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Geosynthetics applications for heavy load railway mitigation

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ABSTRACT: The railroad system of the largest steel manufacturer in Taiwan has been in operation for ten more years. Due to the extremely heavy load and frequently cyclic loading, serious pumping problems had appeared along the rails, and resulted in aggressive ground settlements and distortion of rails. In an attempt to solve such engineering problem, geosynthetics applications of separation andreinforcement were proposed as solutions to the observed engineering problems. In order to verify the proposed designs, the authors execute a test sections plan to evaluate performance of different geosynthetics designs. In this paper, process and results of soil investigation and test section evaluation are presented. Instrumentation measurements obtained fourmonths after the test section installation imply that proposed mitigation methods have provided a feasible solution to the railroad pumping problems under extremely excessive cyclic loads.

1 INTRODUCTION

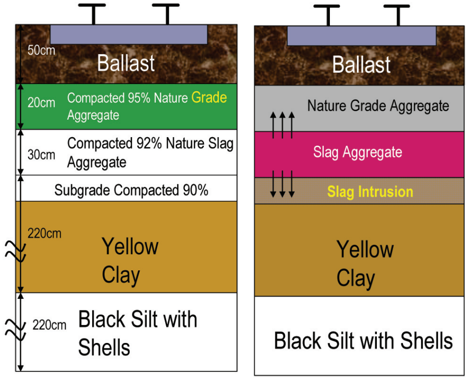
The railroad system of the largest steel manufacturer in Taiwan, China Steel Company (CSC), has been in operation for ten more years. It affords mainly the transportation of heavy furnace liquid steel. The rails bear very heavy torpedo shuttles that weight 500 to 800 ton individually (Figure 1). Due to the extremely excessive load and frequently cyclic loading, serious pumping problems had appeared along the rails, causing aggressive ground settlements and distortion of rails. Geosynthetics applications of separation and reinforcement were proposed as solutions to mitigate the pumping and serious contamination of aggregate and ballast layers. Concept of geosynthetics design is focus on how to stop fine grade material intrusting to the subbase layer, as well as providing better reinforcement of the bearing soil layer. Convenient construction and effective cost are also important considerations. In attempt to solve the described engineering problems, an extensive soil investigation and monitoring program was first conducted to identify the failure mechanism. Data of soil boring, test pits, seismic reflection survey, and piezometers were collected to access the ground conditions. Results of soil investigation show that the fine content of base material has contaminated the bearing layer, and the torpedo cars' passages has caused high pore water pressure. A full-scale test sections were then executed in order to further identify the efficiency of the proposed mitigation measurements. Geocomposite that made of rigid grid and nonwoven geotextile, and combination of flexible grid, and separated nonwoven geotextile were designed in the test sections. Instrumentation such as settlement plates and piezometers were also installed to evaluate the separation and reinforcement functions of geosynthetics.

Figure 1. CSC railway system.

In this paper, process and results of soil investigation and test section evaluation are presented. Instrumentation measurements obtained an year after the test section installation imply that proposed mitigation methods have provided a feasible solution to the railroad pumping problems under extremely excessive cyclic loads. The designed test sections appear to be able to justify performance of different geosynthetics designs for the heavy load railroad system. Moreover, despite the difference of strength properties and manufacturing process, the geo-composite and flexible grid-nonwoven geotextile combination appear to have similar mitigation performance for subbase contamination. Reinforcing mechanism and combined function of separation of geosynthetics are also carefully analyzed and discussed in this paper.

2 SOIL INVESTIGATION

Total three boreholes were logged on the site, and two of them were installed with electrical piezometers immediately after boring. Two test pits were also excavated to observe the subbase contamination condition. Figure 2 shows the result of the soil exploration. As shown in Figure 2, the original railroad base is composed of 50 cm ballast on top of 20 cm natural aggregates and 30 cm slag aggregates. Subgrade material is backfilled yellow clay of about 2 m in thickness. Under the yellow clay layer, there are natural hydraulic sand deposits. The yellow clay is believed to be degraded and becomes the major source of the pumping material after long time operation of heavy railroad transportation. Figure 3 shows the test pit excavation result. As shown in Figure 3, the contamination condition was further verified; the subgrade material has intruded aggressively and contaminated the subbase up to about 60 cm.



