Preface

It is my great pleasure to present herein the results of the recent international activities of the Japanese Geotechnical Society (JGS). You can find here the first release of the English translation of a variety of JGS technical regulations and more will follow later. These regulations address the fundamental elements of construction practice through establishing a systematic approach from soil investigation to design analysis and performance prediction.

It is well known that the success of construction practice depends on the quality of material tests, field investigation, and design calculation that have been validated through many experiences. Those methodologies are specified by codes. In case that field investigation is carried out in a wrong way, the obtained data does not suit the design calculation. Because of the strong interdependence between practice and code, construction projects should employ both practical technologies and related codes in an assembled body. To facilitate this, JGS is now translating its codes.

As the Vice President for Asia of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE), the natural conditions in Asia are very difficult as exemplified by many severe natural disasters and very thick soft clay deposits in river deltas. Typhoons/cyclones provide a huge amount of precipitation in many parts of Asia and increase the amount of river sedimentation. Thus, tens of meters of very soft deposit is encountered. It is very meaningful for Asian engineers to develop a system of construction practice that suits this difficult natural conditions. The first step toward this goal is the development of a new code in which natural conditions in Asia and even past experiences are taken into account. Because the JGS codes have been developed under the natural environment in Asia, they can provide Asian engineers a starting platform for better Asian codes.

Nothing is perfect in this world. For example, many criticisms are made against uncertainties involved in Standard Penetration Tests (SPT). However, SPT provides us with specimens of subsoils for direct inspection. Moreover, many practical formulae rely on correlation with SPT data. Therefore, it is more meaningful to improve the details of SPT practice and stablish a code for SPT rather than discarding SPT as a non-standardized penetration test. Thus, it is important for all practitioners to make efforts to establish new codes. The provided JGS code can be a good starting point for this.

I would cordially invite you all to pay attention to this code to get a better scope on soil mechanics and geotechnical engineering.

Best wishes

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Japanese Geotechnical Society Standards －Geotechnical and Geoenvironmental Investigation Methods－

1 Procedure for Translating Standards into English

This document contains the geotechnical and geoenvironmental investigation standards of the Japanese Geotechnical Society (JGS). The work of translating the standards into English is scheduled to take about 3 years from 2014. The English language standards are scheduled to be published in 3 separate volumes (Vol. 1 to Vol. 3) in order of priority of those standards most frequently used by practitioners. This is because we want to provide engineers with these Japanese geotechnical and geoenvironmental investigation standards as soon as possible to enable them to understand and refer to Japanese survey equipment together with Japanese geotechnical and geoenvironmental investigation standards. We feel that by translating into English the technical investigation standards that are used by Japanese engineers every day, the standards will be more meaningful for geotechnical and geoenvironmental investigations.

The following tables show all of the geotechnical and geoenvironmental investigation standards produced by JGS. This table of standards shows the order of publication according to the color of the standard. The standards shown in white characters against a colored background are standards that will be published in 2015 (Vol. 1). The standards with a shaded background will be published in the second round (Vol. 2), and the standards with no color will be published in the third round (Vol. 3). By publishing in English the JGS standards that are most frequently used by engineers, engineers will be able to easily refer to these geotechnical and geoenvironmental investigations standards in the course of their work.

The Japanese Geotechnical Society has cultivated specialist engineers, scholars, and researchers for over more than 60 years. The geotechnical and geoenvironmental investigation standards produced by the Society incorporate much of the know-how that has matured over this long period. By carrying out geotechnical and geoenvironmental investigations, design, and research with these standards by your side, the Japanese Geotechnical Society hopes that you will be able to contribute to the development of engineering and the economic development of your country.

Japanese Geotechnical Society

Table 1 List of geotechnical and geoenvironmental investigation standards part 1

dark grey	Standards published in the first round (Vol. 1)
light grey	Standards published in the second round (Vol. 2)
white	Standards published in the third round (Vol. 3)

Classification	Title	JGS Number	JIS Number	Vol.
Preliminary geotechnical investigations	Method for engineering classification of rock mass	JGS 3811		1
	Method for investigation on geometrical information of discontinuity distribution in rock mass	JGS 3821		1
Geophysical prospecting and well logging	Method for electrical logging	JGS 1121		2
Soil sampling	Method for seismic velocity logging	JGS 1122		1
	Method for obtaining soil samples using thin-walled tube sampler with fixed piston	JGS 1221		1
	Method for obtaining soil samples using rotary double-tube sampler	JGS 1222		1
	Method for obtaining soil samples using rotary triple-tube sampler	JGS 1223		1
	Method for obtaining samples using double-tube sampler with sleeve	JGS 1224		2
	Method for obtaining soil block samples	JGS 1231		2
	Method for obtaining soft rock samples using rotary tube sampler	JGS 3211		2
Groundwater investigations	Method for measuring groundwater level in borehole	JGS 1311		3
	Method for measuring groundwater level in well	JGS 1312		3
	Method for measuring pore water pressure using electric transducer in borehole	JGS 1313		3
	Method for determination of hydraulic properties of aquifer in single borehole	JGS 1314		3
	Method for pumping test	JGS 1315		3
	Method for determination of hydraulic conductivity of compacted fill	JGS 1316		3
	Method for flow layer logging by tracer	JGS 1317		3
	Method for determination of hydraulic properties of rock mass using instantaneous head recovery technique in single borehole	JGS 1321		3
	Method for determination of hydraulic conductivity of rock mass using injection technique in single borehole	JGS 1322		3
	Method for lugeon test	JGS 1323		3
Sounding	Method for standard penetration test		JIS A1219	1
	Method for mechanical cone penetration test		JIS A1220	1
	Method for Swedish weight sounding test		JIS A1221	1
	Method for field vane shear test	JGS 1411		2
	Method for portable cone penetration test	JGS 1431		2
	Method for portable dynamic cone penetration test	JGS 1433		2
	Method for electric cone penetration test	JGS 1435		2
	Method for soil hardness test	JGS 1441		3
	Method for rebound hammer test on rocks	JGS 3411		3
	Method for point load test on rocks	JGS 3421		3
	Method for needle penetration test	JGS 3431		3
Loading tests	Method for plate load test on soils for road		JIS A1215	3
	Test method for the california bearing ratio (cbr) of in-situ soil		JIS A1222	3
	Method for plate load test	JGS 1521		1
	Pressuremeter test to evaluate index of the ground	JGS 1531		1
	Methods for in-situ direct shear test on rocks	JGS 3511		1
	Pressuremeter test to evaluate mechanical properties of the ground	JGS 3531		1
	Method for borehole jack test	JGS 3532		1
Site density tests	Test method for soil density by the compacted sand replacement method	JGS 1611		3
	Test method for soil density by the water replacement method	JGS 1612		3
	Test method for soil density by the sand replacement method		JIS A1214	2
	Method for measuring in-situ soil density using core cutter	JGS 1613		3
	Test method for soil density using nuclear gauge	JGS 1614		3

Table 2 List of geotechnical and geoenvironmental investigation standards part 2

Standards published in the first round (Vol. 1)
Standards published in the second round (Vol. 2)
Standards published in the third round (Vol. 3)

Classification	Title	JGS Number	JIS Number	vol.
Site measurement of soil behaviors	Method for measuring displacement of ground surface using stakes	JGS 1711		3
	Method for measuring settlement of ground surface using settlement plate	JGS 1712		3
	Method for measuring vertical displacement of embankment using cross arm settlement gauge	JGS 1718		3
	Method for measuring tilt of ground surface using tiltmeter	JGS 1721		3
	Method for measuring displacement of ground surface using extensometer	JGS 1725		2
	Method for measuring ground movement using strain gauge	JGS 1731		2
	Methods for measuring convergence and crown settlement on rocks	JGS 3711		2
	Methods for monitoring rock displacements using borehole extensometers	JGS 3721		2
	Methods for monitoring rock displacements using borehole inclinometers	JGS 3722		2
	Method for pull□out test of rock bolts installed in rock mass	JGS 3731		1
	Method for initial stress measurement by overcoring technique using multi□axial strain gauge	JGS 3741		1
	Method for initial stress measurement by compact conical-ended borehole overcoring technique	JGS 3751		1
Method of investigation for soil and groundwater contamination	Method for obtaining samples for environmental chemical analysis using double tube sampler with sleeve	JGS 1911		2
	Method for obtaining samples for environmental chemical analysis using direct push Method	JGS 1912		2
	Method for obtaining subsurface soil samples for environmental chemical analysis	JGS 1921		2
	Method for obtaining groundwater samples for environmental chemical analysis from monitoring well	JGS 1931		2
	Method of soil gas sampling by direct conduction for environmental chemical analysis	JGS 1941		1
	Method of active soil gas sampling for environmental chemical analysis	JGS 1942		1
	Method of passive soil gas sampling for environmental chemical analysis	JGS 1943		1
	Method for air permeability test in vadose zone	JGS 1951		3

2 JGS and JIS Numbers

Each of the geotechnical and geoenvironmental investigation standards in this list is an investigation standard produced by the Japanese Geotechnical Society. Each standard has “JGS” in front of a number. The “JIS” that is written with each of the JGS numbers is an abbreviation for “Japanese Industrial Standard.” Japanese Industrial Standards are recognized by the Japanese Ministry of Economy, Trade and Industry of Japan and are based on the JGS standard. In these standards, each investigation standard number is given a JGS number and also a matching JIS number. This means that the standard produced by the Japanese Geotechnical Society is a Japanese standard. This is sufficient for users to understand. In practice, either number may be used.

