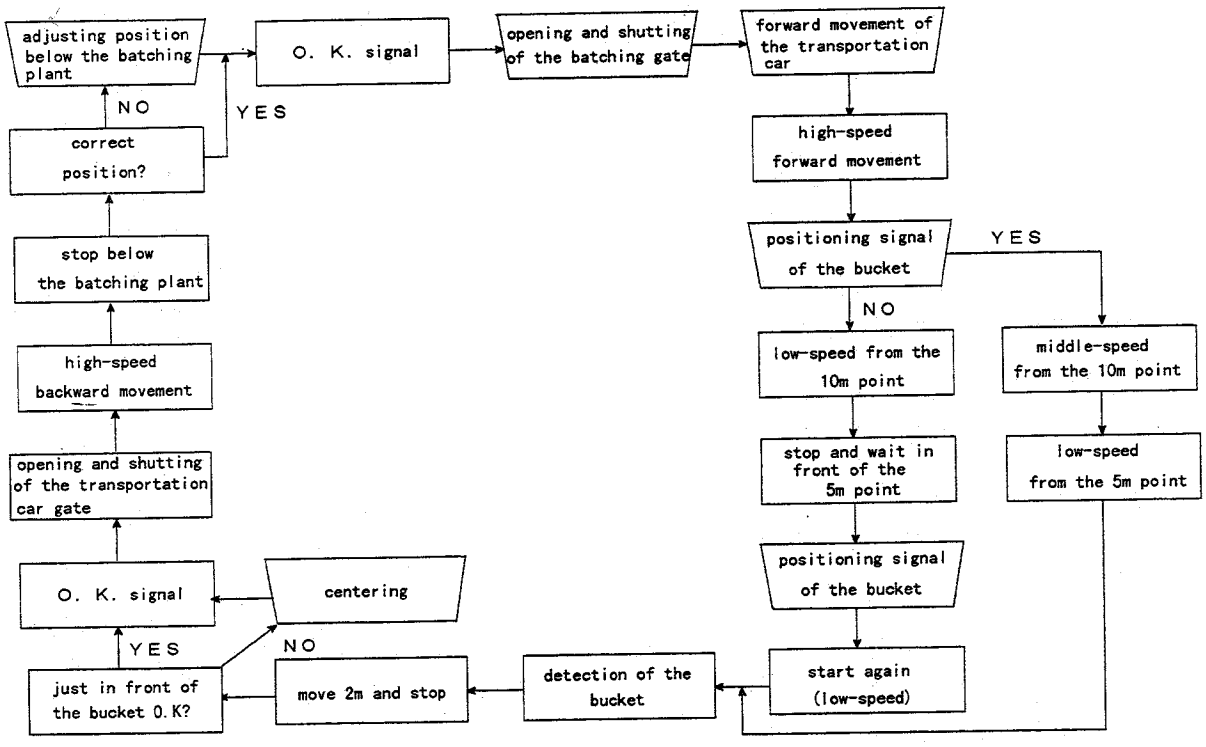


Figure.3 The Automatic Operation Flow Diagram

Dam concrete transport facilities INCLINE

Applicable type of work : Dam construction	Official price :
Classification :	
Purpose of the development : Manpower saving, time-saving	Lease and rental :
Level of practical use : Available on the market	Development company : Ishikawajima-HarimaHeavy Industries Co., Ltd.

Information
Company name : Ishikawajima-HarimaHeavy Industries Co., Ltd.
Address : Ohtemachin 2-chome, Chiyoda-ku, TOKYO, JAPAN
Phone : 03-3244-6478
Fax : 03-3244-5317
E-mail :

1. Application

INCLINE is to be used in the RCD method of dam construction in order to transport concrete produced in the batcher plant to concrete placement.

2. Outline

INCLINE (INCLINE consists of concrete carriage, transfer car and hopper station to transport the concrete from a batcher plant to concre placement) are so designed as to make one-man control system, ie., automated operation among batcher plant, transfer car, and concrete carriage, possible and can be operated by only one operator in the RCD method of dam construction.

① By turning on a start switch for auto-operation in an operating room, transfer car is set under batcher and concrete carriage is set under the rail of transfer car. Then, the signal showing completion of sentering the transfer car and the concrete carriage is transmitted to the batcher plant.

② The gate of batcher plant is opened by receiving the signal. After checking the completion of discharge of the concrete, command to start the transfer car is given.

③ The transfer car stops at the prearranged position over the concrete carriage according to programmed speed-controll pattern and sensor system. Under the condition that the transfer car is set above the concrete carriage properly, the gate of transfer car is opened and concrete is discharged to the concrete carriage.

④ The gate of transfer car is closed after a certain interval and the transfer car returns and stops at the prearranged position according to speed control pattern and sensor system.

⑤ The cocrete carriage starts moving down upon receipt of signal showing that the gate of transfer car is closed. The concrete carriage stops over hopper on hopper station and concrete is discharged from the concrete carriage to the hopper station. In case there is some concrete left in the hopper, the concrete carriage automatically stops in front of the hopper and starts moving again and centering over the hopper upon receipt of the signal that the remaining concrete has been completely discharged.

⑥ The gate of concrete carriage closed after a certain interval and the concrete carriage is reset under the rail of transfer car according to the speed-control pattern. The concrete in the hopper is discharged to a loading platform of a dump truck after receiving either wireless or wired signal from the dump truck driver.

3. Characteristics and effects

1) This system is economical, effective and safe since it can be controlled by only one operator and concrete can be automatically transported and loaded.

2) The system saves time for checking since it automatically perceives concrete left or over-loaded in the hopper which would be caused by delay in the works at the subsequent facility, stops temporarily, and starts again.

3) The INCLINE can also be operated by only one operator even if it has several lanes or is combined with a cable crane.

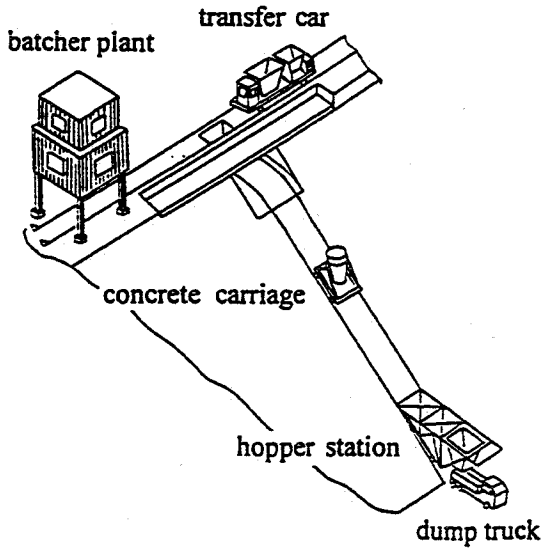


Figure 1. Layout

4. Features of the robotization and automation

o 4.5m³ INCLINE

① Trunsfer Car

TYPE	Two Hoppers Type (4.5m³—Bottom Gate, 3m³—Side Shoot), open/close of Gate by Pneumatic Operation
RAIL SPAN	1435mm (Distance between inside of Rail Tread) 37kg/m Rail
TRAVELING MOTOR	15KW
CONTROL SYSTEM	Inverter Control
TRAVELING SPEED	50 m/min

② Concrete Carriage

SPAN	3,000 mm
WHEEL BASE	5,000 mm
TRAVELING MOTOR	400 KW
CONTROL SYSTEM	Thyristor Leonard
TRAVELING SPEED	160 m/min, 180 m/min
TRAVELING WIRE ROPE	ϕ 42×2 Ropes

③ Hopper Station

SPAN	3,000 mm
WHEEL BASE	11,000 mm
MOORING METHOD	Hydraulic Cylinder Method
LIFT UP SPEED	About 0.4 m/min

5. Work execution record

NAME OF DAM	Type of work
MANO DAM (Fukushima-prefecture)	3m³ Type×1 Lane
SAKAIGAWA DAM (Toyama-prefecture)	4.5m³ Type×2 Lanes

6. Usage Conditions

1) It is possible to operate transfer car and concrete carriage separately and individually.

2) It is possible to open and close the gate of the hopper staition's hopper without a driver getting off the truck.

3) When the concrete placement rises, the hopper station can be operated separately and traveled on the slope, thus the placement level can be reset at the increased level.

4) Traveling drive winch of concrete carriage needs space for installation behind the traveling level of transfer car.

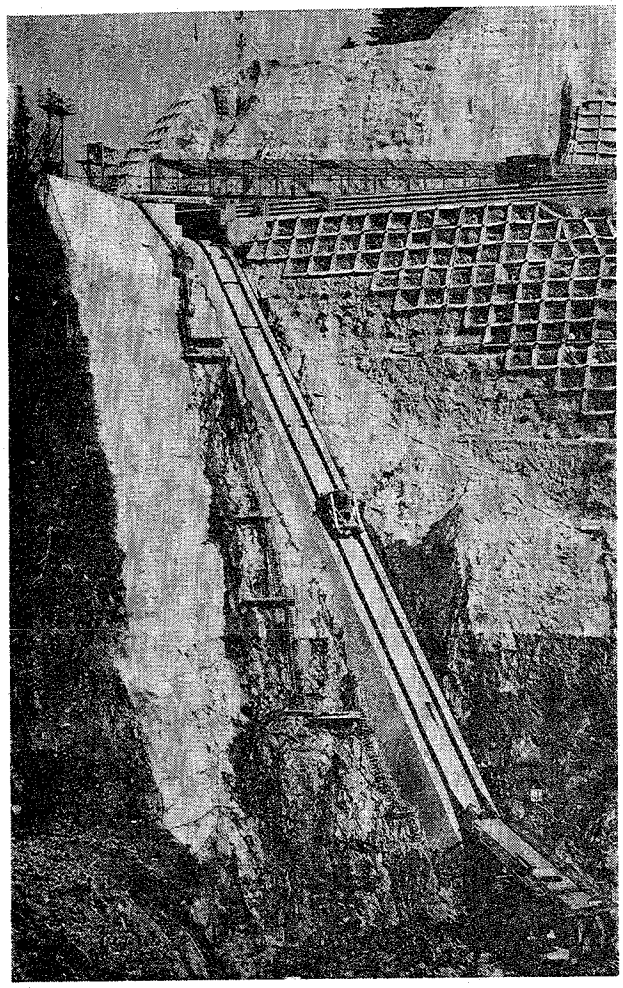


Photo.1. INCLINE

INC-002

Grout Data Control System

Applicable type of work:	Dam Grouting Work		
Classification:	Execution	Official Price:	14 million yen (one system)
Purpose of the Development:	Saving energy and improving quality	Lease and rental:	Partially.
Level of practical use:	Now in use at construction sites	Development:	Toto Electric Industry Co., Ltd.

Information: Company Name: Toto Electric Industry Co., Ltd..
Address: 5-25-4 Ikegami, Ota-ku, Tokyo, 146
Phone: 03-3755-2121, Fax: 03-3754-3153
Responsible Department: Sales Department

1. Application

This system is used to automate execution control, technical control, and daily report preparation during grout injection work at dam construction sites.

2. Outline

In order to prevent grout injection work from having any dangerous effects such as the displacement of the bed rock or other structures, it is essential that the pressure and flow volume of the grout injection not exceed stipulated values.

A simple system designed to automatically control feed pressure and flow volume during injection so that it remains below values stipulated for each concentration level, it gathers pressure and flow measurement data obtained by means of water testing and permeability testing, and this system can producde automatically a wide renge of analyzed results sach as injection control diagrams, Lugeon map performance diagrams, Lu/Ce exceedence rate diagrams, etc.

(Configuration)

The system consists of a [1] dam grout flow volume and pressure control (FPC-100-50) [Sensor valve device and recording adjustment panel] which detects, records, and controls flow volume and pressure during grout injection, [2] data control (DKS-006) which digitally processes the data which has been sensed (recorded in a data recording medium) at the same time as it displays the status of the execution on a display in real time, and [3] daily report preparation (NSS-006) which prepares various reports by entering an IC memory card on which the injection status data has been recorded.

3. Characteristics and effects

① When the conventional execution method is used, it is very difficult for one operator to perform multiple water tests and permeability tests and the grout injection work itself. Multiple operations can be performed easily by taking advantage of the automatic operating functions available with this system.

② The data collection medium used by the data controller and the daily report preparation processor is a non-contact type (molded) IC memory card with superior resistance to environmental conditions and high reliability.

③ Because the sensor valve is a return mode type, it is possible to perform fine adjustments and control of the pressure and flow volume of grout injection.

④ The daily report preparation proseccor can quickly prepare daily grout control reports, and daily, weekly, and monthly reports,

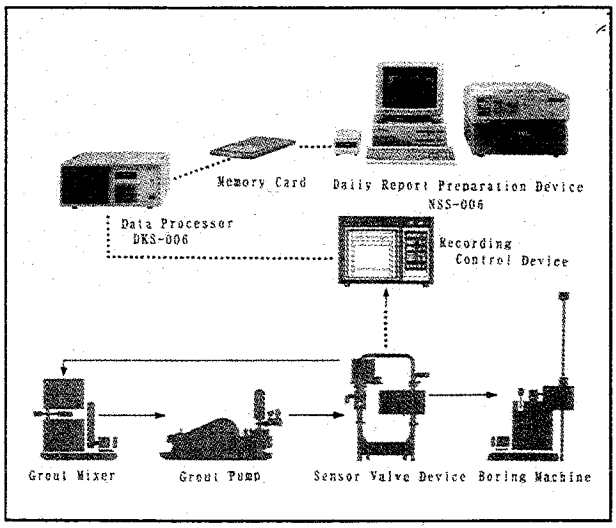


Figure 1. Configuration of the Grout Data Control System

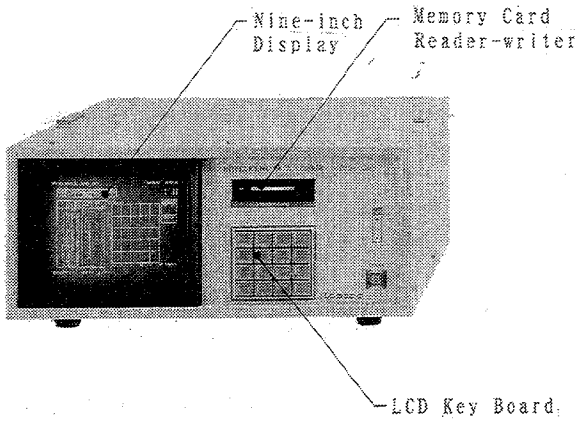


Figure 2. Data Control Device

Table 1. Specifications

Measurement Range	Flow Volume: 1 to 120 liters/min. Pressure: 0 to 60 kgf/cm2
Data Collection Interval	0.1 seconds
Data Recording Interval	Optionally selected between 1 second and 60 seconds
Data Recording Medium	IC memory card (standard 32kb)
Data Recording Time	70 hours (when the recording interval is 1 minute)

etc. along with basic data needed for analysis purposes. These reports are effective for execution management information. Figure 3 shows the format of a daily grout control report.

4. Features of robotization and automation

① The pressure and flow during injection are measured by a pressure sensor and a electric magnetic flow meter respectively.

② The return valve method is used to control the pressure and flow; the open/close state of the valve is changing by controlling the rotation and rotation direction of a motor.

③ The water testing and permeability testing is done by measuring the relationship of the pressure and the amount of permeation at measurement points up to a maximum of 30 levels based on data previously recorded on the memory card of the data control unit, and then the Lugeon value is decided by calculating the amount of permeation (*l*/min) per 1 meter at the pressure of 10 kgf/cm^2.

④ When grout is injected, the pressure and flow are controlled based on preset injection data, control itself is performed according to stipulated blend ratio and injection volume, and injection is finished by the blocking treatmeat (of the data control unit).

⑤ The dam grout flow and pressure control unit returns back the amount discharged by the pump when the injection pressure exceeds the design value (execution specifications) so that an ascent of the pressure is restrained. And because the total pressure against the ground is, under a constant flow volume, proportional to the effected ground surface, and also is related to the amount of grout injected, the flow volume is controlled by returning grout as in the case of pressure, whenever the amount injected exceeds a preset value.

Generally, when grout injection begins, the flow volume is controlled because the grout flows easily, but as the grout begins to fill, the flow volume declines, so the system switches over to pressure control.

5. Work execution record

The following table shows the number of systems delivered from 1989 to 1992.

Organization Constructing the Dam	Number of Orders
Ministry of Construction	8
Regional Public Organization	25
Public Corporation	2

6. Usage conditions

There are none in particular.

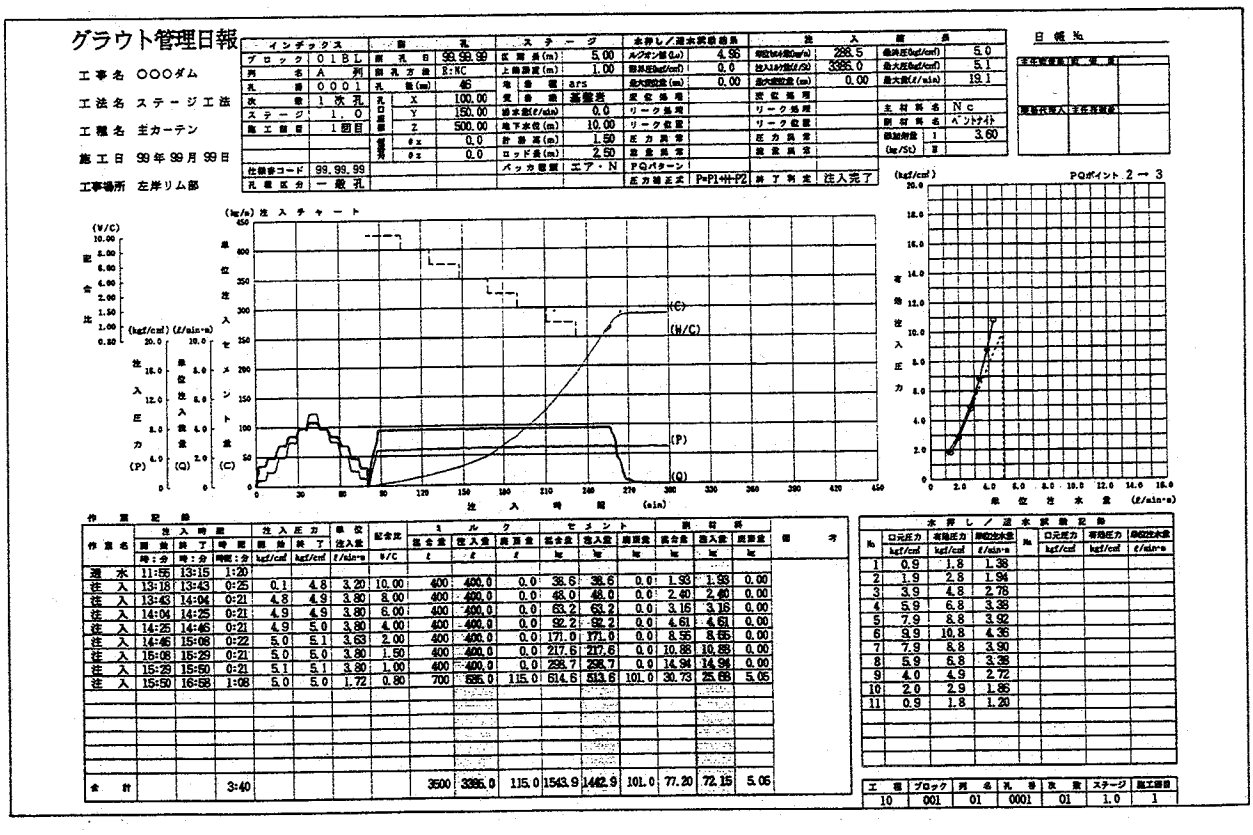


Figure 3 Daily Grout Control Report

Konoike Transfer Car Automatic Control System

Applicable type of work:	The carriage of concrete in case of dam construction	Official price:	
Classification:			
Purpose of the development:	Manpower saving, time-saving, improvement of safty	Lease and rental:	
Level of practical use:	Available on the market	Development company:	KONOIKE CONSTRUCTION CO.,LTD

Information

Company name: KONOIKE CONSTRUCTION CO.,LTD
Address: 6-7,3chome zusi,takatuki,osaka,japan
Phone: osaka(0726)-74-0001
Fax: osaka(0726)-76-3327
E-mail

1. Application

These systems were developed to automate the concrete transportation process in dam construction.

2. Outline

These systems incorporate three types of function.

① The first is automatic control of the concrete transfer car.

② The second is the positioning of the concrete bucket to the concrete loading point .

③ The third is the openig of the gate of the concrete bucket by radio control.

The use of this system releases workers from routine work and improves the safety and efficiency of dam construction.

3. Characteristics and effects

① The concrete transfer car is controled only by push-button located in the concrete batching plant and the crane.

② The bucket car is equipped with a mechanism which automatically position the concrete bucket. The crane operator is able to move the bucket car by using remote control in the rail line of the transfer car . The transfer car is able to load the concrete into the bucket at any point in the rail line. This concrete transportation system can be utilized even if a crawler crane is used.

③ The concrete bucket has batteries for the hydraulic pump. The buckets gate is opened by hydraulic jacks which are operated by a radio remote control system.

④ The systems eliminate the need for a transfer car operator and workers who position the bucket on the rail line.

⑤ It eliminates human error and eliminates the danger which is collision between a worker and the transfer car .

⑥ There is no fatigue of worker and wasted time of unskilled worker. So it is possible to improve the efficiency of the job site.

⑦ There are no workers near the rail line. So it is possible to reduce the fatigue of the crane operator and improve efficiency.

⑧ Concrete is loaded without workers who come into contact with buckets. So safety and efficiency are improved.

These systems can be applied to concrete dam projects in which tower cranes or crawler cranes are used to lift the concrete buckets.

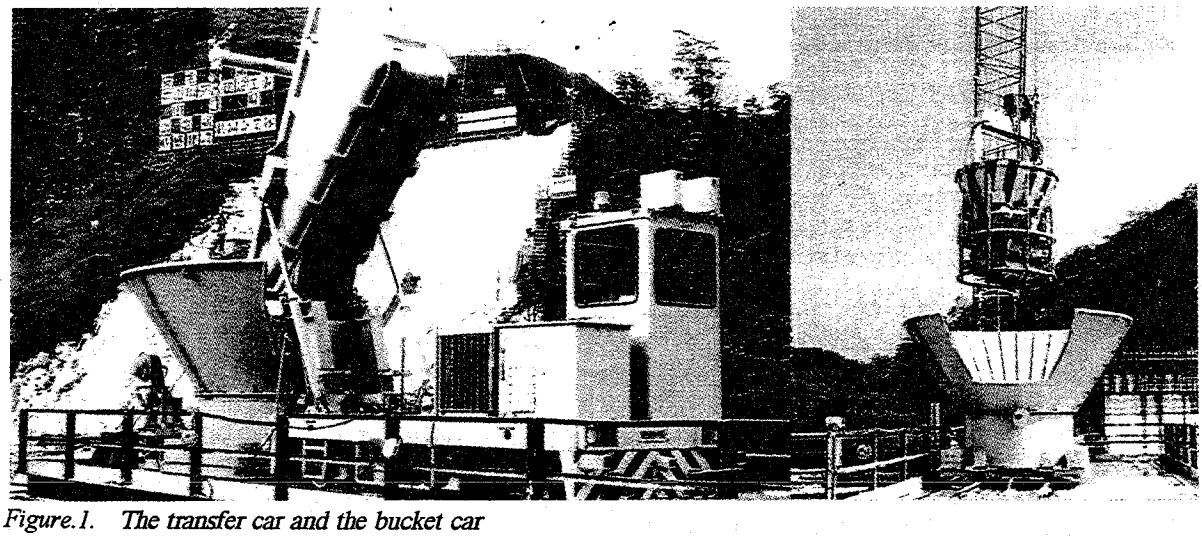


Figure.1. The transfer car and the bucket car

4. Features of the robotization and automation

Transfer car Major specifications	
Size	5940×2000×3200 mm
Weight	9300 kg
Hopper capacity	2.0 m3
Engine power	53 ps
Maximum speed	15 km/h

Backet car Major specifications	
Size	5940×2000×3200 mm
Weight	6500 kg
Power requirement	0.75 kw
Maximum speed	0.5 m/min

① Automatic Transfer Car Control System
The transfer car is loaded with concrete at the batching plant and travels until it reaches the dog of the backet car. After waiting for bucket placement and confirming that the bucket is in place,the transfer car moves forward and pours the concrete into the backet. The transfer car then returns to the batching plant. These processes are carried out automatically with the help of a micro-computer installed in each transfer car.

② Bucket Car System
The backet car , moved by remote control, is equipped with a mechanism enabling it to detect the position of the concrete bucket automatically. The transfer car connects to dogs on the backet cars, so that smooth and precise positioning is assured at all stages of concrete transfer.

③ Remote Bucket System
The remote backet control system comes loaded with features which assure safe and secure operation.

5. Work execution record

Period	1990.12 ~ 1994.3
Ordered by	Yamaguti prefecture ,Japan
Place	Nakayamagawa Dam
Contents	concrete volume 51,000m3

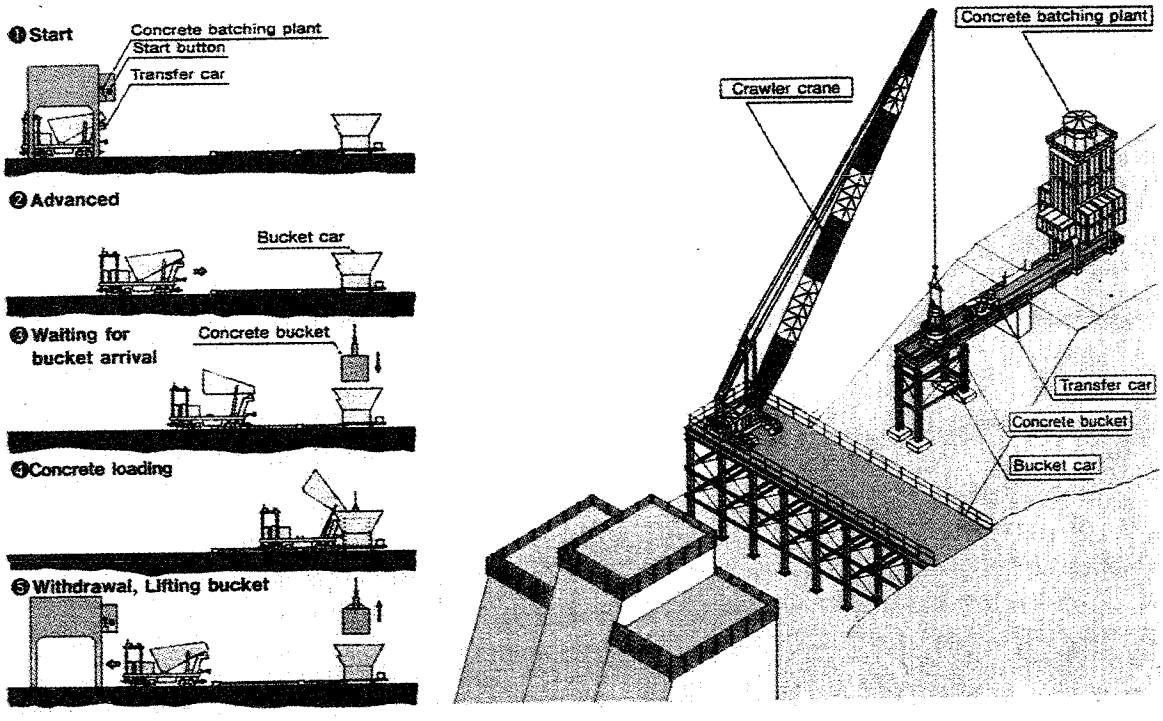
Period	1994.6 ~ 1995.8
Ordered by	Okayama prefecture,Japan
Place	Narai Dam
Contents	concrete volume 31,000m3

Period	1995.8 ~ 1997.10
Ordered by	Hukusima prefecture,Japan
Place	Tajima Dam
Contents	concrete volume 80,000m3

This system was used first at the nakayamagawa dam in the yamaguti prefecture and carried concrete with about 12000 times. As a result, the manpower saving of two work members was attempted and cycle time of about 40 seconds was reduced.

6. Usage condition

① The person makes not enter rail line.
② It doesn't make a decision on the way at the rail line.
③ It sets up a watch camera for the operator of the batching plant to be able to confirm the operation condition of the automatic operation of the transfer car.



Fifure 2. Automatic control system

Concrete-Slab Screeding and Finishing

Concrete Floor Screeding Robot "SCREED ROBO"

Applicable type of work:	Concrete floor screeding work	Official price:	
Classification:	Construction		
Purpose of the development:	Enhancing accuracy, saving labor, improving work environment	Lease and rental:	
Level of practical use:	Commercialization	Development company:	Takenaka Corporation Sanwa Matoron Co., Ltd.

Information	Company name:	Takenaka Corporation
	Address:	21-1, 8-chome, Ginza, Chuo-ku, Tokyo, 104, Japan Public Relations, General Headquarters
	Phone:	03-3542-7100
	Fax:	03-3545-9083
	E-mail	

1. Application

Concrete floor screeding work

2. Outline

This machine is constructed so that a screeding part, which is automatically controlled by a cylinder for horizontal leveling, is suspended from a girder with a truss construction, which moves on rails that can be replaced automatically. The main components of the machine include a screeding part whose height and level are controlled automatically, a girder on which the screeding part moves sideways, saddles and rails for the girder, and a control section.

A general view and the principal specifications are shown in Fig-1 and Table-1, respectively. The total weight is about 880 kg. To make manual assembly possible, the machine is modularized. Moreover, the weight is decreased using aluminum alloy. As a result, assembly/disassembly work can be performed by 2 workers x 0.5 days. The divided weight is 50 kg at maximum, excluding the screeding part (130 kg)

Model	CFR – 350G – AR
Dimensions (L x W x H)	6.3 – 17.3 x 2.2 x 1.9 m
Weight	About 880 kg
Width of the rail	6.0 ~ 17.0 m (1 m pitch)
Screeding Width	15.5 m at maximum
Screeding Part	Double-screw type, length 1.6 m
Sideways Moving Speed	0.8 m/sec at maximum
Moving Speed	0.3 m at maximum
Operation Mode	Fully automatic, level automatic, automatic rail replacement
Power Source	Three phase, 200/220 V, 3 KVA

Table-1 Principal Specifications

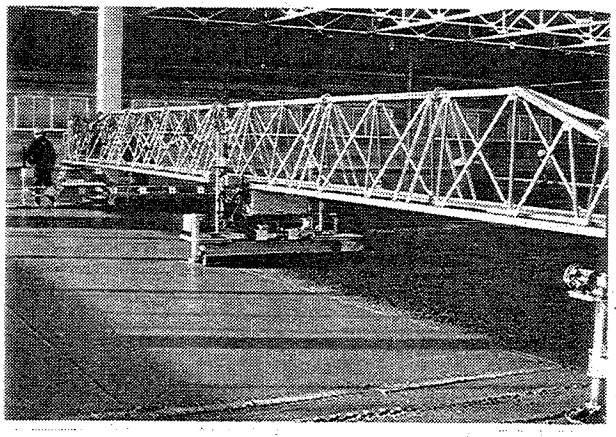


Photo-1 Overall view of SCREED ROBO

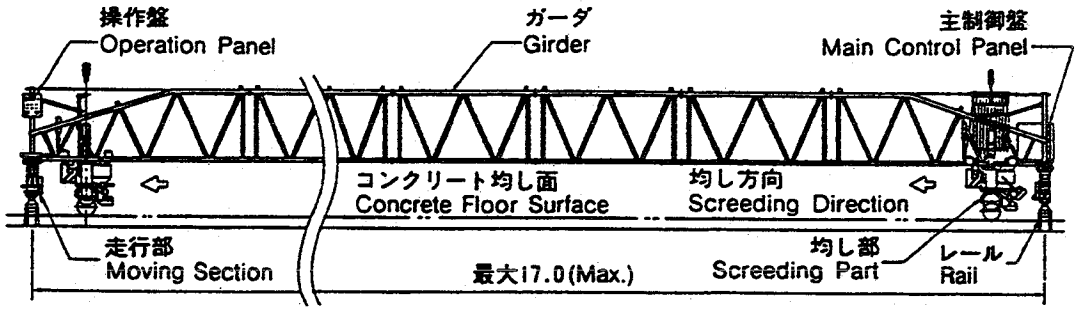


Fig-1 Overall View

3. Characteristics and effects

①Level accuracy can be provided merely by setting simple "girder" and "rails," because level and height are adjusted automatically by a receiving laser beam.
②Replacement can be performed by manpower because the weight of the body is decreased and disassembly is possible.
③The workers are relieved from heavy labor by robotizing the floor screeding work.
④Significant labor savings can be achieved because floor screeding work can be performed by one operator.

4. Features of the robotization and automation

The "screeding part" is, as shown in Fig-2, composed of a screw for removing surplus concrete, a vibration plate for smoothing the screeded surface, a saddle that moves sideways on the girder, and a servo-cylinder for controlling the screw horizontally and at a predetermined height without being affected by deflection of the girder. To detect the position of the "screeding part," an inclinometer is used to detect the level, and a laser beam receiver is used to detect the height.

Fig-3 shows the robot's operating sequence. The girder can be extended to 17 m maximum (screeding length 15.5 m). The screeding width with a sideways movement is 1.6 m, and the lap width is about 0.3 m. Two modes are available: an automatic mode in which all work is automated, and an automatic mode in which screeding work is performed automatically and rails is are replaced by manual operation.

For movement, jacks at both ends of the rails are extended, and movement is performed with the moving saddles and the whole body raised. After movement is completed, the jacks are contracted, the moving saddles are set on the ground, and movement is performed with the rails floating.

