Automation and Robotics in Construction XI
D.A. Chamberlain (Editor)

An invert concrete screeding machine for shield tunnelling

Minoru Suzuki, Hirosi Sakurai,Tsuneyasu Ohnishi, Masanori Kanno, Kimio Kikuchi and Tadao Mikami

Research and Development Institute, Takenaka Corporation 1-5 Ohtsuka, Inzai-Mach I, Inba-gun, Chiba-ken, JAPAN

Abstract

The invert concrete screeding machine was developed to improve screeding accuracy, free workers from hard lab or, reduce any workers, and rationalise work. The screeding machine consists of two guide rails, a moving device to run forth and back between guide rails, a blade with a vibration motor that screeds a concrete face smoothly, and a vertical movement device that moves the blade up and down. This report describes the outline of the invert concrete screeding machine, as well as the results of application of the subway construction work.

1. INTRODUCTION

In the past, invert concrete placing of shield work generally was performed after finishing excavation work and removing steel sleepers for the material−transport temporary railway. In recent years, however, invert concrete placing is performed simultaneously with the excavation of the tunnel itself but behind it to reduce the working period. At this time, the screeding work of invert concrete is performed in a very narrow working space under the steel sleepers for the material transport temporary railway, while material transport trains are passing to move material for excavation work. Therefore, it is difficult to use machines for the work under such conditions and the screeding work is still performed manually which is very troublesome, requiring many workers to perform the job under very low efficiency. Consequently, accurate screeding of invert concrete is difficult to maintain even with skilled workers, due to such bad working conditions.

To solve these problems, we have developed an invert concrete screeding machine with the object of improving screeding accuracy, releasing from difficult work and labor−saving of work.

This report describes the outline of the invert concrete screeding machine and its working example in shield work.

2. OBJECT OF THE DEVELOPMENT

We have studied analysis of invert concrete screeding work, the working plan of the working site, etc., and established the object of development as follows:

1. The screeding machine can be used in a narrow working space.

2. The concrete surface after screeding is maintained to the required screeding accuracy.
3. The screeding work does not affect shield excavation work performed simultaneously.
4. The screeding work does not hinder the concrete placing work schedule.
5. The screeding machine can flatten concrete placed at any set height.

3. OUTLINE OF THE SCREEDING MACHINE

The outline is shown in Fig. 1, Photo. 1, 2, and 3, and the specifications are shown in Table 1.

The invert concrete screeding machine consists of two guide rails, a running device to run the machine forward and backward within the guide rail, a blade to which a vibration motor is attached and which flattens the concrete surface, and a device to move the blade up and down.

Two guide rails are attached to the left and right sides of the bottom of steel sleepers of the temporarily installed railway in the tunnel excavating direction, the sleepers being installed in the shield tunnel at a pitch of about 1 m.

The space for performing screeding work is very narrow --- 26 cm in a vertical direction; moreover, it is widely spread in a flat direction --- 8 m wide left to right and 20 m long. It is necessary to flatten the concrete surface with an accuracy of ± 3.0 cm in such a widespread area. Therefore, the screeding machine is designed to a very small size, by arranging the running device and blade up and down device, etc., in a very low configuration of machine height of 22 cm.

The screeding work is performed by lowering the screeding blade to the set design height, pressing the placed concrete with the screeding blade to a direction, and finishing the specified height at high accuracy.

The screeding machine can be operated easily by remote control.

Table 1 Specifications of Concrete Screeding Machine

Main Body	Dimension	W260 × H240 × L1,970mm
	Weight	250 kgf
	Rail Pitch	2,000 ~ 4,000 mm
	Screeding width	4,000 ~ 8,000 mm
Running Device	Driving force	685.5 N (70 kgf)
	Running speed	1.5 ~ 4.5 m/min
	Electric motor	0.2 kw × 2 200V
Up and Down Motion Device	Stroke	0 ~ 550 mm
	Lifting force	882.6 N (90 kgf)
	Up and Down speed	1.5 ~ 4.5 m/min
	Electric motor	0.2 kw × 2 200V
Performance	Screeding performance	12.7 ~ 72.0 m^2/Hr
	Accuracy of formation	± 30 mm
Vibration Device	High-frequency vibrator	0.4 kw × 1 200V

