Investigation at the Bottom of Railway and an Embankment by Sounding Method

Kazarashi Kenji[1], Takumi Kondo[2], Kozo Okita[3] and Tsuyoshi Okita[3]

[1]Nippon Geophysical Propspecting Co.,Ltd Kansai Branch
(〒543-0033 1-3-24 Dougashiba Tennoji-district Osaka-city Osaka prefecture)
[2]K&O Corporation Co.,LTD
(〒563-0214 6-6-3 Kibogaoka Toyono-cho Toyono-gun Osaka prefecture)
[3]Okita-Ko Co.,Ltd
(〒598-0063 4-3-35 Minato, Izumisano-city, Osaka-Prefecture)

Soil structures such as railway embankment, river levee, etc. are heterogenity in both longitudinal and transverse directions. This heterogenity affects permiability, soil strength against earthquake, etc. For the purpose of safety investigation of soil structures, visual observation, local boring survery for confirmation, and a prior to this, ground-penetrating radar, resistivity sounding survery, and surface wave method have been adopted. At a venue a new sounding testing apparatus, or NSWS testing apparatus is used because this machine enables to comprehend soil composition and its strength in details. This papaer introduces a use of this machine as well as the investigation result. **This paper was presented at Kinki Regional Development Bureau in September, 2014 in Japan.**

Key Words : *Railway Embankment, Safety, New Investigation Technology, NSWS Testing Apparatus*

1. Introduction

Although soil structures, not just old soil structures [a river levee], but relatively new railway embankment as well, appear to be homogeneous, it is in a state of heterogeneity inside, and soil strength is not constant. Usually a boring survey is conducted to such soil structures, but instead a new sounding survey method, or NSWS Testing Apparatus, was used as a more straightforward ground survey method.

The advantages of the NSWS such as lightweight, high mobility, and a diagonal penetration measurement led to useful results, and its procedure and result will be presented here.

2. NSWS testing apparatus 1)（NETIS registration KK-070026）

NSWS (Nippon Screw-Weight System) is a testing machine that complies with the Swedish sounding test in combination with the rotation penetration and penetration by a loading. As depicted in Fig. 1 it is composed of a small power generator, compressor, air pressure control system, operation control and log device, and air/oil pressure control system that converts air pressure to oil pressure, which is different to a conventional loading method. The main body is composed of a rod-rotation motor, surge tank for loading, and cylinder. It automatically records a loading amount, number of rotation, and penetration velocity with 1.08cm pitch. Primary specifications are as follows.

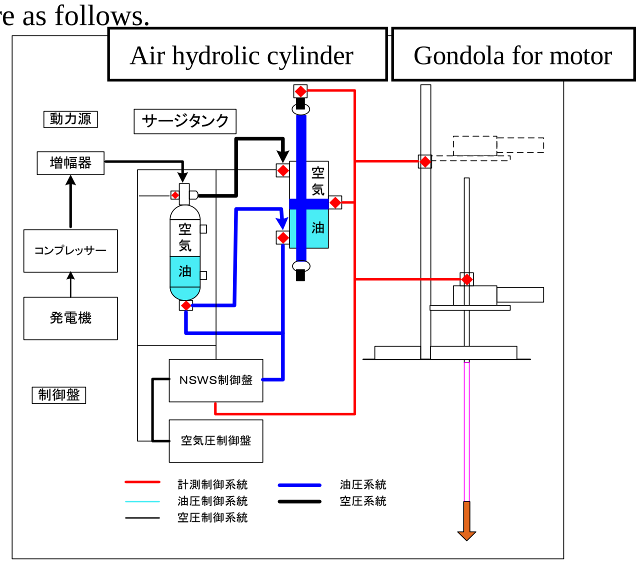


Fig.1 Composition of NSWS Testing Machine and Its Loading System

Primary Specifications:

- Loading: air pressure loading (high penetration capability 0～2500N Variable)
- Measurement: automatic recording of a

number of rotation, loading amount, and penetration velocity

- Data Measurement Resolution: 1.08cm
- Dimensions: 50cm×50cm×170cm (Width X Depth X Height)
- Mass of a Main Body: M=75Kg
- Incidental Equipments: Rods(φ19mm), Drill bit(φ22mm), Sampler

Fig.2 of NSWS Testing Machine, Left)Vertical Right)Diagonal

Characteristics:

- It calculates a converted N-value, bearing capacity, and uniaxial compressive strength from a number of rotation, and loading amount.
- Automatic penetration stop function by setting penetration velocity (It is possible to re-configure its value.)
- Comprehension of soil composition in details including
- self-scuttling, and weak stratums.
- Direction of Measurement: vertical, diagonal, horizontal
- Investigation of ground underneath a building, comprehension of a particular ground location in two or three dimension, identification of ground deformation such as a slip plane, or a thickness of a weak stratum.

Fig. 2 shows a mounting scene of the main device.

Also, a concrete drill bit (φ22mm) is adopted for a tip of a rod instead of a screw point.

The screw point has limitations when penetrating ground with many gravels mixed. With the drill bit increases a penetration capability, and straight advancing ability of rods. And those usually considered impenetrable soil layers such as a gravel layer can be drilled and measured continuously by utilizing 2500N maximum loading; Using the drill bit enables NSWS to be applicable to wide variety of ground types. And, measurement results of soil strength such as a converted N-value are mostly the same as results of SWS machines; Those were examined and confirmed by soil layer experiment, and in-situ experiment.

3. Survey Content

Investigation was conducted at two railway embankments A, and B. Their lengths are about 90m and heights are 5～6m. Investigation locations are chosen based on ground deformations spotted by visual observation, and a result of high density surface wave method. Fig. 3 is a investigation process flowchart.

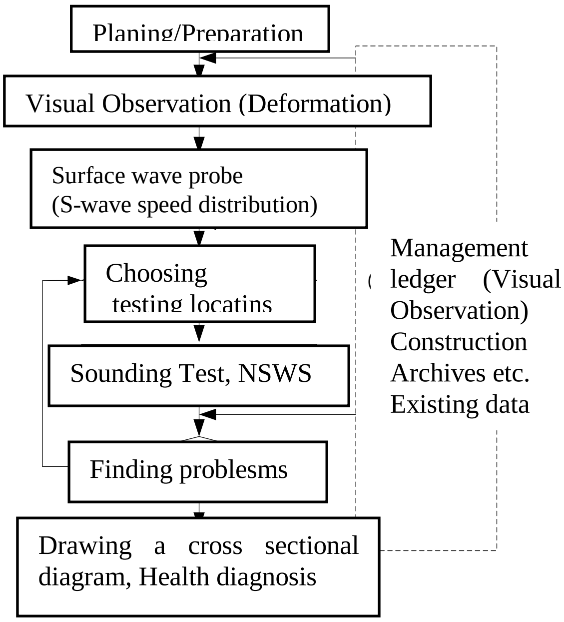


Fig.3 The Procedure of Railway Embankment Survey

4. Embankment A

4.1 Selection of Investigation Locations

Although embankment A had no big deformation such as a gap or subsidence at a slope or on top of the slope, an edge of a formwork that could identify a subsidences some degree was chosen as an investigation location. As indicated in Fig. 4 two vertical measurements and one diagonal measurement were conducted.