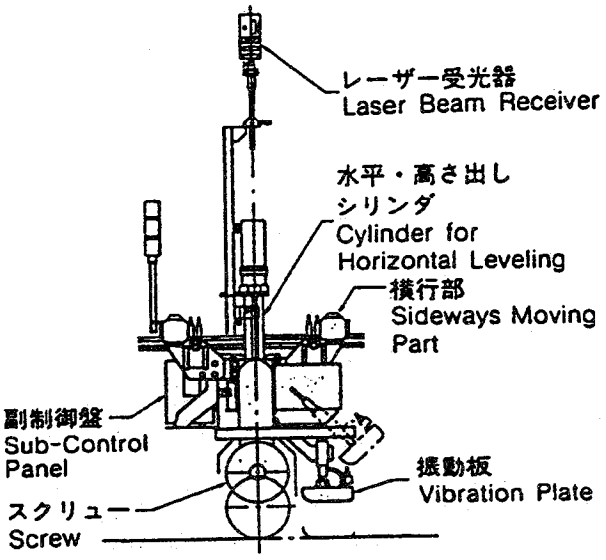


Fig-2 Screeding Part

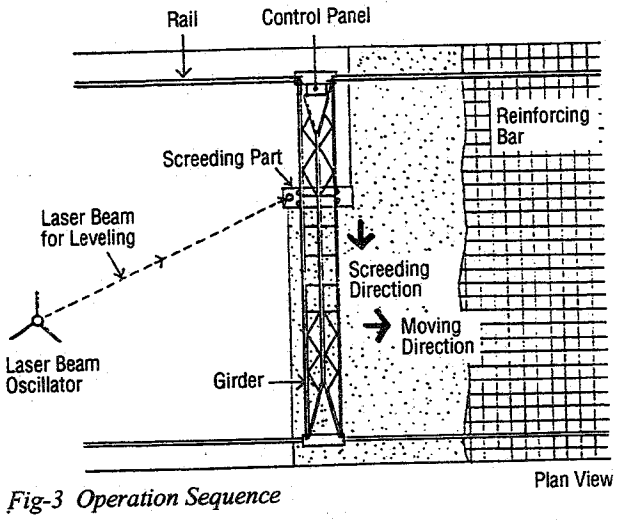


Fig-3 Operation Sequence

5. Work execution record

The number of past works is 50, including screeding work for earth floors of factories and warehouses and floors of office buildings. The area screeded by this robot is 240,000 m².

6. Usage conditions

①Concrete is placed 3 to 5 m at a time in parallel to the girder.
②Concrete is placed at a slightly greater height than the planned screeded level.
③The robot evacuating place and method and cleaning method after concrete screeding work is finished are planned.

CONCRETE-SLAB FINISHING ROBOT

Applicable type of work:	Concrete-slab finishing work	Official price:
Classification:	Autonomous locomotion robot	
Purpose of the development:	Labor saving and cost reduction	Lease and rental:
Level of practical use:	Used in actual work	Development company: Kajima Corporation and Tokimec, Inc.

Information		
	Company name:	Kajima Corporation
	Responsible section:	Technical Development Department, Machinery and Equipment Department, Constructing Group
	Address:	Fujikage Bldg. 1-1-5 Akasaka, Minato-ku, Tokyo 107
	Phone:	03-5474-3781
	Fax:	03-5474-9738

1. Application

Finishing of concrete-slabs in buildings, plants, etc.

2. Outline

Direct concrete-slab finishing is a work conducted to finish concrete surfaces smoothly with the use of trowels after concrete has been placed on a floor. This work has traditionally been the domain of skilled craftmen, but it is an exhausting, backbreaking work, especially in the winter time, when it takes longer for the concrete to set, often forcing them to work until late at night. This robot has been designed to secure a work quality comparable to that of skilled craftmen, and also to save manpower in the execution of this work.

3. Features and Effects

① This is a full-blown self-driven trackless robot that performs slab-surface finishing while moving along travel paths that it automatically determines inside a specified area.

② Its light weight makes the robot suitable for works on the upper floors of buildings, which tend to have a small load capacity. It allows finishing work to be carried out soon after the placement of concrete.

③ The trowel marks are homogeneous, and therefore provide an excellent finishing quality.

④ The robot qualifies for tax incentive measures on mechatronic products.

4. Description of Robotization and Automation

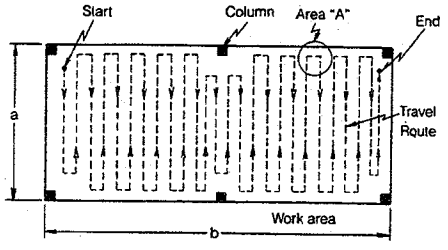
① The robot itself recognizes its current location by using an autonomous navigation device, and conducts all the work automatically.

② It automatically travels within a work area, which can be defined in a simple manner.

③ It repeats traveling along a path pattern according to prior programming.

④ Traveling starting and stopping, as well as emergency stops, can be radio-controlled.

■ Controlling: Only to Indicate the Work Area



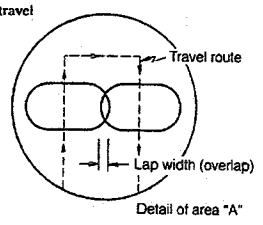
Work area (m)

- Specify the work area by "a" (length) and "b" (width)

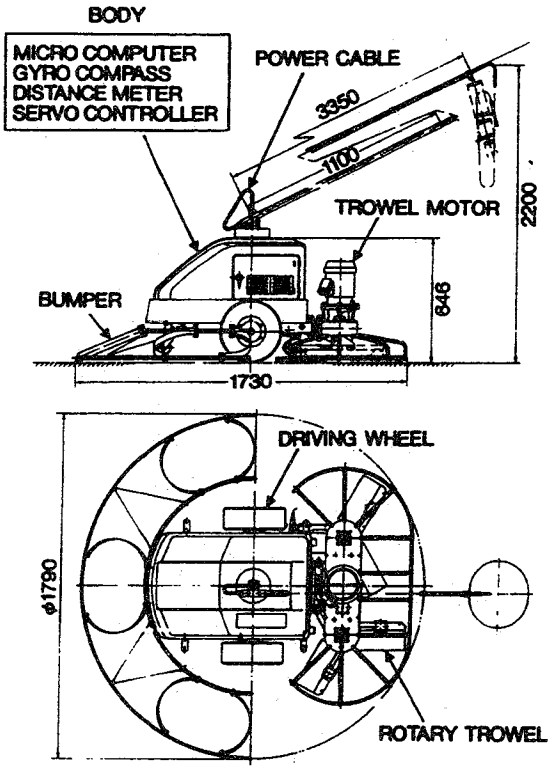
<Variable control data>

① Lap width (mm)
- Width of overlapping finishes will be part of data used to calculate the travel intervals.

② Travel speed (mm/sec.)



Detail of area "A"



Specifications

Item		Description	
Dimensions (Excl. bumper)		1,150 mm (L) × 1,225 mm (W) × 646 mm (H)	
Weight (kg)	Main body	71 kg	Total: 141 kg
	Trowel	54 kg	(Can easily be disassembled
	Bumper	2 kg	into four parts)
Cable handler		14 kg	
Travel Speed		0 - 18 m/min.	
Working Capacity		500 m²/hour (Depending on the concrete quality and weather)	
Control System	Automatic	After the work area is keyed in, touching a button starts automatic operation.	
	Manual	Start/stop, forward/backward movements, and turns can be radio-controlled.	
Control System		Automatic independent navigation system with a microcomputer, gyrocompass, and travel distance sensor.	
Power Supply		200 VAC, 3 phases, 1.5 kVA	
Safety Device	Obstacle detection	Touch sensor	
	Alarm device	Alarm sound	

5. Execution Records

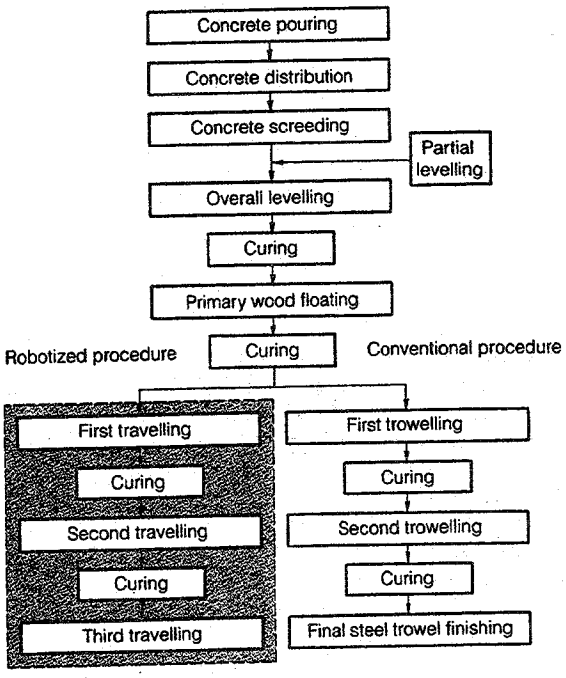
In many buildings, plants, etc..

6. Points of Notice for Use

① The robot operator can work nearby while the robot executes the work.

② The messenger wires necessary to support the power supply cable of the robot need to be laid in the execution area.

■ Concrete Floor Finishing Work Sequence & the Robot's Roles



Note: In the robotized procedure, concrete edges for about 30 cm from columns and walls are to be finished by standard method.

Floor Troweling Robot

Applicable type of work:	Concrete floor direct finishing	Official price:	
Classification:			
Purpose of the development:	Manpower saving, time-saving, improvement of work environment	Lease and rental:	
Level of practical use:	Under burning test	Development company:	EROICA CORPORATION

Information		
	Company name:	HAZAMA CORPORATION
	Address:	Mechanical & Electrical Dept. 2-5-8, Kita-Aoyama Minato-ku Tokyo Japan
	Phone:	03-3405-9251
	Fax:	03-3405-8372

1. Application

Concrete floor direct finishing after manually performed rough smoothing, level checking and screeding

2. Outline

Concrete floor direct finishing depends on manual work of a skilled plasterer. It is hard labor entailing much fatigue.
The floor troweling robot has mechanized and automated the portion of floor finishing work that is done with wooden and metallic trowels, thereby reducing the chore and offering the same work quality as does a skilled plasterer, it is possible to save labor and rationalize the work.
The robot that is compact in size and light in weight has been developed by applying ultrasonic vibration technology to the trowels and employing a newly developed trowel reciprocating system in place of the conventional trowel revolving system.
The robot can be easily introduced in the field.

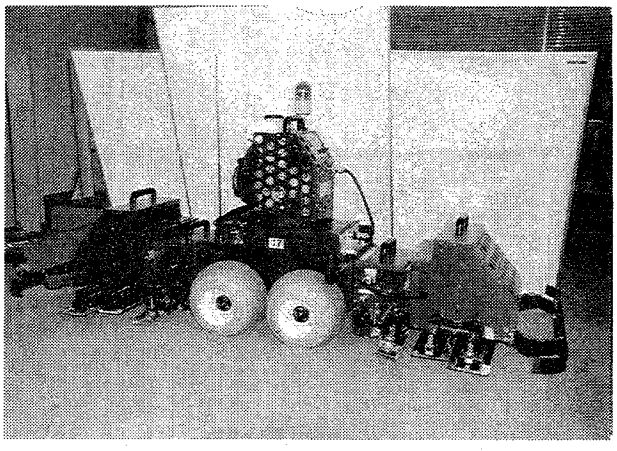


Figure 1. Floor troweling robot

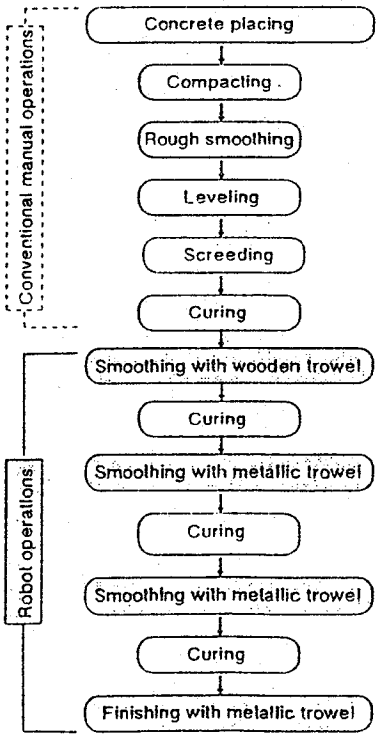


Figure 2. Performing range

3. Characteristics and effects

① The robot is divided into 6 units which can be carried and assembled by hand.
② The assembled robot can be moved or transported by a light van.
③ Before the cocrete bigins to harden -it is soft-,we can make the robot operation start that is light in weight and has 6-wheel drive.
④ The ultrasonic trowel -a trowel fitted with an ultrasonic vibrator- promotes the dense packing of concrete particles at the floor surface. Therefore, like a skilled plasterer, the robot allows a good finished surface to be obtained with a reduced number of finishing strokes.

⑤The safety bumper is improved to have a buffering area which effectively absorbs, by telescopicaction, the travel uder inertia force until the robot completely stops after the bumper s come in contact with an obstacle.

⑥The robot has two operation modes: remote control by radio-control and automatic operation with learning function.

⑦The robot is a self-propelled type having a built-in generator, eliminating the need of a separate power supply.

4. Features of the robotization and automation

Type	Floor troweling robot MHE-1
Length	1990mm
Width	800mm
Height	910mm
Weight	120kg
Finishing width	640mm
Traveling speed	Max. 50cm/sec
Working capacity	Max. 300m²/h
Power supply	High-frequency engine generator (max.output: 1.5KW)
Operation	Computer-controlled automatic operation/ radio-controlled manual operation
Ultrasonic trowel	Oscillation frequency 23.5kHz (two at each end)
Vibroplate	Eccentric exciting motor, exciting force 18kg(one at each end)
Safety devices	Obstacle detection & protection bumper (one at each end), opening detection sensor (two at each end), revolving warning lamp
Sound level	70 dB at distance of 7m

5. Work execution record

Work performed	Client

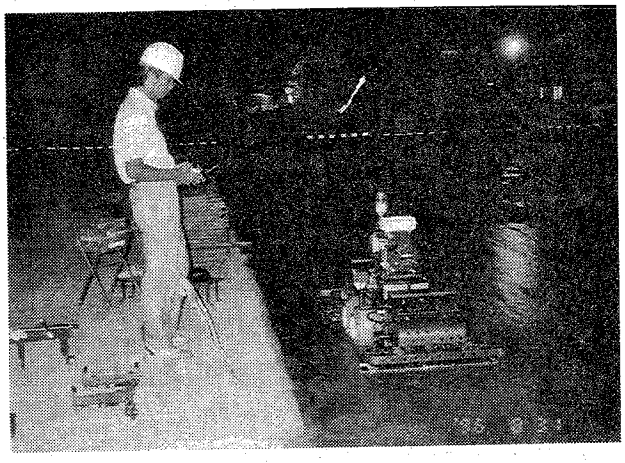


Figure 4. Site operation

6. Usage conditions

Of concrete floor finishing work, only the portion of floor finishing work with wooden and metallic trowels is performed by the robot. Therefore, the rough smoothing, level checking, and screeding following the placement of concrete have to be manually performed as before. Since these operations largely determine the horizontal accuracy of floor direct finish, it is necessary to be performed carefully.

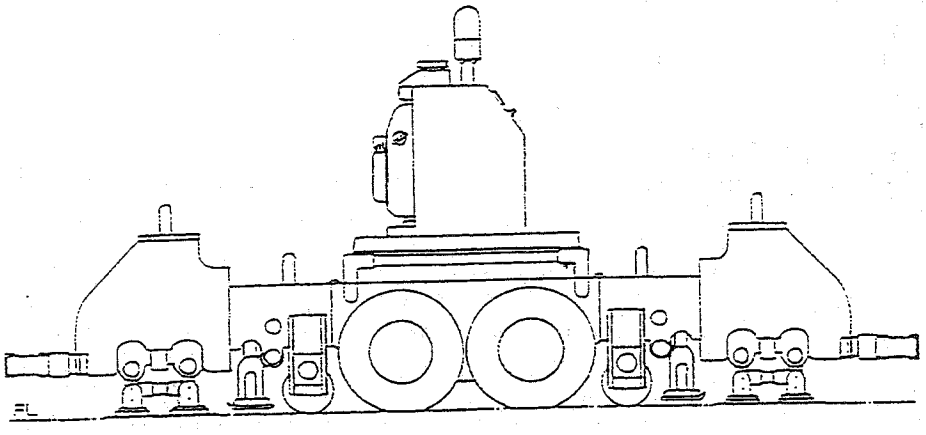


Figure 3. Floor troweling robot

TAPS(Tobishima Auto level Pantograph Slipform)method

Applicable type of works:Construction for Smokestacks,Chimneys,Towers,Silos,Bridge Piers,Caissons	Official price:
Classification:	
Purpose of the development:	Lease and rental:
Level of practical use:Widely in use	Development company:Tobishima Corporation

Information: Company name:Tobishima Corporation
Address: Head Office: 2,Sanban-cho,Chiyoda-ku,Tokyo 102,Japan
Technological research institute:
5472 Kimagase,Sekiyado-cho,Higashikatsushika-gun,Chiba 270-02,Japan
Phone: Head Office: 81-0-3-3263-3151
Technological research institute: 81-0-471-98-7574
Fax: Technological research institute: 81-0-471-98-7585

1.Application

Tobishima Slipform method=TAPS is a new technique for smooth,continuous construction of high-rise structures of all kinds of form.

2.Outline

TAPS method involves a technique of placing concrete inside a bottomless framework while continuously raising the framework by use of 10tf hydraulic jacks.Quick to realize the wide applicability of the technique,Tobishima Corporation took the lead in introducing the slipform method to Japan in 1970.Since then,Tobishima has handled a wide variety of projects using the new process while concurrently advancing research and development efforts aimed at finding new applicability.The slipform method is now generally known for its wide range of application:from smokestacks,chimneys,towers,silos,bridge piers to caissons.

TAPS method represents the most up-to-date version of the method,combining proven features of the past with greater adaptability and higher efficiency.As such,it has been used in many projects not only in Japan but also in many countries overseas.At present,Tobishima Corporation is further engaged in a vigorous technical research and development program aimed at combining all the known advantages of the method for the construction of high-rise long-span structures.

3.Characteristics and effects

The slipform method originally could only be applied to structures with uniform sectional configuration throughout the entire height of the structure.In order to attain wider application,the technology in concrete placing method and framework for the Tobishima slipform method has been improved so that it can be used for structures with wide variation of sectional configuration such as a structure having outside diameter which decreases with height or thickness which decreases with height,or even a structure with step-like changes in form.It can also be used for structures with many openings or with one side supported by natural ground or an existing structure.The Tobishima slipform method also incorporates improvements which assure shorter construction periods and more economic use.

①Precision of dimensions

The framework is designed for proper balance according to the form and dimensions of the structure so that it can be elevated with perfect vertical orientation.When a structure has varying diameter and wall thickness,the rigidity of such a framework is likely to diminish because the degree of dimensional precision tends to decrease.This method,however,uses the system of attaching yokes to girders made of section steel and using jacks and bolts to move these yokes so that the rigidity of the entire framework may remain high insuring the precision of the structure's dimensions.

②Safety

A high level of safety is insured for the workers on the site through the use of such safety facilities as railings,safety nets, working platforms and suspended scaffolds.

③Freedom of form

Since the method allows for the diameter,wall thickness and inclination to be varied in accordance with design requirements,it is applicable to structures of various forms including circular and polygonal smokestacks,chimneys,towers,silos,bridge piers and caissons.

④Shorter construction period

The framework needs to be assembled and dismantled only once and the rate of progress is fast about 3.0m to 8.0m per day in most cases.

⑤Consistent physical characteristics

Since the concrete is placed in one continuous operation,the finished structure is characterized by high degree of water-tightness,air-tightness and evenness.

4.Features of the robotization and automation

Figure.1 is schematic diagrams of Tobishima Slipform method=TAPS.

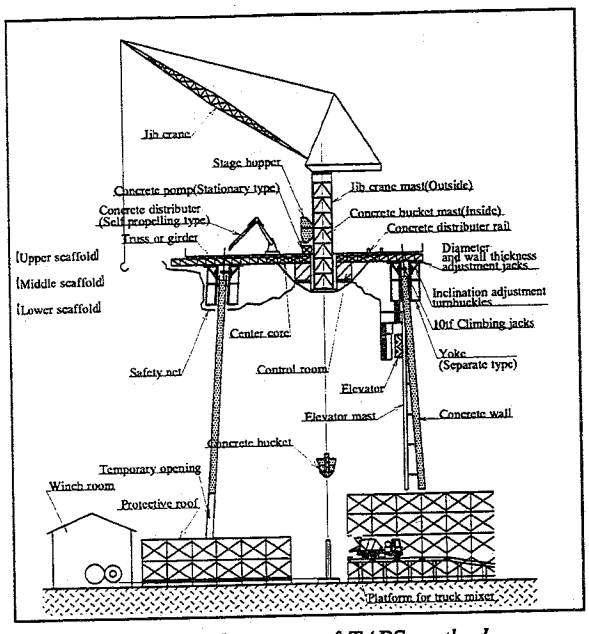


Figure.1 Schematic diagrams of TAPS method

5.Work execution record

TAPS method has been used over 40 projects and total construction extension is over 4,000 meters in the world.The following records are examples in the latest.

Period	1987.10～1990.12
Ordered by	Kansai Electric Power Co.,INC
Place	Nanko Thermal Power Station(*Photo.1*)
Contents	Smokestack,H=200m Diameter:Bottom=26.5m,Top=16.1m Wall thickness:Bottom=1.50m,Top=0.30m

Period	1993.6～1996.10
Ordered by	Tokyo Electric Power Co.,INC
Place	Yokohama Thermal Power Station(*Photo.2*)
Contents	Smokestack,H=200m Diameter:Bottom=37.5m,Top=25.5m Wall thickness:Bottom=1.12m,Top=0.30m

Period	Under construction(1995.11～1998.2)
Ordered by	Tokyo Electric Power Co.,INC
Place	Chiba Thermal Power Station(*Photo.3*)
Contents	Smokestack,H=200m Diameter:Bottom=30.0m,Top=18.2m Wall thickness:Bottom=0.80m,Top=0.30m

6.Usage conditions(Remarks)

For details please refer to Tobishima Corporation.

Photo.1 Nanko Thermal Power Station smokestack

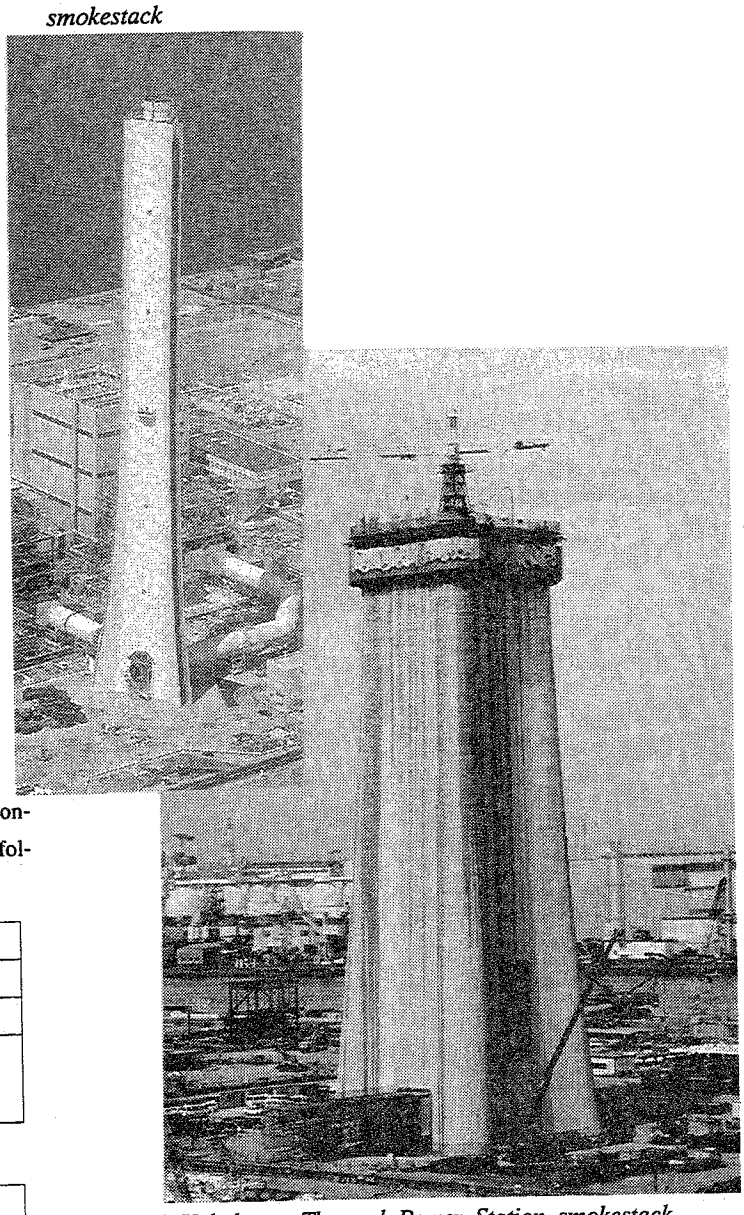


Photo.2 Yokohama Thermal Power Station smokestack

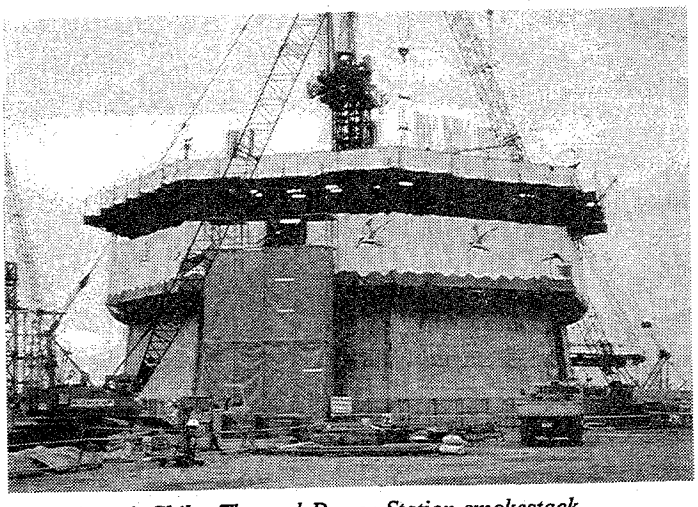


Photo.3 Chiba Thermal Power Station smokestack

Cranes and Autonomous Trucks

New mini crane from Japan can ride on the van, can go up and down the stairs "KALCATTA" (LM15-1)

Applicable type of work: narrow space crane work	Official price: 3,200,000 yen
Classification: mini crane	
Purpose of the development: To reduse manpower and emancipate from hard work	Lease and rental: -
Level of practical use: Available on the market (using in Japan 60)	Development company: KOMATSU Ltd. and Asahi Chemikal Construction Materials Co. Ltd

Information
Company name: KOMATSU Ltd.
Address : 2-3-6 Akasaka Minato-ku, Tokyo 107, Japan
Construction Robotics Dept.
Phone : 03-5561-2707
Fax : 03-3586-7053 (81.3-3586-7053)
E-mail : shigeo_ohno@komatsu.co.jp , shigo-o@aix.or.jp
URL :http://www.komatsu.co.jp/product/kansys/lm15/index-e.htm

1. Application

Narrow space crane work
(for Autoclaved Lightweight Aerated Concrete Panels)

2. Outline

New mini crane **LM15-1** is compact (can ride on the van by crawler), easy (:A.C. 100 V, wireless remote control) but powerful (3.0m /150 kg) and can go up and down the stairs. (with conditions attached)

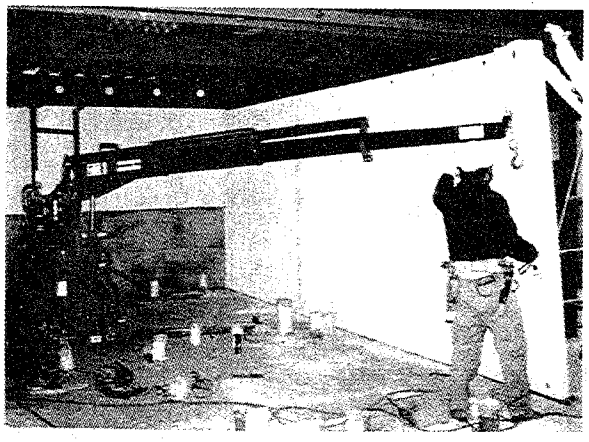


fig1.LM15-1
*(can work in a small space: 4*4m)*

3. Characteristics and effects

[Characteristics]
(1)can ride on the van by rubber crawler: ***fig2.***
(2)can go and down the stairs by rubber crawler (with conditions attached): ***fig3.***
(3)compact size: ***fig.4***
(4)power source:A.C. 100V(can get in small house always)

[Effects]
(1)to reduce manpower (3→2)
(2)emancipation from hard work

fig5. the work now without LM15-1

4. Features of robotization and automation

(1)Weighit:520kg
(2)Outreach/lifting capacity:
1.2m/350kg, 2.1m/225kg, 3.0m/150kg
(3)Max height:4200mm (4)Min height:0mm
(5)Max outreach:3000mm (6)Min outreach:1200mm
(7)Slewing angle:330 degrees (8)Length:960mm
(9)Width:790mm (10)Height:1970mm
(11)Power source:A.C. 100V(Crane unit)
D.C. 24V(crawler unit)→battery
(12)Method of operating:wireless remote control
(13)A safety device:a buzzer for over lifting capacity
(14)Method of separation into two pieces:by two pins
(15)Weight of each piece:crane unit→300kg, crawler unit →150kg, outriggers(4)→70kg

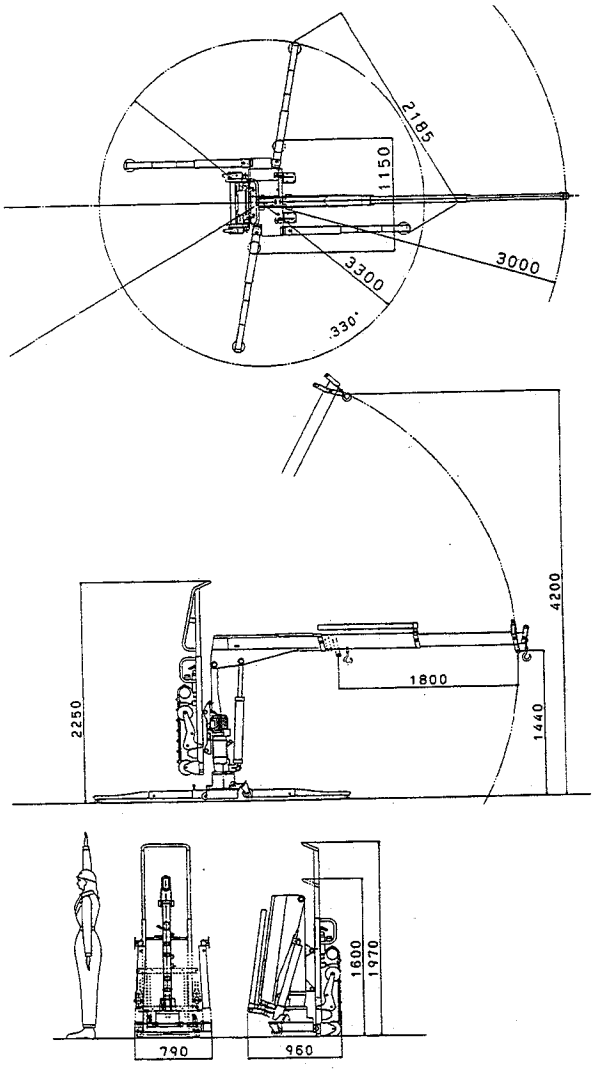


fig6. dimentions

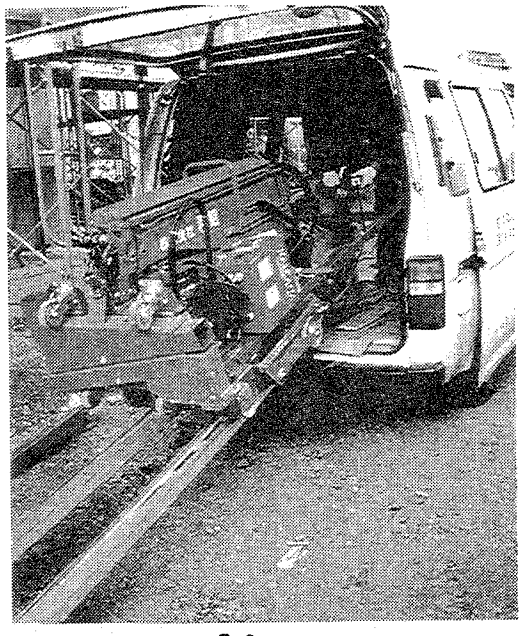


fig2.

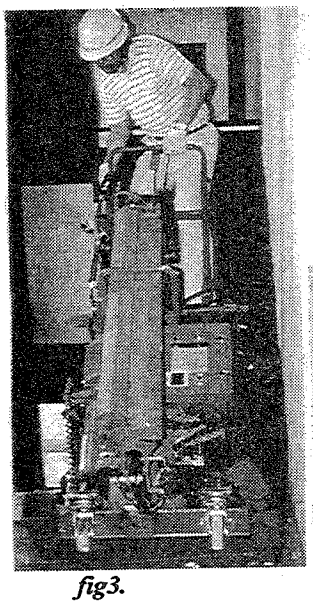


fig3.

