Geogrid Reinforced Lightweight Tire-Chips Sand Geomaterials for Embankments on Soft Ground

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ABSTRACT
Construction of highway embankment using strong but lightweight geomaterials over soft ground will alleviate problems of instability and long-term settlement. Backfills of retaining structure can also be constructed using lightweight materials resulting in lower earth pressure and improved economics. There are a variety of lightweight geomaterials available. However, the large volume needed in embankment and backfill construction often places limits on the use of costlier manufactured lightweight materials. This study utilized lightweight rubber tire-sand mixtures reinforced with geogrid for embankment on soft ground. The test embankment is constructed in the campus of Asian Institute of Technology (AIT). The geogrid reinforced embankment system is extensively instrumented in the subsoil and within the embankment itself in order to monitor the behavior of the lightweight reinforced embankment both during construction and in the post-construction phases, and thereby to evaluate its performance. Settlements of embankment were observed by surface and subsurface settlement plates. Excess pore water pressures were observed by open stand pipe piezometer. Lateral wall movement was monitored by digitilt inclinometer. Geogrid movement was monitored by high strength extensometer wires. It is concluded that the behavior of rubber tire-sand mixture and geogrid reinforced embankment is suitable for application of lightweight geomaterials in highway construction and bridge approach embankments.

1. INTRODUCTION

Construction of highway embankments on soft ground faces problems of high settlement and stability. Lightweight materials can be used as backfills in retaining structures and in the construction of embankments resulting in lower earth pressure and greater stability on soft ground. In recent years, there has been a growing emphasis on using industrial by-products and waste materials in construction. Used rubber tire is the one of waste material that can be used as backfills of wall embankment. Because of the low specific gravity of scrap tire relative to that of the soil solids, tire chips alone or in mixtures with soil offer an excellent lightweight and strong fill material.

Due to the advantage of lightweight geomaterials for geotechnical application on soft ground, the performance of full scale embankment test made of rubber tire-sand mixture reinforced with geogrid was constructed to study its behavior. The settlement of embankment was observed and analyzed with existing data. Excess pore water pressure during and after construction were also monitored to evaluate consolidation settlement. Lateral wall movement and geogrid movement were measured with the help of digitilt inclinometer and high strength extensometer wire respectively. Finally, the performance of embankment is evaluated in order to clarify geotechnical application on soft ground area.

The applications of used rubber tire as lightweight material by full scale test were studied by many researchers. Humphrey et al. (2000) reported that tire shreds were used as lightweight fill for construction of two 9.8 m high highway embankments in Portland Jetport Interchange, Maine. The embankment was topped with 1.22 m of granular soil plus 1.22 m of temporary surcharge. Settlement plates were installed at the top and bottom of each tire shred layer to monitor settlement. It was found that the predicted compression was significantly greater than the measured value. Tweedie et al. (1998) constructed shredded rubber tire test wall that can accommodate approximately 100 m^3 of backfill. The size of tired shreds used in the study was in the range of 38 mm to 76 mm. The horizontal stress distribution for tire shreds at the rotation of 0.01H was compared with the active earth pressure for the granular fill. For granular material as backfill, the larger stress distribution is considerably larger than from the tire shreds fill, with the resultant horizontal force from the tire shreds being approximately 35 % less than that of the granular fill. The full scale test embankment was constructed by using shredded tires as lightweight backfill with geogrid reinforcement (Hsieh et al. 1998). The embankment heights varied from 5 to 7 m with the geogrid reinforced vertical masonry facing on the north side. The size of shredded tires varied from 100 to 500 mm. Due to the compressibility of tire chips, it was recommended that the thickness of a single layer of tire chips not exceed 2 m. It was shown that the use of 300 mm-thick tire chips with soil inter layers can significantly reduce the embankment settlement.

