Chapter 4. Materials Tested

4.1. Introduction

Index and property tests were conducted on the base and filter materials used in the filter tests. These tests included the following:

- Specific Gravity
- Grain size distribution (sieve and hydrometer)
- Atterberg Limits
- Standard Proctor compaction test
- Consolidated-Undrained triaxial tests
- Flexible wall permeability tests

4.2. Tests on Teton Dam Core Material (Base Material)

Specific gravity tests were conducted in accordance with ASTM D854. A value of specific gravity, G_s, equal to 2.699 was determined for the Teton Dam core material. The value of specific gravity was required in order to reduce the hydrometer test data.

The grain size distribution was determined using sieve and hydrometer tests in accordance with ASTM D422. The test specimen was first passed through at #10 sieve, and the material passing was subjected to a hydrometer analysis. After the hydrometer test was concluded, the entire test specimen was washed over a #200 sieve, and a sieve analysis was conducted on the material that was retained after the washing process. The grain size distribution of the Teton Dam core material is shown in Figure 4.1.

The Teton Dam core material, used as the base material in all filter tests, has a maximum particle size of about 2 mm and about 75% fines. The soil has about 25% sand, 65% silt, and 10% clay-sized particles. From the gradation curves, the particles sizes pertinent to filter design, which are listed in Table 4.1.

