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Lightweight Geomaterials for Bridge Approach Utilization on Soft Ground Area

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ABSTRACT

Construction of bridge approach highway embankment using strong but lightweight geomaterials over soft ground will alleviated 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 is a variety of lightweight geomaterials available. However, large volume needed in embankment and backfill construction often places limits on the use of costlier manufactured lightweight materials. This study is aimed on used 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 wall both during construction and in the post-construction phases, and thereby to evaluate its performance. The unit weight of rubber tire sand mixture 30:70 by weight is 13.6 kN/m^3 compare to conventional backfill sand of 18.0 kN/m^3, it is lighter by about 75 %. The settlement magnitude of 122 mm at original ground is less when compare to conventional backfill. Differential settlements are small, so this type of lightweight material is appropriate for highway bridge approach utilization.
Key words: lightweight geomaterials, embankment, geogrid

INTRODUCTION

Construction of highway embankments on soft ground faces problems of high settlement and instability. 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, however, 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 embankments. 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. The application of lightweight geomaterials on soft ground foundation has been summarized by Miki (1996) as follows:

- Reducing residual settlement of low embankment road built on soft ground
- Minimizing differential settlement between approach embankment and structure, to prevent lateral movement of piled structures

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- Minimizing deformation when constructing near adjacent structure
- Minimizing residual settlement for high standard dikes and artificial islands
- Reducing the construction period substantially
- Achieving nearly maintenance-free infrastructure

The behavior of geosynthetic reinforced embankments over soft soil has attracted considerable attention both in practice and in academic research (Rowe and Li, 2005). To find the factors contributing to low mobilization of reinforcement strains and forces, Chai and Bergado (1993) studied the behavior of 8.5 m high embankment, reinforced with 2 layers of geogrid, on a 8 m thick of very soft to soft silty clay. Oikawa *et al*. (1996) constructed a 6 m high embankment, reinforced with 5 layers of geogrid, on a 10 m thick layer of peat. Their study showed that the reinforcement layers made construction possible and resulted in rigid-footing-like behavior of embankment.

The use of rubber tire as lightweight material by full scale test were studied by many researchers (Humphrey *et al.,* 2000). Tire shreds were used as lightweight fill for construction of two 9.8 m high highway embankments in Portland Jetport Interchange, Maine, U.S.A. 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 seen 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 this wall 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 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.

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 use of digitilt inclinometer and high strength extensometer wire, respectively. Finally, the performance of embankment is evaluated in order to clarify geotechnical applications on soft ground area.

MATERIALS AND METHODS

The test embankment was constructed in the campus of Asian Institute of Technology (AIT), Thailand. The general soil profile consists of weathered crust layer of heavily overconsolidated reddish brown clay over the top 2 m. This layer is underlain by soft grayish clay down to about 8.0 in depth. The medium stiff clay with silt seams and fine sand lenses was found at the depth of 8.0 to 10.5 m depth. Below this layer is the stiff clay layer.

Both laboratory and field tests were conducted on the foundation subsoil and the backfill material to determine the parameters for analysis and design. Subsoil samples were obtained at the site location prior to the construction of the test embankment. The field tests including vane shear tests were performed prior to the installation of any instrumentation and the subsequent construction of the test embankment.

Test for subsoil sample

Soil samples were obtained from the borehole at the construction site down to a depth of about 8 m to the bottom of the soft clay layer. Index tests, consolidation tests and unconfined compression tests were performed on the subsoil samples. The in-situ strength of the subsoil was measured by field vane shear test. Figure 1 summarizes the subsoil profile and relevant parameters. Laboratory consolidation tests were performed on subsoil samples from to different depths to determine the coefficient of consolidation and compression index.

