Utilization of integrated geophysical investigation for near surface surveying

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Integrated geophysical investigation has been playing an important role in the near-surface surveying because only it can provide high-resolution, quantitative, and reliable information to the near surface as continuous 2D or 3D profiles. Near-surfaces, mainly composed of man-made strata, weathered layers, and Holocene soft sediments, inherently imply small-scaled irregular or various structures. It means conventional geotechnical boring is inadequate to reconstruct surface 2D geology of the region of interest because of its sparseness. Recently, identification and engineering characterization of local heterogeneity in the near surface has become more important in the viewpoint of sustainable and cost-effective utilization of existing infrastructures. Enhancement of resiliency against natural disasters is also one of the current issues in Japan. Development and utilization of field measurement techniques have been required to deal with the above issues.
The integrated geophysical investigation, we proposed first for the safety assessment of levee systems, is not merely a combined field application of several geophysical methods, but a geotechnical characterization method for the near surfaces. Making use of measured S-wave velocity and resistivity, we assess the safety condition of a levee system on underseepage. Soil types, permeability, and seismic resistance are evaluated.
Case histories of the integrated geophysical investigations successfully applied to levee systems, road embankments, and pavements are presented in association with brief introduction of newly developed field measurement techniques.

Keywords: Near-surface, Integrated geophysics , S-wave velocity, Resistivity , Geotechnical characterization

Geophysical Survey in Engineering Geology and Integrated Geophysical Survey

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In The Integrated Geophysical Survey proposed by Inazaki and Levee Consortium, the process of safety assessment of levees based on geophysical surveys from the planning to the evaluations have been organized. It also have presented the semi-qualitative interpretations by means of the combination of S-wave velocity and resistivity. The idea of integrated geophysical survey is expected to improve the applications of geophysical surveys in engineering geology.
Various geophysical surveys have been applied to many engineering geology projects. However, reliability of geophysical surveys is questionable in some cases, and this situation have brought the feelings of mistrust to many geologic engineers although geophysical surveys have been expected as a powerful method. The Society of Exploration Geophysicist of Japan has worked toward standardization of the method of geophysical surveys to improve the reliability of surveys. However, it could be considered that viewpoint of using survey results to geotechnical interpretation was weak. From this background, The Integrated Geophysical Survey Committee has been organized.
The Integrated Geophysical Survey Committee has established 3 working groups, and the following activities have been carried out. In the working group 1, the documentary searches and case studies have been made to investigate applications and development of the integrated geophysical survey. According to the documentary searches, the combination of S-wave velocity and resistivity is utilized for evaluation of ground condition in the field of levees survey, and integrated geophysical survey are conducted. However, in the field of tunnel survey, ground conditions are evaluated by seismic refraction survey in many cases. The electric or electromagnetic survey, together with seismic refraction survey, have been usually adopted for detecting weak zone, where these results have been interpreted qualitatively. In the field of landslide and slope survey, the combination of P-wave velocity and resistivity have been also used for the evaluation of ground conditions. However, its usage also have been a qualitative manner in many cases.
In the working group 2, the research on the interpreting methods have been made to improve performance of the evaluation of ground conditions. According to the case studies on combined interpretation using plural geophysical surveys data, interpretation methods are divided to 3 categories, which are the cross plot method, the method based on empirical relationship and the method based on Rock Physics. The cross plot method are simple and effective when a large amount of surveys data and physical property testing results on the site is available. The method based on empirical relationship, which is the extension of the cross plot method, is more general, and many relational expressions have been proposed. However, these empirical relationship could not apply to the interpretation beyond based geological conditions, limitations of the relationship, and so on. The method based on Rock Physics is sophisticated and is expected to apply to various geological conditions. However, a large amount of surveys data and physical property testing results is demanded to construct constitutive law, and a lot of work is also demanded to validate the constitutive model. A selection of the interpreting methods is depended on quality and quantity of the available data.
The working group 3 have dealt with the digital standard formats and electronic delivery of geophysical survey results. The purpose of the working group is to improve performance of geophysical surveys, and it is considered that the improvement contribute to the growth of the

geophysical survey utilization in engineering geology.
In this report, the present situation of geophysical surveys and applications of integrated geophysical surveys will present.

