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DEVELOPMENT OF RIPRUP SUPPLY TYPE MOUND LEVELLING MACHINE

Y. Suzuki, Manager, T. Hirakata, Construction Specialist, K. Onodera, Engineering Specialist, Yokohama Machinery Improvement Office, Second District Ports and Harbors Construction Bureau, Ministry of Transport
R. Okude, Manager, Machine Technology Department, Port and Harbor Research Institute

ABSTRACT

In this paper, the authors describe an outline of the riprup mound levelling machine and the results of being used at the construction site of deep-sea breakwater at Kamaishi Harbor. The top faces of the mounds are levelled over supplying with rubbers by the machine. So the machine consists of a riprup supply unit and a mound levelling unit. The author's group have already used it at Kamaishi several times and have gotten desired results.

1. PREFACE

Structure of breakwaters, as a peripheral facility of ports and harbors is generally the mixed structure type composed of caissons and riprup mounds, and top surfaces of these riprup mounds for installing caissons are still levelled by manpower using divers.

However, port and harbor constructions recently tend to be conducted more in the offing and in waters with large depths, where construction woks obliged to be performed under severe oceanic climate conditions. Under such conditions, the diving time of divers is limited for their health, so that causes the reduction of working hours and the lowering of work efficiency. Furthermore it become difficult to secure the necessary number of divers due to decrease in number of divers and advancement of divers' age. That means manpower levelling is very hard to cope thoroughly with such as deep-sea works.

Under these circumstances, Second District Port and Harbor Construction Bureau, Ministry of Transport started the development and research activities about mechanized execution of levelling work from 1976, and fabricated an experiment machine in 1983. After that, through demonstrative experiments of building riprup mounds and improvements, the machine was accomplished in 1989. The machine is new in use at the mouth of Kamaishi Harbor where the deep-sea breakwaters for the prevention of tsunami disaster are under construction. The depth of its installation is approximately –65m and the machine works at the site of –25 ~ –32m depth which means the top of the riprup mound.

This report described an outline of the riprup mound levelling machine and the results.

2. BACKGROUND OF DEVELOPMENT OF THE MOUND LEVELLING MACHINE

So far riprup tops for caisson installation were –10m ~ –15m in general, but under the recent trend of harbor constructions that breakwaters are constructed more in the offing and under larger water depths, many breakwaters are planned with –20m or deeper riprup tops for caisson installation.

In case of riprup levelling by divers under these large water depths, there are problems such as lowering of work efficiency due to reduction of dividing time, safety problems, etc.

(Problems on manpower riprup mound levelling under large water depths)

1) Oceanic climate conditions
   Response to degradation of conditions is difficult, and refuge takes time.
2) Diver boat
   Rope mooring is dangerous because of large freedom to cause large sways and turns.
3) Supporting equipment
   When riprup is 100 kg/each or heaviar, a crane is required and work efficiency goes down.
4) Diving equipment
   Diving hoses often drift to be entangled with anchor ropes and other divers: it is dangerous.

5) Divers

Compared to shallow water areas up to –15m of water depths with ones of –25m the diving time is reduced very much and the sight also become worse. Under a water depth of –25m, the volume of final levelling of a diver is approx. $4m^2$ per day and it is only 50% or so compared with work under –15m of water depth.

Table 2 Age composition of divers
(Helmet diving)

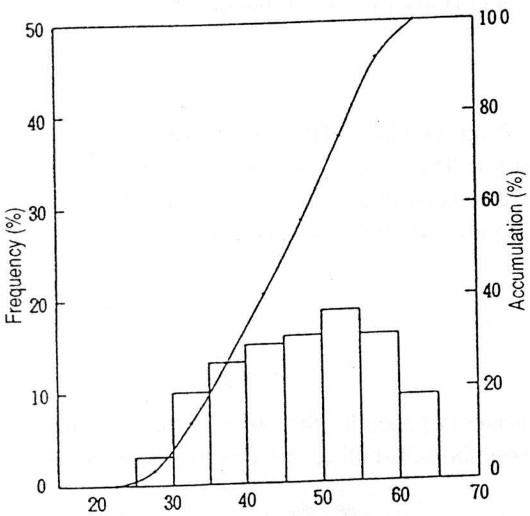


Table 1 Number of divers who passed diving skill qualifying test
(1981 – 1st half of 1991)

Branch	Class 1	Class 2	Class 3	Total	Application
Sapporo Branch	144	86	26	256	Hokkaido
No. 1 Branch	105	38	35	178	1st construction Bureau
No. 2 Branch	268	167	134	569	2nd Construction Bureau
No. 3 Branch	216	208	134	558	3rd Construction Bureau
No. 4 Branch	319	180	238	737	4th Construction Bureau
No. 5 Branch	59	39	17	115	5th Construction Bureau
Okinawa Branch	31	23	20	74	Okinawa
Total	1,142	741	604	2,487	

(Including hookah and scuba)

According to the number of divers registered by diving skill qualifying test, divers who are engaged in harbor construction works are 2,487 persons (Table 1). For their age composition, divers who are in 20s of age are 7%, 30s are 24%, 40s are 31% and 50s are 43%. Their average age become advanced year and year, so it is difficult to collect enough number of young divers (Table 2).

