Shimizu Smart Tunnel

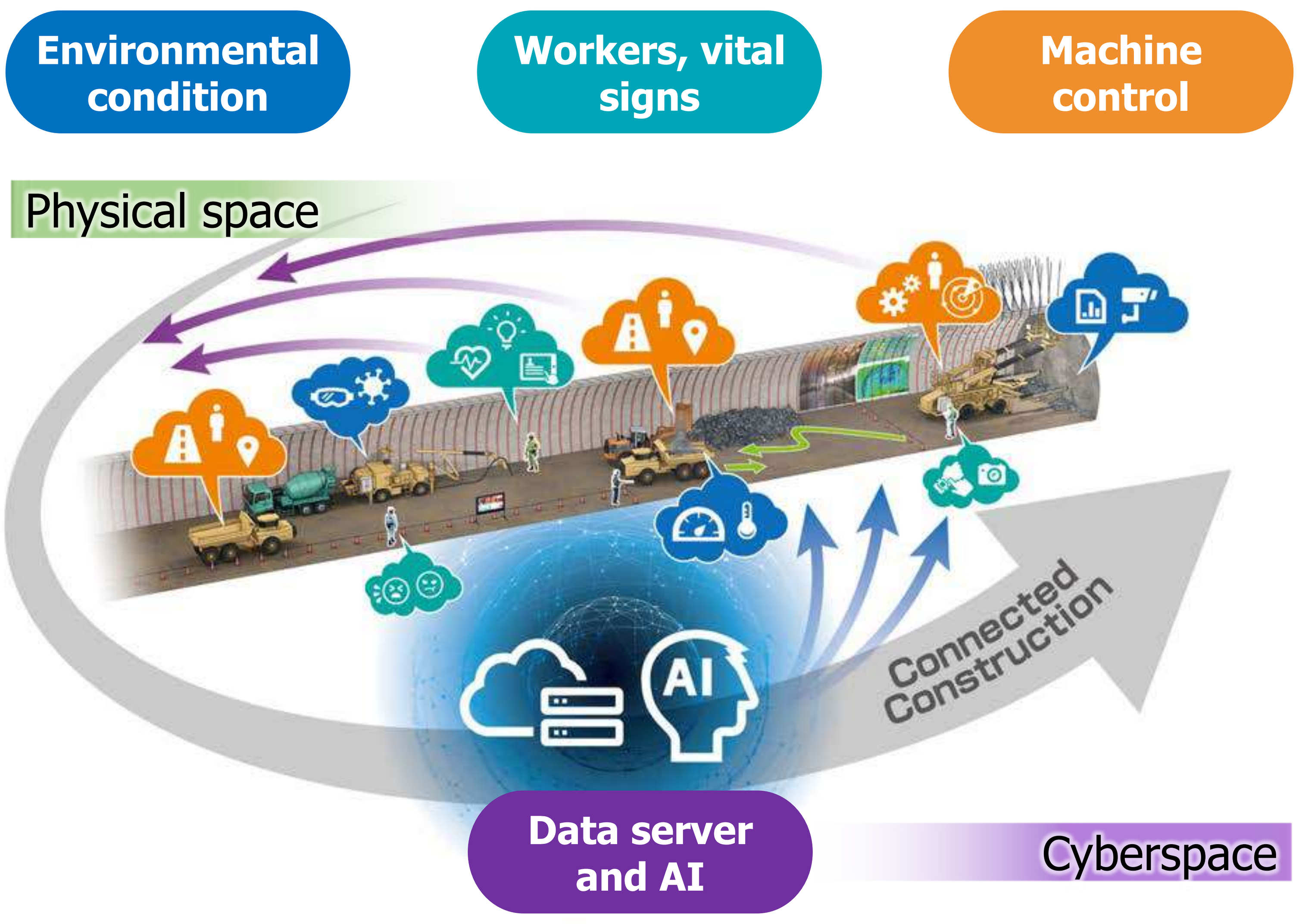
- For the next-generation tunnel construction management -

الأنفاق الذكية من شيميزو

- سعياً نحو إدارة إنشاء أنفاق الجيل القادم -

"Shimizu Smart Tunnel", a next-generation advanced tunnel construction management system, is being developed for the aim of drastically improving the productivity and safety of tunnel construction projects in line with the government-sponsored "Society 5.0" vision, depicting our future human-centered society where economic growth and the resolution of social issues are concurrently achieved. The system collects, analyzes and shares all digital information related to your tunnel construction project, including worker information and their work condition, equipment and the surrounding natural environment.

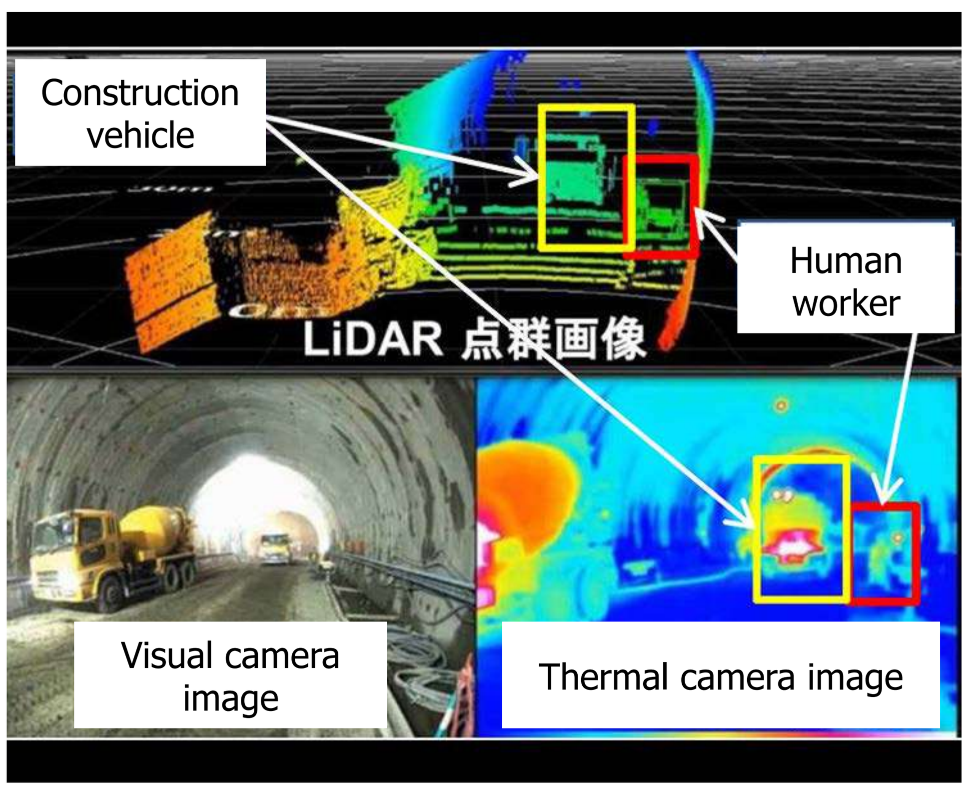
Digitally integrated, advanced production control capability (safety and quality) realized by collection, analysis and sharing of all relevant information



Elemental technologies

■ Safety monitoring system

The system helps assure a safe working condition and improves work efficiency. For example, the system monitors and senses minute vibration of the tunnel faces to detect signs of potential collapse. It also observes the position and activities of the people and equipment being engaged in the work and have them analyzed by AI to evaluate the appropriateness and effectiveness of the work being done.



■ Biological data analysis

The system collects and analyzes vital sign information of the workers to monitor their physical condition, reducing potential health risks and contributing to greater productivity.

■ Remote witnessing system

The system allows the project owner's inspectors to remotely witness the inspection process without actually visiting the site, contributing to greater inspection and management efficiency for both the project owner and the contractor and potentially making way for a more flexible work hour management.

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Use of AI capability to optimize tunnel excavation planning
Shield Excavation Planning Assistance System

تحسين خطط شق الأنفاق بواسطة الذكاء الاصطناعي
نظام دعم خطط شق الأنفاق باستخدام الدرع

Traditionally, shield excavation parameters are calculated by on-site engineers prior to each excavation session for planning purposes.
The proposed system has a self-learning AI capability which sets conditions and calculates excavation parameters from the given information and then reviews the calculated values for improvement. The system repeats this cycle of calculation, review and improvement until an optimally calculated set of parameter values are obtained.
The calculation capability is useful not only in the planning stage prior to each excavation session but also for work instruction preparation tasks after the actual excavation work has started, potentially contributing to on-site work hour reduction. Currently the system is being tried out in an actual project for effectiveness validation.