Keywords: geophysical survey, integrated geophysical survey, engineering geology

Interpretation template for the integrated geophysical investigation

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Theoretical background or physical based models for an interpretation of geophysical survey results is necessary for converting velocity and resistivity to other geotechnical properties or soil type classification. If the physical theory was completely developed to simulate geophysical properties from others, any required parameters could be obtained by solving an inverse problem. However, subsurface is heterogeneous and too complicated to formulate perfectly, and the geophysical property is affected many factors; therefore, it is not easy to solve the inverse problem. In contrast, preparing an interpretation template by a forward modeling based on simple physics based models and obtaining the parameters by comparing the interpretation template and observation seems to be practical solution. This approach is called rock physics template analysis in the reservoir characterization, and it has been used for facies and fluid discrimination (Avseth et al., 2005). In this method, only few specific properties are target parameters and others are regarded as constant values. Nonetheless, it will be a useful and practical solution by selecting dataset before applying it. Especially, this method will be valuable when the data set has limited numbers of observations because inversion and statistical approach is more beneficial for a dataset that consist of many kinds of properties.

A cross-plot analysis is a basic tool for the integrated geophysical survey. Particularly, S-wave velocity and resistivity cross-plot is accepted for a river levee survey. Thus, we created the interpretation template for the cross-plot of S-wave velocity and resistivity to estimate clay content and porosity. The clay content ranging from 0 to 1 represents volume fraction of clay in a sand and clay mixture. It can be regarded as a soil type. Porosity is a fundamental property of soil to indicate volume fraction of each phase (solid, water, and air). Additionally, the porosity can be regarded as an index of looseness for the same soil type.

We adopt unconsolidated sand model (Avseth et al., 2005) for velocity model. The model is based on Hashin-Shtrikman lower bound that calculates the effective elastic property of a mixture of two phases: one is solid and the other is an aggregate of grains. The elastic property of the grain aggregate is calculated by Hertz-Mindlin theory, but it sometimes overestimate for a sediment of shallow subsurface. Thus, Walton model is also available for it. The clay content is a parameter of the solid phase; therefore, S-wave velocity is associated with clay content.

In general, parallel circuit model is accepted to represent resistivity. Resistivity is not affected by soil type below water table, while soil type can be a dominant factor for unsaturated shallow subsurface soils. In the resistivity model, clay content and porosity are included in the conductivity of excess conductivity; therefore both parameters relate to the resistivity.

By calculating S-wave velocity and resistivity for any combinations of the clay content and porosity, we can create the interpretation templates for estimating clay content and porosity. Using the interpretation templates, we obtain soil type classification map and porosity distribution along a river levee.

S-wave velocity and resistivity are presently computed by considering only soil type and volume fraction of each phase. But, it is possible to calculate new template to estimate saturation by treating soil type is constant. In addition, using a range of uncertain input parameter, probabilistic interpretation template is also possible to be computed. Although it is difficult to implement whole theory in the model; instead, making interpretation templates from a simplified model will be effective for the interpretation of geophysical surveys.

Keywords: interpretation template, cross-plot

An attempt at model-based quantitative rock mass classification using integrated geophysical data

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Rock mass classification has been widely used for designing and constructing engineering structures such as tunnels and dams. There are several classification methods proposed such as RMR and Q-value. As these methods, however, are somewhat qualitative and subjective, it has been long recognized that the rock mass classification thus obtained strongly depends on the engineers who make classification. We have, therefore, studied a classification method which can more quantitatively and objectively classify the rock mass grade with multiple geophysical data based on rock physics.
This proposed method applies rock physics models to multiple geophysical data measured in the rock mass for relating them to the rock mass grade. In this study, seismic P-wave velocity and resistivity measured in a few boreholes on a planned tunnel route are modeled with the shaly sand model as an effective medium model for seismic velocity and Glover’s equation for resistivity to estimate the relationship between these geophysical properties. Then RMR measurements with rock core samples obtained in the same boreholes as geophysical logs are compared to the geophysical data through the estimated relationship in order to have a rock mass classification map with geophysical data. Using the map, a rock mass classification of the rock mass along the tunnel formation is obtained and evaluated through comparison with the conventional classification. This comparison clearly proves feasibility of the proposed method in practical use.