For diving, experience is an important factor. However, unlike other jobs, sufficient physical strength is required, so the age advancement is a serious problem. In case of large water depths, not all divers are available and the number is limited consequently. A large-scale harbor construction may take ten years or longer for constructing breakwaters, and it is extremely difficult to secure a sufficient number of divers locally around the place of construction.

Judging that riprup levelling at by divers under water depths of –25m ~ –32m at Kamaishi is not possible in consideration of the situation as above, mechanized execution of work was planned through engineering developments. Thus development of the mound levelling machines were started in the fiscal 1976.

3. Outline of the mound levelling machine

The machine (Photo 1) is composed of a riprup supply unit and a mound levelling unit. The former unit (Photo 2) is composed of a hopper, chute, buoyancy tank and a suspension pedestal, and it supplies riprup which is dumped from the barge to the hopper of the unit. For this purpose, the

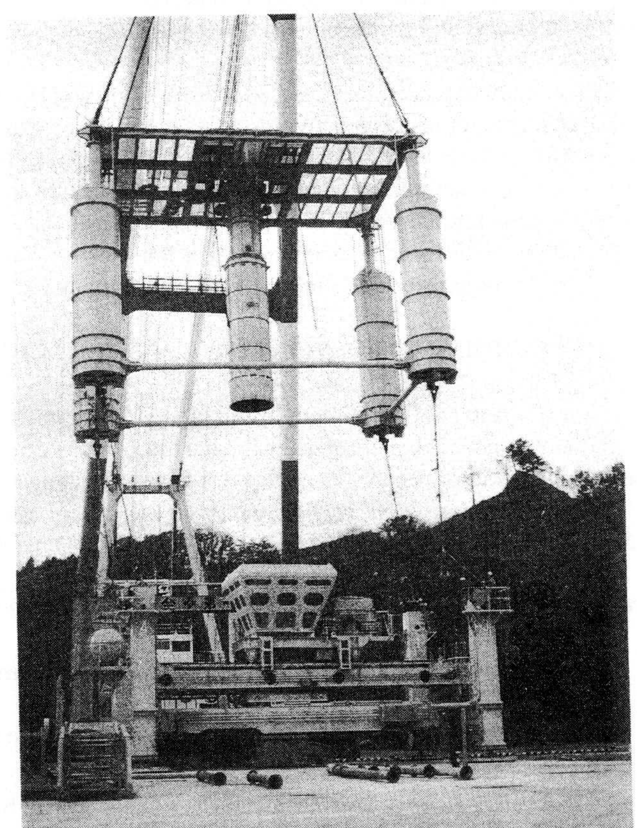


Photo 1 The mound levelling machine

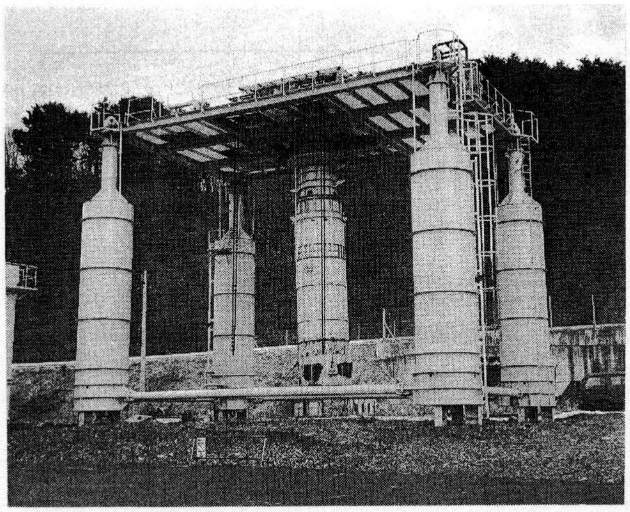


Photo 2 Riprup supply unit

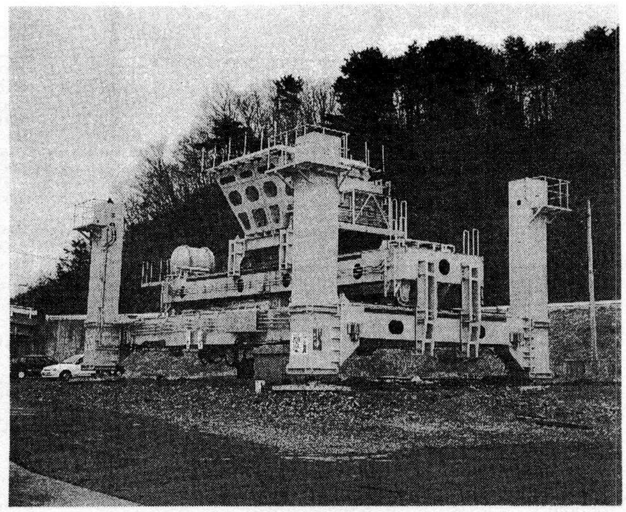


Photo 3 Mound levelling unit

buoyancy tank floating at sea adopts the TLP (tension leg platform) system so as to minimize influence of waves.

This system, adopted for wave observation systems and the production platform of floating type oil production systems, aims to minimize the away of the riprup supply unit by reducing the swaying area of the structures and by giving tension to wire ropes (legs) connecting the mound levelling unit with the buoyancy tank of the riprup supply unit. By this, the riprup supply unit is made a flexible structure, and the weight of steel members was reduced.

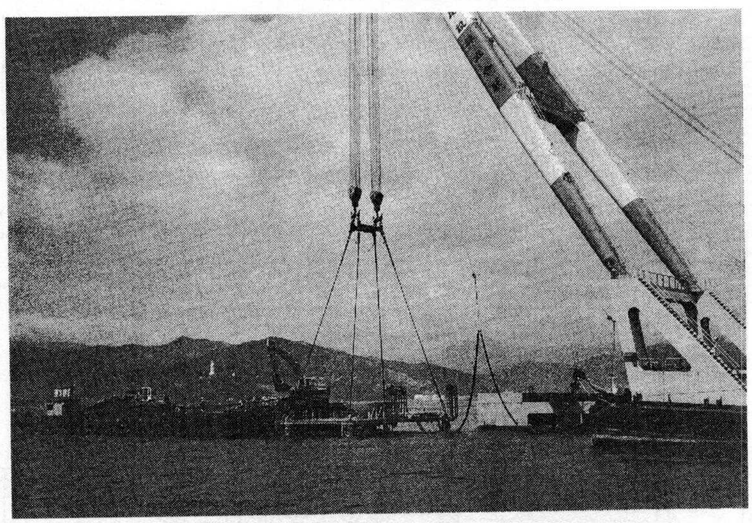


Photo 4 Riprup levelling

The latter unit (Photo 3) provides a structure and functions for levelling riprup mounds under –32m of water depth, and is composed of a horizontal pedestal having four expansion legs, a chute trolley consisting of a hopper and a chute, and a traveling trolley moving on the horizontal pedestal.