3 Sponsors of the Translation of the Standards into English

The English language versions of these standards have been produced through donations from Japanese construction companies, design consultants, and testing organizations. The Japanese Geotechnical Society expresses its heartfelt thanks to each company that has made a donation.

An advertisement for each company that has made a donation will be published at the end of the standards. We would be pleased if you would refer to these advertisements when using these geotechnical and geoenvironmental investigations standards and use the advertised products and services in your work.

Geotechnical and Geoenvironmental Investigation Methods

Table of Contents

Japanese Geotechnical Society Standard (JGS 3811-2011)
Method for engineering classification of rock mass

1 Scope

This standard specifies a method for classifying rock mass in engineering terms, based on the results of surveys and tests of rock mass outcrops. Appendix A shows the engineering classification system for rock mass.

Note 1: These outcrops are required to be of sufficient size to enable confirmation that the rock is rock mass as defined in 3.1. Accordingly, the outcrops shall be approximately several meters or more on a side.

Note 2: This standard may be applied to the engineering classification system of rock mass obtained by means of boring cores.

2 Normative references

The following standards shall constitute a part of this standard by virtue of being referenced in this standard. The latest versions of these standards shall apply (including supplements).

JGS 2521	Method for uniaxial compression test on rocks
JGS 3821	Method for investigation on geometrical information of discontinuity distribution in rock mass
ISO 14689-1	Geotechnical investigation and testing — identification and description of rock

3 Terms and definitions

The terms and definitions used in this standard are as follows:

3.1 Rock mass

Natural ground composed of rock material.

Note: In general, discontinuities and various degrees of weathering and alteration are distributed in the rock mass.

3.2 Rock material

Aggregations of minerals that have undergone various degrees of consolidation and binding. These aggregations form rock mass sections that do not include discontinuity.

3.3 Rock

General term for both rock material and rock mass.

3.4 Discontinuities

Joints, cracks, and other planes that interrupt the mechanical continuity of rock material. These planes are mechanically weak, with zero or extremely low tensile strength.

Note: The spacing of discontinuities is defined as the vertical distance between adjacent discontinuities belonging to the same sets.

3.5 Matrix

Fine-grained, glassy, or amorphous matter that fills the gaps between larger rock material fragments and mineral particles making up rock material.

Note: Sedimentary rock and igneous rock are sometimes referred to as matrix and groundmass rock, respectively. In this standard, both shall be referred to generally as matrix.

3.6 Foliation

A planar structure formed by the planar arrangement of mineral particles making up the rock.

Note: Conversely, rock with no observable foliated structure is referred to as massive.

3.7 Classification element

A basic property of rock mass, used for the classification of rock mass in engineering terms (see Appendix B and Appendix C).

Note: The basic properties of rock mass used for classification include physical properties of the rock material and other constituent materials, properties relating to the discontinuity of the rock mass, the weathered state of the rock mass, and other properties.

4 Surveys and Tests for Categorization by Classification Elements

In order to classify rock mass in engineering terms, the following surveys and tests shall be performed. These surveys and tests shall provide results of sufficient precision to determine the applicable category of the classification element.

Note: The surveys and tests necessary for a particular rock classification shall be selected in advance of carrying out the surveys and tests in accordance with the stage of classification.

4.1 Test of rock material strength

The strength of rock material in the engineering classification of rock mass shall be expressed in terms of uniaxial compressive strength and shall be determined in accordance with JGS 2521.

Note: Where it is difficult to determine the uniaxial compressive strength directly, a uniaxial compressive strength estimated according to the precision required for the study using one of the following indirect methods may be used.

(1) By correlation against the tensile strength of the rock material (in accordance with JGS 2551)
(2) By correlation with the ultrasonic wave velocity of the rock material (in accordance with JGS 2110)
(3) By correlation with the reaction to impact (in accordance with JGS 3411)
(4) By correlation with a point load test on the rock material (in accordance with JGS 3421)
(5) By correlation with the results of a needle penetration test (in accordance with JGS 3432)
(6) Sounding by a hammer
(7) Estimation based on the rock material type

4.2 Survey of foliation

Determine the presence or absence of foliation by means of a study of plane splitting, plane spacing, rock texture, and other properties.

Note: Foliation may occur in any type of rock material, but they are typically found in crystalline schist, gneiss, phyllite, and other metamorphic rock.

4.3 Survey of discontinuity

Based on the results of a study conducted in accordance with JGS 3821, investigate the spacing between discontinuities, the number of sets of discontinuities, aperture, roughness, and filling material.

Note 1: If there are several sets of discontinuities and the spacings between planes are comparatively narrow, the apparent spacing may be considered to be the spacing between discontinuities.

Note 2: Use a crack scale or a feeler gauge or similar to measure the aperture of a discontinuity.

Note 3: Overall roughness consists of large-scale surface irregularities (wavelike, stepped, and planar irregularities) on which small-scale secondary and tertiary irregularities are superimposed. Accordingly, two different scales of observation shall be used: large scale (over a length of approximately 1-2 m) and small scale (over a length of 10 cm). The method shall be selected according to the scale being observed.

Note 4: In this standard, quartz veins, calcite veins, and other hard mineral veins shall not be treated as filling material.

4.4 Survey of the grain size of the constituent materials in rock material

Investigate the predominant particle size of the rock material. The predominant particle size shall be the one with the most dominant content by volume.

Note: If the rock material can be broken down to its constituent particles and a grain size analysis can be conducted, the results of this test can be used. However, if the grain size analysis is not possible, a visual inspection or a tactile test of the rock material surface may be conducted to determine whether the predominant particle size is sandy, silty, clayey, or rougher than sand.

4.5 Survey of fragment content

Investigate the fragment content of the rock. In this standard, the fragment content shall be expressed in terms of volumetric content and if necessary, shall be estimated from a fragment distribution study using a two-dimensional section of the rock mass outcrop.

4.6 Survey of layer thickness

Investigate the layer thickness. The method used to measure the layer thickness shall be equivalent to that used for the measurement of spacings between discontinuities.

Note: Here, layer thickness shall refer to the vertical distance between the bedding planes of a single layer.

4.7 Survey of weathering and alteration

In this standard, variations in color of rock material and discontinuities, and variations in the particle structure and texture of the rock material, as well as the proportion of each variation, shall be investigated to determine the degree of weathering.

Note: Hereafter in this standard, the term "weathering" shall be considered to include all modes of alteration except special cases.

4.8 Other studies

Existing geological references for the location shall be used to obtain information about the rock mass structure, the geological origin of the rock, the rock type, and other characteristics. If necessary, a relatively wide-ranging geological investigation that includes the outcrop in question shall be conducted.

5 Classification of Rock Mass

Based on the results of the surveys and tests, the engineering classification of rock mass shall be carried out in the following order: primary classification, secondary classification, tertiary classification, and subclassification. Of these classification stages, subclassification shall be implemented only as needed, and shall be carried out after the required classification elements have been selected. Figure A.1 shows the system of the engineering classification of rock mass.

The following symbols shall be used to denote the classification:

[ ] indicates the primary classification
{ } indicates the secondary classification
( ) indicates the tertiary classification

The format shall be "primary classification • secondary classification" — "tertiary classification" / "subclassification".

5.1 Primary classification

The primary classification shall be based on the uniaxial compressive strength of the rock material.

Rock mass consisting of rock material with a uniaxial compressive strength of approximately 25 MN/m^2 or greater and weathered rock mass consisting of rock material with a uniaxial compressive strength of approximately 25 MN/m^2 or greater in its natural state shall be categorized as "hard rock mass" [H].

