【様式４】

“Technical Research and Development for Road Policy Quality Improvement”
Study Summary

No.	Title	Principal Researcher
No.27－3	Development of cost-effective methods for aseismic examination and reinforcement of valley-filling embankment	Prof. S. Shibuya, Kobe Univ.

Regarding a number of currently in-service valley-filling road embankments with low profile of aseismicity, new developments were achieved as for a cost-effective/rational method for investigating the current aseismicity by performing physical surveys as well as in-situ soundings, and also a cheap method without any sophisticated techniques for improving the aseismicity by reinforcing the toe of embankment with soil-bag structure.

1. Backgrounds and Objects

When evaluating the current aseismicity of a number of in-service road embankments in Japan, technical developments for making quick, cheap and reliable assessment of the aseismicity, together with a cost-effective countermeasure to increase the aseismicity of them are urgently needed. It is the objective of this study to develop cost-effective methods for evaluating the current aseismicity, and for reinforcing the valley-filling embankments.

2. Activities in Research Period

Aseismic assessment is based on the available documents such as the construction record and the checking list of the cited embankment. A simple method in use for evaluating the current aseismisity by using physical surveys combined with various soundings is examined for several test sites (Fig.1).

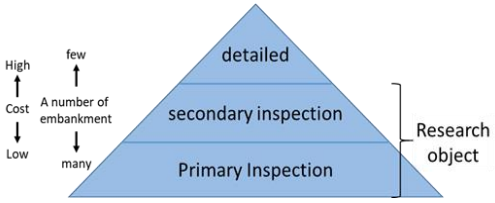


Fig 1. Process of seismic diagnosis embankment

Aseismic reinforcement is achieved by reinforcing the toe of embankment by using the soil-bag structure (Fig.2). An assembly of well-graded/well-compacted soil bags is tightened by using anchors in order to resist against seismic loadings. Moreover, the performance of this newly developed aseismic method was examined in shaking table test using a prototype embankment. The stability as well as deformation behavior of the embankment is successfully verified by limit equilibrium method and numerical analysis.

3. Study Results

Aseismic assessment;

i) Revised checking sheet with which the current stability of the cited embankment may primarily be evaluated is developed. In this sheet, potential drawbacks of the embankment as well as the near-future scenario for possible disaster, together with its scope, are both properly cited by recording any harmful symptoms with time.

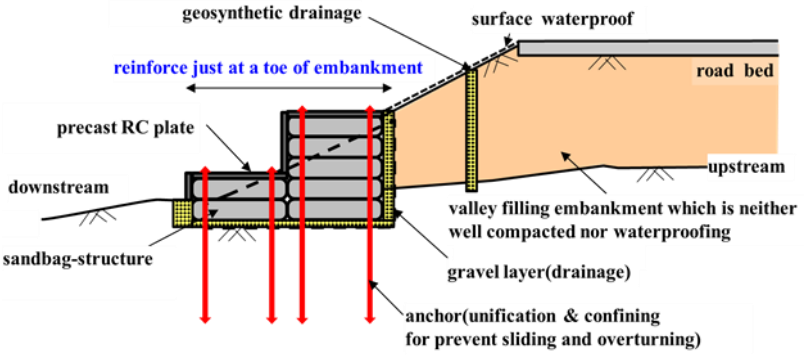


Fig 2. Aseismic reinforcement at the toe of embankment using sandbag-structure

ii) Superiority of the proposed primary inspection method compared to the currently available method was successfully proved in terms of assessing properly the current aseismicity by performing site inspection on several road embankments in Kinki district.

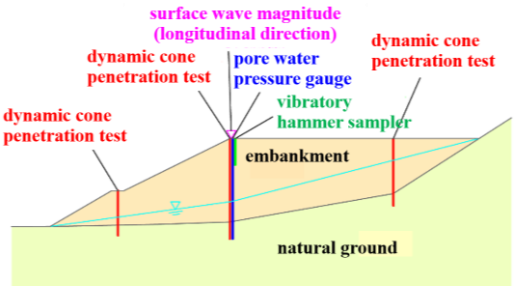
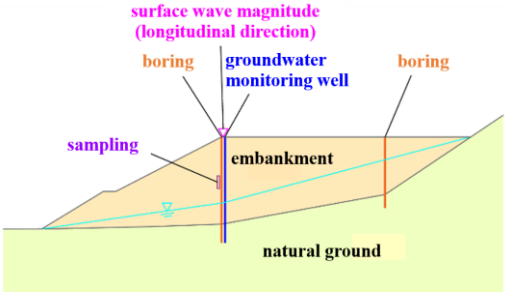
iii) The proposed secondary site investigation method with in-situ surface-wave survey coupled with dynamic cone penetration test was carried out for low-profile seismicity embankments which were cited through the primary inspection. The detailed site investigation with standard penetration test and soil sampling was comparatively performed. It was verified that the proposed secondary investigation brought about the factor of safety, Fs, that was just slightly lower than the Fs from the detained site investigation (Table 1). The results strongly suggest the capability of the proposed site investigation method in use for screening embankments exhibiting poor aseismicity.