Four expansion legs can be expanded independently each other to secure the level of the unit on the seabed. The level adjustment is at first conducted by measuring the sea depth by hydraulic sensors attached to four corners of legs, then by operating oil pressure cylinders. Each leg has a bottom plate at its bottom end, and the neck is designed to swing matching the slope of the seabed by ball joint.

Also, to absorb shocks at bottom landing of the machine, a shock absorbing unit is provided.

Riprup supplied to the riprup supply unit is stored in the chute of the mound levelling unit through the expansion chute, and levelling is conducted simultaneously with discharging by operating the horizontal pedestal and chute pedestal. By one anchoring, $40m^2$ of levelling is possible.

Control and monitoring are performed by personal computer through a control panel located on the crane barge.

4. MAJOR ITEMS

Major items of the mound levelling machine are shown in Table 3, and the working fleet and machinery are shown in Table 4.

Additionally, a general allocation is shown in Fig. 1.

Table 3 Major items

Spreading area	5.0m × 8.0m (40m²/shift)
Dimensions	Overall length 14.4m × overall width 9.1m × overall height 8.55m (in case of minimum stroke)
Weight	Approx. 240t (levelling unit: approx. 165t, supply unit: approx. 75t)
Horizontal pedestal	Expansion leg type (maximum stroke length 3.5m)
Travelling pedestal	Oil pressure drive pin & sprocket system, motor 30kW)
Chute pedestal	Oil pressure drive pin and pinion system, motor 30kW)
Hopper capacity	Approx. 19m³
Residual riprup detecting unit	Proximal switch type measurement (0.36m pitch, 7-step) Echo sounder type measurement (bottom step)
Chute	1.9m× 1.7m (mouth size)
Working sensor	Echo sounder × 2: frequency 400kHz Hydraulic sensor × 4: for −70m of water depth
Riprup supply unit (tension leg platform system)	Overall length 14.4m × overall width 9.1m × overall height 13.15m
Riprup supply chute	Expansion type (diameter 1.5m × length 22.8m)
Control system	Personal computer (NEC9801XL)