Rock mass other than "hard rock mass"— in other words, rock mass consisting of rock material with a uniaxial compressive strength in the fresh state of less than approximately 25 MN/m^2 — shall be categorized as "soft rock mass" [S].

Note 1: The 25 MN/m^2 value of uniaxial compressive strength set as the boundary between "hard" and "soft" rock mass is a general guideline rather than a strict boundary.

Note 2: Weathered rock shall be categorized according to the assumed uniaxial compressive strength of the rock material in its fresh state. This may be roughly estimated by identifying the rock type and basing the strength on a large quantity of existing test data.

Note 3: Here, "soft rock mass" is equivalent to rock mass that, in Japan, is primarily sedimentary and pyroclastic rock from the Paleogene and subsequent eras.

5.2 Secondary classification

The secondary classification shall be based on the structure and texture of the rock.

Hard rock mass [H] shall be categorized as either "Massive" {M} or "Foliated" {F} depending on the crystal grain arrangement, structure, and other characteristics.

Soft rock mass [S] shall be categorized as "Massive" {M} (rock mass consisting of rock material with homogeneous constituents), "Rudaceous" {R} (rock mass consisting of fragment and matrix), or "Interbedded" {B} (rock mass with layers made of different constituents stacked in thin layers). (See Fig. 1.)

Note 1: "Hard massive rock mass" HM shall include rock mass with stacks of layers with different properties such as alternating sandstone and shale layers, rudaceous rock mass, and other heterogeneous rock mass. In general, however the engineering properties of hard rock mass are greatly affected by the presence of discontinuity, so these types of rock mass are also treated as "massive."

Note 2: With regard to "soft rock mass," rock mass that can be treated as homogenous in engineering terms shall be categorized as "soft massive rock mass," while rock mass that is required to be treated as heterogeneous shall be categorized as "soft interbedded rock mass" or "soft rudaceous rock mass."

Note 3: "Soft interbedded rock mass" SB shall be rock mass whose a single layer thickness is approximately 60 cm or less on average, and in which multiple layers with different lithological characteristics are stacked alternately. Here "a single layer" shall refer to a distinct rock with generally uniform grain size, lithological characteristics, and other characteristics, and having clear bedding planes with the upper and lower layers.

5.3 Tertiary classification and subclassification

The tertiary classification and subclassification shall be based on two classification elements that dominate the engineering properties of each of the rock mass classifications obtained in the secondary classification process. The result is presented as a symbol representing each classification element.

Table B.1 and Table C.1 show the classification elements and the categories and respective symbols for tertiary classification and subclassification, respectively. Figure B.1 shows the categories for "roughness of discontinuity" and Table D.1 shows the categories for "weathering."

Note: Subclassification shall be used when there is a need to supplement the tertiary classification.

5.3.1 Classification of hard massive rock mass HM

Hard massive rock mass HM shall be classified as follows.

a) Tertiary classification shall be based on the two categories of "rock material strength" and "spacing between discontinuities."

b) Subclassification shall be based on "degree of weathering," "number of sets of discontinuities," "aperture of discontinuity," "roughness of discontinuity," and "presence or absence of filling material."

Note 1: Many igneous and sedimentary rocks are classified in this category.

Note 2: Of the classification elements relating to discontinuities, "aperture of discontinuity" is easily affected by loosening as a result of excavation, so the outcrop should be carefully checked for its suitability for observation.

5.3.2 Classification of hard foliated rock mass HF

Hard foliated rock mass HF shall be classified as follows.

a) Tertiary classification shall be based on the two categories of "rock material strength" and "spacing between discontinuities."

b) Subclassification shall be based on "degree of weathering," "number of sets of discontinuities," "aperture of discontinuity," "roughness of discontinuity," and "presence or absence of filling material."

Note 1: Hard foliated rock mass HF shall include crystalline schist, phyllite, slate, and other metamorphic rocks with pronounced foliated structures, as well as rock mass with strongly mechanical anisotropy that has a similar structure and texture.

Note 2: The handling of classification elements used for tertiary classification and subclassification shall be the same as for HM rock mass.

5.3.3 Classification of soft massive rock mass SM

Soft massive rock mass SM shall be classified as follows.

a) Tertiary classification shall be based on the two categories of "rock material strength" and "predominant particle size."

b) Subclassification shall be based on "degree of weathering" and "spacing between discontinuities."

Note: Soft massive rock mass SM shall include sandstone, mudstone, and other soft sedimentary rock, tuff and other homogenous pyroclastic rock, and so on.

5.3.4 Classification of soft rudaceous rock mass SR

Soft rudaceous rock mass SR shall be classified as follows.

a) Tertiary classification shall be based on the two categories of "matrix strength" and "fragment content."

b) Subclassification shall be based on "degree of weathering," "predominant particle size of matrix," "boulder content," "predominant fragment diameter," and " fragment strength."

Note 1: Soft rudaceous rock mass SR shall be made up of fragment and matrix. In general, the fragment is harder than the matrix. This classification also shall include autobrecciated lava with soft matrix, melange, the so-called olistostrome strata, rock mass made up of fragment and matrix observed in groups of layers, and similar rock.

Note 2: When the rock mass consists of fragment with a generally uniform particle size of several mm, such as lapilli tuff, it may be treated as soft massive rock mass.

Note 3: "Matrix strength" shall be recorded in the same category as "rock material strength." If there is a high fragment content and it is difficult to determine the matrix strength (uniaxial compressive strength) directly, the needle penetration test method or another suitable method is required to be used.

Note 4: "Boulder content" shall be defined as the volumetric content of fragments with a diameter of 200 mm or greater. "Predominant fragment diameter" shall refer to the most dominant fragment diameter in terms of content by volume. "Fragment strength" shall be recorded in the same category as "Rock strength," but in many cases it is difficult to determine the uniaxial compressive strength directly, so a point loading test or other suitable method is required to be used.

5.3.5 Classification of soft interbedded rock mass SB

Soft interbedded rock mass SB shall be classified as follows.

a) Tertiary classification shall be based on the two categories of "difference in layer strength category" and "component ratio of weak layers." See Table 1.

Note 1: "Hard layer" and "weak layer" shall indicate the hardest layer and weakest layer, respectively, of the layers making up the interbedded rock mass.

Note 2: "Component ratio of weak layers" shall be the volumetric content of weak layers out of the whole.

Note 3: "Difference in layer strength category" shall be the combination of "layer strength" D, E, F, and G for hard layers and "layerstrength" D, E, F, and G for weak layers, as noted in Table 1.

Note 4: If it is difficult to determine directly the strength of layers that are less than several centimeters thick, the needle penetration test method or another suitable method is required to be used.

b) Subclassification shall be based on "degree of weathering" and "average thickness of weak layers."

Note 5: "Average thickness of weak layers" shall be the average vertical distance between the bedding planes of the weakest layer.

Note 6: If it is necessary to evaluate the properties of each layer, the target layer shall be clearly indicated and then the "soft massive rock mass" classification shall be applied and the results must be appended.

5.3.6 Fracture zone classification

Rock mass that forms fracture zones may be classified by applying the classification methods for hard and soft rock mass shown in Fig. A.1, Fig. 1, Table B.1, and Table C.1. If these methods are applied, append the letter "f" before the primary classification symbol to indicate that the zone is a fracture zone.

6 Reporting

The following items shall be reported.

a) Classification names and symbols and classification elements used

Note 1: Classification names resulting from primary and secondary classification, and classification symbols determined in primary, secondary, and tertiary classification, as well as subclassification, shall be reported.

Note 2: Whether or not subclassification was carried out and, if it was, the reason for the decision to use or not use classification elements shall be reported.

Note 3: If there is more than one classification name and symbol, these shall be listed together with boundary lines using a figure or the like.

b) Method used to determine the categories for classification elements and the results achieved

Note 4: Evaluation and judgment of classification elements are done based on the results of surveys and tests. Various methods may be used depending on the stage of the study, the required precision, and so on. Accordingly, the method used to determine the categories for classification elements shall be provided.

c) If the method used deviates in any way from this standard, give details of the method used.

d) Other reportable matters

Note 5: Geological information is crucial for a determination of the engineering properties of rock mass. Accordingly, when geological information is available from existing geological references, geological investigations, and the like, it is recommended to note this information. Examples may include the geological age of the target rock mass, stratum name, rock type, nearby geological structures, geological origin of the rock, and so on.

