Quality of embankment slope based on compaction energy: A case study

Suman Manandhar, Noriyuki Yasufuku, Kiyoshi Omine, *Taizo Kobayashi, Hemant Hazarika, and **Mitsuru Taniyama
Department of Civil and Structural Engineering, Kyushu University, Fukuoka, Japan
* Department of Civil and Architectural Engineering, Fukui University, Fukui, Japan
**Asakawagumi Construction Company, Wakayama, Japan

1 INTRODUCTION

Soil compaction is the densification of the ground to expel maximum amount of air by applying some external load mechanically which avoids later consolidation. Soil compaction methodology is accomplished to improve the mechanical and physical properties of earthworks to prevent from failures occurred by settlement of foundations, subgrades, bases, airfield pavements, and embankment slopes. Further, laboratory dry density is used to identify the condition of embankment paying attention to the quality (Day, 1998).

A collaboration joint research with Asakawagumi from Wakayama Prefecture has led to investigate medium sized embankment slope at Iwade Shi, Wakayama. The study was focused on the compacted embankment slope. The main objective is to understand the current situation of constructed embankment slope and evaluate the quality based on traditional compaction methodology.

The embankment slope has dimensions of 24 m in length with north and south facing slopes at 1:1.8 slope gradients. The height of the slope from the ground level is 2 m. The slope gradients of east and west are 1:1 and 1:3 respectively (Fig. 1).

The embankment has been built spreading soils layer by layer. Local soils of Wakayama were used to make the embankment. At first 30 cm layer had been compacted on the ground level by sheep foot roller compactor. Then, 30 cm soil layer had been overlaid on it and 2 m high embankment was built. Care should be taken that, the compactor had been used to compact soils in horizontal levels only. Then, bucket of excavator was used to create the beautiful slopes without considering the compaction energies. Fig. 2 shows the construction site and equipments used to build up the embankment slope.

The quality of the embankment slope without any treatment is vulnerable to slope failure when it is subjected to rainfall or vibration. Therefore, it is necessary to check the dry density and water content of the slope. In this aspect field and laboratory tests have been carried out to check the current situation of the embankment slope.