Table 3 Working fleet and machinery

Name	Standard, performance	Q'ts	Usage	Remark
Floating crane	L50×B23×D4.25M 300t	1	Hoisting of mound levelling unit	
Tugboat	Steel, D3300ps	1	Towing of floating crane	
Barge	50×18×3.5m Steel, 2000t loading	1	Supply and carrying of riprup	
Tugboat	Steel D1300ps	1	Turning and towing of barge, towing of floating	
Rock carrier boat	Immobile, 480m3 loading	1	Carrying of riprup	
Pusher boat	Steel 840ps	1	Towing of riprup carrier and barge	
Anchor lifting boat	5t hoisting	1	Anchor lifting of crane boat	
Crane barge	Immobile,70t hoisting	1	Installation and removal of anchor	
Pusher boat	Steel, 840ps	1	Pushing of crane barge	
Traffic boat	FRP	1		
Watching boat	FRP, 24ps	1	Watching	
Backhoe	1.2m2	1	Loading and supply of riprup	Barge mounted
Engine generator	200kVA, 50Hz	1	For mound levelling unit and measuring instruments	
.Shovel loader	2.3m3	1	Riprup supply	Barge mounted
Auto positioning system	Polar fixed	1	Positioning of riprup levelling unit	

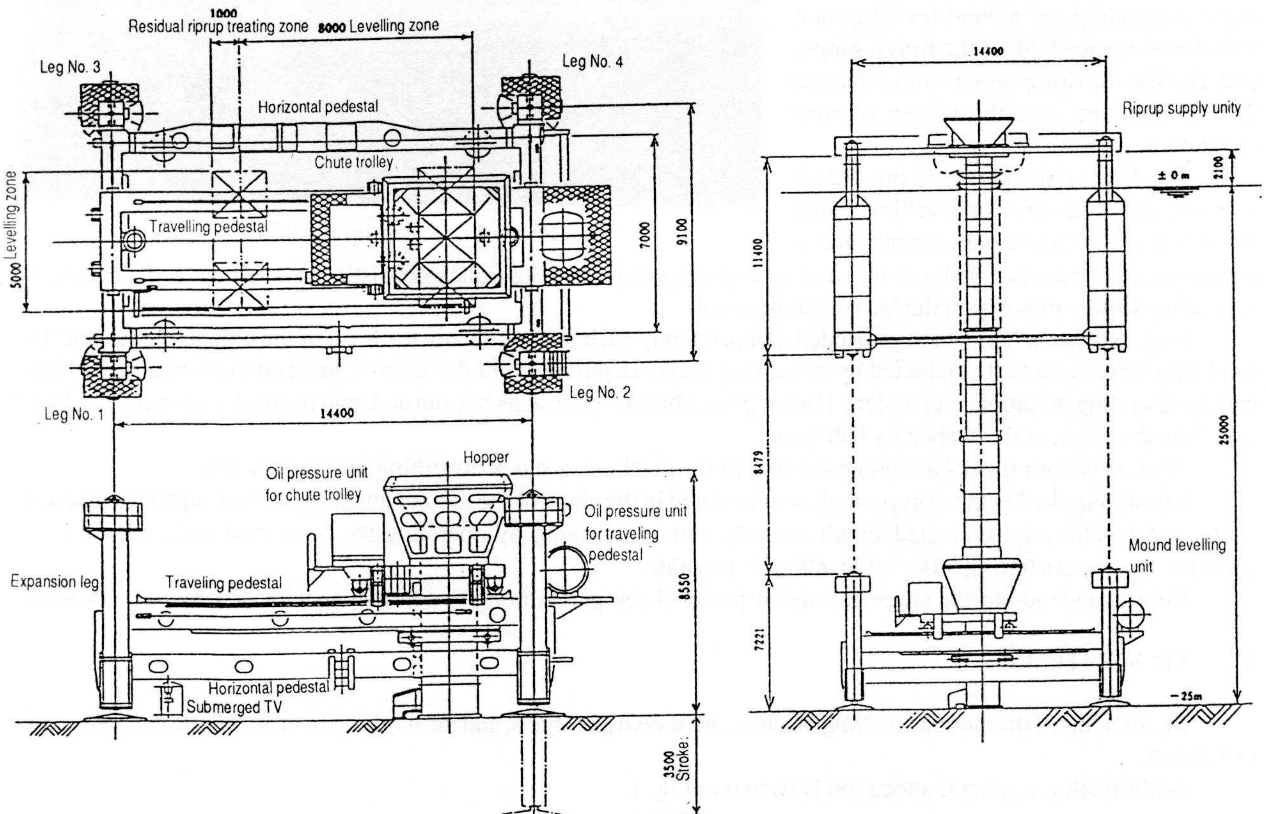


Fig. 1 General allocation of riprup mound levelling machine

5. Work procedure of the mound levelling machine

The work procedure of the machine is shown in Fig. 2. A situation of mound levelling work is shown in Fig. 3.