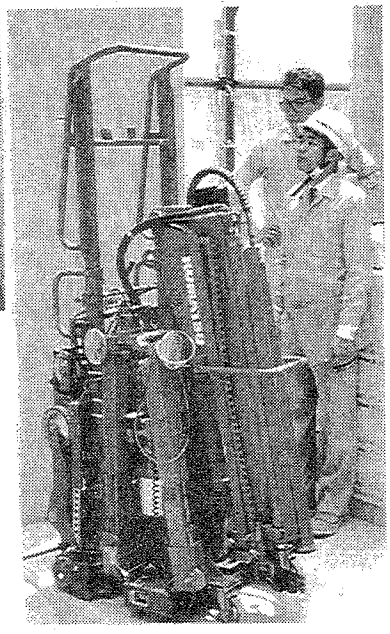


fig4.

5. Work execution record

(1)first introduction in 1995
(2)more than 60 have been well received in Japan
(3)main user are working for [Autoclaved Lighitweight Aerated Concrete Panels] by this one

6. Usage conditions

(1)When go up or down the stairs(rubber crawler by electric motor), needs one or two opereter.

Material-Handling System for Interior Finishes

Applicable type of work: Conveyance for interior finishes	Official price:
Classification:	
Purpose of the development: Manpower saving, time-saving, improvement of work environment	Lease and rental:
Level of practical use: Available on the market	Development company: Shimizu Corp., Mitsubishi Heavy Industries, Ltd.

Information		
	Company name:	Mitsubishi Heavy Industries, Ltd.
	Address:	Marunouchi 2-5-1, Chiyoda-ku, Tokyo 100, JAPAN
	Phone:	+813(3212)9126
	Fax:	+813(3212)9833
	E-mail:	

1. Application

Conveyance for interior finishes; plasterboards, channels, lightings, pipes, ducts; in the building under construction.

2. Outline

When the structural construction is nearing completion, various interior construction works; interior finishes, plumbing, lighting and so on; are performed in every place within the construction site at once. Storing all the building materials used for those works in the site is difficult because of maintenance and limited space of construction site. Therefore those materials are required to carry in just on time and bring to workshops in the site as soon as their arrives. Handling of materials sometimes interrupts skilled workers on the job, productivities of their works are declined. Furthermore handling sometimes continues until midnight to be in the time for tomorrow's work, it is also hard for workers.

A material-handling system for interior finishes was designed to move plasterboards, channels, lightings, pipes, ducts, and so on. The system consists of an automated high-speed lift, three special AGVs, and a system controller as shown in figure 1. The lift is an ordinary high-speed one but it is modified according to the automated operation. The AGV is newly developed because traditional lifting ones are too heavy and inflexible in site environment.

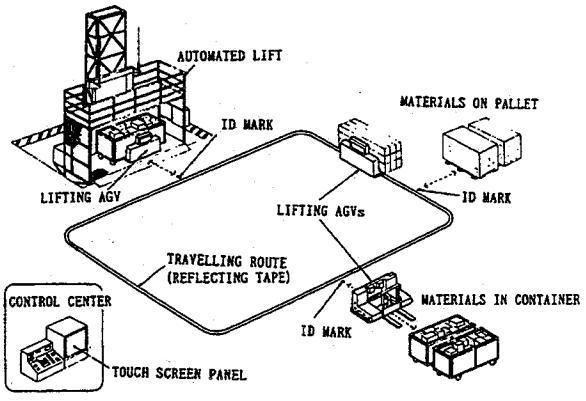


Figure 1. Configuration of Material-Handling system

3. Characteristics and effects

Characteristics and effects of this system are as follows:

(1) Materials are lifted to a specified floor and those are automatically picked up and moved to storage by the AGVs.
(2) In general, Handling of materials requires three to four workers. This system enables workforce reduction.
(3) This system not only deliver containers but also withdraw them.
(4) Even long materials are loaded, the AGV can travel narrow way of construction site with its side fork type forklift.
(5) The AGV equipped with a lift mechanism enables to handle maximum 1,300kg of load, and long materials. The vehicle's own weight is 700kg, one third of traditional lifting AGV.
(6) Silent and clean environment is kept by the motor-actuated AGVs. Since the power of motors is supplied from batteries, the AGV requires no power supply cable.
(7) The automated lift can elevate the AGV.

4. Features of the robotization and automation

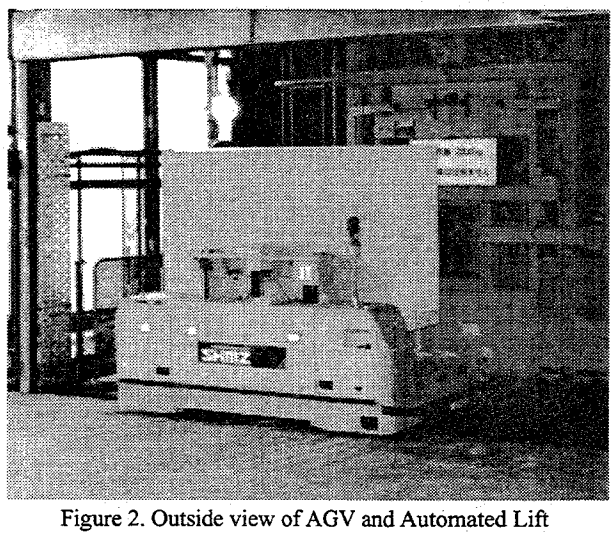


Figure 2. Outside view of AGV and Automated Lift

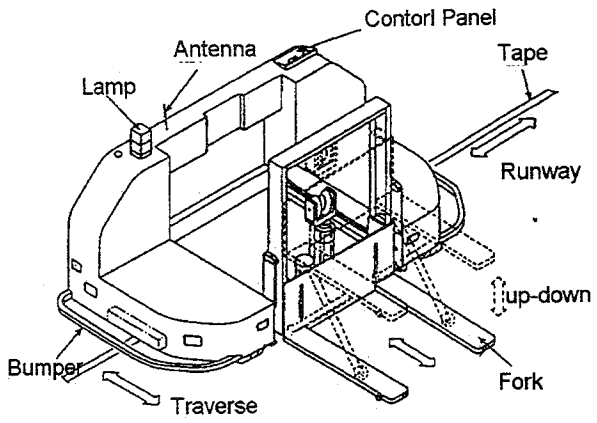


Figure 3. Configuration of AGV

(1) The AGV consists of the side-fork and a traveling mechanism. Loading the material is automatically performed as follows:
- The AGV stops the side of the material been loaded.
- The side-fork mechanism is pushed out under the material.
- Two forks of the side-fork mechanism rise with their scissors type lifting device, then the material is on the forks.
- The side-fork mechanism equipped with rollers is drawn toward the traveling mechanism.
- The forks go down and the material is loaded on the AGV.

(2) The AGV having the individual steering mechanism can move traverse direction.

(3) Moving routes of AGVs can be easily changed according to the site's condition. Unloading places are also easily specified by a PC with a touch-screen panel.(see Figure 3)

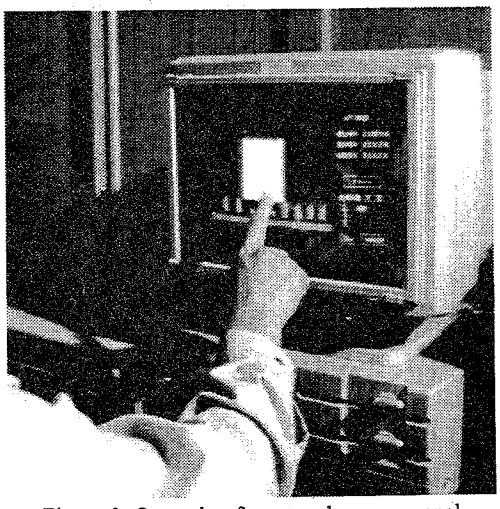


Figure 3. Operation from touch-screen panel

(4) The system is able to control maximum three AGVs per floor, or five per system.

(5) Equipping with safety devices such as touch sensors, the AGVs run safely.

(6) The command of the material loading place of the AGV from control center, is sent to the AGV via the glass fiber. Then the AGV travels along the tape which point the route of it, loads the material, travels toward store place, and leaves it there.

Table 1. Specifications of Material-Handling System

<< AGV >>

TYPE	Side-fork type lifting AGV
RATED CAPACITY	1,300kg
RATED SPEED	40m/min
RADIOUS OF TURN	3m
DIMENSIONS	L=2,500mm, W=1,300mm, H=1,000mm
DRY WEIGHT	700kg
POWER SOURCE	DC24V BATTERY

<< LIFT >>

RATED CAPACITY	2,000kg
RATED SPEED	100m/min
LIFT HEIGHT	Max. 300m
POWER SOURCE	3 ϕ AC200V, 50/60Hz

5. Work execution record

Makuhari-Fijitsu building (tentative name), NM building (tentative name), Chuo-godo chosya building (tentative name)

6. Usage conditions

(1) The number of AGVs is planned according to floor area of the building.

(2) Putting materials on a palettes or in a container is preferable to use this system efficiently. When the material without container nor palette is left on the floor directly, placement of 10cm-squared lumbers on the floor is necessary to keep clearance for forks of the AGV.

LIGHT WEIGHT MANIPULATOR

Applicable type of work:	Fitting interior materials	Announced Price:	Seven million Yen (Attachments are optional)
Classification:	Construction work		
Purpose of development:	Labor saving, improving productivity, and improving working environment	Lease and rental:	Available
Level of practical use:	Actual use for construction work at site	Developed company:	TOKYU CONSTRUCTION CO.,LTD.

Information	Company name:	TOKYU CONSTRUCTION CO.,LTD.
	Address:	3062-1,Soneshita,Tana,Sagamihara-City,Kanagawa,Japan
	Phone:	0427-63-9533
	Fax:	0427-63-9505

1. Application

This manipulator is used for work to handle heavy equipment and machines, and to fit interior materials.

2. Outline

For ceiling work in interior construction in the past, temporary stagings composed of stepladders and staging boards were built up first over a wide area, on which workers carried out their jobs. Therefore, every time when the place of work changes, the stagings were disassembled, moved, and built up again to spend plenty of time. Since this light weight manipulator serves as a mobile staging with a strong and flat work stage, it does not requires conventional temporary stagings, saves time spent for disassembling, moving, and building up temporary stagings, and can improve safety of work. A combination of the manipulator, various attachments, and adapters makes it possible for a worker to carry out not only ceiling work, such as fitting equipment and machines, fitting subboards, and handling light weight steel members and finishing boards, but also work to fit heavy items to all locations, such as fitting plaster boards or slates on to wall and laying slates or OA floor on the floor.

Storing dimensions	With outrigger:1,490(L)×712(W)×1,500(H)mm. Without outrigger:1,260(L)×712(W)×1,500(H)mm.
Weight	Weight of body:560kg. Weight of attachment:30kg. Weight of work stage:45kg (a unit).
Working dimensions	Manipulator: Maximum height 2,590 mm (excluding reversing arm). Reach of tip Minimum height:870 mm (excluding reversing arm). Maximum height:1,760 mm (excluding reversing arm). Mast stroke: 400 mm. Workable ceiling height: Not more than 3,030 mm.
Carrying capacity	Carrying capacity of manipulator:150kg Reversible weight:120kg
Power supply	Truck:DC24V Manipulator:AC200V

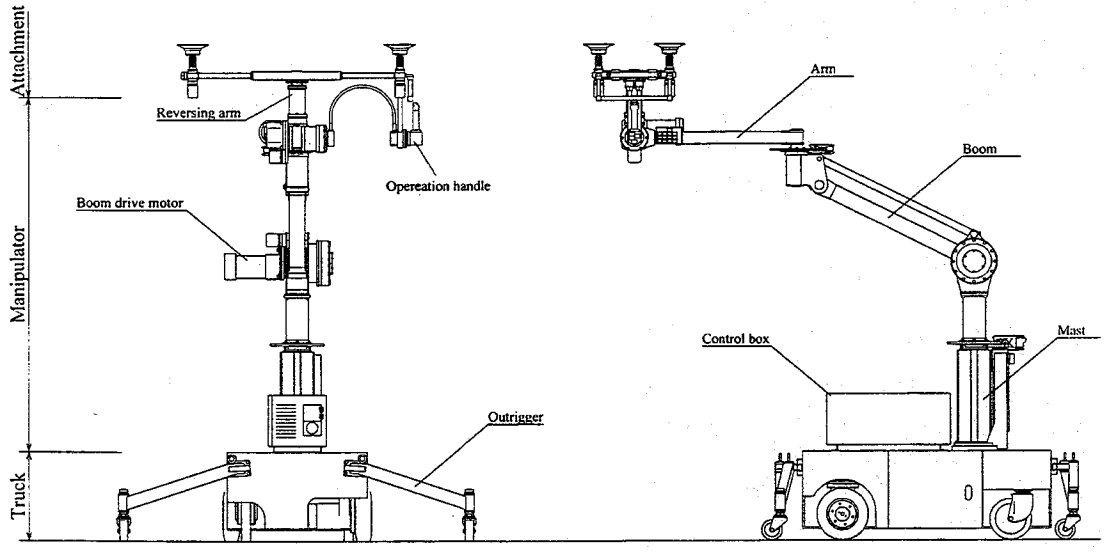


Figure 1. Outline

3. Characteristics and effects

(1) Since the body of the manipultor and work stage can move on the floor freely as one body, building up conventional temporary stagings over a wide area is not required,

(2) Formation of a flat work stage eliminates stumbling and falling of workers.

(3) Heavy or long structural members can be fitted by a few workers.

(4) The manipulator is operated by a worker using a handle provided near the tip of the manipulator. Employment of a manual manipulator easy to handle facilitates fine positioning work.

(5) The manipulator is provided with a reversing arm that turns up and down by 180 degrees, which makes it possible to suck and fit interior materials as they are.

(6) All devices used can be stored in a small volume, allowing for the manipulator to pass a doorway and to be loaded in an elevator of the building. Therefore it can be used up to the highest story even after dismantling temporary cranes for the construction work.

(7) Attachments and adapters can be fitted and removed easily. This makes time and labor that different types of work require minimal.

(8) The use of a combination of various attachments, adapters, and mobile stage can realize staging-less work for general interior construction work.

4. Features of robotization and Automation

(1) A brake provided to each joints of the manipulator can hold the position of the manipulator tip securely. This brake is released by a touch of a worker to the attachment, and locked again automatically by discontinuing the touch.

(2) A contact sensor provided on the suction attachment monitors pressing force all the time, and if an excessive force is applied in fitting ceiling boards or floor materials, the boom stops operation to prevent a damage accident.

(3) The upper and lower limit positions of the manipulator can be set freely to the ceiling and stage heights. This prevents a collision of the tip of the manipulator to the ceiling or the top side of the stage even when the suction attachment is not mounted.

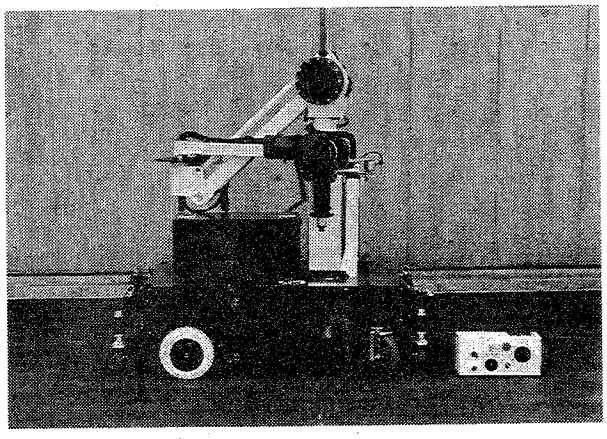


Photo.1. Stored Condition of Body

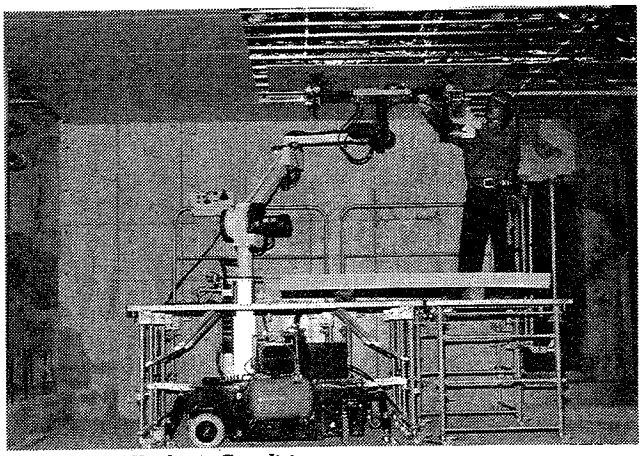


photo.2. Working Condition

5. Actual Results

Up to now (as of December, 1996), trials were carried out at the following 13 construction sites (where we were the contractor).

6. Matters that Require Attention About Use

(1) A big bump, slope, doorway, or other obstacles must not be present on the floor where work is done.

(2) The construction site must have a crane with a capacity of 600 kg or more.

Autonomous truck system

Applicable type of works: Hauling and dumping operations	Official price:
Classification:	
Purpose of the development: Manpower saving, improvement of work environment	Lease and rental:
Level of practical use:	Development company: Komatsu Ltd.

Information Company name : Komatsu Ltd.
Address: Custum Engineering Div. 2-3-6 Akasaka Minato-ku, tokyo 107, Japan
Phone: 81-3-5561-2753
Fax: 81-3-5561-4715

1. Application

Hauling and dumping operations by Autonomous truck system especially for application in mines and quarries.

2. Outline

The basic principle is that an operator teaches each course to one autonomous dumptruck by driving along the same course. Then, the dumptruck travels automatically along the teaching course. Errors of position measurement caused by slipping of tires are corrected by using laser reflector poles on the course. Start the system, select the course, start traveling, each procedure can be remotely instructed from a loading machine.

Fig1 is the model course of automatic operation for fleet control. A is an unloading position, D is a loading position. B is a waiting position to avoid collision with others. The autonomous truck hauls a load from D to A, returns empty from A to D. Course data of A-B, B-C, C-D, D-A is automatically stored to IC memory card of one truck by driving along the hauling course once. The course data can be used for other trucks, too.

As to the change of a loading position, a loading machine operator can change the teaching course automatically by indicating the change length from a loading machine. It can be changed up to maximum length of 5 meters at one operation. By using this function, the operator dosen't need to teach a new course again.

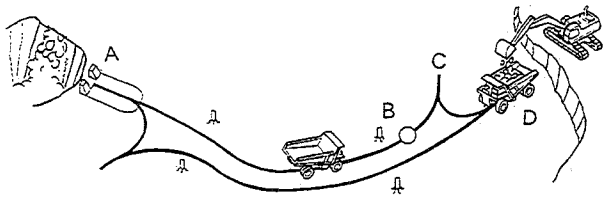


Fig1 Automatic operation of autonomous truck system

Photo.1 Autonomous truck system

3. Characteristics and effects

① Three dumptrucks can be controlled by one operator. So, the loading machine operator can control four machines.

② Each course can be input only by driving along the same course. So, the operator can use this system easily.

③ Each truck can travel slopes of grades up to 12%. This system is not so restricted by the condition of job sites.

④ The same system can be installed to current HD325-6 (Capacity 32t), HD465-5 (46t) and HD785-3 (78t) dumptrucks.

4. Features of the robotization and automation

	Major specifications	Autonomous truck system
1	Base machine	HD785-3 HD465-5 HD325-6
2	Operation method	Selection from unmanned programmed operation, radio-control travel and manual operator.
3	Setting of travel course	Course data are automatically input during manual operator travel, then edited and recorded in memory.
4	Unmanned operation function	Automatic steering, start, stop, travel speed control and dumping by program
5	minimum course width	10m
6	Maximum travel speed	Forward : 30km/h, Reverse : 10km/h
7	Position control error	Stop position : 0.5m maximum Travel position : 2m maximum
8	Travel speed error	10% of set travel speed

① Autonomous truck system consists of 6 controllers shown by Fig.2. Those controllers' missions are supervisor, navigation, safety control, man-machine interface, radio control and travel control. They are connected by serial data link to constitute a network system.

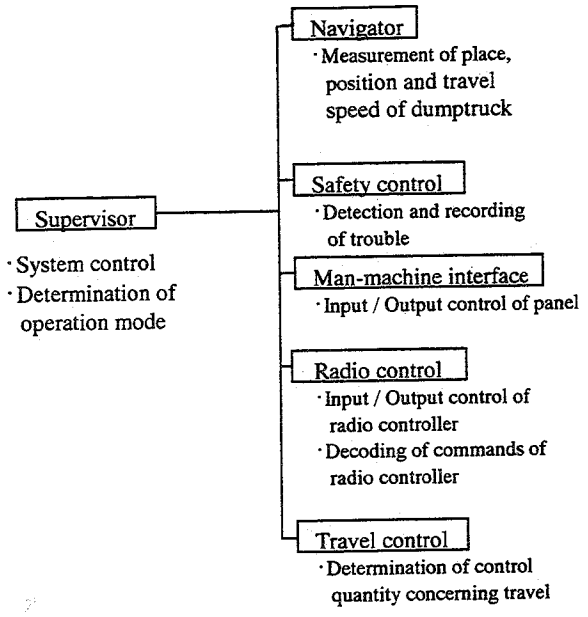


Fig.2 Control system configuration

② Fig.3 is the block-diagram of teaching-playback operation. The controller compares the actual travel data with the teaching course data, present position X, Y, direction θ, velocity V of trucks. From the result of the comparison, the controller indicates the dumptruck accelerator control, brake control and steering control.

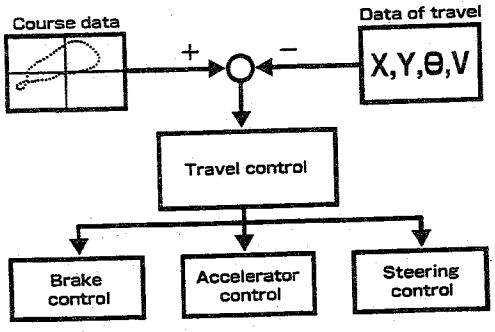


Fig.3 Principle of automatic operation

③ Fig.4 shows the safety system. It is consist of three obstacle detectors. Laser radar can detect up to a length of 100 meters. Supersonic sensor can detect up to length of 12 meters. Touch-sensor can detect obstacle which is touched.

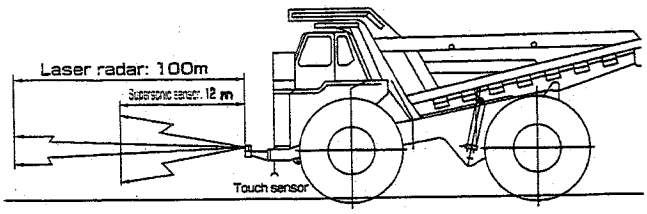


Fig.4 Obstacle detector system

④ Fig.5 is the system configuration of the autonomous dumptruck.

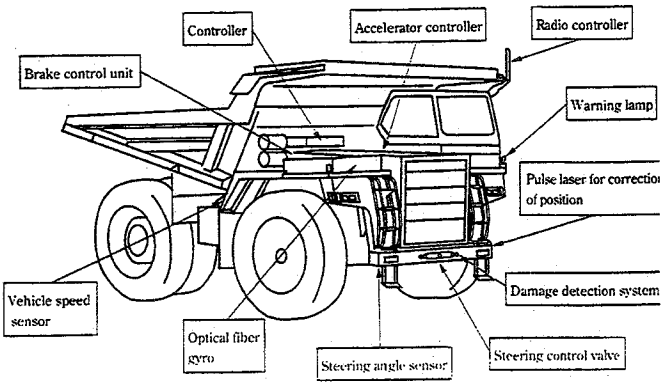


Fig.5 System Configuration

5. Work execution record

Type of work	Client	Dump trucks
Quarry	A Co.	3×HD785-3
	B Co.	3×HD465-5
	C Co.	2×HD325-6
Construction	D Co.	1×HD785-3
	E Co.	3×HD465-5
Test	Komatsu	2×HD325-6

6. Usage conditions

① The hauling course had better to be only autonomous trucks and establish a system for keeping course free other vehicles, people and machinery.

② Minimum course width is 10 meters side.

③ Minimum steering radius of setting course is 15 meters.

④ Maximum grade of hauling course is 12%.

Welding and Positioning of Structural Steel Members

Automatically adjusting system of plumbing structural steel column
TO - Plumb Navi

Applicable type of work: Adjustment of plumbing structural steel column	Official price:
Classification:	
Purpose of the development: High accuracy, time-saving, improving safety	Lease and rental:
Level of practical use: Feasible	Development company: Toda Corporation

Information Company name: Toda Corporation

Address: 1-7-1 Kyobashi, Chuo-ku, Tokyo, 104 Japan

Phone: +81-3-3535-1401

Fax: +81-3-3535-1405

Email: TOD00105@niftyserve.or.jp

1. Application

Automatically adjusting system of plumbing column is used for correcting variation of structural steel columns.

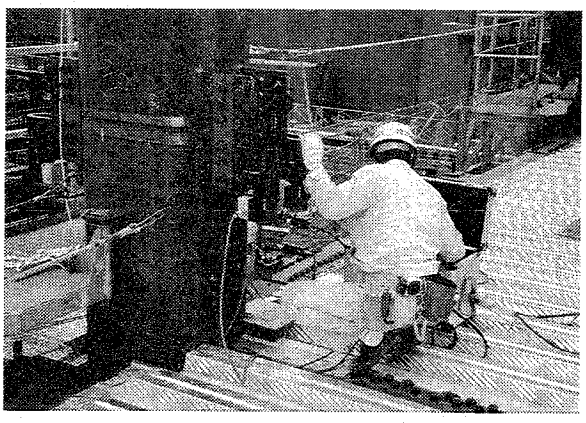


Photo. 1. Automatically adjusting system of plumbing column.

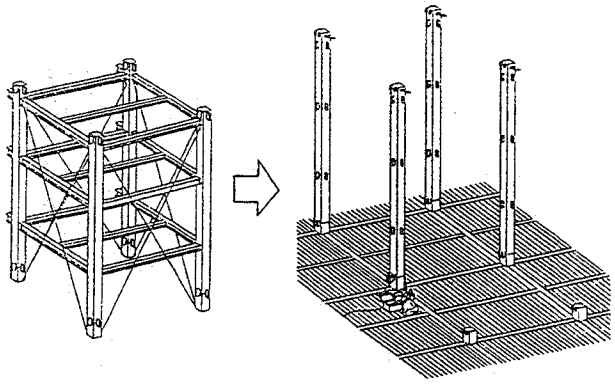


Figure 1.

1. Outline

The Automatically adjusting system of plumbing column is a system which corrects variation of column by turning four vis-jack installed at a column by a motor instead of using wires. This motor is automatically controlled according to the measured data. The system is composed of the measuring system and the adjusting system. The measuring system is composed of plumbing device, CCD camera which is installed at picture treatment apparatus, monitor and a target tag which is made of acryl-resin and stuck to the top of the structural steel column.

The adjusting system is composed of a sequencer which controls motor according to the data brought by the measuring system, four motors and four vis-jacks of which vis has the tensile strength of 5 ton.

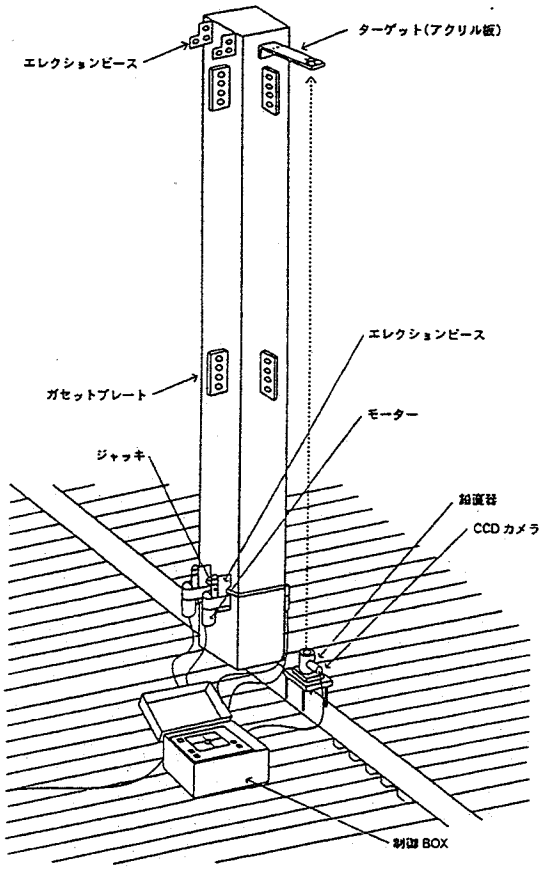


Figure 2. Components of system.

3. Characteristics and effect

① The system controls plumbing columns with high accuracy of tolerance within ±1 mm, so the girders can be easily set.

② The system is safe, so as not to use a wire which passes through a deck in plumbing columns.

③ The adjusting work gets along at the same pace of 10-15 minutes as the temporary plumbing column work which precedes the adjusting work, so the adjusting work hardly affects the plumbing work.

④ Once the apparatus is set, plumbing columns are automatically adjusted, so everyone can handle it.

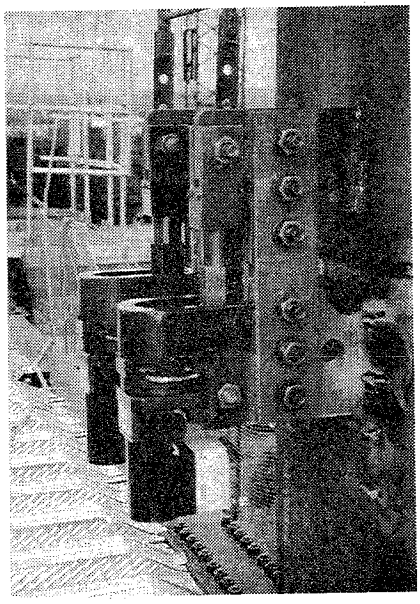


Photo. 2. Around the jack.

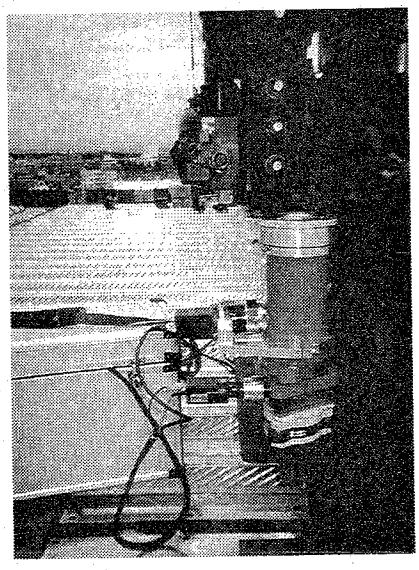


Photo. 3. Plumbing device.

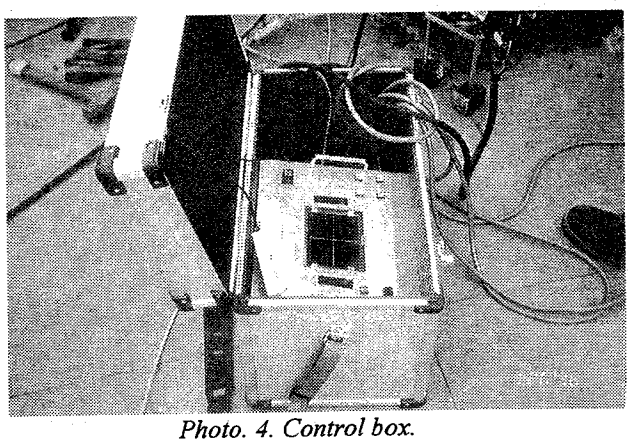


Photo. 4. Control box.

4. Features of the robotization and automation

The system captures pictures of targets by use of CCD camera, and the information which indicates the position of the center of gravity of a target is converted to digital data by use of the picture treatment apparatus, the plumbing column is adjusted by controlling motors and jacks automatically in compliance with the data.

5. Work execution record

Sep. '96	
Location	Chitose-shi, Hokkaido, Japan
Application	It was in use for plumbing 2nd and 3rd piece of structural steel column.
Oct. '96	
Location	Nakamura-shi, Kochi-ken, Japan
Application	It was in use for plumbing 2nd and 3rd piece of structural steel column.

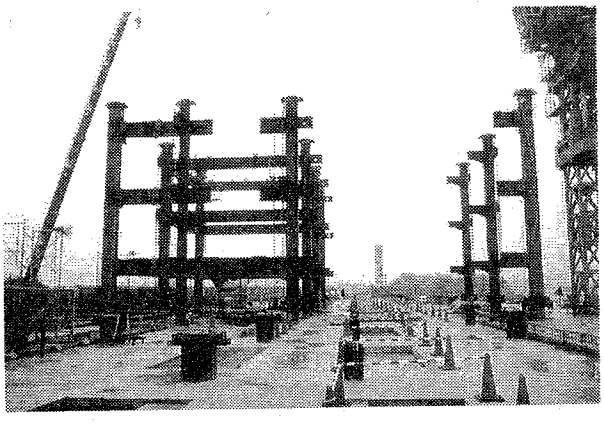


Photo. 5. State of plumbing columns.

6 . Usage conditions

The system cannot be in use in rainy days, because it is not water-resistant.

Column Welding Robot

Applicable type of work:	Steel column welding	Official price:	
Classification:			
Purpose of the development:	Manpower saving, improvement of work environment	Lease and rental:	
Level of practical use:	Available on the market	Development company:	Shimizu Corporation, Mitsubishi Heavy Industry Ltd.,

Information		
	Company name:	Shimizu Corporation
	Address:	2 - 3 , Shibaura 1-chome, Minato-ku, Tokyo, Japan
	Phone:	03 - 5441 - 0107
	Fax:	03 - 5441 - 0886

1.Application

Horizontally multi-layered welding of a joint between two columns of structural steel.

