## Soil Correlations

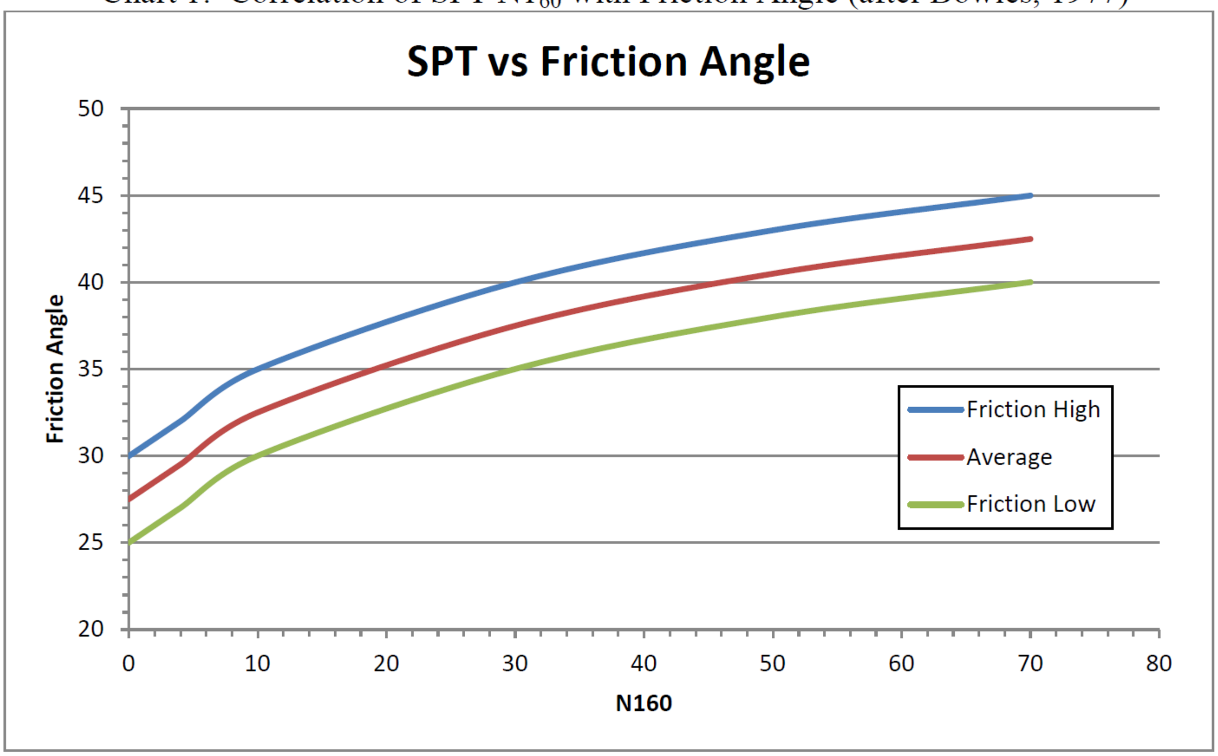
This section of the Geotechnical Manual presents the SPT correlations to be used for friction angle (phi angle) and unit weight. The correlations use Standard Penetration Test (N) values corrected for overburden and hammer efficiency ($N1_{60}$). Usage of correlations for geotechnical design is addressed in the various design sections of the Geotechnical Manual. Other correlations, e.g. CPT correlations and shear wave velocity correlations are found elsewhere in the Geotechnical Manual.

## Cohesionless Soil: Friction Angle

Correlations of SPT blow counts to cohesionless soil friction angle and unit weight follow Bowles (1977) and are consistent with many of the NHI manuals used by the department. The correlations use Standard Penetration Test (N) values corrected for overburden and hammer efficiency ($N1_{60}$).

Use Chart 1 to correlate $N1_{60}$ to the friction (phi) angle.

Chart 1: Correlation of SPT $N1_{60}$ with Friction Angle (after Bowles, 1977)




Choose the friction angle (expressed to the nearest degree) based upon the soil type, particle size(s), and rounding or angularity. Experience should be used to select specific values within the ranges. In general, finer materials or materials with significant (about 30+ %) silt-sized material will fall in the lower portion of the range. Coarser materials with less than 5% fines will fall in the upper portion of the range. The extreme range of phi angles for any $N1_{60}$ is five degrees, so the adjustment factors for particle size and roundness should be only a degree or two. The following bullets provide help in determining which value to select for a given $N1_{60}$ and soil type:

