No. 0092-14-03 Wisconsin Highway Research Program September 2015

WISCONSIN DEPARTMENT OF TRANSPORTATION

PUTTING RESEARCH TO WORK

BRIEF

Permeability and Lateral Load of Granular Backfill Behind Abutments

To ensure appropriate long-term performance of abutment systems, backfill material must have good drainage characteristics with less susceptibility to erosion and post-construction volume changes, and the abutments must have good drainage features that are properly designed and constructed. The current WisDOT Bridge Design Manual recommends using pervious granular backfill material behind bridge abutments. The granular backfill material is assumed pervious or free-draining based on its grain-size distribution properties. There is a need to investigate, however, whether abutment backfill materials in the WisDOT specification actually meet the assumption of the freely-drained condition.

What is the Problem?

The current design of backfill behind abutments uses a qualitative approach that assumes that granular backfill is "free-draining" (any water that infiltrates into the granular backfill will rapidly drain out of the system) based on the specified grain size distribution. This assumption, however, does not consider the rate of water infiltration, the permeability of the granular backfill, the effects of water retention on lateral earth pressure distribution and the short- and long-term effectiveness of the pipe underdrain. In addition, alternative materials including Recycled Asphalt Pavement (RAP) and Recycled Asphalt Shingles (RAS) have been proposed to replace the specified granular backfill. The hydraulic and mechanical characteristics of these materials, which control lateral loads on abutments, have not been sufficiently tested.

Objectives

The objective of this research is to conduct laboratory, numerical and field studies to evaluate drainage capacity and lateral loads of granular backfill materials, including natural and recycled materials, to determine if the criteria based on the grain size distribution satisfy free-draining assumptions for the backfill materials.

Methods

The researchers conducted laboratory testing, field testing and numerical analysis to achieve the objective of this research. Four of the materials were obtained from bridge construction sites in Wisconsin. RAP and RAS materials were obtained from stockpiles at Mathy Construction Company in Onalaska, Wisconsin. The natural materials include: a) grade 1 granular backfill from Badger Road and b) structure backfills from Slovak Valley Creek Bridge, Schwartz Road Bridge and Hobbles Creek Bridge. Laboratory testing involved characterizing the materials in terms of gradation, classification, erodibility, permeability, shear strength and volume change (e.g., water induced collapse). Scaled abutment model testing was performed to assess pore pressure dissipation rates for the different materials and calibrate input parameters to predict drainage using finite element analysis (FEA). Field testing involved in situ permeability, shear strength and moisture content testing, and monitoring lateral earth pressures and pore pressures behind abutment walls at the four bridge sites.

Results

Researchers found the following results from laboratory and field tests:

Laboratory Tests

- The permeability of the four bridge site materials varied from 0.0002 to 0.1100 cm/s. Using empirical equations can result in over-estimation of the material permeability.
- Laboratory compaction tests reveal a definable bulking moisture content range for natural materials for which the density is low. The implication of bulking moisture content is that the materials placed and compacted at or near that moisture content can exhibit collapse upon wetting. Bulking moisture content was not evident for RAP and RAS materials. RAP and RAS materials exhibited collapse upon wetting and creep under constant loading. RAP and RAS produced vertical strains of about four to five percent under constant loading. Therefore, any post-construction settlement related to collapse can be problematic and should be avoided.

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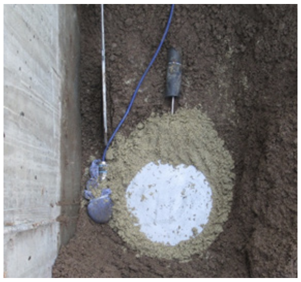
- Direct shear tests indicated friction angles of the four bridge site backfill materials ranging between 27 and 33 degrees, with apparent cohesion values ranging between 4 and 12 kPa. Shear strength parameters could not be determined for the RAP and RAS, because of their creep behavior.

Abutment Model and Numerical Analysis

- Similar to American Association of State Highway and Transportation Officials (AASHTO) (1993) base layer drainage design, a material that can drain 95 percent of the water within one hour is considered as "free-draining" in this study. The bridge abutment model tests revealed that the drainage time to achieve 95 percent drainage varied between 28 minutes and three hours for three materials (two materials obtained from bridge sites and RAP). In one of the backfill materials, fine particles eroded through the drain tile sock during free drainage that caused clogging and only 60 percent of pore pressure dissipation occurred at 24 hours. Erosion occurred because the material contained 99 percent passing the No. 40 sieve, and the drain tile sock consisted of No. 40 size opening. By adding a geocomposite vertical drain along the face of the wall for this material, nearly 100 percent of drainage occurred within ten minutes without any erosion.


Vertical Earth Pressure Cell and Pore Pressure Sensor Installation at Hobbles Creek Bridge

- Abutment model testing indicated that the addition of geocomposite vertical drain can substantially increase pore pressure dissipation rates and avoid material erosion. The FEA results demonstrated that numerical analysis can be used to predict pore pressure dissipation rates with high accuracy. As the permeability of the backfill material increased, the pore pressure dissipation rates also increased.

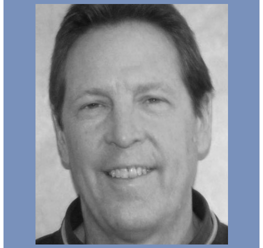
Field Tests

- Results indicated that field conditions are more complex than the simple linear stress distributions typically assumed in the design for lateral earth pressures. Lateral earth pressures were greater than assumed in design over a majority of the monitoring period of this study. Pore pressures behind an abutment wall were observed at one site following flooding. Predicted pore pressure dissipations using numerical analysis matched well with the measured values.

Recommendations

- To improve drainage performance, material erosion and post-construction, wetting-induced collapse should be minimized, and materials with higher permeability characteristics must be selected. The particle size limits of the structure backfill and grade 1 granular backfill should be modified by limiting sand and silt size contents.
- A drainage design that involves the addition of an active geocomposite vertical drain system along the face of the wall along with geotextile wrapped around the drain tile is recommended. The vertical drainage system can substantially increase drainage times.
- Addition of quality control/quality assurance (QC/QA) guidelines to project specifications is suggested to better control lift thickness and backfill moisture. Based on the type of construction equipment observed on projects, it is suggested that the lift thicknesses should be limited to 150 mm. Further, extensive wetting of the placed material is recommended to reduce post-construction, wetting-induced collapse.
- QC/QA testing and observation is recommended for new construction. The dynamic cone penetrometer (DCP) device is recommended to measure the penetration resistance of the fill materials and determine lift thicknesses and uniformity. The air permeameter test (APT) device is recommended as a rapid method for in situ permeability.
- RAP and RAS materials exhibited collapse upon wetting and creep under constant applied load in the laboratory. These characteristics can result in unwanted post-construction settlements in the backfill material; therefore, they are not recommended for use as abutment backfill materials.

Project Manager



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This brief summarizes Project 0092-14-03,
"Permeability Performance and Lateral Load for Granular Backfill behind Abutments"
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