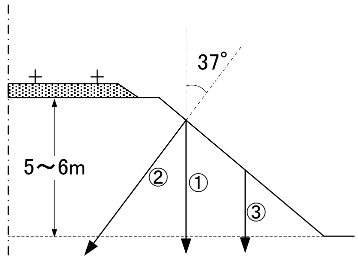


Fig.4 Embankment A, Survey Locations

4.2 Sounding Test

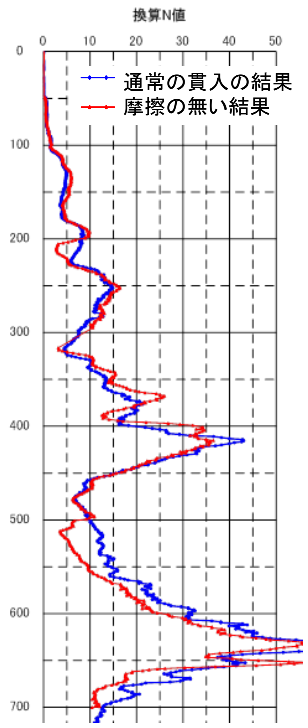


Fig.5 Evaluation of an Impact of Rod's Friction

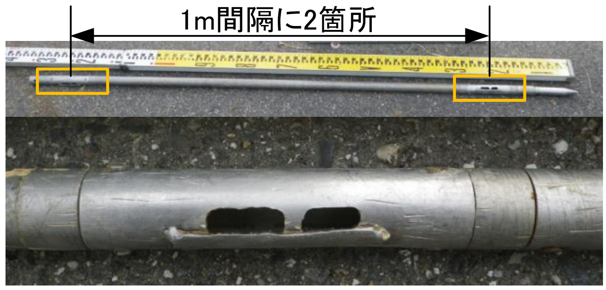
1) An Impact of Friction of Rods

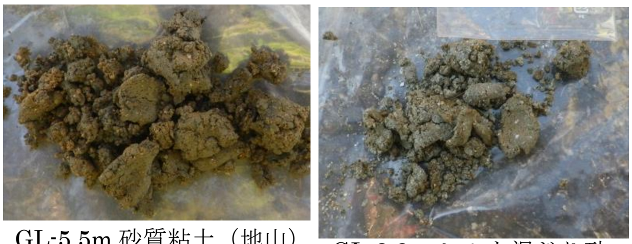
As mentioned before, a diameter of the drill bit (φ22mm) and a diameter of the rod (φ19mm) are almost the same therefore; one could hypothesize that friction of the rods could affect a measurement value. In order to evaluate this, at location ① an ordinary penetration test was carried out,and at 0.5m away from ① another penetration test was conducted after widening the survey hole every 2m depth and eliminating friction. As indicated in Fig. 5, from 0 to 5m there is no difference in results of two holes confirming that an impact of friction toward the measurement value is negligibly small.

2) Soil Type Classification

Soil types of the test hole were identified by visual observation of a sample collected by a small amount sampler that samples with a backward rotation system as depicted in Fig. 6 after listeing penetration sound and conducting sounding test.

Fig. 7 shows parts of samples, and Table 1 is a observation result.





GL-5.5m 砂質粘土（地山）褐灰　含水少

GL-3.2m シルト混じり砂（盛土材）灰含水少

採取深度(m)	土　　質		色調	含水状態
0.5	礫混じり砂	盛土材	茶褐	なし
1.2	粗砂		黄褐灰	微少
2.2	粗砂		黄褐灰	少ない
3.2	シルト混じり砂		灰	少ない
4.5	砂質粘土		褐灰	少ない
5.5	砂質粘土		茶	少ない

Table 1 Embankment A, No. 1 hole, Sample (Visual Observation)

