

Hitachi Shield Machine

HITACHI

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Hitachi Tunneling Technology Explores Tomorrow's Geofront (Underground Space)

Hitachi. The Geo-Frontier with Rich Experience and Achievements

Hitachi stands at the front of geotechnical and geological engineering. Today, Geofront development is essential for modern urban life supported by underground traffic systems, information networks, and infrastructure including electricity, gas, water and sewerage. Hitachi developed the world's first earth pressure balanced shield in 1976. Since then, Hitachi delivered a wide variety of shield machines, winning an acclaim for dependability and reliability. Hitachi shield technology has always responded to stringent requirements -- deeper, longer, quicker and higher precision tunneling.

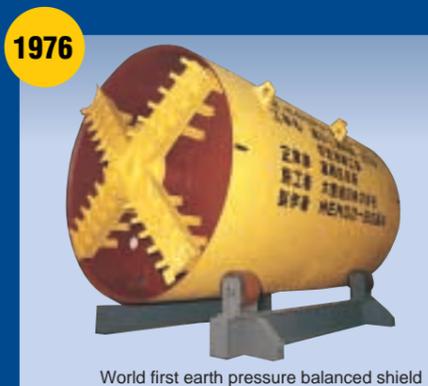
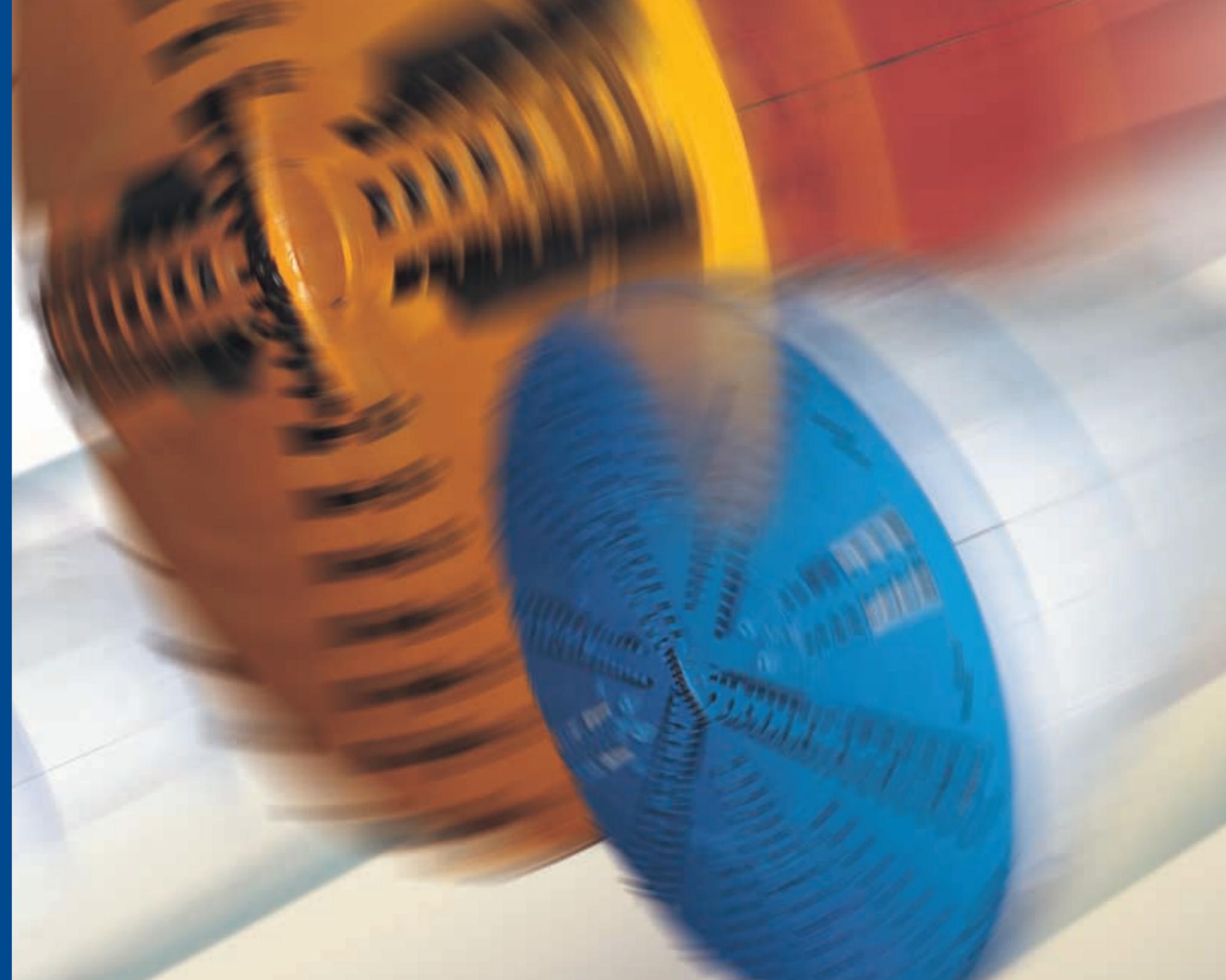
Breakdown of shields

Shield face	Excavation mechanism	Shield type
Fully enclosed	Rotary cutter	Earth pressure balanced
		Slurry
Fully open	Excavator	Mechanical
		Semi-mechanical
Partial open	Hand mine shield	Open
		Blind

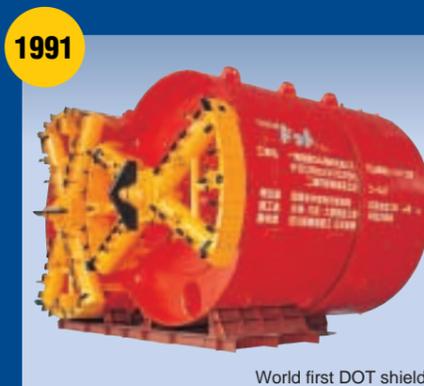
Major Achievements

Delivery record: 911 units (1973 to 2003)

Shield type	Delivery unit	Maximum diameter (m)
Earth pressure balanced shields	529	9.36
Slurry shields	140	14.14
Open shields	242	9.922



World first earth pressure balanced shield



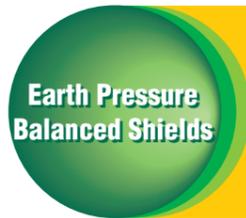
World first DOT shield



Ultra-large section slurry shield (14.14 m dia.)



