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題目(和文)	現地調査と統計分析に基づく河川堤防を構成する沖積堆積物の水理特性に関する研究
Title(English)	A study on the hydraulic characteristics of alluvial sediments in river levee systems through field surveys and statistical analysis
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Thesis outline

In the river levee systems, the foundations consisting of alluvial sediments of different formations are related to the leakage events. For a more accurate evaluation of piping risk, the primary goal of this study is to quantitatively reveal the hydraulic characteristics of alluvial sediments, taking natural levees as an example.

The thesis is composed of 8 chapters.

In Chapter 1 “Introduction”, the background and objectives of this research are addressed.

In Chapter 2 “Literature review”, the related research and background knowledge are introduced, focusing on the mechanism of piping, the relationship between piping and alluvial landforms, and the existing testing methods for hydraulic conductivity.

In Chapter 3 “Statistical studies on hydraulic conductivities of the levees along the Kinu River”, a statistical study is performed on the hydraulic characteristics of the levees along the Kinu River, using the existing database. The limitations in the accuracy and abundance of the existing database are exposed, manifesting the urge for a detailed field study.

To obtain the data for further discussion, in-situ tests with proper scale and spatial density are needed. GP test, a kind of portable device for the in-situ seepage tests in the vadose zone, is a potential choice for the study. To clarify the applicability, the representative volume, and the limitation of the GP test in alluvial environments, a series of studies are introduced in Chapter 4 “Studies on the GP test in a model ground”, Chapter 5 “Studies on the GP test by numerical simulations”, and Chapter 6 “Verifications of the GP test in the field”. The focus is cast on the reliability of the estimated hydraulic conductivity and the representative volume of the test. Although errors are involved due to the unsaturated soil properties and the groundwater level, it is revealed that by using Reynolds’ solution with a conservative capillary factor, the GP test can be practically applied in the alluvial environment to the evaluation of risk related to underseepage. In anisotropic soil, the GP test gives conservative estimations for the hydraulic conductivity in the horizontal direction, which is favourable for the estimation of piping risk. In layered ground with different soil layers, the GP test tends to capture the existence of permeable layers, which is favourable for the estimation of piping risk. The representative volume of the GP test (under the setting of a radius of 3 cm and a constant head of 15 cm) in sandy or silty soil can be simplified to a column with a radius of 6~20 cm and a height of 17~25 cm; in clayey soil, the representative volume should be a column closely surrounding the auger hole. In conclusion, the GP test can be properly applied in the alluvial environment, for

the evaluation of safety against underseepage in river levees.

In Chapter 7 “Studies on the hydraulic characteristics of alluvial sediments in the Kokai River”, a case study is conducted on the hydraulic characteristics of alluvial sediments in the Kokai River. In the field surveys, the hydraulic characteristics of natural levee sediments are studied by performing sounding tests, GP tests, and laboratory soil tests. By relating the response of the handle penetrating stick and the observations from the trial pits, a relationship in soil classification can be built, based on which soil profiles can be roughly grasped. Five kinds of depositional facies are distinguished in the site around R 38.9k of the Kokai River, among which two depositional facies are identified to be natural levee sediments. The natural levee sediments in the tested sites consist of laminar structures of silt to silty sand, with an average hydraulic conductivity of in the order of E-06 m/s. Using the data from the field survey, numerical models of the natural levee sediments can be built by applying indicator Kriging or indicator simulations. To study the effects of heterogeneity on piping risk, seepage analyses are performed on the numerical model of natural levee sediments. It is revealed that the heterogeneous natural levee sediments may lead to an increase in piping risk, while catastrophic piping failure is unlikely to develop. Larger piping risks are expected to be met in more extreme cases.

In Chapter 8 “Conclusion and recommendation”, conclusions from Chapters 3 to 7 are summarized. Limitations of the study are addressed, based on which recommendations for future study are given.

In summary, a way to study the heterogeneous natural formations, and the methodology to integrate the field observations into risk evaluations are demonstrated. Contrasting to the generally accepted belief that natural levees are critical to the piping risk, it is proven that natural levee sediments with relatively low hydraulic conductivity are unlikely to lead to catastrophic piping failures. Similar studies can be conducted on other alluvial sediments like sand dunes, point bars, crevasse splay, or abandoned channels.