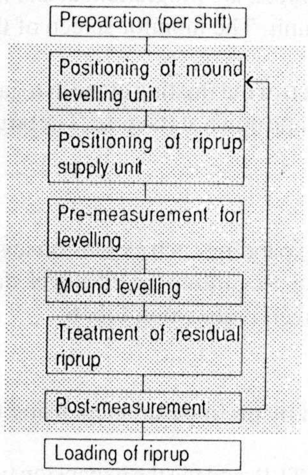
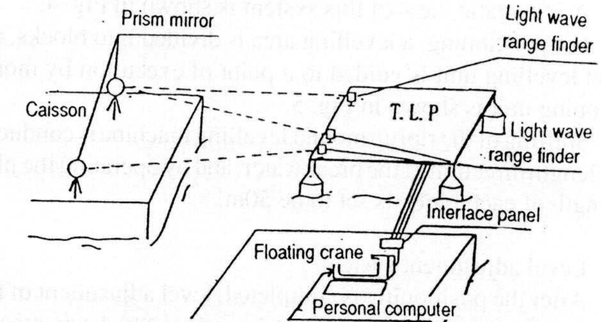


Fig. 2 Work procedure



Equipment configuration

Machine type	Q'ts	Specification
Auto collimation light wave range finder	3	Measuring range : 9 element prism, 2km Accuracy of distance measurement: ± (5+15*10 6*D)mm D=Distance measurement
Reflector with light emitter	2	Infrared LED, wavelength 940mm, 9 element prism
Calculator with CRT display	1	Oki if 600 Model 20
Interface box	1	Input data : Distance measurement (3 data), RS-232C 3 lines
constant-voltage power source unit	1	Output power source: DC± 2V, DC± 15V, DC5V Input power source: AC100V± 10%2A 50/60Hz