3.1. Running Device

As shown in Fig. 2 and Fig. 3, the running device is installed between lightweight channels facing each other, in the style of a hanging−type monorail car, and is made to run forward and backward within this lightweight channel. The left and right running device is connected with a truss frame. The running device consists of a front wheel and a motor−driven rear wheel so that it can run itself, and a tension roller is attached to the center of the body frame of the running device to maintain frictional driving−force during running.

To the front and rear of the running device body frame, a pair of guide rollers is installed to prevent contact with the inside of the guide rail and to perform smooth running. Scrapers are installed to the front of the front wheel and the back of the rear wheel, to remove obstacles in the guide rail such as concrete.

The running speed can be selected from two stages of high speed and low speed depending upon the status of work and each can be adjusted based on the controller.

3.2. Screeding Blade Up and Down Moving Device

Two parallel link arms, moving up and down, are installed at the center of the running device body frame, as shown in Fig. 4. This parallel link arm is constructed to be hung with wire cable, and is devised to move to any desired height, due to the winding up or winding down of wire cable by a small motor winch. The wire winding drum is connected through a synchronous shaft so that up and down motion of the parallel link arm at the right and left sides is maintained horizontally.

The edge face of the screeding blade is devised to be kept always perpendicular to the concrete surface at any height due to the parallel motion mechanism of the link arm, so that the screeding surface of concrete can be finished to high accuracy.

The screeding height can be set to any height due to the limit switch attached to the parallel link arm, and is made to secure an accurate screeding height by adjusting the limit switch.

3.3. Screeding Blade

The screeding blade is made of equal angle, with a high frequency vibrator attached at the center, as shown in Fig. 4 and Photo. 4. Screeding work is performed by the blade. It moves on placed concrete as a bulldozer.

A desired frequency of vibration can be given to the screeding blade due to the setting of inverter control, and optimum vibration due to the characteristics of concrete can be selected, so that the concrete surface can be finished smoothly. The blade is hung from the up and down moving device through a rubber shock absorber, so that the vibration will not be transmitted to the main body of the machine.

3.4. Guide Rail

The guide rail consists of a combination of two lightweight channels 125 mm high and 50 mm wide as shown in Fig. 3, and Photo 2, and two of them are arranged parallel left

and right in the tunnel excavating direction at a 4.0−m interval. The length of one guide rail is 5.0 m, both ends of which are made to be connected with bolts, and is able to be extended easily according to the length of concrete to be flattened. An angle bar is installed at each outside upper part of the lightweight channel, so that fixing of the guide rail to the steel sleeper and movement of the guide rail to the next placing site can be made easily.

3.5. Carrier for Moving and Fixing

The carrier for moving and fixing performs fixing of the guide rail to the steel sleeper, and movement to the next working place. The carrier is installed in the steel sleeper in a position astride it, as shown in Fig 3.

A screw jack is attached to the upper side of the carrier so that it will be fixed to the sleeper by tightening the jack. Four rollers are attached to the underside of the carrier to support the angle part of the guide rail with these rollers. Therefore, the equipment can easily be moved to the next working place by loosening this jack and pulling the guide rail to the moving direction.

4. RESULTS OF WORK

An outline of the work presently carried out and work results are as follows:

4.1. Outline of Work

Underground railway work	M−ward, Tokyo−to
Finished inside diameter	D=8, 600 mm ~ D=8, 800 mm
Minimum curve radius	R=203.00 m
Maximum grade	−3.5 % ~ +3.5 %
Slump of cast concrete	18 cm
Compressive strength of cast concrete	100 kg/cm ^{2}
Area of one−time casting	About 130 m ^{2}

At present, about 5,000 m2 have been finished.

4.2. Accuracy of Screeding

The finished form of the invert concrete was measured with automatic level equipment. The floor level was measured for 5,000 m ^{2} at a different work site (264 points).