Keywords: rock mass classification, integrated geophysical data, rock physics model

Investigation of the depth of steel pile embedment by the integrated geophysical exploration

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In this report, we applied plural geophysical exploration and investigated the cause that a tunneling machine collided in other structure during construction.
A flood gets up in the urban area and becomes the social problem by localized torrential rain in late years. A reservoir to save rainwater is built underground temporarily to prevent a flood. However, a neighboring construction is forced for the underground facilities because the urban area underground is crowded.
We often understand the depth of embedment of the established structure from drawings in the construction under the established structure. However the drawings may be missing with the old structure. When there is a drawing, a trouble may occur while we construct the underground structure because of the difference of the real structure or the depth of embedment.
The depth of embedment of the steel pile is investigated by magnetic survey. However we cannot usually be informed the direction from the borehole using by the conventional magnetic survey. We were developed the borehole vector magnetometer (BVM) to solve this problem (Oshida et al., 2006). BVM is arranged the three component magnetic sensor and measure the three dimensional magnetic fields by the residual and induced magnetization of the steel pile. BVM data estimate a three dimensional position of the tip of pile by analyzed wavelengths and the amplitudes of the three measurement waves.
It was estimated that a tunneling machine had already collide a steel pile by the construction status. It presents the existing abutment pier basement of steel and the complicated structure including the soil retaining piles as well as the steel pile when we confirm the existing drawings. Therefore we planed the BVM and the seismic velocity logging to estimate the depth of embedment of the steel pile. The seismic velocity logging is technique using the transmitted P wave velocity of the steel pile which is larger than that of the soil. We impact the structure itself to produce P wave. Then we can measure the P wave velocity only for steel pile to intend for because P wave does not propagate to other structures. We can estimate that it is an object surely even if the large P wave velocity and BVM anomaly is detected.
As a result of investigation, the following information was provided.
(1) A point of inflection of the travel time curve is accepted in GL-15.5m by seismic velocity logging. This depth is estimated the embedment of the steel pile.
(2) The calculated P wave velocity is the 4.3km/s of the depth zone assumed to be the steel pile by the seismic velocity logging that is clearly larger than the velocity of the soil.
(3) We interpreted difficult to estimate the depth of embedment until GL-14m because the BVM waves of the magnetic fields complicated by the borehole neighborhood construction for example the abutment pier or the soil retaining piles.
(4) However we could estimate the depth of embedment by the independent BVM wave of GL-15.6m, and the depth almost agrees with point of inflection depth of the seismic velocity logging.
(5) We concluded the depth of embedment of the steel pile in consideration both survey results.
(6) We could consider that the tunneling machine is collided the existing steel pile from depth of GL-15.6m because the upper edge of the tunneling machine is GL-14.5m
Even in the case of complicated structure, this report was able to raise its certain result by the integrated geophysical exploration that combined the seismic velocity logging with BVM. The cause

that the depth of embedment deeper than the construction completion drawing is unclear for the moment, but it will be investigated that an underpinning construction and the change of the route are considered based on this result in future.

