Effect of long-term static load on the L-shaped retaining wall installed with thinned wooden pile and fiber optic geogrid using BOTDR method

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ABSTRACT
In this study, the effect of long-term static load was observed on the pile head together with straining of geogrid using optical fiber carried with an actual vehicle dump truck on the constructed L-shaped retaining wall using BOTDR method. The change in strain measured immediate after the construction was found to be decreased after four months due to stress relaxation on the geogrid. The strain under static live load was checked to a virtual rear portion of the L-shaped retaining wall and at the central portion of the bottom panel width of L-shaped retaining wall. The straining on geogrid is found to be relatively small and can bear the load of the dump truck to some extent.

RÉSUMÉ
L'objectif de cette étude était d'observer l'effet à long terme d'une charge statique sur la tête du pieu en utilisant un camion-benne comme chargement et la déformation du géotextile en utilisant de la fibre optique et la méthode BOTDR (réflectométrie). Il s'avère que la déformation mesurée immédiatement après la construction a diminué après quatre mois en raison de la relaxation des contraintes sur le géotextile. La déformation sous charge statique a été mesurée avec la roue arrière du camion à la position de la portion arrière virtuelle du mur de soutènement et de la position centrale de son panneau de fond. Il se trouve que la déformation du géotextile est relativement faible et est capable de supporter la charge du camion dans une certaine mesure.

1 INTRODUCTION

The Ariake Sea coastal area is comprised of viscous and highly compressible soft ground with 10-30 m thick soft clay deposits. These lowland areas are at high risk to construct any civil engineering structures in addition to the effect of sea level rise. Hence, it is required to build engineering structures such as embankments to protect from sea flooding due to high tide. Several researchers and professionals are hence practicing different geotechnical methods such as deep mixing column, basal reinforcement, steel grid reinforced embankment as one of the ground improvement techniques (Shen and Miura 2001, Chai et al. 2002, Bergado and Teerawattanasuk, 2008). With the advancement of reinforced concrete with deep mixing methods, wooden piles had been extensively utilised to build the structures in these lowland regions (Miura, 2008) in the contrary. Since, Saga prefecture belongs to chief resources of artificial forest, woods have become an alternative source for human civilization. Besides, wood is considered as environment friendly to use in foundations because is not affected with any metallic and acidic contaminations and is prevented by decaying of wooden structures. As a result, salinization and leaching can be prevented to ground water and sea water (Kamon et al. 1996; Kitazume and Takahashi, 2008). As with the economic booming together with the advancement in engineering in this modern era, these wooden structures have been replaced by concrete and steel piles. As a result, wooden piles had been aligned in shades in priority regardless of the size of the structure which have been still considered as one of the traditional methods. In this reason, some publications utilizing wooden raft and pile foundation structures have discussed the effects on the laboratory and at the site (Pounchompu et al., 2012; Manandhar et al. 2014a; Manandhar et al. 2014b).

Miyazoe et al. (2008) studied the applicability of wooden pile-bottom slab foundation on soft ground and implemented at the bottom panel system structure of the foundation. The design and the construction manuals has been published with application to the waterway box culvert and precast L-type retaining walls. Further, a reinforcing material such as geotextile has been incorporated to reduce the load acting on the wooden pile emphasised specially upon the effective use of thinned wooden short piles. It is aimed at effective use of short length thinned wooden pile.

The load meter was installed to thinned wooden pile head which was used for the L-shaped retaining wall foundation along the road construction site, Ashikari district of Saga Prefecture, Japan. The pile head load was subjected to reinforcing material with and without (additional planning) (initial plan) to measure the permanent straining of the reinforcement.

In this research, the effect of long-term static load was observed on the pile head together with strain measurement of geogrid using optical fiber carried with an actual vehicle dump truck on the constructed L-shaped retaining wall using BOTDR (Brillouin Optical Time-Domain Reflectometry) method.