World first Jack-drive DPLEX shield



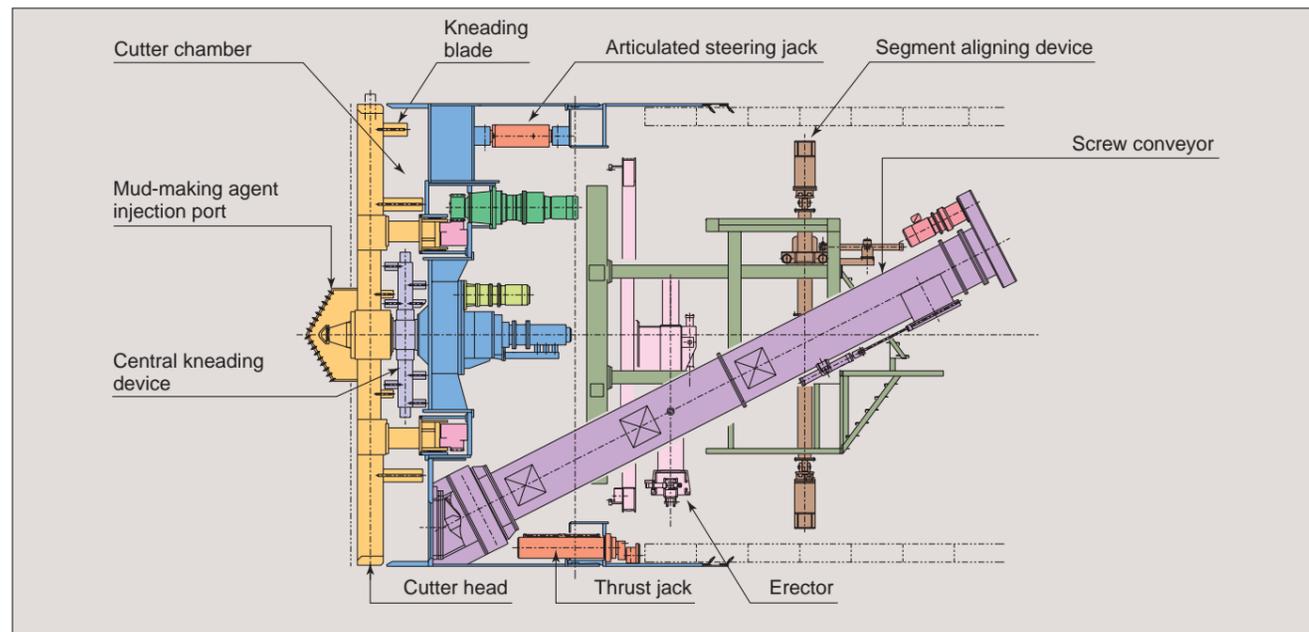
A Wide Range of Applications, from Soft to Water-Bearing Degraded Gravel Strata

Earth pressure balanced shield

The earth pressure balanced shield excavates the strata with cutter bits, injects the additive into excavated soil, and forcibly kneads it with the kneading blades at the rear of cutter head to improve its plastic fluidity and impermeability. The resulting muddy soil is fully filled in the cutter chamber and the screw conveyor. Using the thrust jacks increases the pressure of the excavated soil in the cutter chamber to counterbalance the tunnel face earth pressure at rest plus groundwater pressure. When the shield advances, the discharge of excavated soil is controlled with the soil pressure detector at the bulkhead. Thus the advance of the shield and the discharge of the excavated soil are kept in balance during tunneling operation.

Features

- Applicable to various strata, from soft soil to gravel, because the excavated soil can be changed to muddy soil with high plastic fluidity and impermeability.
- Tunnel face can be sustained by muddy soil pressure to minimize ground settlement.
- Ground water can be cut off with the impermeable layer formed by muddy soil in the cutter chamber and screw conveyor.
- Appropriate backgrouting control can be achieved, because the muddy soil is filled in the chamber and at the periphery of the shield to shut out the backgrouting agent.
- No full-scale muck treatment facility is required, because muck can be discharged by belt conveyor and muck car, or discharging pump to the surface of ground, and is carried out by dump trucks to a disposal yard after solidification.



