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The standard penetration test as we know it today was first described by Karl Terzaghi and Ralph Peck (1947). At that time the equipment had been in use for more than 30 years as a sampling tool, albeit rather crude. The sample is invariably highly disturbed and is of limited value. The original equipment was modelled around similar equipment used in the USA and attributed to Colonel Charles R Gow in 1902. The original sampler was driven at the bottom of the borehole using a 110lb hammer. Around 1927 part of the Raymond piling group, the Gow Company began using a split spoon sampler of 2 inches diameter. Around the same time a similar system was being used by Sprague and Henwood. In both systems the weight was winched by hand. The split spoon sampling tool, which comprised a thick walled tube with a cutting shoe on one end, was driven into the bottom of a borehole with blows from a 110lb hammer. Powered winches were not reported until 1937. The equipment was not standardised and it is recorded that the drop weight ranged from 110lb to 140lb. The height the weight was dropped was related to that which a man could comfortably lift on the winch, usually 30 inches. It was not until Terzaghi and Peck (1947) when describing the sampling system suggested that the number of blows required to drive the sampler over 1 foot. Seating the sampler into the base of the borehole was required prior to carrying out the test. The seating blows were recorded for 6 inches beyond the base of the borehole. Terzaghi suggested that by recording the number of blows valuable information might be obtained at little cost and that the information may be of some use in soils where little other information could be obtained, such as granular soils and he coined the term Standard Penetration Test. Up to this point there were few other tests which might indicate the potential competence of granular soils. Palmer and Stuart introduced the solid 60 degree cone in 1957. This has been incorporated into the test form we use today. It should be noted that comparisons between results using the split spoon open shoe and a solid cone show considerable variability in some soils,

To commence the test the base of the borehole should be cleaned removing any loose material. The SPT tool is connected to rods and lowered to the bottom of the borehole. Testing commences with two 75mm (3 inches) increments over which the number of blows should not exceed 25, these are defined as the seating blows. If the number of seating blows reaches 25 before driving the full 150mm the seating drive is stopped and the seating is recorded as 25 blows for the length driven.

Blows are counted for each of the next four 75mm of penetration giving a further 300mm (12inches) penetration. If the number of blows over these four increments reaches 50 in total the test is stopped. The test result is reported as the number of blows to achieve 300mm penetration ie the penetration resistance N. where the number of blows reaches 50 the result is reported as n= 50 blows for the penetration achieved mm. It is important that in addition to the number of blows that the casing depth hole depth and water level are recorded prior to commencing the test.

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In some cases the tool will sink into the base of the borehole under its own weight, this self weight penetration should be recorded.

Examples of SPT test results

Sample	Depth (m)		Standard Penetration Test										Casing	Water
Type	From	To	Self-penetration weight (mm)	75	75	PEN (mm)	75	75	75	75	PEN (mm)	N	Depth, (m)	Level, (m)
SPT	2.00	2.45	0	5	6	150	7	9	10	12	300	38	2.00	dry

Example showing full penetration of SPT with N value of 38

Sample	Depth (m)		Standard Penetration Test										Casing	Water
Type	From	To	Self-penetration weight (mm)	75	75	PEN (mm)	75	75	75	75	PEN (mm)	N	Depth, (m)	Level, (m)
SPT	3.00	3.555	105	1	1	150	1	0	1	1	300	3	3.00	1.00

Example showing Self Penetration of 105mm and N value of 3 for the full 300mm penetration.

Sample	Depth (m)		Standard Penetration Test										Casing	Water
Type	From	To	Self-penetration weight (mm)	75	75	PEN (mm)	75	75	75	75	PEN (mm)	N	Depth (m)	Level (m)
SPT	15.50	15.95	0	9	11	150	16	19	15	-	175	-	15.50	3.25

Example showing SPT refusal during the third test drive increment recorded as 15 for 25mm giving n 50 for 175mm

When the test is carried out below the water table it is essential that a positive head or water balance is applied to prevent upward water flow in the borehole. In fine grained granular soils this will cause loosening of the soil and SPT values will be significantly reduced. Water balance is seen as an important necessity when conducting SPT tests and provision should be made to ensure that water balance in maintained in the borehole before and during the test. Failure to do so will invariably change the soil density in proximity of the base of the borehole and results will be unreliable.

Many authors have also noted that significant disturbance can be present in the base of larger diameter boreholes which will affect not only the sample quality but also the measures SPT value.

