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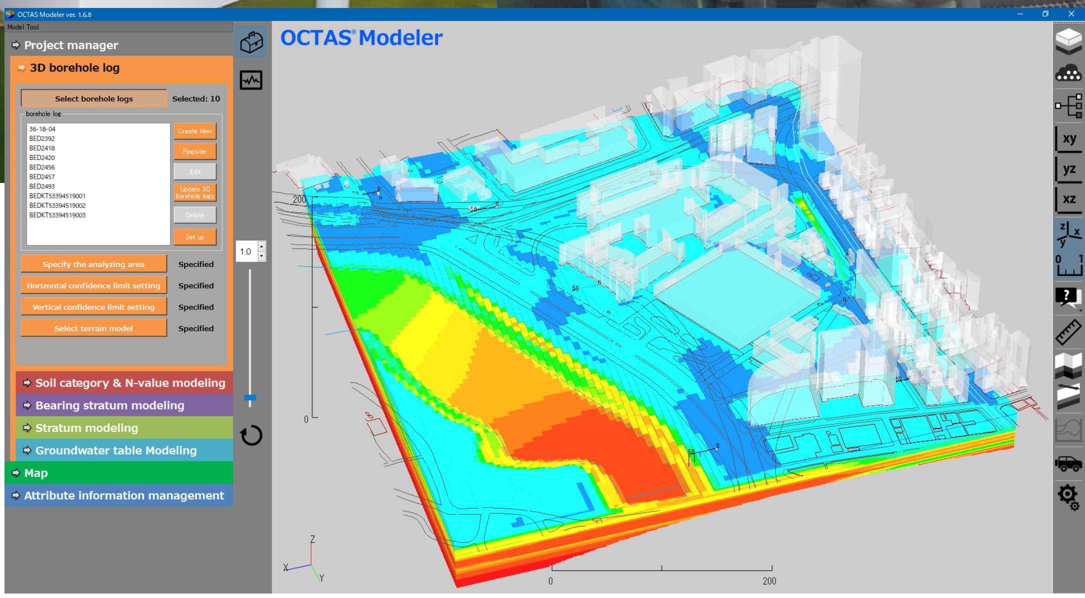
Infrastructure Development Institute—JAPAN



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TAPS - Al-Mg Plasma Arc Thermal Spray Coating for Corrosion Protection

High durability and low maintenance costs for bridge components in harsh environments

1. Introduction

Kawakin Core-Tech is a top Japanese manufacturer with more than 70 years of history engaged in the development, design, manufacture, and sales of seismic devices (seismic isolation and dampers), and structural bearings, and expansion joints for bridges and buildings. We are ready to respond to global needs for safety and reliability, and we look forward to supporting you in your project.

2. Outline

Components made of steel in bridges are expected to suffer remarkable corrosion damage from water leakage if not adequately protected. This is particularly troublesome for bridge components such as bridge bearings (Figure. 1) since their location complicates regular inspections and maintenance operations.Moreover, their complex shapes are challenging to be evenly coated, and any scratch that occurred during transportation or installation can easily trigger the appearance of rust in these damaged areas. This will lead to continuous, labor-intensive, and costly maintenance operations that will expand the structure's life cycle cost.

Corrosion is a process of degradation in which the metal is being oxidized by its surroundings, usually H_2O and O_2. As a result, a continuous metal loss and a compound that we know as rust are formed and deposited on the surface (Figure. 2).

The most common approach to avoid the appearance and development of corrosion is to provide a coating layer to physically prevent water and oxygen from coming into contact with the steel, and preventing the formation of rust (Figure. 3). Paint coatings follow this approach, but regular repainting is necessary because of the degradation of the paint caused by its exposure to wet and dry cycles of direct sunlight and rainwater. When the paint coating is cracked, rust starts to form, and the expansive nature of this rust will increase the size of the crack, accelerating the deterioration process (Figure. 4).

Paint only forms a protective layer, but other technologies have been developed to provide sacrificial protection that can overcome these disadvantages of paint coatings. When steel is coated with metals with a higher ionization tendency than Fe, such as Cr, Zn, Al, or Mg, rust develops faster in the coating and protects the base material (Figures. 5 and . 7).