As shown in Fig. 5, the screeding accuracy due to the invert screeding machine is small dispersion (σ =9.03 mm).

4.3. Labor−saving

Screeding work, requiring about 11 hr with 3 persons with conventional manual work, was completed with 2 persons with an actual working time of about 3 hr by use of the screeding machine, and labor−saving was obtained.

5. FUTURE TASKS

Several tasks have been generated as a result of the on-site work:
1. Disposition of Cable and Related Components
At present, a long cable is used for power feed and operation, necessitating complex handling. A change in power feeding method or wireless operation will be studied in the future.
2. Protection of Guide Rail
Plywood plate, etc., is used to protect the guide rail from intrusion of concrete during concrete placing. The structure of the guide rail and a simple method of protection will be studied in the future.
3. Durability
Because little experience of operation has been obtained so far, the durability of the main body or guide rail will be continuously studied and demonstrated in the future.

CONCLUSION

Due to the development of the invert concrete screeding machine, uniformity of screeding accuracy, labour-saving of work, and rationalisation have become possible. In the future, we will improve this invert concrete screeding machine and contribute to labour-saving, rationalisation of work and improvement of quality.

REFERENCES

1. Aoyagi et al, Development of the automatic Screeding Machine Mounted on a Girder for Concrete Placing Work, the 9th. International Symposium on Automation and Robotics In Construction, l992 June, Volume 2, pp 603-610