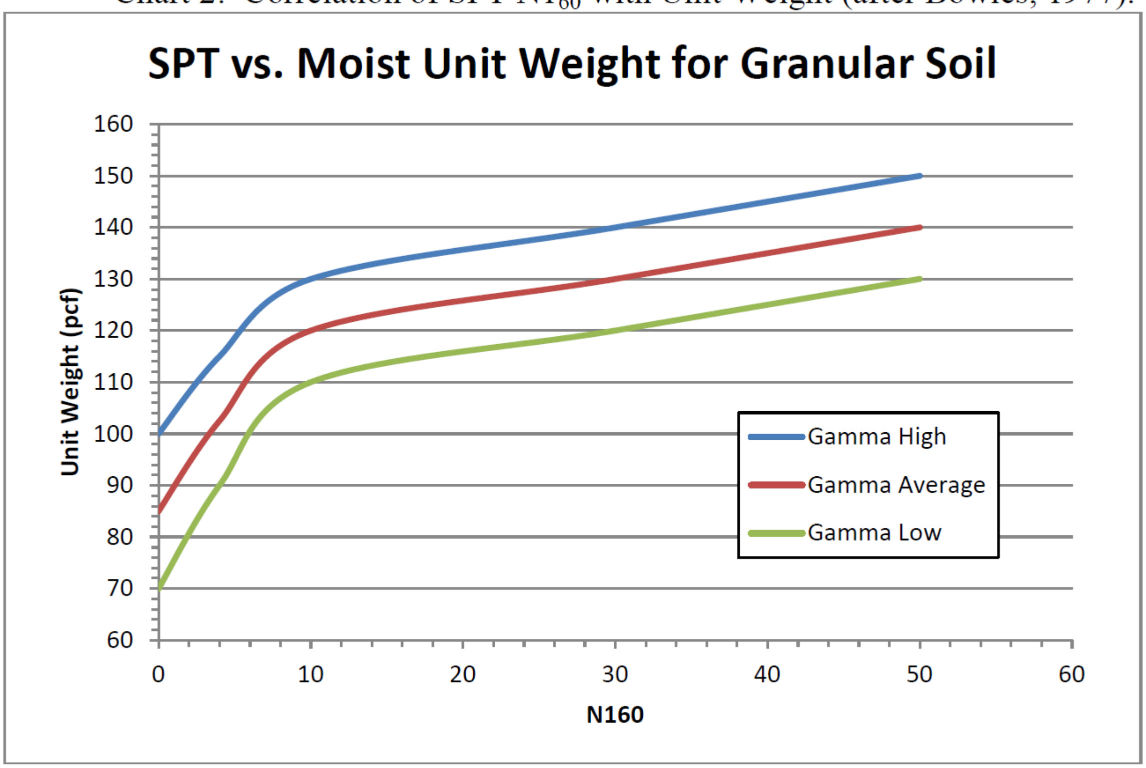
- Use the maximum value for GW
- Use the average for GM and SP
- Use the minimum for SC
- Use the minimum + 0.5 for ML
- Use the average +1 for SW
- Use the average -1 for GC
- Use the Maximum -1 for GP

Values may also be increased with increasing grain size and/or particle angularity and decreased with decreasing grain size and/or increasing roundness. For example, an SP with $N1_{60}$ = 30 could be assigned phi angles of 37, 38 or 39 degrees for fine, medium and coarse grain sizes respectively.

**Cohesionless Soil: Unit Weight**

Use Chart 2 to correlate $N1_{60}$ to the moist unit weight for cohesionless (Granular) soil.

Chart 2: Correlation of SPT $N1_{60}$ with Unit Weight (after Bowles, 1977).