Figure-1 Corrosion of bridge bearings

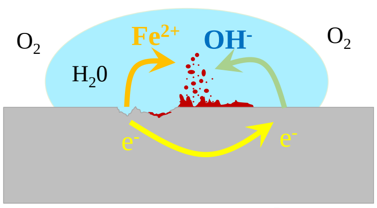

Figure-2 Corrosion mechanism

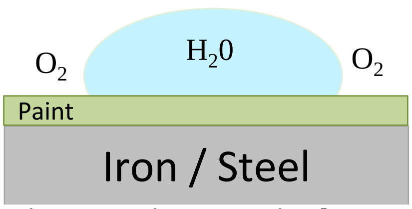

Figure-3 Paint protection layer

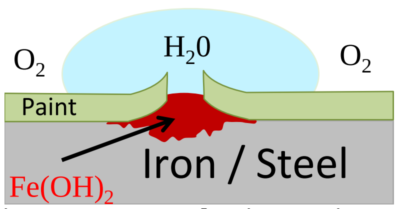

Figure-4 Damaged paint coating

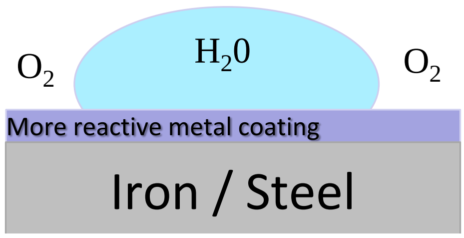

Figure-5 Metal coating

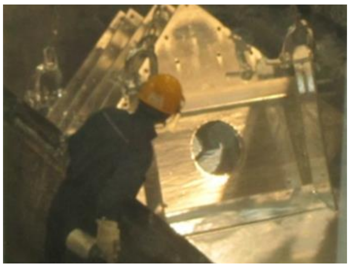

Figure-6 Hot-dip galvanizing

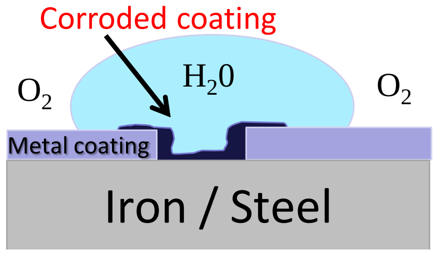

Figure-7 Sacrificial protection

A standard anti-corrosion method that applies this principle is hot-dip galvanizing. In this case, the base metal to be protected is immersed in a kettle containing molten Zn (Figure. 6). Since Zn's melting point is 420 °C, high strength materials cannot be hot-dip galvanized because their material strength will be reduced. In a corrosive environment, Zn will oxidize and form a stable Zn oxide layer that will prevent the corrosion of the Fe and cover scratches (Figure. 7), conferring long-term corrosion protection. However, in marine environments, this protective coating becomes extremely porous, unstable, and it is easily washed away. Consequently, corrosion is developed, degrading the base material after a short period of exposure.

Due to the need to develop a durable, easy-to-use and cost-effective method to protect bridge steel components in harsh environments, a study group formed by professionals in the field was established in 2013. They have held activities to develop a patented method to protect steel girders, bolts, bearings, and other bridge components against corrosion. This new Japanese technology (Transfer Arc Plasma Spraying or TAPS®) is based on melting and spraying a wire of Al-Mg alloy onto a metal surface using a plasma arc spraying method.

3. Detailed Description

Al and Mg have excellent characteristics to be used for protective coatings. However, due to their high melting point (higher than 600 °C), it is costly to melt them and apply them as Zn is used in hot-dip galvanizing. Furthermore, high temperatures can affect some materials creating distortions and strength degradation. TAPS proposes the application of Al and Mg through plasma arc thermal sprayingto make the most out of these two metals' excellent corrosion protection characteristics. This is a process in which a modified gas or electric arc welding equipment equipped with compressed air is used to melt and project a metal wire onto a steel surface (Figure. 8)

(1) Main features of TAPS

(a) Long-lasting anti-corrosion protection.

The accelerated corrosion tests with salt spray carried out on steel plates, nuts and bolts highlight the excellent anti-corrosion performance of TAPS which can be six times more durable than the performance of hot-dip galvanizing method under marine environmental conditions. (Figure. 9). In the test, specimens were treated with different anti-corrosion coatings, i.e., heavy-duty anti-

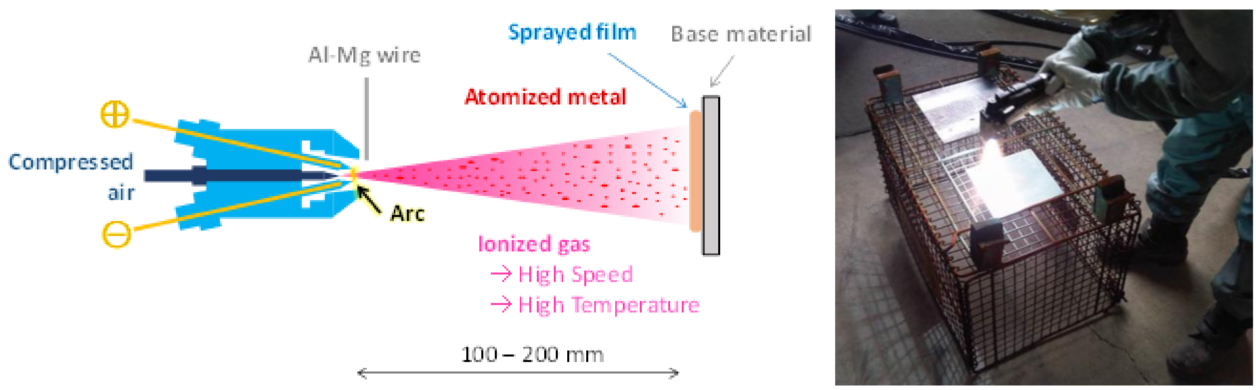

Figure-8 Al-Mg plasma arc thermal spray application

Specimen	Start of the test	After 6,000 hours
Al-Mg Plasma Arc Thermal Spray		
Heavy-duty anti-corrosion paint coating (Type C)		
Hot-dip galvanizing		