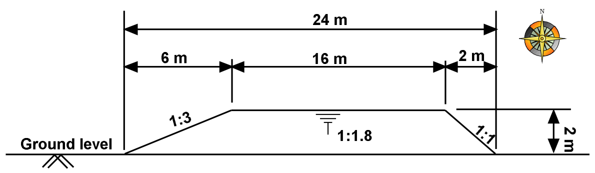

Fig. 1 Sectional view of the embankment slope

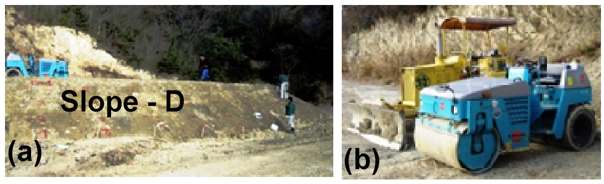

Fig. 2 (a) Constructed embankment slope (b) Sheep foot roller and excavator

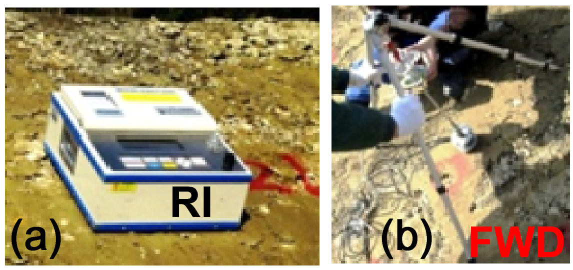

Fig. 3 (a) Field density measurement by RI method (b) FWD

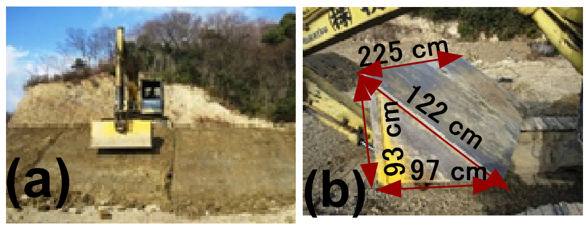

Fig. 4 (a) Reconstructing slope (b) Measurement of bucket

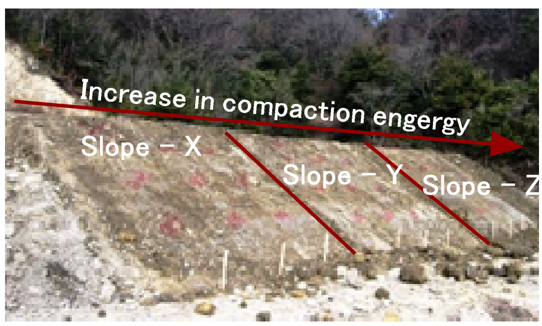

Fig. 5 Recreated slopes with different compaction energy

2 FIELD AND LABORATORY TESTS

The field investigation has been divided into two parts. First, the investigation of initially built up of the embankment slope. Second, the slope has been modified with different compaction energies and continued the same tests.

The south facing slope has been named as Slope-D (Fig. 1). Similarly north facing slope has been termed as Slope-E. In the first part of investigation, Slope-D was divided into grids and field tests had been performed on it. On the slope, density measurement by Radio Isotope (RI) method and Falling Weight Deflectometer (FWD) were measured and processed the data on desk (Fig. 3). Proceeding, in the second part, the Slope-D had been modified into three different types of slopes (Slope-X, Slope-Y, and Slope-Z) by reconstructing the slopes with asserting different types of compaction energies. During reconstructing slopes, bucket of excavator had been used in loose condition. Slope-X was built with low compaction energy. In this case, only slope was shaped by pushing and tamped slightly. Then, Slope-Y was built with increasing compaction energy with increasing tamping and pushing with bucket. At last, Slope-Z was built with more compaction energy with the same bucket by relatively high tamping. Here, it should be noted that the tamping of slope was performed to check the quality of slope regardless of amount of energy required to make the safe slope. Fig. 4 shows the photographs of reconstructing embankment slopes. Fig. 5 shows the reconstructed slopes with different compaction energies. Afterwards, similar field measurements of RI and FWD (Ninomiya 2009) were taken after constructing grids within the slopes. Soil samples from Slope-D and recreated slopes were taken for determination of natural water contents and compaction test were performed in the laboratory. Free fall of 4.5 kg rammer from 45 cm height with 92 blows per layer for 3 layers of soils was considered in the experiment (JIS A 1210). Through the test, optimum water content and maximum dry density of embankment soil were determined (Fig. 6).

3 RESULTS AND DISCUSSIONS

In the moisture-density relationship curve in Fig. 6, the dry densities measured by RI in the field for slopes, D, X, Y, and Z were plotted with their respective natural water contents. The water content of embankment slope exceeds the optimum water content obtained from standard laboratory test. At the initially built up Slope-D, water content is more than two times from the optimum water content level and dry density is below the laboratory test. Similarly, in recreated slopes X, Y, and Z, increasing in compaction energy improve dry densities but corresponding water contents also increased. This indicates that the initially built embankment has not been considered near to the standard moisture-density relationship which will degrade the quality of the embankment slope. Correspondingly, Figs. 7 and 8 show the relationship between dry densities measured by RI and soil stiffness by FWD. The data measured on all slopes show scattered. Further, the measured data have been averaged from representing slopes and analyzed as shown by Figs. 9 and 10. It shows that soil stiffness and dry densities have increased with increasing compaction energies for slopes X and Y. However, the dry density of Slope-Z increased with relatively high compaction energy, stiffness decreased because the water content of this recreated slope was increased on tamping.

4 CONCLUSIONS

A case study of the embankment slope has indicated that increasing the compaction energies, dry densities increase but water content is quite high compared to optimum water content which will degrade the quality of the embankment slope. Soil stiffness measured by portable FWD in the field also strongly supports that the higher water content decreases the stiffness of the slope. Therefore, at first, it is necessary to control the water content before construction i.e., the dry area might be suitable to construct embankment. Afterwards, the process of making slopes must receive compaction energy homogeneously otherwise occurrence of inhomogeneity in slope will degrade the quality.