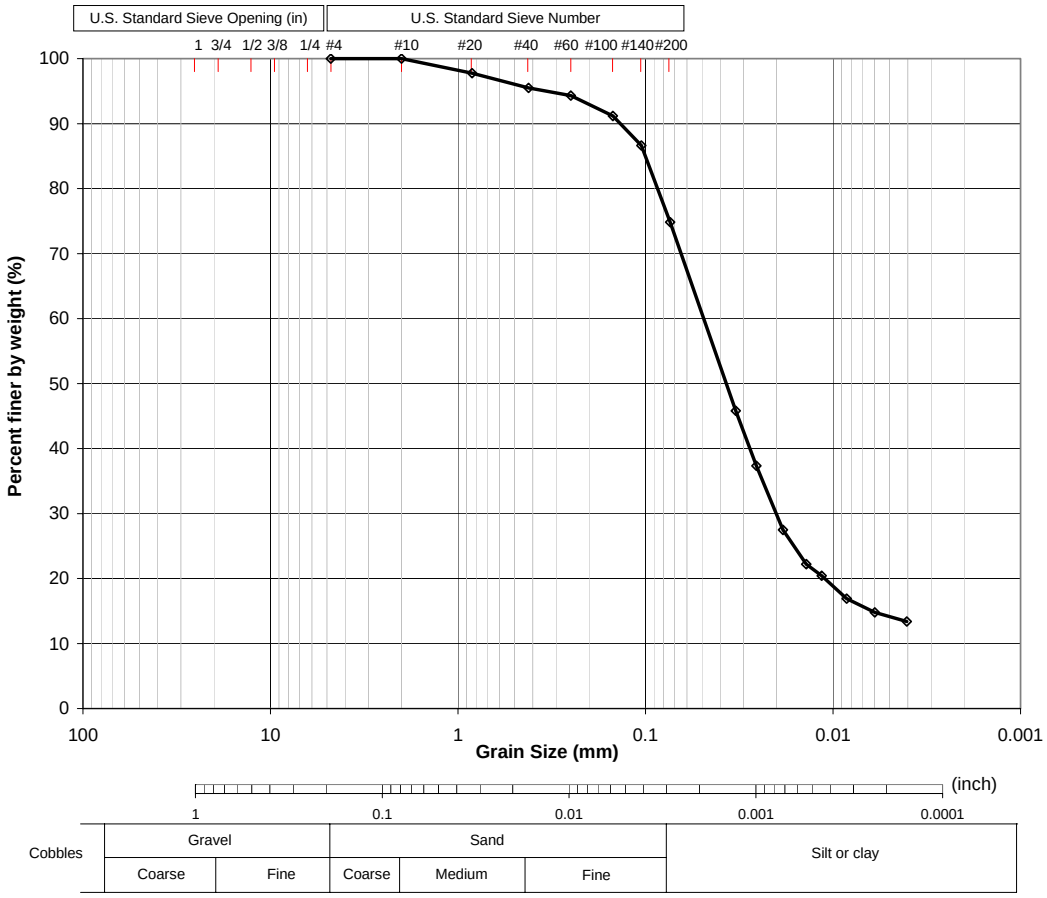


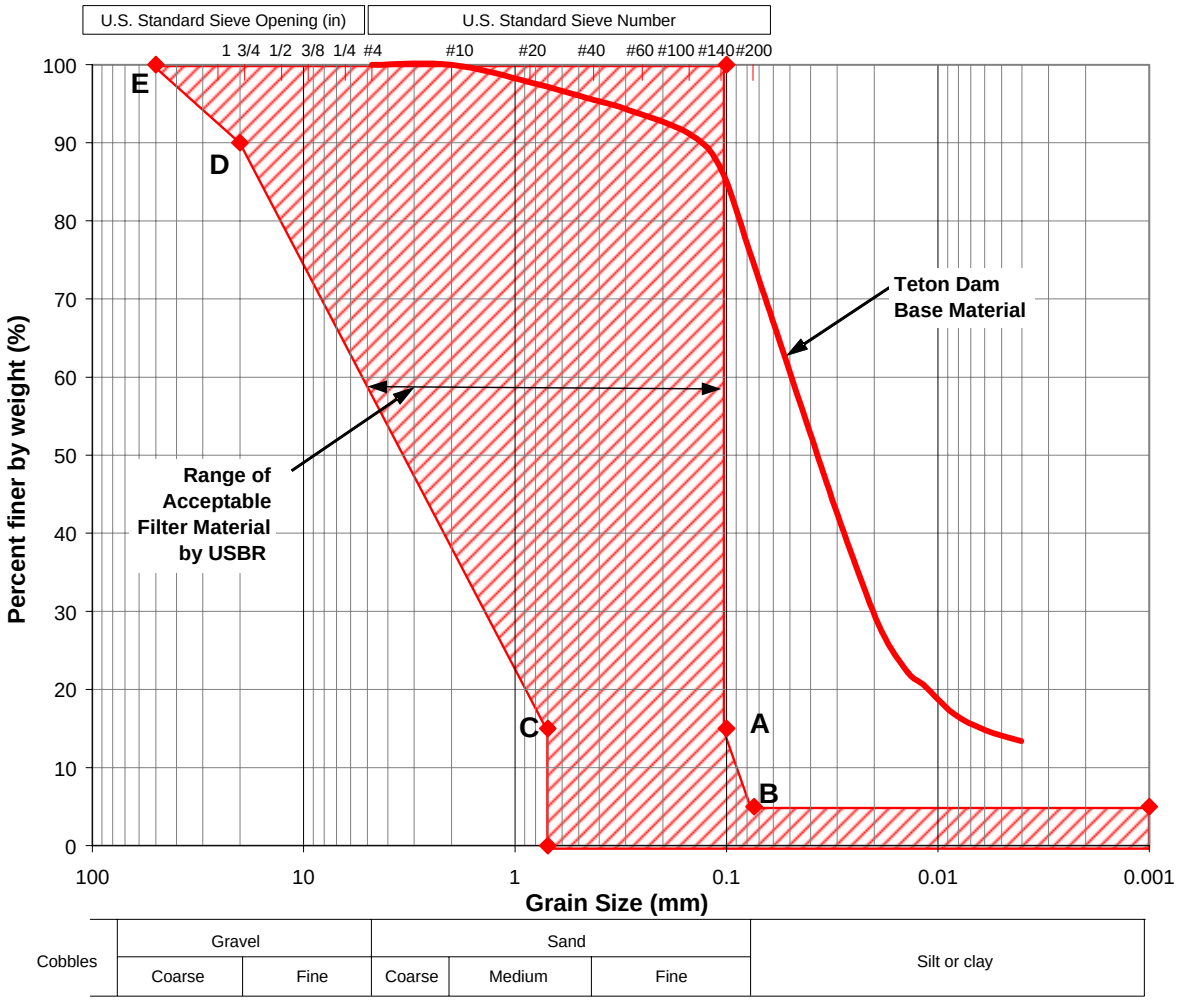
Figure 4.1 Grain size distribution of Teton Dam core material

Table 4.1 Particle size diameters corresponding to different size fractions for Teton Dam core material

Percent passing	Diameter (mm)
90	0.140
60	0.033
30	0.020
15	0.006
10	≈0.001

Based on the gradation curve of the Teton Dam core material, a range of acceptable filters, according to current USBR specifications, can be determined. A soil that plots within the boundaries shown on Figure 4.2 would meet the USBR specifications, provided that the soil contains non-plastic fines.