Specimen	Start of the test	After 6,000 hours
Al-Mg Plasma Arc Thermal Spray		
Hot-dip galvanizing		

Figure-9 Results of accelerated corrosion tests performed in steel plates and bolts

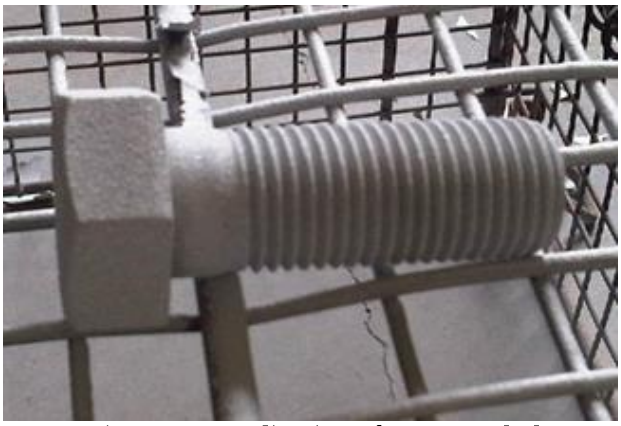

Figure-10 Application of TAPS on bolts

Figure-11 TAPS application equipment

corrosion paint coating, Zinc hot-dip galvanized coating and Al-Mg thermal sprayed coating.

The test pieces were then inserted in a chamber where they underwent wet cycles, i.e., the test pieces were sprayed with water and salt and endured humid cycles and dry cycles that were switched automatically to simulate marine environmental conditions.

After approximately 9 months (6,000 hours) of exposure in the accelerated test, rust was observed in the cross-cut areas of the steel plate test pieces coated with heavy-duty paint coating and in the hot-dip galvanized bolts and plates.

On the other hand, test specimens coated with Al-Mg plasma arc thermal spray showed a highly stable protection layer during the whole duration of the accelerated test.
Apart from this, the results of a series of outdoor exposure tests, which were conducted in Japan, Vietnam, or Myanmar, also highlight the excellent anti-corrosion properties of the test specimens treated with Al-Mg Plasma Arc Thermal Spray after years of exposure.

(b) Applicable in high-strength bolts, including the thread.

The temperature of the molten metal applied to the base material is not high. Thus, TAPS is an anti-corrosion method that can be applied to high-strength materials, such as high-strength bolts (Figure. 10), without creating strength degradation or distortions. Kawakin can also apply this coating evenly to the threaded part.

(c) Applicable on-site

The necessary equipment to apply TAPS on steel components is compact and portable (Figure. 11) and can be used at a construction site. This makes TAPS an appealing technology for repair and maintenance projects.

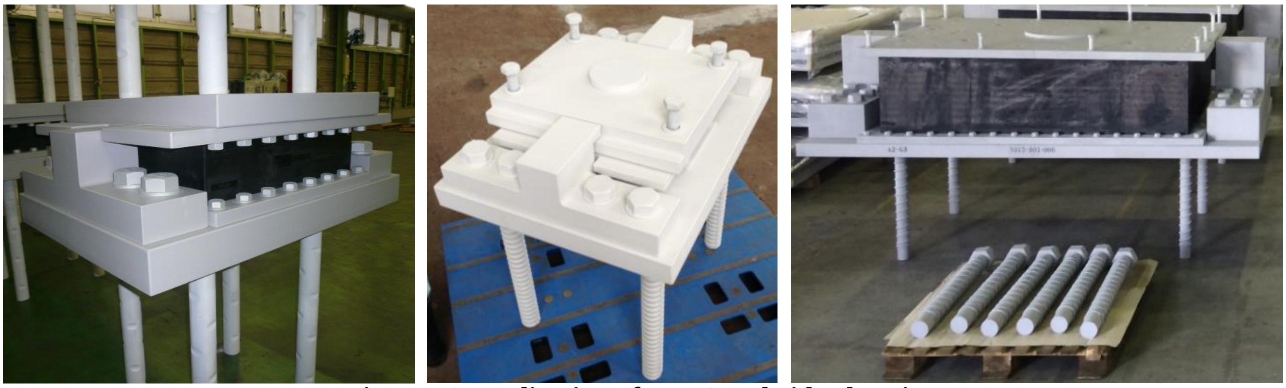

Figure-12 Application of TAPS on bridge bearings

Figure-13 TAPS application on expansion joints

4. Scope of application

Al-Mg Plasma Arc Thermal Spray is a Japanese technology used to protect different steel bridge members, including steel girders, bridge bearings, expansion joints, and high-strength bolts.

