Tunnel Boring Machines

(SHIELD & TBM)
Bringing vision into reality.
Today the technology to realize those dreams exists.
Building on our experience.
Applied technologies to make tomorrow's dreams come true...today.

- that bring visions into being.
From small bores to very large bores, long distance and deep underground excavations, or even tunnels with a highly specific cross-section and sharp curves. Kawasaki Tunnel Boring Machine’s supply record has exceeded the 1,400 units mark.
### Slurry Shield Machine

#### Stabilized cutting face
By using slurry with a high specific gravity and high viscosity to pressure-control the cutting face, stability is obtained even under high water pressure.

#### Super-large diameter tunneling
Kawasaki’s self designed periphery and support structure endows wider cutter chamber which enables to develop an extensive range of slurry shield bores, from small to super large, even exceeding 14m diameter.

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**Slurry shield machine layout**

- Slurry feeding pipe
- Rear section working deck
- Tail seal greasing device
- Operating panel
- Oil tank unit
- Starter panel
- Transformer panel
- Cable reel
- Hose drum
- Plunger valve
- Segment
- Segment feeder
- Grease pump unit
- Hydraulic pump unit
- Crusher
- P2 pump

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*Cutters exchange device*
Earth Pressure Balanced Shield Machine

Stabilized cutting face
The cutting chamber filled with cutting muck is infused with a suitable additive agent to stabilize the cutting face. Kawasaki continues to improve additives for highly permeable soils. In doing so, Kawasaki has developed ever-larger earth pressure balanced shield machines with greater speed and power.

Ongoing evolution
Kawasaki has developed dual-mode earth pressure shield machines by augmenting mechanisms that efficiently excavate and remove hard soil. Such superior functions have enabled Kawasaki to achieve high-speed tunneling of 600 m or more per month with machines designed for digging subway tunnels.
Mixed Ground Shield Machine

Cutter disk shapes for different types of ground
Either flat or dome-shaped cutter can be selected according to the characteristics of soil such as density, size and strength of gravels, boulders and rocks.

Selection of cutter disk
There are two types of cutter disk. One is a disk-front-crushing-type (mainly used for Slurry Shield Machines) which crushes boulders by front disk and then carries them into the cutter chamber. And the other is a non-disk-front-crushing-type (mainly used for Earth Pressure Balanced Shield Machines) which carries largest possible boulders into the cutter chamber without crushing them.

Selection of disk roller cutter
To excavate bedrock strata (Photo A), we use Kawasaki’s disk roller cutter which we have developed for TBM and be well proven its performance by a lot of achievements. To excavate gravel and boulder strata (Photo B), we use super-hard-carbide-tip inserted disk roller cutter, which prolongs the life of disk. Both types of disk roller cutter can be easily replaced from the inside of cutter chamber.

Mixed ground shield machine layout

![Mixed ground shield machine layout](image)

Photo A Bedrock stratum (granite with compressive strength of 125 MPa)

Photo B Boulder stratum (density 90%)

Photo A 6.7m earth pressure balanced shield machine

Photo B 6.63m slurry shield machine

Photo A 7.9m earth pressure balanced shield machine

Photo B 6.63m slurry shield machine

Photo A 2.63m earth pressure balanced shield machine

Photo B 2.47m slurry shield machine for bedrock

Photo A 3.05m earth pressure balanced shield machine for bedrock

Photo B 3.38m earth pressure balanced shield machine
Full Shield TBM

Suitable for broad range of ground conditions
Because of a cylindrical shell structure, the Full Shield TBMs can be suitable for broad range of ground conditions, from tough rocks to soft strata including fracture zones.

Large internal space
The cylindrical shell structure secures large space of the internal center of TBM, which enables safety maintenance and efficient operation.

Variety of discharge systems
The best discharge system can be selected from variety of discharge systems, such as belt conveyor, screw conveyor, slurry discharge and jet pump transportation according to diverse ground conditions.