2. FULL SCALE TEST EMBANKMENT

2.1 Instrumentation Program

The test embankment was constructed in the campus of Asian Institute of Technology (AIT). The general soil profile consists of weathered crust layer of heavily overconsolidated reddish brown clay over the top 2.5 m. This layer is underlain by soft grayish clay down to about 8.0 m depth. Medium stiff clay with silt seams and fine sand lenses were found at the depths of 8.0 to 10.5 m. Figure 1 summarizes the subsoil profile and relevant parameters. The embankment system was extensively instrumented both in the subsoil and within the embankment itself. Since the embankment was founded on a highly compressible and thick layer of soft clay which will dictate the behavior of the embankment to a great extent, several field instruments were installed in the subsurface soils. The 3D illustration of full-scale field test embankment is shown in Fig. 2. The instrumentation in the subsoil were installed prior to the construction of the geogrid reinforcement wall and consisted of the surface settlement plates, subsurface settlement gauges, temporary bench marks, open standpipe, groundwater table observation wells, inclinometers, dummy open standpipe, dummy surface settlement plates and dummy subsurface settlement gauges. Six surface settlement plates were placed beneath the embankment at 0.45 m depth below the general ground surface. Settlements were measured by precise leveling with reference to a benchmark.

The measurement of the subsurface settlements was similar to that of the surface settlements. Twelve subsurface gages, six of which were installed at 6 m depth, the rest at 3 m depth below the general ground surface at different locations. Two dummy gages were also installed at depths of 3 m and 6 m. The pore water pressure was monitored by the conventional open stand pipe piezometers. Six of these were installed in the soft clay subsoil at 3 m and 6 m depth from the ground level. Two of dummy open standpipes were installed at the area nearby temporary benchmarks.