Note 6: Information relating to the rock mass outcrop targeted in the study shall be clearly noted. For example, this may include whether it is a natural outcrop or an excavation face or other artificial outcrop, the size of the outcrop, the excavation method (in the case of an artificial outcrop), and other relevant matters.

Note 7: If photographs and sketches of the rock mass have been produced, these materials shall be appended.

Hard rock mass [H]

Rock strength 25 MN/m^2 or greater or fresh rock strength 25 MN/m^2 or greater

- Massive {M}: Hard massive rock mass, HM
  Rock material with no significant planar/schistose texture
- Foliated {F}: Hard foliate rock mass, HF
  Rock material with significant planar/schistose texture

Soft rock mass [S]

Fresh rock strength less than 25 MN/m^2

- Massive {M}: Soft massive rock mass, SM
  Homogenous constituent materials
- Rudaceous {R}: Soft rudaceous rock mass, SR
  Composed of fragment and matrix
- Interbedded {B}: Soft interbedded rock mass, SB
  Rock material of different constituent materials stacked in alternating layers

Fig. 1 Configuration and nomenclature for primary classification and secondary classification

Table 1 Layer strength combinations and symbols for soft interbedded rock mass

		Strength category for weak layers			
		D	E	F	G
Strength category for hard layers	D	DD	DE	DF	DG
	E		EE	EF	EG
	F			FF	FG
	G				GG

Appendix A
(Standard)

Engineering classification system of rock mass

A.1 Engineering classification system of rock mass

Fig. A.1 shows the engineering classification system of rock mass.

Primary classification → Secondary classification → Tertiary classification → Subclassification

Hard rock mass [H] → Massive [M] / Foliated [F]

Tertiary classification (Rock material strength (MN/m²) × Spacing between discontinuities (mm): 2 000, 600, 200, 60, 20):

Rock material strength (MN/m²)		I	II	III	IV	V	VI
	A	A I	A II	A III	A IV	A V	A VI
100	B	B I	B II	B III	B IV	B V	B VI
50	C	C I	C II	C III	C IV	C V	C VI
25	D	D I	D II	D III	D IV	D V	D VI
10	E	E I	E II	E III	E IV	E V	E VI
5	F	F I	F II	F III	F IV	F V	F VI

Subclassification:

No.	Degree of weathering	Number of sets of discontinuities	Aperture of discontinuity	Roughness of discontinuity	Presence or absence of filling material
1	w_1	n_1	a_1	r_{sr}	f_1
2	w_2	n_2	a_2	r_{sm}	f_2
3	w_3	n_3	a_3	r_{ss}	f_3
4	w_4	n_4	a_4	r_{wr}	
5	w_5	n_5	a_5	r_{wm}	
6	w_6		a_6	r_{ws}	
7				r_{pr}	
8				r_{pm}	
9				r_{ps}	

Soft rock mass [S] → Massive [M] / Rudaceous [R] / Interbedded [B]

Massive [M] — Tertiary classification (Rock material strength (MN/m²) × Predominant particle size (mm): 2, 0.063, 0.002):

Rock material strength (MN/m²)		I	II	III	IV
	D	D I	D II	D III	D IV
10	E	E I	E II	E III	E IV
5	F	F I	F II	F III	F IV
1	G	G I	G II	G III	G IV

Subclassification:

No.	Degree of weathering	Spacing between discontinuities
1	w_1	s_1
2	w_2	s_2
3	w_3	s_3
4	w_4	s_4
5	w_5	s_5
6	w_6	s_6

Rudaceous [R] — Tertiary classification (Matrix strength (MN/m²) × Fragment content (%): 50, 20, 10):

Matrix strength (MN/m²)		I	II	III	IV
	D	D I	D II	D III	D IV
10	E	E I	E II	E III	E IV
5	F	F I	F II	F III	F IV
1	G	G I	G II	G III	G IV

Subclassification:

No.	Degree of weathering	Predominant particle size of matrix	Boulder content	Predominant fragment diameter	Fragment strength
1	w_1	p_1	b_1	g_1	h_1
2	w_2	p_2	b_2	g_2	h_2
3	w_3	p_3		g_3	h_3
4	w_4	p_4		g_4	h_4
5	w_5				h_5
6	w_6				h_6
7					h_6

Interbedded [B] — Tertiary classification (Difference in layer strength category × Component ratio of weak layers (%): 10, 30, 50, 80):

Difference in layer strength category	I	II	III	IV	V
Equal	E.g., DD I	E.g., DD II	E.g., DD III	E.g., DD IV	E.g., DD V
One level	E.g., DE I	E.g., DE II	E.g., DE III	E.g., DE IV	E.g., DE V
Two levels	E.g., DF I	E.g., DF II	E.g., DF III	E.g., DF IV	E.g., DF V
Three levels	DG I	DG II	G III	DG IV	GD IV

Subclassification:

No.	Degree of weathering	Average thickness of weak layers
1	w_1	t_1
2	w_2	t_2
3	w_3	t_3
4	w_4	t_4
5	w_5	t_5
6	w_6	

* Classification of SM shall be noted if necessary.

Fig. A.1 Engineering classification system of rock mass

Appendix B
(Standard)

Classification elements and categories for hard rock mass

B.1 Classification elements and categories for hard rock mass

Table B.1 shows the classification elements and categories for hard rock mass.

Note: Figure B.1 shows the nomenclature and symbols used to depict large- and small-scale surface shapes and a standard roughness model. It should be noted that the large-scale roughness model in the figure is a conceptual diagram drawn with the surface irregularities slightly exaggerated.

Table B.1 Classification elements and categories for hard rock mass

<table>
<tr><td>Classification element</td><td colspan="18">Category</td></tr>
<tr><td rowspan="2">Rock material strength (MN/m^2)</td><td colspan="3">A</td><td colspan="3">B</td><td colspan="3">C</td><td colspan="3">D</td><td colspan="3">E</td><td colspan="3">F</td></tr>
<tr><td colspan="3">100 or more</td><td colspan="3">100 - 50</td><td colspan="3">50 - 25</td><td colspan="3">25 - 10</td><td colspan="3">10 - 5</td><td colspan="3">5 or less</td></tr>
<tr><td rowspan="2">Spacing between discontinuities (mm)</td><td colspan="3">I</td><td colspan="3">II</td><td colspan="3">III</td><td colspan="3">IV</td><td colspan="3">V</td><td colspan="3">VI</td></tr>
<tr><td colspan="3">2000 or more</td><td colspan="3">2 000 - 600</td><td colspan="3">600 - 200</td><td colspan="3">200 - 60</td><td colspan="3">60 - 20</td><td colspan="3">20 or less</td></tr>
<tr><td rowspan="2">Degree of weathering</td><td colspan="3">w_1</td><td colspan="3">w_2</td><td colspan="3">w_3</td><td colspan="3">w_4</td><td colspan="3">w_5</td><td colspan="3">w_6</td></tr>
<tr><td colspan="18">Table D.1</td></tr>
<tr><td rowspan="2">Number of sets of discontinuities</td><td colspan="4">n_1</td><td colspan="3">n_2</td><td colspan="4">n_3</td><td colspan="3">n_4</td><td colspan="4">n_5</td></tr>
<tr><td colspan="4">One sets</td><td colspan="3">Two sets</td><td colspan="4">Three sets</td><td colspan="3">Four sets</td><td colspan="4">Random</td></tr>
<tr><td rowspan="2">Aperture of discontinuity (mm)</td><td colspan="2">a_1</td><td colspan="4">a_2</td><td colspan="3">a_3</td><td colspan="3">a_4</td><td colspan="3">a_5</td><td colspan="3">a_6</td></tr>
<tr><td colspan="2">0.1 or less</td><td colspan="4">01 - 0.25</td><td colspan="3">0.25 - 0.5</td><td colspan="3">0.5 - 2.5</td><td colspan="3">2.5 - 10</td><td colspan="3">10 or more</td></tr>
<tr><td rowspan="2">Roughness of discontinuity</td><td colspan="2">r_{sr}</td><td colspan="2">r_{sm}</td><td colspan="2">r_{ss}</td><td colspan="2">r_{wr}</td><td colspan="2">r_{wm}</td><td colspan="2">r_{ws}</td><td colspan="2">r_{pr}</td><td colspan="2">r_{pm}</td><td colspan="2">r_{ps}</td></tr>
<tr><td colspan="18">Fig. B.1</td></tr>
<tr><td rowspan="2">Presence or absence of filling material</td><td colspan="6">f_1</td><td colspan="6">f_2</td><td colspan="6">f_3</td></tr>
<tr><td colspan="6">Absent</td><td colspan="6">Partially filled</td><td colspan="6">Fully filled</td></tr>
</table>

Small scale (10 cm) / Large scale (1-2 m)	Rough: r	Medium (relatively rough): m	Smooth: s
Stepped: s	r_{sr}	r_{sm}	r_{ss}
Wavelike: w	r_{wr}	r_{wm}	r_{ws}
Planar: p	r_{pr}	r_{pm}	r_{ps}

Fig. B.1 Categories for the roughness of discontinuity

Appendix C
(Standard)

Classification elements and categories for soft rock mass

C.1 Classification elements and categories for soft rock mass

Table C.1 shows the classification elements and categories for soft rock mass.