Shield Excavation Planning Assistance System

Excavation planning by AI

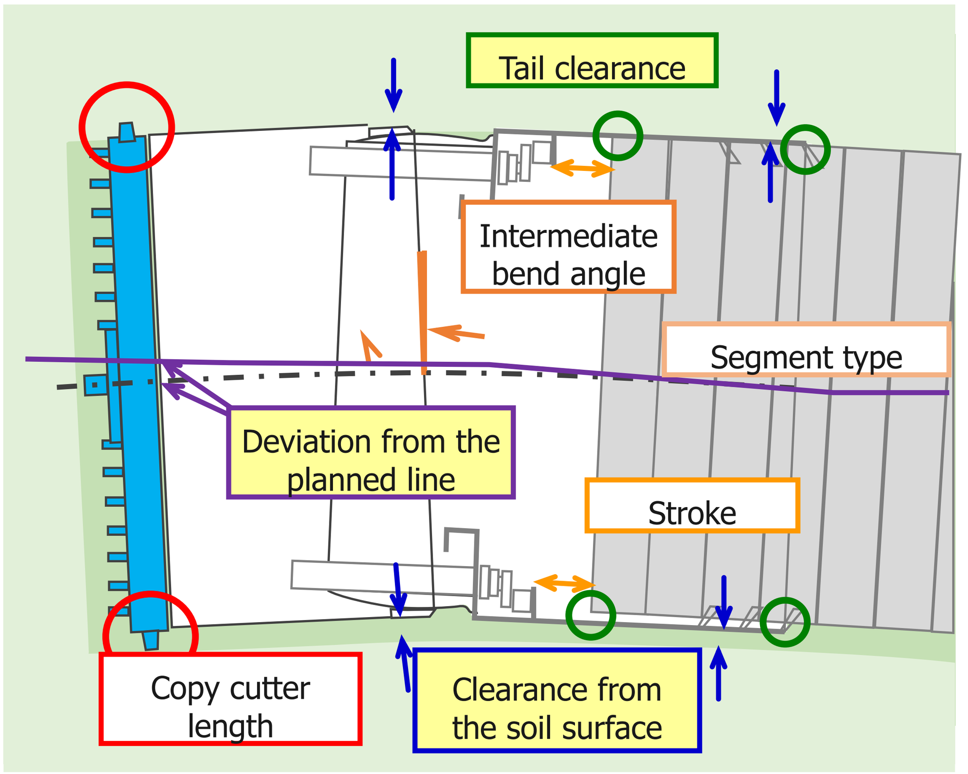
Shield machine operation planning
Segment planning

Currently

Calculation is done based on theoretical values
Careful, time-consuming calculation and review required for curved sections

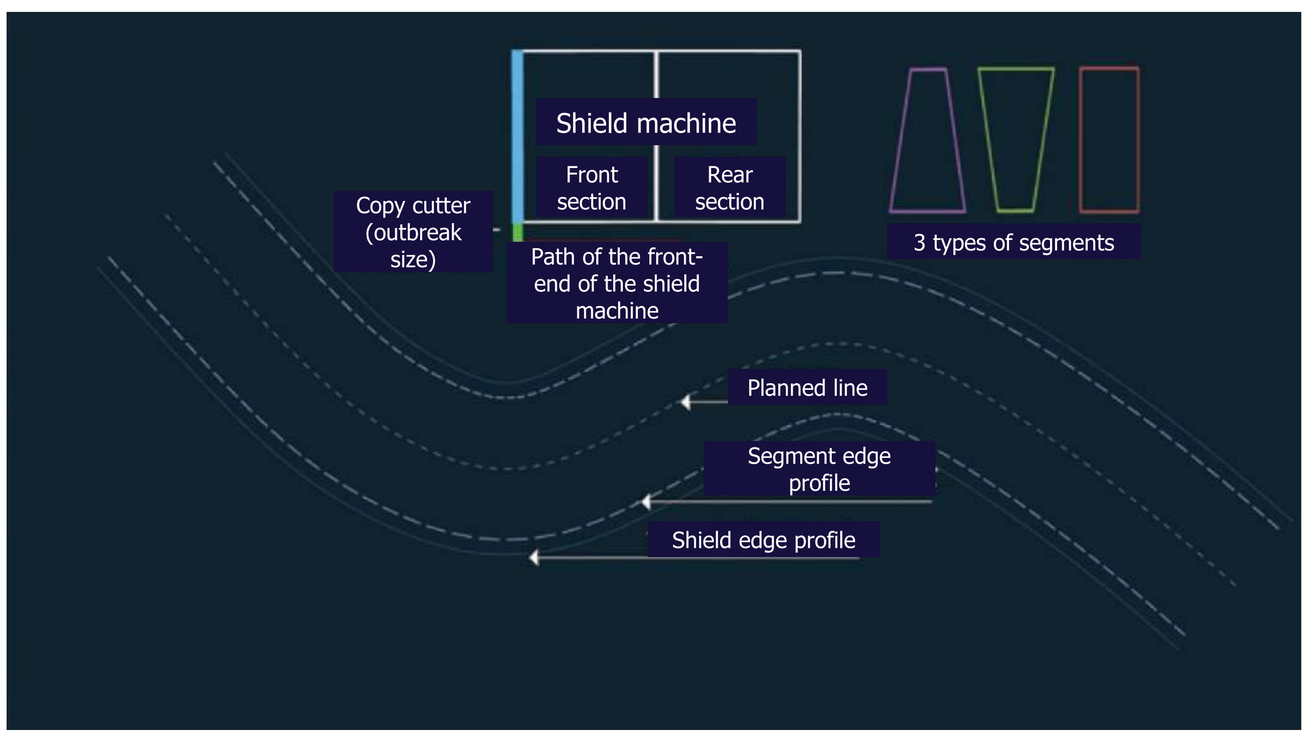
Shield Excavation Planning Assistance System

Autonomous simulation by AI
Obtains an optimally calculated set of parameter values
Useful for ongoing excavation instruction preparation

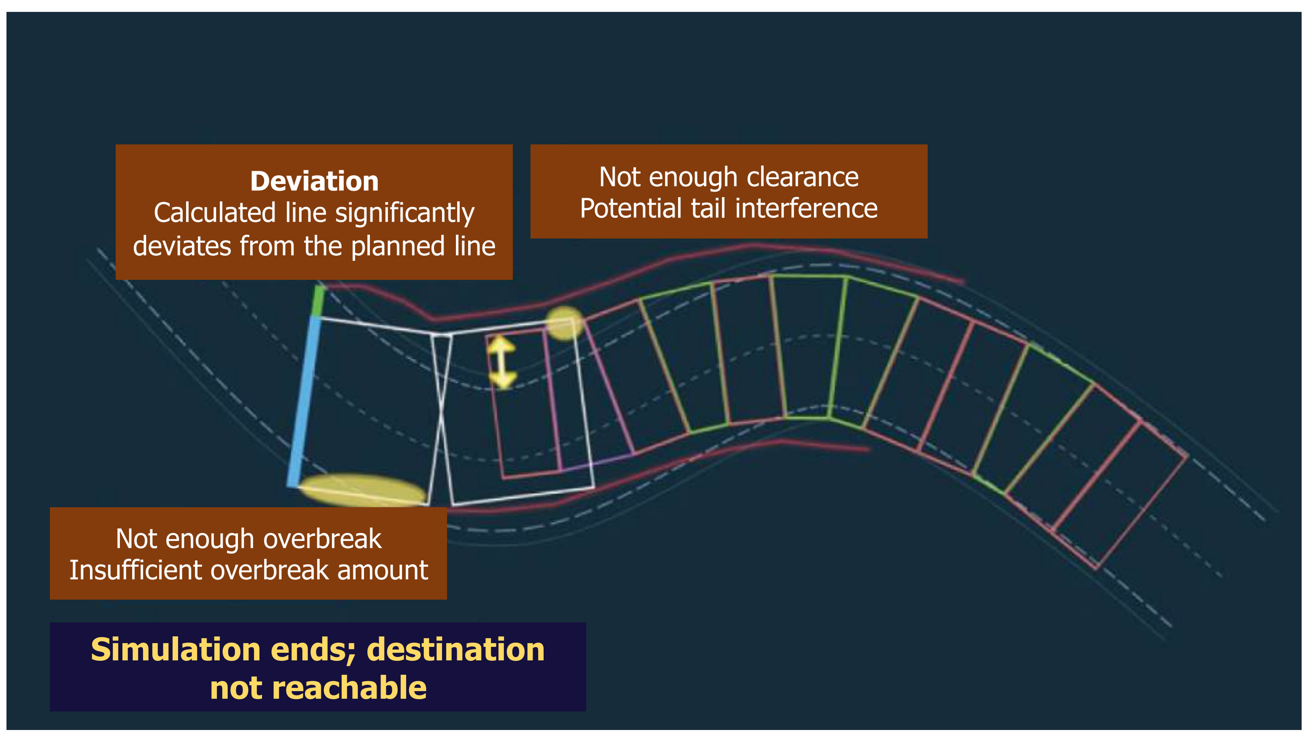


Excavation simulation image

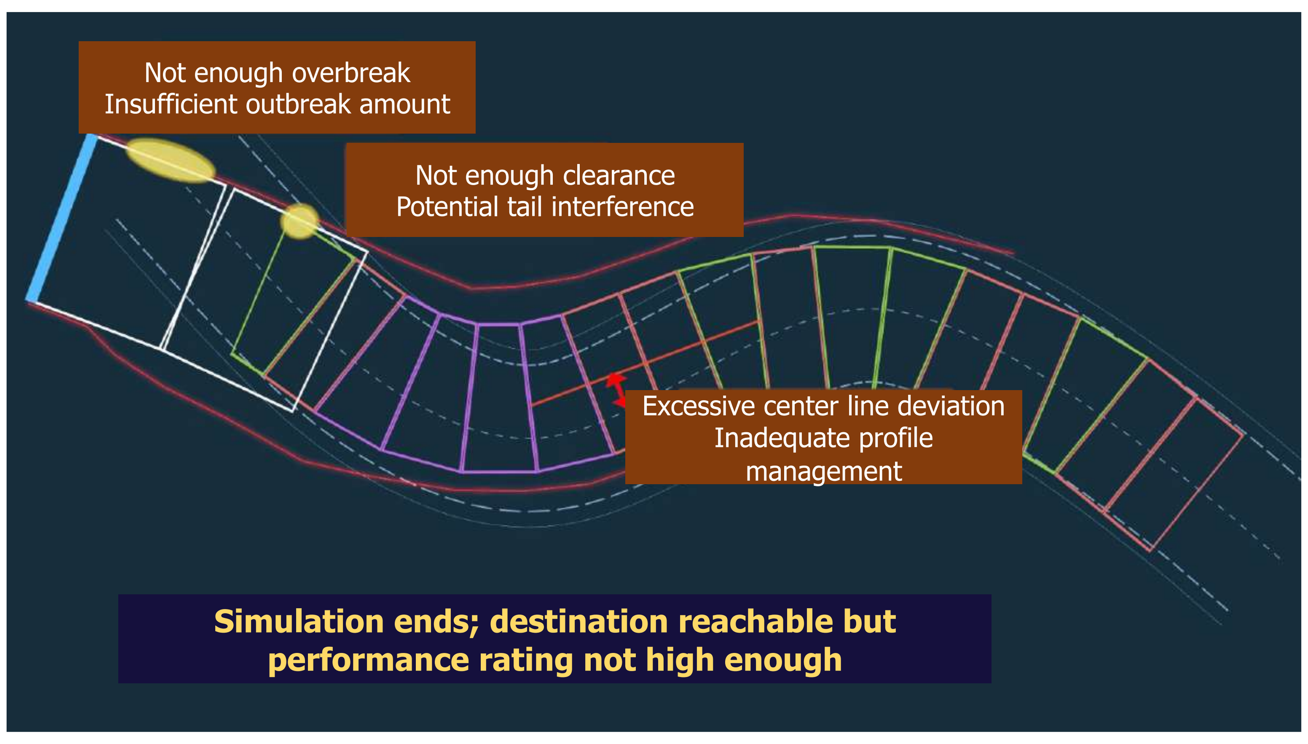
Shield excavation planning by the system is done somewhat like virtual gaming. From the given information, the system sets conditions and runs excavation simulation to calculate the performance rating. This cycle of simulation, calculation and evaluation is repeated until the highest rating is achieved, from which an optimally calculated set of parameter values is obtained.