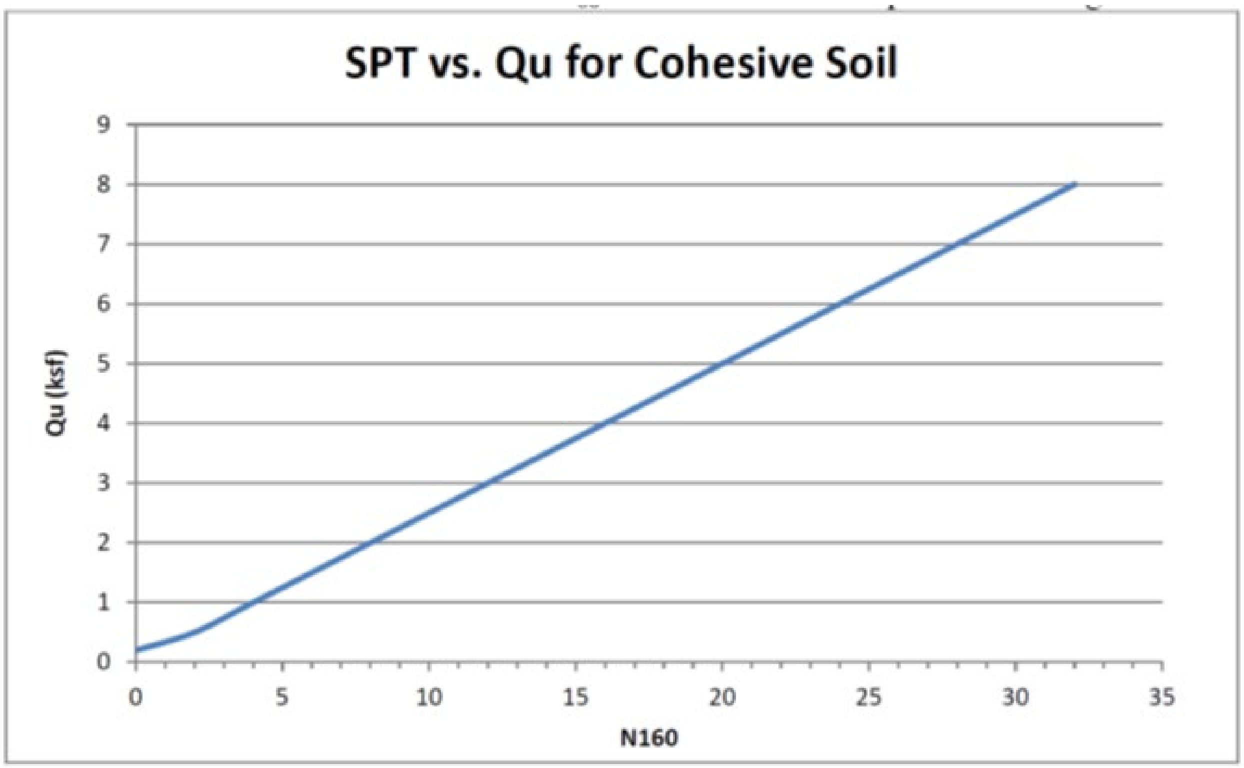
Choose the unit weight expressed to the nearest five pcf for the soil type based on the following guidelines:

- Use the higher values for well-graded sands and gravels and average values for poorly-graded sands and gravels.
- Use lower values for elastic silt, and clayey or silty sands and gravel.
- Deduct up to 20% for dry soils.

**Cohesive Soil: Unconfined Compressive Strength (Qu)**
**Undrained Shear Strength (Su)**

The standard practice is to determine shear strength of cohesive soils in the field based on measurements with torvane, pocket penetrometer, or vane shear. It is not acceptable to use SPT correlations to determine shear strength or to assign consistency values. For preliminary studies, use Chart 3 to assign shear strength values when only SPT values are available. Usually this is applicable when data are available from old as-built LOTBs where field or laboratory strength tests are not available.

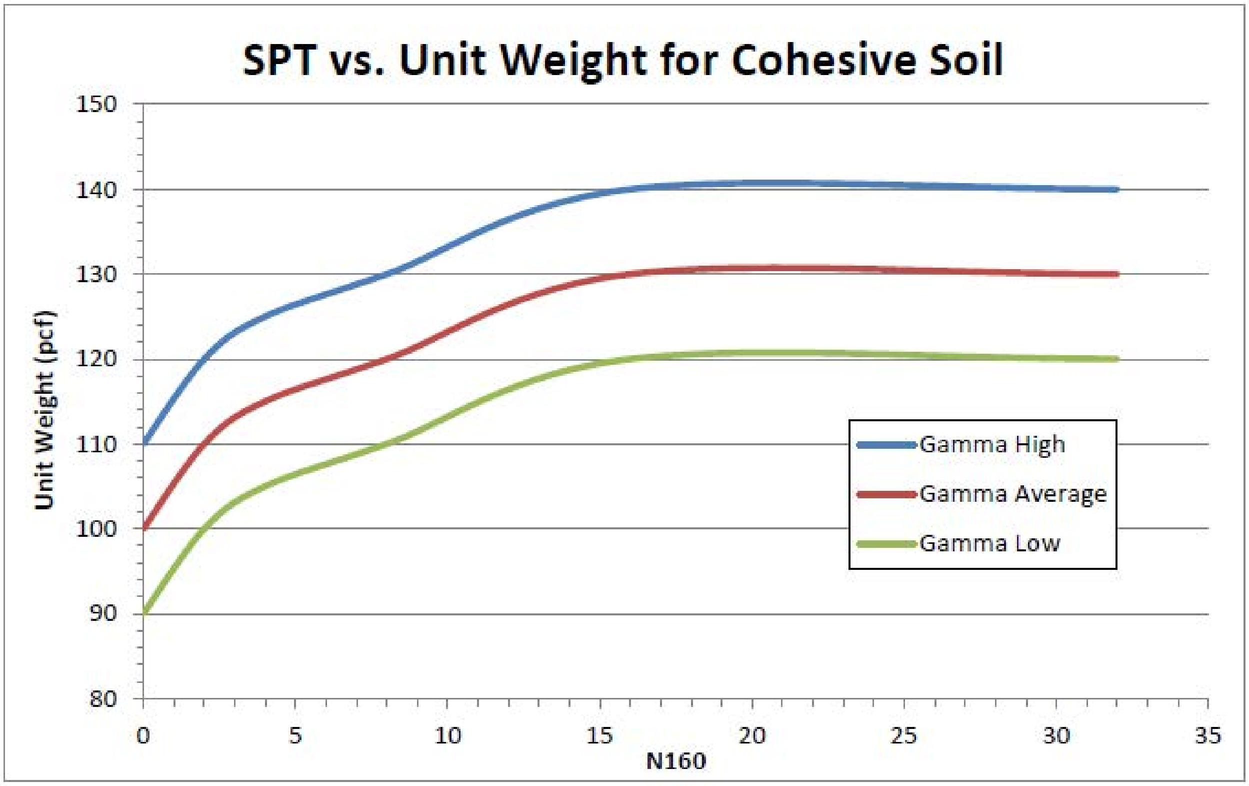
Chart 3: Correlation of SPT $N1_{60}$ to Unconfined Compressive Strength
(after Bowles, 1977)