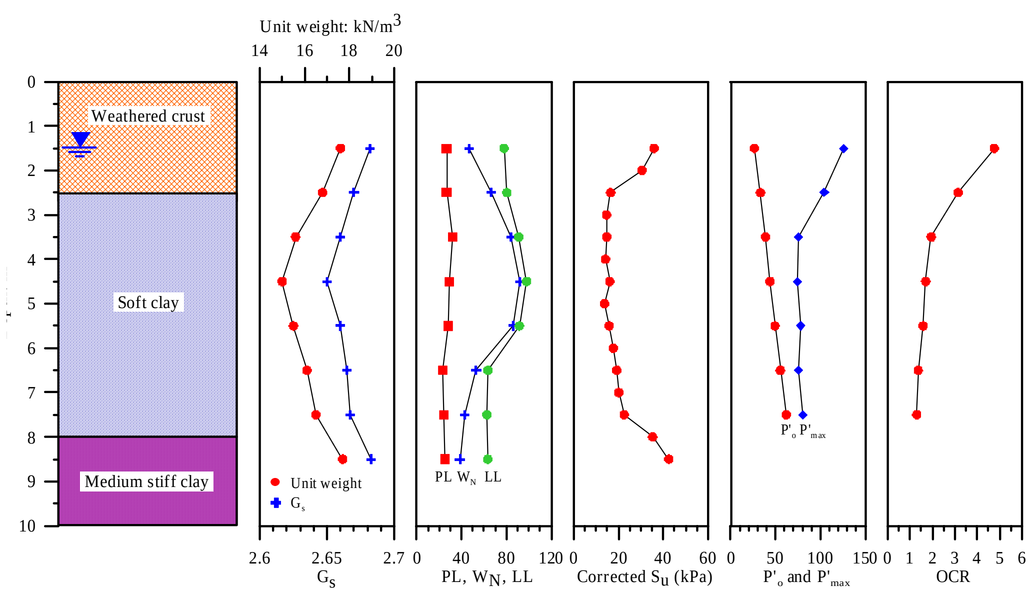

Figure 1. Subsoil profile and relevant parameters

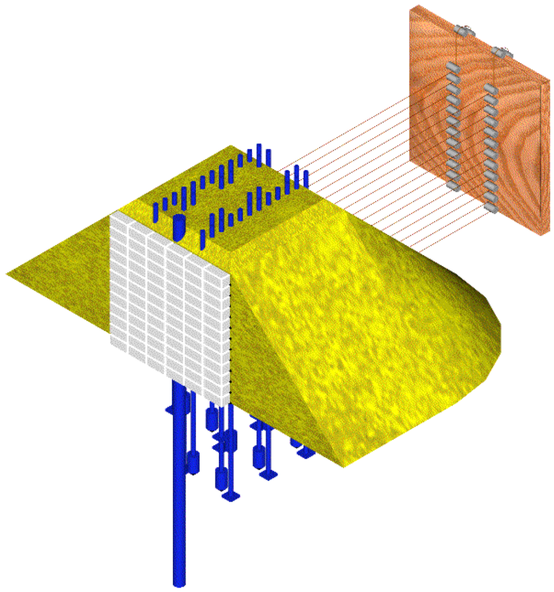

Figure 2. Schematic 3D view of full scale test embankment with instrumentation

2.2 Embankment Construction

The construction of the wall involved the precast concrete block facing unit with geogrid reinforcement. The rubber tire chips were mixed with sand in the ratio of 30:70 by weight. The backfill was compacted in layers of 0.15 m thick of 0.6 m thickness to density of about 95% of standard proctor. The compactions were carried out with a roller compactor and a hand compactor near instrumentation such as settlement plate, stand pipe and inclinometer. The degree of compaction and the moisture content were checked regularly at several points with a nuclear density gage. Wherever, the degree of compaction was found to be inadequate, addition compaction was done until the desired standards were met. The sand backfill was used as the cover for the rubber tire chips-sand for reducing a self-heating reaction. The thickness of the cover was 0.6 m and a non-woven geotextile was used as the erosion protection on side slope. Hexagonal wire gabions were used on both side of the concrete facing. Figure 3 illustrates the completed embankment construction (Tanchaisawat et al., 2007).

Figure 3. Completed embankment construction

3. RESULTS AND DISCUSSIONS

3.1 Observed Settlements

The observed surface settlements are illustrated in Fig. 4. During the construction period, immediate elastic settlements were observed. The rate of settlement was low in all the surface and subsurface settlement plates during the construction period. After the construction, the rate of settlement was higher but after 172 days from the end of the construction. After 210 days from the end of construction, the maximum settlement was 122 mm as recorded in surface settlement plates near the facing. This is because the weight of the concrete facing is more than the embankment and the forward tilting of rigid facing. Along the cross section of the embankment, settlement is decreased from front (122 mm) middle (112 mm) and back (104 mm). The different of settlement along the cross section of embankment is almost the same, its show that continuous embankment loading acted on the ground. The average surface settlement on the ground after 210 days from the end of construction is about 111 mm.

The observed subsurface settlements beneath the test embankment are shown in Fig. 4. Settlement rate was high after the end of construction. The maximum subsurface settlement at 3.0 m was 112 mm and occurred at the front section of the embankment near the concrete facing and the minimum settlement was 79 mm and occurred at the middle section of the embankment. While the maximum subsurface settlement at 6.0 m was 89 mm and occurred at the middle section of the embankment and the minimum settlement was 76 mm and occurred at the front section of the embankment. The settlement profile shows that the heavy concrete facing influences the settlement near the surface and settlement at deeper depth is influence by the embankment.