2.Outline

Welding is one of the most effective method for joining metals. Welding at job site shall be carried out by arc manual welding, gas shield arc semi-automatic welding or arc semi-automatic welding and stud welding. there are many factors involved in assessing the quality of a steel welded joint i.e. the welding conditions and the skill of welders. The working conditions of welding a column to column joining at job site are poor since the welding accompanies sparks, sparkless, heat, and a welder should work at a high place. Therefore, the shortage of welder becomes a serious problem today.

The welding robot developed by Shimizu and Mitsubishi Heavy Industry enables automated horizontally multi-layered welding on construction site. The welding system consists of a robot equipped with a welding gun, separable rails attached to the column for robot traveling, a control box, and a carriage that transports a power source, a wire feed machine, and so on.

It also has an advanced welding control system. The welding shape between the columns is detected by a laser sensor system. Then the robot selects the appropriate welding condition from its data base system and applies it.

3.Characteristics and effects

①The robot can weld sites and corners of a column at the same time.
②Since the operation of the robot is easy, a welder can manage several robots simultaneously.
③It can weld various shapes of columns,e.g., cylinder, square.
④The advanced welding control system provides excellent quality of welding.

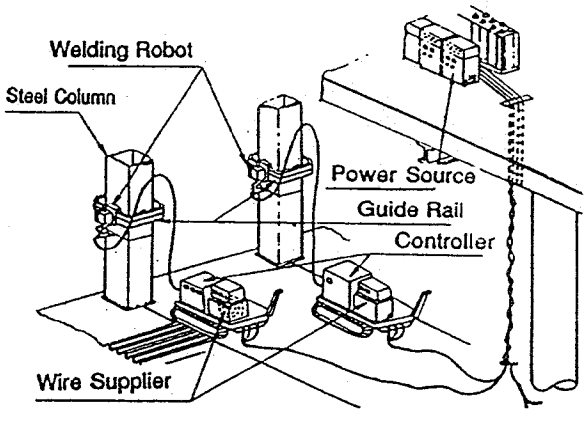


Figure 1.Welding robot system

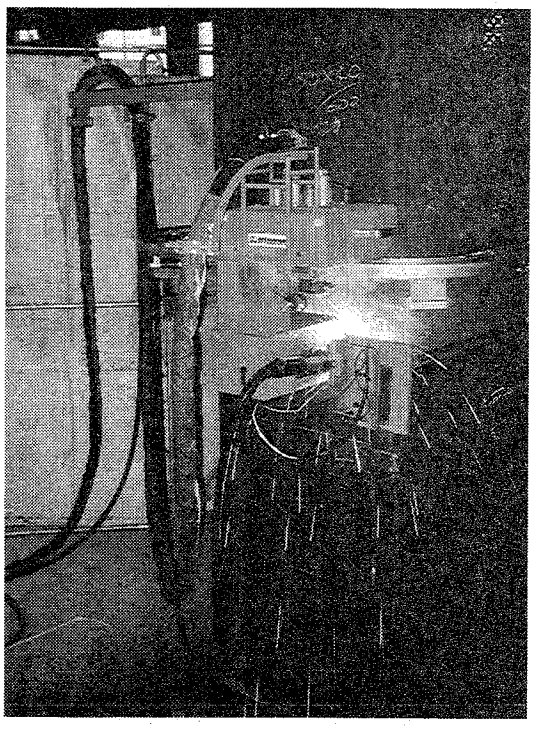


Figure 2.Welding robot in operation

4.Features of the robotization and automation

Specification of the welding robot is shown in Table 1.

5.Work execution record

Used in 10 steel structured buildings in Tokyo, Nagoya and Hiroshima, in Japan.

Table 1.Specification of the welding robot

Equipment	Item	Specification
Body of robot	Type of robot	Adaptive controlled and rectangular robot
	Number of axis	4 axes (3 orthogonal axes and torch axi)
	Kind of motor	DC servo motor
	Moving capacity	X-Y axis: 90mm Z axis: 110mm Angle of welding torch : ±45°
	Size of outward form	W290×L280×H360
	Weight	19 kg
Guide Rail	Structure	Separeted rail (8 parts)
	Weight	5kg maximum per 1 part
Control Device	Teaching method	Automatic recognizing method for groove by lazer sensor
	Control system	Continuous path control
	Controlled object	Welding current Voltage, Welding speed Angle of welding torch
	Self-diagnosis function	Lack of welding wire and shield gas Breaking off of arc
	Voltage	AC100V±10%
	Size of outward form	Control panel W520×L500 ×H520mm Control box W100×L200 ×H50mm
	Weight	Control panel : 40kg Control box : 1kg

Table 2.Applicable conditions of steel columns

Item	Conditions
Type of column	Built box column, Steel tube column Square steel tube column
Width of column	550~1,200 mm
Thickness of column plate	under 80 mm
Root gap	6 mm≦ G ≦12 mm
Misalignment	under 3 mm
Accuracy of column width	under ±3 mm
Groove angle	25° · 30° · 35°

6.Usage conditions

The welding conditions for columns in applying the robot are shown in Table 2. The robot can be applied to not only box columns but also steel tube columns by changing the guide rails and the control software. On the development, it was a serious issue how is the product accuracy and the erection accuracy of columns that the robot can be applied for. But the issue was overcame by having various database in the robot for welding conditions. If the construction accuracy is within general extent(for example, root opening is from 6 to 12 mm), the robot can be applied to welding from the first layer.

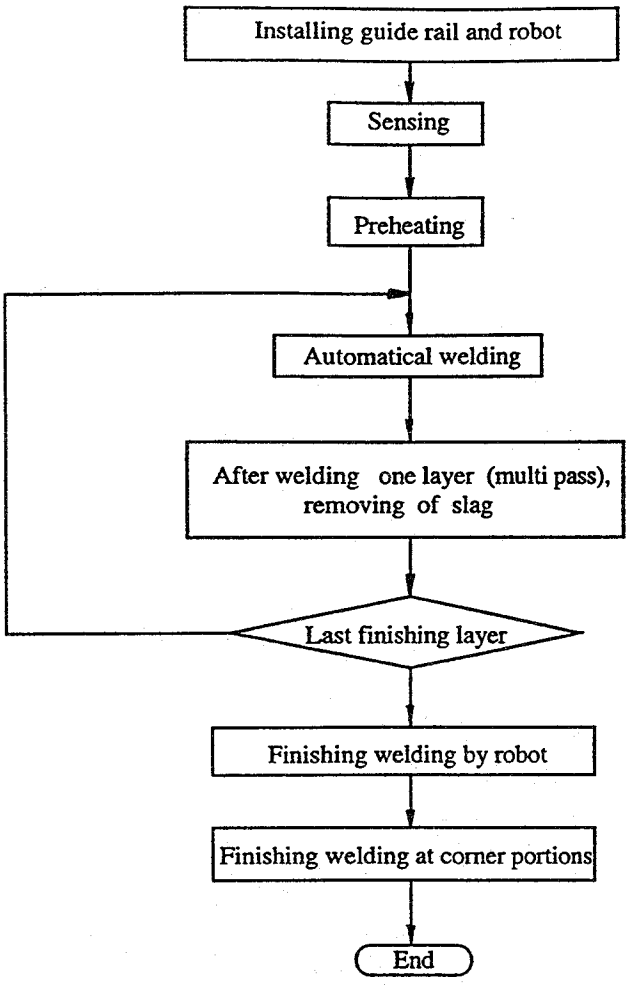


Figure 3.Process of robot welding

"T-UP " Building Construction Method

Applicable type of work: Erection of structural steel	Official price:
Classification: Execution of Work	
Purpose of the development: New Technology, Man-power saving, Improvement of work environment, Improvement of quality	Lease and rental:
Level of practical use: Application in construction sites	Development company: Taisei Corporation

Information

Company name: Taisei Corporation
Address: Sanken Bldg. 25-1, Hyakunin-cho 3-Chome, Shinjyuku-ku, Tokyo 169, Japan
Phone: 03-5386-7557
Fax: 03-5386-7577
E-mail: morimasa@kiku.taisei.co.jp

1. Application

This system is used to erect the structural steel frame for high-rise buildings at high speed.

2. Outline

The T-UP system is a totally mechanized construction system for high-rise buildings. It was developed by treating a building construction site as a production plant, with the aim of improving productivity and the work environment. The uppermost floor of the high-rise building, along with various fittings and equipment, is first built at ground level. It is then jacked up floor by floor and used as a production platform for the remainder of the building. In one sense, it is like a huge self-generating robot in which the platform is the body and the cranes fitted both above and below the platform are its arms. Figure 1 shows the components making up the platform.

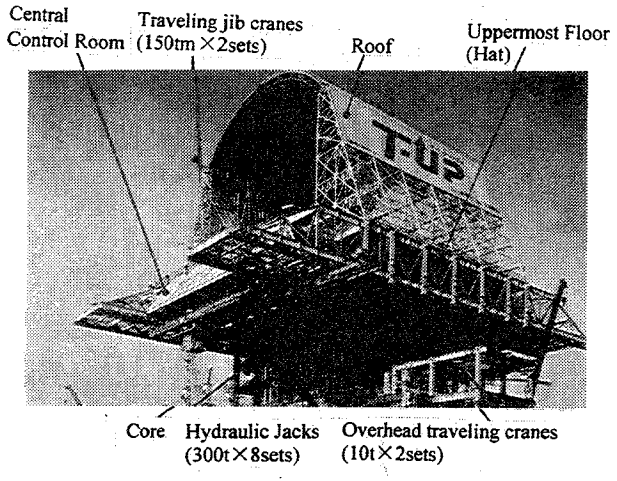


Fig.1 Components making up production platform

3. Characteristics and effects

(1)Crane operations and erection work take place both above and below the platform, so space utilization is maximized and a substantial reduction in construction period is achieved. Further, the use of large prefabricated components results in a considerable improvement in crane operation efficiency.

(2)The large components are prefabricated under strict quality control at production plants both on and off site. Erecting these precision components on each floor using the platform equipment ensures consistent high quality.

(3)The platform reduces the effects of bad weather on the construction schedule. Further, mechanization and prefabrication reduce the volume of construction waste while also offering a clean work environment.

4. Features of the robotization and automation

The procedure used for construction with this system is outlined below.

(1)Erect a few floors of the supporting steel structural frames.

(2)Install guide columns with built-in hydraulic jacks (with a capacity of about 300 tf) at approximately eight support points.

(3)Erect the structural steel framework for the uppermost floor (called the "hat") on the ground. Mount traveling jib cranes on the hat and construct the temporary roof. (See Fig. 2)

(4)Jack the hat up slightly to allow overhead traveling cranes to be mounted on the underside of the hat.

(5)Carry out a test run of the whole system. Once testing is finished, the hat functions as a production platform from which skeleton work begins in cycles from the ground floor up.

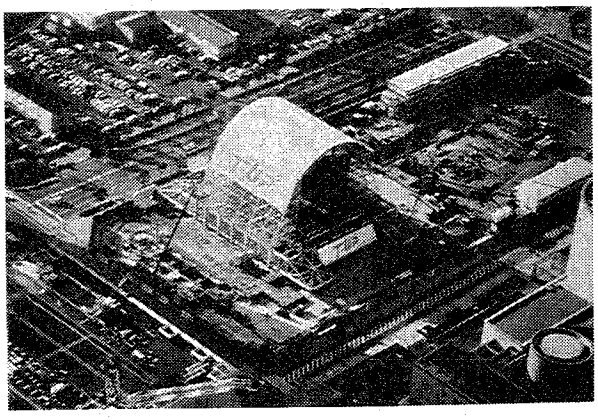


Fig.2 Production platform being built on the ground

Fig.3 Typical floors under erection

(6)Using a cyclic procedure, erect structural steel for the building core using the two traveling jib cranes on the hat, and install structural steel, exterior PCa wall panels, unit floors, and other components by two overhead traveling cranes around the core. The rise rate is one floor in three days. (See Fig. 3.)

(7)When the hat reaches top floor height, disassemble the cranes and the steel support brackets for the temporary roof and cranes.

(8)Settle the hat on the top of the building and carry out final skeleton work.

(9)Complete work around the penthouse and remove the traveling jib cranes before finishing skeleton work.

5. Work execution record

Owner: Mitsubishi Heavy Industries, Ltd.

Designer: Mitsubishi Heavy Industries, Ltd., Mitsubishi Estate Co., Ltd., and Taisei Corporation

Constructor: Joint venture of 15 companies sponsored by Taisei Corporation

Construction period: From April 1992 to March 1994

Lot area: 20,176 m²

Building area: 6,178 m²

Total floor area: 110,918 m²

Number of stories: 2BF, 33F (regulation height: 34F)

Structure: SRC underground, S aboveground

Maximum height: 151 m

Use: offices, cultural facilities, and shops

The overall construction period, expected to be 30 months using conventional construction methods, was reduced to 24 months for a gain of 20%. A work rate of one floor in three days was achieved. Skeleton work on the upper floors was little affected by bad weather because of the protection afforded by the temporary roof.

6. Usage conditions

(1)Although most suitable where floor plans are similar from the lowermost to uppermost floor, some degree of variation can be handled by the system.

(2)Although the system is applicable to any high-rise building of 20 stories or more, it is most effective where there are 30 stories or more.

(3)It is most effective if the applicability of the system is studied at the design phase.

(4)It is possible to draw up optimal plans for the number and capacity of cranes and the specifications for the platform project by project.

Remote shackle releasing system
----- Mighty Shackle Ace -----

Applicable type of work:	Steel column and beam erection	Official price:	
Classification:			
Purpose of the development:	Safety, improvement of working efficiency	Lease and rental:	
Level of practical use:	Available on the market	Development company:	Shimizu Corporation, Eagle Clamp Co.,Ltd.

Information		
	Company name:	Shimizu Corporation
	Address:	2 - 3 , Shibaura 1-chome, Minato-ku, Tokyo, Japan
	Phone:	03 - 5441 - 0107
	Fax:	03 - 5441 - 0886

1.Application

Remote shackle releasing for structural steel erection.

2.Outline

Structural steel erection is performed by repeating following sequence.

(1)Move steel member such as column or beam to its final position by a crane with shackle.
(2)Fix the steel member with temporary bolts.
(3)Release the shackles from steel members.
(4)Adjust the column to be vertically with wires.
(5)Connect steel members tightly with high- tension bolts or weldings.

Steel structure erection is one of unsafe work in construction site because its requires scaffold-men to work on unsafe, high and narrow place.

A Mighty Shackle Ace, a remote shackle for structural-steel erection, improves safety and work efficiency. It consists of a pair of special shackle and wire, electric cylinders to release keys and shackles, a controller, a receiver for radio control and batteries. The keys of shackles equip with double-lock mechanisms for safety.

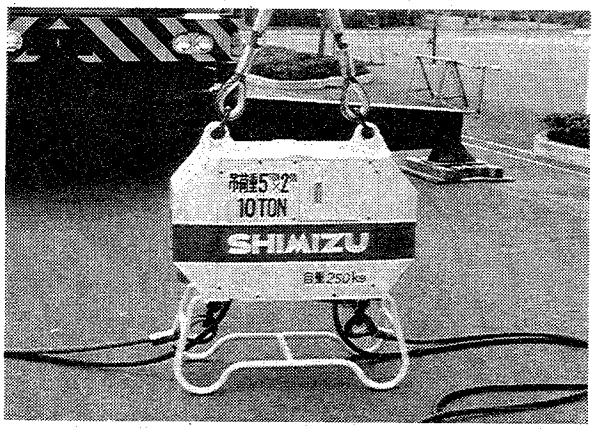


Figure 1.Outside view of the Mighty Shackle Ace

3.Characteristics and effects

The advantages of using this device are as follows:

①It frees scaffold-men from climbing high places to release shackles.

②Time efficiency.

③Wide applicability not only steel columns and beams, but also curtain wall and etc.

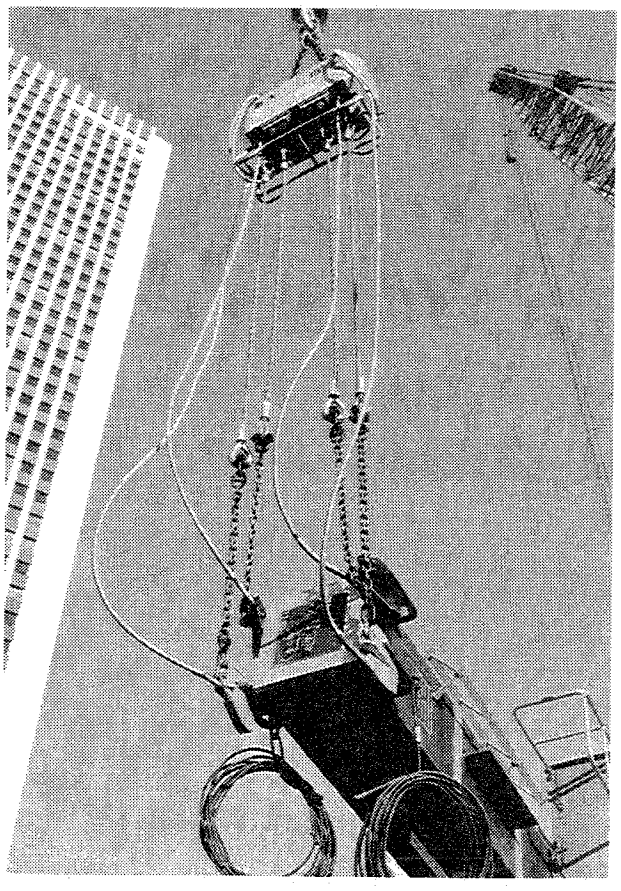


Figure 2.The Mighty Shackle Ace in operation

4.Features of the robotization and automation

Specification of the Mighty Shackle Ace are described below:

Type	ADSR - 12
Lifting capacity	12 ton
Dimensions	W = 415, L = 950, H = 965 (mm)
Weight	250 Kg
Weight of a clamp	12 Kg
Power source	Battery (12V × 2)
Control system	Wireless remote control

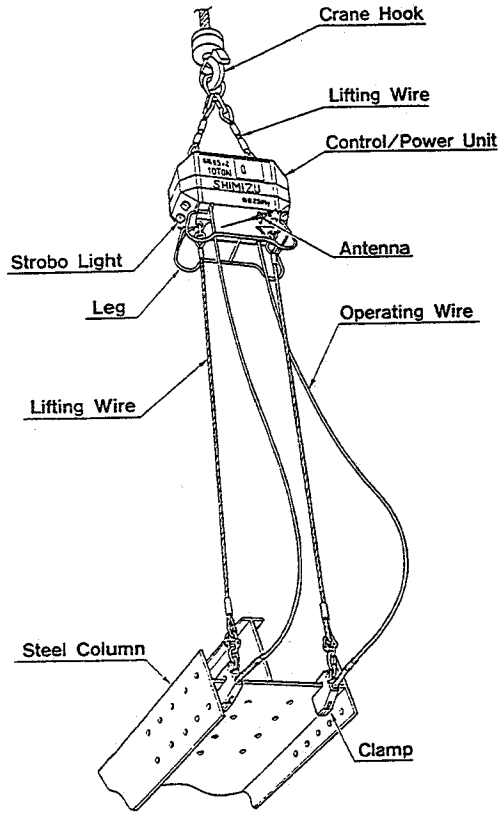


Figure 3.Components of the Mighty Shackle Ace

5.Work execution record

More than 500 units have been supplied for construction companies and rental companies and used in many steel structured buildings in Japan.

6.Usage conditions

As shown in Figure 4, the clamp is provided with a double locking mechanism for the sake of safety at the time of the detaching operation. The unlock operation is carried out by an electric motor drive cylinder connected to a push pull wire in an operating wire sheath.

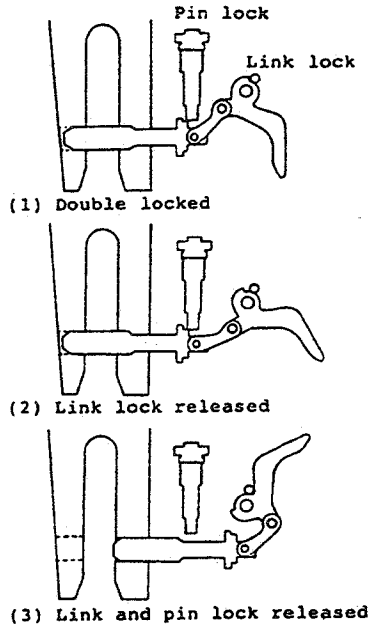


Figure 4.Double locking mechanism

Fire-Resisting and Paint Spraying

Fire-resisting Rock Wool Spraying Robot

TN - Fukkun

Applicable type of work: Spraying Semi-wet Fire-resisting Rock Wool on steel structural members	Official price:
Classification:	
Purpose of the development: Improvement of work environment, spray work at narrow or hazardous area	Lease and rental:
Level of practical use: Feasible	Development company: Toda Corporation, Nozawa Corporation

Information Company name: Toda Corporation
Address: 1-7-1 Kyobashi, Chuo-ku, Tokyo, 104 Japan
Phone: +81-3-3535-1401
Fax: +81-3-3535-1405
Email: TOD00105@niftyserve.or.jp

1. Application

Spraying fire-resisting rock wool (semi-wet type) on steel beams of buildings. This system has been developed to be effective for splaying narrow areas where workers cannot reach, such as the space between steel beams and cladding panels.

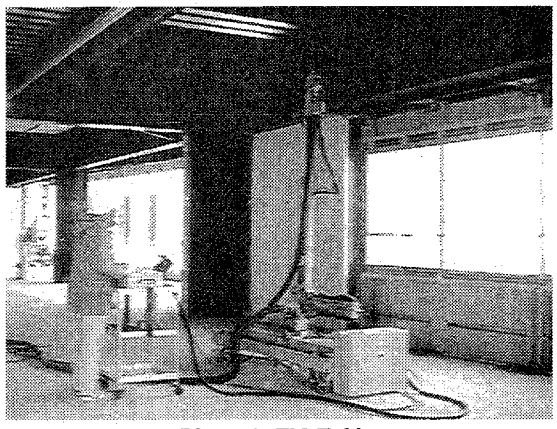


Photo.1. TN-Fukkun

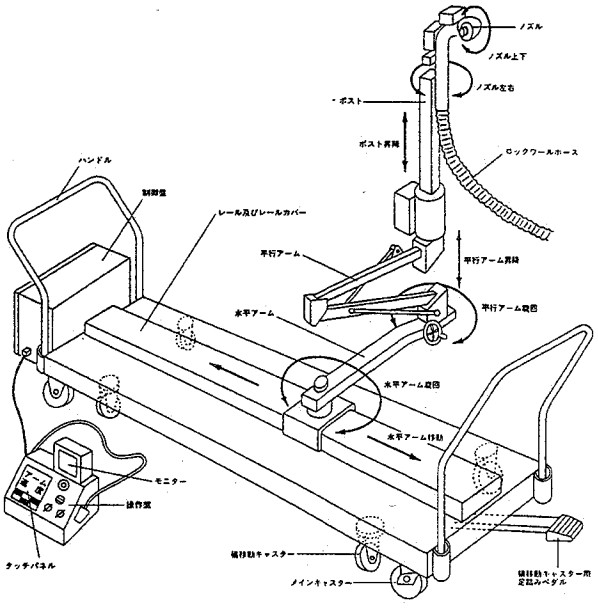


Figure 1. Layout

2. Outline

This system is composed of a carriage, an articulated arm which has a spray gun and a video camera at its tip, and a control system. The carriage has two separate wheel units, one is for usual moving, another is for lateral movement against beams. The two wheel units can be switched easily by stepping on a pedal on the platform. The articulated arm can move horizontally and vertically to reach any designated areas, while the whole portion of the arm slides above the carriage up to 1,500 mm. Also, the splay gun swings vertically. On behalf of the combination of dedicated movements and computerized control system, the system accomplishes flat result at any time in any conditions.

3. Characteristics and effect

(1) A small sized splay gun can go through narrow areas, which enables the system to splay back side of beams at the periphery of a building through a narrow slit between steel beams and cladding panels.

(2) Because of the advantage mentioned above, cladding panels can be installed before the splaying work and result in a elimination of hazardous works at the edge of buildings.

(3) The swing motion of the splay gun makes a flat result, even within a narrow space.

(4) A remote-operation of the system improves work environment.

(5) The system eliminates the cost for scaffoldings.

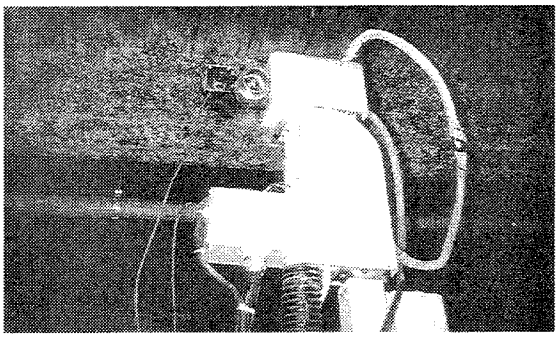


Photo.2. Splay gun

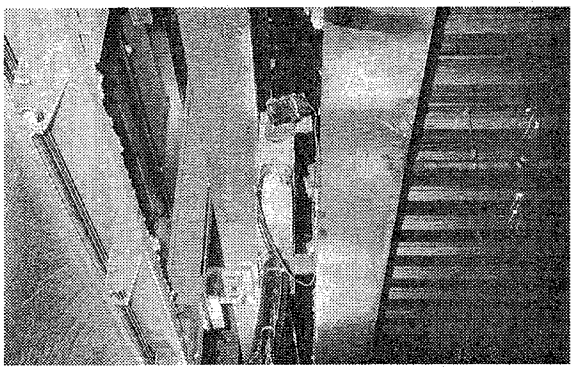
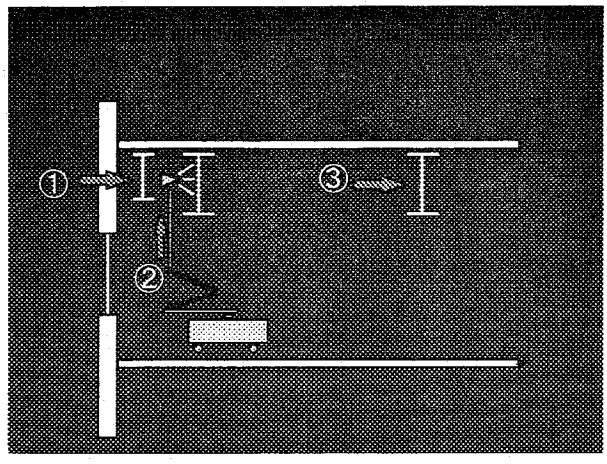


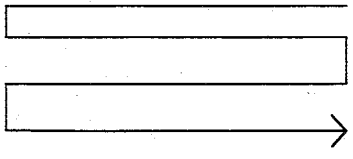
Photo.3. Splaying at a narrow area

4. Features of the robotization and automation

(1) The thickness of splayed rock wool can be adjusted easily by touching the surface of the control panel.

(2) Setting the system at a position, the arm makes a inline movement automatically and splays one side of a beam at the length of 1,500mm.





1,500mm

Figure 2. Automatic movement and the area

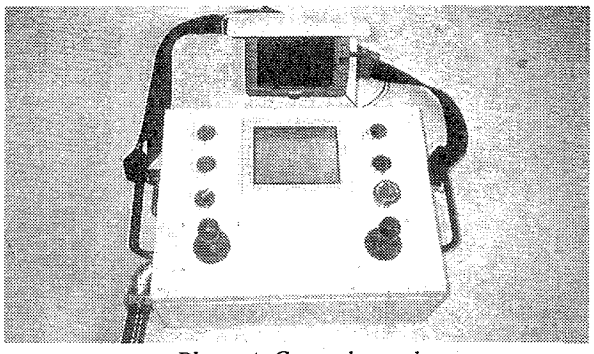


Photo.4. Control panel

5. Work execution record

Feb. '96	
Location	Nagoya, Japan
Application	Peripheral steel beams at a office building
Oct. '96	
Location	Tokyo, Japan
Application	Peripheral steel beams at a office building
Jan. '97	
Location	Kouchi, Japan
Application	Peripheral steel beams at a office building

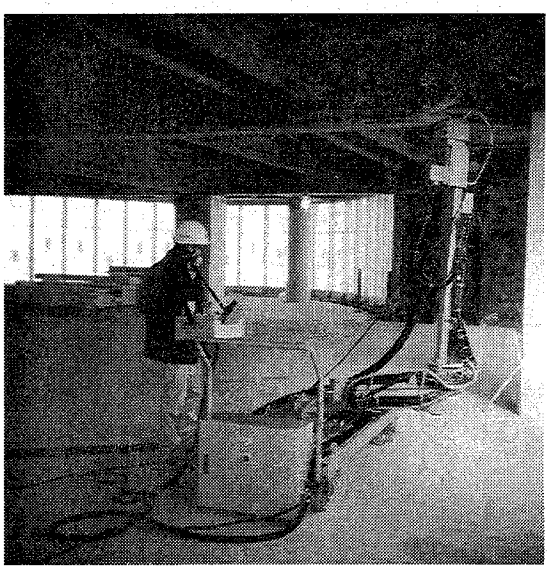


Photo.5. operating

6. Usage conditions

The system does not include a plant unit to prepare material. The control system must be adjusted to fix the thickness of splayed rock wool according to the ability of the plant unit.

EXTERIOR-WALL PAINTING ROBOT

Applicable type of work:	Painting work	Official evaluation: Official price:	None To be specified separately
Classification:	Work execution		
Purpose of the development:	Improvement of the work environment, and an increase in productivity	Lease and rental:	To be specified separately
Level of practical use:	Used in actual work	Development company:	Kajima Corporation and Kajima Mechatro-Engineering Co., Ltd.

Information		
	Company name:	Kajima Corporation
	Responsible section:	Mecha-tronics Development Section, Machinery and Electrical Engineering Department, Construction Group
	Address:	Fujikage Bldg. 1-1-5 Akasaka, Minato-ku, Tokyo 107
	Phone:	03-5474-3781
	Fax:	03-5474-9738

1. Application

This robot is applied to painting work (both for repair and new construction works) on the external walls of buildings.

2. Outline

In consideration of the diverse field conditions existent on job sites and versatility in use, three different types of painting robots have been developed, in the following order: the mast-elevating type, the "gondola" (suspended scaffold)-mounted type, and the dedicated suspension jig type. These robots have been put to practical use since being employed at eight job sites on a trial basis for verification purposes. These robots are capable of painting a wall in a band with a maximum width of 4 m to a prescribed height, and can be employed in all four painting processes (primer coat, middle coat, beading spray, and finishing coat). The robots can be easily controlled, and perform painting jobs automatically while being controlled by an operator via an operation panel located on the ground.

3. Features and Effects (Gondola-Mounted Type)

The features and effects of this robot are as follows:

① Has an execution capacity three to five times higher than that of manual work.

② Can secure a painting quality equal to that of a skilled painter.

③ Can paint walls with uneven surfaces (maximum of 150 mm of unevenness).

④ Work can be conducted safely by one robot operator and two persons in charge of paint supply.

⑤ Because an ordinary general-purpose gondola (suspended scaffold) and traversing equipment can be used with this system, the initial cost and running cost can be kept low.

⑥ When the robot is detached from the gondola, other ordinary work can be conducted from the gondola.

4. Description of Robotization and Automation (Gondola-Mounted Type)

The gondola-mounted type of exterior-wall-painting robot system employs a robot main unit installed under an ordinary general-purpose gondola commonly used in construction work, as shown in Fig. 1. The traversing equipment adopted for this robot is also a commonly-used drive unit that works a gondola in the transverse direction. The entire system is composed of the robot itself, a control board and operation panel, work-monitoring equipment, a "gondola" or suspended scaffold, traversing equipment, and paint-feeding equipment.

The painting quality has been improved through the addition of various functions to the system, among which is one that measures the distance from the painted surface to the spray gun so as to maintain a constant distance between them, even on uneven wall surfaces. Another function is that of nozzle oscillation control, which is intended to prevent uneven painting at the intersection of painting bands. Moreover, the system is equipped with two nozzle units for increased painting capacity.

Photo 1 depicts the application of this robot, and Table 1 summarizes its specifications.

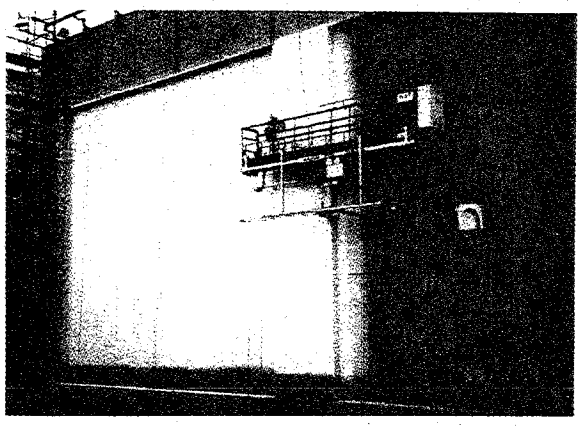


Photo 1. Field Application of Robot

Table 1. Specifications for the Exterior-Wall Painting Robot

Painting material	Multiple-coat type of acrylic rubber-based water-proof facing agent
Maximum painting width	4 m transversely
Painting capacity	Primer coat 290 m²/hr (airless with 2 spray guns) Middle coat 200 m²/hr (air spray with 1 spray gun) Beading spray 150 m²/hr (air spray with 1 spray gun) Finishing coat 290 m²/hr (airless with 2 spray guns)
Traversing speed	40 m/min.
Rotation angle of the nozzle	± 90° laterally ± 45° vertically
Spraying equipment	Automatic gun, paint-feeding pump
Control	Automatic painting with unevenness detection sensor Operation interlocked with the vertical movement of the gondola Nozzle oscillation control at the painting joint
Operation	Selectable between Automatic and Manual via the ground operation panel.
Dimensions	5.4 m (length) × 0.8 m (width) × 1.5 m (height)
Weight	340 kg (for mounting on a gondola)
Power supply	200 VAC, 3 phases

5. Execution Records

The following work was actually performed using the three types of robots:

(1) Four nuclear-powered buildings
(2) Two multiple-dwelling houses
(3) Two laboratory buildings

6. Points to Consider

The painting robots are particularly effective in application to buildings with extensive concrete exterior walls, such as nuclear-power generation plant buildings and warehouse buildings.