2 FIELD INSTRUMENTATION AND OBSERVATION

The field site and instrumentation location are aligned along the Jianbei Ashikari line road construction business in Saga Prefecture at Ogi Ashikari Dome land by Saga Ariake Sea coastal road maintenance office "Michiaratame-chi - No. 0130338-009-2008 fiscal year. The Jiangbei Ashikari line road improvement (local road) (General) construction". It is an L-shaped retaining wall constructed in engineering wards with height of 1.6 m and plan length is extended up to 18.0 m.

The main objective of the study is to reduce the load on the thinned wooden pile head installed inside the precast L-shaped retaining wall using geotextile and strain measurement with aid of optical fibre based on designed construction manual for the bottom panel system. The site investigation was performed with in-situ tests of cone penetration test, field density test and Swedish sounding test at the targeted locations. The cone penetration test, the adhesive strength of the foundation ground, the field density test, the unit volume weight and the Swedish sounding test of the backfilled soil of the retaining wall were performed in order to understand effective internal friction angles of the backfilled soil.

In order to observe the straining and effect of long-term static load, two optical fiber sensors have been installed on load meter and a reinforcing member has been installed in the head of the wooden pile. Figures 1, 2 and 3 illustrates the plan views of the thinned wooden pile location, the load meter and the test respectively. In addition, Figures 4 and 5 show photographs of installation condition of load meter and layout perspective of optical fiber sensor in connection with the reinforcement.

3 EFFECTS OF THIN WOODEN PILE HEAD LOAD

The cone penetration test results (Fig. 3) shows that the foundation of the L-shaped retaining wall installed at the site transferred the adhesive force of 9.19 kN/m^2 from cohesive soil of the earth's surface to the depth of 2.7 m below the ground which has followed down through a 60 cm thick intermediate sand layer (Ground Investigation

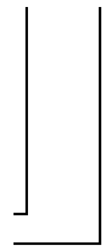

Figure 1. Plan view of wooden pile installation

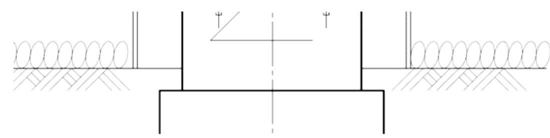

Figure 2. Plan view of load meter installation

Method, 2003). The cohesion of the bottom cohesive soil layer is identified to be 14.02 kN/m^2. The results of field density and Swedish sounding tests have identified the wet density (γ_t) and the internal friction angle (ϕ) of the backfilled soil were 12.1 kN/m^3 and 26.2º respectively (Ground Investigation Method, 2003a).

Measurements were carried out for about 160 days under the condition that the traffic load is not given at both construction stages of wooden pile installation, refilling and subgrade course work, and construction completion. Thereafter, the running test with an actual vehicle dump truck was implemented to measure with the live load. The traveling position of the dump truck is a virtual back and bottom version center position of the L-shaped retaining wall. The test condition is shown in Figs. 6 and 7.

Figures 8 and 9 show the changes with time of the pile head reaction force in the original plan and the time course of the pile head reaction force in addition plan respectively. The results illustrate that the first pile head load in the construction stage increased almost linearly. Meanwhile, the pile head load after construction completion tends to increase in spite of the absence of the upper mounting load. This may be due to an increase in unit volume weight of back filled soil by rainwater penetration, increase of the peripheral surface friction force of wooden pile, even can be considered, such as differences in the distribution of pile head load acting on the 5 wooden piles . Load acting on the wooden pile