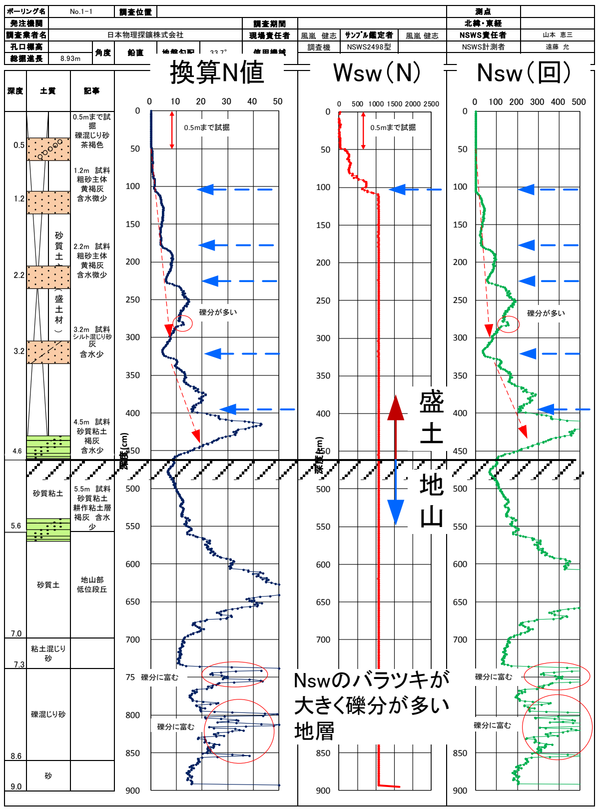


Fig.8 Embankment A, at ① Vertical Direction, Test Result Diagram

3) Sounding Test Result

Fig. 8 is a diagram of NSWS test result, converted N-value, loading amount[Wsw], and a number of half-rotation[Nsw] at location ① of embankment A.

Following Inada-style N-value conversion equation(1) was used to calculate the converted N-value.

$N = 0.002W_{SW} + 0.067N_{SW}$ (1) (applicable when a soil type is mostly sand.)

One could tell that the converted N-value increases gradually from 0 to 10 at 1 to 3.2m depth, 10 to 20 at 3.2 to 4.2m. On top of that, at the interval of 0.5 to 1m a step function like behavior, a sharp rise within 0.1m, can be observed at 5 locations. These sharp changes are believed to be paved surfaces of roller compaction that was created during an embankment construction work.

A boundary at GL-3.2m, one of sharp changes in the converted N-value, has different soil type, color hue, and behavior of the converted N-value; one believes it is a boundary of the upper embankment and lower embankment. One assumes that embankment material that had many gravels was used to construct the lower embankment since the embankment has a greater fluctuation in the converted N-value.

Fig. 9 is a cross sectional diagram of the embankment A test result. Both diagonal measurement ②, and vertical measurement ① gradually increase the converted N-value from 1m depth and have similar inflection points that indicate roller compaction paved surfaces, therefore; one could assume soil layers as depicted in Fig. 9. On the other hand, one could tell at location ③ up to 2m depth the converted N-value was equal to or less than four, very loose relative density.

5. Embankment B

5.1 Selection of Investigation Locations

Table 2 Embankment B, No. 1 vertical hole, Sample (Visual Observation)

採取深度(m)	土　質		色調	含水状態
1.2	礫シルト混じり砂	盛土材	淡黄灰	少ない
2.2	粘土混じり砂		淡黄灰	少ない
3.2	砂質シルト		黄褐	多い
4.2	礫混じりシルト質砂		黄褐	多い

Fig.10 Embankment B, a Gap Deformation, Thinning Deformation

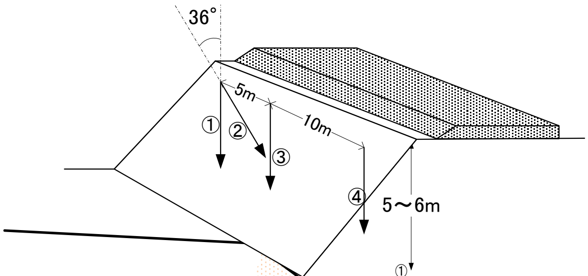


Fig.11 Embankment B, Survey Locations ①, ②, ③, ④

As indicated in Fig. 10, at embankment B following deformations were identified: a gap at the top of the slope, and a subsidence at a top of the formwork.

Because of those deformations, as indicated in Fig. 11, investigation locations were chosen as three vertical penetration, and one diagonal penetration at a upper part of the slope along an edge.

5.2 Sounding Test

Fig. 12 is vertical measurement data at location ①, and Fig. 13 is diagonal measurement data at location ②.

