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## **Chapter 7**

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# **Foundation Preparation, Removal of Water, and Excavation**

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# Chapter 7

# Foundation Preparation, Removal of Water, and Excavation

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### 645.0700 Introduction

Earthwork operations on a project consist of working with the native soil or rock and existing terrain. The success and stability of most projects rely heavily on a properly designed and properly prepared foundation. Preparing the foundation typically involves removal of topsoil, grubbing to remove roots, excavation, and often requires dewatering. The importance of preparing the foundation as specified cannot be overemphasized.

The inspector must be familiar with the lines, grades, and typical sections shown on the drawings; the specifications that control the work; and with the layout or staking of the work. The inspector must carefully review the geologic, soil mechanics, and design reports and other information such as test pits and rock cores relating to the foundation, dewatering needs, and the removal and placement of earth and rock materials. Undesirable foundation materials and conditions that could lead to poor performance or the failure of a structure may not be detected until foundation preparation operations are underway. The inspector must be able to recognize these undesirable foundation materials and conditions and consult with the responsible engineer if there is any doubt that the materials are suitable for use in the foundation. The inspector must know the intent and extent of excavations and the specified use of the excavated materials.

Since the planned line and grade of a foundation is determined from limited information about the materials that will be encountered, it is often necessary to change the limits of foundation excavation during the course of the work. Approval by the contracting officer or owner is needed for any change including any significant amount of excavation beyond the planned limits or additional dewatering efforts. Delaying approval of a change can be costly. The inspector's prompt recognition of the need for a change and timely action taken to quantify and describe the change are crucial in preventing costly delays. Complete documentation of all conditions and construction activities is crucial to determining costs associated with any change. The inspector must be aware of how delays can impact the schedule and be able to document specific items that may be needed to assess the cost of a delay. Documentation related to foundation work, removal of water, and excavation should include:

- test results and actions taken to correct non-compliance with specifications
- details of changed or differing site conditions
- details of work delays including the exact times when work is stopped and allowed to resume and when work actually resumes
- documentation of other works being accomplished at the same time that a portion of the work is delayed
- items that may be of value if it becomes necessary to negotiate a modification settlement, settle a dispute, defend against a contract claim, or investigate a deficiency

In addition to verifying compliance with foundation preparation requirements, recognizing the need for changes, documenting all activities, and verifying any changes in the work are approved, the inspector must pay particular attention to safety. Excavating is dangerous work, and safe working conditions in an excavated area may need to be verified by a competent person. Buried utilities also pose a hazard in the area being excavated. The inspector must recognize hazardous conditions and notify the owner or contractor of obvious hazards or when a competent person is needed to verify safe operation and compliance with reasonable industry standards for excavation safety.

The inspector's general responsibilities related to foundation preparation, removal of water, and excavation activities include:

- verifying safe conditions exist when excavating and working in excavated areas
- arranging for staking and quantity surveys or verifying that these surveys are being performed by the contractor if so specified
- verifying that work is performed in a safe manner and adequate care is taken to protect the safety of the public
- verifying that earthwork is graded and drained, as specified, at all times
- checking alignment and grade of excavations and embankments to verify specification compliance

- promptly recognizing potentially unsuitable materials and notifying the responsible engineer when such materials are encountered at or beyond excavation limits
- performing the necessary tests to verify specification compliance
- verifying that changes are addressed by an approved contract modification prior to beginning changed work
- documenting:
  - test results and actions taken to correct noncompliance
  - details of changed or differing site conditions
  - details related to work delays
  - any items that may be of value if it becomes necessary to negotiate a modification settlement, settle a dispute, defend against a contract claim, or investigate a deficiency
  - daily activities

## 645.0701 Installation

### (a) Foundation preparation

A properly prepared foundation is essential for a safe and effective structure. The foundation must support the structure, and the structure must be in full contact with the foundation. For this chapter, the foundation is defined as the soil and rock located beneath the structure such as a dam, concrete slab, or other permanent structure.