5. Anticipated Results

(1) Long durability of steel components even in harsh environments.

Compared to conventional coatings, the superior anti-corrosion protection capacity of TAPS provides more durability to steel bridge components located in marine areas. Based on theaccelerated test results explained before, , the expected durability of TAPS in marine environments could be around 100 years.

(2) Lower life cycle costs

Steel components treated with TAPS have a longer life cycle, and thus, direct and indirect costs related to repainting and maintenance operations are greatly reduced. This leads to significantly lower life cycle costs of the bridge structures.

(3) Safer infrastructures

Bridge bearings and expansion joints are critical bridge components since their performance is directly linked to the stability and serviceability of the structure. TAPS prevents deterioration of these components even in harsh environments, leading to safer, more reliable, and more resilient structures for an extended amount of time.

6. Record of implementation

The Al-Mg Plasma Arc Thermal Spray technology is an anti-corrosion coating with an extensive track record of applications in Japan. NEXCO, i.e., a company that manages the Japanese highway network, has officially adopted this technology in its design and construction standards for the anti-corrosion protection of bridge bearings.

Apart from Japan, TAPS has also been applied in essential bridge projects in Asia and Africa due to its capacity to prevent the appearance of rust in steel bridge members located in harsh environments. Some of these project references are summarized in Figure 14. In most of the selected examples of these applications, the bridges were typically located in a marine environments where high concentrations of airborne salinity were observed. In these projects, the application of

INTERNATIONAL PROJECTS

Mombasa Southern Bypass & Kipevu New Container Terminal Link Road PK-1
Country : Kenya
Year of completion : 2018
Products : bridge bearings with Al-Mg thermal spraying

New Bridge Across River Nile at Jinja
Country : Uganda
Year of completion : 2017
Bridge type : Cable-stayed
Products : Large-scale bridge bearings and lateral supports

The Kanchpur, Meghna and Gumti 2nd Bridges Construction Project
Country : Bangladesh
Year of completion : 2020
Products : seismic isolators, bridge bearings, expansion joints, and drain basins with Al-Mg thermal spraying

PROJECTS IN JAPAN

Ikema Bridge
Prefecture : Okinawa
Year of completion : 1992
Bridge type : PC continuous box girder
Products : Viscous dampers with Al-Mg thermal spraying

Uminonakamichi Bridge
Prefecture : Fukuoka
Year of completion : 2014
Bridge type : Arch
Products : Bridge bearings with Al-Mg thermal spraying

Suehiro Bridge
Prefecture : Tokushima
Year of completion : 1975
Bridge type : Cable-stayed
Products : Bridge bearings with Al-Mg thermal spraying (retrofit)

Figure-14 TAPS project references

TAPS in the steel components of both rubber and steel bridge bearings, and expansion joints, brought incredible benefits such as the extension of life cycle for bridges and the reduction of the life cycle costs.

7.Conclusion

Corrosion is one of the most determining factors affecting the deterioration of bridges, especially in those viaducts located in marine environments. Therefore, providing durable anti-corrosion protection coatings for critical steel components of bridges is of great importance to ensure the durability and serviceability of these structures.

TAPS is a Japanese technology developed to provide exceptional corrosion protection by melting and spraying Aluminum-Magnesium alloy wire onto a metal surface using a plasma arc spraying method.

The extensive experimental testing and application track records on bridge bearings and expansion joints highlight the benefits of this anti-corrosion coating, specifically its:

- **High-durability:** Six times more durable than conventional anti-corrosion coatings in marine environments.
- **Wide range of applications:** Applicable to high-strength bolts, including the threaded part.
- **Cost-effectiveness:** The superior durability will lead to remarkably lower life cycle costs of the bridge.

8.Contact Information

Please contact us for further information on TAPS or other of our bridge devices and technologies using the contact information below. Our engineers and business professionals will be happy to assist and provide guidance in all stages of your project.

- **Company**: Kawakin Core-Tech Co., Ltd.
- **Department**: Int. Business Department
- **Job title**: Int. Business Development Manager
- **Person in charge**: Javier Lopez
- **E-mail:** info@kawakinkk.co.jp
- **Tel:** +81 48 259 1117
- **Web:** www.kawakinct.co.jp/english

OCTAS Modeler

1. What is OCTAS Modeler?

The OCTAS Modeler is a compact BIM platform with three-dimensional visualization and modeling functions for geological and geotechnical models. It stores and manages geological survey data, geological interpretation data, geological and geotechnical risk information, and attributes information such as readable data, which can be utilized in subsequent construction processes (Figure.1).