Tests for interaction between geogrid and rubber tire sand mixture

Geogrid reinforcement used for embankment construction was tested to study the interaction of the geogrid with the rubber tire chips-sand mixture. Pullout test and large scale direct shear test were used for investigating the pullout and direct shear resistance. The pullout resistance of geogrid reinforcements depends on the sand content in the tire chips-sand mixtures. The pullout resistance increased with the increasing sand content in the mixture. The applied normal stresses were significant factors for pullout resistance, which increased with the increasing normal stresses. The failure modes of geogrid reinforcements were slippage failure at the normal stresses of 30 and 60 kPa, and tensile failure at the high normal stresses of 90 and 120 kPa. The direct shear resistance of geogrid reinforcements depends on the sand content in the tire chips-sand mixtures and increased with the increasing sand content. The applied normal stresses were significant factors for direct shear resistance, which increased with the increasing normal stresses. From overall test result of rubber tire chips-sand mixture compaction, pull out and large scale direct shear, Polyfelt geogrid TX100/30 and 30:70 rubber tire sand mixture which has cohesion of 12 kPa and friction angle of 22° (Prempramote, 2005) are appropriate material for full scale embankment construction (Tanchaisawat *et al.*, 2006).

Instrumentation program

The geogrid reinforcement 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 Figure 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

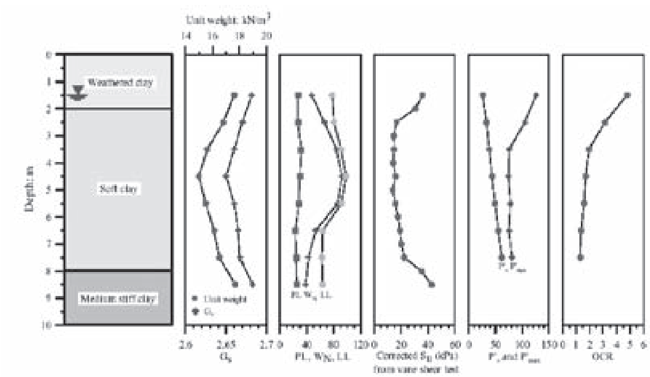

Figure 1 Subsoil profile and relevant parameters.

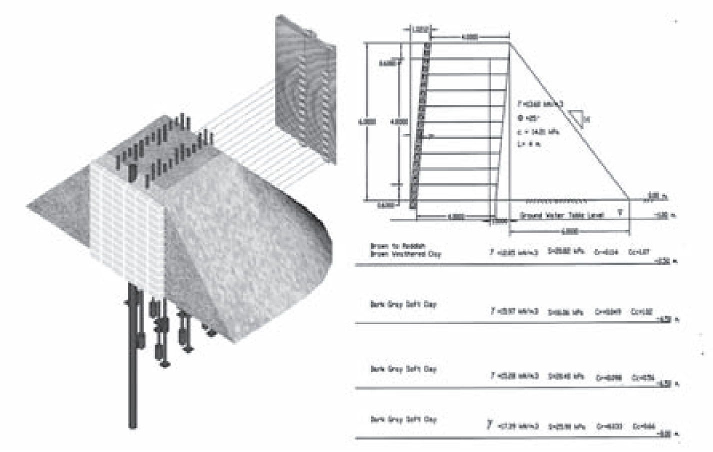

Figure 2 3D drawing and side view of test embankment.

piezometer, groundwater table observation wells, dummy open standpipe piezometer, 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 gauges, 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 gauges 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 general grand level. Two of dummy open standpipe piezometer were installed at the area nearby temporary benchmarks.

Construction of embankment

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 with a hand compactor near instrumentation such as settlement plate, piezometer and inclinometer. The degree of compaction and the moisture content were checked regularly at several points with a nuclear density gauge. 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 geotextiles 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 (Kanjananak, 2006).

RESULTS AND DISCUSSION

Surface settlements

The observed surface settlements of the test embankment are illustrated in Figure 4. During the construction period, immediate (elastic) settlements were observed. The rate of settlement was low for all the surface and subsurface settlement plates during the construction period.

Figure 3 Completed full scale test embankment Construction.