(a) original design (b) contaminated section

Figure 2. Result of soil exploration.

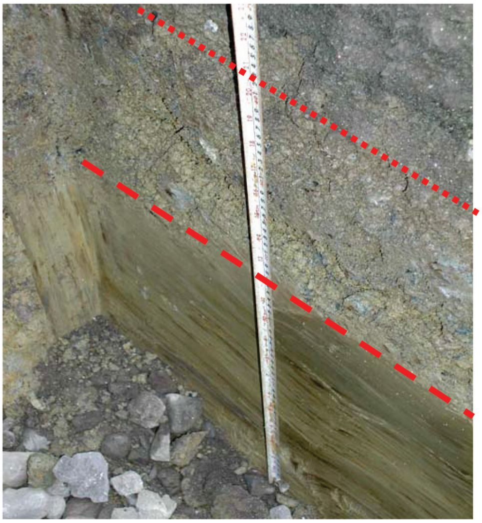


Figure 3. Test pit result.

3 TEST SECTION DESIGN AND INSTALLATION

In an attempt to mitigate the serious pumping problems and contamination of railroad subbase layer, geosynthetics applications of separation and reinforcement were proposed as a feasible solution. Concept of geosynthetics design is focus on how to stop fine grade material intrusting to the subbase layer, as well as providing better reinforcement of the bearing soil layer. Convenient construction and effective cost are also important considerations. Table 1 shows the designed geosynthetic material requirement. As shown in the table, two different designs were adapted, one is to use geo-composite that made of rigid grid and nonwoven geotextile, the other is to use combination of flexible grid with separated nonwoven geotextile.

Table 1. Requirement of Geosynthetics.

Geosynthetics		Requirement
Geo-composite	Geogrid (rigid)	Tult = 30 × 30 kN/m, AOS = 39 mm
	Geotextile	Effective opening size = 125 μm
Geogrid (flexible)		Tult = 150 × 150 Kn/m
Geotextile		Effective opening size = 125 μm

In order to verify the proposed mitigation designs, the authors conducted a test section plan to evaluate performance of different designs. Four testing sections were designed. Each section was 20 m long and 4 m in width, with a 10 m long buffer zone in between. Figure 4 also shows the detail of section design. Section

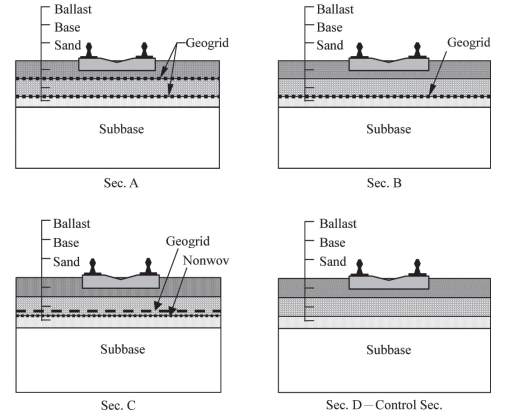


Figure 4. Test section design.

A is designed with geo-composites at both interfaces of ballast-subbase and subbase-subgrade. Sections B and C are designed with geosynthetics at subbase-subgrade interface, using geo-composite and flexible-nonwoven combination respectively. Section D is the control section that no geosynthetics were installed, yet the subbase were resumed to the original design.

Figure 5 shows the test section installation. By taking advantage of the geosynthetics, the subgrade material of the test sections were not compacted to 90%, a 10cm thick sand layer was used to provide the function of workplace and drainage blanket for installing geosynthetics. Fine sand of passing sieve #40 ~#100 with D_{85} = 0.425 mm was selected as the blanket material on the basis of filtering criteria.

Figure 5. Test section installation.