Table C.1 Classification elements and categories for soft rock mass

Classification element	Category						
Rock material strength (MN/m²)	D	E	F	G			
	25 - 10	10 - 5	5 - 1	1 or less			
Matrix strength (MN/m²)	D	E	F	G			
	25 - 10	10 - 5	5 - 1	1 or less			
Difference in layer strength category	DD/EE/FF/GG	DE/EF/FG	DF/EG	DG			
	Equal	One level	Two levels	Three levels			
Predominant particle size (mm)	I	II	III	IV			
	2 or more	2 - 0.063	0.063 - 0.002	0.002 or less			
Fragment content (%)	I	II	III	IV			
	50 or more	50 - 20	20 - 10	10 or less			
Component ratio of weak layers (%)	I	II	III	IV	V		
	10 or less	10 - 30	30 - 50	50 - 80	80 or more		
Degree of weathering	w_1	w_2	w_3	w_4	w_5	w_6	
	Table D.1						
Spacing between discontinuities (mm)	s_1	s_2	s_3	s_4	s_5	s_6	
	2000 or more	2 000 - 600	600 - 200	200 - 60	60 - 20	20 or less	
Predominant particle size of matrix (mm)	p_1	p_2	p_3	p_4			
	2 or more	2 - 0.063	0.063 - 0.002	0.002 or less			
Boulder content (%)	b_1	b_2					
	10 or above	Below 10					
Predominant fragment diameter (mm)	g_1	g_2	g_3	g_4			
	630 or more	630 - 200	200 - 63	63 or less			
Fragment strength (MPa or MN/m²)	h_1	h_2	h_3	h_4	h_5	h_6	h_7
	100 or more	100 - 50	50 - 25	25 - 10	10 - 5	5 - 1	1 or less
Average thickness of weak layers (mm)	t_1	t_2	t_3	t_4	t_5		
	600 or more	600 - 200	200 - 60	60 - 20	20 or less		

Appendix D
(Standard)

Categories of weathering stages of rock mass

D.1 Categories of weathering stages of rock mass

Table D.1 shows the categories of weathering stages of rock mass.

References

ISRM 1977: Suggested methods for the quantitative description of discontinuities in rock masses

Table D.1 Categories of weathering stages of rock mass

Term	State of weathering/alteration	Category
Fresh	No signs of discoloration or other weathering/alteration in the rock material. Only slight discoloration in the major discontinuity.	W_1
Slightly weathered/ altered	Discoloration observed in rock material and discontinuity.	W_2
Moderately weathered/altered	Rock material is discolored brown but the discoloring extends to less than half of the rock mass volume. The fresh and discolored or brownish rock is evident in a discontinuous framework structure or nuclear pattern.	W_3
Highly weathered/altered	Rock material is discolored brown and the coloring extends to more than half of the volume. The fresh and discolored or brownish rock is evident in a discontinuous framework structure or a nuclear pattern.	W_4
Completely weathered/altered	All of the rock material has become discolored or has become brownish soil or altered minerals. The original texture of the rock mass appears to have hardly changed at all.	W_5
Residual soil/altered	All of the rock material has turned into soil or altered minerals. The rock mass structure and texture of the rock have collapsed and cannot be determined. There are major changes in volume, but in the case of weathering there is no significant movement of the soil.	W_6

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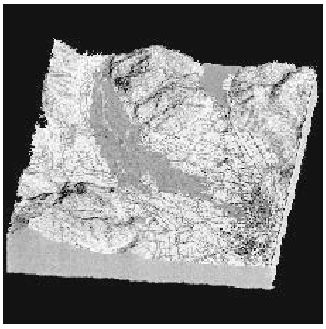

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The construction of civil engineering structural shall be considered the effect of the earthquake.
The earthquake caused by the fault movement is increasing and can be roughly predicted the damage scale by examining the active faults in a vicinity of construction site.
Our company offers a high degree of reliable data by the advanced investigation technology over half a century.

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We pursue improvments of customer satisfaction in every aspect and are always creating new values.

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We aim for the realization of a safe and secure society for all via laboratory tests of geomaterials.