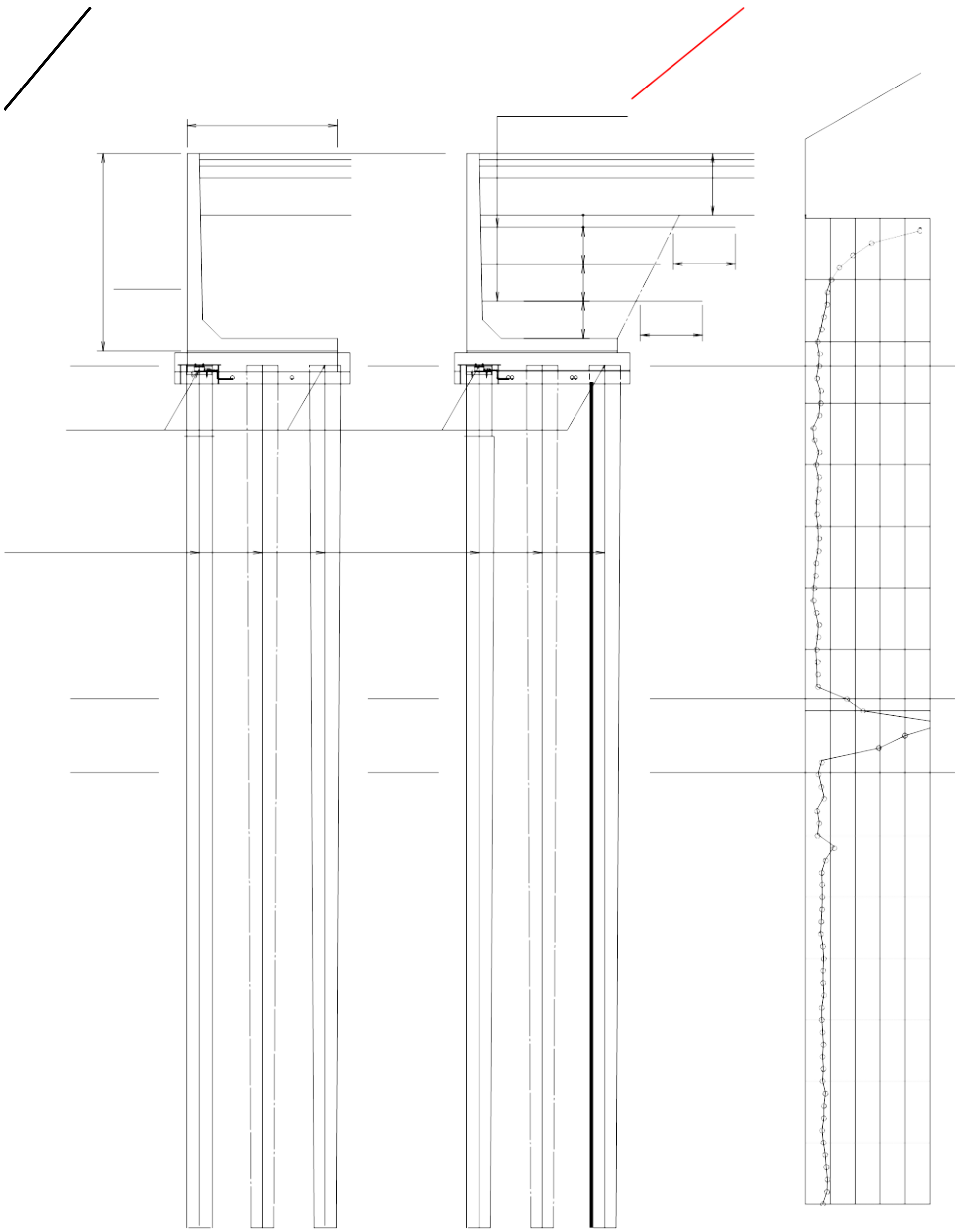

Figure 3. Representation of sectional view of pile installation for original and additional plans together with soil profile and cone penetration test results

increases with time, it can be said that it tends to approach the allowable circumferential surface bearing capacity q_a = 28.9 kN/pile. The pile head load acting on the front pile observed as larger as 4.4 kN than the rear pile before piles under the conditions of the original plan. The result obtained almost same value in additional planning condition. There are some reasons considered as that the reduction of the load acting on the front pile was due to the installed reinforcement, equalization of load acting on both rear and front piles due to the installed reinforcement, and so on.