Keywords: Neighboring construction, Steel Pile, Depth of embedment, Magnetic survey, ,Seismic velocity logging

Study on the prediction of the large shallow landslides areas using Airborne Electromagnetic Survey, hydrological investigation and water quality investigation

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In recent years, the investigations of deep-seated catastrophic landslides and volcano using airborne electromagnetic survey have been carried out. And, the study on prediction of sediment disasters occurrence areas gradually progresses. On the other hand, recently, many shallow landslides disasters including Hiroshima in 2014, Izu-Oshima island in 2013 and Nachi river basin in 2011 were occurred. If we can predict the collapse occurrence slopes by using airborne electromagnetic survey, we can easily decide the priority of the constructions of sabo dams and make the evacuation systems. In this study, we nominated Nachi river basin where large shallow landslides were occurred in 2011 for an example and examined the difference of the resistivity characteristics of collapse and non-collapse slopes from the result of the airborne electromagnetic survey.First, we arranged the relationships between geological features and resistivity distribution. Because Nachi river basin is parted in the area of Kumano Acidic Rocks (granite porphyry) and the area of Kumano Group (sandstone mudstone alternative rock), we considered whether these were distinguishable by the resistivity distribution. Next, we put the collapse slopes on the map of the resistivity distribution and examined the resistivity of the collapse slopes. Final, we paid our attention to the pattern of resistivity contour lines and the rate of change in the resistivity. We examined the difference of them about collapse and non-collapse slopes of Nachi river basin.Kumano Acidic Rocks (granite porphyry) had high resistivity and Kumano Group (alternated sandstone and mudstone layers) had low resistivity. As a result, we can express geological borders very well by airborne electromagnetic survey. In addition, we understood that the most of the collapse slopes were distributed near the geological border. From this, it is thought that collapses were occurred by the difference in geological properties of the plumb direction. About the difference of the collapse and non-collapse slopes, we found that the collapse slopes have vertical pattern of resistivity contour lines against the slope directions. And we found that the areas of the large rate of change in resistivity are disappeared at the upper parts of the collapse slopes about the collapse slopes. On the other hand, about the non-collapse slopes, we found that the resistivity contour lines were parallel with the slope directions and the areas of the large rate of change in resistivity are continued at the upper parts of the slopes. The resistivity contour line shows the structure of geological features. Because the resistivity contour lines of the collapse slopes are vertical, the geological structures of the collapse slopes are vertical and it is thought that Kumano Acidic Rocks (granite porphyry) penetrates Kumano Group (alternated sandstone and mudstone layers) vertically. In addition, when geological structure is vertical, infiltrated water is hard to flow to the slope lower part, and it is thought that water level under the ground is easy to rise and the slope is easy to be collapsed. It is thought that the areas of the large rate of change in resistivity expresses water level under the ground. Because the areas of the large rate of change in resistivity are disappeared in the collapse slopes, it is thought that drainage abilities were low. Above all, in the risk evaluation of the shallow landslides, it is thought that we can evaluate the water levels under the ground and the drainage abilities of the groundwater by using the airborne electromagnetic survey.

Keywords: Airborne electromagnetic survey, Hydrology, Ion concentration, Shallow landslide

Demonstration Experiment of Geothermal Reservoir Exploration Techniques: Three-Dimensional Seismic Survey in the Yamagawa Geothermal Field