Although both embankment A and B are mostly composed of sand, the con-

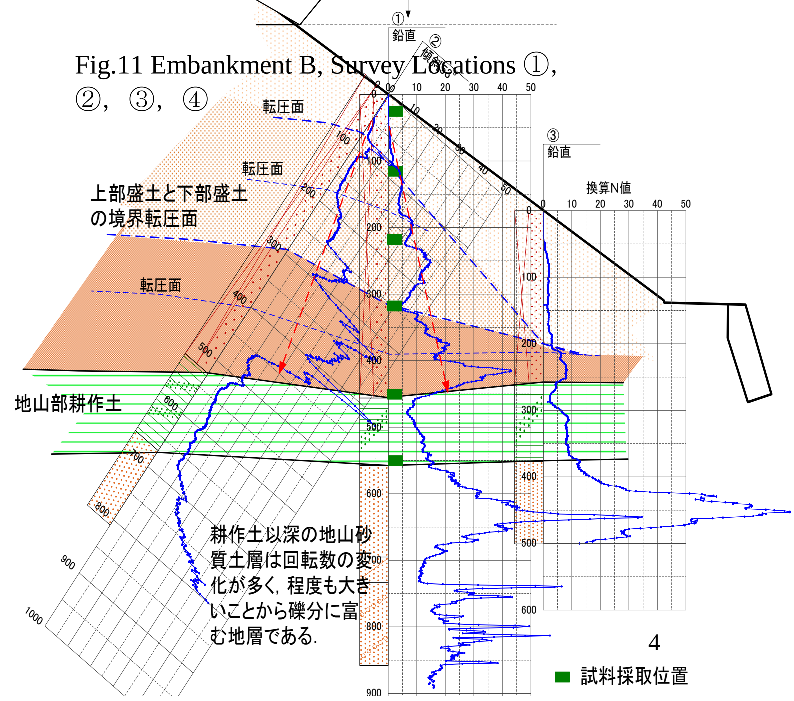


Fig. 9 - Embankment A, a Cross-Sectional Diagram of Sounding Test Result

verted N-value of embankment A increases as the ground depth increases. On the other hand, at embankment B down to GL-4m at location ① and down to GL-5m at location ② the converted N-values are equal to or less than 4, "very loose" relative density. Especially, at GL-3.0～3.5m of location ① it sinks by itself with 300 to 400N loading, extremely loose.