Changes in the pile head reaction force at the time of running test 1 is shown in Fig. 10. The dump truck is allowed to run at a speed of about 250 m/sec in order to measure the pile head load. Consequently, the pile head load was identified to be affected with the live load significantly. In addition, the difference between the pile head load of the rear pile and the front pile at the initial plan was 5.88 kN which was larger in difference in the post-pile in the additional plan by 2.09 kN.

4 MECHANISM OF STRAIN MEASUREMENT USING FIBER OPTIC GEOGRID

A single fiber optic cable installed in the ground can obtain more accurate strain measurement using Brillouin Optical Time-Domain Analysis method. Installation of thousands of strain gauges along a single cable into the required earthwork structure can provide recent condition of the ground (Minardo et al., 2012). In addition, several pioneer researchers have practiced the usage of fiber optic strain sensors for geotechnical investigations (Dewynter et al., 2009; Olivares et al., 2009; Iten, 2011; Zeni et al., 2015). In this research the mechanism of fiber optic geogrid straining has been observed through its measurement technology with its structure in order to know the straining owing to long-term static load and live load.

4.1 Measurement Technology

Modern civil engineering society is adopting new optical fiber sensing technology and progressing rapidly throughout the world in various sub-sectors of its discipline. In particular, a single optical fiber can measure the light transmission time of the optical fiber attenuation and distortion on the information of the displacement of phase and the temperature distribution which have been directly implemented for the maintenance of landslides and river embankments to measure the displacement of the ground (the Ministry of Land, Kato et al., 2000).

The scattered light generated in the optical fiber by subtle fluctuations of the bending and density of the glass, the part of the property is the light which comes back as a reflected light. The scattered light is in proportion to the strain amount of the optical fiber, has been found to vary frequency. The strain amount was measured using

Brillouin Optical Time-Domain Reflectometry (BOTDR) method. The BOTDR method can measure the straining in a wide spectrum at 50 mm interval. Figure 11 shows the measurement principles of BOTDR.

4.2 Fiber Optic Geogrid Structure

Since the sensors are required impact resistance and durability in construction, and have a structure which incorporates a fiber optic to the geogrid, embankment material can be measured at the wide range of cohesive soil to gravelly soil. The optical fiber be inserted at the centre of the aramid fiber and it has a structure in which the aramid fibers are coated with polyethylene (Figs. 12 and 13). Furthermore, the lattice structure measure the frictional resistance of geogrid sufficiently fill material and can follow the distortion of the fill material (Tatsuta et al., 2005).

Figure 4. Load meter installation condition

Figure 5. Situation of reinforcement

Figure 6. Dynamic loading test situation

Figure 7. Dynamic loading test situation, cross view

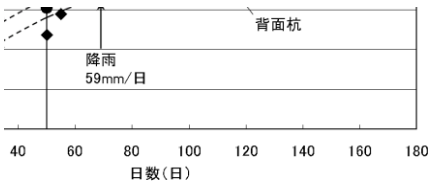

Figure 8. Pile head reaction force due to time (initial plan)

Figure 9. Pile head reaction force due to time (additional plan)

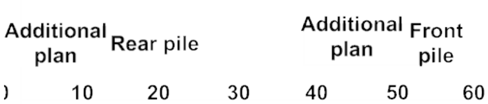

Figure 10. Pile head reaction force during live load

Figure 11. Representation of optical fiber

4.3 Straining due to Long-Term Static Load

Graphs represented by Figs. 14 and 15 are straining of geogrid measured for 160 days during construction and after the pavement. The previous laying of geogrid is set as the initial value to measure the rate of straining. Measurement results taken on June 19, 2009 are the amount of straining immediate after the completion of the construction. The amount of straining has decreased after four months due to the stress acting on the geogrid by relaxation. The values of the aforementioned pile reaction force have also changed over time which can be due to changing of the internal stress of the backfill soil of the retaining wall. In particular, at the upper geogrid, it has equivalent straining approximated with the initial value.