Atterberg limits (ASTM D4318) were determined for the Teton Dam core material. A Liquid Limit of 26.4%, a plastic limit of 24.1%, and a plasticity index of 2.3% were determined. These Atterberg limit results are shown plotted on a plasticity chart in Figure 4.3. Based on the gradation curve and the plasticity characteristics, the Teton Dam core material classifies as a sandy, inorganic silt of low plasticity (ML).



* Note:

A is minimum D_{15F} for permeability.

B is maximum 5% fines content limit.

C is maximum D_{15F} for restraint.

D is maximum D_{90F} for based on considerations of segregation.

E is maximum particle size of filter .

Figure 4.2 Range of gradations meeting USBR specifications for granular filters

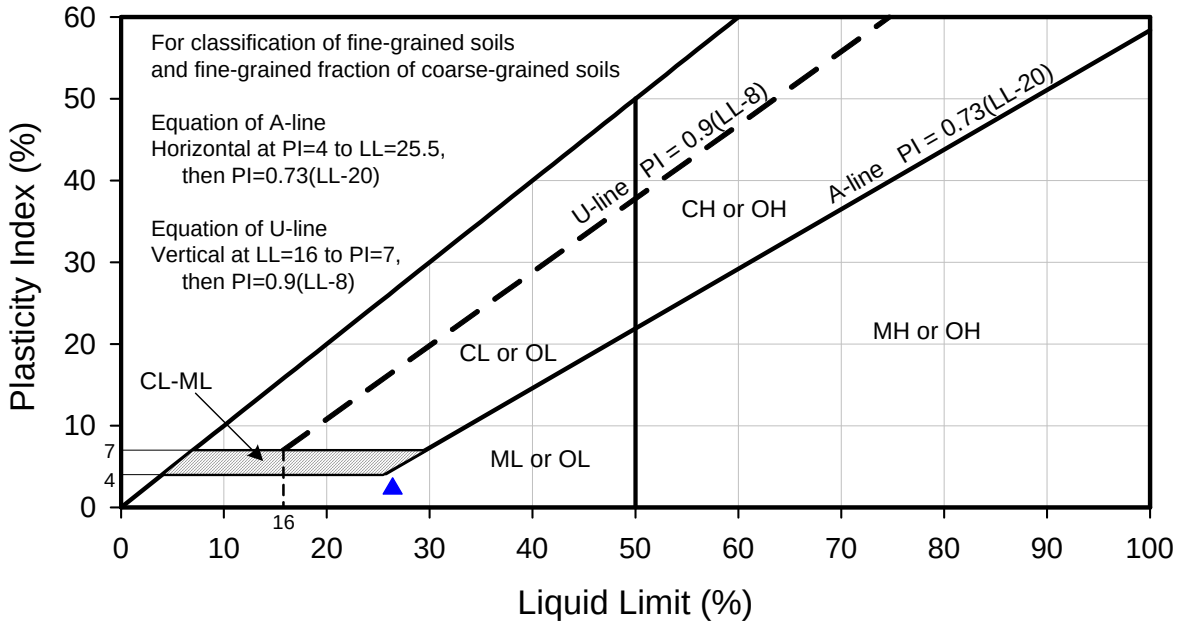


Figure 4.3 Plasticity chart showing Teton Dam core material (After ASTM D2487)

A standard Proctor (ASTM D698) compaction test was conducted on the Teton Dam core material. The compaction curve is shown in Figure 4.4. A maximum dry density of 106.8 pcf and an optimum water content of 16.1% were determined. Values of relative compaction and water contents relative to optimum in the subsequent parts of this report are referenced to these values.

