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Post-construction performance of a two-tiered geogrid reinforced soil wall backfilled with soil-rock mixture

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ABSTRACT

There have been very few studies on the application of soil-rock mixtures as the backfills of geogrid reinforced soil retaining walls with due concern for their long-term performance and safety. In this study, a 17-m high two-tiered reinforced soil wall backfilled with soil-rock mixture was instrumented for its performance under gravity load after construction. The instrumentation continued for 15 months. It is found that soil-rock mixtures with small rock content (<30%) have the potential to be used as the backfill materials of geogrid-reinforced retaining walls, but special attentions should be given to compaction quality, backfill–geogrid interaction, and installation damage to geogrids. Reinforcement slippage is possible because of the large particles, but it was small in this case and ceased to develop nine months after the end of construction. Compressibility difference between reinforced and unreinforced backfill might led to rotation of the upper tier. Using the estimated soil strength, the predictions of reinforcement loads by the FHWA methods were 100% higher than the estimated ones from measured strains.

1. Introduction

Use of locally-available geological materials as the backfills of geosynthetic reinforced soil retaining walls can further increase the cost-effectiveness of this type of earth structures, provided that the structure performance can be satisfactory. Since the emergence of geosynthetic reinforced soil technology, considerable efforts have been directed to test the feasibility of using different marginal backfill soils with cohesive contents or large percentage of non-plastic fines (e.g., Benjamim et al., 2007; Liu et al., 2009; Ling et al., 2012; Yang et al., 2012a), but very few studies have been reported on the application of soil-rock mixtures.

Soil-rock mixtures are commonly found geological materials in many places. According to many design guidelines of reinforced soil walls (e.g., Berg et al., 2009), if the materials are to be used as backfills, the rock content (particle size larger than 76.2 mm) should be removed, which considerably increases the construction cost. It is still not known if soil-rock mixtures with small rock content (<30%) can be used as the backfill materials of reinforced soil walls.

On another issue, there have been extensive full-scale test results on the performances of single-tiered reinforced soil walls (Allen and Bathurst, 2002; Benjamim et al., 2007; Bathurst et al., 2009; Kongkitkul et al., 2010; Yang et al., 2009, 2010; Horpibulsuk et al., 2011; Huang et al., 2013), but those of multi-tiered walls were still limited (Yoo and Jung, 2004; Yoo and Kim, 2008; Yoo et al., 2011; Stuedlein et al., 2012), although many high reinforced soil walls are now built in tiered configurations, and some analyses have shown that multi-tiered configuration may improve the performance of reinforced soil walls (Leshchinsky and Han, 2004).

In Shandong Province, China, a 17 m high two-tiered reinforced soil wall backfilled with soil-rock mixture was instrumented and monitored until 15 months after the end of construction. The soil-rock mixtures have a rock content of 15–25%. This study focuses on its post-construction performance, while its responses during construction were reported elsewhere (Yang et al., 2012b). It is hoped that the results from this field instrumentation will shed light on the application of soil-rock mixtures as backfill materials of reinforced soil walls. The results will also add to the literature of the full-scale test results of multi-tiered walls.

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2. Field instrumentations

The two-tiered reinforced soil wall is located in Laiwu City in the middle of Shandong Province, China. It serves as a retaining wall of a large oxidized pellet facility in a steel plant. The hard-rock ground underneath the retaining wall has a very uneven surface; hence a concrete step-foundation was prepared before wall construction, as shown in Fig. 1. The wall is 17 m high, divided into a 7.9 m lower tier and a 9.1 m upper tier at an offset of 2 m. The total length of the wall is about 300 m. The modular block facings of both tiers were designed to have a 1:10 slope. The facing of the lower tier was directly placed on the concrete foundation without any fill in the front, as shown in Fig. 1. Construction of the retaining wall started in late March of 2010 and ended in early May of the same year. After the construction, no sizeable surcharge was applied on the backfill surface during the monitoring period.