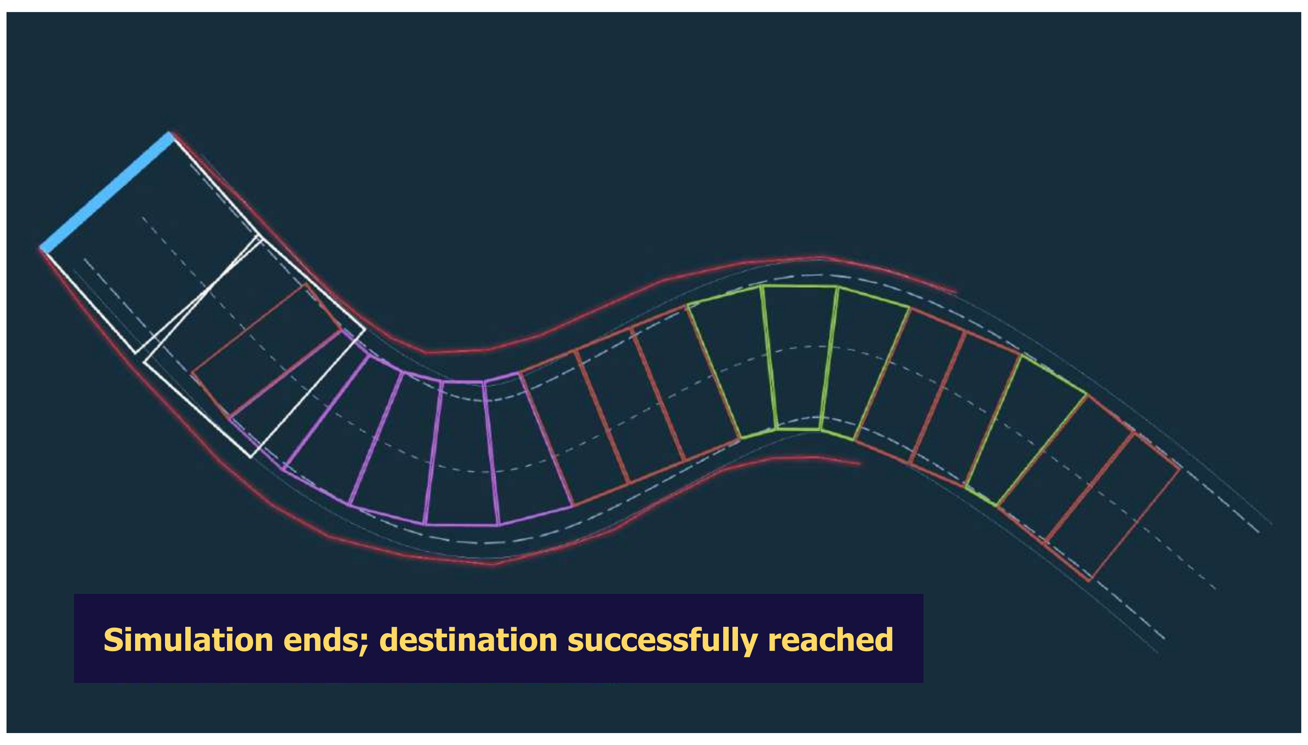
⓪ **Setting conditions for simulation**
As the calculation basis, AI is given preliminary information about the tunnel being constructed, the shield machine and the segments planned. AI then sets conditions for simulation based on the given data.



① **Initial simulation phase**
Early simulation result revealed that the tunnel dug by the initially calculated values will significantly deviate from the planned line.
The shield machine will not be able to dig through to the planned destination point.



② **Intermediate simulation phase**
With improved parameter values, the shield machine would be able to dig through to the destination point but the performance rating is still not high enough and suggests room for improvement.



③ **Planning complete**
With the highest performance rating obtained, the calculated values are deemed the optimum set and will be applied to actual excavation planning.

The Shield Excavation Planning Assistance System has been jointly developed with the Nagoya Institute of Technology.

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Heavy reinforcement bars can be handled with ease

Reinforcement Bar Installation Assisting Robot

توزيع قضبان التسليح الثقيلة بسهولة

روبوت مساعدة توزيع قضبان التسليح

Overview

The Reinforcement Bar Installation Assisting Robot has a manipulator arm designed after the human arm. A human worker operates the robot’s control grip to move the manipulator arm to handle the reinforcement bars for installation. The hand-guiding mechanism realizes a work space where human workers and robots work in harmony.

Features

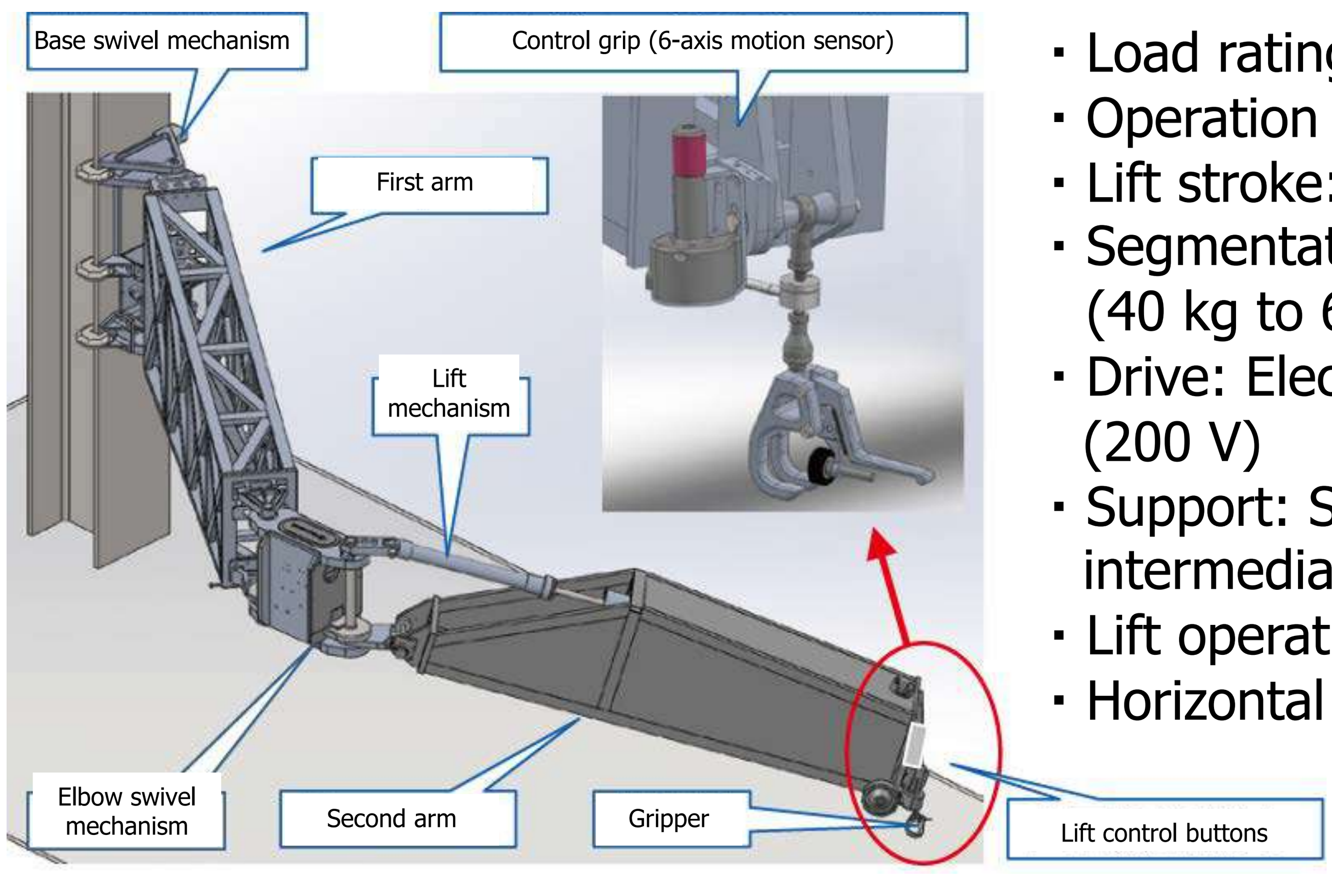
① Manpower saving
Reinforcement bar installation can be completed with one operator and two other assisting workers. Normally, installation of 13-m D51 reinforcement bars (approx. 210 kg per bar) requires a crew of seven to eight workers. With the Assisting Robot, the same work can be completed with less than half the manpower.

② Reduction in heavy object handling
All heavy object handling is done by the robot, reducing the physical stress of reinforcement bar installation workers.

③ Better safety
The operator can operate the installation robot while checking the surrounding for potential hazards and interference. The robot is designed with a great focus on safety as it will immediately stop in place when the control grip is released.

