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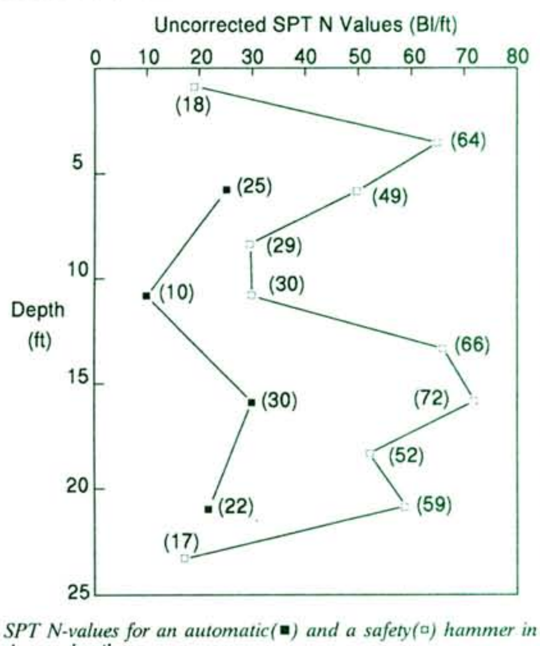
SPT IMPROVEMENTS

by George G. Goble

In much of the world, the Standard Penetration Test (SPT) remains the subsurface investigation technique of choice for geotechnical engineers. The test is well established in practice, provides a soil sample, and a vast amount of local experience and correlation data have been collected by practitioners. In cases where it has been used in competition with other methods such as the Cone Penetration Test (CPT) for pile capacity prediction, it has done about as well as the other methods. In many applications such as liquefaction evaluation or pile driveability prediction, the fact that the test is dynamic seems to be an advantage.

Two problems exist. First and most seriously, at least in North America, standardization lacks in the performance of the test. The graph below was published by Finno in 1989 to demonstrate this point. Secondly, although a soil sample and an N-value are obtained, electronic measurements might also be made during the test. Thus, after initial studies at the University of Colorado, GRL and PDI have responded to these shortcomings with an essentially self-funded research program. Funding and field support have also been received from the FHWA, the Colorado DOT, NIST and the Bureau of Reclamation.



SPT N-values for an automatic(■) and a safety(□) hammer in the sand soil.

This research has addressed three areas of interest. First, force and acceleration measurements on steel-to-steel impacts, characteristic of SPT systems, were studied. In the past, SPT measurements frequently failed the quality checks that are usually applied to measurements on pile driving systems. Second, differences in SPT driving equipment have been evaluated by measuring the energy transferred to the rod. Finally, analytical methods were developed to extract wave equation dynamic soil parameters from SPT measurements.

Studies of the measurements have shown that the best quality force measurements are obtained from an instrumented section of the drill rod that is being used for the test. Foil strain gages are directly bonded to the rod and the rod is then calibrated. This approach avoids dynamic effects that can be present in some commercial load cells.

Velocity is almost always calculated from acceleration measurements. Previous accelerometers did not make these measurements reliably for the steel-to-steel impacts of most SPT driving systems. Recently developed state-of-the-art accelerometers have performed well on SPT tests and the problem now seems to be solved. In any event, the quality of force and velocity measurements can be checked by verifying that the two measurements are proportional at the time of impact. We believe that our success in routinely making these measurements over the past two years shows that we have completed our first research task.

With the availability of correct force and velocity measurements, it is possible to perform sort of a calibration test of a particular drill rig. The energy transferred to the drill rod can be correctly calculated from the measurements by integrating the product of force and velocity. This procedure has been used in the Pile Driving Analyzer® (PDA) for more than 25 years in measuring the performance of pile driving systems. With the driving energy measured for a particular drill rig, the N-value can be adjusted to some selected standard value of energy. Seed and others have suggested that the standard energy should be 60% of the theoretically available energy. The corrected N-value can then be calculated using the correction suggested by Schmertmann where N_{60} is the corrected N-value for the "standard" 60% SPT efficiency, E_m is the measured transfer efficiency (measured energy divided by the available energy) of the system in percent, and N_m is the observed N-value.

$$N_{60} = \frac{E_m}{60} N_m \qquad (1)$$

The value of the correction procedure can be illustrated using results from a test program that was organized by the Seattle Section of ASCE. At the test site, a loose sand was possibly liquefaction sensitive (GRL Newsletter No. 25). A number of different drill rigs were tested in close proximity to each other, and energy was measured on several of these rigs with wide variability in energy transfer and measured N-values.

AS THE YEAR ENDS

We thank you, our clients, colleagues and foundation professionals for the trust that you have placed in us and our work during the past year. We wish you and all our readers a peaceful, healthy and successful New Year and a continued mutually beneficial cooperation.

An example of the correction procedure is the N value of 22 recorded at 35 feet penetration under an automatic hammer with transfer efficiency of 91%. Substituting into Eq. (1) yields $N_{60} = 22(91)/60 = 33$. Obviously such a correction might seriously affect conclusions drawn from the data.

Over the past two years, GRL has performed about 40 energy calibration tests. A substantial amount of data has been generated and evaluated and will soon be available to the profession. It may allow for recommendations of typical efficiencies including mean values and coefficients of variation for various types of driving systems. For example, certain automatic hammers such as the system manufactured by the Central Mine Equipment Company will probably show values between 85 and 95%. The cathead-and-rope operated safety hammer may range between 65 and 80%; donut hammers will be still lower. Any cathead-and-rope operated systems are likely to have a high variability. Systems whose winch is spooled by the weight of the hammer will have efficiencies as low as 20%. Probably N-values from such inefficient systems cannot be reliably corrected with Eq. (1).

In the past, the PDA was used to perform these tests. Pile Dynamics, Inc. has now developed a simple, compact system (see enclosed flier) for measuring force and velocity on SPT systems, calculating the energy and recording the results. This equipment will reduce the cost and complexity of SPT rig evaluation. GRL has also done further research on analytical methods to evaluate the SPT data to increase its usefulness. The results of this work will be discussed in a future GRL Newsletter ■