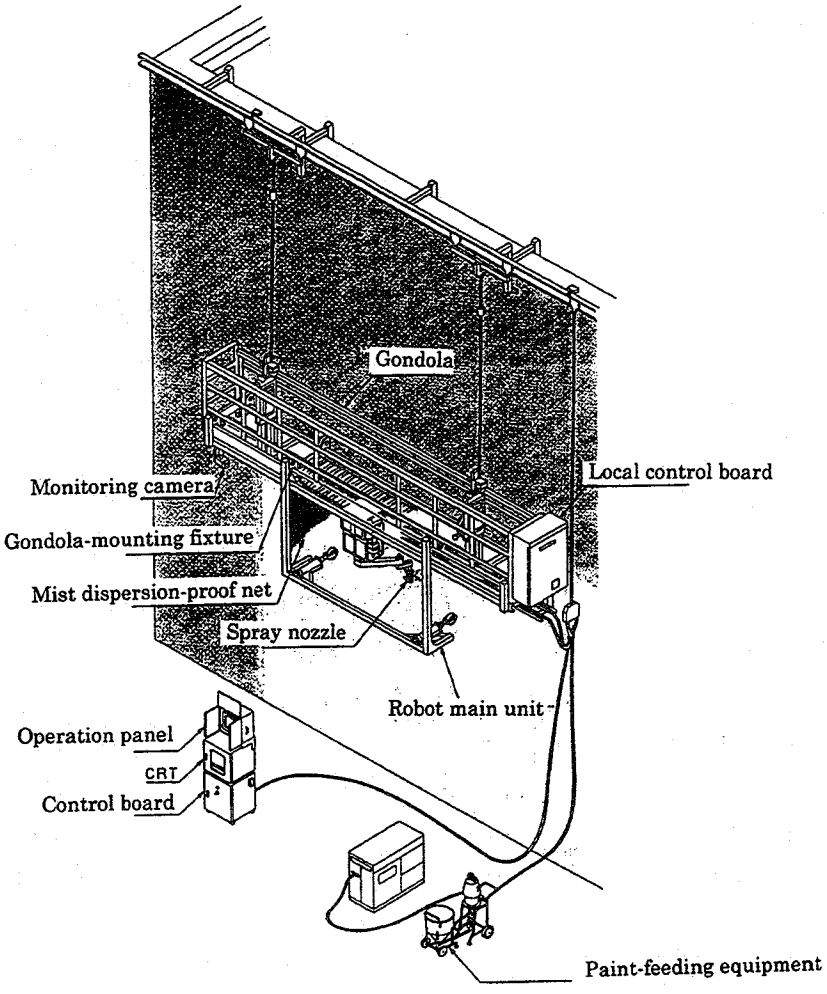


Fig. 1.

System Configuration of the Exterior-Wall Painting Robot

Robot For Painting Exterior Walls

Applicable type of work: Painting Exterior Walls	Official price:
Classification: Execution of Works	
Purpose of the development: Man-power saving, Instead of skilled workers, Improvement of work environment, Improvement of quality	Lease and rental:
Level of practical use: Application in construction sites	Development company: Taisei Corporation

Information

Company name: Taisei Corporation
Address: Sanken Bldg. 25-1, Hyakunin-cho 3-Chome, Shinjyuku-ku, Tokyo 169, Japan
Phone: 03-5386-7557
Fax: 03-5386-7577
E-mail: morimasa@kiku.taisei.co.jp

1. Application

This robot automates painting operations on the PCa concrete exterior walls of high-rise buildings.

2. Outline

The robot was developed to automate the repainting of exterior walls on a high-rise building with a height of 219.5 m and with 53 stories above ground and 3 below. The extremely complex geometry of the exterior walls made it very difficult to plan a robotized painting procedure.

The design requirements for the robot were as follows.

(1)The need for manual masking work before painting operations should be eliminated.

(2)No paint mist should escape from the robot during operation.

(3)The robot should be designed such that no unpainted areas are left on complex wall textures (such as cut-stone patterns).

(4)The robot should work ten times faster than manual painters.

(5)A minimum paint thickness of 50 microns should be assured.

3. Characteristics and effects

(1)The high coverage rate (100 m²/hr.) leads to a substantial reduction in painting time.

(2)Operations are computer-controlled, so no special painting skills are required.

(3)Greater paint uniformity is assured than with manual painting.

(4)Painting within the closed hood prevents the escape of paint mist.

(5)Painting operations are safer because there is no need for operators to work at high elevations.

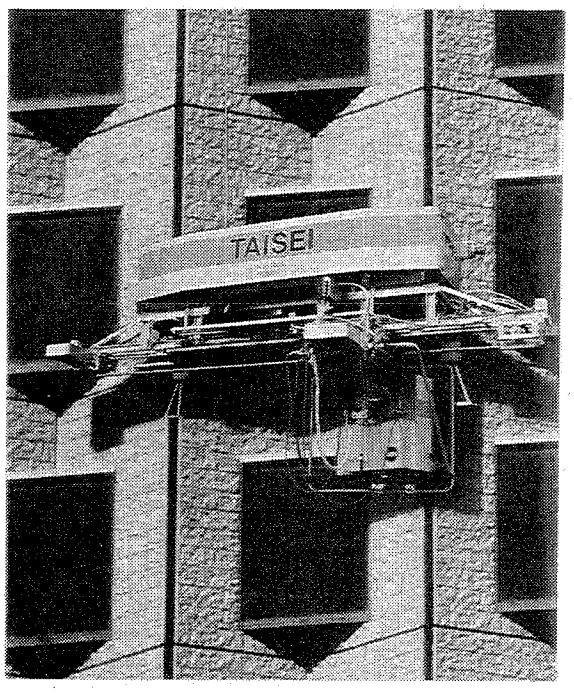


Fig.1 Operation

	Item	Capacity, Dimensions & Weight
Roof Section	Roof car	Hanging load 1.4 tons Descending speed 8 m/min. Ascending speed 16 m/min. Power consumption 7.5 kW (400V) [winch]
	Painting equipment	Power consumption 7.5 kW (200V)
	Paint tanks	80-liter×2 units
	Painting pump	13 liters/min. max.
	Compressor	10 HP
Robot Section	Dimensions, weight	5m×1.6m×2.0m (L×W×H), 1.4 t.
		Power consumption 5 kW (200V)
	Carrier	
	Compressor	2.2 kW (200V)
	Controls	Programmable controller (with NC) Sensors for distance of up/down movement Flaw detecting sensors
	Hood	750mm×600mm (W×H)
	Painting speed	100 m²/H
	Spray guns	Eight airless type units

Fig.2 Specifications

4. Features of the robotization and automation

(1)System configuration

In rough terms, the system consists of three units: a robot unit housing the movable spray guns that lay paint on the wall; a roof carriage that lifts the robot unit up and down; and a painting equipment unit which supplies paint to the robot unit.

(2)Control system overview

The robot is controlled with two programmable controllers, one in the robot unit and the other in the roof carriage. The former processes signals from sensors in the robot and uses the results to control the servo system; the latter takes control of the system as a whole.

(3)Painting operations

The robot sprays paint over a 75 cm wide by 60 cm high rectangular area in one step. It then moves horizontally and sprays again, repeating the process until a 60 cm high band has been covered. The robot then moves downwards by 60 cm and repeats the process. In moving vertically, the robot detects the joints between concrete panels and measures its vertical distance from the joints.

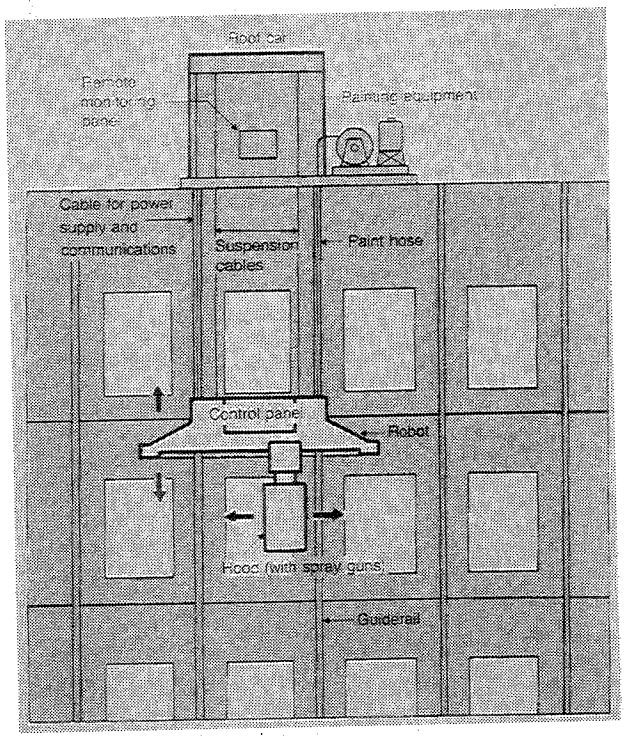


Fig.3 System Configuration

5. Work execution record

(1)Application record

Period: From September 1988 to May 1989 (including winter break)

Building: Shinjuku Center Building (in Tokyo)

Total area painted: 47,700 m^2

(2)Performance

As compared with manual painting, the robot was able to reduce the work period by four months (30%) and the number of workers by 1,463 (74%), respectively.

6. Usage conditions

(1)Rail slits for wall maintenance equipment must be present on the exterior walls.

(2)It is necessary to install equipment on the roof to support the robot.

(3)Painting operations must be suspended when the wind velocity exceeds 12 m/s.

Vacuum-adhering and self-travelling system, Polishing and Painting robot

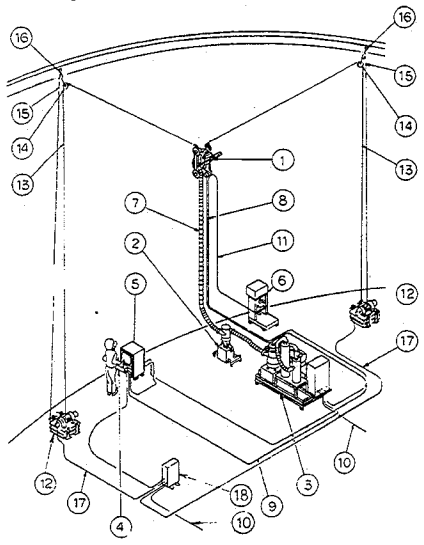
Applicable type of work:	Polishing and Painting	Official price:	
Classification:	Surface preparation and coating		
Purpose of the development:	Manpower saving, time-saving, Improvement of work environment	Lease and rental:	
Level of practical use:	Available on the market	Development company:	
Information	Company name: Address: Phone: Fax:	URAKAMI Research & Development Co. Maruyoshi bldg. 4-17-24, Konandai, Konan-ku, Yokohama, Japan 234 + 81 + 45 + 833 + 5033 + 81 + 45 + 832 + 5081	

1. Application

While adsorbing by vacuum on the wall of the structures and self-propelling along the surface, it does the polishing work for surface preparation and the painting work.

2. Outline

This robot system (refer to figure-1 and figure-2) is composed of a main unit, which adsorbs by vacuum on the wall and self-propels, and a support unit which is installed on the ground. The main unit is equipped with a suction disk fastened with many polishing cloth tips by means of magic tapes, four drive wheels and a roller system paint brush. Also, the support unit is composed of a Roots type vacuum pump unit, a bag filter unit, two auto tension winch units and a electric control unit. When the pre-painting surface preparation work, the suction disk of the main unit is rotated and does the polishing work efficiently . At the same time, the removed dust is collected by the bag filter unit. Also, when the painting work, the paint supplied from a paint pump is applied on the surfacre by means of the roller system paint brush attached to a reciprocator on the main unit. The surface preparation work and the painting work above mentioned of the main unit are operated by a operator on the ground by remote control being monitoring pictures from a ITV camera attached to the main unit. Also, the operation of the support unit is automatic operation. The Roots type vacuum pump is used not only as a source of suction for the removed dust to be recovered but also as a source of suction for the main unit to adhere to the wall. In case the pump stops because of a power failure, two auto-tension winch units are used to prevent the falling down of the main unit.

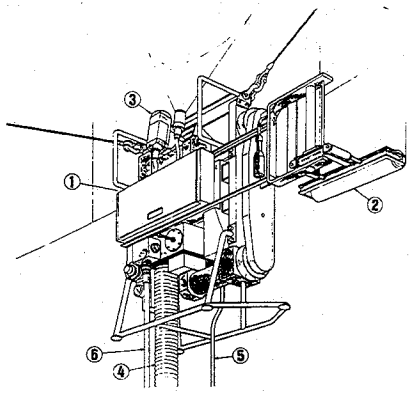


① Main Unit
② Bag Filter
③ Roots Vacuum Pump
④ Remote Control Box
⑤ TV Monitor
⑥ Paint Pump
⑦ Suction Hose
⑧ Control Cables
⑨ Remote Control Cable
⑩ Power Cable
⑪ Paint Hose
⑫ Auto-Tension Winchs
⑬ Wire Ropes
⑭ Sheaves
⑱ Control Panel

Figure 1. Polishing & Painting System

3. Characteristics and effects

① While adsorbing by vacuum on the processing surface strongly and self-propelling freely on the surface by remote control, the main unit can do the polishing work and the painting work.
② The suction disk has three functions which work at the same time such as the adhering function, the polishing function and the vacuum cleaning function.



① Rotating Suction Disk
② Roller Type Paint Brush
③ ITV Camera
④ Suction Hose
⑤ Paint Hose
⑥ Control Cable

Figure 2. Detail of Main Unit

Major Specifications:	
MAIN UNIT	
Type	UMP400
Grinding Width	approx.330 mm
Painting Width	approx.370 mm
Travelling Speed	max.6 m/min.
Weight	approx. 80 kgf(at grinding) approx.130 kgf(at painting)
Dimensions	approx.980 ×650 ×350 mm
SUPPORT UNIT	
Suction Pressure	max.-5000 mmAq
Suction Air Volume	max.6 N m³/min.
Vacuum Pump Motor	22 kw
Weight	approx.2500 kgf
Dimensions	approx.2200×3000×2000 mm

③ The dust on the surface is powerfully adsorbed and collected by the high-speed air flow which is adsorbed into the suction disk of the main unit. Therefore, the environment pollution doesn't occur.
④ Because it doesn't need a scaffolding, the worker don't has a danger of falling down from the scaffolding so the safety improves.
⑤ Because it can be operated by remote control, the labor of the worker can be reduced.
⑥ Because it is equipped with the auto-tension winch units as a safety guard, even if the vacuum pump stops incase of power failure, the main unit is prevented from falling down.
⑦ It can work adsorbing and self-propelling on the processing surface of any material, for example steel plate, stainless steel plate, concrete, glass, plastic and tile.
⑧ It can also adsorb on the surface with some unevenness such as welding seam line at a steel plate and joint line at a concrete wall.
⑨ It is possible to use on the wall, ceiling surface and floor surface.

4. Features of the robotization and automation

① The main unit is operated by remote control.
The two inverters of the control unit adjust the running speed and control the running direction of the main unit But, as for the control of the running direction, it corrects the direction automatically using a inclination sensor.
② As for the quality control of the polishing work or the painting work, the conditions of the processed surface are monitored regularly by ITV camera and TV monitor.
③ The each auto-tension winch unit has a dram which rolls up a wire rope, when the paying-out speed of the wire rope was exceeding the speed which is set beforehand, the wire rope is automatically braked.
As the double fall prevention measure of the main unit, the main unit is equipped with the safety guard system which detects a vacuum decline of the suction disk with a pressure sensor and prevents the main unit to fall down automatically.

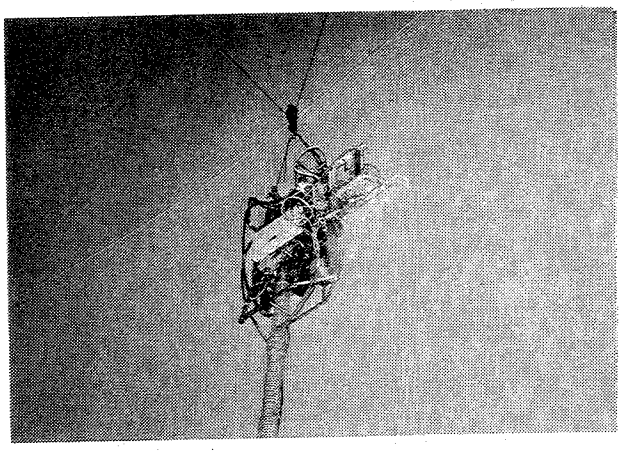


Figure 3.
Photograph of Main Unit of Polish & Paint robot

5. Work execution record

Country: Japan
Type of work: Used for containment vessels of nuclear reactors at nuclear power generating plants.

6. Usage conditions

① Boss and difference should not be on the processing surface. But, the welding seam line is not a problem.
② The curvature of the processing surface radius should be equal to or more than 3mR.
③ Oils and fats shouldn't stick to the processing surface.
④ In case of the lap painting, it must be taken the interval time for about 24-48 hours for the paint coated to be dried up sufficiently.
⑤ The air-less paint sprayer can be loaded to the main unit instead of the roller system paint brush.

WALL SURFACE OPERATION ROBOT

Applicable Work:	Cleaning, coating, and diagnostic check on detachment of tiles on the surface of wall.	Announced Price:	
Classification:	Construction work.		
Purpose of Development:	Improving working environment, workability, and quality	Lease/Rental: Undecided:	
Level of Practical Use:	Actually used at site.	Development company:	TOKYU CONSTRUCTION CO.,LTD

Information:		
	Company name:	TOKYU CONSTRUCTION CO.,LTD
	Address:	3062-1,TANA,SAGAMIHARA-CITY,KANAGAWA 229,JAAPAN
	Phone:	0427-63-9533
	Fax:	0427-63-9505

1. Application

The purpose of this robot is cleaning, painting (in one color), painting a design, and the diagnosis of detachment of tiles on the wall surface of buildings and the like.

2. Outline

In the past, various work on wall surface has been done manually using scaffolds built up to cover the objective wall surface or temporary gondolas, raising many problems due to the fact that such work is dangerous and dirty and the similar. Significant improvement of the term and cost has been disturbed by the time and man-hours required for building up and dismantling temporary scaffolds.

The wall surface operation robot that has been developed recently uses the base that travels by suction on wall surface according to a program. It can carry out cleaning work being combined with an attachment (a wire brush or shot-blast machine). Replacing the attachment fitted to the arm of the robot, various duties, such as general painting in one color, drawing a design in several colors, making a diagnosis on detachment of tiles on wall surface, can be done by one robot only.

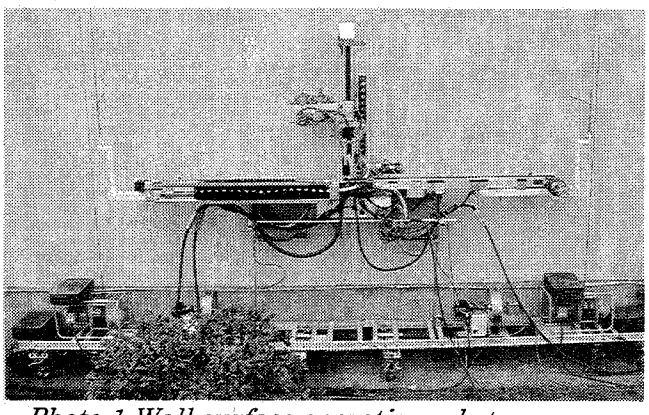


Photo.1. Wall surface operation robot

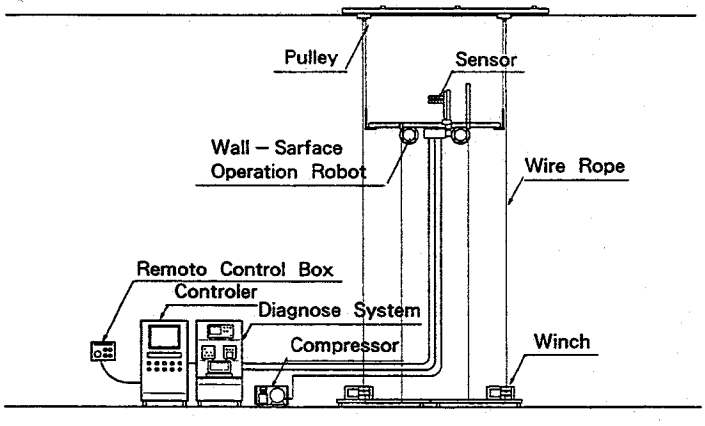


Figure1.System configuration

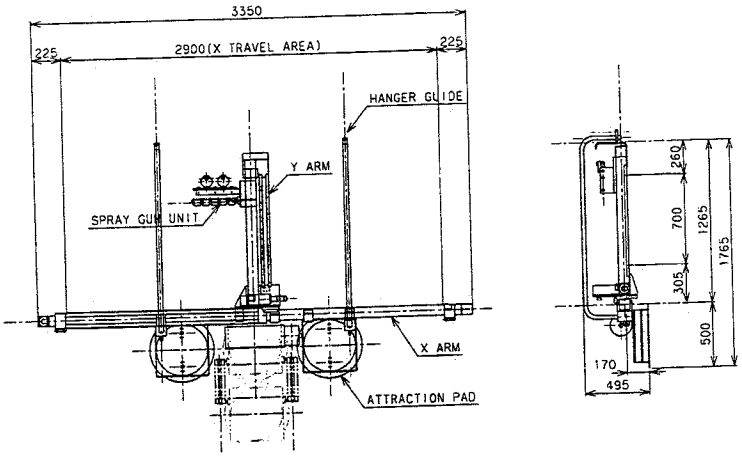


Figure2. Configuration of Wall surface operation robot

3. Characteristics and Effects

(1) The robot can be installed anywhere because its system composition is very simple.
(2) The robot can be operated remotely on a remote control box or automatically by a program.
(3) Operational conditions can be confirmed on real time through the camera provided on the attachment holder.
(4) Cleaning, painting, the diagnosis on detachment of tiles, and the like can be made by replacing the attachment of one robot.
(5) Since the blower of the robot absorbs paint mist in coating work or powder dust in cleaning work, working environment at s site is not affected adversely.
(6) Hung by a wire, the robot goes up and down on wall surface by a winch mounted on the ground.
(7) The robot is stabilized by two suction pads provided on the body of the robot, and this can also absorb the reactive force of the work.

4. Description of Robotization and Automation

Outwardform dimensions	length: 1,765mm width: 3,350mm height : 495mm
Weight	80kg
Arm dimensions	X axis: 3,350mm Y axis: 1,050mm
Working area	X axis: 2,900mm Y axis: 700mm
Painting system	High volume low pressure 5hed

(1)The robot can convert a design made on a PC into a drawing data to draw it and paint automatically.
(2) Numerical data being input on the touch panel, the robot can carries out work, such as cleaning, painting in a color, and diagnosis of detachment of tiles, automatically.
(3) Since the result of a diagnosis of detachment of tiles are stored together with location data, and can be indicated on CAD data, it can be displayed visually.

5. Actual Work Results

Up to now (December, 1996), this robot was used in the following two construction site.

Type of Work	Term	Inspected Area
Diagnosis of detachment of tiles for an office building	January, 1996	528.7 m^2
Diagnosis of detachment of mortar for a warehouse building	March, 1996	186.7 m^2

6. Matters that Require Attention About Use

(1) The robot can not carry out work sometimes on and around a projection and opening.
(2) For the diagnosis of detachment of tiles, suction can not be available sometimes when joints of tiles are wide and deep and in other conditions.

Inspection and Maintenance

Service Robot for Facade Cleaning and Tasks of Inspection and Maintenance

Applicable type of work	Cleaning and inspecting horizontal and vertical as well as curved Facades	Official price:	on request
Classification	Service Robots		
Purpose of the development	Facade cleaning and inspection	Lease and rental:	
Level of practical use:	Development of customised solutions	Development company:	Fraunhofer Institute for Factory Operation and Automation

Information		
	Company name:	Fraunhofer Institute for Factory Operation and Automation
	Address:	Elbstraße 3-5, D-39 104 Magdeburg Germany
	Phone:	+49 (0) 391 / 4090-0
	Fax:	+49 (0) 391 / 4090-345
	E-mail:	schmucker@iff.fhg.de

1. Application

Cleaning of glass facades as well as service and maintenance.

2. Outline

A new generation of service robots is conquering the service sector market. Now that robots have revolutionized industrial production, they are also beginning to prevail in the service sector. Wherever monotonous, dirty and dangerous work must be done, service robots are being used more and more.
The Fraunhofer Institute for Factory Operation and Automation (IFF) in Magdeburg, Germany, is intensively exploring facade cleaning robot systems. Interest in this area is generated by the fact that big buildings with homogenous designed facades with relatively flat surfaces are ideal for automated cleaning. These surfaces are also often difficult to access by people, and personnel costs are high. Moreover the automatic facade cleaning systems have the advantage, that the robot fits in the architecture more than conventional gantries.

3. Characteristics and effects

If the task of cleaning a facade is given to a service robot system, the robot could reduce expensive personal costs.
A facade cleaning robot gives important benefits compared with personal cleaning:

- short cleaning times for large surfaces
- low operating costs, no personnel costs
- cleaning of difficult-to-access areas
- flexible cleaning cycles, cleaning of especially dirty facade areas or cleaning on demand
- consistent value and aesthetic appeal through ease of regular cleaning
- ecologically friendly cleaning

Another interesting benefit may be publicity and the message of a modern enterprise or building which is given to tenants, visitors and customers by such an automatic cleaning robot system.

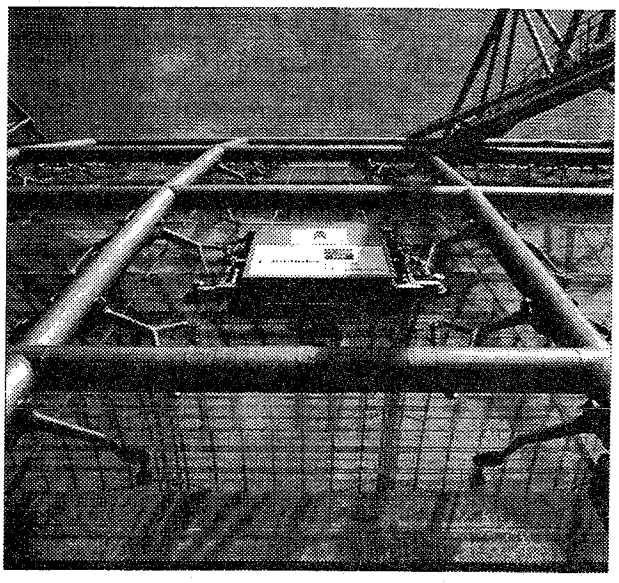


Photo-1 The glass building and the robot

4. Features of the robotiziation and automation

The building
The building a first cleaning robot was developed for is the central building of Leipzig Trade Fair, Germany. This building is completely built with glass and steel. The vaulted glass hall, jewel of the new Leipzig Trade Fair, is 243 meters long, 80 meters wide, and has a central height of 28 meters. A surface area of 25,000 square meters is covered by glass. The hall has an external steel support structure with the glass panes attached under the steel at a distance of 0.35m. Due to architectural restrictions no changes at the facade or the steel carrying construction were allowed.

The required Robot dimensions
The robot dimensions are strictly fixed according to the building construction:

- Maximum height: 30cm
- Maximum width: 1.5m
- Maximum weight: the glass panes allow a maximum robot weight of 250 kg. Also an optimal force-

distribution is needed to avoid any overload on the glass surface.

The robot moves through the small tunnel on the glass. The robot itself has a very flat shape to match the tunnel geometry.

The development of the robot shared in following tasks:

- automatic positioning of the robots at the segments
- construction of the robot, the maximum dimensions of the robot are fixed, all drives and electrical elements, the rope, water and cable drums and the cleaning units must be mounted on the robot
- kinematics of the robot
- navigation of the robot, control algorithms
- multisensory system
- user-friendly operator surface

Principal description of the automatic cleaning robot
At the apex of the roof, a trolley has been installed to position the robot which can then ride the entire length of the ceiling. On both sides of the trolley there are elevators to lower the robots down the glass surface and lift them back up again.

The robot moves directly on the glass on particularly coated wheels, in order to prevent the smallest scratch. The robot is navigated by two Kevlar ropes, at which it is connected with the trolley. In this kind minimum deviations in the motion can become balanced. Within the upper range the robot is driven by a fifth wheel; in the lower section the gravity is sufficient to the drive. Thus it is guaranteed that the robot can move over the distance of 45 meters exactly. All rope-, piping- and cable drums are attached on the robot. Therefore they do not have to be pulled over the glass surface. They are put down on the glass. Thus a damage of the silicone seals and of the glass surface is prevented.

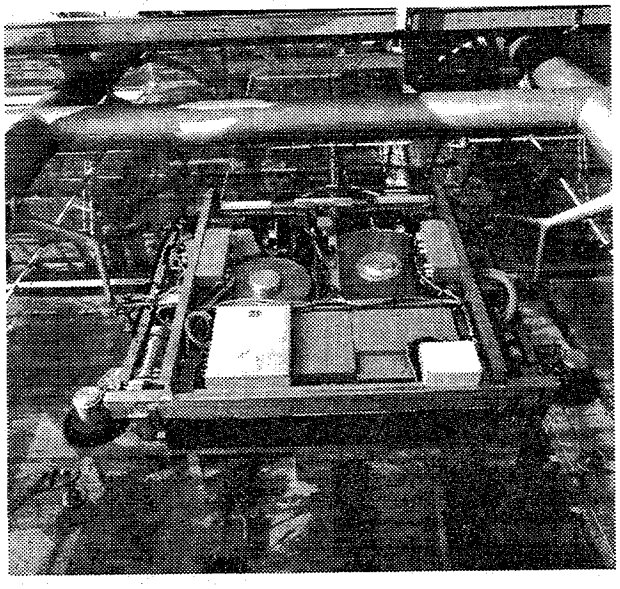


Photo-2 A view inside the robot

Cleaning procedure
The glass panes are cleaned with a roller brush at the front end of the robot. The lateral glass areas are cleaned by rotating plate brushes. These brushes are extendable and swivelable, so that the area behind the glass hanging can be cleaned too. The cleaning exclusively takes place with warm water without cleaning agents. For ecological reasons no
chemical additives are used. To avoid water stains the cleaning water is deionized.

5. Work execution record

The design of the robot and the cleaning procedure depends on different conditions. The most important point is the architectural design. Now the cleaning robots have to be developed especially for any building, there exists no 'allround' system yet. Of course, a modular system for different facade types must be used in future. Facade cleaning robots could work at any building with a large glass facade and with a homogenous shape.

With presented application an example of a facade robot was shown. The robot shown moves on a curved glass area. The Fraunhofer Institute for Factory Operation and Automation in Magdeburg-Germany develops at present a robot particularly for perpendicular facades.
Apart from the employment for the facade cleaning tasks of the maintenance and inspection form the application field of the service robot. Therefore, the Fraunhofer Institute for Factory Operation and Automation in Magdeburg-Germany offers the development of customer specific systems according to the desires of the customer.

6. Usage conditions

The system presented here works fully automatic. The operator gives only the number of segments which have to be cleaned. Everything else is controlled by the system itself.
In addition, with a customized development a partly automated solution is possible.

Surface Preparation System "BIBER" ("BEAVER")

Applicable type of work:	Surface coating removal/Surface preparation for restoration and/or construction	Official price:	
Classification:	Construction		
Purpose of the development:	Labour saving, improving work, Environment, upgrading quality	Lease and rental:	possible
Level of practical use:	Commercialization	Development company:	Groh, Prischmann & Schulz, Forschungs-, Entwicklungs- und Vertriebs- GmbH & Co. KG

Information		
	Company name:	Groh, Prischmann & Schulz, Forschungs-, Entwicklungs- und Vertriebs- GmbH & Co. KG
	Address:	Saalmannstraße 7-9, D-13403 Berlin, Germany
	Phone:	0049 / 30 / 413 50 71
	Fax:	0049 / 30 / 413 60 40
	E-mail:	

1. Application

Millions of square metres of facade await renewal each year. Either the general state of the building demands urgent renovation, or ecologically and economically practical insulation is lacking. A study stated about 75 million square metres of surface in urgent need of restoration in the new German states.
Additionally the cleaning and the preparation of technical surfaces, e.g. ships, tanks, has to be done.

2. Outline

The BIBER System consists of three components: toolhead, a telescoping manned platform or another lifting unit, and a vacuum cleaner.

The toolhead is the most innovative part of the whole system. The principal application is the removal of roughcast or other old coating by means of a brush. For other areas - the scrubbing or brushing of large surfaces - appropriate applications are being developed. It is the attachment- and drive-housing for rapidly rotating tools, such as mills, brushes and cylinders.

A telescoping manned platform is the key to the optimal application of the system. In no time the work platform can be replaced by the BIBER System toolhead. The telescoping lift offers innumerable use, for example wherever and whenever a lack of space (or money) prevents the erection of scaffolding. Small repairs can be carried out, even at tremendous heights.