Aseismic reinforcement;

Various laboratory tests were performed to examine the effects of properties of soil in the bag in terms of

shear strength as well as creep characteristics, and also to elucidate the effects of aseismic reinforcement by the soil-bag structure. Based on these test results, the prescribed effects of aseismic reinforcement were successfully depicted in a shaking table test using a prototype embankment. Moreover, superiority of the proposed aseismic reinforcement method when compared to other comparative methods was well demonstrated in terms of various aspects such as cost and easiness of construction. Regarding the case record of an embankment collapsed in the past, the relationship between the factor of safety and the height of reinforcement was manifested (Fig.3), bearing in mind the design and construction in engineering practice.

Table 1. Economic comparison of secondary inspection

	secondary inspection proposed in this research	conventional secondary inspection
inspection Spec.	 work days : about 2 days	 work days : about 10 days
Cost(yen)	3.4million (except surface wave magnitude : 2.7million)	5.4million (except surface wave magnitude : 4.7million)

4. Papers for Presentation

1) T. Kuda, S. Toshito, R. Tajima, S. Kataoka, S. Shibuya : Small shaking table test in the development of aseismic reinforcement at the toe of embankment using sandbag-structure , Kansai Geo-Symposium 2016 , pp.119-124, 2016.

2) T. Ebisu, T. Mayumi, Y. Nabesima, S. Nonami, S. Kataoka, S. Shibuya: A study on primary inspection method of existing road embankment, Kansai Geo-Symposium 2016, pp.167-172, 2016.

3) S. Nonami, T. Ebisu, S. Kataoka, S. Shibuya, K. Tani, K. Chino: Proposal for a simplified and cost-effective method for evaluating the stability of existing embankment through case study, Japanese Geotechnical Journal, (in press).

4) S. Kataoka, T. Kuda, S. Shibuya, H. Nakazawa, R. Tajima and T. N. Lohani : Study on the development of a new aseismic reinforced construction method by using soil-bag stacks at the toe section of the embankment, Proc. of the 16th ARC 2019, (in press)

5) S. Shibuya, K. Tani, S. Kataoka, H. Nakazawa: Aseismic Reinforcement of in-service Embankment using "Soil-bag Structure", The Japanese Geotechnical Society, Geotechnical Engineering Magazine, Vol.66, No.6, Ser.No.725, pp.28-31, 2018.

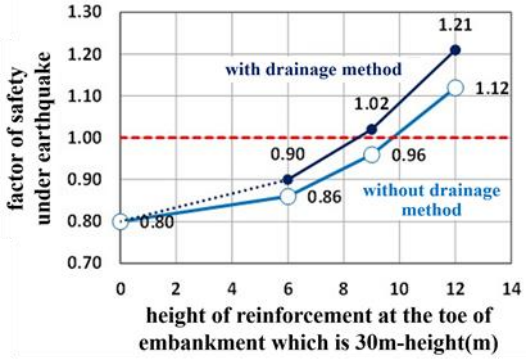


Fig 3. Relationship between the height of reinforcement and Fs

5. Study Development and Future Issues

【Aseismic assessment】 "Manual for checking the stability of embankment(tentative)" should be prepared, and its use in engineering practice may be promoted. The proposed secondary investigation method should also be implemented, and the applicability may be examined by having case records.

【Aseismic reinforcement】 Further examination into long-term durability of soil bag, together with the sustainability of prestressing is required. Development of design and construction method of the soil-bag structure for high-rise embankment is also needed. The performance of multi-layered soil-bag structure subjected to seismic loading should be evaluated in shaking table test.

6. Contribution to Road Policy Quality Improvement

The proposed aseismic methods in this study would facilitate to increase the number of poor road embankments to be cared due to the merits; i.e., quick and cheap. Mitigating road embankment against earthquake may also be enhanced by using the new technology.

7. References, Websites, etc.

Shibuya/Kataoka Laboratory, Kobe Univ.: www.research.kobe-u.ac.jp/eng-geotechlab/