Consolidated-Undrained triaxial tests were conducted on compacted specimens of the Teton Dam core material. The triaxial specimens were compacted to a relative compaction of 90% at water content near the optimum water contents using a Harvard miniature compaction apparatus. The test specimens had a nominal diameter of 1.38 inches and a height of 2.8 inches. The specimens were tested in an automated triaxial testing apparatus manufactured by the Geocomp Corporation of Boxborough, Mass. This device provides automatic back-pressure saturation, consolidation, and shearing. Four tests were conducted at consolidation pressures of 2.5, 5, 10, and 15 psi. The specimens were slightly anisotropically consolidated in order to maintain a compressive stress in the loading linkage of the testing apparatus.

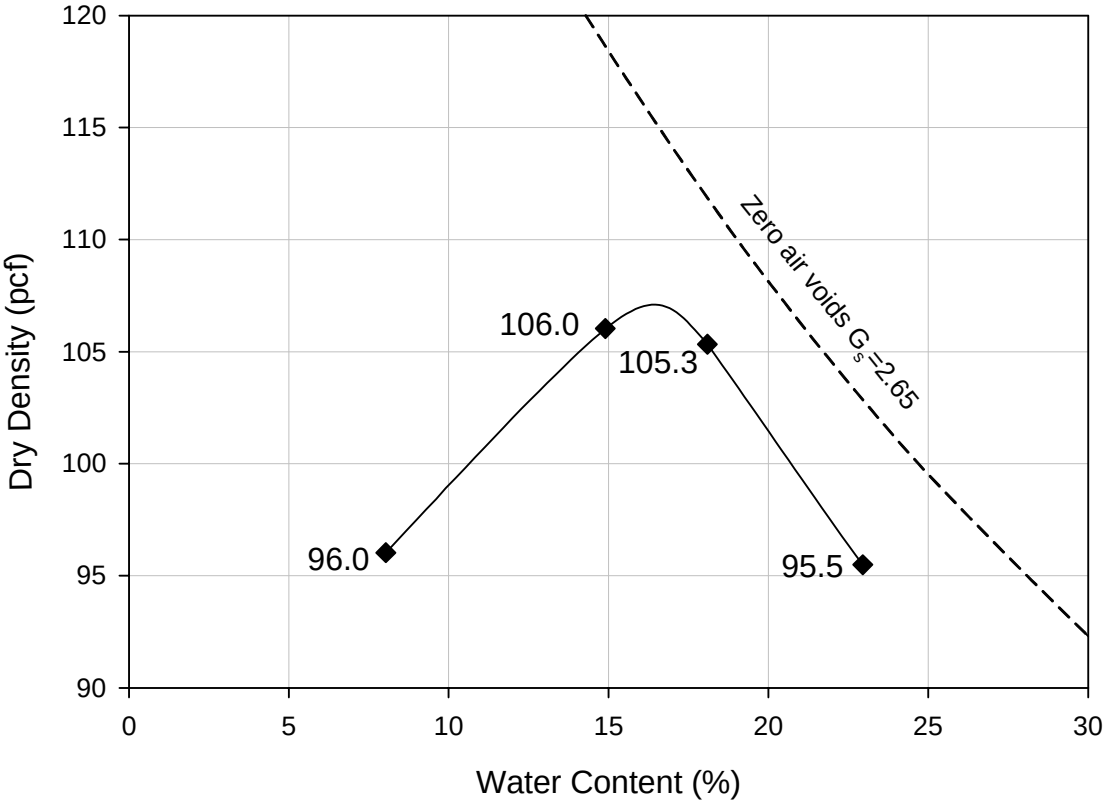


Figure 4.4 Standard Proctor compaction curve for Teton Dam core material

Figure 4.5 shows the effective stress paths measured for the CU triaxial tests. In this figure, $q = (\sigma_1 - \sigma_3)/2$ and $p' = (\sigma_1 + \sigma_3)/2$. The solid dark line shown on the figure is the K_f line derived from the test data. This line corresponds to $\phi' = 30$ degrees and $c' = 1.04$ psi.

A flexible wall permeability test (ASTM D5084) was conducted on a compacted test specimen of the Teton Dam core material. The test specimen was compacted in a

1/30ft^3 compaction mold at a relative compaction of 90% of the standard Proctor maximum dry density at the optimum water content. The test specimen was back-pressure saturated and then consolidated to an isotropic stress of 2.5 psi. The sample was permeated at a hydraulic gradient of about 5. From this test, the coefficient of permeability of the Teton Dam core material was found to be 1×10^{-6} to 1.5×10^{-6} cm/s.