④ Easy, simple operation
The control grip and the lift control buttons are easy-to-operate. Even novice operators can quickly learn to skillfully oper ate the robot.

Specifications



- Load rating: 250 kg
- Operation radius: Approx. 5.0 m
- Lift stroke: Approx. 2.0 m
- Segmentation: 4 segments (40 kg to 60 kg per component)
- Drive: Electrically powered (200 V)
- Support: Supported by an intermediate pile
- Lift operation: Control buttons
- Horizontal operation: Control grip

First arm and control panel

Second arm

Gripper

Operation steps

Operate the robot to grip a bar

Carry the bar assisted by the robot

Install the bar

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Visualization of objects buried underground
Shimz AR Eye Buried Object View

تطبيق التحكم المرئي بالإنشاءات تحت الأرضية
لعرض الإنشاءات غير المرئية Shimz AR Eye

Overview of the system

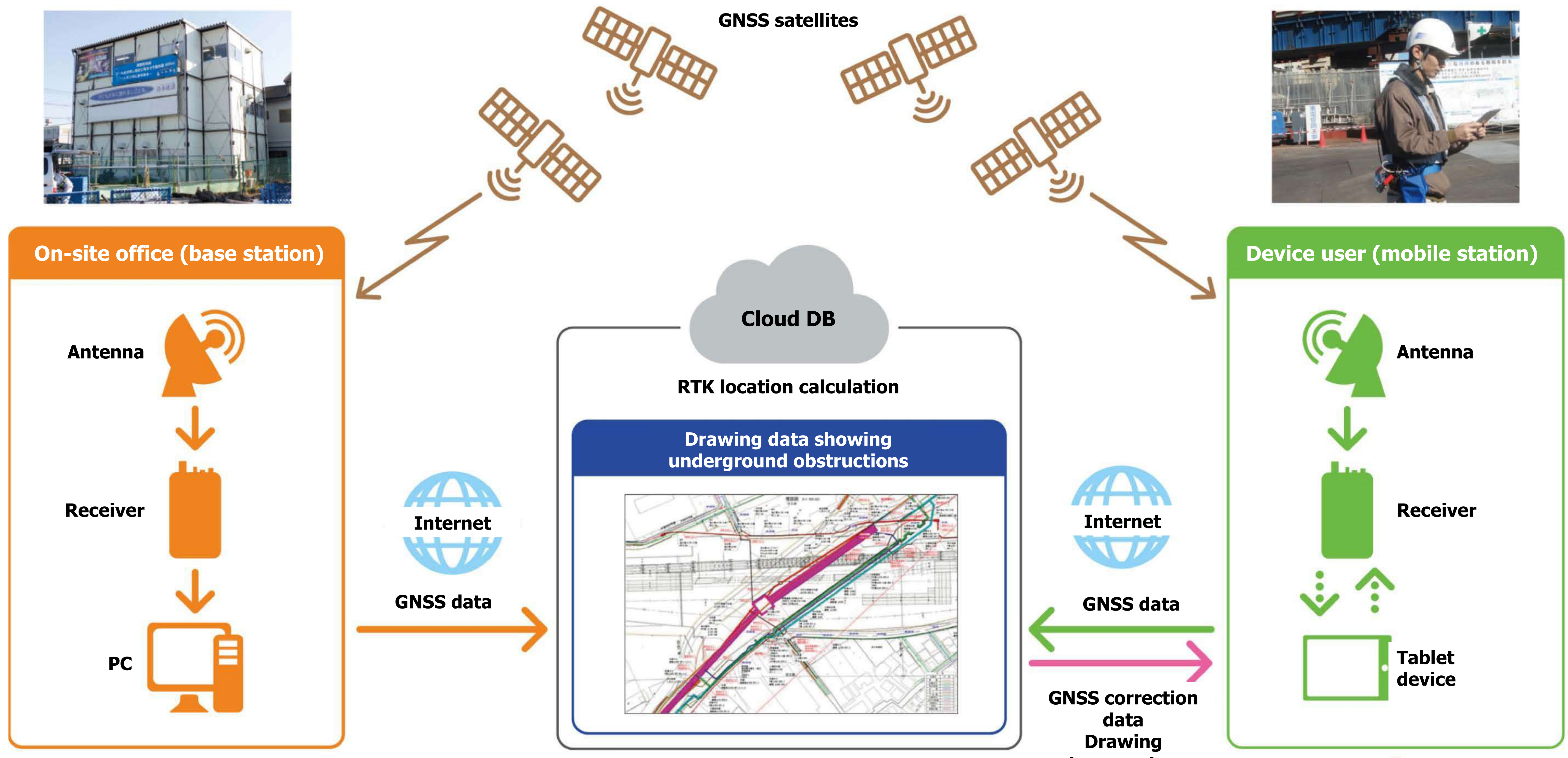
The system projects the drawing data of underground objects onto the actual camera view shown on the tablet, visualizing what are buried unseen under the ground.
Human workers will be dependably reminded of underground obstructions, contributing to greater efficiency of excavation work without the need of checking printed information on paper each time.

Features

- Positional relationship between the device user and the underground obstruction is displayed on a real-time basis.
- Where GNSS-based[※1] positioning is available, the combination of a compact antenna and a receiver offers excellent mobility and adaptability to a wide range of operations.
- Where GNSS positioning is not available, the system can be operated based on SLAM[※2] navigation.
- Latest information of all underground obstructions will be stored in a database for centralized management.

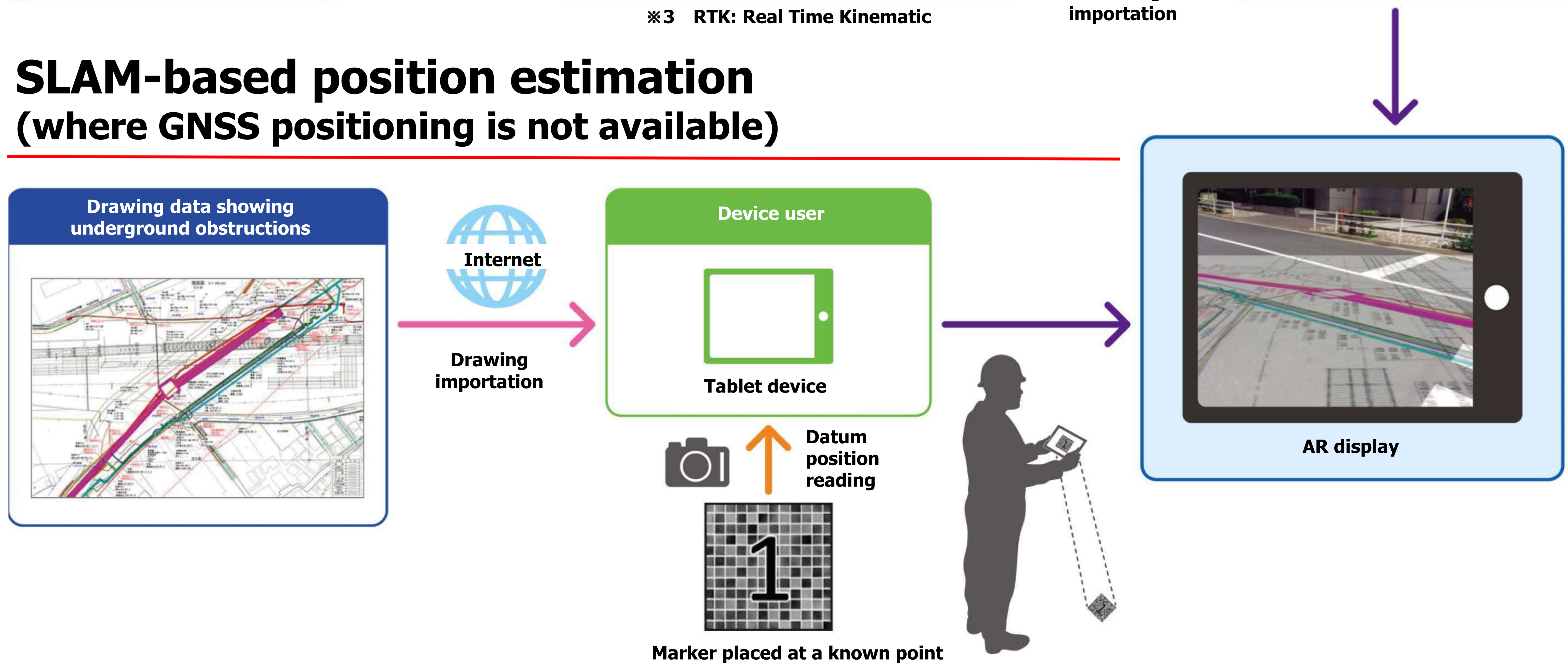
※1 GNSS: Global Navigation Satellite System
※2 SLAM: Simultaneous Localization And Mapping

GNSS positioning



※3 RTK: Real Time Kinematic

SLAM-based position estimation (where GNSS positioning is not available)



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TOKYO-GAIKAN Expressway Owada Section Project

أوتوستراد طوكيو غايكان إنشاءات أوادا

Project Summary

The project section is part of TOKYO-GAIKAN Expressway that goes around the center of the metropolitan Tokyo in an approximately 15 km radius. A box-shaped road enclosure of approximately 1668 m has been placed mainly by open-cut excavation. Part of the sidewalls of the large cross-section box culvert enclosure has been built using our newly-developed half-precast construction method.