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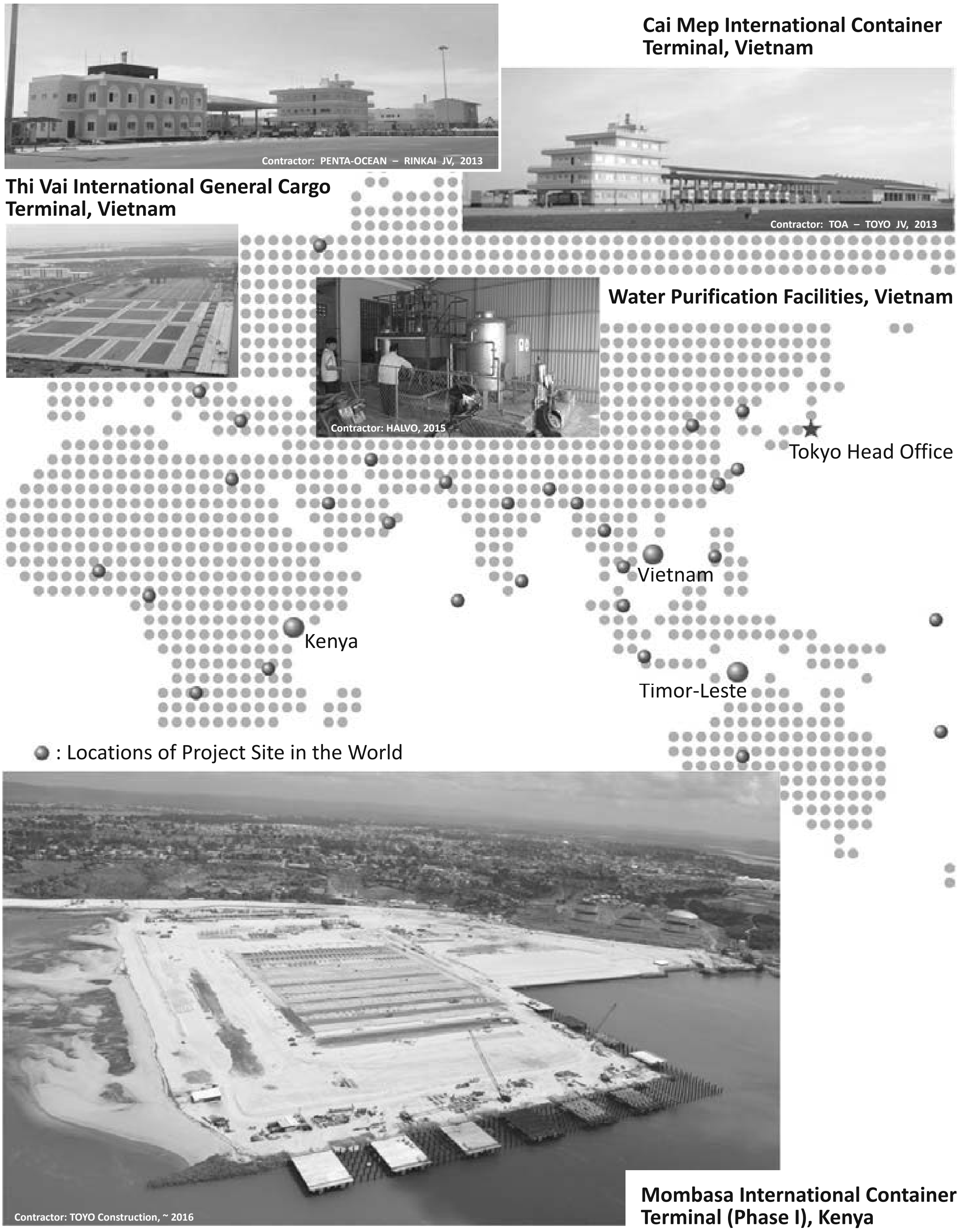
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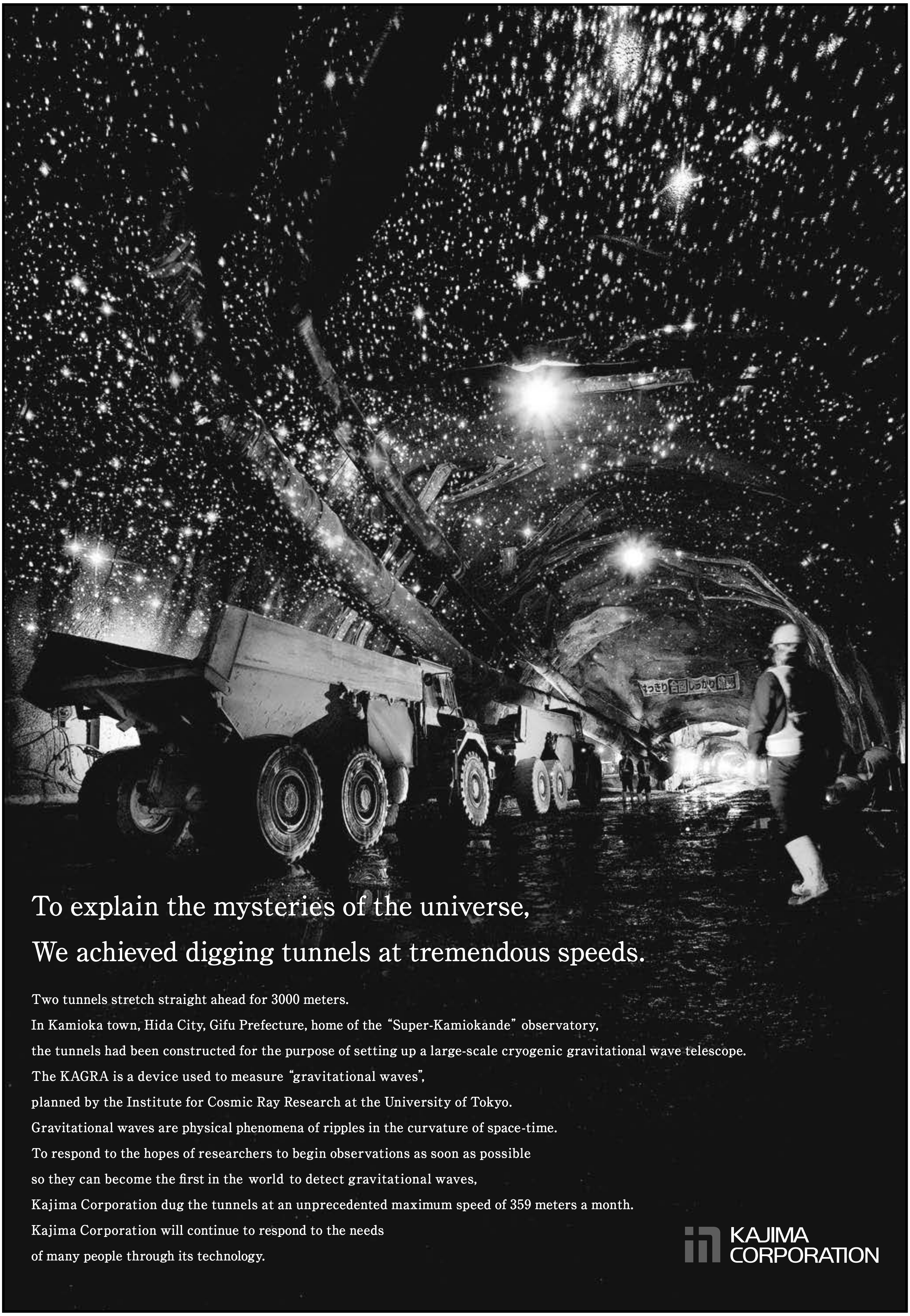
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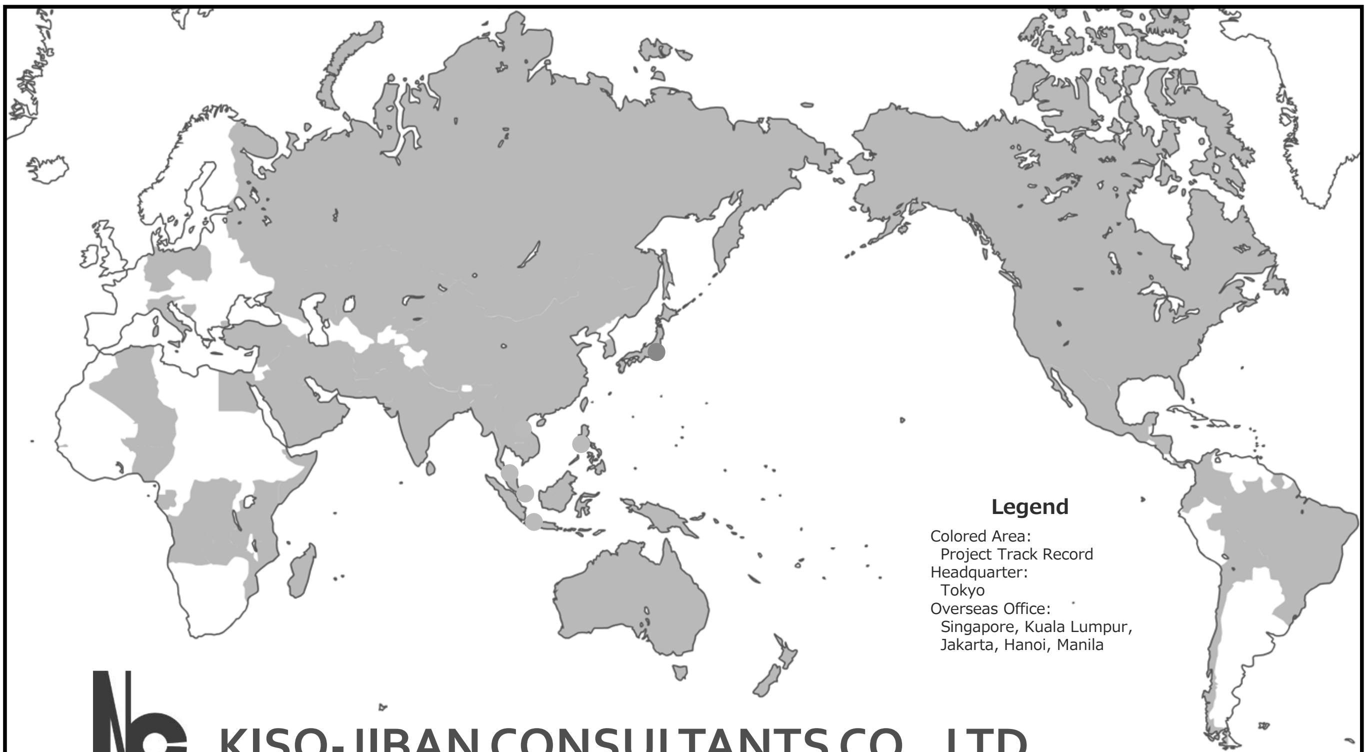

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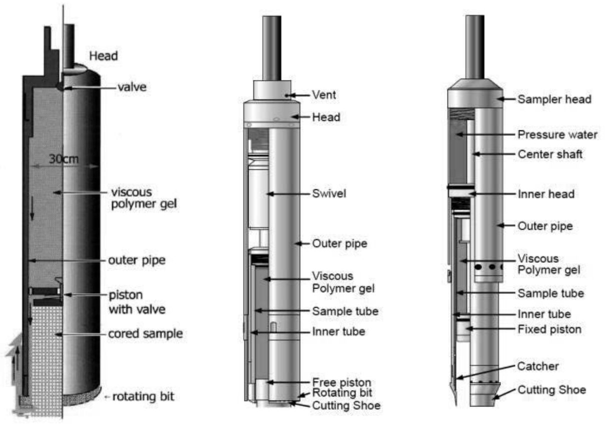
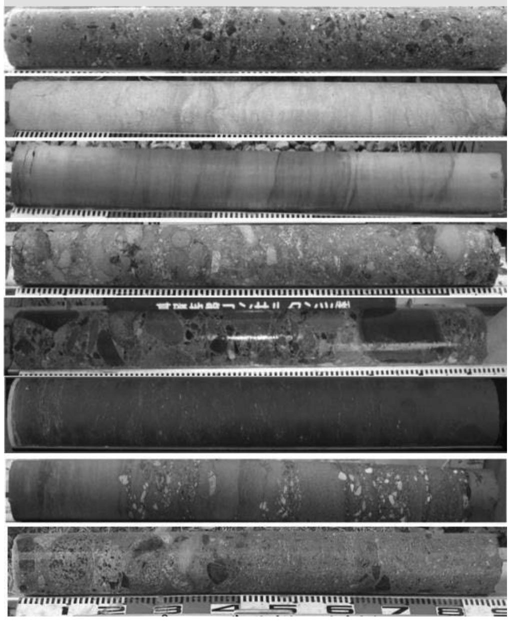
Among existing sampling technologies, the most noteworthy technology should be Gel-Push Sampler which was developed by KISO-JIBAN. Gel-Push Samplers enable to obtain undisturbed soil samples on fragile soft ground.

