5-2010

Optimization and Management of Materials in Earthwork Construction

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Abstract
This research provides solutions to identifi ed problems through better management and optimization of the available pavement geotechnical materials and through ground improvement, soil reinforcement, and other soil treatment techniques.

Keywords
Civil Construction and Environmental Engineering

Disciplines
Civil Engineering

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tech transfer summary

This research provides solutions to identified problems through better management and optimization of the available pavement geotechnical materials and through ground improvement, soil reinforcement, and other soil treatment techniques.

Objectives

- Evaluate the engineering properties of embankment materials by mixing different soils, such as the select and unsuitable soils in different proportions.
- Evaluate the permeability of mixed materials.
- Evaluate the use of flowable mortar in place of conventional backfill material around a drainage pipe.

Problem Statement

Natural earth materials play an important role in the design and construction of geotechnical systems. Different earth materials, such as soil and rock, have been used in the construction of various geotechnical systems, including foundations, retaining walls, embankments, road and airfield pavements, box culverts, and bridge abutments.

The choice of particular geo-materials for a construction project depends on the type and purpose of the geotechnical system itself. Some geo-materials, such as peat, muck, expansive/swelling soils, and collapsible soils, however, cannot be used in any type of construction because the severity of post-construction damage they may cause can be disconcerting. Often, site soils are unacceptable for the intended function and must be improved or replaced with better quality materials.

Research Description

As a result of forensic investigations of problems across Iowa, a research study was developed aimed at providing solutions to identified problems through a better management and optimization of the available pavement geotechnical materials and through ground improvement, soil reinforcement, and other soil treatment techniques.

The overall goal was worked out through simple laboratory experiments, such as particle size analysis, plasticity tests, compaction, permeability, and strength tests. A review of the problems suggested three areas of study: pavement cracking due to improper management of pavement geotechnical materials, permeability of mixed-subgrade soils, and settlement of soil above the pipe due to improper compaction of the backfill. This resulted in the following three areas of study:

1. The optimization and management of earthwork materials through general soil mixing of various select and unsuitable soils and a specific example of optimization of materials in earthwork construction by soil mixing.

IOWA STATE UNIVERSITY
Institute for Transportation

May 2010

RESEARCH PROJECT TITLE
Optimization and Management of Materials in Earthwork Construction

SPONSORS
Iowa Highway Research Board (TR-501)
Iowa Department of Transportation
(InTrans Project 04-162)

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2. An investigation of the saturated permeability of compacted glacial till relation to validation and prediction with the Enhanced Integrated Climatic Model (EICM).

3. A field investigation and numerical modeling of culvert settlement.

This project consists of the following three areas of research.

Optimization and Management of Earthwork Materials through Soil Mixing

Three soils available for earthwork construction are classified as select, suitable, and unsuitable soils (Table 1). Unsuitable soils consist of some expansive/swelling or collapsible soils with low density and low strength, which should be disposed of at least 3 feet below subgrade elevation.

Due to the availability and the fact that unsuitable soils are cheaper than select soils, making use of unsuitable soils can reduce the cost of earthwork construction. In this research, two unsuitable soils were mixed with six select soils at various proportions (unsuitable: select = 25%:75%, 50%:50%, and 75%:25%) to investigate how the engineering properties can be improved at different select-unsuitable ratios.

Permeability of Compacted Glacial Till Related to Validation and Prediction with the Enhanced Integrated Climatic Model (EICM)

Moisture and temperature are two environmental variables that affect the performance of pavement structure and subgrade. These variables have been incorporated in the Mechanistic-Empirical Pavement Design Guide through a sophisticated climatic modeling tool called the Enhanced Integrated Climatic Model (EICM). Permeability of the subgrade soil is a required input for this model.

One of the major tasks undertaken in developing the EICM is the development of improved estimates of saturated hydraulic conductivity, ksat, based on soil index properties such as fine contents, P200, effective diameter, D60, and plasticity index, PI. This estimation is used when field and laboratory data are not available and has been proved to have a good agreement with an extended database. However, EICM model has some limitations; it can only predict the permeability of compacted soils at optimum moisture contents under standard Proctor compaction. To expand this empirical model for practical purpose, a more comprehensive model was developed in this study for Iowa soils.