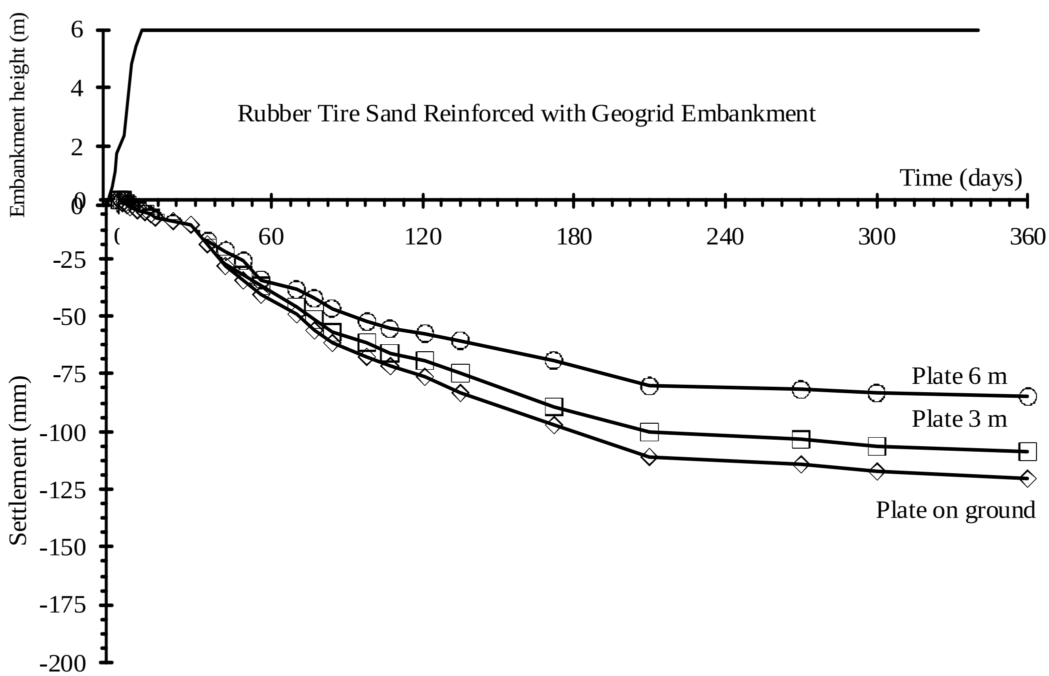

Figure 4. Observed average settlements at different depths

Figure 5 demonstrates the comparison of the maximum settlement between conventional sand backfill reinforced with hexagonal wire mesh (Voottipruex, 2000) and the lightweight embankment in this study. The maximum settlement of lightweight embankment was 130 mm compared to 400 mm for conventional backfill without foundation treatments.