**Cohesive Soil: Unit Weight**

Use Chart 4 to correlate $N1_{60}$ with the Unit Weight of cohesive soil.

Chart 4: Correlation of SPT $N1_{60}$ with Unit Weight (after Bowles, 1977).




Comparing field pocket penetrometer and/or torvane readings to Chart 4 is a good way of determining whether high or low values should be used. For example, if the pocket penetrometer reading for a clay with $N1_{60}$ = 10 is about 2.5 ksf (the same as the value shown in Chart 3) the unit weight should correspond to the average value. If the pocket penetrometer reading is higher, the unit weight should be increased from the average, and if the pocket penetrometer reading is lower, the unit weight should be decreased from the average.

In the absence of SPT data, unit weights can be estimated using Charts 3 and 4 and the strength data (e.g., pocket penetrometer reading). For example, from Chart 3, a pocket penetrometer value of 5 ksf corresponds to an SPT $N1_{60}$ value of 20. Chart 4 shows the average unit weight of a cohesive soil with SPT $N1_{60}$ = 20 is 130 pcf.

## Sampler Size Conversions to SPT N-value

When sampler sizes vary from that of a SPT sampler (per ASTM 1586), conversions are needed to modify the field SPT N-values. For conversions to SPT sampler from other sampler sizes where weight (140 lb.) and height (18 inches) do not vary from ASTM 1586, the following table provides conversion values for common alternate sampler sizes.

Table 1: Conversion Values for Sampler Sizes

| Sampler Type | Outside Diameter (inches) | Inside Diameter (inches) | Conversion to SPT N-value | |
|---|---|---|---|---|
| | | | Clay | Sand |
| 1.41-inch | 2.0 | 1.375 | 1.00 | 1.00 |
| 2-inch | 2.5 | 1.95 | 0.85 | 0.63 |
| 2.4-inch | 3.0 | 2.4 | 0.65 | 0.41 |
| 2.5-inch | 3.875 | 2.5 | 0.24 | 0.13 |

## 1-inch Diameter Driven Sampler

Some As-built LOTBs include 1” diameter sampler data and use soil descriptors that differ from current practice. The following table lists these descriptors, 1" soil tube blow counts, and associated SPT blow counts. The 1” soil tube blow counts are obtained by driving a 1” sampler one foot with a 25-pound hammer dropped one foot.

Table 2: Density/Consistency descriptor conversions for 1" Soil Tube (Closed Tip)
(Ref: Handbook of Engineering Geology, State of CA Division of Highways, 1958)

| Density/Consistency | | 1" Soil Tube -- Blows Per Foot | | | Standard Penetration Blows Per Foot |
|---|---|---|---|---|---|
| Granular | Cohesive | Sand and Gravel | Silt | Clay | |
| Very Loose | Very Soft | 0-50 | 0-50 | 0-60 | 0-5 |
| Loose | Soft | 50-100 | 50-180 | 60-250 | 5-10 |
| Slightly Compact | Stiff | 100-350 | 180-1000 | 250-1000 | 10-20 |
| Compact | Very Stiff | 350-525 | 1000-2000 | 1000-4000 | 20-35 |
| Dense | Hard | 525-1500 | 2000-5000 | 4000-5000 | 35-70 |
| Very Dense | Very Hard | 1500+ | 5000+ | 5000+ | 70+ |

## References


- Bowles, J. E., 1977, *Foundation Analysis and Design*, McGraw-Hill, Inc., New York