Fig.14 ① at GL-3.2m, ③ at GL-3.4m

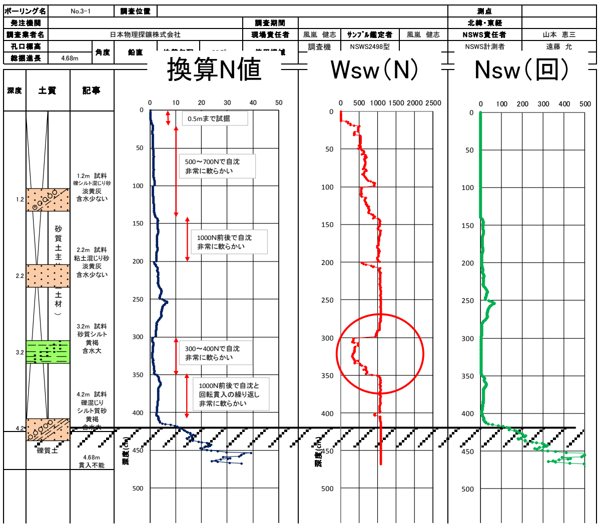


Fig.12 Embankment B, Test Result Diagram at location ①, Vertical Direction

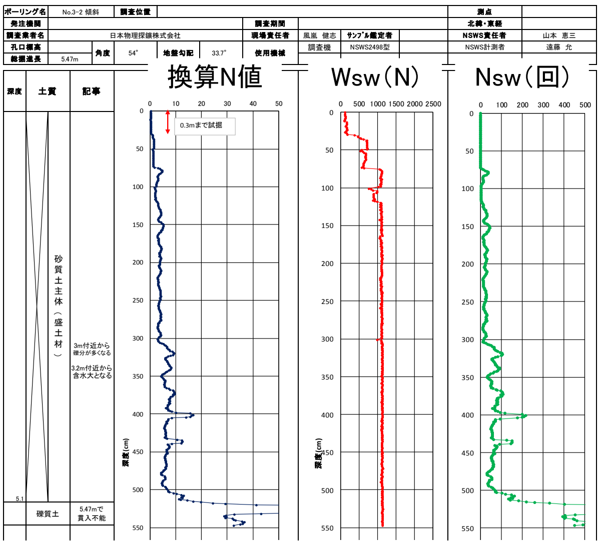


Fig.13 Embankment B, Test Result Diagram at location ②, Diagonal Direction

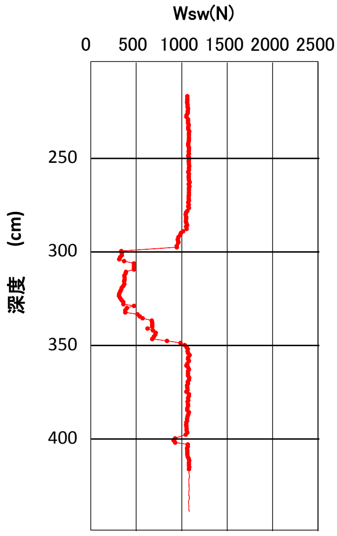


Fig.14 Wsw around GL-3m at ① Vertical Hole

On the other hand, as indicated in Fig. 13 at ② diagonal hole a loading amount is constant, 1000N, from 1.2m, and from GL-3m a converted N-value becomes about eight that indicates a different ground situation from location ①. Because of these analysis, one could conclude that the saturated weak stratum does not extend toward the center of the embankment and planned an additional vertical survey.

Fig. 14 is the result of loading amount[Wsw] at GL-3m and nearby at location ①, a vertical penetration, and an example of a self-scuttling of NSWS testing machine.

1. Right before GL-3m, penetration velocity increased drastically, exceeding a setup value; At this moment, penetration and rotation stopped automatically.

2. Subsequently, NSWS resets the loading to 0N and starts over the measurement

3. It continues to sink by itself until 3.3m with 300 ～400N.

4. From 3.3m to 3.5m it gradually increases the loading until it reaches 1000N.

5. At 3.5 NSWS starts rotation.

Fig. 15 and 16 are a cross-sectional diagram of ① ②, and longitudinal section profile of locations ①-③-④, respectively.

As indicated in the longitudinal section profile at this range of depth an increase tendency cannot be detected, and down until 4m depth, the layer has the converted N-value equal to or less than five, a very loose sand oriented layer. And, from ①, and ③ detected a very loose and saturated clay stratum with 0.5m thickness at 3m and 4m depths, respectively. This loose area dose not extend toward the center of the embankment but corresponds to the gap deformation at the top of the slope and the subsidence at

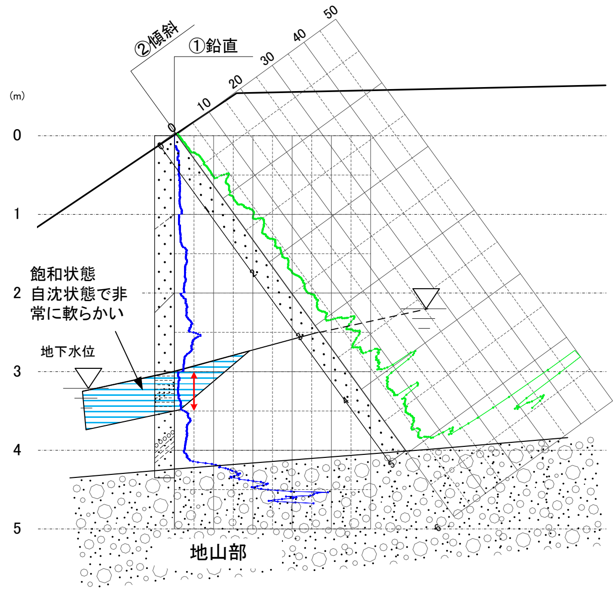


Fig.15 Locations ①②, Converted N-Value, Cross-Sectional Diagram

the slope; One could tell this loose area is one of causes of these deformations.

