EXECUTIVE SUMMARY

The presence of swelling clay beneath roadway poses problems to roadway rehabilitations design and construction. Roads constructed over clay areas are subject to potential deferential settlement and deformation due to: a) volume changes caused by swell or shrink; b) low shear strength; c) high moisture content; and d) clay structure including dipping or horizontal bedding. Soil borings are typically taken at 0.4 or 0.8 km (0.25 or 0.5 mi) interval for geotechnical verification. Although direct soil sampling provides the best information in terms of soil type and Atterberg Limits of Soils, it is limited: a) set boring intervals may miss critical clay-rich zones; b) geologic interpolation between borings may not be representative; and c) great potential to miss large expanses of clay.

Thus, there is a need to utilize geophysical technology such as the frequency domain electromagnetic induction (EMI) method to map clays beneath roadways, fill the gaps between the soil sampling locations, and assist in focusing the soil sampling program in areas with the greatest risk for clay problems.

Blackhawk, a division of ZAPATAENGINEERING, in coordination with the Federal Highway Administration (FHWA), Central Federal Lands Highway Division (CFLHD), conducted multi-phase surface geophysical investigations using various EMI instruments on SR537, Rio Arriba County, near Dulce, New Mexico. These investigations lead to a full scale EMI production survey, utilizing the new Geonics EM31-3 at Natchez Trace Parkway, Mississippi to rapidly and accurately locate clay-rich zones beneath long stretches of roadways.

The main purpose of this multi-phase program was to demonstrate the effectiveness of the EMI method as a state-of-practice geophysical imaging tool for mapping the presence of clay seams beneath roadways. More specifically, the overall objectives of this program were:

- To locate and map the spatial distribution of clay beneath the roadway.
- To determine the depth and thickness of the clay.
- To integrate the geo-electric sections into Plan and Profile (P&P) format.
- To evaluate the empirical relationships between measured geophysical parameters (e.g. bulk conductivity) and Atterberg Limits of Soils (e.g., plasticity index).
- To demonstrate the engineering benefits of the EMI method as a production tool to rapidly and accurately locate clay seams beneath roadways.

This report covers the results from the multi-phase geophysical investigations program at the Dulce site with emphasis on the Phase III study. A summary of the results obtained from the Natchez Trace Parkway survey is also discussed. Based on the results obtained from the multi-phase investigations and the Natchez case study, the following represents the conclusions and recommendations of the EMI method in mapping clay seams for roadway applications.

- Phase I investigation concluded that frequency-domain EMI profiling would be the only cost-effective, rapid method capable of mapping, in sufficient detail, the lateral extent of conductive soils in the roadbase over the 16 km (10 mi) of surveyed area. Modifications to the field techniques clearly indicated what additional data would be required to resolve clay materials beneath the roadway, in the engineering P & P drawings. Thus, a follow-up Phase II was conducted.

- Phase II investigation, using the EMI techniques measuring the bulk electrical conductivity of the subsurface, demonstrated that a useful geo-electric section could be developed and integrated into the P & P format. The P & P information provided an effective means of prioritizing areas of concern with clay-rich soils.
- Phase III investigation provided the opportunity to demonstrate the effectiveness of the new Geonics EM31-3 frequency domain EMI instrument as a viable state-of-practice geophysical tool for preliminary site assessment. The EMI P & P data, in terms of measured soil conductivity were evaluated to identify 20 boring locations using a prioritization scheme that classified areas along the 16 km (10 mi) roadway as low, moderate, or high potential clay content.
- Natchez case study demonstrated the efficiency of the EMI method as a production tool for mapping the spatial variation of soil conductivity within the road base. The EMI survey was conducted along 55 km (34 mi) of roadway and completed in four field days. Preliminary maps were produced within one to two days following data collection. The EMI P & P data were used to identify 41 boring locations with soil sample analysis.
- Soil conductivity information derived through EMI methods can provide valuable qualitative information for the evaluation of road base materials during the design phase.
- Soil conductivity information can be used to guide the soil-boring program by targeting the most likely locations with potential swelling clay problems.
- The correlation between bulk conductivity and Casagrande Plasticity Classification may be used as a quick evaluation tool for predicting Casagrande soil type along the entire length of roadway surveyed.
- It is critical for the geotechnical engineers to understand the in-situ behavior of soil. Current practice of soil classification is based on laboratory testing. These tests use disturbed soil samples may not represent real ground conditions. Implementation of geophysical techniques such as the EMI would provide better understanding of the overall soil behavior. This geophysical investigation has demonstrated the effectiveness of the EMI method, as a promising tool to support geotechnical engineering investigations.

Overall, the EMI method is a fast, efficient, and cost effective geophysical tool for mapping spatial variations in soil conductivity beneath roadways with non-metal reinforced pavement types. A strong correlation between soil conductivity and the Atterberg Limits of Soils were not established, however, a qualitative evaluation of areas with increased potential for high plasticity clay content can be estimated from the EMI data. The EMI method can be used to focus the drilling programs during project site investigations, road rehabilitation, and construction. The EMI method may provide significant cost savings by reducing construction cost overruns.

REPORT ORGANIZATION

The Executive Summary provides a summary of the geophysical study, results, and recommendations.

Chapter One provides a brief background on engineering problems related to the presence of clay and an overview of the three-phase geophysical program investigations.

Chapter Two details the geological background and the site setting of the survey area.

Chapter Three describes the geophysical methods and instruments used during the investigations.

Chapter Four describes data acquisition procedures.

Chapter Five details the data processing process and the EMI modeling.

Chapter Six summarizes the results of the geophysical surveys, the correlation of geophysical and geotechnical data, and the advantages of the EMI method.

Chapter Seven is a case study detailing the EMI Clay Seam Mapping on the Natchez Trace Parkway in Mississippi.

Chapter Eight states the conclusions and recommendations derived from this report.

The certification and disclaimer, the acknowledgement, and references are listed at the end of the text.

Appendix A presents Plan and Profile Electromagnetic Maps from Dulce, New Mexico.

Appendix B presents comparison plots of EMI data versus soil sample (0.9 - 1.5 m (3 – 5 ft)) analysis results, Dulce, New Mexico.

Appendix C presents comparison plots of EMI data versus soil sample (1.5 – 3.0 m (5 – 10 ft)) analysis results, Dulce, New Mexico.

Appendix D presents comparison plots of EMI data versus soil sample analysis results, Natchez, Mississippi.