Full shield TBM layout

<table>
<thead>
<tr>
<th>Cutter head</th>
<th>Articulation jack</th>
<th>Main gripper</th>
<th>No.1 belt conveyor</th>
<th>No.2 belt conveyor</th>
<th>Dust collector</th>
<th>No.3 belt conveyor</th>
<th>Oil tank unit</th>
<th>Starter panel</th>
<th>Transformer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front gripper</td>
<td>Thrust jack</td>
<td>Shield jack</td>
<td>Erector</td>
<td>No.1 belt conveyor</td>
<td>No.2 belt conveyor</td>
<td>Dust collector</td>
<td>No.3 belt conveyor</td>
<td>Oil tank unit</td>
<td>Starter panel</td>
</tr>
</tbody>
</table>

30 mR, articulate 6'
30 mR excavation
Break through

φ 4.55m full shield TBM compatible belt conveyor discharge with screw conveyor system.
(screw conveyor/belt conveyor discharge system)
Open Gripper TBM & New Open TBM

Simple structure
The Open TBM is comprised of cutter head, cutter head drive, main beam, gripper and roof support. This simple structure enables workers to treat cutting face at adjacent point to cutter head.

Extremely powerful in stable ground conditions
Open TBM shows high performance and economical excavation in solid bedrock conditions. It is suitable for straight excavation as digging direction is regulated by beam structure.

The advantages of combination of Full Shield TBM and Open TBM
Kawasaki’s new Improved Open TBMs have two different strengths from both Full Shield TBMs and Open TBMs. One element comes from Full Shield TBMs which are suited for various ground conditions and another feature comes from Open TBMs which are suited for high-speed operation in solid bedrock conditions. This new Improved Open TBMs can treat looseness from and falling of fragile soil, simultaneously it can enables workers to treat cutting face at adjacent point to cutter head.

Open Gripper TBM layout

New open TBM layout
Special Shield Machine

Customized special shield machines for diverse conditions
Kawasaki provides fully customized special combination of shield machines to satisfy customer’s various needs for bore size, geological feature, particular ground condition, etc.

Aporo Cutter

**APORO: All Potential Rotary Cutter**
The machine can excavate not only circular shaped sections, but rectangular shaped, horse-shoe shaped, and another non-circular shaped sections. Cutting head has high-precision control system, which can keep planned excavated section.

**Features**
1. Rectangular, horse-shoe shape, and another non-circular shaped can be selected as excavated section.
2. It can also cut sound-hard ground and obstacles.
3. Cutting head can be reused by remounting to another shaped shield bodies.

Variation of Aporo Cutter excavation section (example)

- Circle
- Rectangular
- Horse-shoe shaped

H&V (Horizontal & Vertical) Shield Machine

In the past, the excavation of subway station sections were accomplished using cut-and-cover tunneling methods or by expanding existing tunnels. However, because of the impact on above-ground activities and the large numbers of critical subterranean structures under congested urban areas, four-face H&V shield machine is deployed to excavate simultaneously the subway car tunnel and station platform area.

**Features**
1. The world’s first shield machine equipped with a parallel articulating mechanism (H&V mechanism). It enables the excavation of wide tunnels with uniquely shaped sections, which makes high-precision positioning control possible.
2. It equips four cutters on the same surface.

Dual-Mount Branching H&V (horizontal & vertical) Shield Machine

This machine enables excavation of two proximate parallel independent tunnels in the same direction. These tunnels will take apart to the different direction in the middle of tunneling. Each shield continues to excavate as a separate, independent machine after their divergence.

**Features**
1. After tunneling by tandem ream position, upper and lower shield machines excavate independently to different directions subsequently to the divergence in underground.
2. When used for tandem tunneling, the articulation angles of the upper and lower shields are calculated by a relative midsection difference to control the roll position.
3. These machines perform excavation of sharp curve with a minimum radius of 15m (articulation angle: max. 13° for both left and right direction) in both positions of tandem ream and independent.

Detachable Three-Section Shield Machine

Previously two simple circular shield machines and one three-section shield machine was required, but nowadays, Kawasaki’s technology enables to excavate both station part and station-to-station tunneling with single shield machine which consists of one circular shield and twin semicircular side shields that are designed to be easily mounted and detached.

The detachable three-section method makes it possible to reduce the size of the shield machine and rear compartment equipment, as well as to centralize the operating base.

