Geotechnical Site Characterization, Robertson & Mayne (eds) © 1998 Balkema, Rotterdam, ISBN 90 5410 939 4

Summary of Standard Penetration Test (SPT) energy measurement experience

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ABSTRACT: The purpose of this paper is to review experience with SPT energy measurements. SPT data are important for determination of most all engineering properties in sands and are especially critical in determining earthquake liquefaction resistance. It is common practice to normalize SPT data to 60% drill rod energy delivery. Measurements have been performed since the late 1970's. Early SPT energy measurements were taken using force transducers in the drill string. These methods were standardized in the 1980's in ASTM D-4633. In the 1990's new instrumentation allows for measurement of acceleration on the drill string. New measurements are being performed by integration of the product of force and velocity. There are sometimes significant differences in the two methods. This paper will evaluate any differences in the energy measurement methods, and will make recommendations for correction of penetration resistance data. Practitioners currently are revising the ASTM standard. The paper will also make recommendations on future standardization. For some equipment and systems which are operated correctly, assumed energy transmission values can be used.

1 INTRODUCTION

A new method for measuring energy was developed in the 1990's. This method allows for measurement of acceleration on the drill sting. Data is being collected and evaluated. The older force measurement data differs from the new force velocity approach in many cases. These differences may affect normalization methods. This paper will review the problems with both methods and make recommendations for their future use.

2 FORCE SQUARED (F2) METHOD

Schmertmann and Palicios (1977) explored the F2 method in 1977. For perfect one dimensional wave prolongation, the energy consists of equal components of strain and kinetic energy. Efforts to use accelerometers in those days were not successful, so they integrated the square of the force. They used strain gage load cells placed at both the top and bottom of the drill rods. An extensive series of measurements with differing drill rods, and hammers to depths of 75 ft. were conducted. They found that the majority of sampler penetration occurred during the first wave pulse. This was fortunate, because the F2 method cannot be applied past the tensile wave return. After a study of energy transfer, they concluded the at the energy measured in the top cell was inversely related to SPT N values. A wide variation in energy for differing hammer systems was discovered

The F2 method is defined as follows;

$$E_i = \frac{cK_1K_2}{AE}\int_o^{\Delta t}[F(t)]^2\,dt \qquad (1)$$

where:

A = cross-sectional area of the drill rods above and below the force transducer,

c = velocity of the compression wave in the drill rods = $(e/\rho)^{1/2}$, approximately 5120 m/s for steel,

E = modulus of elasticity of the drill rods,

E_i = maximum energy transmitted to the drill rod during the impact event,

F(t) = dynamic force in the drill rod as a function of time,