

THE STANDARD PENETRATION TEST: IT'S ORIGIN, EVOLUTION AND FUTURE

An AGS seminar by the site investigation working group

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The SPT as we know the test today

THE STANDARD PENETRATION TEST

Used to obtain penetration resistance N

The number of blows required to drive a 60 degree cone or split spoon 300mm using a 63.5kg hammer falling 760mm



Timeline of the SPT development

- **1902:** Colonel Charles Gow introduced a 1in. (25mm) tube sampler to provide samples from washbore boreholes, using a 100lb hammer winched by hand.
- **1927:** The Raymond Piling group incorporating the Gow Company reported to be using 2in (50mm) sampler with spit spoon. A similar system in use around the same time by Sprague and Henwood. At this time the drop weight was not standardised and ranged from 110lbs to 140lbs. The drop height was about 30ins
- **1947:** Terzaghi and Peck describe the test and suggest that by counting the blows “useful information might be obtained”. At the 1947 conference on Soil Mechanics in Texas, Terzaghi coined the phrase **standard penetration test**
- **1957:** Palmer and Stuart introduce the 60 degree solid cone.
- **1963:** Pilcon developed the Trip Monkey release mechanism
- **1975:** Following decimalisation in the UK the drop weight was standardise as 65kg and the drop height 760mm (although this was not adopted at the time)
- **2008:** Measurement of E_r was possible for the first time commercially in the UK.

Standardisation of the test procedure

- **1957:** BS CP2001 includes penetration tests in Appendix J201 and notes that “All test are empirical and their value lies in the amount experience behind them.”
- **1967** BS 1377. Included as a sampling method where blows are recorded. Suggests results are modified when carried out in fine sand.
- **1975:** BS 1377 5.4 test 19 Specified a check valve and venting ports; test configuration of 65kg hammer falling 760mm
- **1990:** BS1377 Part 9 A standardised test procedure is described. Several caveats are given to ensure a standard test procedure. Recommend a solid cone when carried out in granular soils and the notation SPT(C)
- **1999:** BS 5930. commentary suggest test results are only indicative with empirically derived relationships
- **2005:** BS EN ISO 22476 Part 3 Further standardisation with the introduction of Energy Ratio determination a prerequisite. Requires rod stiffness to be considered (AW to 20m then BW below)
- **2015:** BS 5930 *“gives an indication of RD and other parameters these are at best approximate,”*

The SPT test

BS EN ISO 22476 Part 3 (2005)

Drive Weight Assembly	
Overall mass	≤ 115 kg
Hammer mass	63.5 ± 0.5 kg
Drop height	760 ± 10 mm
Drive head (anvil) mass	unspecified

- Rod straightness to be assessed and < 1 in 200
- The energy ratio should be assessed.



photograph courtesy of Equipe Group

Calculation of Energy Ratio (Er) as given in BS EN

The force transmitted to the rod is calculated as:-

$$F(t) = A_a \times E_a \times \varepsilon_m(t)$$

B.4.3 The basic equation for the energy E which passes into the drive rods is:

$$E(t') = \int_0^{t'} F(t) v(t) dt$$

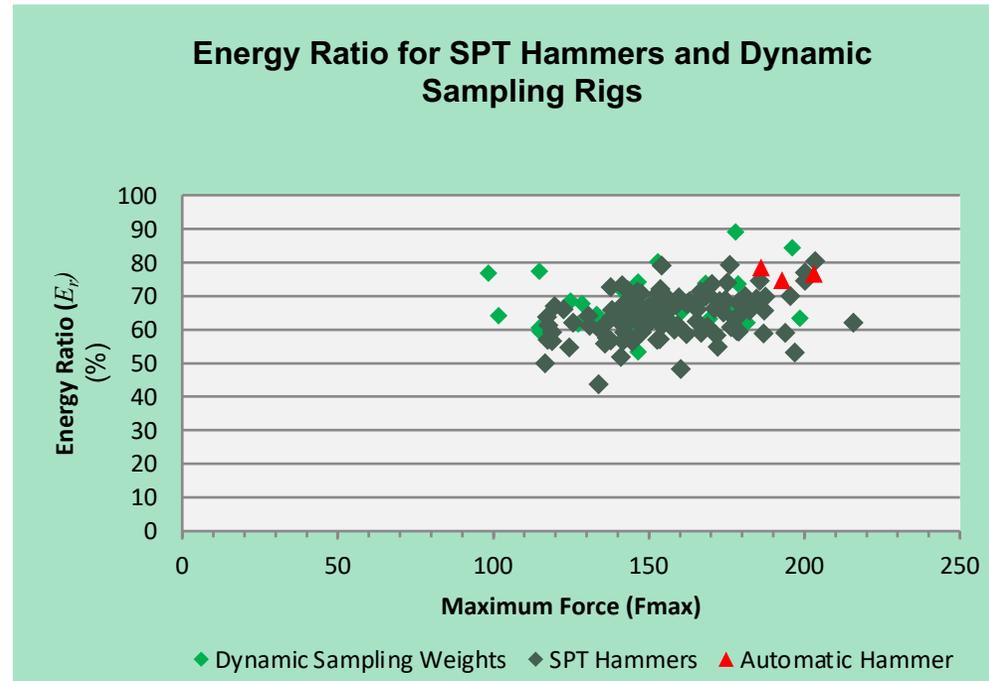
The hammer energy to take into account is the mean value obtained from at least five-measurements:

$$E_{\text{meas}} = \frac{1}{n} \sum_1^n E$$

The hammer energy ratio which characterises each dynamic penetrometer is given by:

$$E_r = \frac{E_{\text{meas}}}{E_{\text{theor}}} \leq 1$$

Results of Energy Ratio tests



Maximum value E_r 89%

Minimum value E_r 43%

Energy Ratio measurement

The range in energy ratio's will have a significant effect on the resulting corrected N value when correction factors are applied. The Standard indicates that for general design and comparison purposes in sands, the N value should be adjusted to a reference energy ratio of 60%, by the following equation:

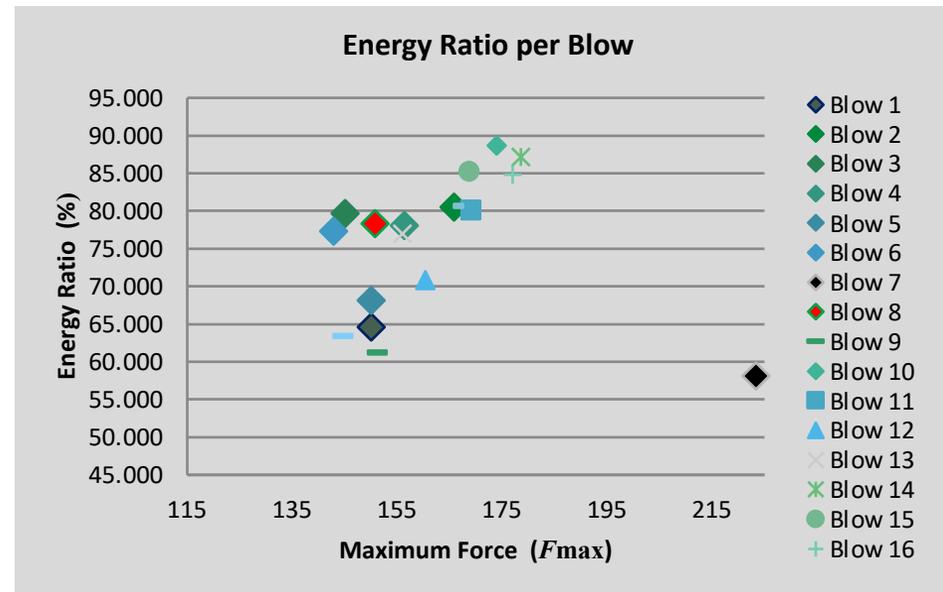
$$N_{60} = \frac{E_r}{60} N$$

where N is the blow count and E_r is the energy ratio of the specific test equipment

Using the data in the previous graph

If the energy ratio of two SPT hammers used on the same project in a uniform strata were 43% and 89% then the uncorrected values of N if 25 blows were recorded in the field would be corrected to 17 and 35, respectively

Results from SPT hammers



Results from a poorly maintained hammer

Energy decay and other effects

- Depth of test may contribute to a decline in energy ratio of up to 28% Lukiantchki (2015). Skempton (1986) suggested a correction for rod lengths of less than 10m, below this depth the effect is less clear.
- There is a potential difference between using the open spoon and the solid cone. Thorburn (1986) suggested this may be as much as 100% in granular soils and chalk although, in the latter, the effect was not seen on all sites. Montague, 1990
- The intervals are marked on the rods generally using chalk the penetration is measured judging by eye against a datum usually the top or the casing.
- Blows are counted manually for most tests



Some thoughts...

“There can be little doubt that the SPT N value is a very poor basis upon which to calculate foundation settlement.” Clayton, 1995

“The soil strength parameters which can be inferred are approximate” “The test result is dependant on the diameter of the borehole and should not be regarded as standard penetration tests.” BS 5930, 1999

Many of our relationship curves have been developed over the years and have been used to convert N values to a geotechnical parameter, most of these were based on SPT tests where the energy ratio was not measured.

The future.....

- Should we abandon the SPT for better and more expensive tests... a few high quality tests are worth more than numerous bad tests?
- Should we try to bring the SPT into the 21st Century with energy measurements for each blow and automatic penetration measurement and blow counts?
- Further research to confirm design data for previous work and relationship formula and graphs using SPT where the energy ratio is taken into account.

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