**Features**
1. The tunnel between stations is excavated using a simple circular shield.
2. After reaching the station drive shaft, semicircular side shields are attached to both sides of the simple circular shield, and the station platform section tunnel is excavated.
3. After reaching the station arrival shaft, the semicircular side shield are detached, and the section to the next station is excavated using the unit as a simple circular shield once again.
**Lateral Lead Three-Section Shield Machine**

Equipped with advanced rotating cutter heads on each side, an oscillating ("wagging") cutter head ensures space between the machines in the center section and independent rotating cutter heads in the center section to achieve even greater excavating efficiency than Kawasaki's detachable three-section shield machine. The slurry removal systems are combined into a single system.

**Branch Route Shield Machine**

When the shield machine has reached the divergence point, the divergence shield emerges from the inside of the machine and each shield continues to perform its own independent excavations. Because this construction method allows the divergence operation to be completed underground, there is no need to prepare a departure shaft for the divergence shield machine.

**Construction method**

1. The mainline shield machine tunnels as far as the divergence point with the divergence shield machine installed inside.
2. At the divergence point, the forward body section and the exterior skin plate of the center body section of the mainline shield slide forward and the divergence shield emerges to begin excavation.
3. After divergence, both the mainline and the divergence shield machines simultaneously continue their excavation progress.

**Draw Shield Machines Allow Recycling**

**MSD Shield Machine**

The shield's external casing and internal unit are constructed as independent units, and the internal (drive) unit is removed following completion of tunneling of the first section. It is taken to the departure shaft, where a new external casing is fitted, and excavation is then begun on the next construction section. Because the shield's internal unit is reused, there is no need to construct an arrival shaft. The drive shaft can also be set up anywhere along the construction route.

**MMST Shield Machine**

H7.86m×W3.05m multi-axial rectangular slurry shield machine

**DPLEX Shield Machine**

H7.67m earth pressure balanced DPLEX shield machine

## Supply Record

Kawasaki plays an active role in projects around the world
### Project reference ①

#### The Dover Channel Undersea Railroad Project

Largest tunneling project in the 20th century——

The 52 km Dover Tunnel, the largest tunneling project of the 20th century, was completed by its Anglo-French operators, Eurotunnel, in 1991. Two Kawasaki TBMIs (8.78 m bore, each 13.745 m long) were utilized for this large-scale project linking Calais, France and Folkestone, England with two single-track railroad tunnels (7.3 mφ) and one service tunnel (4.5 mφ).

The state-of-the-art TBMIs tunnelled approximately 100 m beneath the ocean floor (1 Mpa), with a maximum monthly advance of 1,200 m and continuous underground excavation at distances up to 20 km. Their performance earned worldwide praise for Kawasaki's advanced technological capabilities.

The project was chosen as the best 10 projects in the 20th century of railway section on “Monuments of Millennium” by ASCE.

<table>
<thead>
<tr>
<th>Type</th>
<th>Shield TBM × 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>Ø8.78m×13.745m</td>
</tr>
<tr>
<td>Application</td>
<td>Railroad</td>
</tr>
<tr>
<td>Area</td>
<td>Dover channel</td>
</tr>
<tr>
<td>Order enterprise</td>
<td>EURO TUNNEL</td>
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<tr>
<td>Customer</td>
<td>T.M.L.</td>
</tr>
<tr>
<td>Length</td>
<td>20,009m</td>
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<tr>
<td>Zone</td>
<td>T2 T3</td>
</tr>
</tbody>
</table>

### Project reference ②

#### CTRL (Channel Tunnel Rail Link)

Kawasaki shield machine got further credence in Europe.

CTRL project consists of Phase-1 which was planned to accelerate the speed of the Eurostar in England terrain after it comes out from the Dover tunnel and Phase-2 which was planned to change the location of hub station from Waterloo to St Pancras at north of Thames river.

Kawasaki supplied two shield machines for Contract-220 section and got the further recognition in Europe.