GP-D type (Single Tube Sampler Type)	GP-Tr type (Triple Tube Sampler type)	GP-S type (Thinwall Sampler type)



Undisturbed Samples Obtained with GP Sampler



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Geophysical Survey & Analysis

KISO-JIBAN has developed and innovated a number of geophysical survey technologies as well as analysis software.

One of our notable geophysical survey method, 3D seismic refraction survey, enables the visualization of elastic wave velocity for underground structure.

For geotechnical analysis, we leverage our technical expertise and our experience in choosing method and forming judgment.

Being an international company, we are capable to work with all major international standards such as ASTM (American), BS (British), EN (European), DIN (German), and GOST (Russian).

As a pioneer, we are committed to keep listening to our clients and to move forward to the future.

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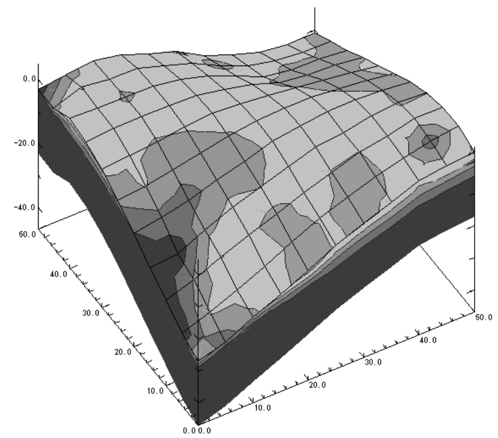

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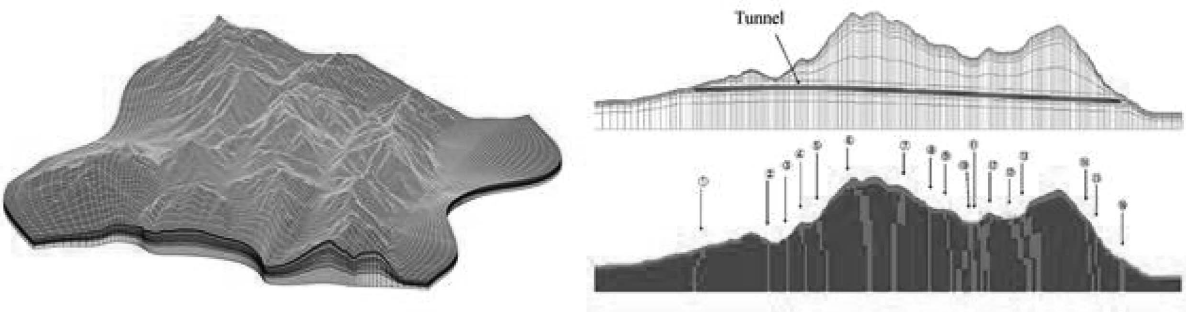

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A&S Soil Improvement Method (Absorption and Subsidence Soil Improvement Method)

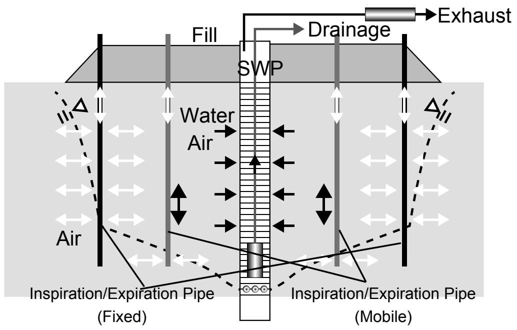
Summary

This method is able to improve soil property in a short term by 3 points.

①Suctioning pore water by Super Well Point Method(SWP)

②Improve permeability by inspiration and expiration in the ground

③Promote consolidation settlement by loading fill



Diagrammatical view: A&S Soil Improvement Method

Feature

①Subsidence convergence in only 3months

②The cost will be half or less than deep mixing method

③The applicable depth is around 50m (Experience:30m)

④It controls residual settlement surely

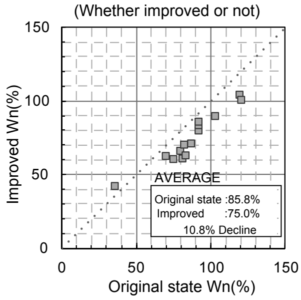
⑤Compact construction facilities

⑥Only the pipe of the SWP is left

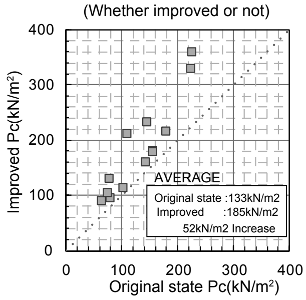
Cunstruction

Result

Comparing naturarl water content
(Whether improved or not)



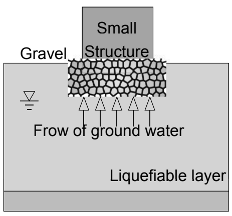
Comparing Consoilidation yield stress
(Whether improved or not)



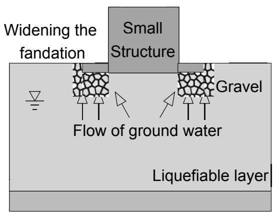
Gravel Support Method

Summary

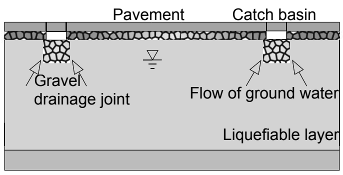
The gravel support method reduces liquefaction-induced damage of small structures or outdoor facilities by improving only the ground surface with highly permeable gravel layer.



newly-constructed structures
(Gravel layer)



pre-existing structures
(Gravel layer+ Widening the foundation)



outdoor facilities
(Gravel drainage joint)

Applicability

(1)Structures which meets all four conditions below

①Weight : less than 5t/m²

②Short side length : less than 15m

③Thickness of the foundation (pre-existing structures only) : larger than 50cm

④No habitable room

(2)Outdoor facilities

Advantage

①Liquefaction-induced damages can be largely reduced by improving only the surface layer

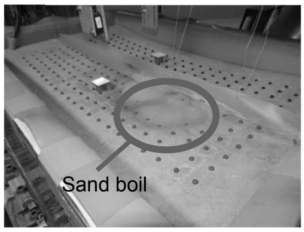
②Can significantly reduce the cost in compare with other existing methods

③Is application to wide variety of construction conditions

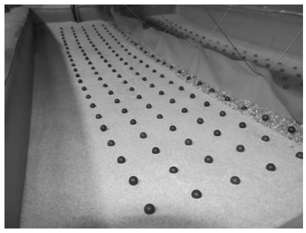
④Can be constructed without stopping the operation of facilities