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An experimental three-dimensional (3-D) seismic survey was conducted in the Yamagawa geothermal field, Kagoshima, Japan for verifying its efficiency for geothermal reservoir exploration. This demonstration experiment was conducted by Japan Oil, Gas and Metals National Corporation. JOGMEC is developing several geothermal exploration methods to locate geothermal reservoirs more accurately by applying recent technologies used in other sectors such as oil, gas, and metal mining. Reflection method is one of the most promising geophysical survey methods which delineate subsurface geology precisely. It is proven in the oil sector that seismic method, especially 3-D seismic, reduces geological risks and increases success rates in drilling. However, many of geothermal fields in Japan exist in mountainous area. Seismic surveys might suffer from a rough topography and complicated geological structure. Since effectiveness and cost of seismic survey in Japanese geothermal area are arguable, the Yamagawa 3-D survey had the following aims. First, high density 3-D data were collected to show proper images of the geothermal reservoir. Second, several subsets with different survey designs were extracted and their images were compared to determine the relative cost-effectiveness. Since the Yamagawa geothermal field has a smooth topography comparatively, it allowed us to collect high density 3-D seismic data. The area of the survey was about 32 sqkm (4.5 km in N-S and 8 km in E-W). Both wireline telemetry system having 3,134 channels and 1,855 wireless nodes were used for the receiver lines. Two types of vibrators (18 tonnes and 7.4 tonnes), a fleet of 4 vehicles for each type, were uses for seismic source. While the larger vibrators were used at 988 shot points, the smaller vibrators were used at 2,274 shot points. Maximum Displacement Sweep technique enriched the low frequency components of the source frequency band. Sweep frequencies of 3-60 Hz and 4-60 Hz were used, respectively. Sweep length was 16 seconds. Number of sweeps is defined shot-by-shot as follows: 3 or 4 sweeps for the standard shot points and 8 or12 sweeps for the high energy shot points. The high energy shot point was distributed at every 200 m or less so that refraction tomography could be analyzed more properly.

Data processing is being conducted at the time of writing this report. The preliminary results have depicted complicated structure in the volcanic region and shown a consistency with geological information from the wells. We plan to conduct several decimation tests that evaluate 3D and 2D geometries. Full Waveform Inversion, attribute analysis, and an integrated study with gravity, magnet-telluric, and well data will also be applied in the next phase.

Keywords: Geothermal, Yamagawa, Fault, Fracture, 3D, Seismic


Survey Map
Yamagawa 3D Seismic
Source Point
Receiver Line
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Estimating of infiltration path using 3D simulation of groundwater flow and resistivity survey

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Resistivity survey is a useful method for noninvasively imaging continuous water flow in soil because water saturation increases electrical conductivity. Several methods have been applied to determine the water flow in soil by monitoring the resistivity change that is associated with variation in water saturation or water salinity. A change in resistivity before and after infiltration provides a 3-D image of the water flow; however, a detail distribution of resistivity sometimes cannot be obtained because of the inherent limitation of the observation data (i.e., number of measurements, time represented, and measuring sensitivity). However, a resistivity change is caused by the water flow in soil, and the water flow is governed by the seepage phenomenon; therefore, a method that uses data from resistivity surveys and seepage analyses would be effective. Thus, a water flow model was developed, which compared the water content converted from resistivity survey data as well as water content simulated from hydraulic models. This method provide both an image of the water flow and the properties of the hydraulic conductivity; however, if the number of measurements is low, the resistivity obtained from inversion remains uncertain because of spatially varying resolution. Comparing water content values obtained from resistivity surveys with those from water flow simulations includes a 3-D inversion uncertainty. However, according to the coupled approach, the observed resistivity data are directly used for determining the hydrological properties. In this method, water content simulated from water flow analysis is converted to a resistivity model, and a resistivity survey is conducted using this model to interpret the results. The simulated resistivity data are compared with the field observations to estimate the water flow hydraulic properties. This method can reduce the spatial uncertainty of the 3-D invasion because the resistivity model is constrained by the seepage analysis data. One dimensional hydraulic properties were inverted from 1-D water flow simulations, whereas, using 2-D hydraulic properties were inverted via Bayesian and multi-criteria inversion and via neural networks. However, few studies investigated 3-D hydraulic properties using 3-D water flow simulation and 3-D resistivity survey data. Inversion of 3-D hydraulic properties is best but it is difficult because reconstructing the 3-D conditions is complex, and there are many unknown parameters. In this study, we propose an easy the method to estimate hydraulic properties of the shallow soil layer, which is responsible for many hydraulic problems in the field. To evaluate this method, numerical and field experiments ware conducted. In the numerical experiment, the resistivity survey provides an image of the preferential flow; however, the infiltration locations are unclear. Assuming that high hydraulic conductivity zones exist somewhere, an analysis of saturated–unsaturated seepage is conducted for several water-flow models with different locations of high hydraulic conductivity. Subsequently, a resistivity survey is implemented based on the water content that was simulated by seepage analysis. The high hydraulic conductivity location of the model that provides the minimum errors corresponds to the high hydraulic conductivity location of the numerical field model. In the field, resistivity is measured during groundwater recharge experiment in a pyroclastic plateau. This resistivity survey provides an image of the preferential flow; moreover the high hydraulic conductivity location of the model that provide the minimum errors corresponds to filling water rage, whereas that of the model that gives the maximum errors