<table>
<thead>
<tr>
<th>Type</th>
<th>Dual-mode earth pressure balanced shield machine × 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
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</tr>
<tr>
<td>Application</td>
<td>Railroad</td>
</tr>
<tr>
<td>Area</td>
<td>England</td>
</tr>
<tr>
<td>Order enterprise</td>
<td>Union Railways</td>
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<tr>
<td>Customer</td>
<td>Nishimatsu- Cementation Skanska JV (NCS)</td>
</tr>
<tr>
<td>Length</td>
<td>7,540.9m 7,546.5m</td>
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<tr>
<td>Zone</td>
<td>Up Line Down Line</td>
</tr>
</tbody>
</table>

**Construction diagram**

- **[DUAL MODE]**
  - **MODE 1** In hard soils: Achieves high-speed excavation and highly efficient debris discharge. In soft soils: Excavates by stabilizing the cutting face with appropriate pressurized muck.
Tokyo Bay Aqua-Line

The 15.1 km Tokyo Bay Aqua-Line highway, one of Japan’s largest public works projects of the 20th century, opened to traffic in 1997. The 9.6 km section between Kawasaki City and Umihotaru is the world’s largest seabed shield tunnel. Three Kawasaki super large diameter shield machines (14.14 m dia., 13.5 m long) were utilized for the project.

To meet the challenge of the ultralarge diameter and long-distance tunneling under intense water pressure (0.5 MPa), Kawasaki’s shield machines were equipped with devices for underground clocking and a high-precision automatic segment erector combining the most advanced technology and know-how in the industry. These shields were recognized globally as introducing a new chapter in the history of Japanese shield technology.

<table>
<thead>
<tr>
<th>Type</th>
<th>Slurry shield machine X 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>ø14.14m × 13.5m</td>
</tr>
<tr>
<td>Application</td>
<td>Road</td>
</tr>
<tr>
<td>Area</td>
<td>Tokyo Bay (Kawasaki—Kisarazu)</td>
</tr>
<tr>
<td>Order enterprise</td>
<td>Trans - Tokyo Bay Highway Corporation</td>
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<tr>
<td>Customer</td>
<td>MAEDA TEKKEN FUJITA JV</td>
</tr>
<tr>
<td></td>
<td>NISHIMATSU TODA ZENTAKA JV</td>
</tr>
<tr>
<td></td>
<td>KAJIMA KÔNÔKE SUMITÔMO JV</td>
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<tr>
<td>Length</td>
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<tr>
<td>Date</td>
<td>Oct.1994 ~ Apr.1996</td>
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<tr>
<td>Date</td>
<td>Apr.1995 ~ Jul.1996</td>
</tr>
<tr>
<td>Date</td>
<td>Apr.1995 ~ Jun.1996</td>
</tr>
<tr>
<td>Zone</td>
<td>Central Tunnel Kisarazu North (No.1)</td>
</tr>
<tr>
<td></td>
<td>Central Tunnel Kawaijin North (No.1)</td>
</tr>
<tr>
<td></td>
<td>Kawasaki Tunnel Kawaijin North (No.1)</td>
</tr>
</tbody>
</table>

Tokyo Bay Gas pipe - Line

Long - distance, High Pressure, High speed excavation

Owner : The Tokyo Electric Power Co., Ltd.
Area : Tokyo Bay
Period : Nov. 2003 ~ Mar. 2005
Machine : ø3.62 m Slurry shield machine
Boring Length : 9,030 m
Soil Condition : Sandy, Clay, Gravel
Water Pressure : Max. 0.67 MPa
Max. Monthly Advance : 1,168 m / month
Average Monthly Advance : 665 m / month

The Central Circular Route Shinagawa North Line

Large bore, Long - distance

Owner : Metro politon Expressway Co., Ltd.
Area : Tokyo (Shinagawa ~ Meguro)
Machine : ø12.55 m E.P.B Shield machine
Boring Length : 8,030 m
Soil Condition : Sand, Gravel, Medium sand, Mad stone, Sandy stone
Water Pressure : 0.5 MPa
Minimum radius of Curves : R=230 m

Range

For all uses and all diameters, for all geological condition there is a Kawasaki solution.
Kawasaki selects the optimum cutting edge shape and cemented carbide tip arrangements based on Kawasaki’s expertise and achievements. Kawasaki is also conducting studies to improve the wear-resistance of carbide tips in long-distance tunneling.