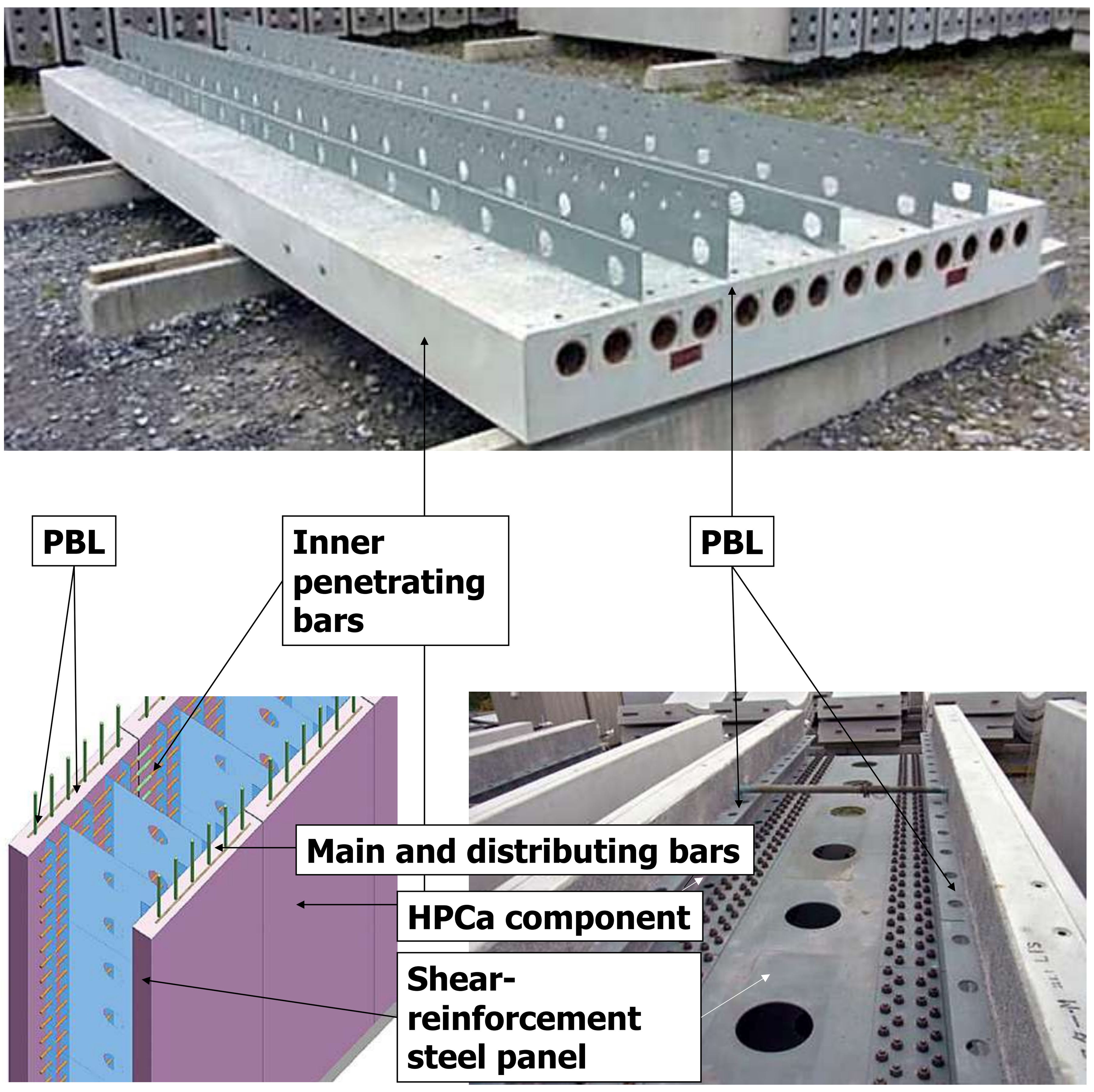
- **Project owner**: East Nippon Expressway Company Limited
- **Contractor**: Shimizu-Maeda-Toyo joint venture
- **Project completion**: July 2019
- **Location**: Chiba, Japan

Half-precast (HPCa) construction to build box culvert sidewalls

・The large-size precast concrete construction was achieved with the aim of productivity improvement by having a simple, non labor-intensive structure to save manpower.

・Features an integrated structure comprising HPCa panels with embedded main and distributing bars and serving also as the outer formwork, "Perfobond strips, hereinafter PBL" for the inner penetrating bars, and shear-reinforcement steel panels.

・Experiments proved that the HPCa construction will provide an equivalent or superior structural performance (shear/flexural capacity) to that of standard reinforced concrete (RC) construction.



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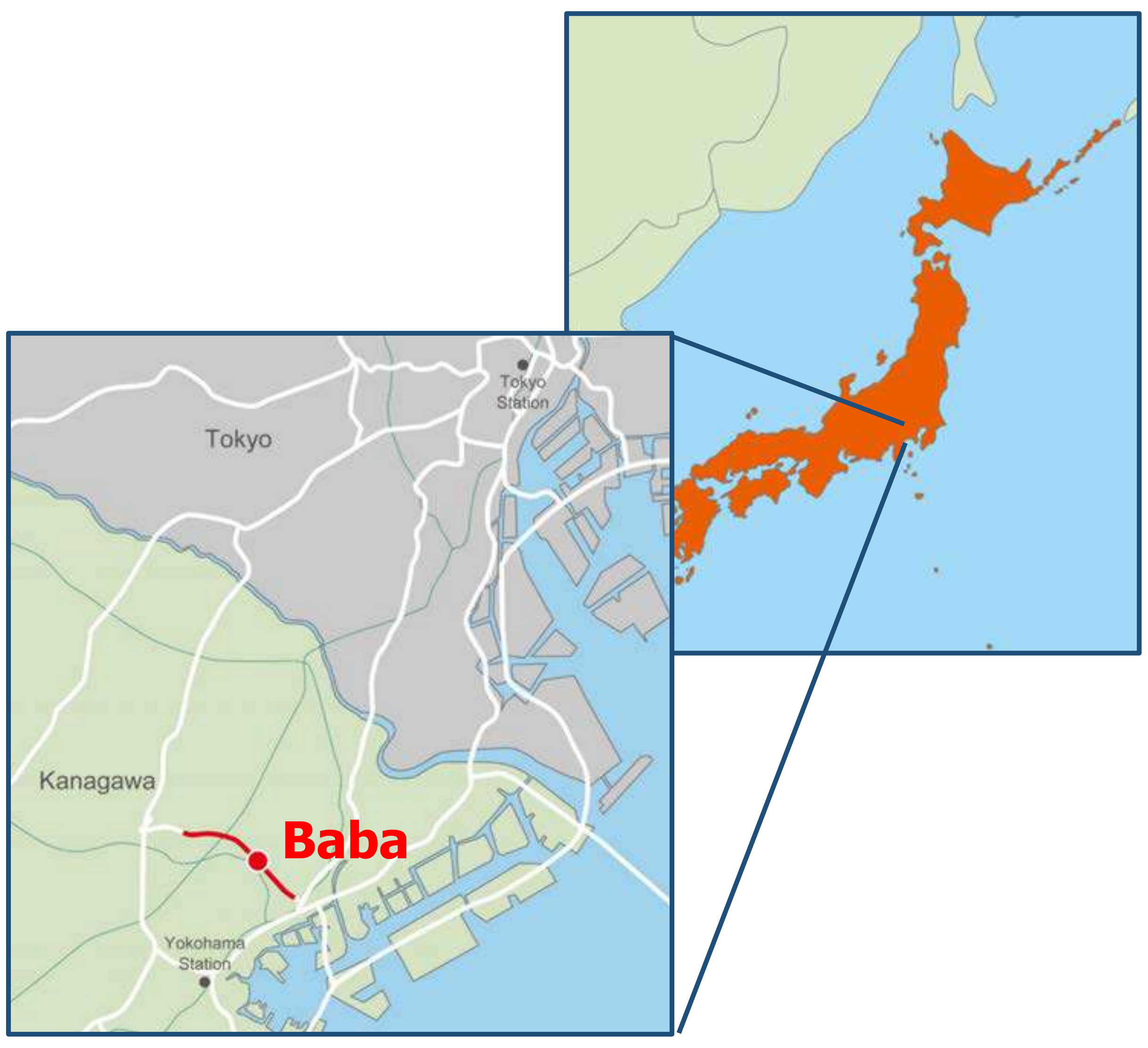
Yokohama Kita-Line of Metropolitan Expressway Baba Interchange Project