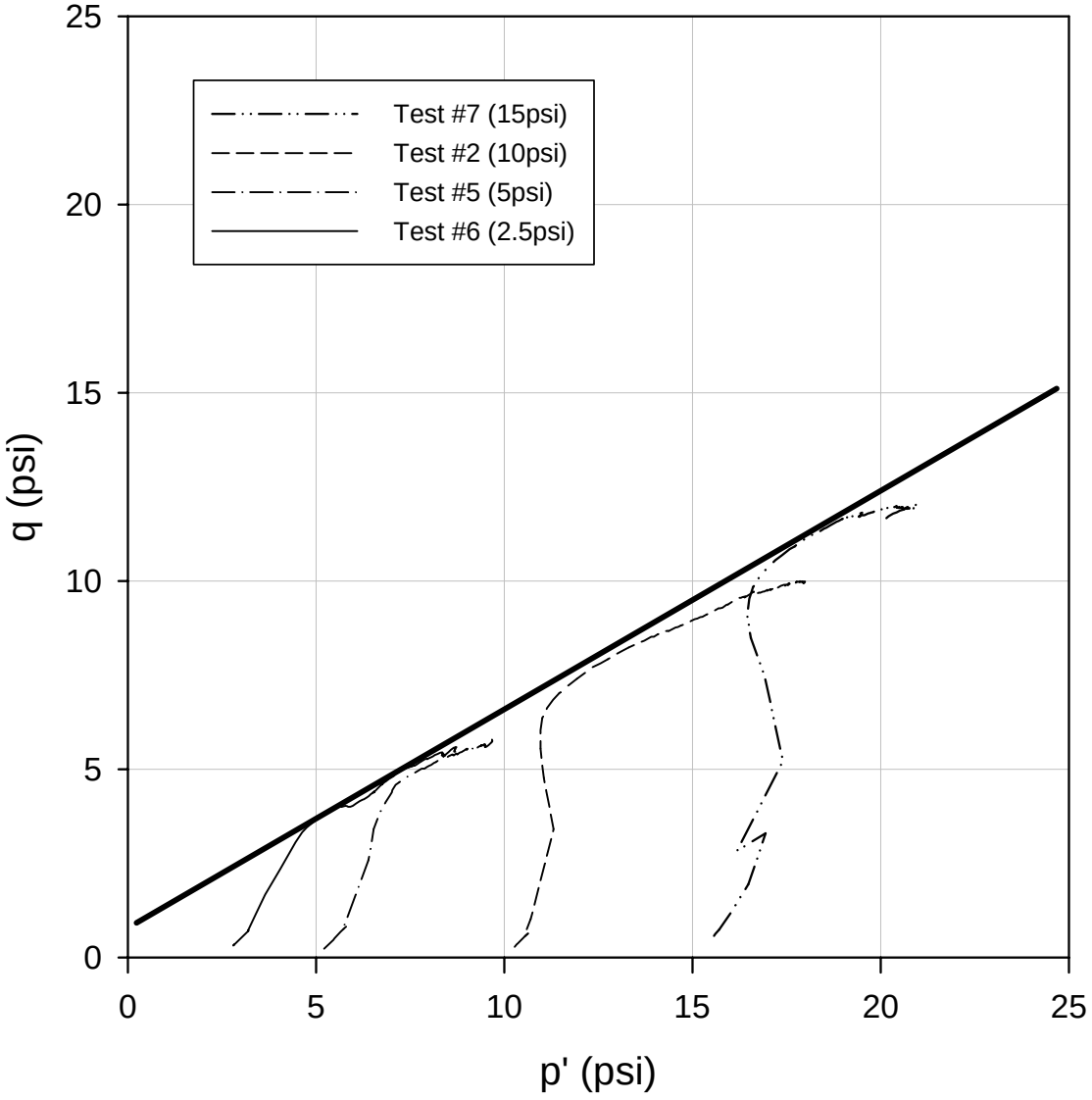


Figure 4.5 Effective stress paths for CU triaxial tests conducted on Teton Dam core material

4.3. Tests on Filter Material

Various filter materials were used in this research. The initial tests (Tests 1 through 5) used the filter soil from the Ochoco Dam that was provided by the USBR. Tests 7 and 8 used a filter material fabricated from commercially-available quartz sands. Tests 9 through 12 used the Ochoco filter material, and the remaining tests used the Horsetooth Dam filter material.