8.96 m dia. earth pressure balanced shield

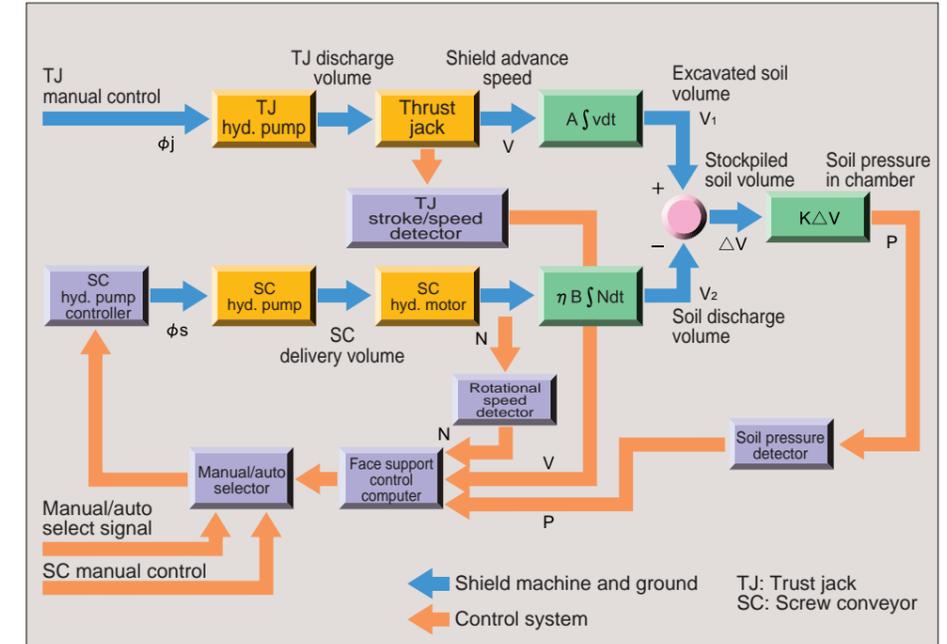
Application	Subway
Strata	Sand, clay, gravel
Overburden	22 m
Excavation distance	502 m
Radius of curvature	125 m
Description	Double-track subway section excavation Articulated steering device



Automatic tunnel face support system

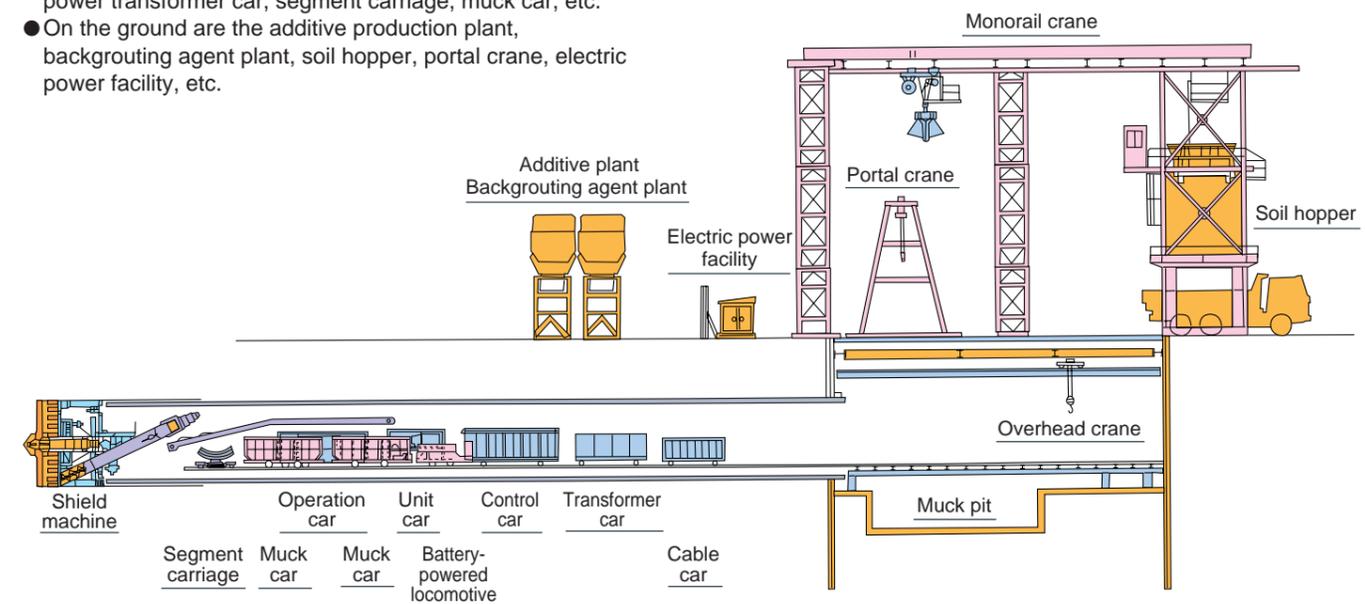
This system automatically adjusts the discharge of excavated soil according to the advance of shield machine, no more, no less. This helps maintain the tunnel face at rest. In short, to properly balance the volume of excavated soil and that of discharged soil (i.e., rotational speed of the screw conveyor), the discharging rate of excavated soil is adjusted automatically with soil pressure changes in the cutter chamber. This always keeps the soil pressure in the cutter chamber at the desired level.

Control chart



System explanation

- The shield system comprises the shield, additive injection device, additive production plant, and other facilities.
- In the tunnel are the shield power unit car, power transformer car, segment carriage, muck car, etc.
- On the ground are the additive production plant, backgrouting agent plant, soil hopper, portal crane, electric power facility, etc.



From Soft Stratum to High Water Pressure Ground, The Slurry Shield Systematizes Excavation and Soil Discharge

Slurry shield

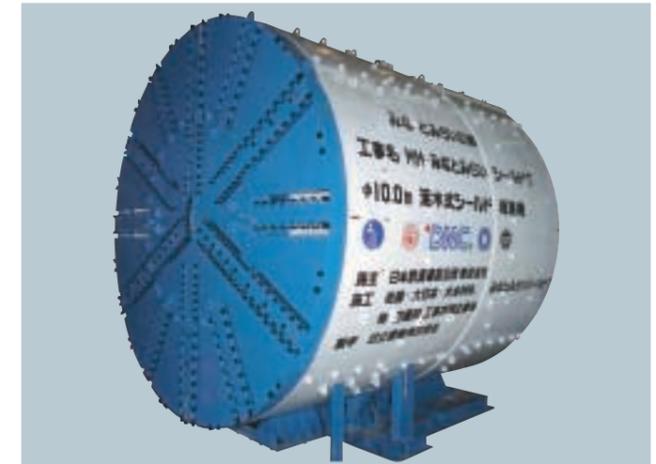
Slurry, treated to the required specific gravity and viscosity, is pressure-fed into the cutter chamber located ahead of the bulkhead, to support the tunnel face by the pressure of the slurry and the viscosity of the slurry permeated into the tunnel face against the earth pressure and groundwater pressure. This yields productive tunneling. The excavated soil is mixed with the slurry and pumped out through the slurry circulation equipment to the slurry treatment plant at the surface of the ground. This streamlines and automates the delivery of slurry. The slurry shield can also be equipped with additional crusher, etc, depending on kinds of strata.