خط يوكوهاما الدائري الشمالي إنشاءات مخرج ومدخل بابا

Project Summary

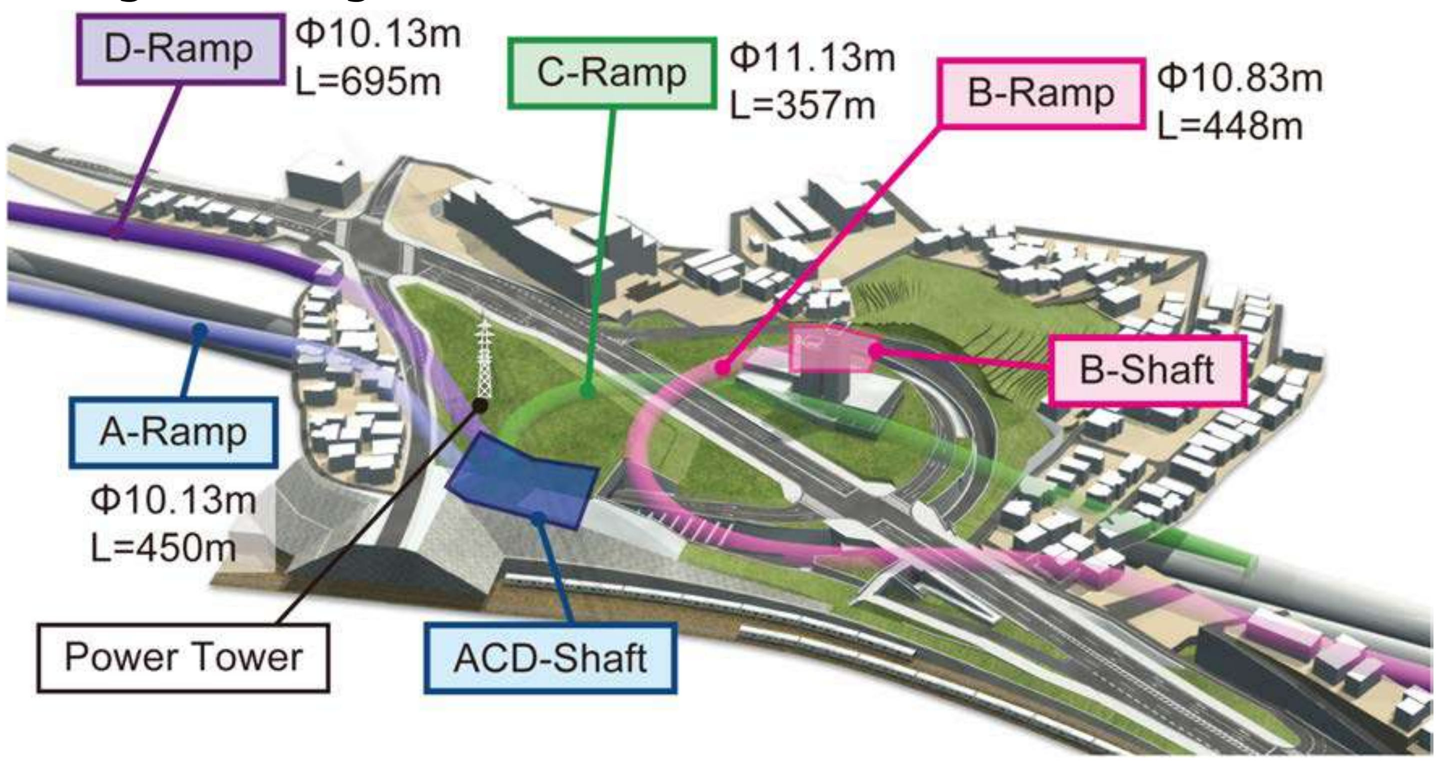
This project is designed to build four ramp tunnels, which serve as an entrance to and an exit from Metropolitan Expressway, by a combination of open-cut excavation and shield tunneling methods. The shield tunneling work involves a large cross-section with an outer excavation diameter of greater than 10 m and has an unprecedentedly demanding set of parameters including: ① tunnel geometry with sharp curves (minimum curve radius: 50 m) and steep inclinations (i = -7 to -8%), ② shallow overburden (approximately 1.3 m where shallowest) ③ digging through soft soil directly under existing structures including a power tower and private buildings, and ④ connecting to the through-traffic tunnel under the ground (smallest separation distance ≒ 0.2 m).

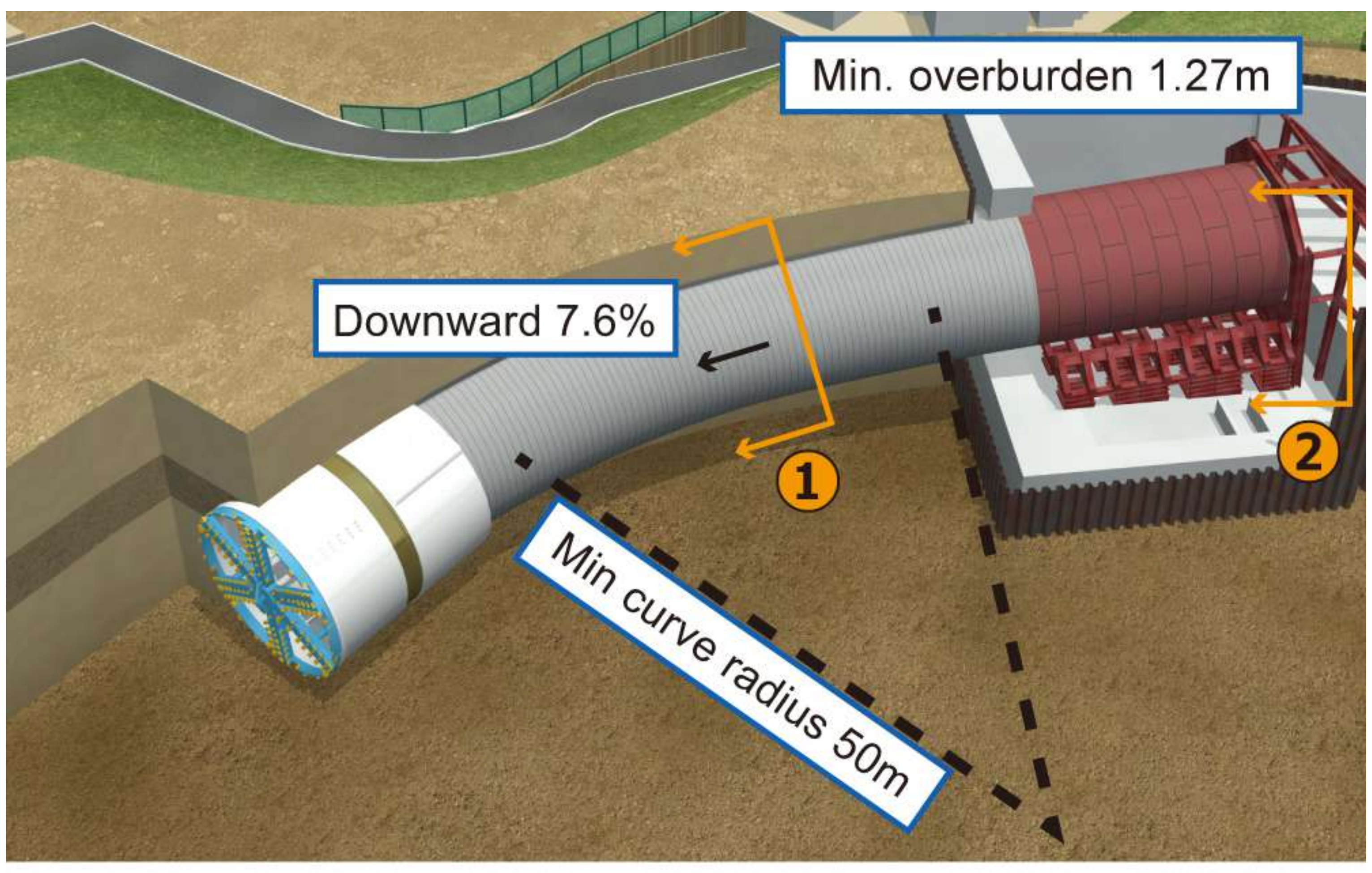


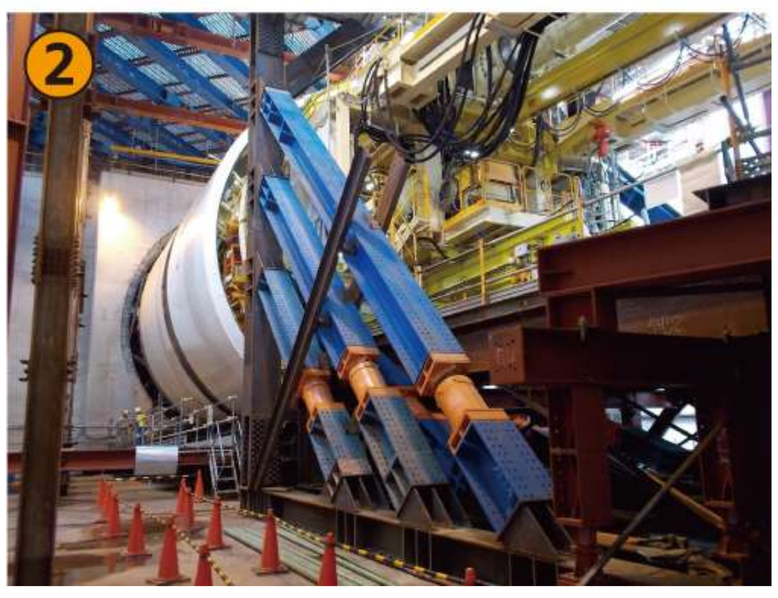
- **Project owner**: Metropolitan Expressway Company Limited
- **Contractor**: Shimizu-Tokyu Specific Construction Work joint venture
- **Scope of work**: Four ramp tunnels over a length of approximately 1036 m
- **Location**: Kanagawa, Japan

Large-cross-section shield tunneling involving sharp curves, steep inclinations and shallow overburden

