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PENETRATION TESTING TODAY

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The Standard Penetration Test (SPT) is the most common subsurface investigation method for deep foundation projects. It requires driving a sampler connected to a steel rod 18 inches (460 mm) deep into a soil strata with a 140 lb (64 kg) ram dropping 30 inches (760 mm). A soil sample is retrieved for classification and laboratory testing, while the number of hammer blows required to penetrate the rod the final 12 inches (300 mm) is referred to as the "N-value" and is a gauge of soil strength and liquefaction potential during an earthquake.

The N-value is not very accurate, in large part because of an uncertain energy transfer caused by the variety of hammer models and operator techniques. Energy measured in the SPT rod has been shown to vary between 25 and 95% of the theoretical potential energy. Such a broad range in energy transfer can have a profound influence on the measured N-value, with the potential for overly conservative or dangerously un-conservative foundation design and liquefaction analysis.

Recognizing the potential for erroneous foundation designs, many State Departments of Transportation are having their own SPT rigs, or those of their consultants, calibrated through dynamic energy measurements. The resulting calibration factor converts the N-value to a standardized N₆₀, which corresponds to a nominal 60% energy transfer.

Additional information on soil strength can be obtained by attaching a torque wrench and transducer to the top of the SPT rod after the sampler has been driven and the N-value determined, but before the soil sample is retrieved. GRL Engineers, Inc. has performed such torque tests quickly and efficiently. The resulting torque versus rotation curve indicates a peak and a residual shear strength value that correlates well with the set-up soil strength and pile shaft resistance during driving. For some soils it may be necessary to perform the torque measurements some time after SPT driving to be able to determine the full soil setup strength.

There is evidence that gravelly soils can liquefy during earthquakes. Reliable methods for determining the liquefaction potential in gravelly deposits are therefore needed. SPT and Cone Penetration Tests (CPT) are not adequate for this purpose, since they may provide inaccurate or no results in coarse to very coarse grained soils. The Becker Penetration Test (BPT) has been designed to yield a blow count that can be correlated with the SPT N-values for liquefaction potential analysis in such materials

The Becker Drill Rig is a truck mounted double-acting diesel hammer that drives a double-walled 6.6 inch (168 mm) diameter pipe. The Becker pipe can be driven either open-ended, with disturbed samples collected via an airlift in the annulus between the two walls, or closed-ended, when the Becker test is simply a penetration test. As in the SPT test, the blow count required to advance the Becker pipe is recorded over one foot (300 mm) increments. As with all diesel hammers, however, the Becker hammer transferred energy varies depending on temperature, soil resistance, pipe length, hammer conditions and other



PDA monitoring of the Becker test improves its accuracy.

factors. For this reason it is critical to measure the Becker hammer energy transfer efficiency to "correct" the blow count. The accepted practice normalizes the blow count to a transfer efficiency of 30% and refers to the corrected Becker blow count as a BPT N₃₀. The Becker energy measurements are made with a short instrumented section of a Becker drill rod that is placed at the top of the Becker pipe string. A Pile Driving Analyzer® (PDA) then collects strain and acceleration records, calculates transferred energy and records the measurements.

In addition to the correction of energy, the BPT N₃₀ value needs correction for the effects of shaft resistance on the Becker pipe. CAPWAP® analysis of the PDA records yields the soil resistance distribution, and the BPT N₃₀ values can then be adjusted for the effect of skin friction determined by CAPWAP analysis. GRL has also assessed the skin friction acting along the pipe shaft by means of a quick static uplift test, by measuring the load with standard PDI strain transducers and measuring the displacement with extensometers. The Becker hammer pipe extraction system provides the uplift load.

GRL has proposed an innovative use for the Becker system: The very mobile Becker hammer is deployed to a potential deep foundation location before completion of design. The Becker pipe is driven to a penetration of interest while instrumented with either a local or a remote PDA (PAL-R). After completion of short and/or long term instrumented restrikes, CAPWAP analysis is performed on data from end of installation and from restriking. The Becker pipe is then withdrawn and utilized at another site. The Becker test with the PDA and CAPWAP results provides information on both short and long term in-situ soil strength and pile driveability and therefore results in a more economical foundation design and installation.

PDA monitoring of SPT and Becker tests significantly improve the accuracy of geotechnical investigations and resulting interpretations. Considering the grave consequences of misinterpretations of soil strength and liquefaction potential, more and more geotechnical engineers throughout the world specify PDA penetration and energy measurements for improved reliability.

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