When preparing any foundation, organic soils must be removed because they are subject to decomposition and volume changes. Excavation is required to reach the specified depth of the foundation surface where the foundation has sufficient bearing strength to support the structure. Permeable soils or those containing soluble materials generally must be removed from dam foundations.

Prior to any excavation, it must be determined if there are any underground utilities in the work area. See section 645.0701(c)(3), Buried utilities.

Conditions that the inspector should watch for in the foundation preparation include:

- soft foundation material that can become displaced by the structure
- differential foundation consolidation, causing cracking in the earthfill or concrete structure or breaking of the bond between the foundation and the structure
- soft foundation material caused by saturation from seepage or groundwater
- slippage planes in the foundation that would allow displacement of the structure
- permeable strata in the foundation that permit seepage, causing uplift pressures that can result in boils, sinkholes, or damage to the structure
- potentially undesirable materials or conditions that are unexpected or were not discovered in the geologist's subsurface exploration

- the presence of woody materials and other organic materials in the foundation
- the presence of buried utilities in the work area
- surface materials that were left unprotected and have dried and shrunk, producing cracks that may provide avenues for seepage and internal foundation erosion

### (1) Clearing and grubbing

Foundation preparation usually begins with clearing, grubbing, stripping, and cleaning of the areas upon which a structure will be built. These operations are designed to remove materials having undesirable engineering qualities, such as low shear strength, high compressibility, undesirable permeability, or other characteristics, that could interfere with compaction operations and/or provide a poor surface for a structure foundation.

Clearing and grubbing entails removal of trees, brush, large roots, and other woody growth to expose the soil prior to earthwork operations. Clearing consists of removal of aboveground obstructions, including trees, vegetation, felled timber, brush, and debris. Grubbing includes removal of objectionable belowground obstructions or material including stumps, roots, logs, and debris.

The plans and specifications for any project should delineate the clearing and grubbing limits, the depth of removal, and the method of disposal. The inspector must know the specified limits of the work, see that they are marked on the ground, and assure the work is conducted within these limits as to not damage adjacent property. The inspector must also verify surveys are made prior to clearing and grubbing when necessary for computing payment quantities.

The inspector may be required to verify that machinery does not operate within the drip line of specific trees and that the drip line of those trees are marked or fenced to protect the area within the drip line.

The timing and rate of clearing and grubbing must comply with requirements in the specifications related to sediment and erosion control. These requirements are usually listed in the items of work and construction details in Construction Specification 2, Clearing and Grubbing. Alternatively, they may be listed in Construction Specification 5, Pollution Control.

The inspector's responsibilities related to clearing and grubbing includes verifying:

- the limits for clearing and grubbing are clearly marked
- surveys are completed prior to clearing and grubbing when necessary for computing quantities
- all materials are removed and disposed of as specified
- the contractor's operation does not damage adjacent property
- the contractor's operation does not damage trees that are not to be removed
- burning is performed according to local ordinances and job specifications
- the timing and rate of clearing conforms to specifications

### (2) Structural removal

Removal of existing structures is sometimes necessary prior to the installation of new structures. Structural removal is generally performed concurrently with the clearing and grubbing operations. Existing structures commonly removed in U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) work include fences, pipes, and concrete structures. The location and method of salvage or disposal of these items should be specified in Construction Specification 3, Structural Removal. The sequence or timing of structural removal may also be specified. The inspector must verify that the structures are removed to the specified depth and extent and salvaged or disposed of as specified.

The inspector's responsibilities related to structural removal include verifying that:

- the limits for structural removal are clearly identified
- all materials are removed and either salvaged or disposed of as specified
- the contractor's operation does not damage adjacent property
- burning is performed according to local ordinances and job specifications

### (3) Stripping

In the process of foundation preparation, foundation stripping generally follows clearing and grubbing and structural removal. Stripping consists of the removal of sod, topsoil, boulders, vegetation, roots, and any unsuitable materials that remain on or just beneath the surface after the completion of clearing, grubbing, and structural removal. Unsuitable materials may also include soils that, due to inherent wet conditions, will not support the structure.