Features

- The tunnel face is supported by slurry pressure. So ground settlement is minimized.
- Ground water pressure to the tunnel face is counterbalanced with slurry pressure. This is effective for the ground under high ground water pressure, such as sea bottom, river-crossing tunnel, and deep tunneling.
- The excavated soil is discharged together with slurry. So clean working conditions in tunnel are kept and long-distance tunnel is easy to handle.

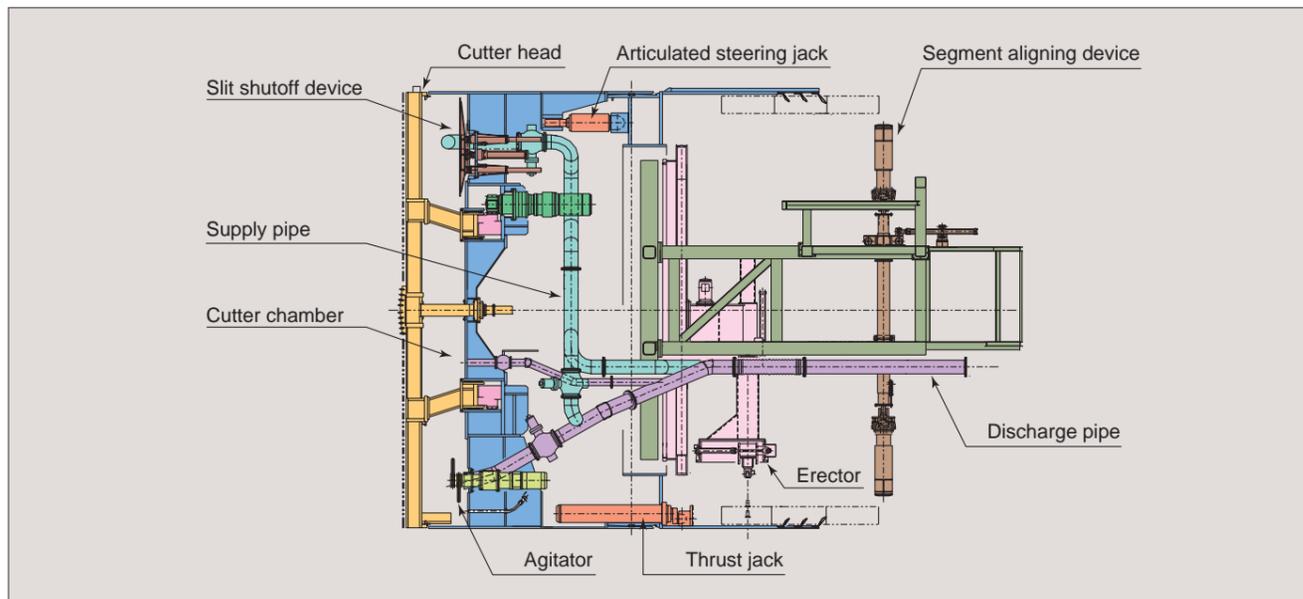
10.0 m dia. slurry shield

Application	Subway
Strata	Hardpan, sand
Overburden	22.9 m
Excavation distance	530 m
Radius of curvature	225 m
Description	Double-track subway section excavation Articulated steering device