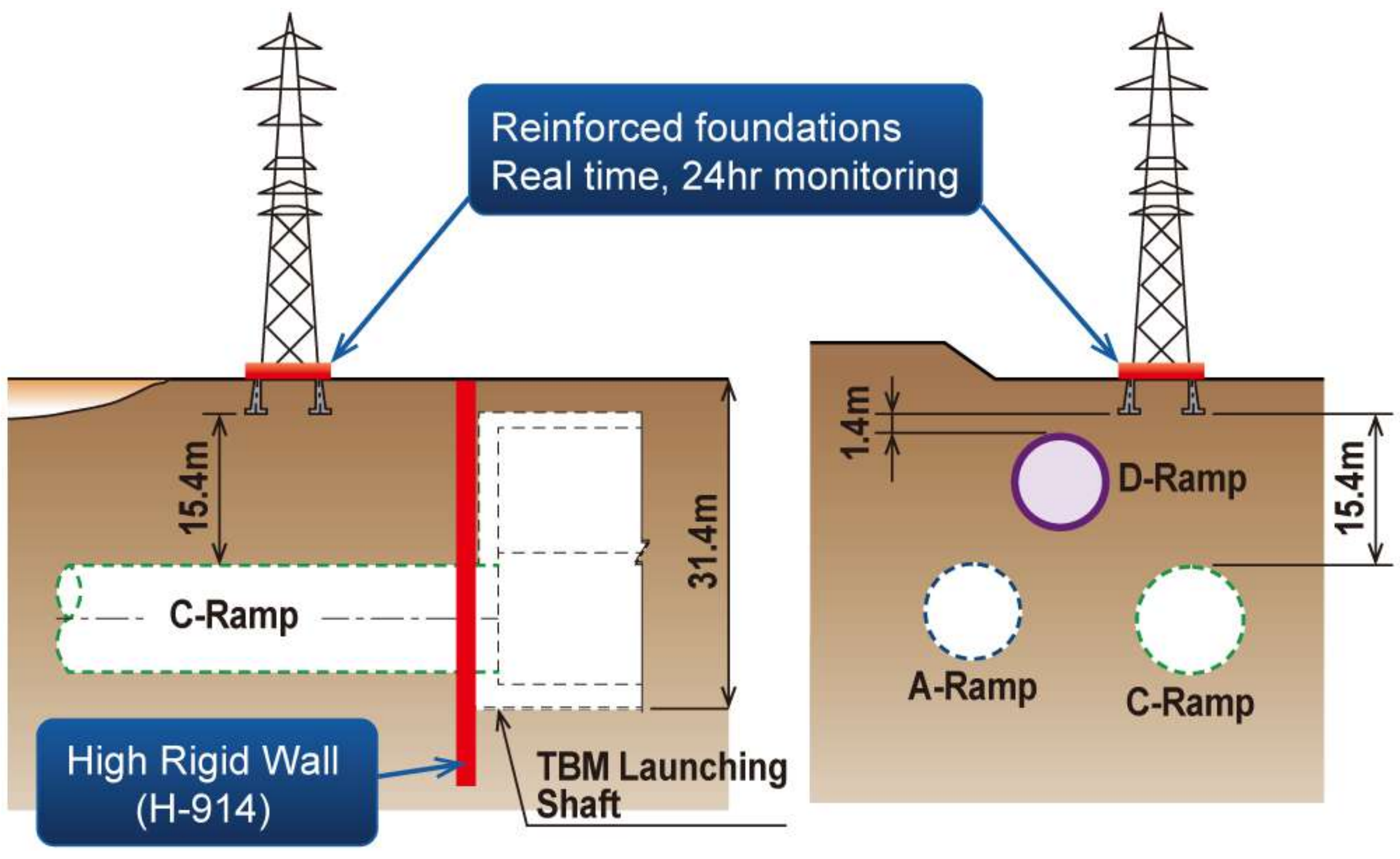
There are two launching shafts for the tunnel; B-shaft for B-ramp tunnel and ACD-shaft for A-ramp, C-ramp, and D-ramp tunnels. The diameter of each tunnel was designed as the minimum curve radius of each tunnel. Smaller curve radius requires larger tunnel diameter to secure design viewing distance.



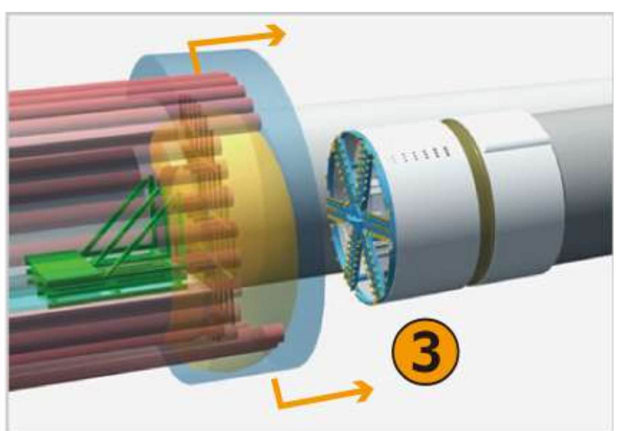




Three tunnels are located under the existing power tower. The original foundation of the tower, consisted of four independent structures, was reinforced prior to tunneling. The displacement of the foundation was measured automatically.



Prior to arrival of a new TBM, a protective wall was installed. The New TBM was connected to the existing main tunnel, without disturbing main tunnel's function as underground expressway (just one lane of main tunnel was closed) .



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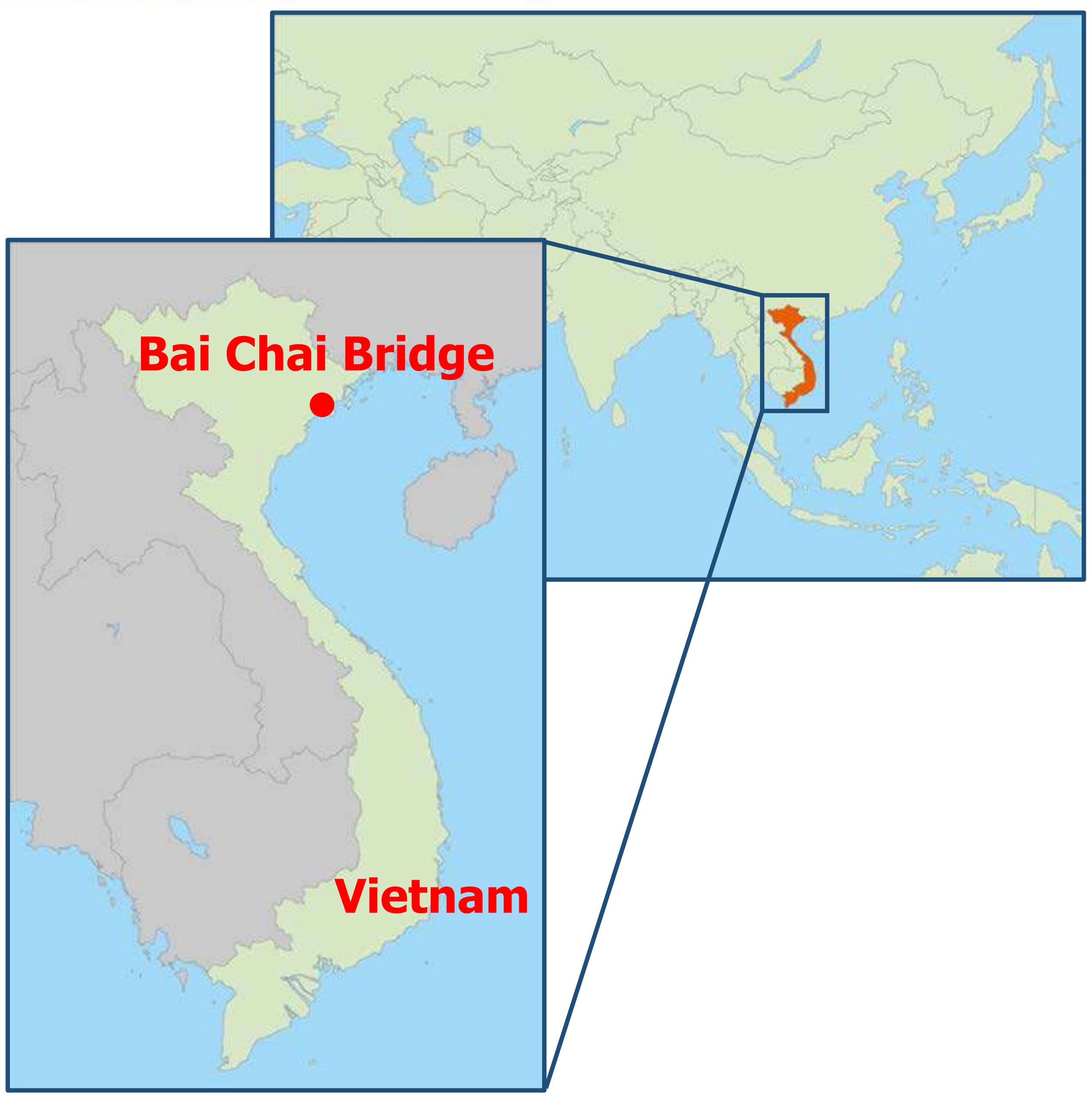
The Bai Chay Bridge Construction Project (Package BC-2)

مشروع إنشاء جسر باي تشاي (Package BC-2)



Project Summary

The Bai Chay Bridge, over Hạ Long Bay (world heritage) in the northeastern part of Vietnam, is a six-span continuous cable-stayed PC bridge with a total length of 903 m. It has the world's largest (as of the construction date) center span of 435 m as a single plane cable-stayed bridge. To resist the 50-m/s cross wind during typhoons, a series of latest and most advanced technologies are adopted to the bridge construction including wind tunnel tests using whole-bridge models, use of a reinforced box-shaped cross section, the liquid damper-based vibration reduction system inside the main towers, and a monitoring system based on optical fiber-assisted distortion measurement.

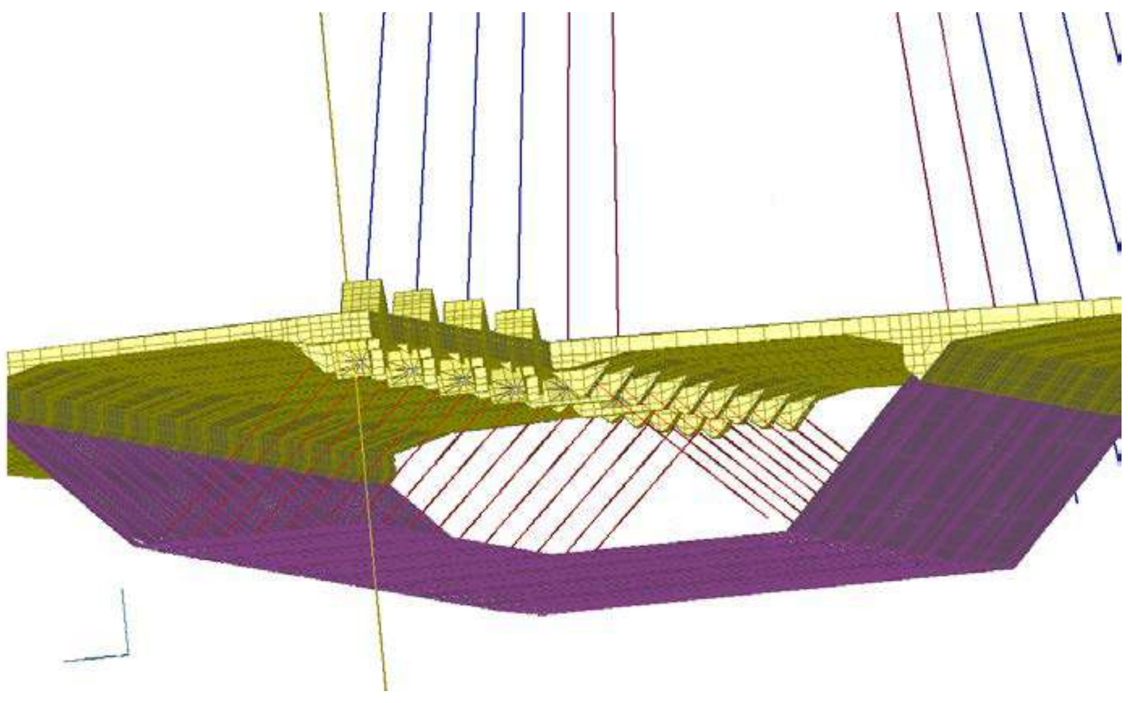
- **Project owner**: Project #18 Management Office of the Ministry of Transport of Viet Nam
- **Design supervisors**: Japan Bridge & Structure Institute, Inc. / Pacific Consultants International / TEDI / Hyder-CDC joint venture
- **Contractor**: Shimizu-Sumitomo Mitsui Construction joint venture
- **Completion**: November 2006
- **Scale and structure**: Six-span continuous cable-stayed PPC bridge
  Total bridge length: 903 m, center span: 435 m, width: 25.3 m
  Foundation: Three pneumatic caissons
- **Location**: Viet Nam