Fig. 4 Work boat positioning measurement system

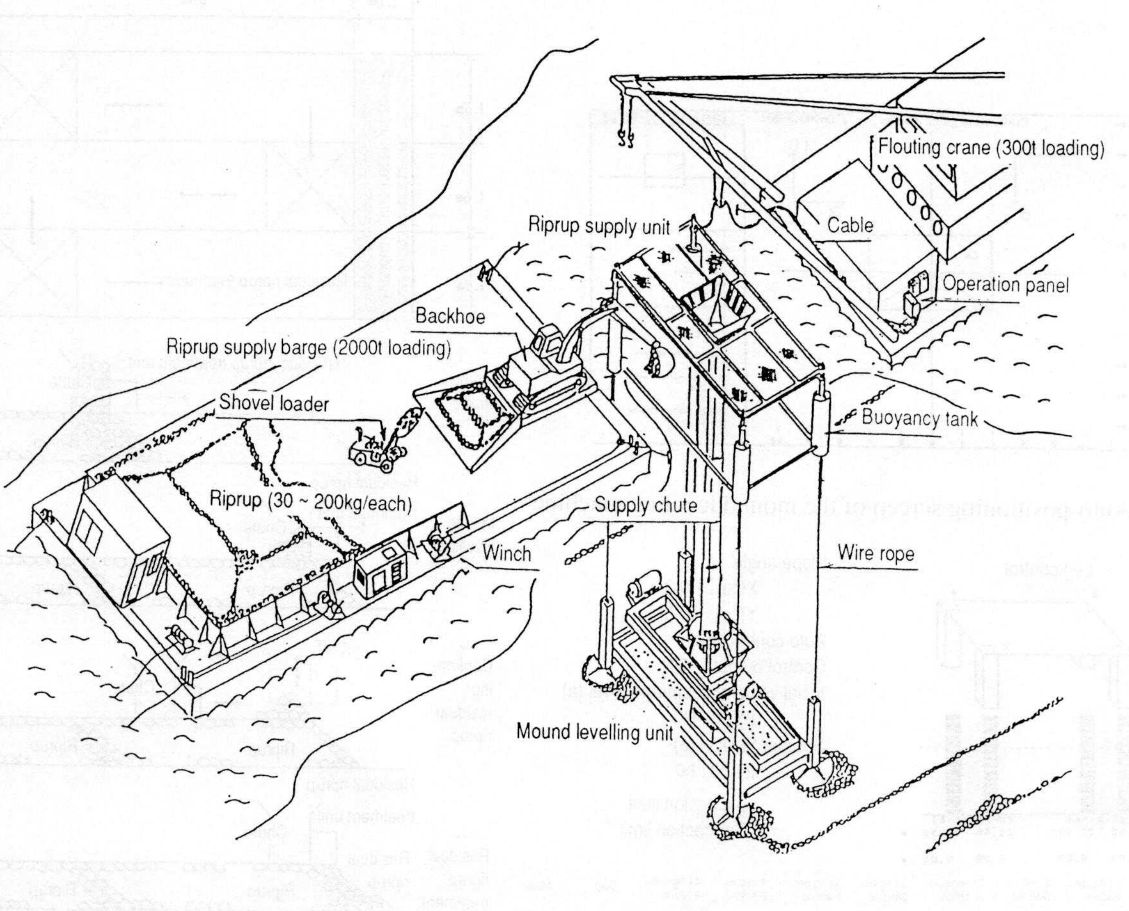


Fig. 3 Riprup spreading

(1) Positioning of the mound levelling unit

Positioning of the mound levelling unit is performed by the barge positioning measurement system which is the measurement by combination of three auto-collimation light wave range finders and two reflectors.

A schematic view of this system is shown in Fig. 4.

For positioning, a levelling area is divided into blocks, and coordinates of each block are programmed, and the mound levelling unit is guided to a point of execution by monitor of the positioning unit. The monitor screen of the positioning unit is shown in Fig. 5.

Shifting of the riprup mound levelling machine is conducted by the operating winch of the floating crane in regard of the length direction of the breakwater, and by operating the jib of the floating crane up and down at traverse. The target lap length of each block is set to be 50m.

(2) Level adjustment system

After the positioning is completed, level adjustment of the machine is done by expanding each expansion leg in accordance with values of the hydraulic sensor which are attached to each expansion leg. Regarding the tide level, data of the tide gage is input directly to the personal computer for the revise. The CRT screen is shown in Fig. 6.

(3) Mound levelling work

After adjusting the level of the machine, the relief of the mound face is studied by pre-measurement using the echo sounder of the mound levelling unit, and then levelling work is started.

Riprup is supplied by the backhoe of the riprup supply unit through the hopper of TLP, and via the expansion type supply chute, stored in the hopper of the mound levelling unit. After that, mound levelling is conducted by operating the chute trolley and travel trolley by remote control from the control room (two operators) of the floating crane.