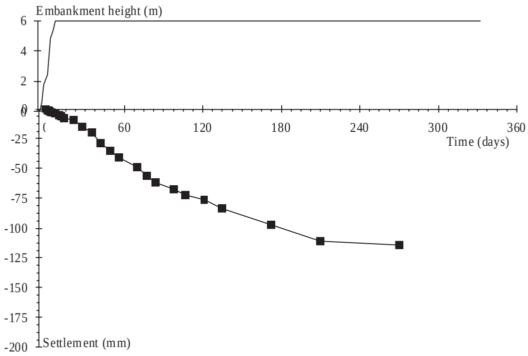

Figure 4 Observed surface settlement at original ground level.

After the construction, the rate of settlement was higher 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 by surface settlement plates near the facing. This is because the weight of the concrete facing is higher than the embankment and the forward tilting of rigid block. 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, showing 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.

Subsurface settlements at 3 m and 6 m depth

The observed subsurface settlements at 6.0 m depth beneath the test embankment are shown in Figure 5. Settlement rate were high after the end of construction. The maximum subsurface settlement at 3.0 m was about 112 mm and occurred at the front section of the embankment near the concrete facing, and the minimum settlement was about 79 mm and occurred at the middle section of the embankment. While the maximum subsurface settlement at 6.0 m was about 89 mm and occurred at the middle section of the embankment, and the minimum settlement was about 76 mm and occurred at the front section of the embankment. The settlement profile shows that the heavy concrete facing influence the settlement near the surface and settlement at deeper depth are influence by the embankment weight induce stress themselves.

Excess pore water pressure

The excess pore water pressure below embankment area was obtained from open stand pipe piezometers. 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 foundation subsoil. After 50 days, the excess pore water pressure tends 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 tend to dissipate to lower value than that at 6 m depth due to the effect from embankment lightweight loading effect more on shallow depth.

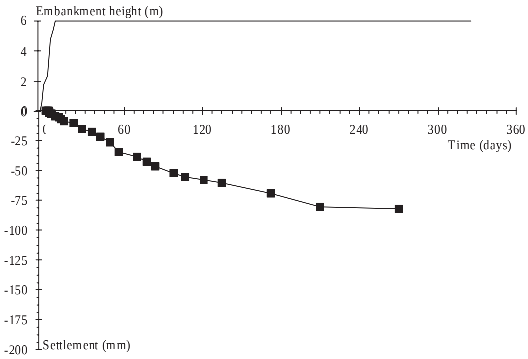

Figure 5 Observed subsurface settlement at 6 m depth.

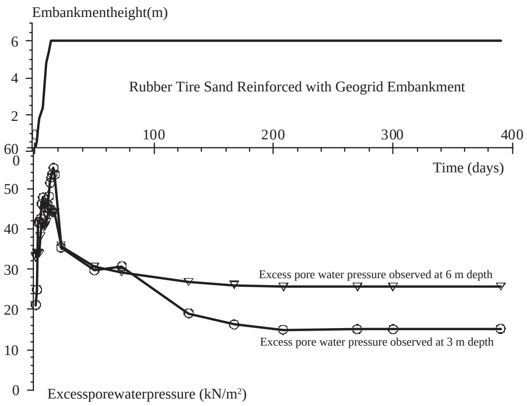

Figure 6 Observed excess pore water pressure below embankment.

CONCLUSIONS

The conclusions that can be drawn from this study are summarized below.

- The unit weight of rubber tire sand mixture 30:70 by weight is 13.6 kN/m^3, compared to conventional backfill sand of 18.0 kN/m^3, it is lighter by about 75 %. This lightweight geomaterials can be used for embankment construction on soft ground area to reduce total settlement of structure
- Settlement magnitude of 122 mm at original ground is less when compare to conventional backfill. Differential settlements are small, so this type of lightweight material is appropriate for highway bridge approach utilization.
- For soft clay compression, subsurface settlement shows maximum settlement of 89 mm, hence soft clay foundation does not compress much compare to conventional backfill of 300 mm and it is possible to reduce subsidence of area nearby highway bridge approach.
- The excess pore water is built up after 15 days since the end of construction, and start to dissipate after 50 days since the first layer of backfill compaction. The excess pore water pressure became constant to start consolidation period after 120 days. The effect of embankment loading acted more on 3 m. depth be cause of its lightweight.

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