

Louisiana's Continuous Intrusion Miniature Cone Penetration Test System

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The engineering properties of foundation materials are important input to the design of transportation facilities, such as embankments, pavements, and bridges. Investigation of ground conditions requires the same level of attention as is given to engineered and manufactured highway construction materials, such as concrete, asphalt, and steel. Consequently, state departments of transportation invest significant amounts of time and money in such investigation, in both the field and the laboratory.

The electronic cone penetrometer has recently gained popularity as an in situ site characterization tool. The cone penetration test (CPT) consists of pushing an electronic probe into the ground to measure both tip and side resistances as the cone is advanced. CPT data are used to identify soil types; determine subsurface soil stratigraphy; and estimate various engineering soil properties for use in analysis, design, and construction.

Problem

The Louisiana Department of Transportation and Development uses various methods in performing subsurface investigations for the design of a structural foundation or pavement or the repair of a failed embankment slope. Conventional drilling methods, auger borings, and laboratory analysis of undisturbed and disturbed soil samples are commonly employed. In addition, LADOTD operates two 20-ton CPT vehicles that have the capability to characterize the subsurface to depths of more than 50 m.

Until 1981 Louisiana allowed the use of highly plastic clay in the construction of embankments. Depending on the mineralogy, this material often has a high shrink-swell potential. During hot dry periods, shrinkage of the clay results in the formation of large tension cracks. Repeated wet and dry cycles cause these cracks to propagate more deeply into the embankment. Water from rain infiltrates the cracks and reduces the soil shear strength to below the critical value. This eventually results in the failure of the embankment slope.

Slope failures are a common occurrence on many of Louisiana's bridge approach embankments. It is often difficult to determine the location of the failure plane with conventional subsurface exploration techniques. Thus there is a need for a rapid, reliable, and economical CPT system for shallow-depth site characterization that is capable of reaching sites with difficult terrain and soft soil deposits.

Solution

Researchers at the Louisiana Transportation Research Center, working under the Federal Highway Administration's Priority Technologies Program, have developed a continuous intrusion miniature cone penetration test (CIMCPT) system. The Center is using this system, housed in a four-wheel-drive 1-ton all-terrain vehicle, for site characterization at shallow depth (10 m). The system consists of a caterpillar-type continuous-push device powered by a hydraulic motor, a coiling mechanism, a miniature cone penetrometer (see Figure 1) attached to a coiled stainless steel push rod, and a data acquisition system.

The device was developed for use in rapid and economical shallow-depth characterization of sites to determine the engineering soil parameters required in the design of embankments, pavements, and earth structures. Field tests conducted on different soil types showed that the miniature cone detected finer details and thinner layers and pockets of silty or sandy soils as compared with the standard cone penetrometer.

Application

Methods commonly used by LADOTD for repairing failed embankment slopes have included chemical stabilization, geosynthetic reinforcement, and fiber reinforcement. These methods require excavating the soil beyond the failure plane. As noted, it is difficult to determine the location of the failure plane with traditional exploration techniques. Thus, LADOTD engineers have traditionally set excava-

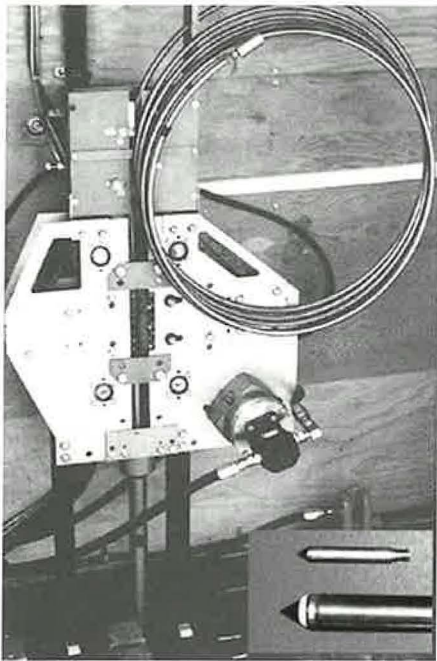


FIGURE 1 Continuous push device with standard and miniature cones (inset).

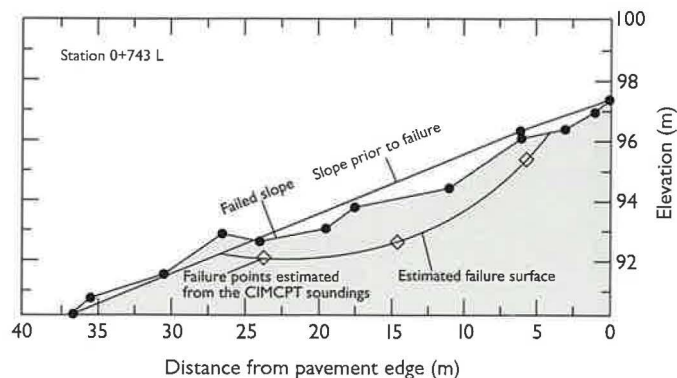


FIGURE 2 Configuration of failure plane in embankment.

tion limits by using conservative judgments based on the geometry of the failed embankments.

The CIMCPT system is better than the other field exploration methods, including the standard CPT system, at locating the weak zones within a soil mass. The miniature cone provides site soil characterization at 4-mm-depth increments. The system was used to locate the failure plane in the embankment of the I-20/Missouri Pacific Railroad overpass near Tallulah, Louisiana. The overall configuration of the failure plane in the embankment was determined from multiple CIMCPT soundings taken along the embankment (see Figure 2). The weak zone at each test location was identified from the cone penetration sounding. The identified failure zones were above the natural ground level. As shown in Figure 2, the identified weak zones were in agreement with field observations.

Benefits

The CIMCPT system was used successfully to estimate the location of the slope failure plane on the Tallulah project. With an average cost of \$8/ft for CIMCPT probings, the cost of the investigation was \$3,480. Had conventional boring techniques been used, a minimum of eight borings would have been recommended, considering that the total length of the slope investigated was approximately 2,700 ft. At an average cost of \$50/ft, the total cost of the borings

would have been \$6,000. Thus the CIMCPT provided net savings for this project of \$2,520, or 42 percent.

It is also believed that the CIMCPT identified the failure plane more accurately than would have been possible with traditional borings. With boring, moreover, it takes on average from 2 to 4 weeks to obtain test results from the laboratory, while the CIMCPT soundings provided better results in only 5 days.

The CIMCPT system can be used under a variety of site conditions involving difficult access, including inclined surfaces, where traditional boring rigs may not be able to reach. The push unit can easily be mounted on other all-terrain vehicles, depending on reaction-weight requirements. The CIMCPT system also requires less manpower and support equipment than traditional boring methods.

The CIMCPT has been used at only one site, and more field experimentation is needed to develop confidence in the reliability of this application. The system also has great potential for use in other applications. Recently, the Louisiana Transportation Research Center completed another study, funded by FHWA, to estimate the resilient modulus of subgrade soils from miniature cone test results. Researchers are currently developing models to correlate the resilient modulus with CPT parameters, basic soil properties, and in situ stress conditions of the soil.

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