As shown in Figure 6, geo-composite and nonwoven geotextile used in Sections A, B, and C were marked in a purpose to track possible installation damage, material creeping, and local deformation evidences upon the re-excavation of the test section which is scheduled in 2005, three years after the installation. In addition to the marks, five settlement plates were installed on top of subbase material of each section to monitoring the performance of different designs (Figure 6). Each settlement plate was 0.9 m center to center.

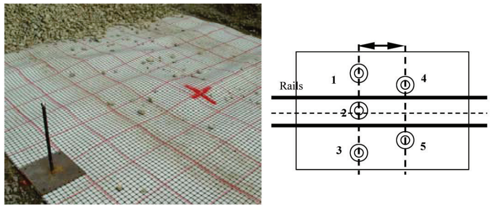


Figure 6. Instrumentation of test sections.

Figure 7 shows the time history of the average settlement measurements seventy-four weeks after the installation. As shown in the figure, both Sections B and C appear to have much less settlement than that of control section. However, Section A still emerges an evident settlement as Section D does despite two layers of geo-composite were installed. Possible reasons for this poor performance might be the rundown drainage condition of Section A, as well as frequent engine brakes and starts of the torpedo shuttles at the section. Sections A, B and C appear no pumping problem seventy-four weeks after the installation, yet yellow clay has pumped out from the ballast again along the controlled section.

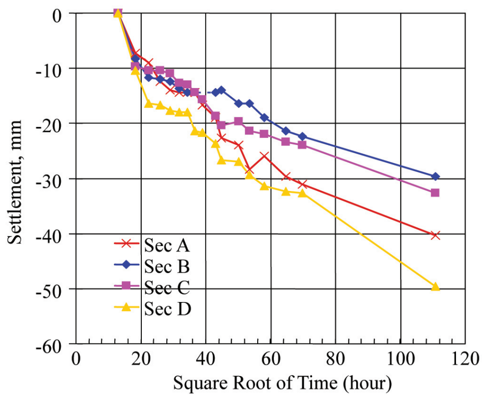


Figure 7. Average settlement of settlement plate 2, 4, 5.

In addition to settlement plate measurements, results of the electrical piezometers installed inside the borehole also verify the benefit of geosynthetics. As shown in Figure 8, the dash line represents the static pore pressure head before installation of geosynthetics; and two solid lines represent pore pressure measurements after three and five months correspondingly. Data shown in Figure 8 indicates that pore pressure, or stress condition, of the subgrade were largely improved by the installed geosynthetics.

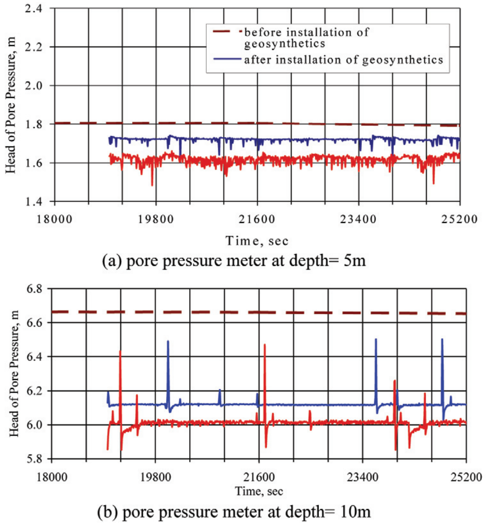


Figure 8. Results of electrical piezometers before and after installation of geosynthetics.

4 CONCLUSIONS

1. Heavy wheel load and frequent cyclic loading caused by the torpedo shuttle operation, as well as the degradation of the subgrade soil contributed the serious subbase contamination of the CSC rail system.
2. Separation and reinforcement functions of geosynthetics are proved to be a feasible mitigation measurement for the serious contaminated railroad subbase and an efficient engineering solution to heavy-load railroad operation.
3. The designed test sections appear to be able to justify performance of different geosynthetics designs for the heavy load railroad system.
4. Despite the difference of strength properties and manufacturing process, the geo-composite and flexible grid-nonwoven geotextile combination appear to have similar mitigation performance for subbase contamination.