Stripping is a common requirement for the construction of dams, dikes, and similar water-impounding embankments. It is also specified when preparing the foundation of most concrete slabs and buildings. The planned depth and extent of stripping and the method of disposal of stripped materials should be specified in Construction Specification 21, Excavation; however, since all unsuitable materials must be removed, the inspector must be able to identify any additional materials to be removed beyond the specified stripping limits.

The inspector should request assistance from the responsible engineer when the quality of the exposed foundation material is questionable. The inspector should report any changes in the depth of stripping to the responsible engineer so that effects of the changes can be evaluated.

Inspectors must look for pockets of soft material as well as stream meanders that may have been overlooked during geologic investigations; a geologist can assist in locating such features at the time of stripping. Several passes of a heavy roller or loaded hauling equipment should traverse over the stripped surface to proof roll the area to reveal any unsuitable materials that may have been overlooked.

Payment for stripping may be specified in such a way that it is paid for under a bid item separate from the bid item for foundation excavation. In this case, the upper limit of foundation excavation may be surveyed after the stripping operation. Optionally, the upper limit of foundation excavation may be surveyed before stripping and the computed foundation excavation quantity reduced by an amount equal to the specified depth of stripping multiplied by the stripped area. If stripping is paid for separate from foundation excavation, the inspector must see that any material the contractor is required to remove below the specified

stripping depth is measured and paid for as foundation excavation.

The inspector's responsibilities related to stripping include verifying that:

- the areas to be stripped are staked per plans
- stripping is performed to the minimum specified limits
- all unsuitable materials are removed and disposed of as specified
- surveys are performed as needed for quantity computations
- the responsible engineer is consulted if there are uncertainties about the suitability of materials
- stripping below the specified lower limits is quantified and paid for as foundation excavation

### (4) Scarifying

Scarifying, or loosening the foundation surface area, allows for proper application of water and improves the bond between earthfill and foundation materials. This operation is applicable primarily to fine-grained soils that present a smooth, slick surface after stripping. Scarifying is not applicable when the foundation consists primarily of coarse-grained soils or stony material. Large rocks brought to the surface when scarifying must be removed prior to placing earthfill.

Holes and depressions left by clearing and grubbing operations and stripping activities should be flattened, scarified, and filled with material of the same type. This material should be compacted to the specified density at the specified water content. When not specified, moisture and density should conform to that of the surrounding foundation material.

The inspector's responsibilities related to scarifying include verifying that:

- all holes or depressions are filled
- materials used to fill holes are compacted as specified
- the foundation is scarified to the extent specified



- large rocks brought to the surface are removed

### (5) Dispersive, collapsible, and soluble materials

Undesirable foundation materials and conditions that can lead to poor performance or the failure of a structure may not be detected until foundation preparation operations are underway. The inspector must be able to recognize these and seek guidance from the responsible engineer if the suitability of the foundation soils is questionable. Three undesirable foundation materials are dispersive clays, collapsible soils, and soils with a high soluble salt content.

If undesirable materials are removed beyond the specified lower limits of excavation, the contractor will be compensated for any associated added work. Thus, it is imperative that accurate surveys are made of the modified lower limits of excavation to compute accurate quantities for payment of additional excavation and earthfill associated with the foundation modification. See chapter 5 of this handbook for more detail on surveying and computing these additional quantities.

**Dispersive clays** are soils that are very erosive and susceptible to internal erosion as well as external erosion. Dispersive clays may be recognized by visual observations in some cases. For example, hillsides that have dispersive clays at the surface are generally eroded with closely formed gullies, despite having very little drainage area above them. Figure 7-1 shows a dispersive clay outcrop. Turbid (cloudy) water in local ponds that rarely clears up is another sign that points to dispersive clays in the watershed.