A sieve analysis was performed on the Ochoco Dam filter material and the gradation curve is shown in Figure 4.6. This material, in the as-delivered condition, would meet the USBR filter criteria for a filter for the Teton Dam core material, and was used for the first series of tests to troubleshoot the testing apparatus.

The production tests were conducted using the Horsetooth Dam filter material. A gradation curve for this filter is shown in Figure 4.7. As delivered, this soil contained 4% fines, and met the criteria for a filter material for the Teton Dam base material. The Horsetooth Dam filter soil was split on different size sieves, and recombined to form test specimens having 0%, 5%, and 15% fines. The gradation curves for these specimens are also shown in Figure 4.7. The plot shows both the as-delivered gradation curve, and the gradation curves of the recombined test specimens.

Maximum and minimum density tests (ASTM D4253 and ASTM D4254) were conducted on the Horsetooth Dam filter soil with different fines contents. The maximum and minimum densities that were measured are given in Table 4.2.

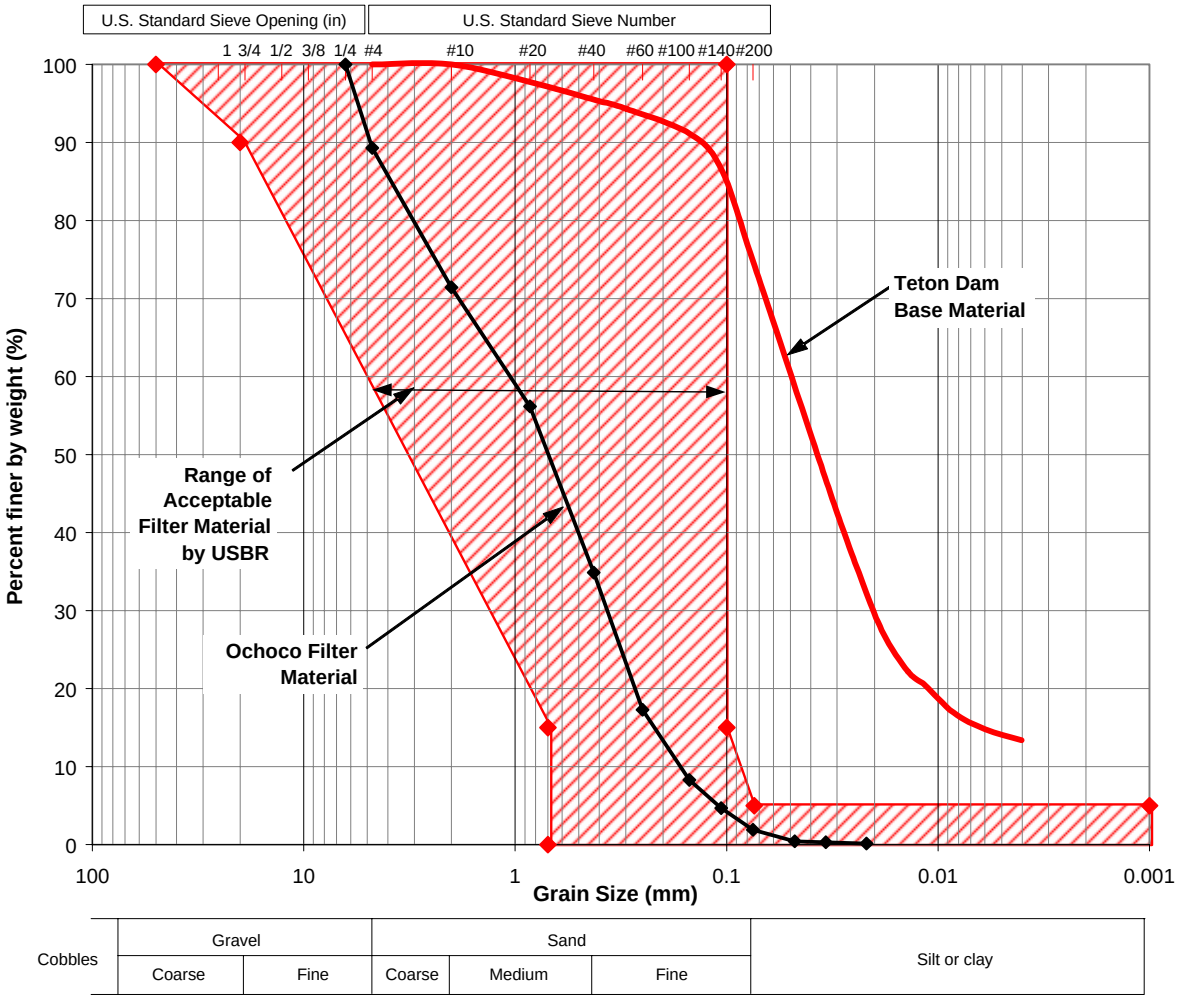
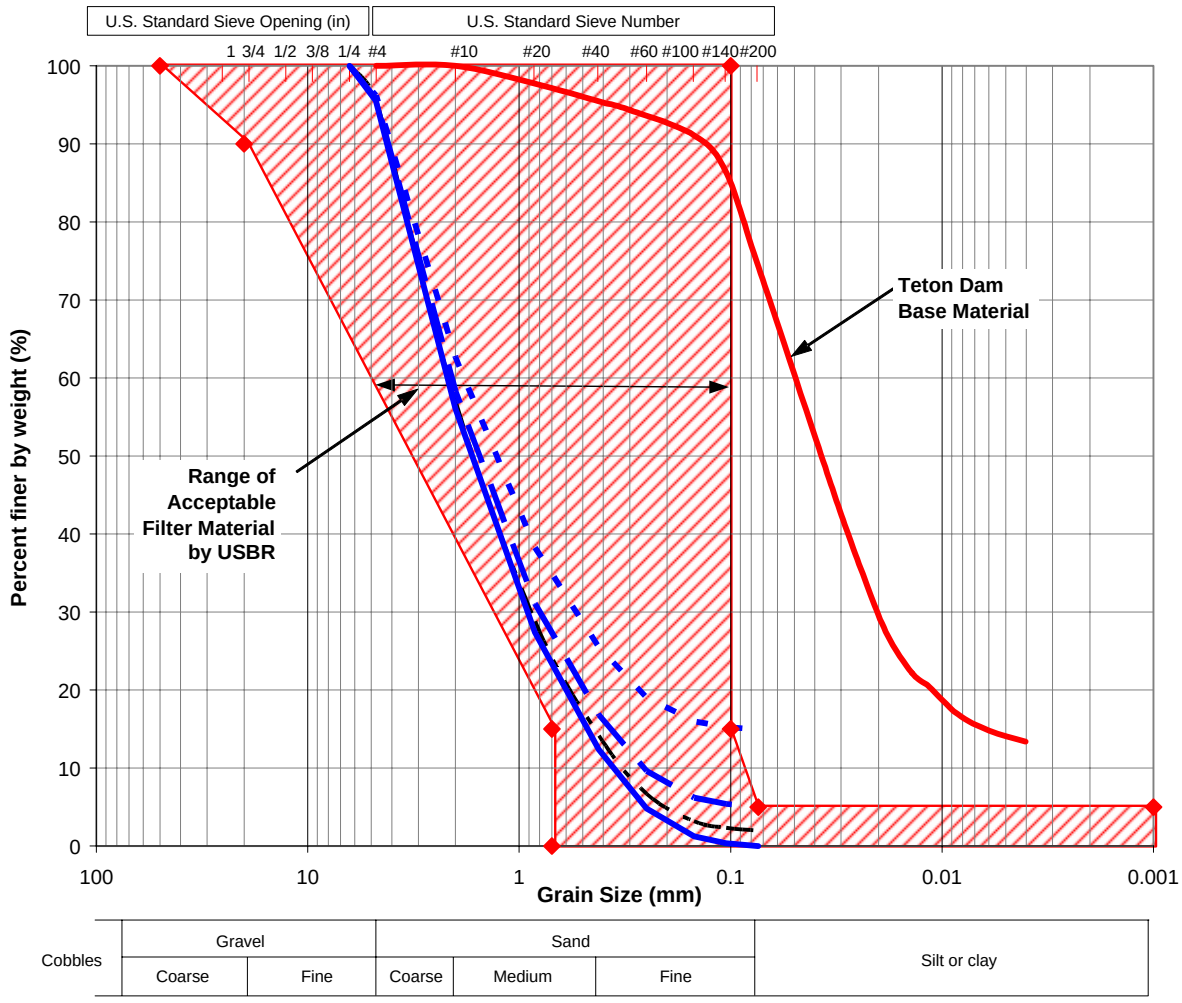