6.75 m dia. slurry shield

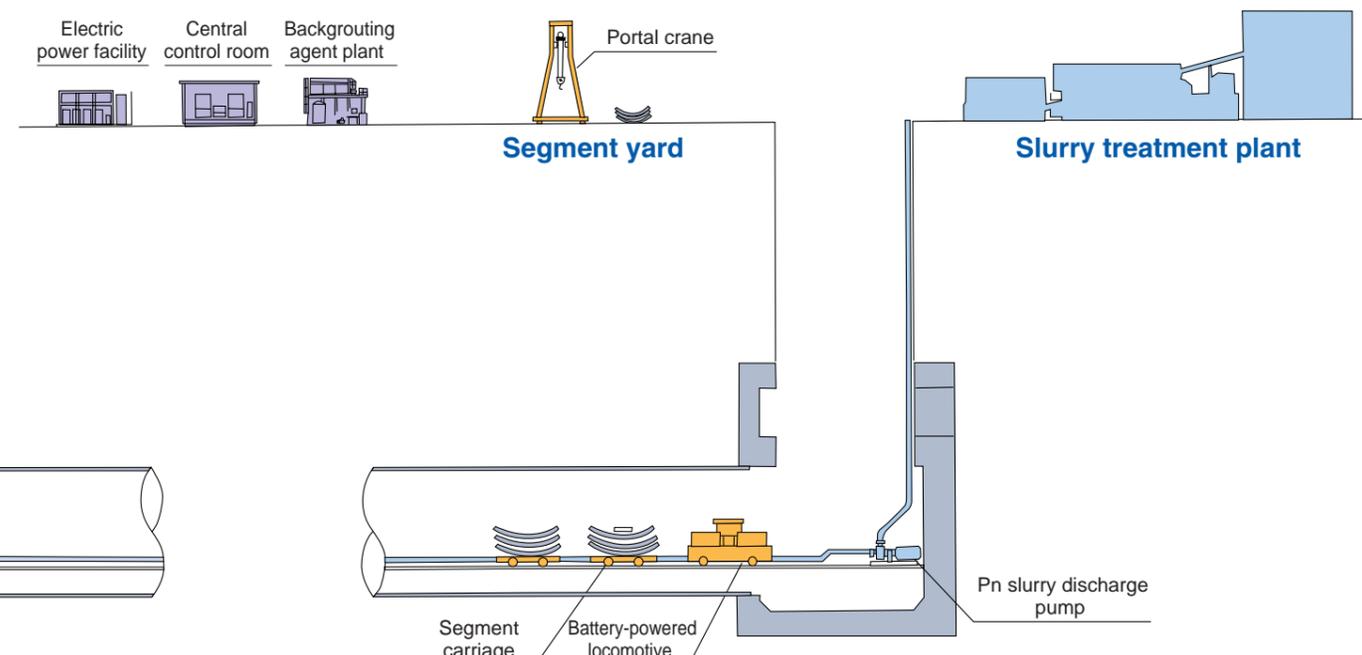
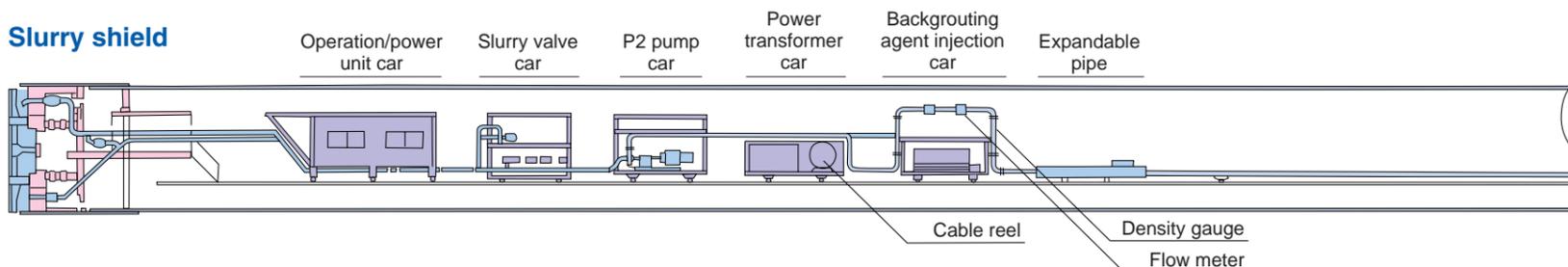
Application	Subway
Strata	Sandy mudstone, fine sand, diluvial sand
Overburden	33.89 m
Excavation distance	1 008 m
Radius of curvature	202 m
Description	Double-track subway section excavation NOMST excavation Hydraulic collapse detecting device



System explanation

- The slurry shield comprises the shield, slurry circulation equipment, slurry treatment plant, and related facilities.
- In the tunnel are the operation/power unit car, slurry valve car, P2 pump car, power transformer car, backgrouting agent injection car, expandable pipe, P3 to Pn pumps, segment carriage, etc.
- On the ground are P1 water supply pump, slurry treatment plant, central control room, backgrouting agent plant, portal crane, electric power facility, etc.

Slurry shield



Typical Earth Pressure Balanced Shields

7.75 m dia. earth pressure balanced shield

Application	Sewerage
Strata	Clayey gravel (up to 600 mm diameter)
Overburden	22.249 m
Excavation distance	1 950 m
Radius of curvature	30 m
Description	Articulated steering device (articulated angle 7°) Spherical joint secondary and third screws



7.15 m dia. earth pressure balanced shield

Application	Subway
Strata	Silty clay, gravel
Overburden	17.7 m
Excavation distance	682 m
Radius of curvature	500 m
Description	Foam shielding using secondary and third screws



5.54 m dia. earth pressure balanced shield

Application	Subway
Strata	Gravel, sand, clay
Overburden	34.18 m
Excavation distance	1 017 m
Radius of curvature	132.25 m
Description	Roller bits Automatic direction control



Typical Slurry Shields

14.14 m dia. slurry shield

Application	Trans-Tokyo Bay Highway (Sea bottom tunnel)
Strata	Clay, sand
Overburden	19.3 m (water depth 31.071 m)
Excavation distance	1 742 m
Radius of curvature	Straight
Description	Long-distance excavation High water pressure (sea bottom excavation) Underground docking using ground freeze method



9.60 m dia. slurry shield

Application	Subway
Strata	Clay, sand
Overburden	22.84 m
Excavation distance	1 653 m
Radius of curvature	850 m
Description	Double-track subway section excavation Long-distance excavation Wear detection bits Collapse detection device



8.25 m dia. slurry shield

Application	Subway
Strata	Diluvial sand
Overburden	25 m
Excavation distance	875 m
Radius of curvature	600 m
Description	Single-track subway section excavation (crossing under river and subway) Cutter head with earth pressure sensor at the end of copy cutter



Shields for Large Gravel Stratum and Rockbed

Efficient Tunneling in Large-Gravel Stratum and Rockbed Thanks to Hitachi's Advanced Tunneling Technology and Rich Experience

Shields for large gravel stratum and rockbed

The cutter head is designed and manufactured according to geological conditions, based on cumulative experience and technology of the earth pressure balanced shields and slurry shields.

Features

- Optimum cutter heads can be selected from flat, semi-dome, dome types according to ground conditions. Roller bits are also arranged to suit geological conditions and geotechnical materials.
- The cutter head is supported with the bearing to withstand cutter torque and eccentric loads.
- Optimum roller bits can be selected to suit strength and kinds of rocks.