Table 1. Current Iowa DOT specification for cohesive soil classification into "select," "suitable," and "unsuitable" categories

Select soils	Suitable soils	Unsuitable soils
Must meet all conditions – typically used in top 0.6m of subgrade	Must meet all conditions – used throughout fill except for top 0.6m of subgrade	Requirements for use at different depths
1. 45 percent or less silt size fraction (0.075 - 0.002 mm)	a. 1500 kg/m3 or greater density (AASHTO T99 Proctor density)	Slope dressing only - peat or muck - soil with plastic limit ≥ 35 - A-7-5 or A-5 having density < 1350 kg/m^3
2. 1750 kg/m3 or greater density (AASHTO T99 Proctor density	b. Group Index < 30 (AASHTO M 145 - 90)	Disposal 1 m below top of subgrade - All soils other than A-7-5 or A-5 having density <1500 kg/m^3 - All soils other than A-7-5 or A-5 containing < 3.0% carbon
3. Plasticity index >10		Disposal 1 m below top of subgrade - A-7-6 (30 or greater) - Residual clays overlying bedrock regardless of classification
4. A-6 or A-7-6 soils of glacial origin		Disposal 1.5 m below top of subgrade with alternate layers of suitable soils - Shale - A-7-5 or A-5 soils having density from 1350 kg/m3 to 1500 kg/m^3

Field Investigation and Numerical Modeling of Culvert Settlement

Culverts are commonly built to deal with the highway drainage needs. However, settlement adjacent to highway culvert has been found shortly after the new highway is open to the traffic. Although it is not perceptible to the naked eyes, it is noticeable in a vehicle driving though these locations. To address this issue, an investigation of the causes of the problem and the development of a solution was undertaken.

The objectives of this portion of the study were to (1) investigate culvert settlement problems in Iowa, (2) review the remediation methods in the literature, and (3) study the select and flowable mortar as backfill options.

Key Findings

1. Mixing with select soil can improve the index properties of unsuitable soil by reducing liquid limit and plasticity index.
2. Experimental results indicate that maximum dry density and UCS both increase, while the optimum moisture content decreases linearly with increasing select proportion.
3. The UCS of the select-unsuitable blends decreases with increasing moisture content.
4. Select blends can be obtained by mixing up to 25% of an unsuitable soil with 75% select soil.
5. Suitable blends can be obtained by mixing 50% of unsuitable soil with 50% of select soil.
6. At 75% unsuitable with 25% select, some soils will be classified as suitable and some as unsuitable.
7. For the soils tested in this study, the addition of unsuitable soils to a select soil in the range of 25% to 50% provides acceptable soils for placement in embankment applications.
8. Laboratory permeability tests are reproducible, provided that the variance of test results are between 50% above and below the averaged value. The higher the moisture content, the higher the variance.
9. Air-dried samples have lower permeability than that of wet samples tested right after they are extruded from compaction mold. The permeability of air-dried samples is from about 56% to 95% of that of wet samples. Air-drying has less effect on the results

Pavement surface distortion caused by settlement, Highway 18 east, Iowa when the samples are compacted dry of optimum than when they are compacted wet of optimum.

10. Permeability of compacted soil decreases with moisture content when it is dry, while the permeability increases slightly with moisture content when the soil gets wetter. The lowest permeability occurs at moisture content of about 2% to 4% wet of optimum.

11. There is a good correlation between log[k(1+e)] and log e when the samples are compacted dry of optimum. However, the correlation in the wet side is poor.

12. A new model of predicting permeability was developed based on the Harrop-Williams (1985) model. The difference between predicted permeability and measured permeability is less than 50%.

13. Moisture content greatly affects the compaction density and strength of select backfill used in pipe trenches. Improper compaction moisture content can lead to low strength and density, thus causing the dip problem of pipe.

14. If the compaction is done properly, the minimum UCS of the good clay select should be around 700 kPa (100 psi) shortly after compaction. However, this select is not readily available throughout the entire state. The averaged tested strength of select materials is about 400 kPa (58 psi), which may be too low for backfilling purpose.

15. Based on the numerical analysis, the use of flowable mortar as an approach backfill material appears to be a simple and reasonably cost-effective method to reduce the potential for developing the bump above the drainage pipe.

Recommendations for Future Research

1. The Atterberg limits variation of these soils is small, with liquid limit and plasticity index ranging from 25 to 41 and 10 to 21, respectively. As a result, it is difficult to discern how the Atterberg limits change as the percent unsuitable is increased. It is recommended that more unsuitable soils with higher plasticity and more granular select soils be collected and mixed to further study the mixing results.
2. The difference between measured permeability and the calculated permeability using the EICM model suggests that compaction energy of the soil sample is different. The proposed model may be improved by considering the relationship between compaction energy and soil permeability.
3. Due to the lack of a completed project on the flowable mortar backfilling option, there was no information available with which to evaluate the pavement performance. Thus, it is recommended that a follow-up study be conducted monitoring a completed flowable mortar backfilled project.