Figure 4.6 Gradation curve for Ochoco Dam filter material



Mixed 5% non-plastic fines with #200 retained Horsetooth Dam filter material

Mixed 10% non-plastic fines with #200 retained Horsetooth Dam filter material

Original Horsetooth Dam filter material

Mixed 15% non-plastic fines with #200 retained Horsetooth Dam filter material

Figure 4.7 Gradation curves for Horsetooth Dam filter material

Table 4.2 Results of Maximum and Minimum density tests

% Fines	Maximum Density γ_{dmax} (pcf)	Minimum Density γ_{dmin} (pcf)
0	120.7	100.2
5	125.5	103.3
15	131.1	107.8

A standard Proctor compaction test (ASTM D698) was conducted on the Horsetooth material with 0% and 5% fines in order to compare relative compactions with relative densities. The compaction curves are shown in Figure 4.8. A maximum dry density of 115 pcf and an optimum water content of 13% were estimated from the curve for the soil having 0% fines. A maximum dry density of 121 pcf and an optimum water content of 12% were estimated from the curve for the soil having 5% fines.

Based on these data, the maximum dry density determined from a standard Proctor compaction test results in a relative density of 76% for the soil containing 0% fines and 83% for the soil containing 5% fines. In reporting the filter test results, relative density was used to characterize the filter materials.

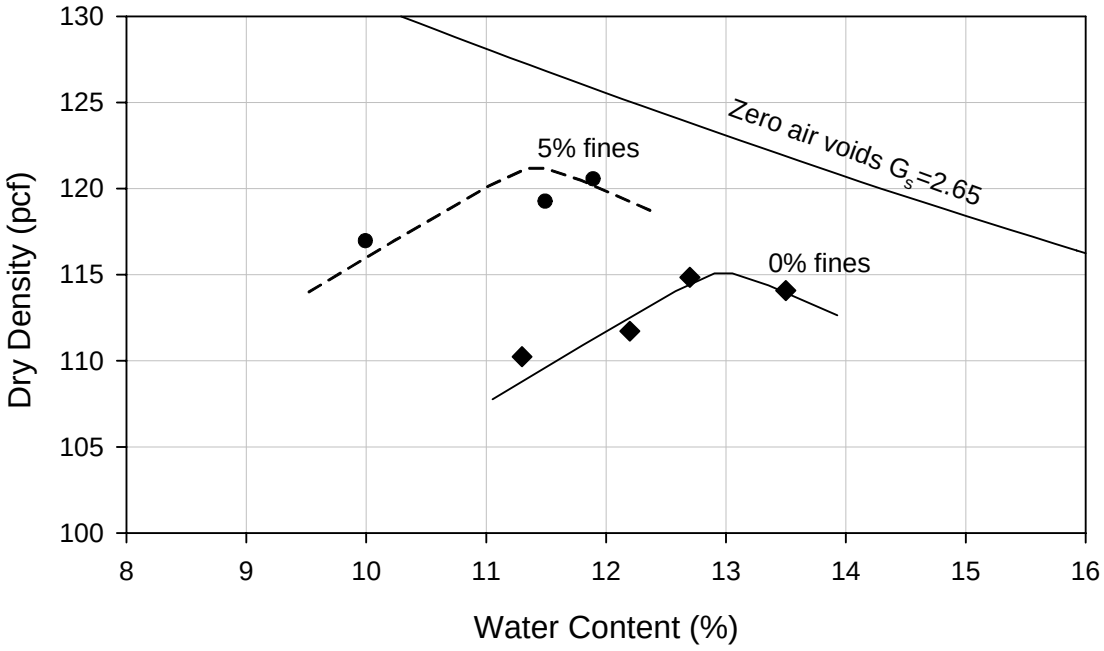


Figure 4.8 Standard Proctor compaction curves for Horsetooth Dam filter for 0% and 5% fines