4.93 m dia. earth pressure balanced shield

Application	Sewerage
Strata	Tuff, weathered slate, limestone
Unconfined compression strength	81.3 N/mm ²
Overburden	16.77 m
Excavation distance	900.7 m



3.28 m dia. earth pressure balanced shield

Application	Sewerage
Strata	Gravel including cobble
Max. gravel diameter	900 mm
Overburden	17.62 m
Excavation distance	1 093.73 m



2.13 m dia. earth pressure balanced shield

Application	Sewerage
Strata	Silty gravel
Max. gravel diameter	400 mm
Overburden	6.87 m
Excavation distance	673.3 m



5.74 m dia. earth pressure balanced shield

Application	Subway
Strata	Diluvial clay, diluvial gravel, chert, weathered slate
Unconfined compression strength	68.6 N/mm ² (chert)
Overburden	17.0 m
Excavation distance	889 m
Radius of curvature	230 m
Description	Single-track subway section excavation Crushing type cutter head

Shields for Acutely Curved Tunneling

A Variety of Articulated Shields Developed for Acutely Curved Tunneling

Shields for acutely curved tunneling

Overcut is necessary to change the attitude of shield in curved tunneling. Therefore articulated shields are adopted to reduce overcut and prevent collapse and loosening of the ground resulting from overcut in acutely curved tunneling. Recently there is the ever-increasing demand such as adopting wider segments and wedge type segments. To meet this requirement various types of articulated shields are designed and manufactured.

Features

Thrust jacks supported on the rear hull

- The thrust jack keeps the positional relationship against segments during articulated tunneling. This also protects segments from damage due to eccentric loads.

Spherical sliding surface

- The articulated sliding surface is spherically finished for well seating of the articulated seal at a large articulated angle, and for higher cutoff ability.

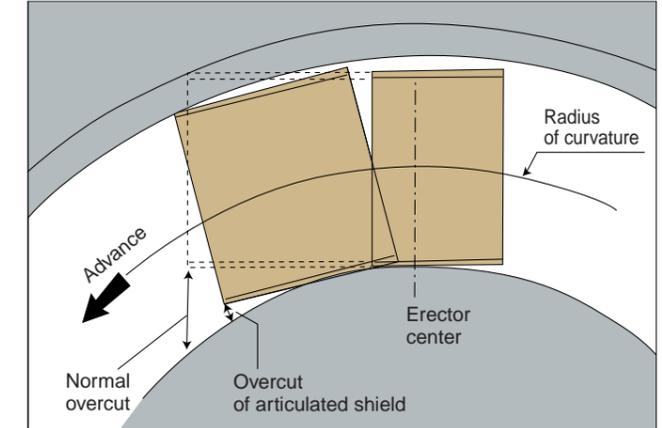
Overcut by copy cutter

- The position and stroke of overcut can be arbitrarily set on the control panel.

4.45 m dia. slurry shield

Application	Sewerage
Strata	Sand, gravel
Overburden	31.5mm
Excavation distance	354.85 m
Radius of curvature	10 m
Max. articulated angle	14.5°

Acutely curved tunneling



Tail Sliding Type

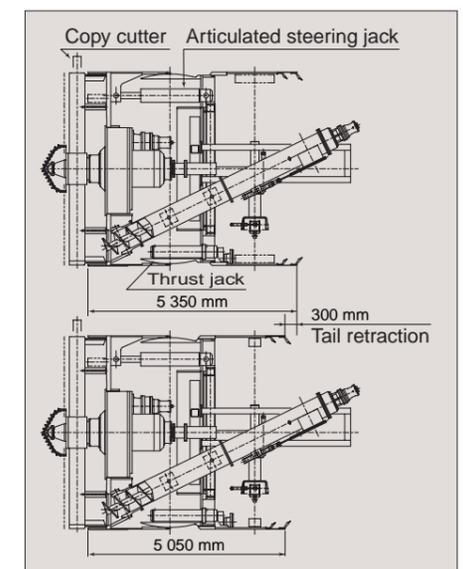
The shield tail is retracted to shorten machine length for acute-curved tunneling.

4.94 m dia. earth pressure balanced shield

Application	Sewerage
Strata	Clayey soil, clayey silt
Excavation distance	1 160 m
Radius of curvature	10 m
Max. articulated angle	13°



Normal machine length	5 350 mm	Articulated angle	13° (each side)
Retracted machine length	5 050 mm	No. of copy cutters	4 including 2 spares
Machine retraction	300 mm	Overcut by copy cutter	400 mm



Various Tunnel Technologies and Methods Developed to Suit Site Condition and Job Requirement

Compound Circular Face Shield Method

The compound circular face shields are designed to suit special geological conditions and job needs. This shield can select the required form of composite section, a combination of multiple circles, unlike conventional single circle.



9.36 m dia x 15.86 m wide DOT shield

Application	Conduits for utility services
Strata	Clay, fine sand, sand
Overburden	17.1 m
Excavation distance	250 m
Radius of curvature	1 600 m

DOT* shield method

* DOT: Double-O-Tube

The DOT shields are a special version of earth pressure balanced shields with compound cutter face, consisting of multiple cutter heads in the same plane. This configuration has good balance of excavation resistance etc. Tunnel face stability, machine position control, excavation control and applicable soil types are similar to those of conventional single circle earth pressure balanced shields.