This platform aims to visualize geological and geotechnical risks that have a serious impact on infrastructure construction projects, sharing risk management information, and passing on the geological and geotechnical BIM (Building Information Modeling) data to the next project phase.

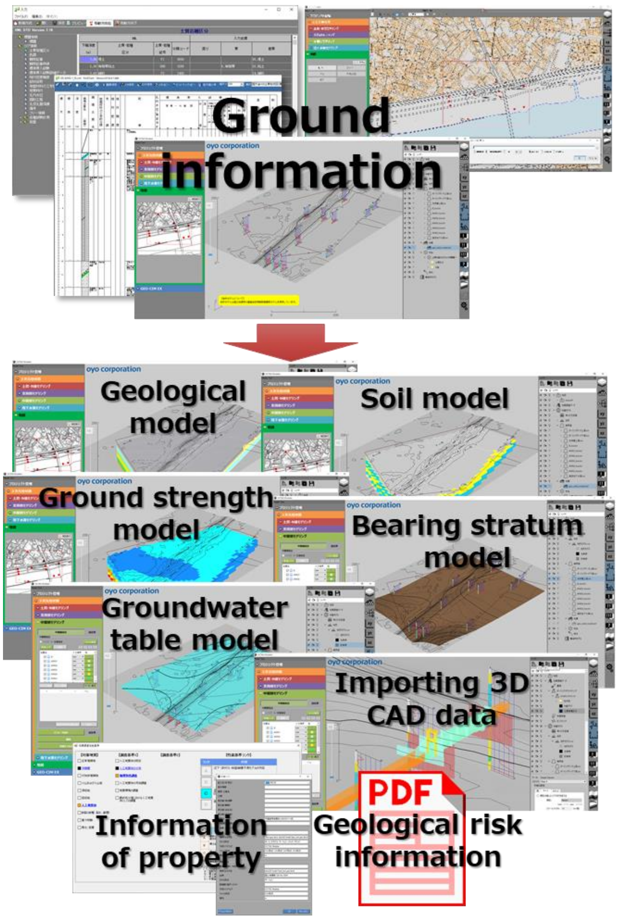

Figure1:Various functions of OCTAS Modeler

2. Background of the development

Geotechnical engineers need to provide reliable geological and geotechnical models at the key stages of the infrastructure life cycle, specifically at the stages of Survey/Design/Construction/Maintenance for an infrastructure. These models include highly specialized information that is professionally handled in two-dimensional drawings and documents.

In response to the expansion of the international BIM market and efforts to improve the productivity of society as a whole through digitization technology, projects using "BIM for Infrastructure" are increasing in Japanese construction market.

Using BIM data in construction projects provide advantages when sharing information among various stakeholders and obtaining a prompt consensus. In addition, the exchange of three-dimensional CAD data is useful for improving practical productivity.

Handling geological and geotechnical information in BIM is causing inevitable changes in the way both information is shared and inherited, which has been dependant on previous two-dimensional drawings and documents.

In order to respond to these changes in the construction environment and fulfill needs, "OCTAS Modeler" has been developed as a three-dimensional geological and geotechnical modeling and management system.

Since many of the important structures, such as urban infrastructure and large plants, are built in plains (open fields), "OCTAS Modeler" targets high-demand three-dimensional geological and geotechnical models constructed on plains.

3. Development concepts

The development concept of OCTAS Modeler is shown in Figure. 2. In the developmental process, we aimed to carry out these followingobjectives.

①. Visualize ground information using a simple procedure

②. Centralize the management of ground information

③. Make important data sustainable

④. Share the same information among stakeholders

⑤. Reducing the costs for updating model with additional ground information

In order to evaluate the quality of three-dimensional geological and geotechnical models, it is necessary to refer to geological survey information, i.e. the fact data, used to construct the model together with the geological interpretation information that shows the concept of modeling.

In addition, the visualization of geological and geotechnical risks and related attributes, together with the models themselves, are important for prompt technical decisions.

In order to save man-power in the process of constructing and updating the three-dimensional geological and geotechnical models, it is necessary to cut down the procedures for modeling, and to update work by adding and reviewing the new data in a short period of time.

For complex geological and geotechnical models such as faults, folds, and cracks in mountainous areas, as well as ground classification and landslide models, we recommend the use of "GEO-CRE", another product of ours, due to its advanced modeling functions (Figure 3).

The three-dimensional geological and geotechnical models created by GEO-CRE is exported as CAD data, then imported into the OCTAS Modeler for the following use.

①Visualize ground information using a simple procedure

- Three-dimensional geological and geotechnical models can be constructed using simple procedures
- Flexible vision in three dimensions from various perspectives
- Superimpose a three-dimensional CAD data structure model
- Three-dimensional geological and geotechnical models can be used as CAD data.
- It is possible to create a cross section or extract data at any location.
- Possible to output cross section using two-dimensional CAD data.
- Point cloud data obtained by drawing can be overlaid and displayed.