4.4 Straining due to Live Load

Figures 16 and 17 represent the time course of the straining at the time of running test. In Test 1, loading was measured at the stationary state of the rear wheel of the dump truck to the virtual rear portion of the L-type retaining wall (1.5 m around in the graph). In Test 2, loading with the wheel was measured at the central portion of the bottom panel width of L-shaped retaining walls (around 0.5 m in the graph). In Test 3, loading was measured immediately after unloading the loading due to rear wheels. Figure 18 shows the wheel position after the dump truck.

Measurement results of straining on October 29, 2009 before running experiment shows the variation of the straining as an initial value reflected by tests 1 and 2 during loading condition in which strain compression side altered to the tensile side in the periphery. Moreover, the remaining influence of loading due to tensile straining to the geogrid immediate after unloading has been understood (Test 3). Subsequently, the loading used with the dump truck accompanied the geogrid shows that the straining on the geogrid is relatively small and be able to bear the load of the dump truck to some extent.

5 CONCLUSIONS

The aim of this study was focused to the retaining wall of the height of 1.2 m or more by achieving equalization of the reduction of lateral earth pressure and the bottom board reaction force using a reinforced material coped with the thin wooden pile to the bottom panel system. The main results are summarised below.

1. The ratio of the pile head load of the front pile and rear pile of the initial plan was 6:4. In contrast, the ratio was observed to be 5:5 for the additional plan when the geogrid was installed. By combining the reinforced material and backfill for the retaining wall, the equalization of the ground reaction force can be expected.
2. It is possible to use small diameter wooden pile of short length by reducing the ground reaction force of equalization and lateral earth pressure.
3. The amount of straining of geogrid is a relatively small in value. Therefore, the reinforcement can be considered standard and cost effective.

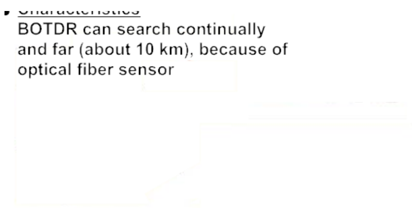

Figure 12. Measuring principle of BOTDR method.

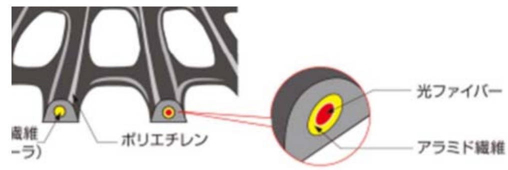

Figure 13. Fiber optic sensor geo structure

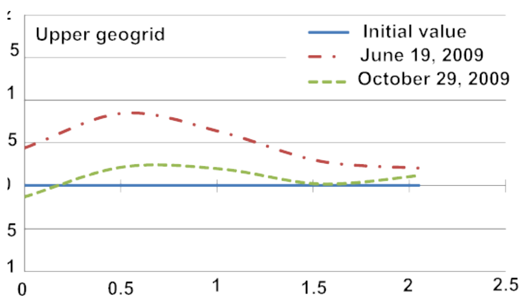

Figure 14. Straining at the upper grid

Figure 15. Aging of the strain (wall grid)

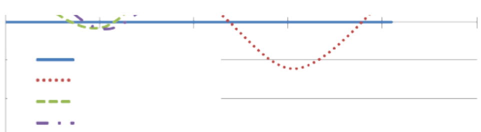

Figure 16. Strain during running test (upper grid)

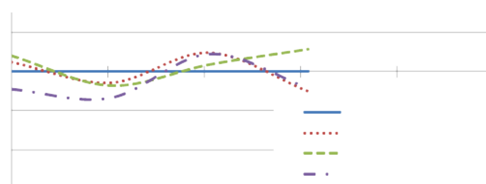

Figure 17. Strain during running test (lower grid)

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Figure 18. Status of the dump truck rear wheel position

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