corresponds to no filling water range. These results indicate that estimating high hydraulic conductivity locations using simulations of the groundwater flow and resistivity survey is possible. This work was supported by JSPS KAKENHI Grant Number 25850170.

Keywords: infiltration path, groundwater flow, resistivity survey

Case study on a newly modulus of deformation considering a continuous state of crack in the tunnel ground

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The physical properties concerning the state of the tunnel ground is very important for the accurate re-modification of tunnel ground classification and numerical analysis in the tunnel construction stage. Therefore, the geological properties ahead of tunnel face might be confirmed by the horizontal drilling survey results. And the physical properties, such as P-wave velocity by the velocity logging, the modulus of deformation by the borehole loading test, and the P-wave velocity results, etc., of the laboratory tests of the bore cores were measured for re-evaluation just before the tunnel excavation. Though, P-wave velocity by the velocity logging is different from a P-wave velocity of bore core in method for measurement and a target range, P-wave velocity by the velocity logging was continuously measured value along the all borehole length with influence of the state of the crack in the tunnel ground. Therefore a coefficient of fissures is found from a core and a ratio of P-wave velocity of the tunnel ground, and the item of the ground classification is corrected by this coefficient of fissures. On the other hand, the modulus of deformation is measured at the loading point as a limitation. However, when the modulus of deformation can be grasped as the continuous distribution, we could obtain the more accurate geo physical data.

In this report, we compiled the geological survey results of national highway tunnels which were constructed into the volcanic rock area in Hokkaido. To obtain the modulus of deformation along the borehole, S-wave velocity along the continuously borehole was calculated using the P-wave velocity by velocity logging, the P-wave and S-wave velocity by the bore core test results. Then, the dynamic modulus of elasticity of borehole was calculated using the dynamic shear modulus of elasticity and the dynamic Poisson's ratio based on the P-wave velocity by velocity logging, the S-wave velocity along the continuously borehole and wet density results of the laboratory tests of the bore cores. This determined dynamic modulus of elasticity is correspond to modulus of deformation considering a state of crack in the tunnel ground, due to the S-wave velocity along the continuously borehole is already considered the coefficient of fissures. After that, the dynamic modulus of elasticity along the borehole was compared with the modulus of deformation by the borehole loading test and the dynamic modulus of elasticity by bore core.

As a results, the dynamic modulus of elasticity along the borehole was obtained as 3,000 - 36,000 MPa. These values are lower than the dynamic modulus of elasticity by bore core, 300 - 68,000 MPa, and higher than the modulus of deformation by the borehole loading test, 400 - 10,000 MPa, due to different of the method for measurement and a target range. Moreover, the proportional relation was confirmed between the dynamic modulus of elasticity along the borehole and P-wave velocity by the velocity logging, as a better tendency than the relationship between the modulus of deformation by the borehole loading test and P-wave velocity by the velocity logging. Thus, the P-wave velocity by the velocity logging is thought to be useful for the estimating the modulus of deformation along the continuously borehole and re-design of tunnel.