②Centralize the management of ground information

- Available as a compact geological and geotechnical information database
- The quality of the ground information can be recorded, so the reliability of the three-dimensional ground model can be understood.
- The BIM for Infrastructure attribute information can be recorded (can be extended if needed).

③Make important data sustainable

- Open formats are adopted for ground information and three-dimensional ground model data.
- Information regarding three-dimensional geological and geotechnical models can be passed on to the post-process.

④Share the same information among stakeholders

- Providing authority to various viewers for free who are able to access the geological and geotechnical information and three-dimensional geological and geotechnical models
- The same project file as the OCTAS Modeler can be reproduced

⑤Reducing the costs for updating model with adding ground information

- Existing geological information can be quickly reused
- Reduces the time and cost of updating the three-dimensional geological and geotechnical models

Figure 2:Development Concept of OCTAS Modeler

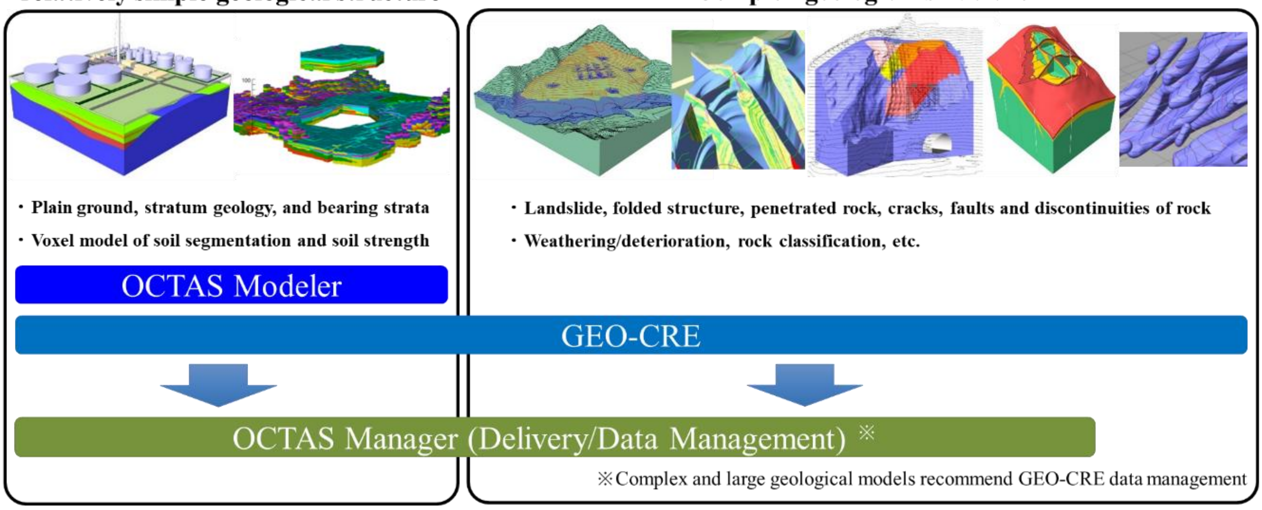

Figure 3: Roles of OCTAS Modeler

Table 1: Software Function Comparison

Main Functions	GEO-CRE	OCTAS Modeler	OCTAS Manager
3D visualization	✔	✔	✔
3D geological and geotechnical modeling	✔	✔	Only browsing
Boring columnar view Input	✔	✔	Only browsing
GIS	-	✔	Only browsing
Cross section creation and 2D-CAD output	✔	✔	✔
Project Management	✔	✔	✔
Attribute information management	-	✔	Only browsing

4. Main features

(1) Data management function

All data are classified into each data category and stored in a predetermined hierarchical folder by the project management function. The geological information handled, the three-dimensional geological and geotechnical models, and their attribute information files are written in an open format so that various construction information system platforms can use them.

For the time being, the attribute information related to the three-dimensional geological and geotechnical models is recorded in an external reference file due to the BIM data exchange standard for the ground not being established yet.

"3-D Geological and Geotechnical Models Inheritance Sheet (URL: https://www.3dgeoteccon.com)" is employed as the external reference file.

For geological and geotechnical risk information, it is stored as a document file, such as a pdf file in the project folder and is displayed by using the link on the screen.

(2) Modelling function

The modelling function allows to develop various three-dimensional models by using simple procedures such as the geological and geotechnical model, bearing stratum model, soil compartment model, soil strength model and the groundwater table model.

BS-Horizon is employed to interpolate a surface, and IDW (Inverse Distance Weighting) is used as a three-dimensional interpolation algorithm for the voxel model. The interpolation algorithm suite can be extended in the future.

(3) Basic Function

The interface consists of three-dimensional viewers and minimal set of function buttons and operation panels. The operation panel has a simple GIS function, a monitoring function, a preview screen, and a data view function that enables retrieval and extraction of time series data (Figure.4) and monitoring data (Figure.5).