**Cutter changing device**

Kawasaki has developed cutter changing device which enables workers to change cutters safely at anytime. Workers can enter into cutter-head from pit situated at rear part of machine so there are no possibilities to expose themselves to dangers of encountering excavated soil and/or water. Using cutter changing device, suitable type of cutters can be selected according to soil condition, and worn cutters can be replaced.

**Features**

- Simple procedure and a short time to replace
  - by using special jig and multi-use air tools.
- High reliability and safety for water-shutoff
  - by shutoff gate and multi seals
  - by checking valves and safety lock system
- High durability
  - Proved by durability test of hundred thousand times replacement work.
- Space- saving
  - Minimum space requirement by compact design.
- The extreme peripheral part arrangement
  - Inclined cutter arrangements make it possible to install cutters at the extreme peripheral angle part.

**Disk roller cutters**

Kawasaki has developed a variety of disk roller cutters through our extensive supply records in various project conditions. These provide maximum performance in bedrock or large gravel.

**Easy cutter replacement**

Kawasaki has developed a revolving-saddle-cutter-mounting-mechanism to replace cutters easily and safely from machine inside. This assures great safety as operators are not required to go outside of machine to replace cutters especially when excavating under collapsible strata condition.

**Bearing seals for cutter head and articulation sections**

**Corresponds to high water pressure, rotation speed, and long distance excavation**

The large-diameter bearing seals were developed by Kawasaki’s design which was improved through many projects experiences. Such bearing seals show their advantages under harsh conditions like long distance, high slurry and high earth pressure excavations.

This technology demonstrates its performance under difficult conditions. These bearing seals were equipped in machines for long-distance high water pressure projects such as the Dover Tunnel and Tokyo Bay Aqua-Line and have proved their superiority.
AFTER SERVICE / SUPPORT

Field service
Skilled engineers support for all technical aspects in project execution from site erection, commissioning to maintenance.

Spare parts
Optimum spares are selected by accumulated experiences to meet customer’s various requirements.

Training
Trainings for machine maintenance, operation and erection in both factory and site enhance operator’s skill and improve project execution efficiency.

Remote support system
Online remote-monitoring system observes machines simultaneously as precautious measure to prevent potential troubles.

Overhaul
TBM’s can be reused by overhauling and refurbishment.

Harima Works
8, Niijima, Harima-cho, Kako-gun, Hyogo 675-0155, Japan
Harima works takes full advantage of its coastal location at the center of the Harima Industrial area facing the Seto Inland’s Sea.

Size
Site area: 444,581 m²
Bilding area: 100,400 m²
Employees: approx. 1,000

Main products: Shield machines, TBM’s, Storage tanks (LNG, LPG, other low temperature liquid storage tanks), pressure vessels and pipings. Equipment related to the space, airport & harbor facilities. Boilers (thermal power plant boilers, industrial boilers, marine boilers), nuclear power plants. Industrial plants (steel plants, chemical plants, cement plants, material handling system, etc.)
Inquiries  (Please fill out following form for our estimation.)

- Client Information
  - Customer name
  - Person in charge
  - Phone No.
  - E-Mail
  - Website

- Project Information
  - Country & Area
  - Owner
  - Project name
  - Application
    - □ Railroad
    - □ Road
    - □ Waterway / Reservoir
    - □ Aqueduct
    - □ Electrical / Gas
    - □ Multi duct
    - □ Others ( )
  - Order schedule
  - Desirable day of delivered

- Machine Information
  - Type
    - □ Open Gripper TBM
    - □ Earth pressure balanced shield machine
    - □ Full shield TBM
    - □ Mixed Ground Shield Machine
    - □ Slurry shield machine
    - □ Others ( )
  - Required number of machines
    - Excavation diameter: ø m
    - Construction length: m
    - Gradient: °/00
    - Minimum radius of curves: m
    - Earth covering: m
    - Underground water level: GL: m
  - Soil conditions
    - Soil type
    - Maximum gravelsize: mm
    - N-value
    - Uniaxial compressive strength: MPa
  - Segments
    - □ Radial insert
    - □ Axial insert
    - Material
    - Dimensions
      - Outside diameter: m / Inside diameter: m / Width: m
      - Planning drawing: □ ( )
  - Any special requirements

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