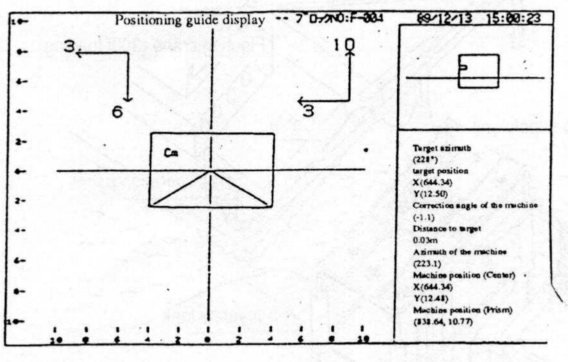


Fig. 5 Auto-positioning screen of the mound leveling machine

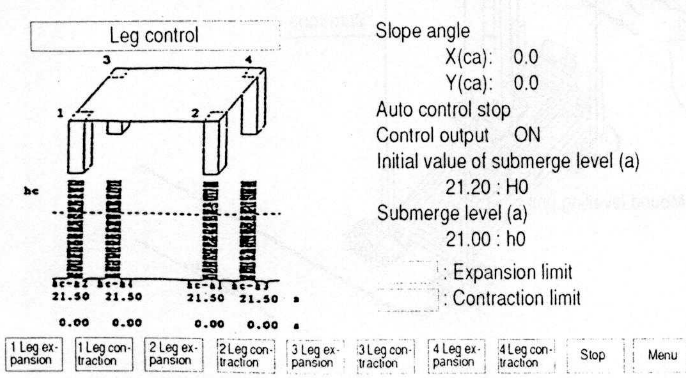


Fig. 6 Level adjustment screen

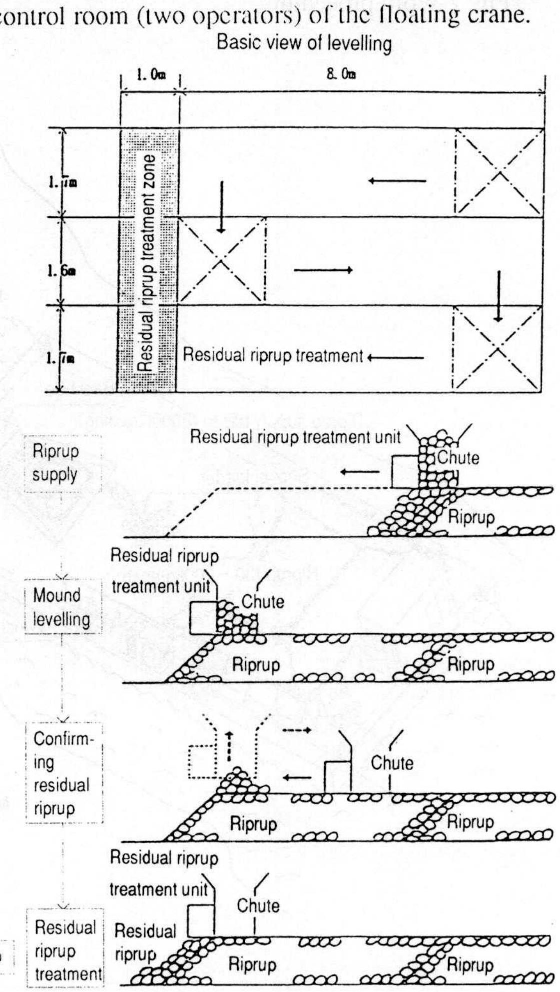


Fig. 7 Schematic view of levelling work

A schematic view of basic levelling work is shown in Fig. 7. By each anchoring, $40m^2$ (5m × 8m) of levelling is possible by moving the chute mouth (1.7m × 1.9m).

After levelling, post-measurement of the mound face is conducted to confirm the result to be within the target standard deviation (σ=10cm).

The post-measurement is conducted by the echo sounders (400Hz, 2 units)

A cycle of levelling work is 2h and 20min from positioning to post-measurement in average, 4 ~ 5 cycles a day. A work standard cycles of a day are shown in Fig. 8.

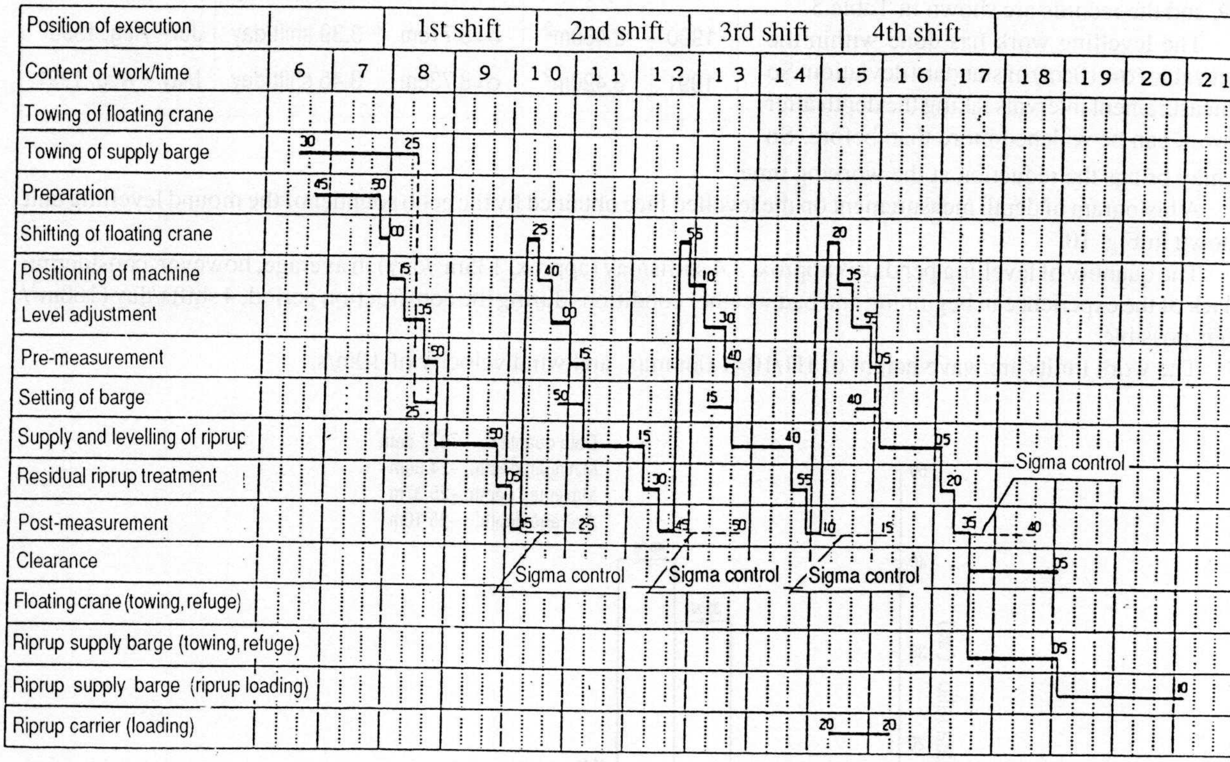


Fig. 8 Standard cycles/day of levelling work

(4) Residual riprup treatment

Residual riprup treatment refers to treatment of riprup remaining in the chute of the mound levelling unit after completing mound levelling.