Characteristics of Works

- Wind-tunnel tests using three-dimensional whole-bridge models to evaluate wind stability during and after construction
- World's first use of a distributed liquid damper system inside the main tower to reduce wind-induced vibration.
- Lightweight box-shaped cross section using steel pipe bracing, proven by demonstration tests.
- Main girder stress evaluation based on precision three-dimensional FE analysis, where geometry in each stage of construction was faithfully simulated.

Wind stability validation by wind tunnel tests

Lightweight box-shaped cross section with steel pipe bracing



Three-dimensional FEM model for stress evaluation

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Ghana International Corridor Improvement Project

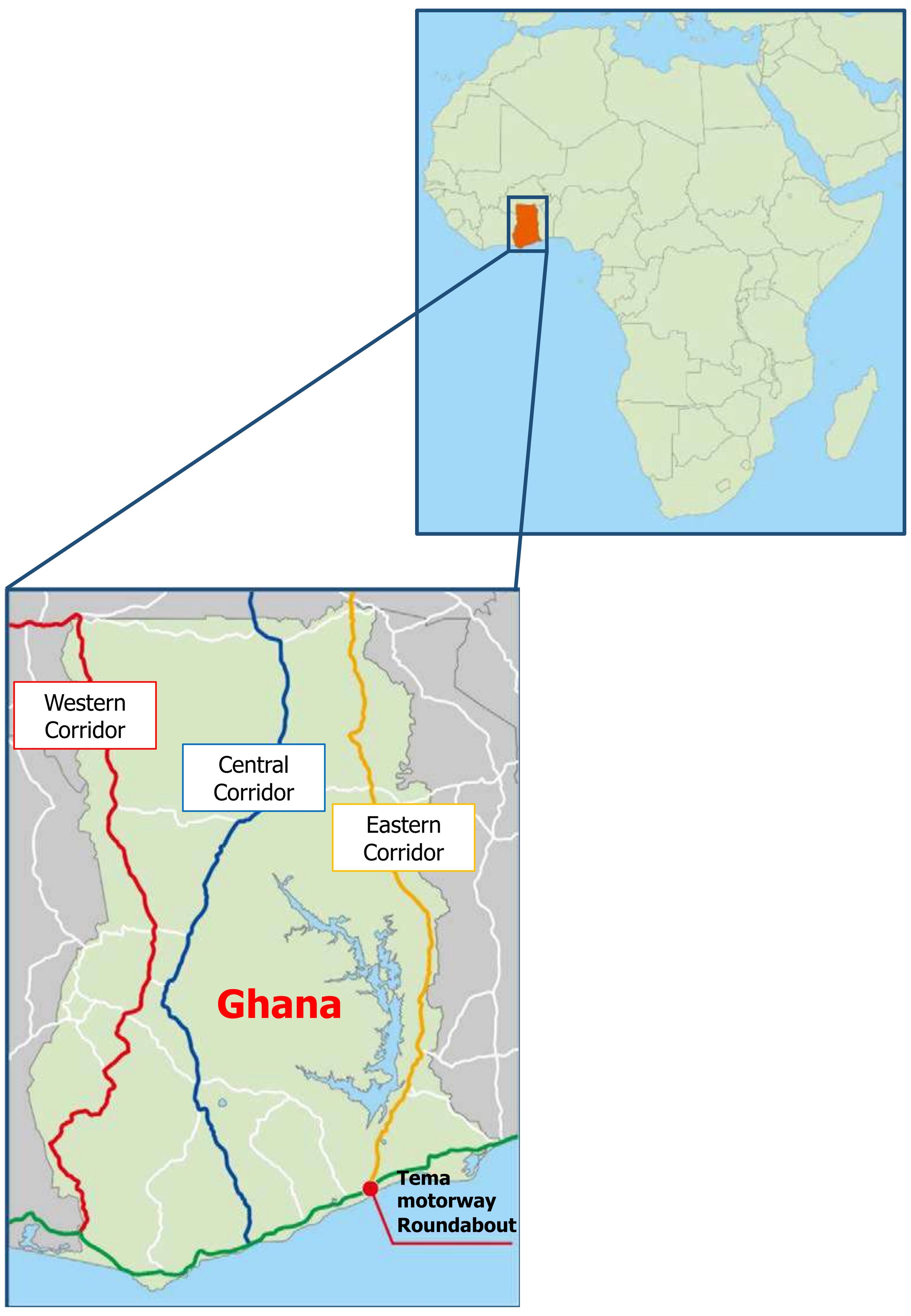
مشروع تحسين ملتقى طرق غانا الدولي

Before work start

Completion image

Project Summary

The Tema Junction is a five-way roundabout intersection connecting two international highways (the Abidjan-Lagos Corridor connecting the coastal cities of West Africa, the Eastern Corridor connecting Ghana and Burkina Faso), and one domestic route connecting to the Ghanaian capital city of Accra. Heavy traffic through the junction is a cause of chronic traffic congestion.
It is hoped that completion of the project will bring better traffic convenience and a smoother and more efficient transport of goods not only in Ghana but also across West Africa.

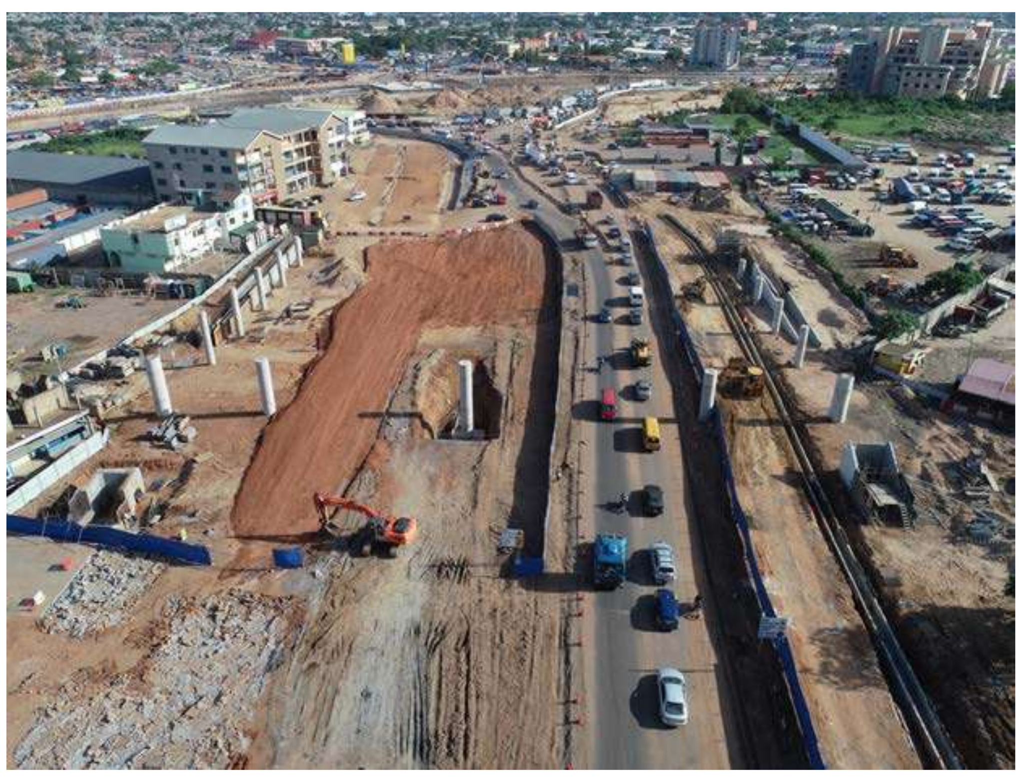


- **Project owner**: Ghana Highway Authority (GHA) under the Ministry of Roads and Highways of Ghana (MRH)
- **Design supervisor**: CTI Engineering International Co., Ltd.
- **Contractor**: Shimizu-Dai Nippon Construction joint venture
- **Project period**: From February 2018 to June 2020
- **Project overview**: ・Construction of an east-west underpass
  Box-shaped section: L = 190 m (B (16.45 m x 2) x H 7.5m), Approach, L = 660 m
  ・Width extension and road improvement (total length = 14,500 m)
  Two lanes each way => To be expanded to three lanes (four lanes both ways => six lanes)
  The existing roundabout will be removed to improve the north-south road geometry.
- **Location**: Ghana

Construction in progress

Box culvert

Concrete casting



Pedestrian Bridge construction

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