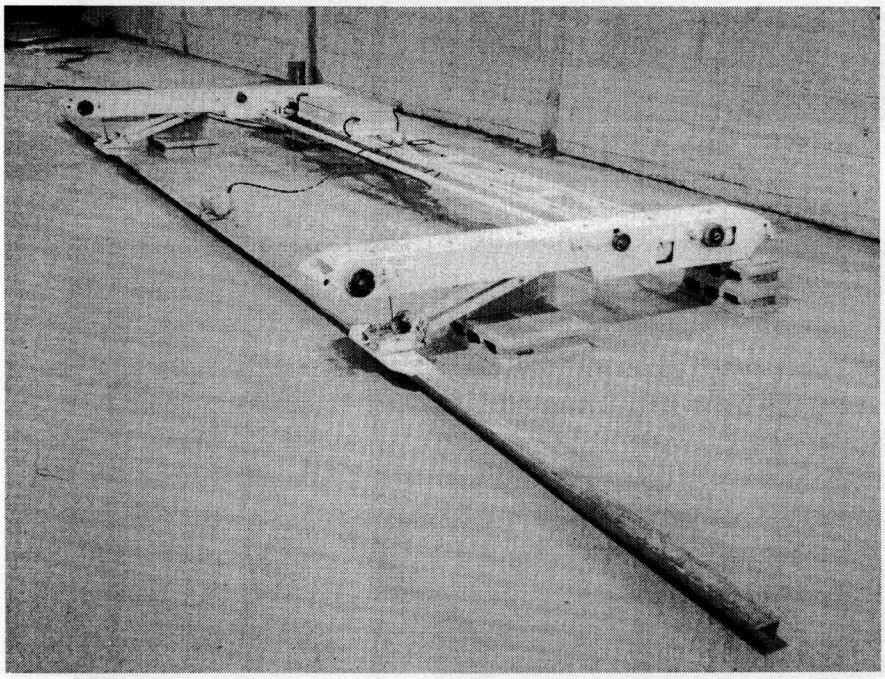


Photo. 1 Concrete Screeding Machine

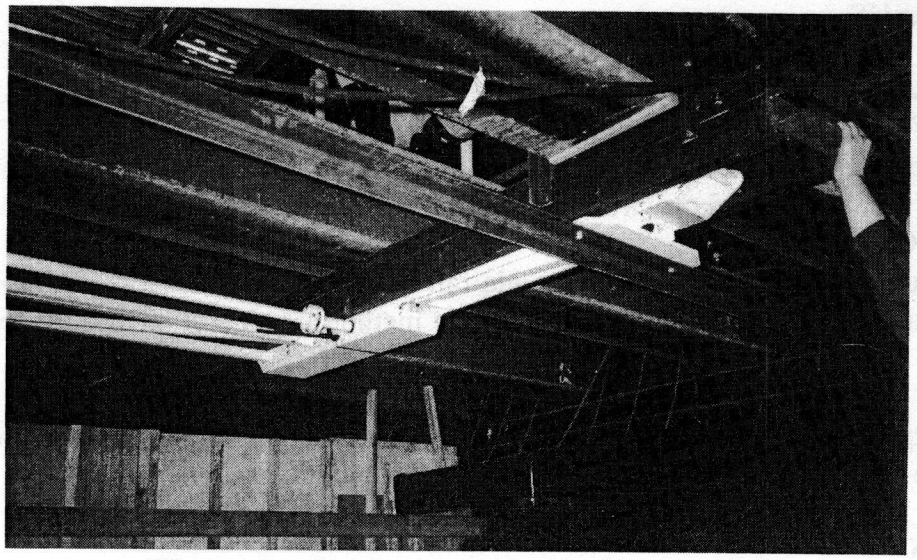


Photo. 2 Guide Rail and Running Device

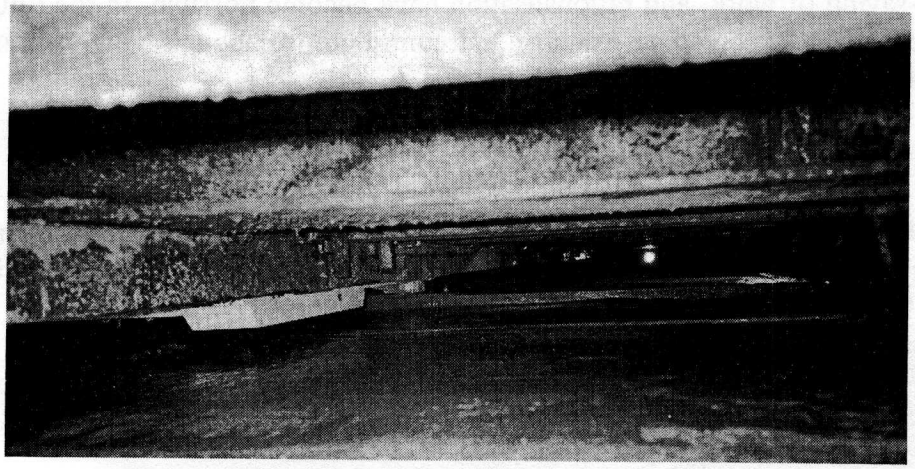


Photo. 3 Screeding Surface

Photo. 4 Screeding Blade