Great care needs to be exercised when conduction the test. The drive distance is generally indicated by chalk marks on the drive rods. The driller needs to judge when the drive distance is reached and make a note of the number of blows to achieve this. Many errors have been observed with this visual assessment part of the process. Some more recent rigs do have automatic recording of drive distance and blows however this is an exception rather than the rule and it generally accompanies the use of an automatic hammer.

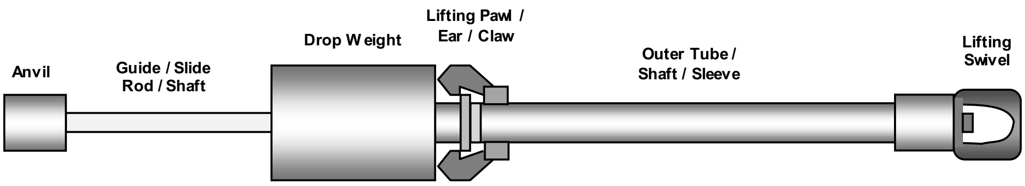
Test methods described by standards have suggested that the total number of blows can be increased to 100 before terminating the test. In reality this would exceed the original test limits and could damage the equipment, at the very least if this is practiced there should be an additional charge for the time and potential risk to equipment. On a more pragmatic note 50 blows would define the granular soils as being very dense or partially cemented. Before scheduling blows in excess of 50, due consideration must be given to what practical use this additional information truly provides and the use of an alternative investigation method might be found more suitable.

There are much wider questions which are frequently raised regarding the use of the SPT. It is clear that the test does not provide a true parameter for the soil tested. The parameters of the test drop height and drop weight are arbitrary. The only redeeming feature is that these parameters have been ostensibly unchanged for over a century and thus there is a significant bank of data for comparison. It must be borne in mind that the test has been unregulated until 2008 when the first energy analyser was introduced into the UK. In effect the test is a crude indication of compactness which bears little or no comparison to real parameters such as strength or compressibility. However the test can be used as a comparative measure having been used for almost a century there is much data which can inform the performance of foundations, structures and materials providing comparisons with the performance of similar results in similar soils for the same end use. Many empirical foundation design relationships have been developed by numerous authors which provide reasonable design outcomes provided an appropriate factor of safety is applied commensurate with the considered level of reliance on the source of the test results.

Since 2005 Eurocode BS EN ISO 22476 – 3 has required the SPT hammer to be tested to determine the energy ratio (Er) on a regular basis. This determination means that the results from all hammers could be normalised to N_{60}. The N_{60} Value is the energy representing 60% of the theoretical energy values assuming a frictionless device. This value was suggested by Skempton (1986) and further by Clayton (1990) as being the average efficiency ratio of hammers he observed.

Efficiency ratio Er = (actual energy of individual hammer / Theoretical energy per blow) %

To obtain the average energy ratio the energy per blow is measured using accelerometers and strain gauges attached to a short section of rod coupled directly below the anvil. The test requires that the tool is in contact with the soil at the base of a borehole it is recommended that AW rods (43.8mm diameter) are used to a depth of 20m and BW rods (54.2mm diameter) if tests are conducted at greater depth the testing specification does not indicate a depth to the base of the test borehole. Practice would suggest that between 6 to 8 m is sufficient in that the energy recorded from the blow is clean and not affected by the energy signal returning up the rod, ensuring the energy from the hammer blow will not overlap and confuse the first energy arrival as the energy pulse passing down the rod registers on the accelerometers and strain gauges.



The standard test requires that the SPT hammer should have a mass of 63.5kg and fall through 760mm. The complete hammer assembly should weigh in total no more than 115Kg. It shall be clean, well maintained and used without lubrication. It must have its energy ratio recorded at least annually and more frequently if deemed necessary.

For the test to be reliable the rods should be straight and the couplers tight. It is recommended that rod straightness is checked after every 20 tests. This is not common practice but can have a significant effect on hammer efficiency. In deep boreholes it is recommended that rod centralisers are used to ensure the rods remain straight in the borehole.

Automatic hammers

These hammers are widely used on rotary rigs because they have a pneumatic system which can be used to power the hammer. Testing has shown that these hammers are much more reliable with more consistent impact energy and generally efficiencies close to 90%. The hammer impact tends to be rapid. The codes suggest that blows should not exceed 30 per minute. The results are reported in a similar fashion to that described above.

Little comparison work has been conducted to determine if these provide comparable results to the conventional drop weight hammers .In particular the rapid impact of each blow provides a near continuous impact which is significantly different to the gravity drop weight method.

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