5 ACKNOWLEDGEMENTS

The authors are pleased to express warm gratitude to Asakawagumi Construction Company to provide financial support as well as accompanying joint research with Kyushu University. The authors are also thankful to Lab Assistant Er M. Nakashima, S. Liu, A. Sinkai, K. Kishimoto, and staffs of Asakawagumi for their strong supports to perform various tests.

6 REFERENCES

Day, R.W. 1998. Relative compaction of fill having oversize particles, J. Geotech. Engrg., ASCE, **115**(10): 1471-1491.

Ninomiya, H., Yasufuku, N., and Omine, K. 2009. Evaluation of slope soundness in rainfall seepage considering degree of compaction, Master's Thesis, Kyushu University: 109.

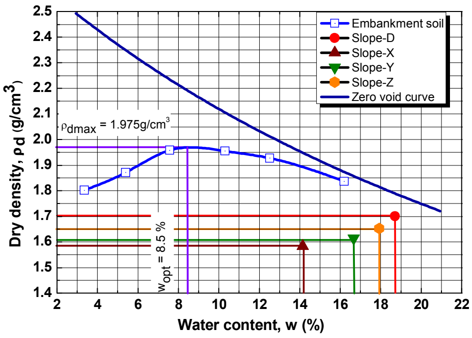

Fig. 6 Compaction curve and dry densities by RI

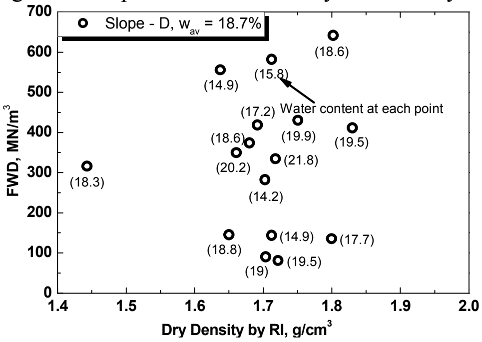

Fig. 7 Scattered values of dry density and FWD of Slope-D

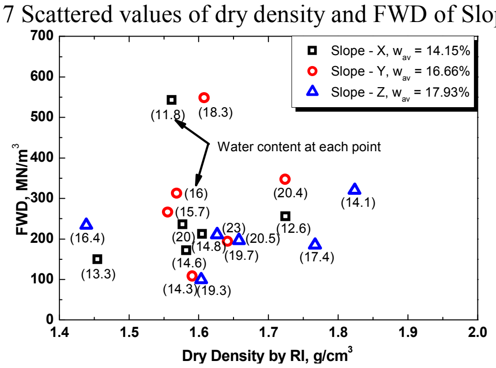

Fig. 8 Scattered values of dry density and FWD of Slopes

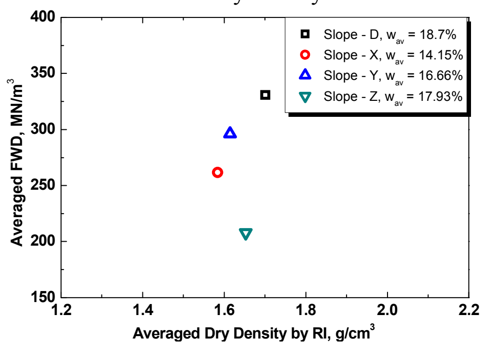

Fig. 9 Averaged relationship between dry density and FWD

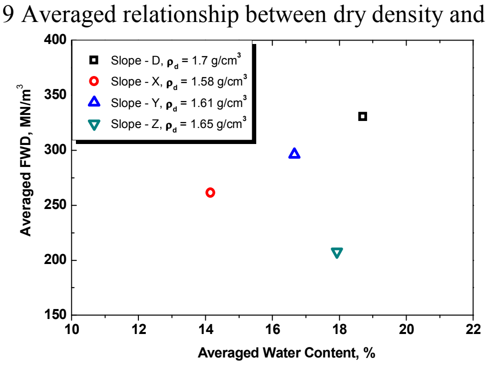

Fig. 10 Averaged relationship between water content and FWD