

From Chapter 4 Soil Formation and Characteristics

U.S. Army (1997) Military Soils Engineering. Field Manual 5-410.

On-line at <http://www.adtdl.army.mil/cgi-bin/atdl.dll/fm/5-410/toc.htm>

Gradation

The distribution of particle sizes in a soil is known as its gradation. Gradation and other associated factors, primarily as applicable to coarse-grained soils, are discussed in the following [paragraphs](#).

Effective Size. The grain size corresponding to 10 percent passing on a grain-size distribution curve (see [Figure 4-5](#)) is called Hazen's effective size. It is designated by the symbol D_{10} . For the soil shown, D_{10} is 0.13 mm. The effective sizes of clean sands and gravels can be related to their permeability.

Coefficient of Uniformity. The coefficient of uniformity (C_u) is defined as the ratio between the grain diameter (in millimeters) corresponding to 60 percent passing on the curve (D_{60}) divided by the diameter of the 10 percent (D_{10}) passing. Hence, $C_u = D_{60}/D_{10}$.

For the soil shown on [Figure 4-5](#)--

$$D_{60} = 2.4 \text{ mm and } D_{10} = 0.13 \text{ mm}$$

$$\text{then } C_u = \frac{2.4}{0.13} = 18.5$$

The uniformity coefficient is used to judge gradation.

Coefficient of Curvature. Another quantity that may be used to judge the gradation of a soil is the coefficient of curvature, designated by the symbol C_c .

$$C_c = \frac{(D_{30})^2}{(D_{60} \times D_{10})}$$

D_{10} and D_{60} have been defined, while D_{30} is the grain diameter corresponding to 30 percent passing on the grain-size distribution curve. For the soil shown in [Figure 4-5](#):

$$D_{30} = 0.3 \text{ mm}$$

$$\text{and } C_c = \frac{(0.3)^2}{(2.4)(0.13)} = .29$$

Well-Graded Soils. A well-graded soil is defined as having a good representation of all particle sizes from the largest to the smallest (see [Figure 4-6](#)), and the shape of the grain-

size distribution curve is considered "smooth." In the USCS, well-graded gravels must have a C_u value > 4 , and well-graded sands must have a C_u value > 6 . For well-graded sands and gravels, a C_c value from 1 to 3 is required. Sands and gravels not meeting these conditions are termed poorly graded.



Figure 4-6. Well-graded soil.

Poorly Graded Soils. The two types of poorly graded soils are--

- Uniformly graded.
- Gap-graded.

A uniformly graded soil consists primarily of particles of nearly the same size (see [Figure 4-7](#)). A gap-graded soil contains both large and small particles, but the gradation continuity is broken by the absence of some particle sizes (see [Figure 4-8](#)).



Figure 4-7. Uniformly graded soil.



Figure 4-8. Gap-graded soil.

[Figure 4-9](#) shows typical examples of well-graded and poorly graded sands and gravels. Well-graded soils ((GW) and (SW) curves) would be represented by a long curve spanning a wide range of sizes with a constant or gently varying slope. Uniformly graded soils ((SP) curve) would be represented by a steeply sloping curve spanning a narrow

range of sizes; the curve for a gap-graded soil ((GP) curve) flattens out in the area of the grain-size deficiency.

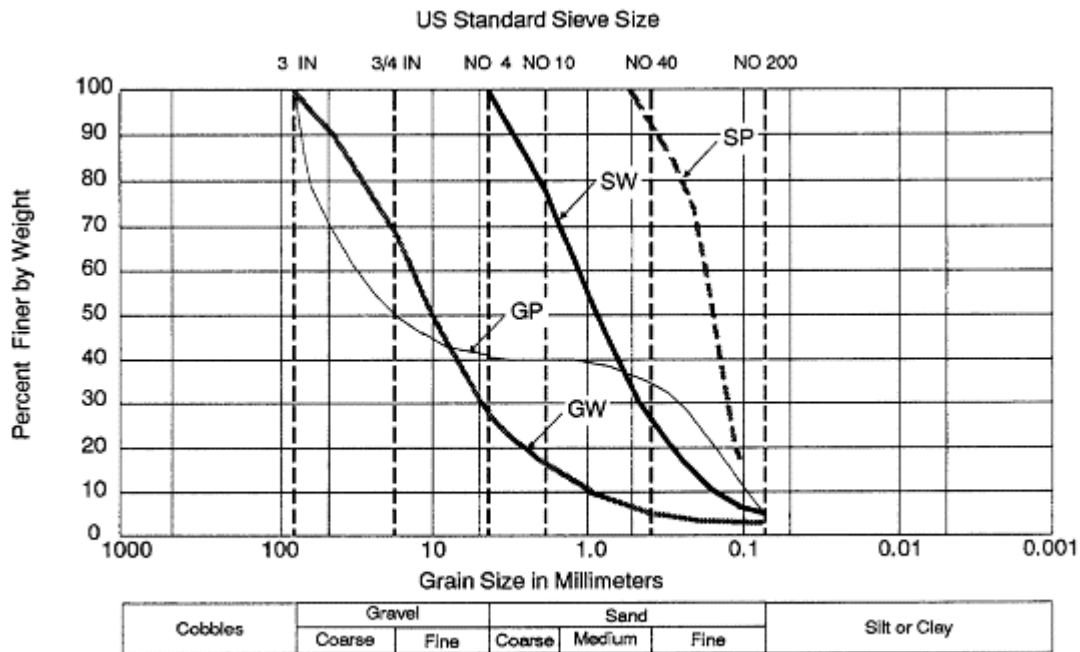


Figure 4-9. Typical grain-size distribution curves for well-graded and poorly graded soils.

Bearing Capacity. Coarse materials that are well-graded are usually preferable for bearing from an engineering standpoint, since good gradation usually results in high density and stability. Specifications for controlling the percentage of the various grain-size groups required for a well-graded soil have been established for engineering performance and testing. By proportioning components to obtain a well-graded soil, it is possible to provide for maximum density. Such proportioning develops an "interlocking" of particles with smaller particles filling the voids between larger particles, making the soil stronger and more capable of supporting heavier loads. Since the particles are "form-fitted", the best load distribution downward will be realized. When each particle is surrounded and "locked" by other particles, the grain-to-grain contact is increased and the tendency for displacement of the individual grains is minimized.