Locally-available soil-rock mixtures were used as backfills in this project. The soil-rock mixtures were considerably heterogeneous, with a rock content (particle size $>$ 76.2 mm) ranging from 15% to 25% by weight. The largest particle size was larger than 20 cm. Excluding the rock content, the soil can be classified as poorly-graded gravel with sand according to United Soil Classification System. Fig. 2 shows a representative grain-size-distribution curve. The rock and gravel contents were weathered products of lime stone, while the rock particles are medium-weathered with visible cracks. The backfills were compacted using a heavy vibratory roller at a thickness of about 30 cm (after compaction), but the region 1.0 m away from the facing was densified by a lightweight vibrating rammer. Backfill compaction quality was monitored during the construction by water replacement method in a test pit (ASTM D5030-04, 2004), resulting in an average moist unit weight γ of 22.2 kN/m^3, but the backfill density varied considerably at different locations, and the dry unit weight γ_d ranged from 19.3 kN/m^3 to 21.4 kN/m^3. Due to the existence of large particles, the shear strength of the backfill was not directly tested. Instead, the design assumed a direct-shear friction angle ϕ of 35° without cohesion based on that of the soil content at medium dense state. According to limited studies on soil-rock mixtures, rock content could increase the friction angle of soil-rock mixtures by 1–5° when the rock content was in a range of 15–25% (Lindquist, 1994; Xu et al., 2011). Therefore, the actual angle of internal friction of the backfills, particularly the well-compacted portion, could be higher than what was used in the design.

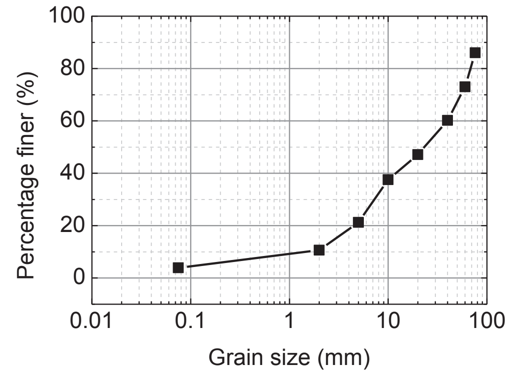

Fig. 2. Representative grain-size-distribution of the soil-rock mixtures.

Three types of HDPE geogrid were used as reinforcements. Fig. 3 shows the load–strain relationships of the geogrids at small strain using multi-rib tensile test as per ASTM D6637-11 (2011). Table 1 shows the strength and deformation properties of the geogrids. The creep strength was obtained as per ASTM D6992-03 (2003). 6 cm of HDPE geogrid was casted in the facing blocks, and connected to the geogrid reinforcement by bodkin joints. The reinforcement length was mainly 14 m in the lower tier and 10 m in the upper one. The reinforcement spacing was 0.3 m in the lower portion of the wall and 0.6 m in the upper portion, the details of which are shown in Fig. 1. The reinforcement layouts were determined as per the Chinese Standard (GB 50290-98, 1998), which satisfied the requirements of internal, external and compound stabilities.

The field instrumentations consist of the horizontal earth pressures at the back of the facings, the strains in selected reinforcement layers, and the lateral facing displacements at the toes and top of the wall. Vertical earth pressures in the backfills were also monitored, but there was relaxation below the pressure cells after certain fill heights, and the results afterwards were not reliable. The pressures and reinforcement strains were monitored during construction, but the lateral displacements were surveyed only after the end of construction. Fig. 1 shows the instrumentation layout. Among the instrumentations, the earth pressures were measured with vibrating-wire pressure cells, the measuring range of which is 0–600 kPa with a sensitivity of 1 kPa. The reinforcement

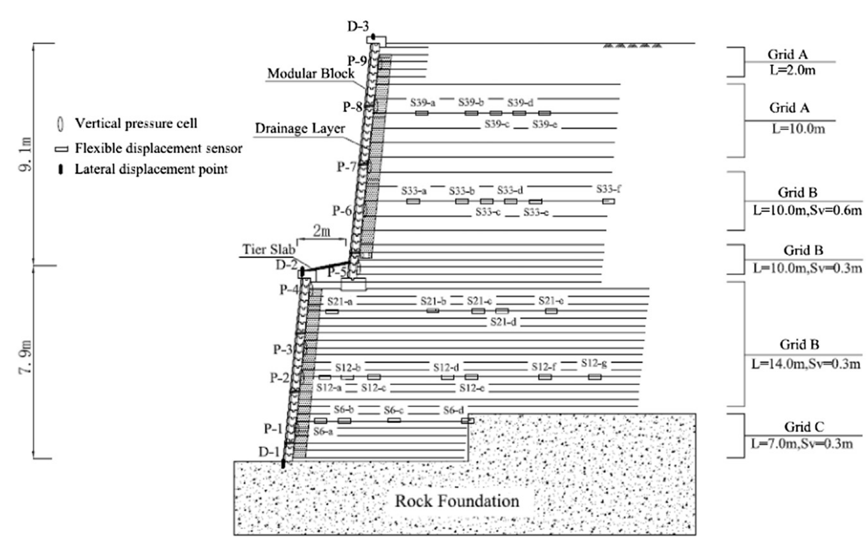

Fig. 1. Field instrumentation setup.