The walkthrough function is a simplified VR that is capable of visualizing a three-dimensional data model through user's eyes (Figure.6). Moving the viewpoint along a walk-through path is also possible.

You can edit, display, and print geological logs as a function of “editing ground information”. You can also create cross-sectional views of various models and output them into two-dimensional CAD cross-sections.

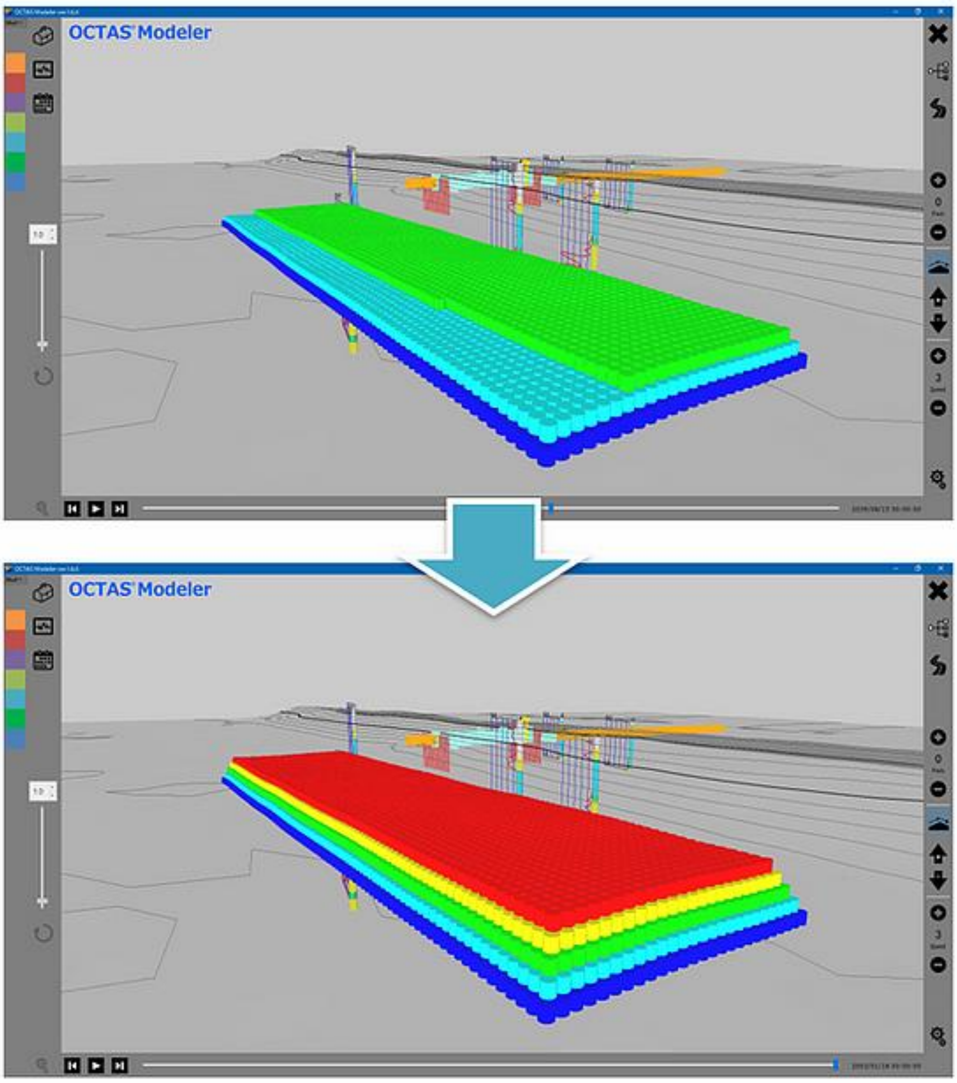

Figure 4: An example of a visualization of time series data

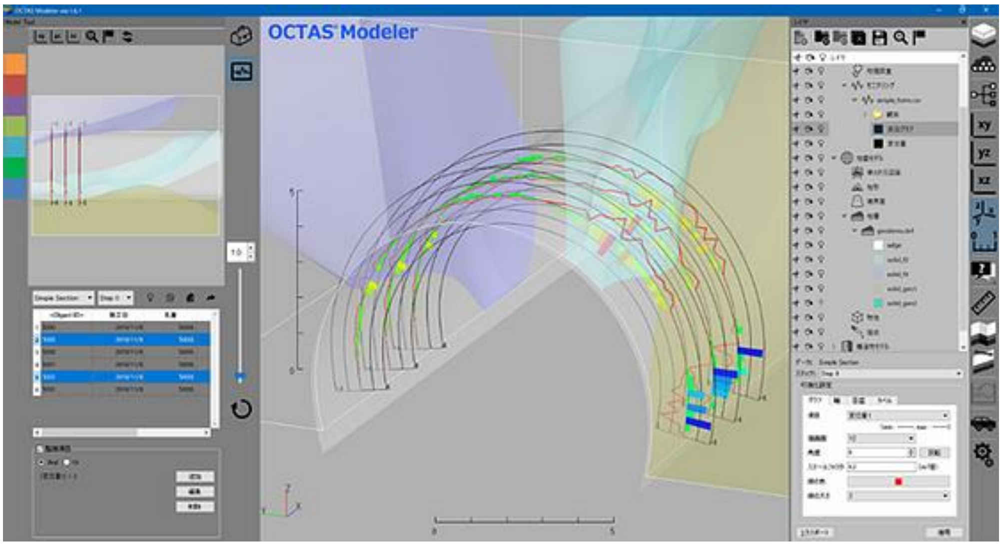

Figure 5: Visualization of monitoring data and an example of retrieval and extraction

Figure 6: An example of a walkthrough display of ground laser point group data

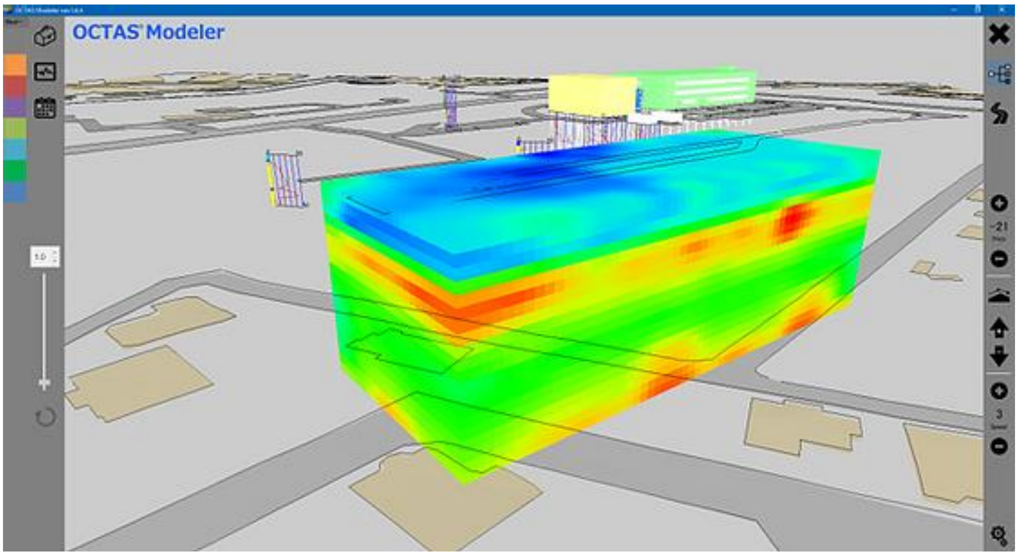

Figure 7:An example of a visualization of 3D geophysical survey data

(4) Visualization function

Three-dimensional visualizable data formats (format extension) are as follows.

- Log data (*.xml http://www.cals-ed.go.jp/mg/wp-content/uploads/guide_bor4.pdf)
- Geophysical exploration data (*.inp (Figure.7) https://www.cybernet.co.jp/avs/documents/pdf/support/avsexpress/ucd_ascii.pdf)
- Topographic data (*.csv)
- Surface model and voxel model (*.csv)
- Colored point cloud data (*.txt, *.las (Figure.6))
- Three-dimensional model with texture (*.wrl)
- Geological model created by other software (*.dxf)
- Measurement/monitoring data (*.csv)

(5) Delivery, inheritance and sharing of data

The dataset of OCTAS Modeler is delivered to clients and stakeholders with OCTAS Manager, which is the free viewer version of the OCTAS Modeler. The OCTAS Manager can be issued from the operation panel of the OCTAS Modeler.

When only limited three-dimensional model data are delivered, a compressed file can be used. This file can also be encrypted for enhanced security.

5. Future prospects

In order to make OCTAS Modeler a convenient communication tool in BIM for infrastructure that is suitable for integrated management of geological information, three-dimensional modeling, and information sharing, we are continuously improving and expanding the various functions of the OCTAS Modeler. The development of the English language interface of the OCTAS Modeler is also underway.

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About IDI and IDI-quarterly

Infrastructure Development Institute-Japan (IDI) is a general incorporated association operating under the guidance of Ministry of Land, Infrastructure, Transport and Tourism of Japanese Government.
IDI provides consulting services to facilitate international assistance to developing countries, to promote international exchange of information and human resources, and to support globalization of project implementation systems targeting both developed and developing countries in the field of infrastructure.

IDI has been publishing a free quarterly journal called “IDI Quarterly” since1996 to introduce information related to public works and construction technologies developed in Japan, to foreign countries. We have distributed the journal to administration officials in more than 90 countries around the world via e-mail.

It will be highly appreciated if you could send us your opinions, impressions, etc. regarding the articles.
We also welcome your specific requests regrading technologies you would like to see on following Quarterly issues.