Expanding the expansion legs, the chute mouth is opened and riprup in the chute is discharged. After that, shifting the chute mouth sideways and lowering the legs to the original level, residual riprup treatment is conducted by residual riprup treatment unit.

Procedure of residual riprup treatment and echo sounder data are shown in Fig. 9.

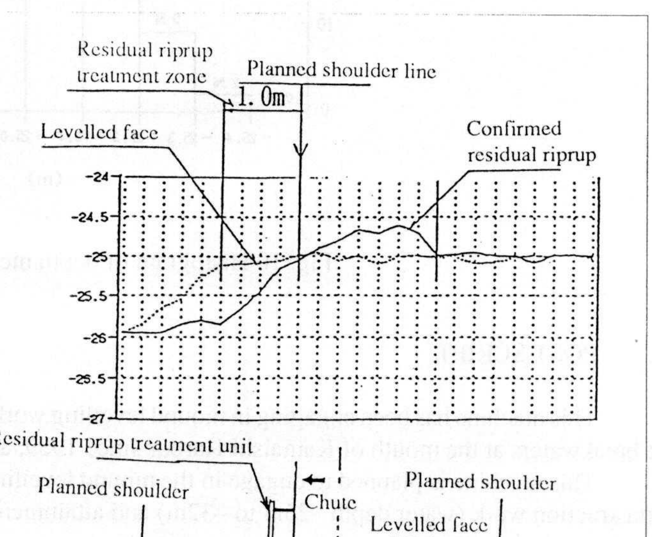


Fig. 9 Confirmation of residual riprup and residual riprup treatment

6. RECORDS OF MOUND LEVELLING

The mound levelling machine is used in full scale for levelling work of riprup varying between 30 ~ 200kg/each in the breakwater construction work of Kamaishi Harbor since 1989, and the records are shown in Table 5.

The levelling work has done within the target value (σ= 10cm) of standard deviation. So the measurement intervals taking the depth after the work can be widened more than before. So that may brings the reduction at the working time.

Table 5 Records of mound levelling

	Levelling area	Levelling accuracy	Levelling rate (average)	Construction period
1989	1,800m^2	σ=8.10cm	3.38 shift/day	Nov – Dec, 1989
1990	2,460m^2	σ=8.71cm	3.39 shift/day	Jul – Aug, 1990
1991	3,420m^2	σ=8.73cm	3.45 shift/day	May – Aug, 1991

A histogram of depth measurement on the levelled face obtained by the echo sounder of the mound levelling unit is shown in Fig. 10.

The quantity of levelling per day is approx. 3.4 shifts/day (approx. 135m^2/day) in average, however, considering the lack of the experience in beginning and bad weather conditions during the construction period, 4 shifts/day (160m^3/ day) is possible.

The work limits are wave height of H1/10=1.0m max. and wind velocity of 10m/s.

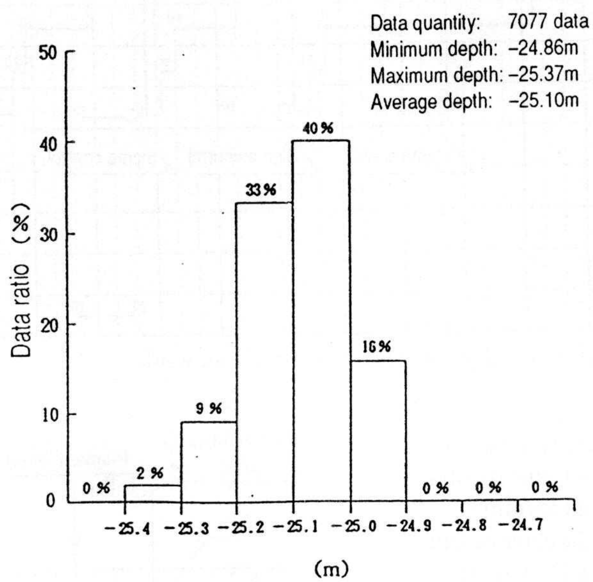


Fig. 10 Histogram of depth measurement (Fiscal 1990)

7. POST SCRIPT

This machine has been engaging in mound levelling work of approx. 8,000m^2 under a large water depth of –25m at breakwaters at the mouth of Kamaishi Harbor since 1989, and has attained expected results as reported above.

This machine is planned to engage in the mound levelling work of approx. 50,000m^2 continuously in the same construction work (water depth –25m to –32m) and attainment of further successful results are awaited.