Keywords: tunnel, ground classification, modulus of deformation

Effects of surface irregularity of embankment on wave propagation

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Phase velocity of surface wave, mainly Rayleigh wave, generated by artificial sources is used in the surface-wave exploration method to estimate a shallow S-wave velocity structure. It has been often used in soil surveys in, for example, river embankment, landfill and residential land. A horizontal layered model with the flat Earth's surface is assumed in data analysis of the method. However, the appropriateness of the assumption has not been sufficiently discussed for its application for a site which has surface and subsurface complex irregularities.
In this study, we investigate effects of surface irregularity on characteristics of surface-wave propagation through numerical experiments based on a finite-difference method to understand its applicability. First, we conducted 3D simulations of wave propagation in shallow soil models with and without surface irregularity considering realistic cases, such as embankment. Then, we derived frequency-dependent phase velocity from synthetic waves obtained on the surface of the models. we also examined effects of slope of embankment and a velocity contrast between surface layers and basement on the surface-wave phase velocity.
The effects of the 3D shape of surface topography are significantly identified in the surface-wave characters in the models with a high velocity contrast between surface layers and basement, when the model has a steep slope on a side of the embankment. In the embankment models, scattered wave generated in the upper surface and the base of the embankment was observed. The estimated phase velocity for the surface wave differs from those of the horizontally-layered model indicating difficulty to deduce a true velocity model. However, the phase velocity for the model having a low velocity contrast is similar to those in the horizontal model even in the models with steep slopes. It is concluded that effect of surface irregularity on the surface wave propagation is small in sites with a low velocity contrast with regardless of surface irregularity.

Keywords: surface irregularity, phase velocity, surface-wave exploration, S-wave velocity

An interpretation result of the integrated geophysical survey at river levee using interpretation template

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Safety of the river levee is assessed from existing soil profiles of the levee body and foundation based on drilling results as well as a detail investigation conducted at a specific location. Even though the soil type is confirmed at drilling locations, typical distance between the drilling wells is about 1 km long, so the soil profile between the wells is basically estimated by an engineer. On the other hand, geophysical survey provides geophysical property at every 10 m, for instance even though it does not directly reflect soil type. Therefore, the combination of the geophysical survey with the drilling results contributes to build a detailed soil profile, and it helps us to determine the location of the detailed investigation.
For a river levee investigation, cross-plot of S-wave velocity by MASW (Multi channel analysis of surface wave) and resistivity by CCR (Capacitive coupled resistivity survey) is used to evaluate levee body and foundation along a river. Here, the soil type classification by the interpretation template, which is proposed by Konishi et al. (2016), is applied to the cross-plot, and the result is verified by drilling.
Interpretation template can be generated by selecting any physical models, but it is hard to judge the validity of the template from the only geophysical dataset. Thus, in principle, the interpretation template must be checked and adjusted by drilling information. In this study, in order to verify the result of the estimated soil type, we separate several existing drilling wells into interpretation wells and validation wells. The interpretation wells are only used for the check and adjustment of the interpretation template, while validation wells are used to compare the estimated soil type with actual one.
The soil type profile estimated from the integrated geophysical survey suggests that the top of the clayey soil deposit is deep between the interpretation wells. The distribution of the clayey soil is confirmed by the validation wells. This result indicates the validity of the soil type estimation from the geophysical survey, and it means that we can build a detailed soil profile by combining the geophysical survey with drilling results.

Keywords: interpretation template, integrated geophysical survey

Integrated Geophysical surveys in levee excavation sites on the Chitose river, Central Hokkaido

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A levee excavation was conducted to construct a new sluice at two sites along Chitose River, Central Hokkaido. The high-density electrical resistivity survey and the surface wave survey were carried out on the levee at the crown and high-water channel before the excavation. The electrical resistivity and S wave tomography were also carried out across the levee at the excavation sites. After the excavation, the short electrode spacing resistivity mapping and the short spacing surface wave survey were carried out at the excavated slope surface to measure directly on the resistivity and S wave velocity (Vs).
The resistivity and Vs structures obtained by the surface surveys were verified by the resistivity and Vs distribution measured on the excavated slope surface. These surveys delineated imhomogeneity of soils in the levee and the basement. Comparing the resistivity and the grain size evaluated by soil tests, the resistivity structure identified a permeable zone in the levee and showed the extension to the basement.

Keywords: Integrated Geophysical Survey, Levee Survey