Comparison with conventional method

Item	Large section	2 parallel shields	compound shield
Tunnel section area	Large A	Medium 0.85—0.95A	Small 0.75—0.85A
Tunnel occupied width	Large L	Horizontal configuration: Large 1.6L—1.7L Vertical configuration: Small 0.65L—0.7L	Horizontally compound: Large L Vertically compound: Small 0.65L—0.7L
Tunnel depth	Deep	Horizontal configuration: Shallow Vertical configuration: deep (bottom tunnel)	Horizontally compound: Shallow Vertically compound: deep
Economical efficiency	OK	OK	good

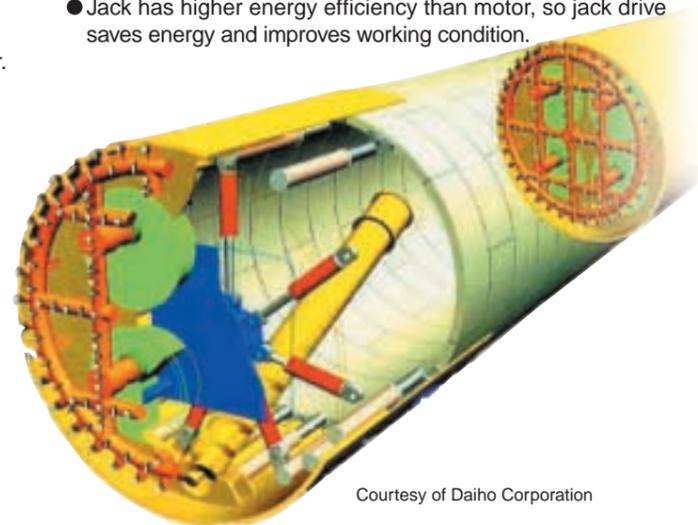
MF* shield method

*Multi Face

The MF shields have multiple cutter heads that are staggered back and forth in the advance direction. Multiple cutter heads can be arbitrarily arranged to suit various forms of sections. The MF shield method is available to both of the earth pressure balanced shields and slurry shields.

Features of jack drive

- Simpler and more compact drive than conventional motor drive.
- Short machine length reduces shaft construction costs.
- Jack has higher energy efficiency than motor, so jack drive saves energy and improves working condition.



Courtesy of Daiho Corporation

J-DPLEX Method Shield

Features of DPLEX*

* DPLEX: Developing Parallel Link Excavation

- Arbitrary shape of section can be excavated with similar-shaped cutters.
- Less cutting torque due to small rotating diameter
- Longer excavation (three-times longer than the conventional) Small rotating radius reduces bit sliding distance and bit wear.



3.28 m dia. J-DPLEX Shield

MSD* Method

MSD method enables docking two shields with different diameters in the ground.

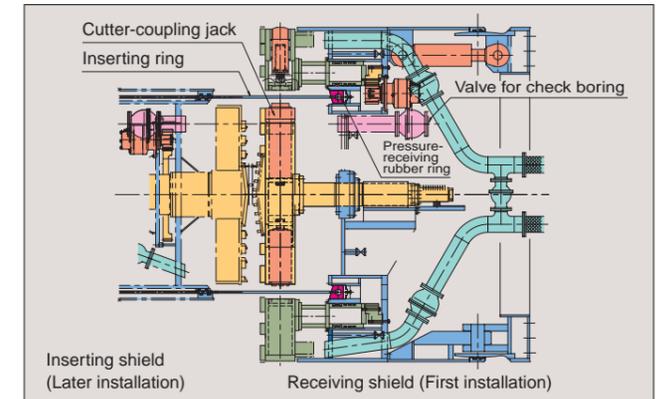
Features

- Since shaft and soil improvement is not required, construction schedule is shortened and construction cost is reduced.
- Since there is no work on the ground, no surrounding environment is affected.
- Safe working condition as docking work is not exposed to ground.



4.5 m dia. receiving slurry shield

*Mechanical Shield Docking Method



Inserting shield (Later installation)

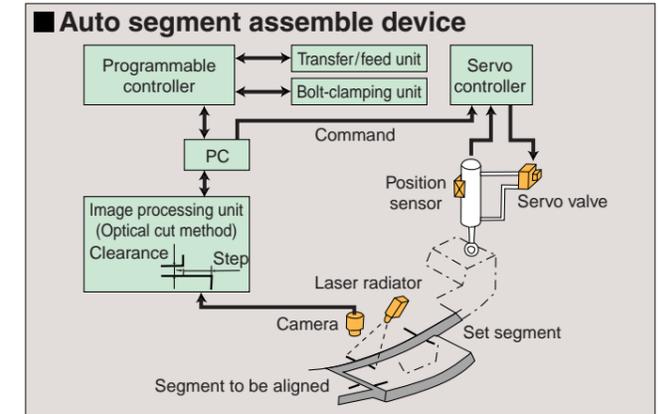
Receiving shield (First installation)

Automatic Segment Assemble Equipment

Automatic segment assemble equipment improves safety, construction precision and working conditions and contributes laboursaving.

Features

- The automatic segment assemble equipment with 7 degree of freedom enables high precision positioning by digital servo control using actuators with position sensors.
- The position and attitude of segment assembled can be detected by optical cut method, and monitored on the display.



9.7 m dia. slurry shield (for subway)



Scope of automation

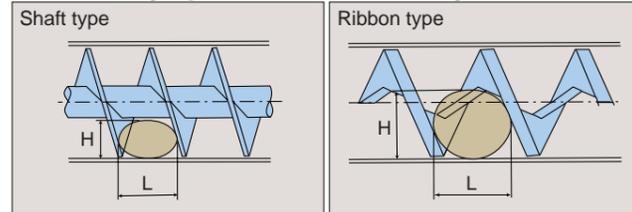
- Gripping, rotating and rough and precise positioning of segments by erector
- Thrust jack pulling operation according to segment assemble position.

Supplementary Devices for a Wide Scope of Applications

Screw Conveyor

For the earth pressure balanced shield, three types of screw conveyors -- shaft type, ribbon type, and edged ribbon type -- are available. They can be selected according to strata, cutoff ability, soil carry space, and job requirements.