The vacuum opening is located behind the drive housing. The vacuum „swallows" the particles loosened from the treated surface, passing them through its hoses to a receptacle. The air is then filtered, and the remaining refuse divided among designated containers. The vacuum cleaner is also specially designed for the cleaning of large surfaces. Furthermore, it supports the logistics at the construction site by its ability to move large quantities of various building materials.
All components of the BIBER System can be used independently of one another. Backhoes, for example, through the use of an adapter, can assume the guide function for the toolhead.

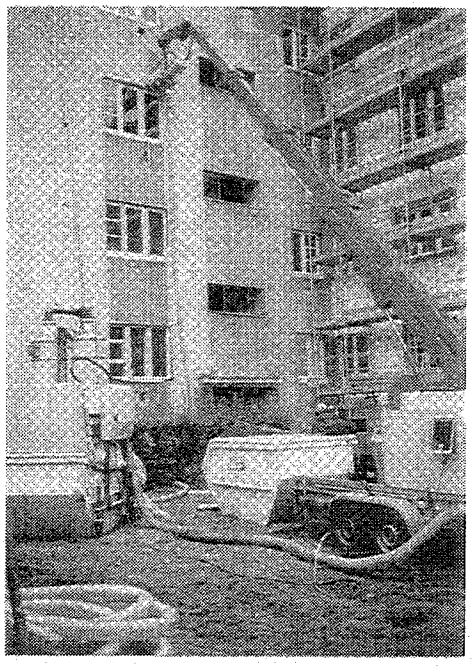


Photo-1 Overall View of System BIBER

3. Characteristics and effects

1) Removal, cleaning or preparation can be performed with an accuracy higher than provided by skilled worker; moreover a uniform surface can be expected.
2) Conventional manual work is reduced to a minimum, so the worker is relieved from the burden of hard and dusty work in uncomfortable positions.
3) Work efficiency can be improved.
4) Removal, cleaning or preparation of surfaces in an urban area brought complains about noise and dust especially from the residents. The BIBER eliminates these complains.
5) Overall the whole work is done by reduced costs.

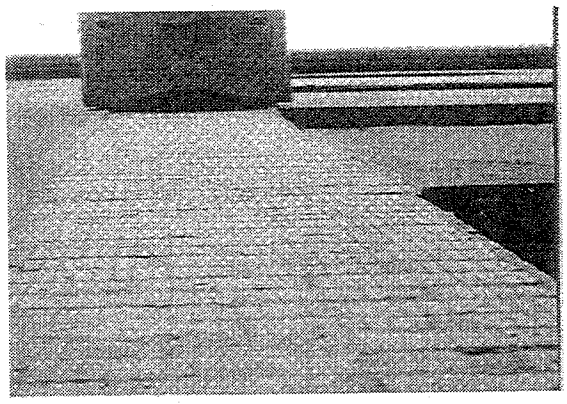


Photo-2 Result of Rough-Cast Removal

4. Features of the robotization and automation

A key to the successful mechanisation of surface preparation is the use of BIBER System microelectronics. All components are using microprocessors for guidance, measurement and adjustment. The data are piped by a common data-bus and are available for each device of the system. In conjunction with the associated application program, the facade is measured, and the volume of surface to be removed is stated. The BIBER System application-software is IBM-compatible. The stored data can be used for further calculations.
The computer enables a gradual manipulation of the telescope arm. This parallel direction guides the machine head in perpendicular lines across the entire pre-measured surface.
At the end the System BIBER is a robot but did not work without an operator because of the demand for an outstanding security-level on a public housing-construction site.

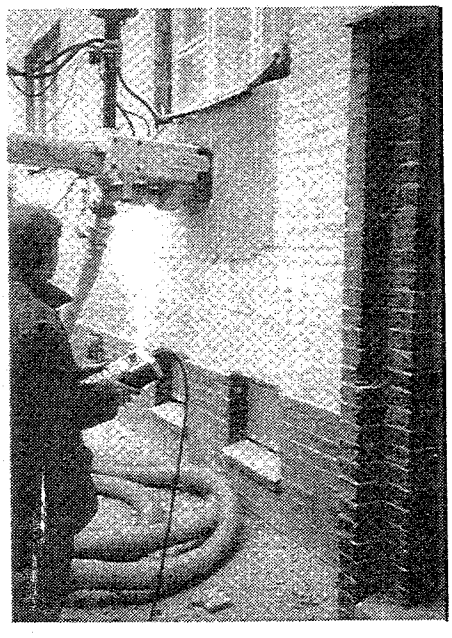


Photo-3 Engine Driver at work

Through intelligent control panel manipulation, the operating of the BIBER System is easy. On a LCD all important data such as distance, angle of inclination are displayed. The data and the signals from the controls load the processor. The results is collision protection and automatic pressure regulation. At least the System is operated by one machinist. It substitutes five up to eight traditional workers. The mounting of the complete BIBER-System can be made be the operator and one handy man.

The BIBER System already offers the foundation for a more thoroughgoing control technology, which will enable the accomplishment of even more complex tasks.

Table-1 Principal Specification

Item	Specification
Toolhead BIBER FK 500	
Dimensions (L x W x H)	1,400 x 650 x 1.200 mm
Weight	about 265 kg
Contact Force on active teeth	0 up to 1000 N
Work Capability	up to 75 m²/h
Working Width	500 mm
Rotation Speed	up to 2000 rpm
Vacuum cleaner BIBER SV 250	
Dimensions (L x W x H)	5,600 x 2,300 x 2,350 mm
Max. Headroom	1,900 mm
Moving Quantity	up to 2 m³
Max. Hose Length	40 m
Telescoping Manned Platform	
Max. Working Height	up to 60 m (depends on chosen type)

5. Work execution record

The number of units sold by manufacturer is 4 with working heights of 22 m, 26 m, 30 m and 40 m. The overall amount of prepared Surfaces is more than 40,000 m² in 2 years (without times with outside air temperatures below 5° Celsius).

Devices for indoor-surfaces are available but not yet sold.

6. Usage conditions

1) There is no need of auxiliary power supply for the system BIBER on the construction site.
2) Openings for access to the construction site are 1.45 m width and 2.3 m in height for outdoor-systems and 1 m width and 2 m height for indoor-systems.

Exterior wall tile inspection robot

Applicable type of work: Diagnose the bonding conditions of exterior wall tiles	Official price:
Classification: Maintenance work	
Purpose of the development: Man-power saving, Instead of skilled workers, Improvement of work environment, Improvement of quality	Lease and rental:
Level of practical use: Application in construction sites	Development company: Taisei Corporation

Information

Company name: Taisei Corporation
Address: Sanken Bldg. 25-1, Hyakunin-cho 3-Chome, Shinjyuku-ku, Tokyo 169, Japan
Phone: 03-5386-7557
Fax: 03-5386-7577
E-mail: morimasa@kiku.taisei.co.jp

1. Application

Exterior wall tile inspection robot was developed to diagnose the bonding conditions of exterior wall tiles quickly and accurately.

2. Outline

Exterior wall tiles lose their bonding strength with age, which if left unattended, shortens the life of the building. To ensure that buildings last their designed life time and to prevent the public hazard of falling tiles, a regular diagnosis of the exterior tile surface is essential together with the necessary repair work. Timely repair work based on the diagnosis will keep the building in good conditions. The robot ascends and descends using the chain suspended from the rooftop parapet, and a row of ten small diagnosis balls in the robot continuously tap tiles and the resultant sound is analyzed. The results of the diagnosis together with locational data are transmitted to the computer on the ground, store in floppy disks, and graphically displayed.

3. Characteristics and effects

1. **Compact and light weight.**
2. **No preparatory work such as assembly of scaffolding and installation of gondolas is required.**
3. **The graphic display of diagnostic results clearly pinpoints the area in need of repair.**
4. **The defect not only the back surface of the tiles but also of the subbase is detected by sound analysis.**
5. **Reduces diagnostic cost.**
6. **A diagnosis of mortar-finished exterior walls can also be carried out by the robot**

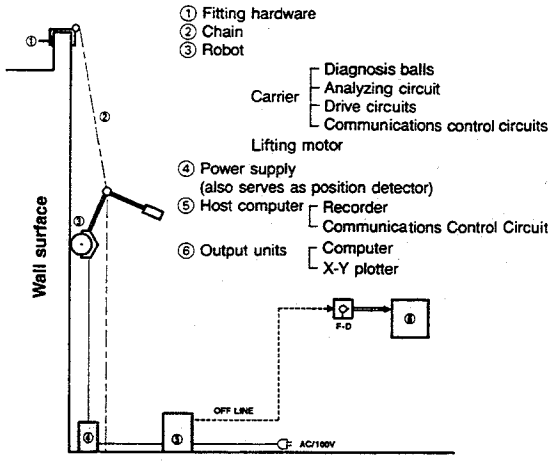


Fig.1 System Configuration

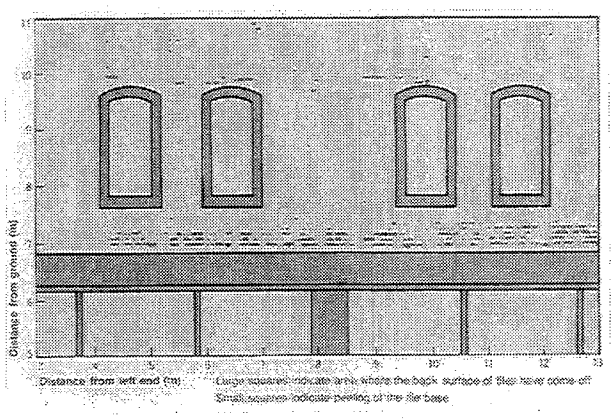


Fig.2 Diagnosis Results

4. Features of the robotization and automation

(1) No special equipment is required for preparatory work such as loading/unloading and assembly and disassembly. The compact, lightweight robot and peripheral equipment can be set up by only two operators.

(2)A graphical display of diagnostic results pinpoints the location of loose tiles. The display differentiates between a tile lose bonding from its bed and the bed itself losing from the wall, so even an unskilled operator can pass judgment on the situation.

(3)The fully automated inspection operation improves safety by eliminating work on scaffolds and wall maintenance lifts at high elevations.

(4)Both tile-finished and mortar-finished exterior walls can be diagnosed by the robot.

	Efficiency	Dimension & Weight
Robot	Diagnosing speed Maximum: 6 m^2/min. Average: 700 m^2/day (Including time for preparation) Diagnosable depth: 40 mm or less Ascent/descent speed: 6 m/min.	Height: 400 mm Width: 1150 mm Depth: 400mm Weight: 70 kg Carrier 30 kg Lifting motor 40 kg Capacity of lifting motor: 0.2 kW
I/O units	Graphic output in size A-3	—

Fig.3 Specifications

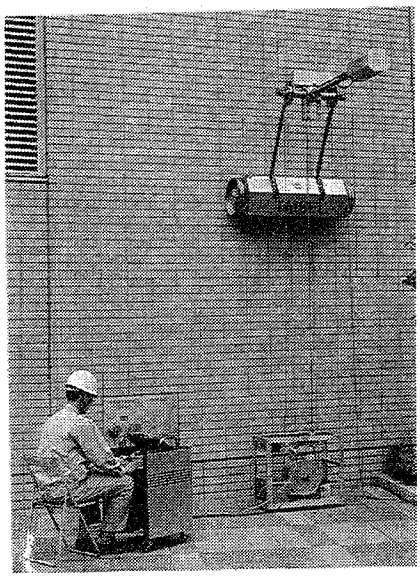


Fig.4 Operation

5. Work execution record

Period	Use	Diagnosis Area(m^2)
1986,5	School	171.8
1986,10	Office	1667.6
1986,11	Office	305.1
1987,5	Office	157.0
1988,4	Office	432.0
1988,8	Office	379.8
1990,2	Residence	241.6
1990,10	Office	158.9
1991,11	Office	234.5

6. Usage conditions

The robot carries out its diagnosis of an exterior wall surface while moving downward/upward over the wall. This places some limits on its applicability depending on the size of the robot and the wall geometry. Basically, flat, vertical walls are ideal.

Other notes:

- Tiles up to 50 mm square and up to 30 mm thick can be diagnosed by the robot.
- Mortar-finished exterior walls coated with elastic paints cannot be diagnosed by the robot.

Ultra Compact Underwater Inspection Robot

Applocable type of work: Underwater visual inspection in complex and narrow place	Official praice:
Classification:	
Purpose of the development : For the underwater visual inspection where man can hardly access or the general inspection system can not be easily applied.	Lease and rental:
Level of practical use: Available on the market	Development company: TOSHIBA CORPORATION Nucler Engineering Laboratry

Information Company name:TOSHIBA CORPORATION
Address:ISOGO ENGINEERING CENTER, 8,Shinsugita-cho, Isogo-ku,YOKOHAMA 235, JAPAN
Phone: +81 45 770 2166
Fax: +81 45 770 2448
E-mail:000093050701@tk01.tg-mail.toshiba.co.jp

1.Application

Underwater visual inspection in complex and narrow places for not only general industry but also chemical plants, nuclear power plants and so on.

2.Outline

This underwater inspection robot has been developed especially to perform visual inspection in copmplex and narrow places. Its spherical body with a diameter of 150mm enable it to move freely through narrow gaps or small pipes using four motor-driven thrusters.

A wide view can be obtained by a camera set on the motor-driven tilt mechanism. Futhermore, the vehicle itself can change its attitude by motor-driven balance weights. According to the target, selection can be made from a wide variety of viewing angle.

3.Characteristics and effect

The system consists of an underwater vehicle, a controller, a control box, a tether cable and a TV monitor.

The entire set, packaged in duralumin cases, is very easy to carry and the system is easy to set up.The system configuration is shown in the Figure 1 and the detail of the underwater vehicle is shown in Figure 2.

The vehicle is easily maneuvered by two joysticks and a volume control to roate the balance weights.

Four thrusters make the vehicle move forward, backward, up, down, and rotate.

By using these motion and attitude change executed with balance weights, the desired video scene can be obtained. The sealless (magnet coupling) stracture makes the vehicle reliable.

And the depth of the vehile is also displaied on the monitor.

4.Features of the robotization and automation

The specifications are as follows.

Underwater Vehicle	
Dimensions	ϕ 150×L200mm
Weight	1.7kg
Water depth	30m max

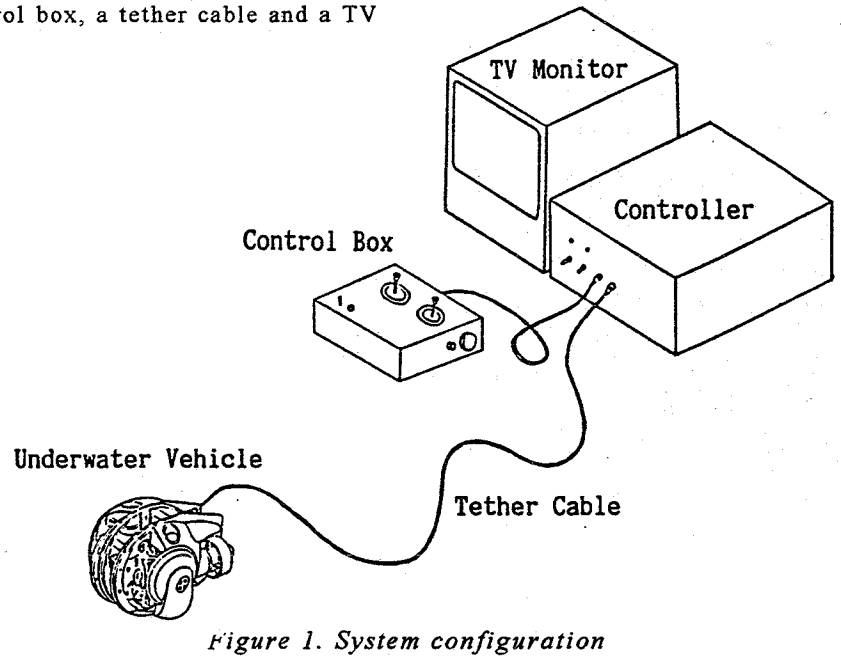
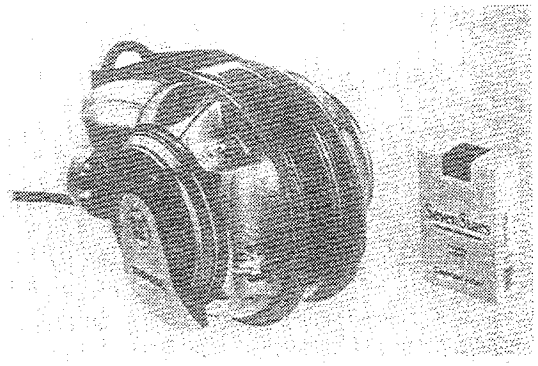


Figure 1. System configuration



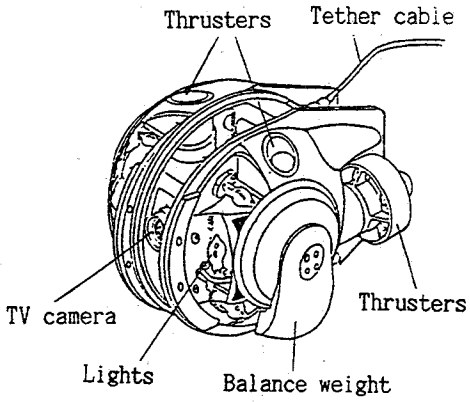


Figure 2. Underwater vehicle

Underwater Vehicle		
Loaded components	1/2 color CCD	· Effective pictuer element: 768 × 494 (380 thousand elemnts)
		· Interchangeable lens(Standard f=4mm, aerial view angle of 92° × 69°)
		· Tilting machanism: ±90degree (Motor-driven)
	Lighting	Halogen lamp 20W × 6 lamps
	Hydraulic pressure gage	Strain gage type,0~36m
Moving function	Up, Down, Forward, Backward, Rotation	
Attitude	Capable of changeing orientation to up or down during operation	
Thrusters	Four electric motor and Magnetic Couplings	
Speed	Continuously variable. Approx.10m/min. max.(hprizontal) Approx. 5m/min. max.(vertical)	

Controller	
Dimensions	W250 × D330 × H146mm
Weight	8.7kg
Power supply	AC 100V × 10A

Control Box	
Dimensions	W170 × D150 × H56mm
Weight	0.8kg
Opatation	2 joystics for movement 1 volume control for rotation of the balance weights.

Tether Cable	
Length	Standard 40m
Characteristic	Buoyant flexible cable

5.work execution record

The system has been demonstrated at the power plants, ironworks and so on. And it's verified that the system works well under actual plant condition.

6.Usage condition

① Underwater vehicle / Cable

- Ambient temperature:10~52℃
- Radiation dose:Below 10^3R/Hr (Below 2×10^4R in integrated dose)

In case of a usage in a high radioactive atmosphere, Radiation tolerant camera can be set on the underwater vehicle.(See figure 3.)

② Controller / Control Box

- Ambient temperature:10~40℃
- Ambient humidity:10~90%

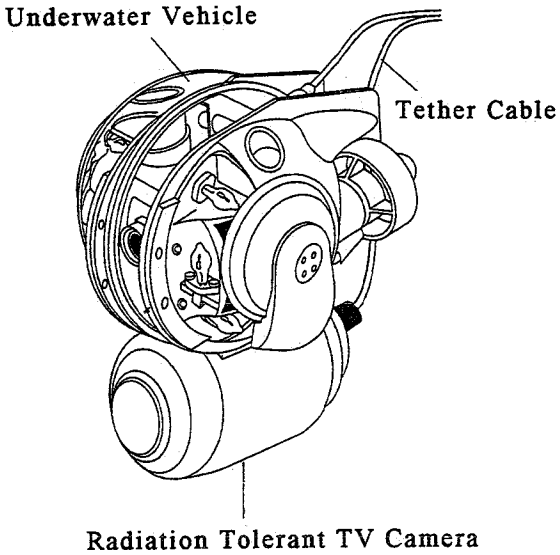


Figure 3. Underwater vehicle with radiation tolerant TV camera

Clean Room Inspection Robot "CRIMRO"

Applicable type of work:	Inspection of HEPA filter leakage, Measurement of cleanliness	Official price:	
Classification:			
Purpose of the development:	Manpower saving, time saving, Prevention of contamination	Lease and rental:	
Level of practical use:	Available on the market	Development company:	KOMATSU Ltd. OBAYASHI CORPORATION
Information:	Company name: KOMATSU Ltd. Address: Research Division, 1200, Manda, Hiratsuka-shi, Kanagawa 254, JAPAN Phone: +81 463-35-9253 Fax: +81 463-35-9288		

1. Application

Measuring the cleanliness of the cleanroom and inspecting the leakage of HEPA filter automatically.

2. Outline

"CRIMRO" is composed of the mobile vehicle and the multi-jointed arm and is equipped with the vision system using CCD camera (Photo 1 and Figure 1). Major specifications are shown in the following table. The measurement of the cleanliness of the cleanroom and the inspection of the ceiling HEPA filter are fully unmanned and automated. In starting the development of the "CRIMRO", the following basic concepts were established.

- Manpower saving (especially reducing heavy works)
-Measurement accuracy improvement
- Contamination reducing.

3. Characteristics and effects

① The fully automated system of the measurement process enables the large manpower saving and the quality improvement.
② Equipped with a multi-joint robot arm, the complex movement can be accomplished.
③ Freely changing the program of the measuring position and movement, an extensive adaptability is achieved.
④ Equipped with a CCD camera vision system, the high accuracy autonomous locomotion is achieved.
⑤ Using clean materials and mechanisms and introducing a remote operation system, the particular contamination is reduced until about one twelfth of the human operation.

4. Features of robotization and automation

The block diagram of "CRIMRO" is shown in Figure 2. The mobile vehicle, the robot arm and the vision system are controlled by the individual micro processors respectively.

(1) Automatic measurement

(a)Inspection of HEPA filter leakage

Description	Specification
Application	・Automatic inspection of HEPA filter leakage ・Automatic measurement of cleanliness ・Manual operation (remote operation)
Function	1)Robot ① Probe scanning device (Multi-joint robot arm) ② Mobile vehicle (2-wheeled drive, mark tracking) 2)Wireless controller 3)Measure equipment (DC drive particular counter etc.) 4)Electric source(Battery, 8 hours continuous operation) 5)Weight 230 kg 6)Dimension ① Mobile vehicle 1000×750×895 mm ② Robot arm 1590 mm (height)
Performance	1)Probe scanning ① Mode Horizontal plane XY scanning Vertical scanning ② Inspection area Horizontal X<700, Y<1500 mm Vertical 1560+α<H<2000+α mm (α≦1000) ③ Scanning speed 60 mm/sec (max) ④ Accuracy ±2 mm 2)Mobile vehicle ① Mode Forward, Backward, Spin turn ② Traveling speed (max) Autonomous 18 m/min Manual 36 m/min ③ Accuracy ±50 mm
Controller	1)CPU 8086+8087 (3 sets) 2)Sensors CCD camera (2 sets) Infrared range sensor Limit switch on bumper Limit switch on scanning probe 3)Wireless system ① Band 144MHz ② Function Command transmission Message reception ③ Effective range 100 m (max)

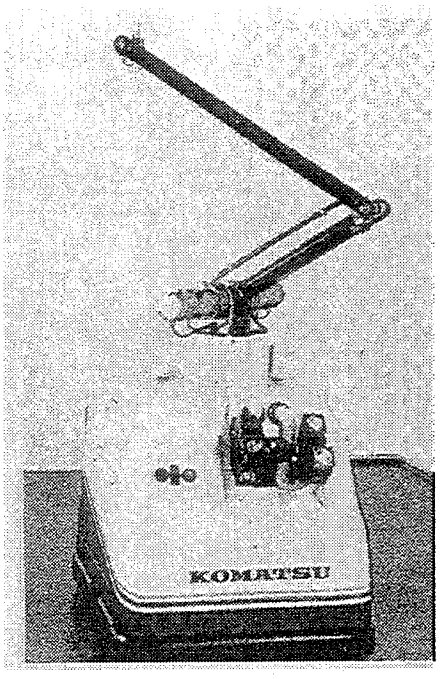


Photo 1. "CRIMRO"

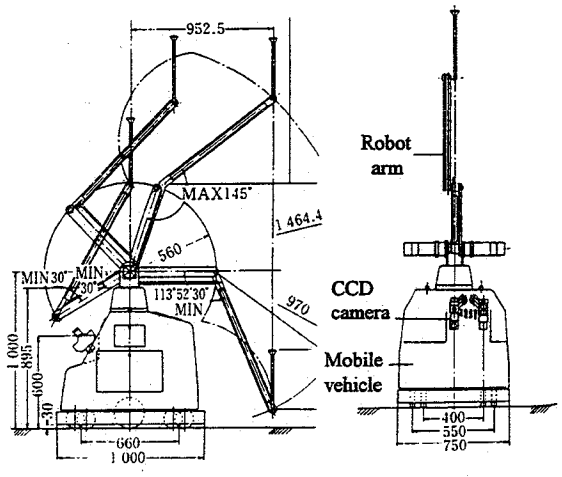


Figure 1. General view of "CRIMRO"

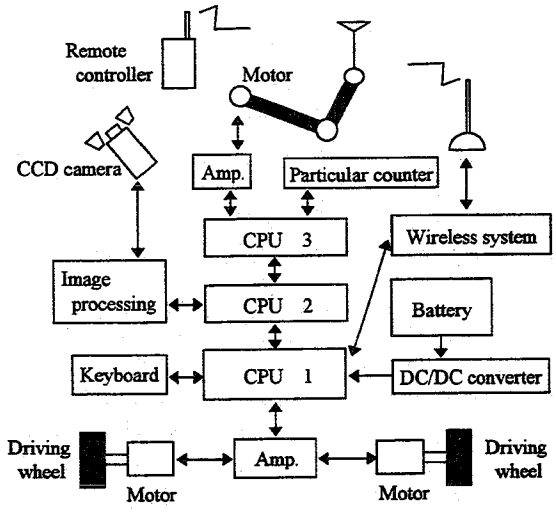


Figure 2. Block diagram of "CRIMRO"

① According to the input data of the cleanroom size, ceiling height and filter layout etc., "CRIMRO" travels autonomously.
② Touching a filter rim with a touch sensor attached on the top end of the sampling probe, "CRIMRO" adjusts its standing position.
③ Scanning a filter with a sampling probe. If the leakage is detected, the computer memorizes the leaking position.
④ Moving to the next position successively. After the whole room has been inspected, "CRIMRO" prints out the test results.

(b)Measurement of the cleanliness
① According to the input data of the room size and measuring positions etc., "CRIMRO" travels autonomously and stops on the measuring position.
② Measuring the intensity of the dust floating in the air. "CRIMRO" can detect the three different height data on the same standing position.
③ After the whole room has been measured, "CRIMRO" prints out the classified intensity data according the dust diameters.

(2)Remote manual operation
"CRIMRO" also can be operated manually using a remote controller.
① The robot arm can be operated freely with a joystick lever of a remote controller. This operation mode is useful to specify the leak position of the filter. And also the robot arm can be operated by the block operation (pre-program operation). This block operation has two modes, the first mode is for the leakage inspection, and the second mode is for the cleanliness measurement. In this operation mode, only pushing a start switch, the robot arm performs a sequential movements for the leakage inspection or the cleanliness measurement automatically.
② Using a joystick lever of a remote controller, the mobile vehicle of "CRIMRO" can be moved forward and backward and also can be turned without changing a position.

5. Work execution record

Period	October, 1991
Ordered by	NEC ELECTRONIC INC.
Place	Roseville city, California, USA
Contents	Cleanroom performance inspection at the completion. Two labors were reduced. Tact time was improved. Inspection quality was improved.

6. Usage conditions

① A battery must be charged fully before use.
② It is desirable that the floor is nearly flat without steps and obstacles.

Climbing Robot RoSy II

Applicable type of work:	Un-manned height-access for automated applications as carrier for work-packages and measurement systems	Official price	depends on application
Classification:	Construction		
Purpose of development:	Avoid dangerous work for human workers	Lease and rental:	yes
Level of practical use:	First inspection projects and commercialisation in 1998	Development company:	Robotersysteme Yberle GmbH
Information:	Company name:	Robotersysteme Yberle GmbH	
	Address:	PO Box 1725, D-92 307 Neumarkt, Germany	
	Phone:	+49(0)9181-4802-0	
	Fax:	+49(0)9181-4802-33	
	E-mail:	hans.yberle@t-online.de	
	WWW:	http://www.bayernweb.de/yberle	

1. Application

Basic function of RoSy II is to carry a great variety of work-packages on vertical to horizontal surfaces made of different materials. RoSy II is specially designed for the inspection of concrete structures like bridges and dams. Due to user requirements desired work-packages and inspection systems can be adapted. Other applications areas:

- Non-destructive testing in civil engineering
- Maintenance and service of high rising buildings
- Style and beautify of large walls
- Cleaning and renewing of high facades

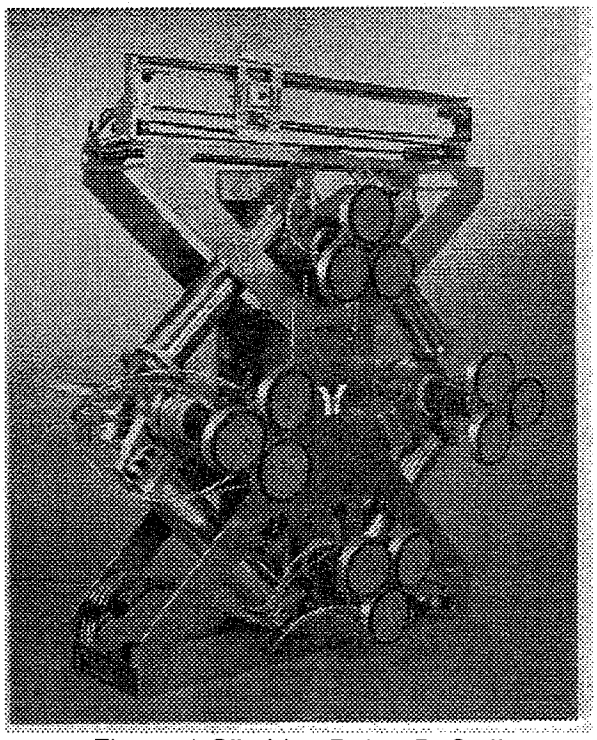


Figure-1 Climbing Robot RoSy II

2. Outline

RoSy accomplishes its work as a carrier system, that can climb on vertical to horizontal surfaces made of different materials. Equipped with any tools RoSy is suitable for a wide variety of tasks. RoSy holds on to the wall with vacuum suction cups and moves on the surface to any direction with an easy patented kinematics. Manually controlled RoSy climbs to its operational area. Here RoSy is able to scan given regions automatically, e.g. in meander form. RoSy can move automatically and in a manual mode stepwise under the control of the operator.
Some sensors and software algorithm monitor continuously the equipment and take care to hold the climber on the surface. For safety reasons each robot foot has its own vacuum sensor. Safe vacuum and surface conditions provided only one foot of the robot will be lifted from the surface and searches for a new safe position.

3. Characteristics and effects

The advantages of RoSy are bipartite. First for present conventional works RoSy can ...

- keep away the worker from dangerous environment
- decrease the costs for scaffolding or access techniques
- execute automatically or remotely sequences of operations

Second RoSy enables absolute new solutions by technical developments and cost reductions e.g. examinations of buildings:

- Inspection of whole surfaces will be enabled
- Quality of the inspection rises by whole surface testing
- New sensors for inspection techniques could be used
- Intensive and repeated inspections save costs for reconstruction by an early detection of damages
- The inspection process, i.e. collecting the measuring data, can be done by a skilled worker. The analysis and valuation of the data makes the expert in his office.

- The qualified test engineer must be appropriate only in exceptions
- The mechanical inspection allows an automatic documentation and storing of the measuring results

4. Features of the robotization and automation

RoSy climbs like an alpinist on the wall. Three legs are always fixed on the surface and the fourth one searches for a new position. When this leg has found its position and only if its three suction cups have got enough holding force the next leg will be lifted. Figure 2 gives an example how RoSy moves to right. The movement of the leg is done by means of telescopic drive units which are driven by DC servo motors.

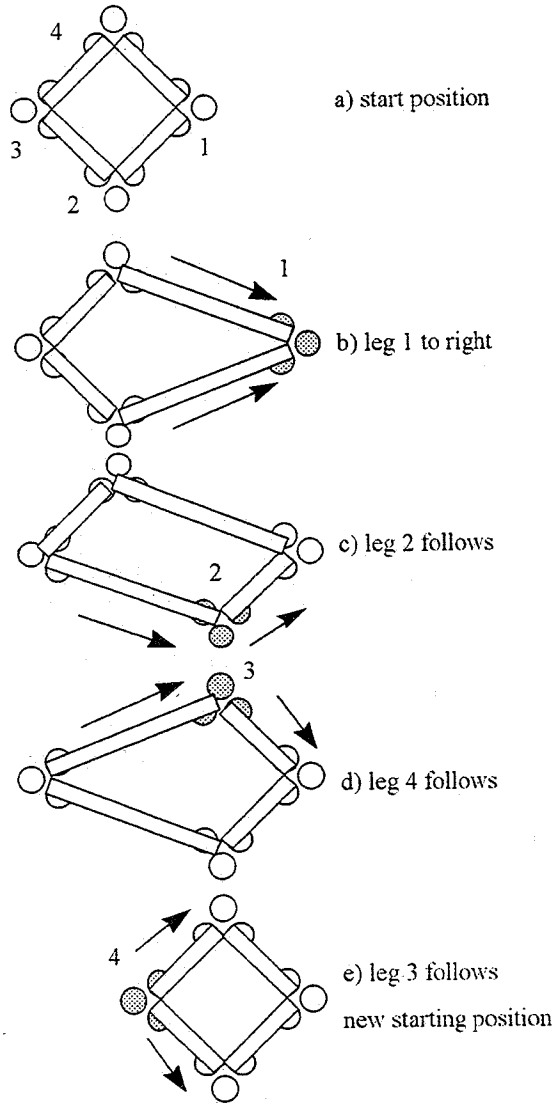


Figure-2 Gait Control of RoSy II

Without maneuvering by its patented cinematic RoSy is able to move immediately in each direction from its position and is able to rotate about its own position.
A manipulator with linear axes is mounted on the top side of the robot to carry different work packages. The next generation will be available with robot arms. The table below shows the basic technical data for RoSy I and RoSy II. RoSy I which is completely pneumatic driven is the prototype of the climbing robot family RoSy.