6. Conclusion

Sounding test was conducted at two railway embankments using NSWS testing machine.

At embankment A, a finer view of soil layers' compositions such as paved surfaces of roller compaction including a boundary of the upper and lower embankments was observed as the result, and soil strength increases as ground depth increases. This is a typical characteristic of embankments.

Embankment B has a "very loose" relative density area at 5 to 6m depth, and within that range of depth, there is a saturated region, a very loose clay stratum, with 0.5m thickness. These are crucial factors for safety evaluation of embankments, and we could report the necessity for a quick countermeasure.

Henceforth, I believe we can contribute to prevention and reduction of landslides caused by guerilla rainfall, and other disasters by verifying the safety of the embankments by conducting an in-situ shear test or in-situ permeability test using NSWS testing machine, or comparing the existing data to new data collected right after a rainfall.

6. References

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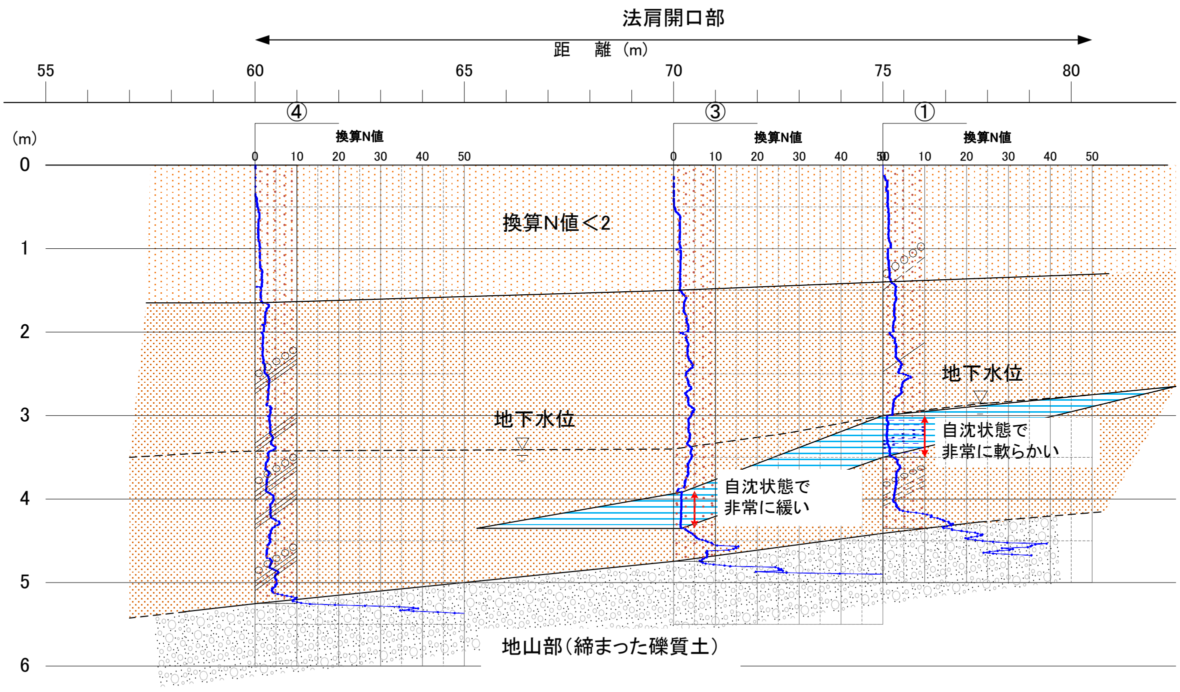

Fig.16 Locations ①-③-④, a Longitudinal Profile of the Converted N-value