Effect of the measures

Verification of the effect of the measures by centrifugal model tests



No measures


Gravel Support Method

Today's Work,
Tomorrow's Heritage

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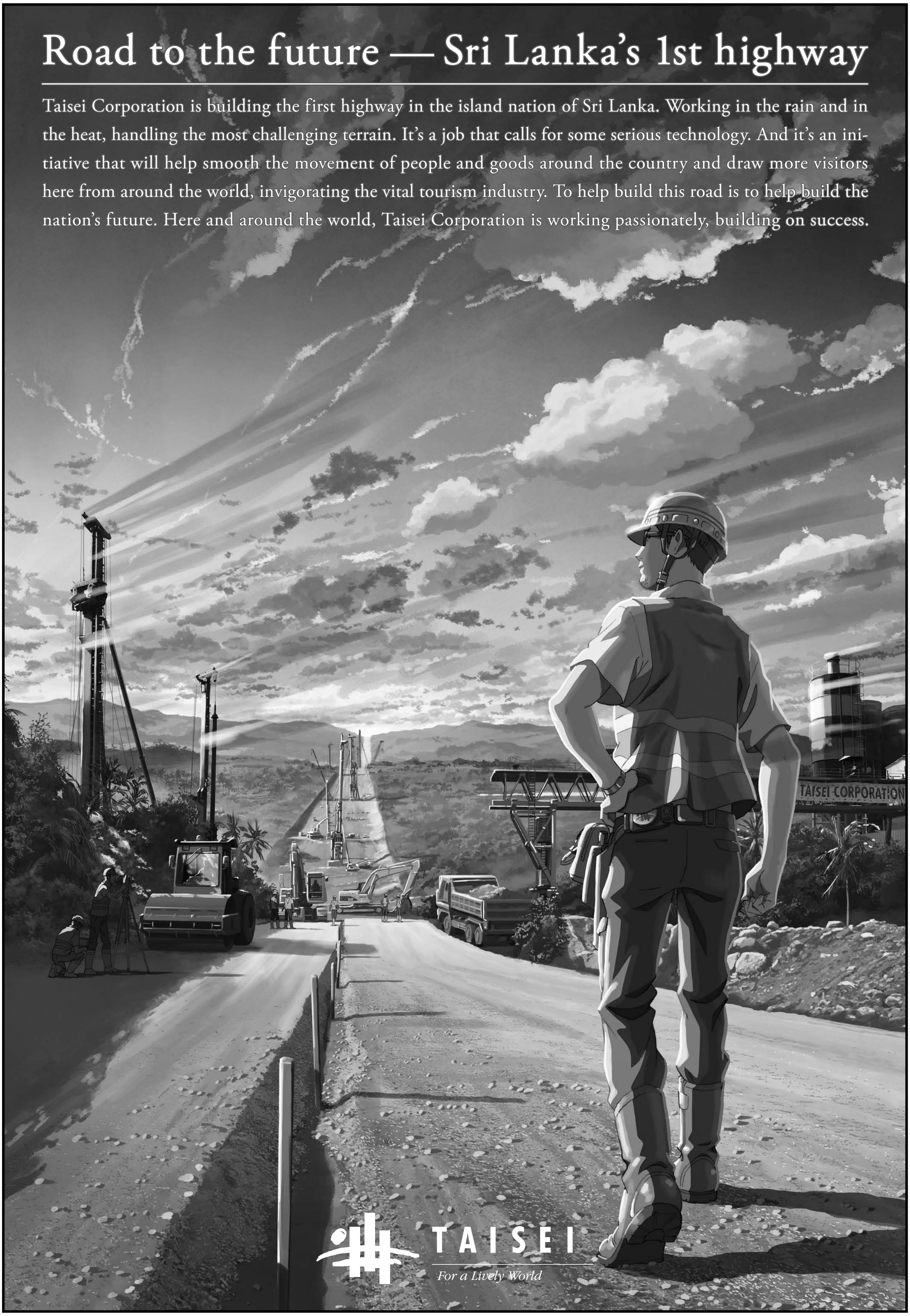
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Taisei Corporation is building the first highway in the island nation of Sri Lanka. Working in the rain and in the heat, handling the most challenging terrain. It's a job that calls for some serious technology. And it's an initiative that will help smooth the movement of people and goods around the country and draw more visitors here from around the world, invigorating the vital tourism industry. To help build this road is to help build the nation's future. Here and around the world, Taisei Corporation is working passionately, building on success.
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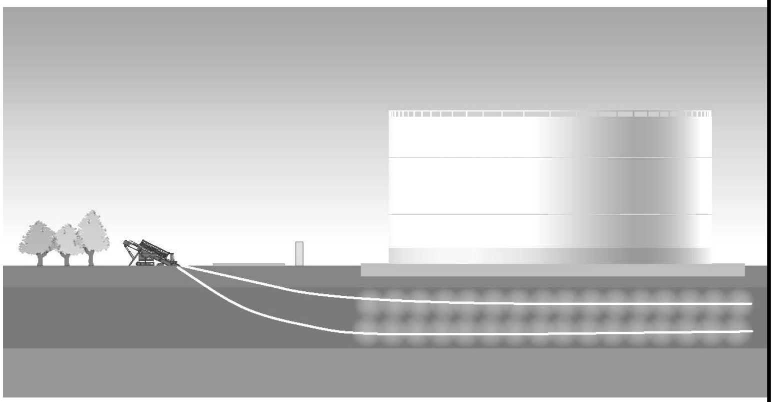
Permeation grouting, void filling and soil remediation beneath existing structures using directional drilling technology



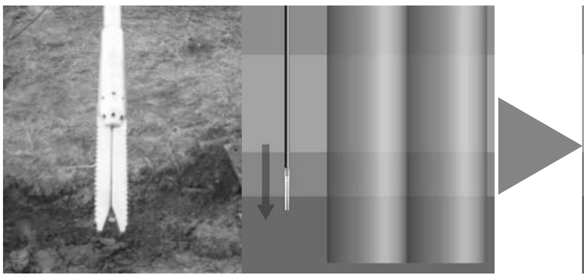
The drilling machine occupies a small area; applicable in narrow spaces

Temporary work pits are not required; low cost and short construction period

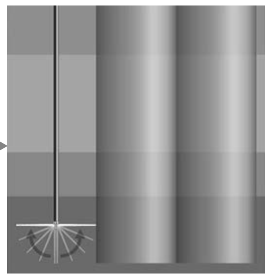
The method allows operation of existing structures during soil improvement works

WinBLADE®

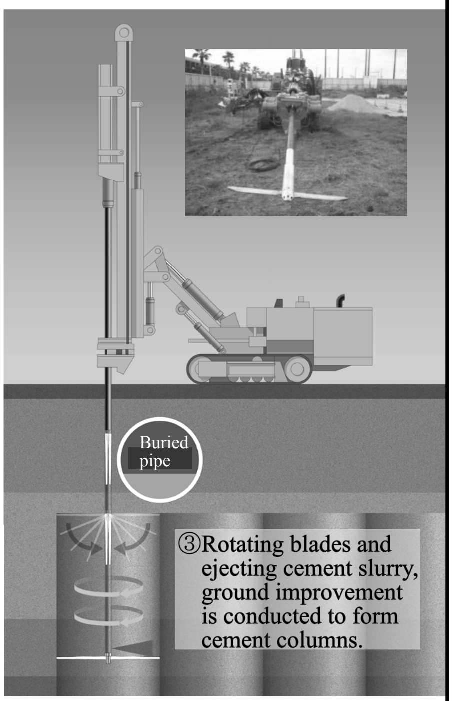
In-situ soil mixing method at narrow spaces adjacent to existing structures using expandable/collapsible mixing blades



①Mixing blades in collapsed state are inserted into ground through casing



②The mixing blades are expanded at the tip of the improvement area



③Rotating blades and ejecting cement slurry, ground improvement is conducted to form cement columns.

High applicability by vertical and diagonal mixing

Less removal work of pavement and buried obstacles

Reliable execution using monitoring and auto control system

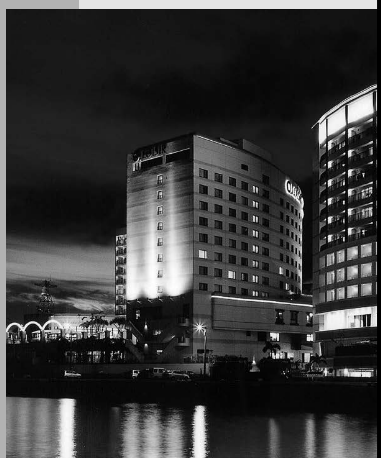
TAISEI

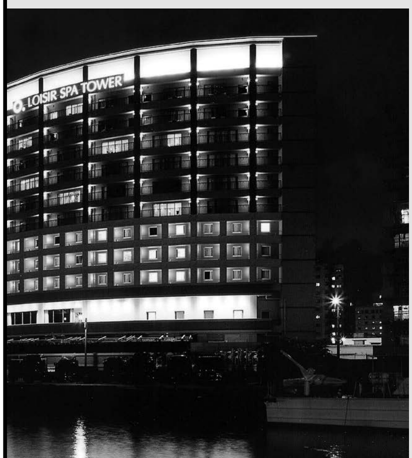
For a Lively World





Giving Shape



LOISIR SPA TOWER