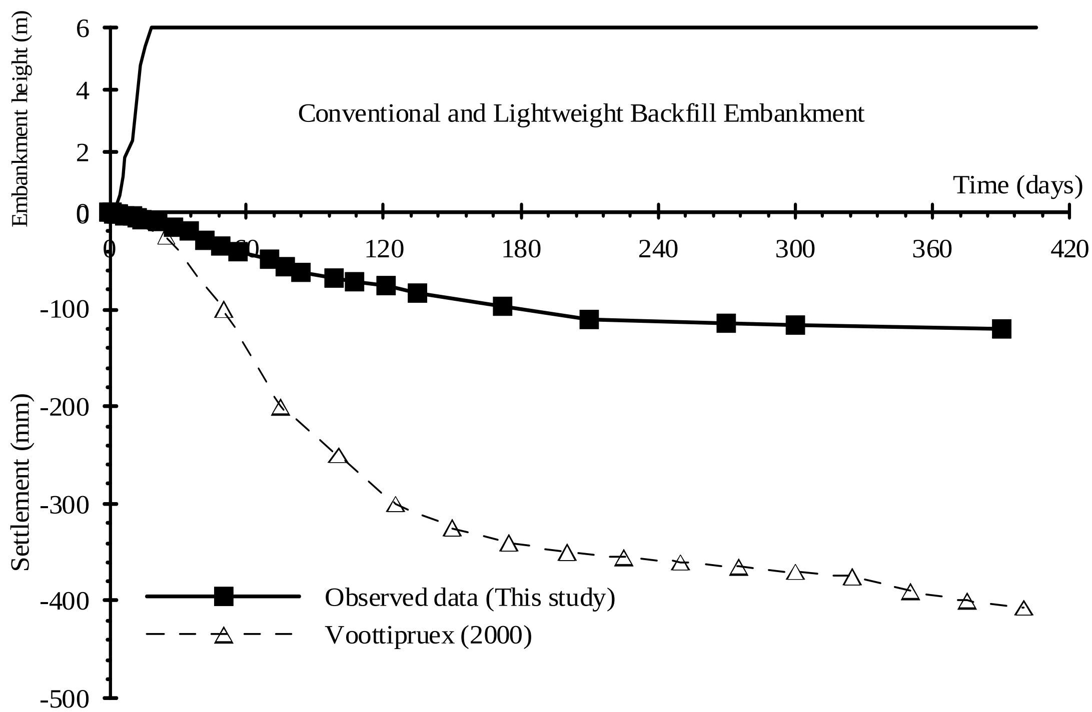

Figure 5. Comparison of settlement between conventional and lightweight backfill

3.2 Observed Pore Water Pressures

The excess pore water pressure below embankment area was obtained from the open stand pipe piezometer. Figure 6 depicted the excess pore water pressure during and after construction at location of front, middle and back of embankment. The maximum pore water pressure occurred at 15 days after full height of embankment at 3 m depth below ground at the back of embankment. The maximum pore water pressure at 3 m depth is 57 kN/m^2 and 6 m depth is 47 kN/m^2. The trend of excess pore water pressure dissipation is an indication of consolidation of soft subsoil foundation. After 50 days, the excess pore water pressure tended to dissipate with time. The excess pore water pressure decreased to 18 kN/m^2 and 25 kN/m^2 at 3 m and 6 m depth, respectively, this excess pore water pressure was constant with time after 120 days from the end of construction. The excess pore water pressure at 3 m depth tended to dissipate to lower value than that at 6 m depth (Tanchaisawat et. al., 2007).

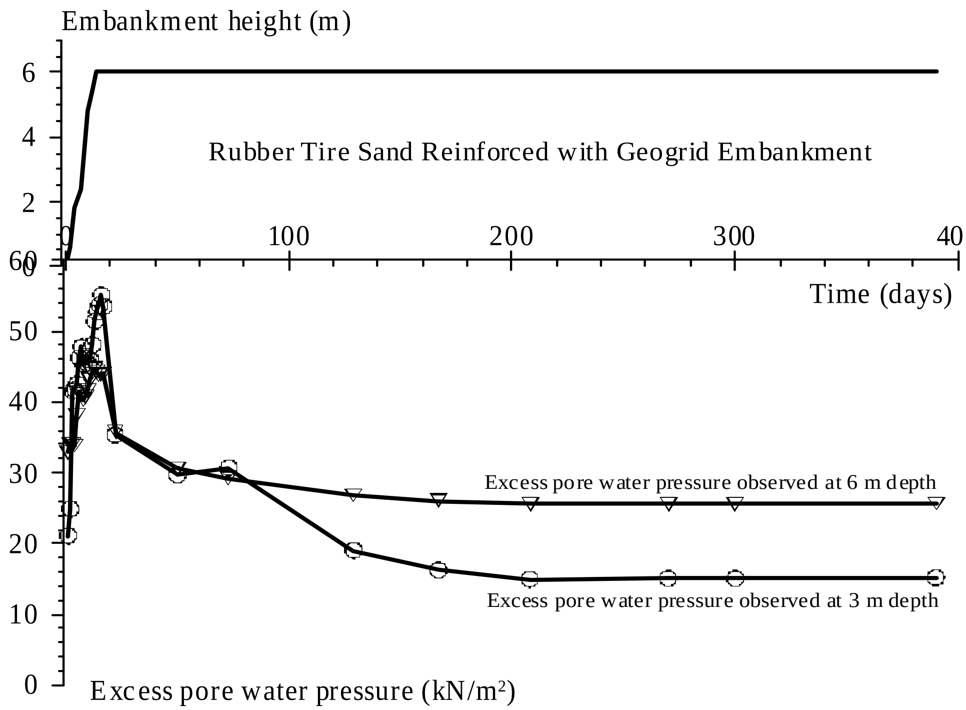

Figure 6. Observed pore water pressures at different depths

4. CONCLUSIONS

The full scale field test embankment was constructed by using rubber tire chips-sand mixtures as the lightweight geomaterials. The geogrid reinforced embankment system was extensively instrumented in the subsoil and within the embankment itself in order to observe its behavior during construction and post construction phases, and thereby evaluate its performance. The unit weight of rubber tire chip-sand mixtures with 30:70 % by weight is 13.6 kN/m^3 compared to conventional sand backfill of 18.0 kN/m^3. The former is lighter by about 75 % than the latter. The total settlement magnitude of 122 mm at ground surface is 67.5% less when compared to the corresponding value of 400 mm for conventional backfill without foundation treatments. The excess pore water starts to build up after 15 days since the end of construction and starts to dissipate after 50 days. The excess pore water pressure becomes constant after 120 days since the end of construction. This lightweight geomaterials reinforced with geogrid can be used for embankment construction on soft ground area to reduce total settlement of structure.

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