Soil carry space of screw conveyor



Screw conveyor diameter and soil carry space (Standard dimensions)

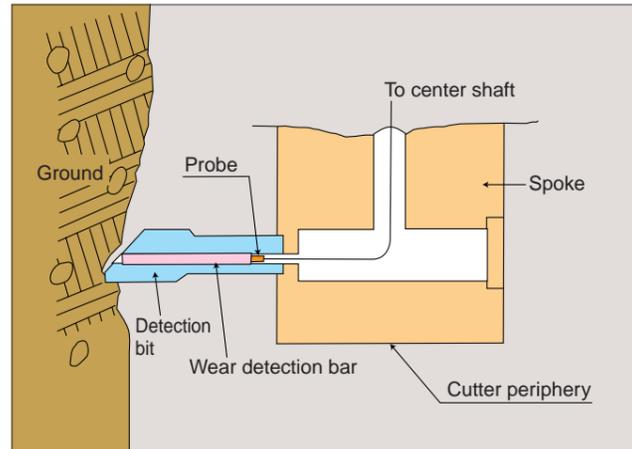
Unit : mm

Shaft type screw conveyor		Ribbon type screw conveyor	
Blade dia. x Pitch	Soil carry space	Blade dia. x Pitch	Soil carry space
200 x 140	75 ^H x 130 ^L	200 x 200	120 ^H x 160 ^L
250 x 210	85 x 195	250 x 200	160 x 170
290 x 210	105 x 195	290 x 270	190 x 230
324 x 210	120 x 195	324 x 300	205 x 250
370 x 220	135 x 230	370 x 350	240 x 300
420 x 280	160 x 260	420 x 400	265 x 350
470 x 280	185 x 260	470 x 450	290 x 380
520 x 330	175 x 310	520 x 500	340 x 430
570 x 330	200 x 310	570 x 550	370 x 480
620 x 420	225 x 400	620 x 600	395 x 520
670 x 420	250 x 450	670 x 650	420 x 570

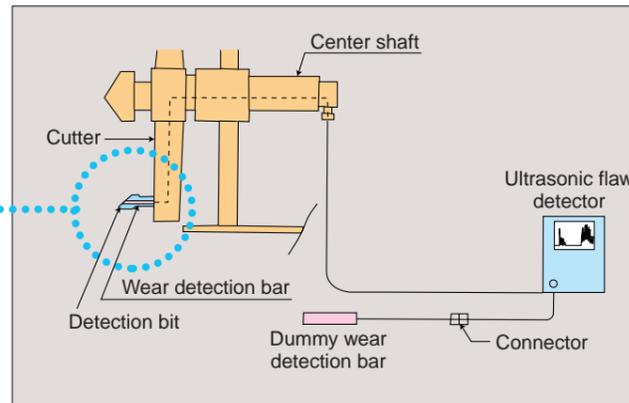
Ultrasonic Bit Wear Detector

● Cutter bit wear can be quantitatively detected.

Bit wear measurement



- The detection bar is located in the detection bit (or dummy bit) to receive ultrasonic wave. The waves are then reflected from the bit, and travel time is measured to detect bit wear.
- Multiple detectors can be arranged at the head cutter.



Collapse Detection System

Underground radar system

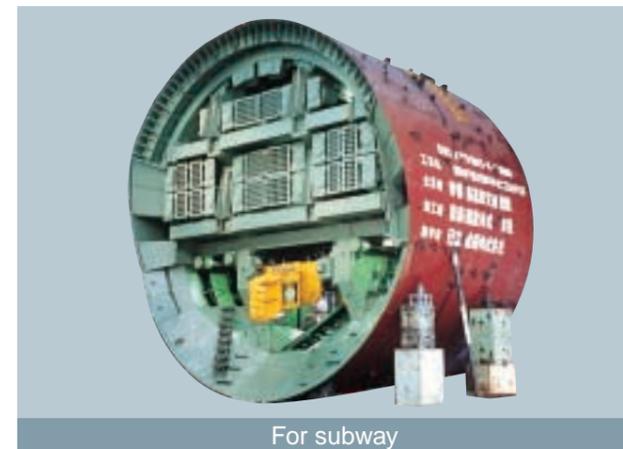
Ground collapse can be detected or measured by radiating electromagnetic waves from an antenna into the ground, and by receiving the reflected waves. An antenna is built in the cutter head for continuous measurement over the full circumference of the shield, obstacles in the ground can be detected by building in an antenna at the front of the cutterhead.



Open Shield and Semi-Shield

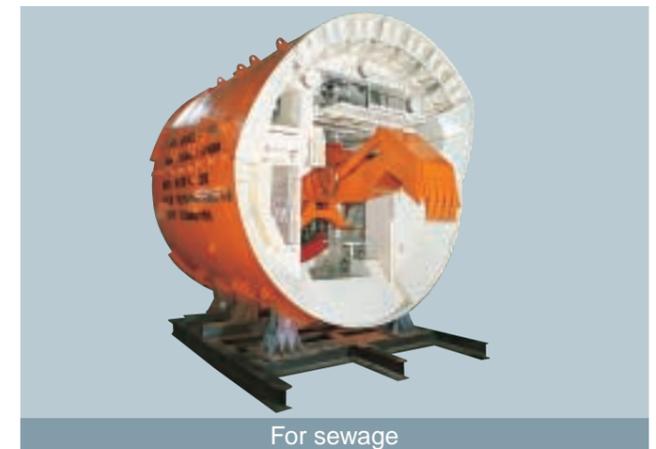
Hand Mine Shield and Excavator-Equipped Shields

9.92 m dia. hand mine shield with RE30 excavator



For subway

6.14 m dia. semi-mechanical shield with RE30 excavator



For sewage

7.23 m dia. self-propelled soft rock shield with load header



For subway

5.52 m dia. self-propelled shield with load header and loader



For channel

Semi-Shields

Earth pressure balanced semi-shield



For water supply and sewage

Slurry semi-shield



For sewage

Hitachi Shield Machine

*These specifications are subject to change without notice.
Illustrations and photos show the standard models, and may or may not include optional
equipment, accessories, and all standard equipment with some differences in color and features.
Before use, go through Operator's Manual for proper operation.*

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