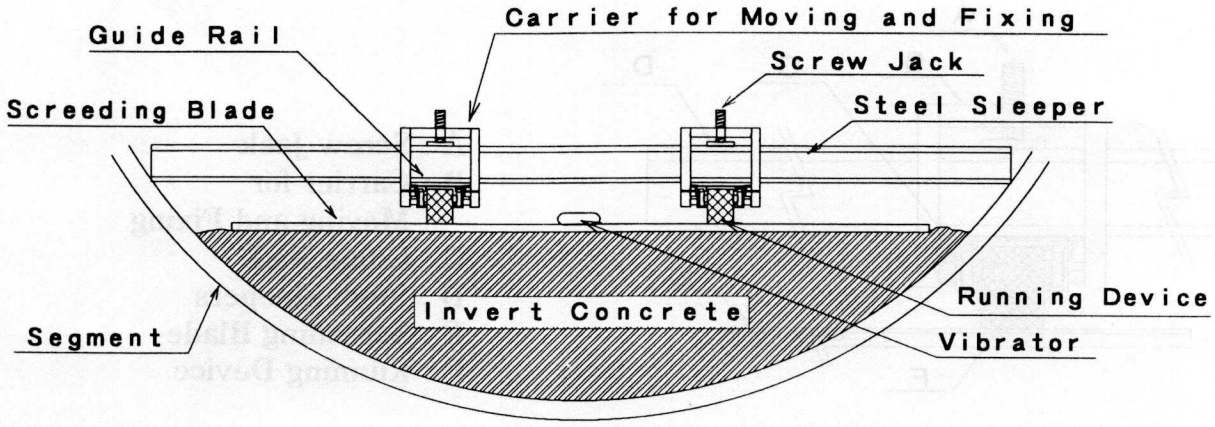
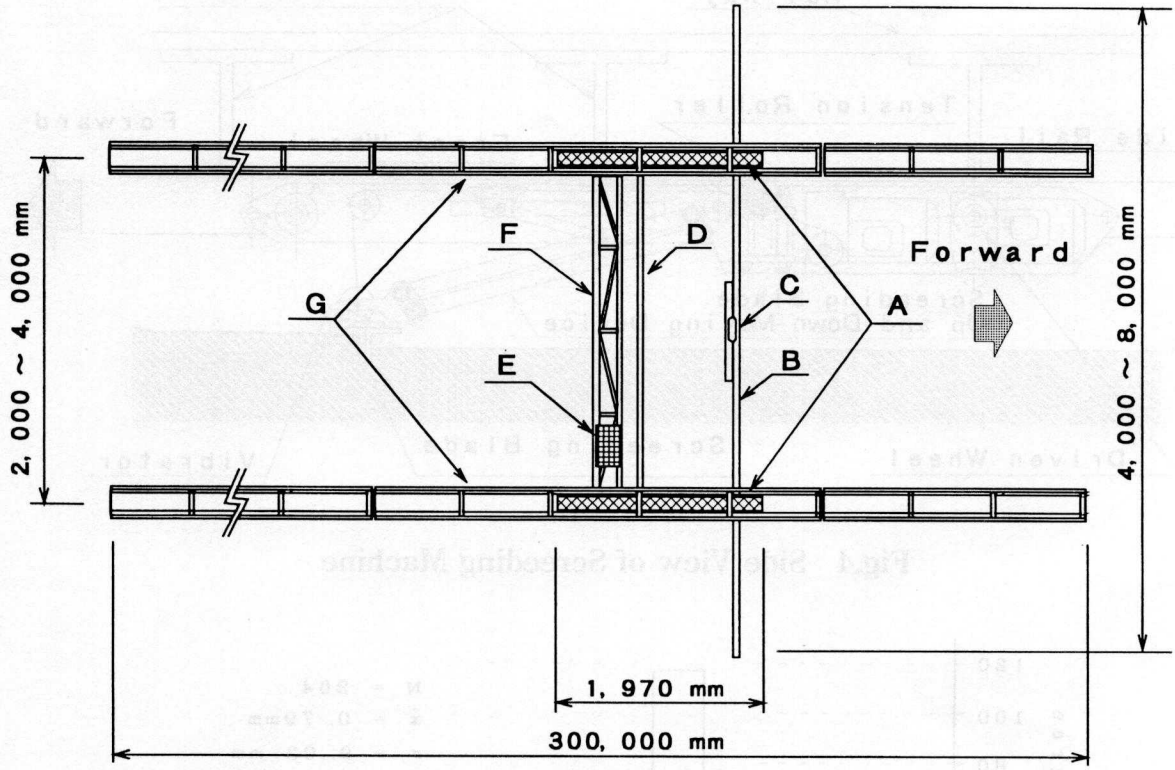


Fig.1 Front View of Screeding Machine



A : Running Device
B : Screeding Blade
C : Vibrator
D : Synchronous Shaft
E : Control Device
F : Truss Frame
G : Guide Rail