Item	Specification RoSy I	Specification RoSy II
Length	500 mm	1200 mm
Width	500 mm	960 mm
Height	170 mm	410 - 580 mm
Weight	25 kg	80 kg
Stride	33 mm	1 to 300 mm
Rotation	± 360°	± 360°
Step over height	5 mm	25 mm, 100 mm under test
Speed max *	500 mm / min	1000 mm /min
Foot holding force **	290 N	660 N
Payload	25 kg	20 kg
Air consumption *	180 - 1200 lpm	180 - 1200 lpm
Umbilical cord	40m	50 m
Operating surface	Concrete and better surfaces	Concrete and better surfaces
Maneuverability	up, down, left, right, turn	up, down, left, right, turn
Drives	pneumatic cylinder	servo controlled DC motors

Table 1 Basic Specification of RoSy

* depending on surface roughness and permeability
** for a vacuum of 50% and friction 0.5

5. Work execution record

First pilot projects for bridge inspections will be done in the early 1998.

6. Usage conditions

- Depending on environment and existing safety rules fall stop equipment should be installed
- Air supply must deliver a constant flow of dry compressed air (8 bar, 1500 lpm)
- Lifting equipment might be necessary for primary access
- Save compressed air supply (redundant) is recommended.
- Power supply necessary (220 V / 500 W without work package)

Vacuum-adhering and self-travelling system, Abrasives-blasting robot

Applicable type of work:	Abrasives-blast cleaning	Official price:
Classification:	Surface preparation	
Purpose of the development:	Manpower saving, time-saving, Improvement of work environment	Lease and rental:
Level of practical use:	Available on the market	Development company:
Information	Company name: URAKAMI Research & Development Co. Address: Maruyoshi bldg. 4-17-24, Konandai Konan-ku, Yokohama, Japan 234 Phone: + 81 + 45 + 833 + 5033 Fax: + 81 + 45 + 832 + 5081	

1. Application

While adsorbing by vacuum on the wall of the structures and self-propelling along the surface, it does the abrasives blast cleaning.

2. Outline

This robot system (refer to figure-1 and figure-2) is composed of a main unit, which adsorbs by vacuum on the wall and self-propels, and a support unit which is installed on the ground. The main unit is equipped with a suction disk, four drive wheels and a abrasives blast nozzle. Also, the support unit is composed of a Roots type vacuum pump unit, a dust collect unit including a bag filter unit, a abrasives blast tank unit, two auto tension winch units and a electric control unit. This robot system jets out abrasives forcefully for the processed surface from the nozzle using compressed air, and does blast cleaning efficiently. At the same time, the used abrasives is processed by the grain size classification system after recovered by suction and is used cyclically, but the powder abrasives is collected by the dust collect unit. The operator on the ground remote-controls the main unit with visual observation. Also, the operation of the support unit is automatic operation. The Roots type vacuum pump is used not only as a source of suction for the used abrasives to be recovered but also as a source of suction for the main unit to adhere to the wall. In case the pump stops because of a power failure, two auto-tension winch units are used to prevent the fallingdown of the main unit.

3. Characteristics and effects

① While adsorbing by vacuum on the processing surface strongly and self-propelling freely on the surface by remote control, the main unit can do the blast cleaning.
② Because the abrasives are blasted inside of the suction disk of the main unit and the used abrasives are recovered by vacuum, the environment pollution doesn't occur.
③ Because the abrasives are used cyclically, abrasives cost can be substantially reduced.
④ Because it doesn't need a scaffolding, the worker don't has a danger of falling down from the scaffolding so the safety improves.

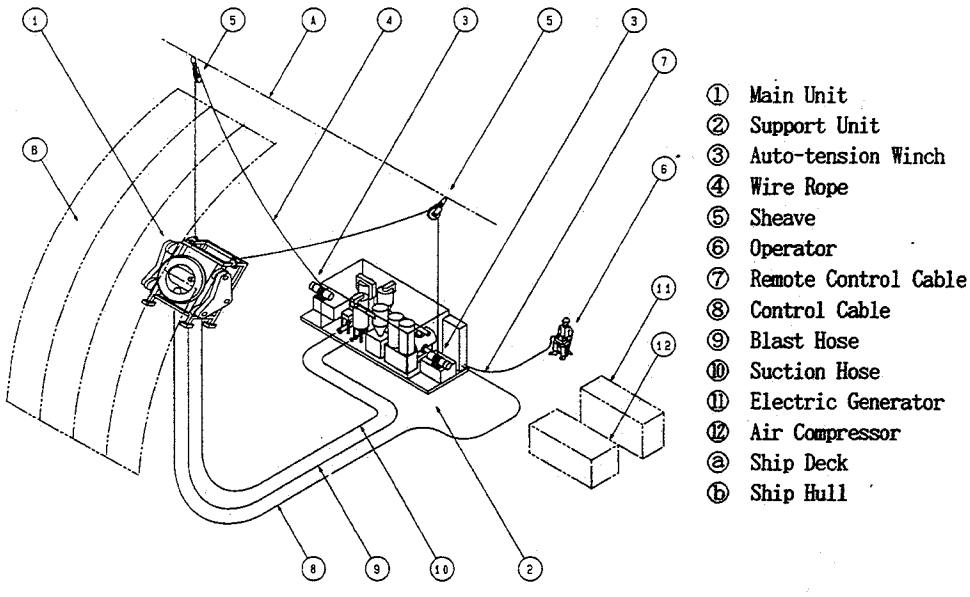


Figure 1. Abrasives Blast & Cleaning System

Major Specifications	
MAIN UNIT	
Type Blasting Width Travelling Speed Weight Dimensions	UA600 approx.400 mm max.9 m/min. approx.350 kgf approx.1320×1130×710 mm
Type Blasting Width Travelling Speed Weight Dimensions	UA400 approx.220 mm max.6 m/min. approx.80 kgf approx.940 ×610 ×310 mm
SUPPORT UNIT for UA600 & UA400	
Suction Pressure Suction Air Volume Vacuum Pump Motor Weight Dimensions	max.-6500 mmAq max.23 N m³/min. 90 kw approx.9000 kgf approx.2300×5750×2440 mm
AIR COMPRESSOR UNIT	
Air Consumption Air Pressure	approx.13 N m³/min. max.13 kgf/cm²

⑤ Because it can be operated by remote control, the labor of the worker can be reduced.
⑥ Because it is equipped with the auto-tension winch units as a safety guard, even if the vacuum pump stops in case of power failure, the main unit is prevented from falling down.
⑦ It can work adsorbing and self-propelling on the processing surface of any material, for example steel plate, stainless steel plate, concrete, glass, plastic and tile.
⑧ It can also adsorb on the surface with some unevenness such as welding seam line at a steel plate and joint line at a concrete wall.
⑨ It is possible to use on the wall, ceiling surface and floor surface.

4. Features of the robotization and automation

① The main unit is operated by remote control. The two inverters of the control unit adjust the running speed and control the running direction of the main unit. But, as for the control of the running direction, it corrects the direction automatically using a inclination sensor.
② Abrasives is continuously jetted out by remote control, and the used abrasives is processed by the grain size classification system automatically after recovered by suction and is used cyclically, and the used powder abrasives aftercrushed is collected by the dust collect unit.
③ The each auto-tension winch unit has a dram which rolls up a wire rope, when the paying-out speed of the wire rope was exceeding the speed which is set beforehand, the wire rope is automatically braked. As the double fall prevention measure of the main unit, the main unit is equipped with the safety guard system which detects a vacuum decline of the suction disk with a pressure sensor and prevents the main unit to fall down automatically

5. Work execution record

Country: Japan
Type of work: Used for oil storage tank ships, Japan navy destroyers, oil storage tanks gas holders and concrete structures .

6. Usage conditions

① Boss and difference should not be on the processing surface. But, the welding seam line is not a problem. At the joint of the concrete surface, the total of the cross-sectional area of concave portion should be equal to or less than 2,000 mm2.
② The curvature of the processing surface radius should be equal to or more than 4mR.
③ Oils and fats shouldn't stick to the processing surface.

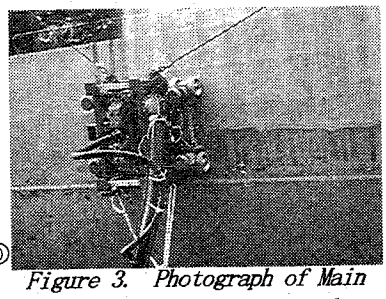


Figure 3. Photograph of Main Unit of Abrasives Blast robot

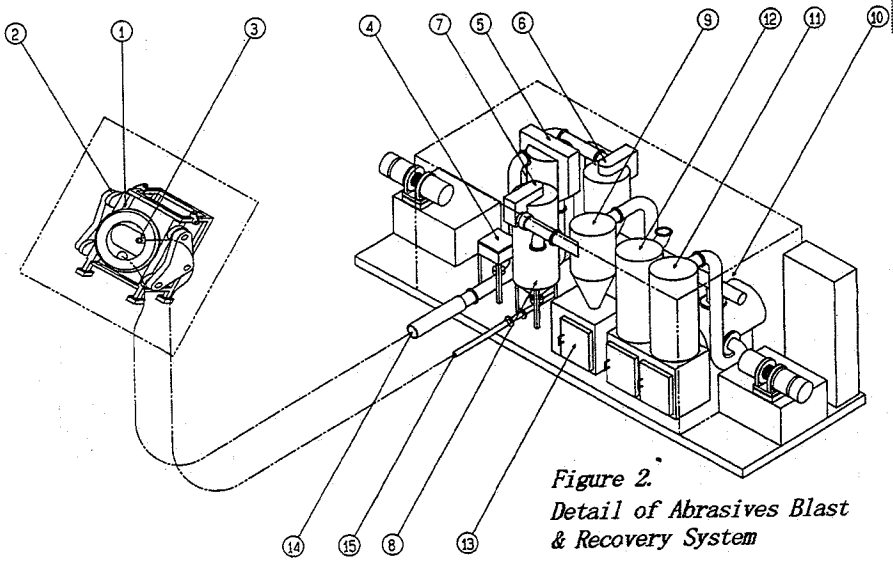


Figure 2. Detail of Abrasives Blast & Recovery System

① Sction Disk
② Driving Wheel
③ Oscillating Blast Nozzle
④ Grit Supply Tank
⑤ Separator & Grit Tank
⑥ Cyclone
⑦ Cyclone
⑧ Continuous Blast Tank
⑨ Cyclone
⑩ Root Type Vacuum Pump
⑪ Bag Filter
⑫ Exhaust Silencer
⑬ Dust Discharge Door
⑭ Suction Hose
⑮ Blast Hose .

Automatic cleaninng system for the under carriage of construction machine "YC300W-1"

Applicable type of work: Cleaning for the under carriage of construction machine	Official price: $68000 (excluding related optinal equipment)
Classification: maintenance	
Purpose of the development: Manpower saving and time saving Improvement of work environment	Lease and rental: (another)
Level of practical use: Available on the market	Development company: KOMATSU Ltd.

Informatin
Company name: KOMATSU Ltd.
Address: 2-3-6 Akasaka Minato-ku. Tokyo 107,Japan
Constructin Robotics Dept. Environmental Control and System Development Business Division
Phone: 03 5561 2707
Fax: 03 3586 7053
E-mail: HISATSUGU KONDOU @KOMATSU,co.jp

1.Applicatin

Cleaning for the under carriage of construction machine.

2.Outline

Recently on the trade to rental or sale of construction machine, the importance of cleaning of construction machine is increasing in order to make life of machine longer and improve impression for users. But to clean it manually is so hard and time consuming.
So we developed new-typed automatic cleaning machine system which makes users satisfied at various requirement as follows.

① The automatic cleaning machine with water jets.

② Cleaning condition selection system featured.

Ⅰ.Using a lot of low-pressure water.

Ⅱ.High pressure water.

Ⅲ. Ⅰ + Ⅱ.

③ Related equipments

Ⅰ.The circulation system for low-pressure water and high-pressure water to be cleaned.

Ⅱ.Soil remove system from mud stock tank.

3.Characteristics and effects

① Characteristcs

Ⅰ.Selectable cleaning condition to realize effective cleaning.

Ⅱ.Machine has 34 programed cleaning pattern that meet most of all construction machines.

Ⅲ.Machine has another functin that can program free cleaning pattern.

Ⅳ.Circulated cleaning water makes less drain, and it means economical.

② Effects

Ⅰ.To reduce cleaning manpower(about 1/3 of manually).

Ⅱ.To reduce cleaning cost.

Ⅲ.Emancipation from hard work.

Ⅳ.To improve impresson of company.

Ⅴ.To improve environment.

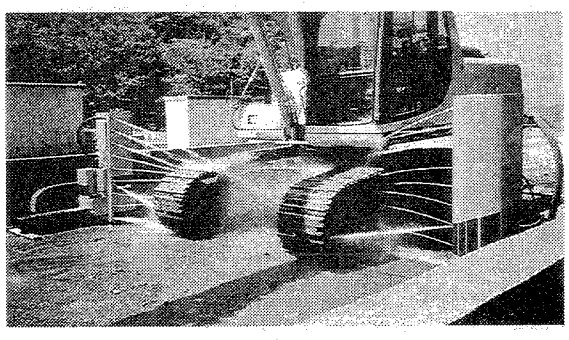


photo.1. Automatic cleaning machine YC300W-1.

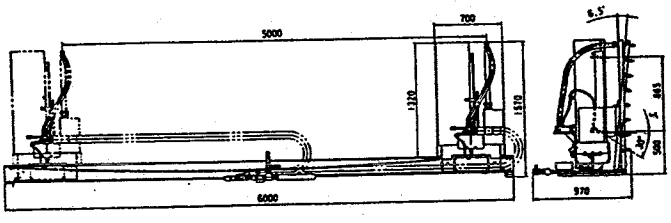


Figure.1. YC300W-1

4.Features of the robotization and automation

Major specifications	YC300W-1
machine weight	635kg (one side)
machine dimension length	6000mm
heigth	1570mm
width	970mm(one side)
water jet presser	low 3～5kgf/cm²
	high 80kgf/cm²
water jet flow	low 400～800 ℓ/min
	high 60 ℓ/min
movement speed	2.0m/min(50Hz)
movement stroke	5000mm
cleaning work area(STD)	l:5000,h:1500,w:4000mm
object machine type	poweshovel,bulldozer,wheel loader,dump truck,etc.
number of programing model	34 models
CPU capacity	8kB
cleaning time	5～40 min
generating power	
machine	300w (AC100V)
pump low pressuer	7.4kw(AC200V)
high pressuer	11kw(AC200V)

① Automatic cleaning program is carried out in accordance with selection of cleaning pattern,machine model and level of dirtiness.

② Every pumps,water circulator and soil remove system are controlled at the same time as one cleaning machine.

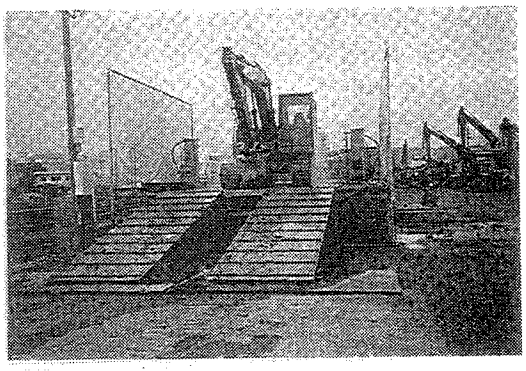


Photo.2. standard stand type system

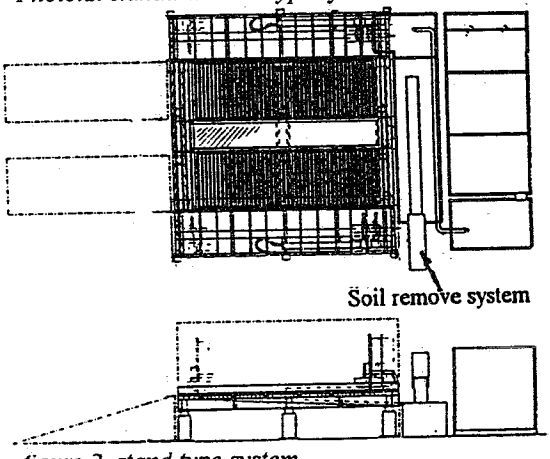


figure.2. stand type system

5.Work execution record

① First introduction in 1995.

② more than 60 sets have been well received in Japanese market.

③ Main user are construction machine distributer and lease campanis.

6.Usage conditions

① Overflow drain has to be made clean by separate tank in accordance with regulation.

② Anti freeze units are available for cold area.

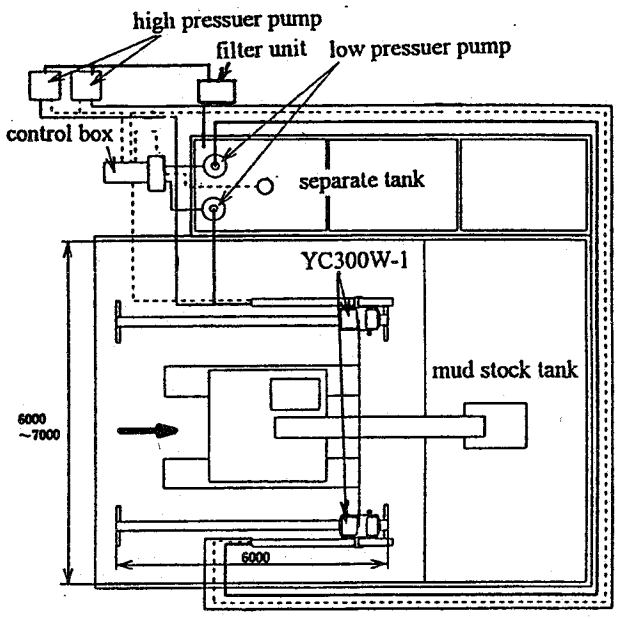


Figure.3.standard pit type system layout

Integrated Building Construction

Automated Construction System for Reinforce Concrete Building

Application type of work:	Building Construction	Official price:	
Classification:			
Purpose of the development:	Improvement of productivity	Lease and rental:	
Level of practical use:	Available on site	Development company:	OBAYASHI CORPORATION
Information	Company name:	Technical Research Institute, OBAYASHI CORPORATION	
	Address:	4-640,Shimokiyoto,Kiyose-shi, Tokyo,Japan	
	Phone:	+81-(0)424-95-0960	
	Fax:	+81-(0)424-95-0904	

1. Application

Construction work for high-rise reinforce concrete building. Also available for steel structure building.

2. Outline

Called the "Big Canopy", the new automated system is a revolution one, which brings with it higher quality, a shorter construction period, and reduced cost. The system's foremost feature is the "Big Canopy" itself, an all-weather, temporary roof structure. The canopy is supported on four corner posts, and is broad enough to overhang on all four sides the entire building under construction.The canopy is raised as construction of the building moves up.When the building reaches its full height, the canopy is dismantled and its perimeter structure jacked down.

3. Characteristics and effects

① High Quality

The building under construction is protected from unfavorable weather by the canopy and high quality production is ensured by using prefabricated materials.

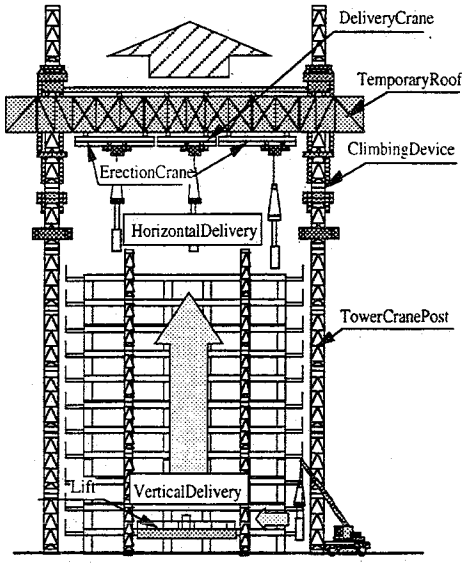


Figure 1.Outline of system

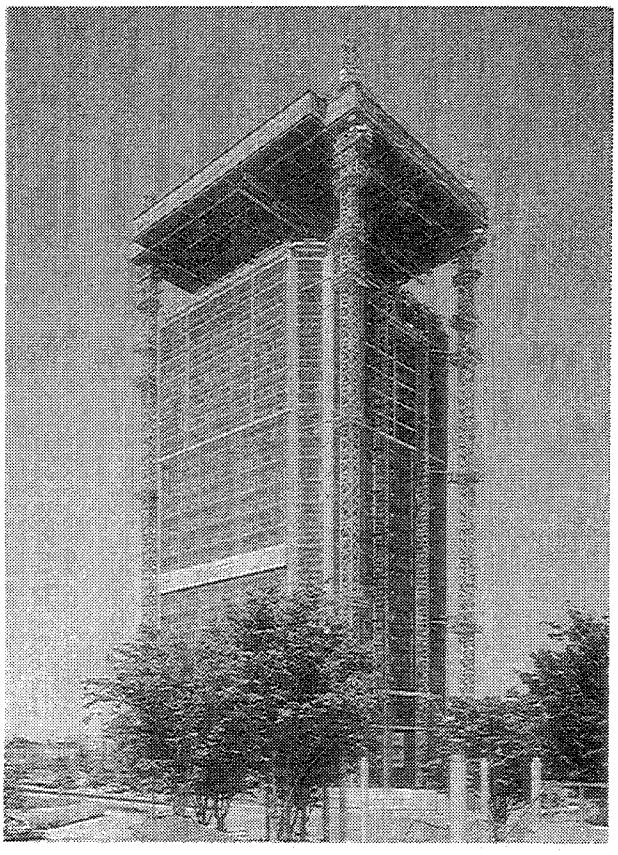


Photo.1.Automated Construction System

② Short Construction Period

The parallel delivery system increases the assembly efficiency. The construction period is reduced by executing the construction of skeleton, equipment and finishing works.

③ Productivity Improvement

The prefabrication and unification of materials, automation assembly work and computerized management for materials improve productivity and reduce the total cost.

④ Comfortable and Safe Environment

Noise levels are guaranteed inside the canopy. A comfortable and safe construction environment is maintained.

4. Features of the robotization and automation

① Synchronously Climbing Canopy

The canopy covers the entire story that is being erected to protect workers from several weather and produce a comfortable and safe environment. Tower crane posts are used as four columns supporting the canopy. This method can be applied flexibly to various building sharps because the post is independent of the building. Adverse conditions such as vibration due to the construction works do not effect the building under construction. The rise of the canopy is performed by climbing equipment of tower cranes. Safety is maintained by synchronized control.

② Parallel Delivery System

A high-speed construction lift and three hoist cranes are combined to deliver the material for assembly. The material is raised to the working story by the lift and passed to the hoist on the delivery girder. The hoist is moved from the delivery girder to the left or right girder and also transports materials throughout the entire working story. The movement of the hoist is entirely automated to improve work efficiency.

Construction Lift	1 pc	load : 6ton winding velocity : 40m/min control method : inverter control	
Traveling Crane		operation way : automatic/manual control method : inverter control	
		load	velocity(max)
Delivery Girder	1 pc	7.5 ton	40m/min
Erection Girder	2 pcs	7.5ton	30m/min
Hoist	3 pcs	7.5ton	33m/min

③ Prefabrication and Unification

By prefabrication the construction members, only assembly works are performed at construction site. On-site work is reduced and simplified, and productivity is increased by introducing the multi-skilled workers. Unification of construction materials results in simple work procedures and efficient erection.

④ Material Management System

This is a computer-supported system which manages large quantities of prefabricated and unificated materials.Planning from the material delivery to the erection and the actual management are rationalized. The amount of labor is reduced by the material management database linking with s shop drawing CAD. The material management is unified by using bar code attached to the materials at the factory. The data includes the erection position and material characteristics required for possible full automatic construction system in the future.

⑤ Standard Schedule for Floors

The construction for the standard floors is carried out in a seven-day cycle. The canopy is raised two floors at a time.The main finishing materials are lifted in advance during skeleton work.

⑥ Canopy Disassembly

The canopy is disassembled on the top of the building, the external frame is lowered synchronously and then safely disassembled on the ground.

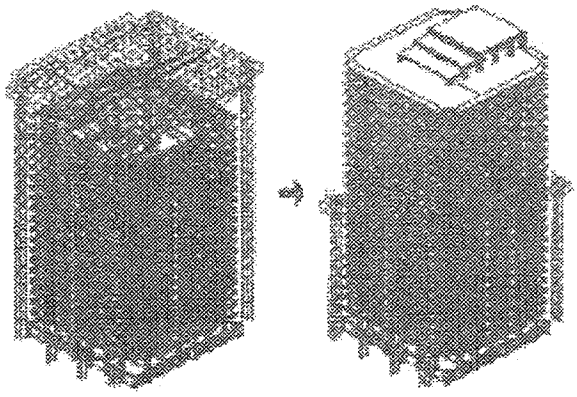


Figure 2.Canopy Disassembly

5. Work execution record

WorkName	Yachiyo Koen Toshi A-gaiku Mansion
Place	Yachiyo-shi,Chiba,Japan
Design	OBAYASHI Corp,.Tokyo Design Office
Const.Period	1995.1 --- 1997.2
Application	Apartment house, Store, Parking
Structure	Reinforce Concrete (partly Steel)
Stories	1 basement, 26stories, penthouse on roof
Total Floor Area	39,352.1m2
apartment No.	254

6. Usage conditions

① This system can cover the building not more than 40m by 40m depending on roof and post structure strength.

② The structure of roof and post must be designed according to the rule of wind force and earthquake force.

③ Roof structure must be raised by hydraulic jacks synchronously, especially keeping not more than 10mm difference on each post.

④ Crane operators must have authorized operating licenses in Japan. But for roof climbing any license is no needed for operators.

Automated Weather-Unaffected Buildings Construction System "AKATSUKI 21"

Applicable type of work: Building construction	Official price:
Classification:	
Purpose of the development: Provides a new comfatable environment in which the construction of high quality buildings can be realized at low cost	Lease and rental:
Level of practical use: Available on the market	Development company: FUJITA Corporation

Information		
	Company name:	FUJITA Corporation
	Address:	4-6-15, Sendagaya, Shibuya-ku, Tokyo 151, JAPAN
	Phone:	+81 (3) 5269 5327
	Fax:	+81 (3) 5269 4647

1.Application

High-rise building construction.

2.Outline

<Basic construction procedure>
This system utilizes the basic construction procedure in which the uppermost floor of the building is structured at the ground level in order to with securing a weather-unaffected space. In this space, various machine devices for the automated construction of a building are installed and the building is made from first floor up in sequence, one floor at a time.

<Basic composition>
This system is composed of numerous newly developed automated machine devices. The plan is made for each machine dividing the entire system roughiy into 3 parts, as folloes:

Sky factory :factory in the air
Ground factory:factory on the ground
Transfer line :vertical automated converyance line

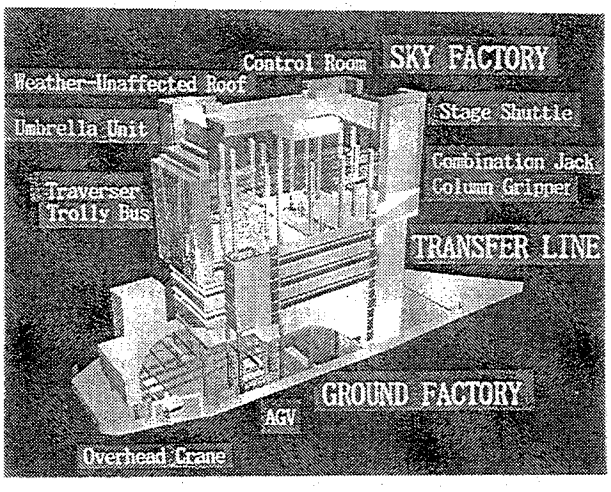


Figure 2. Basic composition

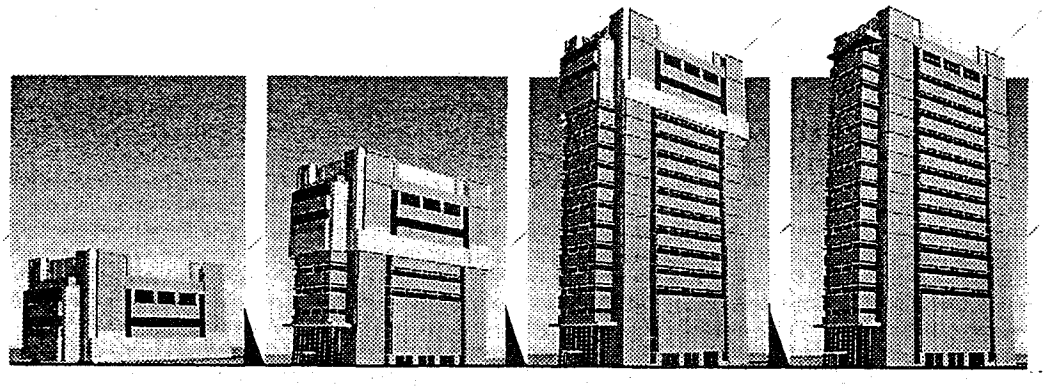


Figure 1. Basic construction procedure

3.Characteristics and effects

①With the aim of reducing labor by 50% and shortening construction periods by 30%, AKATSUKI 21 automates a wide range of construction from structural work to finishing work.

②New and accurate instrumentation technology and mechanical control technology are used together to realize highly accurate, superior construction.

③Efficient construction can be performed by a few skilled engineers.

④Work inside the factories does not annoy neighborswith construction pollution, and can be completed on schedule.

⑤The integrated construction control system, based on an expert system and multi-media (ITV monitoring, CG monitoring and satellite communications), enables advanced schedule control.

⑥Reverse-order application of AKATSUKI 21 to the demolition of buildings ending their life cycle is also possible.

4.Features of the robotization

①Handling of heavy objects, such as structural steel, etc., can carried out highil accurately.

②The combination jack developed can perform synchronized control of plural number of jacks with an accuracy of 0.1mm.

③A large automatic lift of 10 ton capacity has a high accuracy stopping ability and lowering functions of loaded material.

④The robot used for welding of column can perform continuous multilayer build up weld in sideways.

⑤The robot used for spraying operation of fireproof insulation can self-travel.

5.Work execution record

Name	Shuyo-dan Headquarters Building Construction Work
Location	Sendagaya, Shibuya-ku, Tokyo
Design	Nikken Sekkei, Ltd.
Execution	Fujita-Kajima Joint Venture
Construction	1 storey underground (SRC) 16F aboveground
Site area	2,063 m^2
Bldg. area	1,168 m^2
Total floor	13,065 m^2
Max. height	GL +69.8 m
Period	March15, 1994 to June30, 1996 (including the demolition work of an old building)
Use	Office building

6.Usage condition

①It is desirable where the building has many works to be repeated on higher floors.

②The building is desirable to be of structural steel construction.

③Sufficient construction plan will be required accompanied by installation of machine devices.

④Qualification for operation of machine devices will be required.

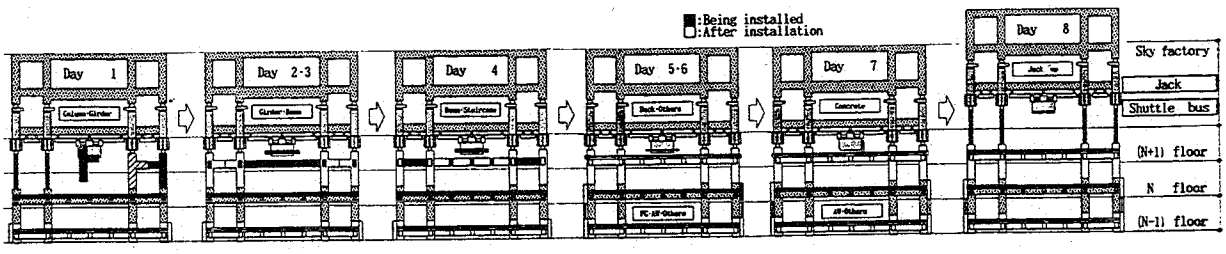


Figure 3. Cycle schedule

Computer Integrated and Automated Construction System
----- SMART System -----

Applicable type of work:	Automated building construction	Official price:	
Classification:			
Purpose of the development:	Improvement of working environment, all-weather site work, Increase of productivity	Lease and rental:	
Level of practical use:	Available on the market	Development company:	Shimizu Corporation, Mitsubishi Heavy Industry Ltd.,

Information		
	Company name:	Shimizu Corporation
	Address:	2 - 3 , Shibaura 1-chome, Minato-ku, Tokyo, Japan
	Phone:	03 - 5441 - 0107
	Fax:	03 - 5441 - 0886

1.Application

Automated high-rise building construction including transportation and assembling of various kinds of materials are prefabricated and/or preassembled in manufacturing companies.

2.Outline

With the automation and robotics technology as its basis, a system tried to achieve maximum integration of various other technologies relating to modernization of construction, i.e. technologies for industrialization and systematization of various components of building, technologies for computerization in site management, etc. Computer also plays a key role as the nucleus of the system.