Fig.2 Plan of Screeding Machine

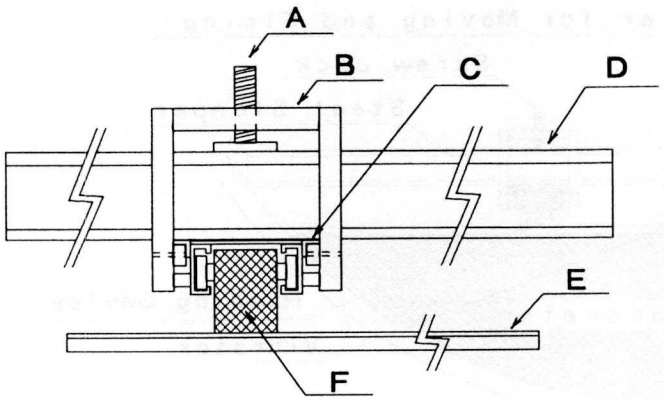


Fig.3 Carrier for Moving and Fixing

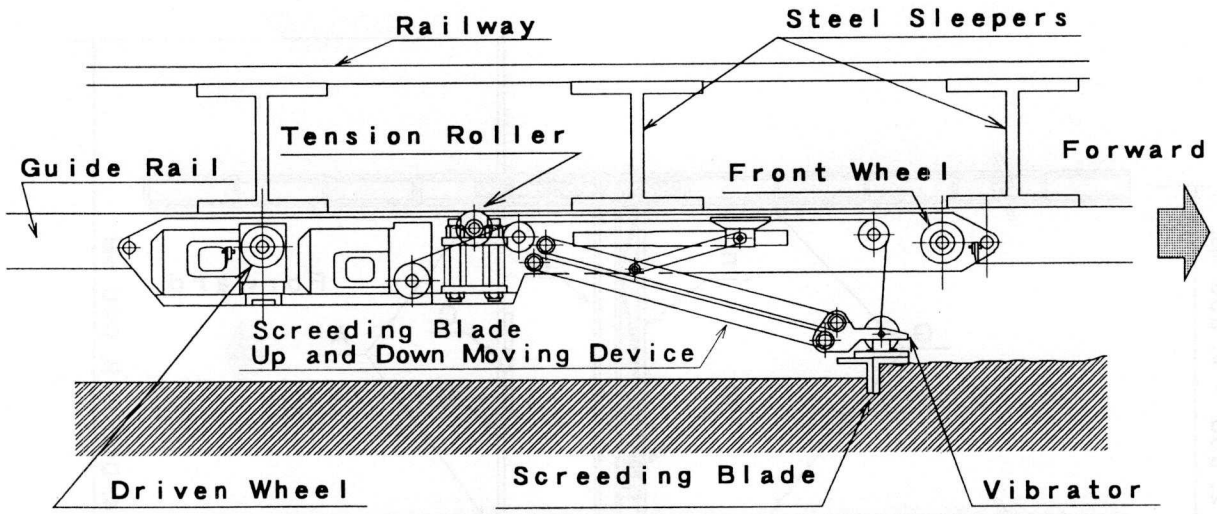


Fig.4 Side View of Screeding Machine

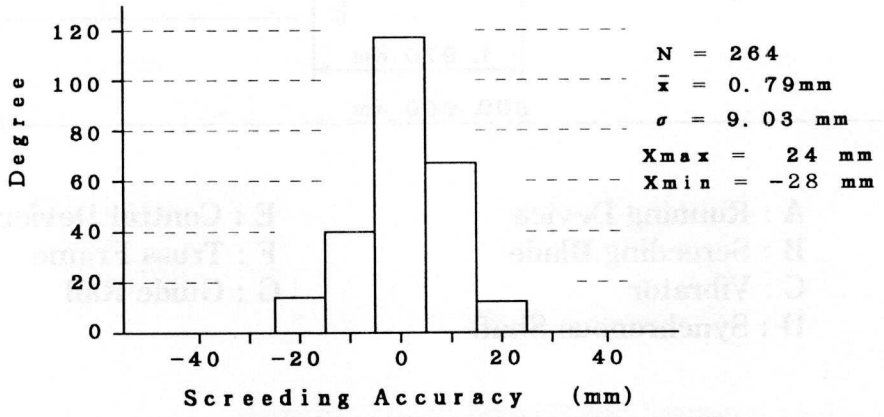


Fig.5 Screeding Accuracy