Shimizu Manufacturing system by Advanced Robotics Technology(SMART) controls all phases of building construction from underground work and superstructure work to finishing and equipment work. It also controls various construction management tasks for automated construction of high-rise buildings.

3.Characteristics and effects

①Improvement of working environment.

Through its all-weather protection, work can be performed safely and in comfort, without being affected by the weather.

②Elimination of dangerous and heavy work.

Workers have been freed from operations with heavy workloads such as assembling structural steel and welding.

③Reduction of man-hour on site.

With effects of introducing computerized control and robotics, and also prefabrication and modularisation, it has been made possible for man-hour requirements to be reduced.

④Shortening of construction period.

The number of days required to complete each floor by the SMART system is greatly reduced, and sharp reduction of construction period is expected.

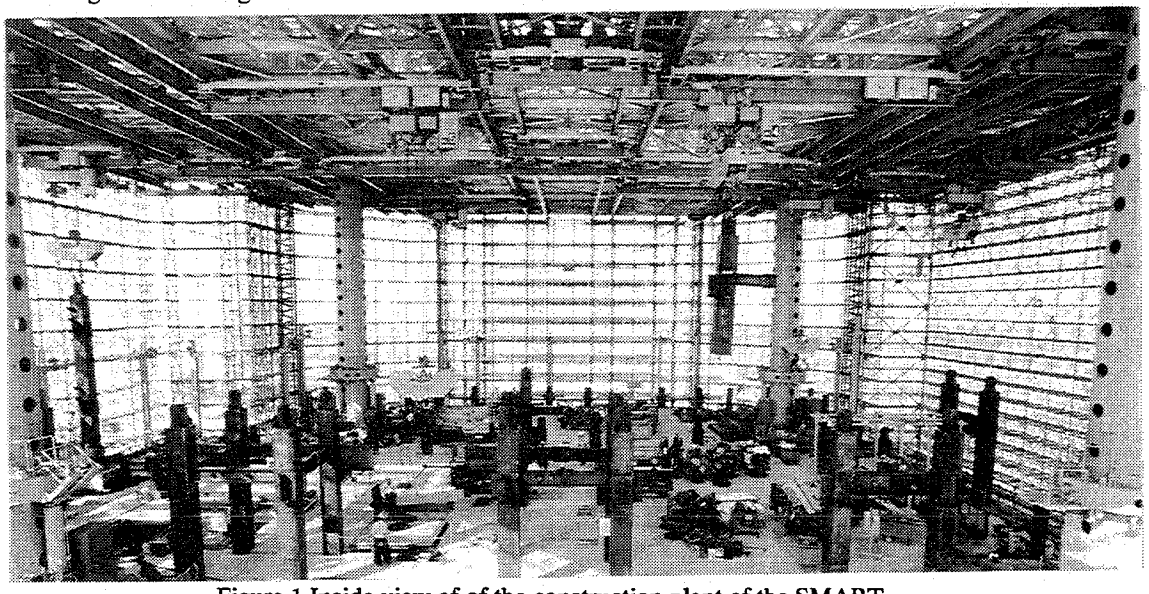


Figure 1.Inside view of of the construction plant of the SMART

4.Features of the robotization and automation

The top floor of the building (Hat-truss) is first assembled on the ground and an operating platform for transporting and assembling structural steel and precast concrete floor planks is formed there. While this platform is being jacked up floor by floor, lower floors are constructed in sequence, as if to add on building blocks, and the superstructure part of the building completed. Various members in the building are hauled continuously using a multiple trolley hoists, overhead cranes and a special vertical crane. A one touch joint system suited to automation mechanization is used to connect structural steel members and member joints are welded automatically by welding robots.

5.Work execution record

①Nagoya Juroku Bank Building

period : October, 1991 ~ February,1994

place : Nagoya city, Japan

contents : number of stories : 20 (above-ground)

total floor area : 20,657 m²

structure : Steel structure (above-ground)

②Rail City Yokohama Building

period : July, 1994 ~ June,1997

place : Yokohama city, Japan

contents : number of stories : 30 (above-ground)

total floor area : 74,927 m²

structure : Steel structure (above-ground)

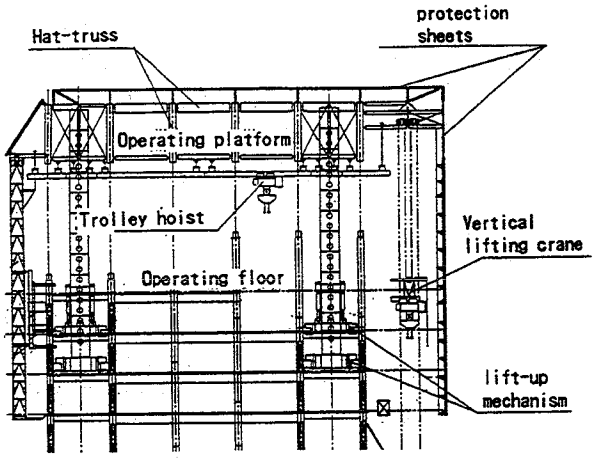


Figure 2.Constitution of the SMART system

6.Usage conditions

This system is applicable for high-rise office and hotel buildings which are of steel-frame construction and involve large amounts of repetitive works.

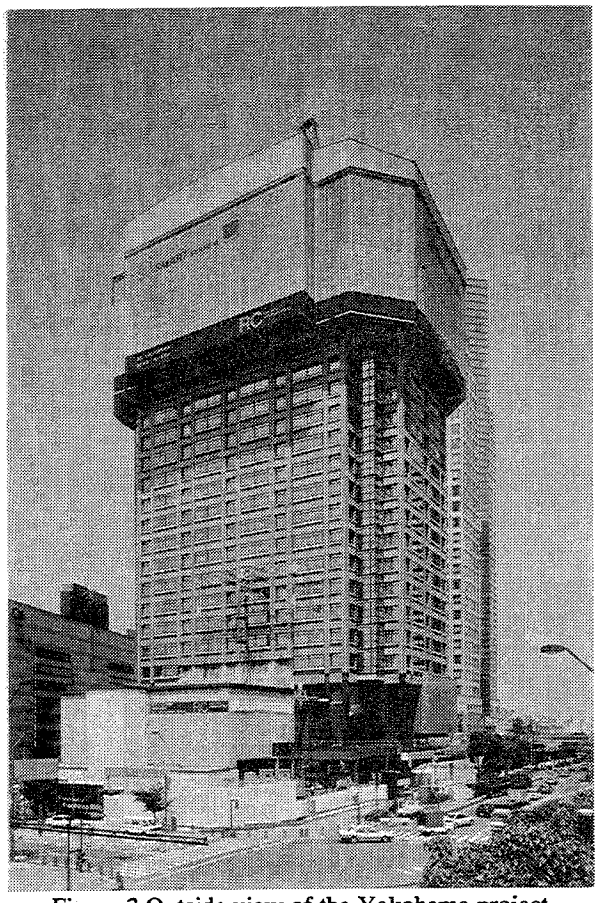


Figure 3.Outside view of the Yokohama project

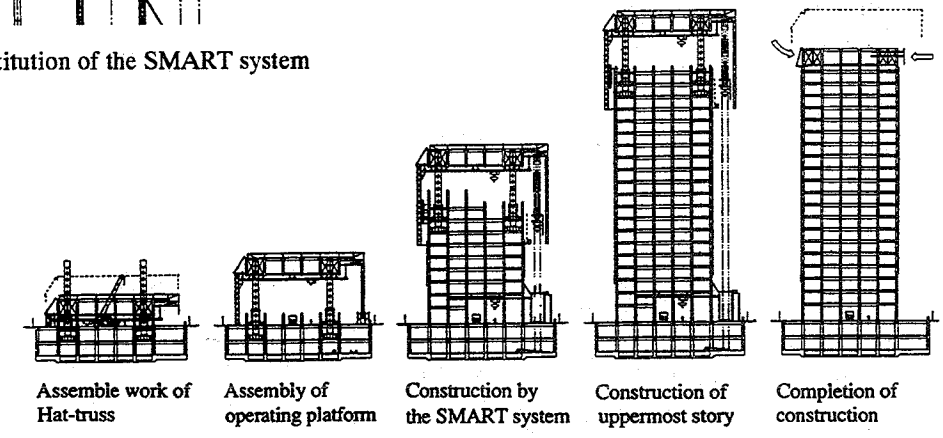


Figure 4.Construction procedure

MCCS (Mast Climbing Construction System)

Applicable type of works: Building Construction	0fficial price:
Classification:	
Purpose of the development: Improvement of productivity	Lease and rental:
Level of practical use: Two actual results	Development company: Maeda Corporation

Information Company name: Maeda Corporation
Address: J.City,5-8 Takamatu,Nerima-ku,Tokyo 179 Japan
Phone: 03-5372-4943
Fax: 03-5372-4949 E-mail: itomo @ jcity.maeda.co.jp

1. Application

All-weather automated construction system for steel flame buildings

2. Outline

MCCS is a new construction system with high safty and high productivity applying a computer-integrated information management. This system is composed of 5 subsystems; MCCS production control system, Climbing system, Conveying system, Assembling system and Measuring system.

① On the ground, uppermost floor which is named CF (Climbing Floor) is constructed at first and covered with Shelter (temporary sheet wall/roof) which has gates. Then Climbing robots, Conveying robots, measuring equipments and control room are instrolled on/under the CF.

② CF is lift up by the climbing robots along Masts which are suporting columns for CF.

③ The construction of first story starts in the space under CF and the space is surrounded by Shelter. After this work, CF is lift up again for next story works.

④ Repetition of one story works continues to the story under the uppermost floor.

⑤ Finally Masts and CF are fixed to the frame of the building, and all robots,equipments and Shelter are taken away.

3.Characteristics and effects

① High Safety
Construction of steel frame and installation of Floor PC panels are performed story by story. Therefore, this method makes other works extremely safe.

② Shortening of Construction Period
Construction in the Shelter protecting affects of all weather shortens the time of works.

③ Reduction of Labors
Construction by same members who are versatile leads reduction of labors.

④ Good Environment Effect
Shelter and Floor PC panels produce not only the clean indoor enviroment but also the well-ordered outdoor enviroment.

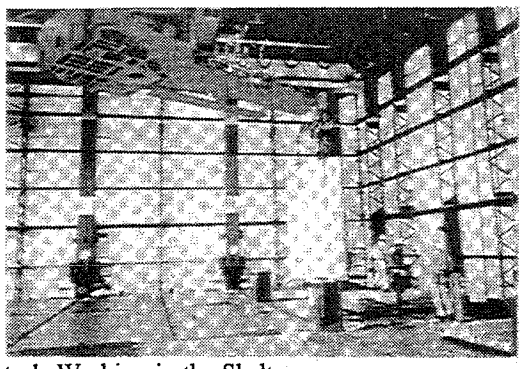


Photo.1. Working in the Shelter

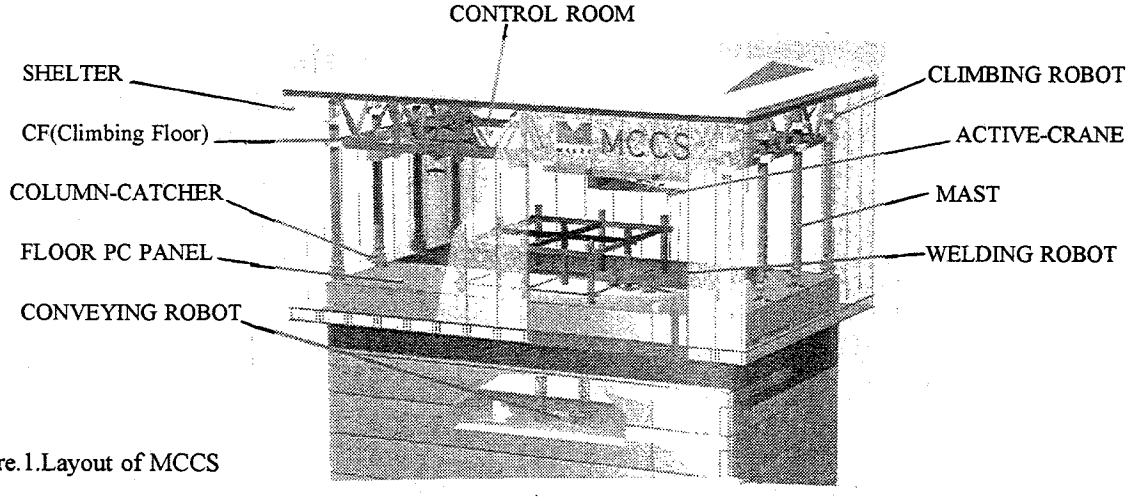


Figure.1.Layout of MCCS

4.Features of the robotization and automation

① Climbing robot
This robot is set to each Mast, and has two oil jacks and two lock pins on top and bottom, which are inserted into holes of Mast. To lift CF up, a computer simultaneously controls all jacks of Masts to extend/shrink and controls all lock pins to be taken in/out. Those robots move just like inchworms.

Jack thrust	100 ton
Jack stroke	610 mm
CF rising speed	0.37 m/min
CF falling speed	0.34 m/min
Mast rising speed	2.45 m/min
Mast falling speed	1.2 m/min

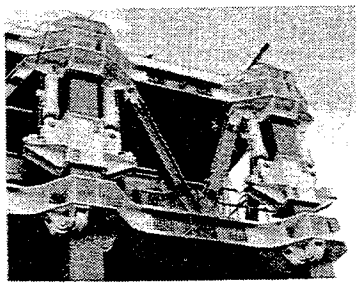


Photo.2. Climbing robots

② Conveying robot
Conveying robot consists of Active-crane and Slide-type-lift. Those are controled by a computer in the control room.

Active-crane is an overhead crane which can swing and move a head of its boom. This can automatically prevent crashing and automatically can carry frame parts and PC panels from the ground to an appointed place by the computer.

Rated load	4.7 ton
Lift	100 m
Swing radius	8 m
Hoisting speed	50m/min, 25m/min
Traveling speed	20 m/min
Trolley speed	20 m/min
Swing speed	1.0 rpm

Slide-type-lift is applied mainly to transport finishing materials vertically and load/unload them by slide-table at an appointed floor by the computer.

Load	1000 kg
Lift	max 40 m
Lift size	length 4000 mm
	width 1100 mm
Speed	20 m/min

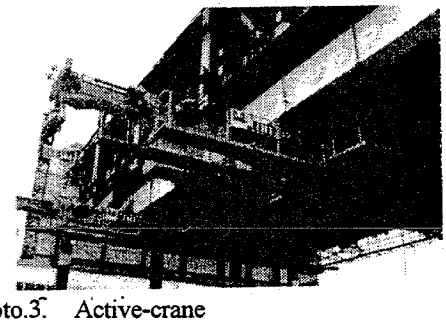


Photo.3. Active-crane

③ Welding robot
This robot is developed to weld joint of column to column. A pair of robots travel on the rails which are set on the column and performs continuous welding whithout end-tabs from the initial layer to the final layer except slag removing and erection piece cutting works.

Application & Size	Square Tube Column	□ 500 ~□ 800mm
	Welded Box-section Column	□ 500 ~□ 800mm
	Tubular Column	ϕ 500 ~ϕ 800mm
Thickness	Box-section,Tubular Column	16mm ~ 50mm
	Square Tube Column	16mm ~ 36mm
Sensing	Wire touch sensor	
Shield Gas	CO_2 (100%) or MAG(80%Ar+20%CO_2)	

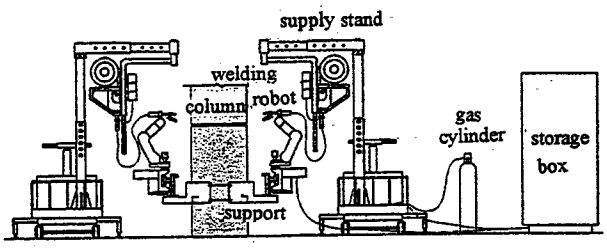


Figure.2. Welding robot

④ Column-catcher
This device is instrolled at the bottom of Mast and automatically catches/detaches the column under Mast and transfers the vertical/horizontal load from CF to column, as a result, it suports CF safely.

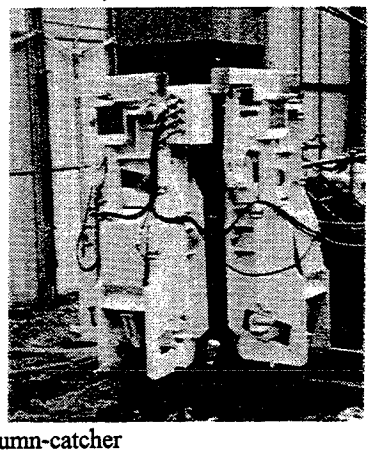


Photo.4. Column-catcher

5.Work execution record

Period	June '92-February '94
Order by	Corporation Sekai-Bunka-sya
Place	4-2-29, Kudan-kita, Chiyoda-ku, Tokyo, Japan
Main use	Office Building
Floors	2 basements , 10 stories, 1 penthouse
Area	Building area 613 ㎡ , Total floor area 6,614 ㎡
Height	Eaves Height 44.7m, Maximum Height 45.5m

Period	April '95-March '98
Order by	Tepco-Building Ltd and two campanies
Place	2-3-1, Mita, Minato-ku, Tokyo, Japan
Main use	Office Building and Undeground Transformer
Floors	4 basements , 8 floors, 1 penthouse
Area	Building area 952 ㎡ , Total floor area 10,807 ㎡
Height	Maximum Height 35.4m

Roof Push up Construction Method

Applicable type of work: Construction of a multi-story office building	Official price:
Classification:	
Purpuse of the development: Improvement of the working envirnment and safety	Lease and rental:
Level of practical use:	Development company: Takenaka Corporation

Information
Company name: Takenaka Corporation
Address: 21-1, 8-chome, Ginza, Chuo-ku, Tokyo, 104, Japan
Pubulic Relations, General Headquarters
Phone: 03-3542-7100
Fax: 03-3545-9083
E-mail:

1.Application

Construction of a multi-story office building

2.Outline

With this method, the roof floor is erected first and then other floors are subsequently constructed by pushing up the roof floor with oil jacks, as shown in Photo.1 and Fig. 1.

By constructing the roof floor, which serves as the roof, work can be performed even when it is raining to keep the planned schedule. Moreover, by collecting construction work and necessary production equipment on the roof floor, it is easy to improve the working environment and safety. Furthermore, automatic and robotic work can be promoted easily compared to the conventional construction method.

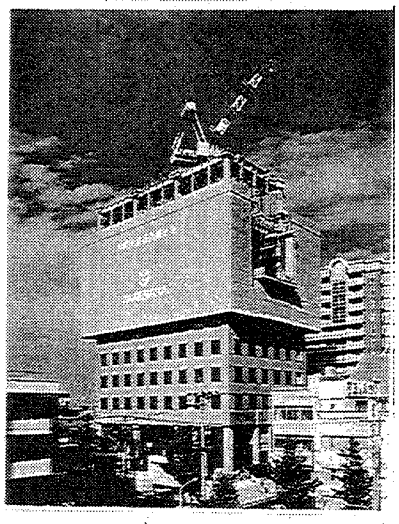


Photo.1 General View of Construction Site

3.Characteristics and effects

1) The weather will not influence construction.

Because the top floor including the roof is constructed first, construction work can proceed irrespective of weather conditions, enabling finishing work to be undertaken at an early stage. In addition construction work can be carried out exactly as scheduled, making a five-day working week possible.

2)A high level of safety can be ensured.

Because construction work can be carried out on completed floor, the amount of construction work at high elevations is reduced and therefore the degree of safty increases drastically.

3)The numberof workers can be reduced. In addition, various workers can be standardized.

Construction work can be carried out by a small number of workers with avoiding concentration of works because each worker can undertake multiple tasks at hand without waiting time.

4)Construction work can proceed without interference due to obstacles in the sky or adjacent areas.

Construction work can proceed at small sites as surrounded by buildings, sites directly underneath a microwave path or land near airport or railway facilities.

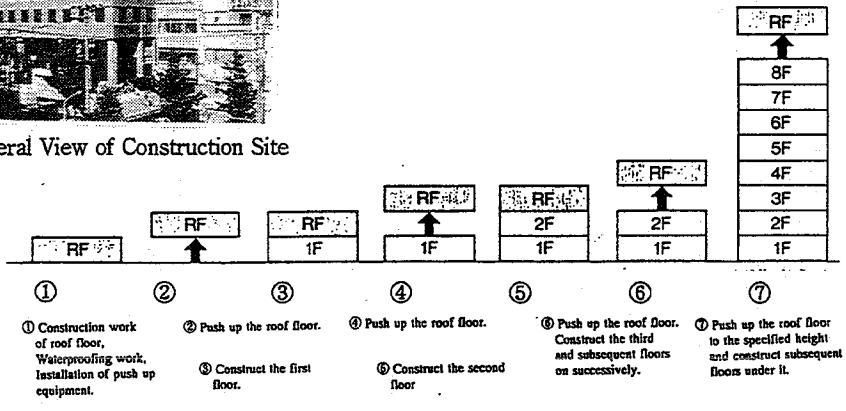
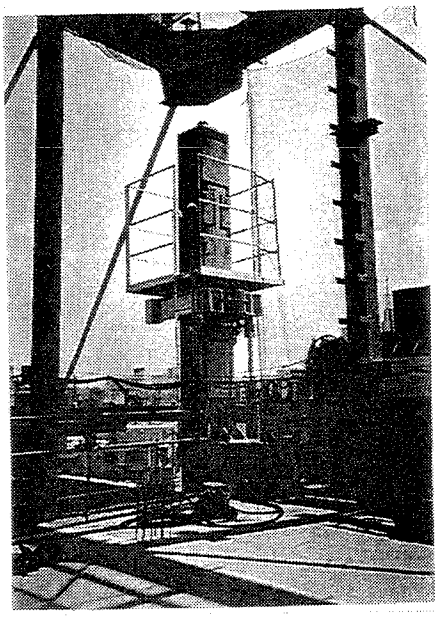


Fig.1 Basic Concept of Construction Method

4.Features of the robotization and automation

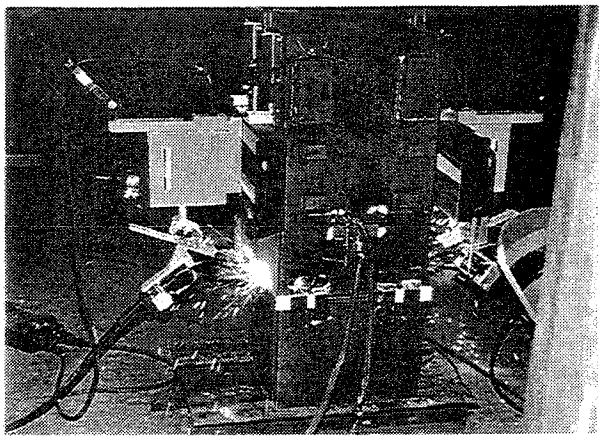
1) Push－up equipment

The equipment pushes up the top floor by anchoring itself to the main construction columns while retaining horizontal precision via automatic level control. It raises the top floor in a safe and precise manner.



2) Welding robots

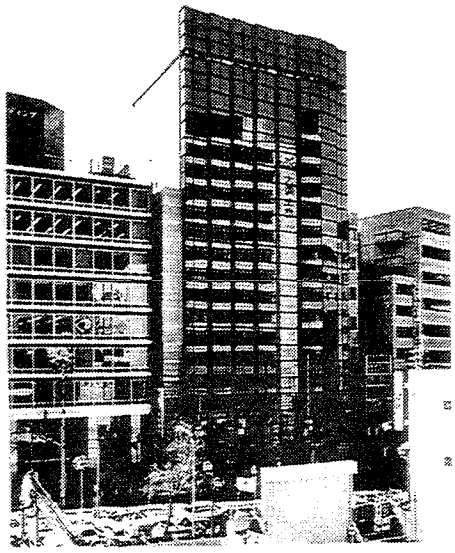
Welding robots contribute to reduced need for human resources, ensure welding quality and improve work efficiency.



3) A construction accuracy management system

This system grasps the current working status instantly.

5.Work execution record



Building name: Yanagibashi Mitui Building
Location: Nakamura－ku Nagoya, Japan
Building area: 682.880 m2
Total floor space: 7,940.822 m2
Structure: RC, SRC, S structure
Scale: B2F, 12F, P1F
Maximum height: 44.95 m
Construction period: Nov.1989－Feb.1991

Building name: Dowa Fire and marine Insurance Nagoya Building
Location: Nishi－ku Nagoya, Japan
Building area: 816.10 m2
Total floor space: 11,880.43 m2
Structure: SRC, S structure
Scale: B2F, 14F, P2F
Maximum height: 68.5 m
Construction period: Oct.1993－May 1995

6.Usage conditions

AUTOMATED BUILDING CONSTRUCTION SYSTEM (AMURAD CONSTRUCTION SYSTEM)

Applicable type of work:	Building construction	Official price:	–
Classification:	Work execution		
Purpose of the development:	Reduction of the execution period and the amount of labor required, and improvement of the work environment	Lease and rental:	–
Level of practical use:	Used in actual work	Development company:	Kajima Corporation

Information
Company name: Kajima Corporation, Technology Promotion Department, Building Construction Technology Division, Construction Group
Address: 1-2-7 Moto-Akasaka, Minato-ku, Tokyo 107
Phone: 03-3404-2011
Fax: 03-3746-7318

1. Application

① Automated execution of building construction

② Extension and remodeling of buildings, and incorporation of seismic-base isolation equipment

2. Outline

The AMURAD Construction System is a construction method based on a completely new idea in which the top floor is completed first in the construction of a building, in opposition to conventional methods in which the first floor is built first, followed by the second floor, the third floor, and so on.

Depiction of the Automated Building Construction System

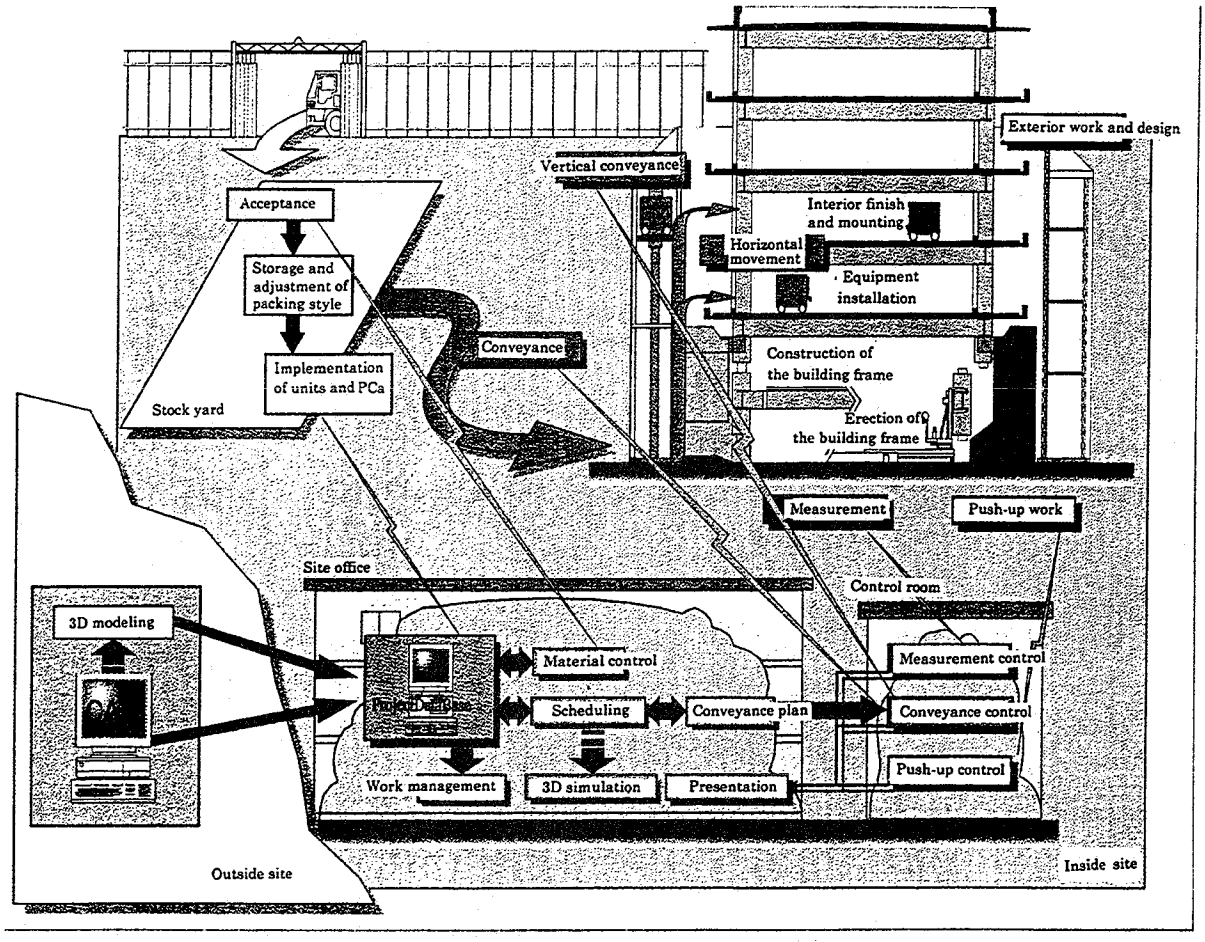


Fig. 1. Building Construction System by CIC

In this new construction method, the completed top floor is pushed up using jacks, and then construction is begun on the floor immediately below. After a floor is elevated using jacks, the related utility work, exterior wall work, interior work, and others such work is conducted. As this process is repeated, a completed building gradually emerges, just as a bamboo shoot grows out of the ground.
The work is conducted under an integrated, computer-based information management system, based on the CIC concept. Fig. 1 illustrates the building construction system based on CIC, and Fig. 2. is a depiction of the AMURAD Construction System.

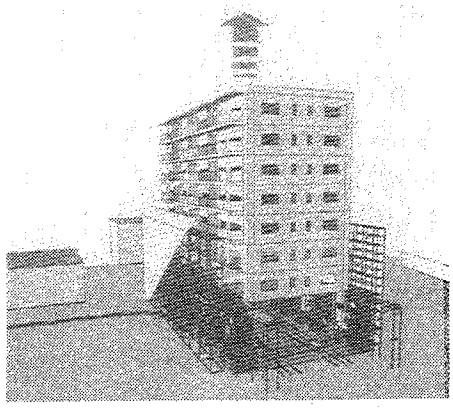


Fig. 2. Depiction of the AMURAD Construction System

3. Features and Effects

① This method enables execution periods to be shorted by 30%, manpower to be reduced by 50%, and discharge volumes of industrial wastes to be reduced by 50%, compared to conventional construction methods.

② The method can be applied to steel (S) structures, reinforced-concrete (RC) structures, or steel-encased reinforced concrete (SRC) structures.

③ Because the method does not require the use of cranes, construction can be conducted in a location with a low ceiling or a small area.

④ This all-weather type of automated construction method provides stable execution quality, and is cost effective, safe, and drastically improves the construction work environment.

⑤ Because a building grows up gradually from the ground, there is less effect on the environment in the neighborhood.

4. Description of Robotization and Automation

To implement the AMURAD Construction System, the following three types of mechanical systems were developed: a push-up system (Z-UP) that jacks up the entire building one story at a time; a building-frame carrying and mounting system (Z-HAND) that carries and installs building-frame members (PCa columns, PCa beams, S beams and FR plates) on the ground-level work floor; and a material carrying system (Z-CARRY) that carries equipment and finishing materials to the second and third work floors.

The Z-UP consists of six units of 600-ton and four units of 400-ton motor-driven screw-type jacks, for a total of ten jack units arranged in the positions of the main columns. By controlling all jacks in a centralized and synchronized manner, the building-frame can be pushed up with a high degree of accuracy (total push-up error of less than 1 mm).

The Z-HAND (five-ton loading capacity) is a piece of mechanical equipment that travels on rails and features the following seven types of movement: traveling, traversing, turning, ascending/descending, inclination of members, and fine-adjustment sliding. This equipment enables building-frame members to be mounted with a high degree of efficiency.
Moreover, the Z-CARRY is composed of conveyor equipment (1.3 ton loading capacity) traveling on a three-dimensional monorail, a traverser that moves sideways to a prescribed position, and a control board. When the destination is specified through the use of bar codes, this conveyor can transport materials automatically. Fig. 3 depicts the three machines installed.

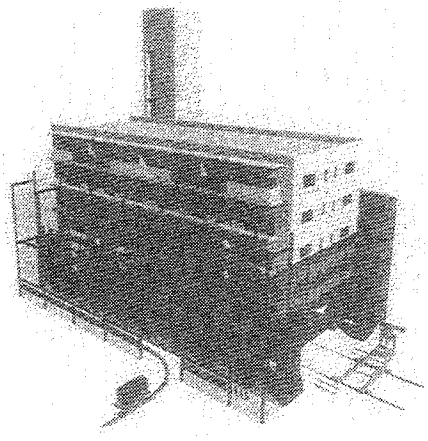


Fig. 3. Depiction of Three Machines Installed

5. Execution Records

① New construction of the Kajima Tikusa Company House Building
   (1) Location: Nagoya-shi, Aichi-ken
   (2) Execution period: Dec. 1995 through Oct. 1996
   (3) Outline of building: SRC structure, nine stories above-ground

② New construction of Office Building
   (1) Location: Toshima-ku, Tokyo
   (2) Execution period: April 1996 through Sept. 1997
   (3) Outline of building: S-structure, 11 stories above-ground and one basement level.

6. Points to Consider

The AMURAD Construction System is intended for application to the construction of medium- to high-rise buildings with 9 to 15 stories and Height/Width ratio of 3.0 or less.

March 1998

Publications Committee
International Association of Automation
and Robotics in Construction