If inspectors suspect that dispersive clays are present at a site, additional verification is important. The most common field test for dispersive clays is the crumb test (ASTM D6572). The crumb test and two other tests for dispersion are described in section 645.0702, Sampling and testing.

**Collapsible soils** are soils that, in their natural state, have a low density (dry density less than 90 lb/ft<sup>3</sup>) and low moisture content (less than 10%). Collapsible soils are common in arid regions (areas with a low annual rainfall of less than 20 in annually) and in windblown and alluvial fan deposits. The soil in figure 7-2(a) was sampled from a trench near a sinkhole at NRCS floodwater retarding dam Lakeview Site 1 in Donley County, Texas (22-in average annual rainfall). Although

**Figure 7-1** Dispersive clay outcrop



**Figure 7-2** Pinholes in collapsible soil (courtesy of Brian Moffat, NRCS Texas State geologist)

(a) Lakeview Site 1 in Donley County, Texas



(b) Attoyac Bayou Site 23 in Nacogdoches County, Texas



much more common in arid regions, collapsible soils have also been found in higher rainfall areas. The soil in figure 7-2(b) was sampled from NRCS floodwater retarding dam Attoyac Bayou Site 23 in Nacogdoches County, Texas (48-in average annual rainfall). As illustrated in these unmagnified photos, collapsible soils generally contain numerous pinholes or slightly larger holes that can be seen by the naked eye.

Low-density (collapsible) soils will consolidate when wetted and loaded. Foundation settlement occurs when the combination of the load imposed by a dam and wetting from water coming from impounded above the dam cause consolidation of collapsible soils. The inspector should notify the responsible engineer anytime the presence of collapsible soils in the foundation is suspected.

Inspectors must visually inspect foundations for soils that contain pinholes. The moisture and density of these materials should be tested by a method that does not disturb the sample. A nuclear moisture density meter may be used to test the moisture and density of the soil (ASTM D6938) if the soil does not collapse when the device for forming the hole is driven into the ground. The nuclear gauge can be operated in backscatter mode so that a hole driven into the ground is unnecessary; but, only density values near the surface can be obtained in this mode. One of the better methods for determining the moisture and density of collapsible soils is to perform a clod test (ASTM D7263, Method A) on an undisturbed sample. This test is described in detail in section 645.0702, Sampling and testing.

**Soluble materials**, such as gypsum and common salts, are sometimes found in arid regions. Foundations that contain soluble materials may experience problems if they become wet. These materials can become suspended in water and flushed from the foundation, resulting in foundation collapse and piping.

Gypsum particles can often be seen with the naked eye in soils that contain appreciable amounts of gypsum. In areas where gypsum laden soils are common, the inspector should be on the lookout for these particles. The inspector should report any occurrence of gypsum particles to the responsible engineer.

A white film of salt on the soil surface is a good indicator that soluble salts, such as gypsum or other com-

mon salts, are present. Otherwise, there is no good way to determine if soluble salts are present other than with a device called an electroconductivity (EC) meter. An EC meter measures the electroconductivity of the soil and gives the results in microsiemens per centimeter ( $\mu\text{S}/\text{cm}$ ) or millimho per centimeter ( $\text{mmho}/\text{cm}$ ). Problems may occur in soils that have an electroconductivity greater than  $300 \mu\text{S}/\text{cm}$  or  $0.3 \text{ mmho}/\text{cm}$ . Soluble salts in these soils could leach out and cause foundation collapse or piping.

The inspector should consult with the responsible engineer when indicators such as gypsum particles or salt films point to a potential for soluble materials onsite.

The inspector's responsibilities related to dispersive, collapsible, and soluble materials include verifying:

- the foundation and surrounding areas are visually inspected for signs of dispersive, collapsible, or soluble materials
- tests to verify the existence of dispersive, collapsible, or soluble materials are conducted when applicable
- the responsible engineer is contacted whenever the presence of dispersive, collapsible, or soluble materials is suspected
- all dispersive, collapsible, and soluble materials are removed from the foundation to the depth and extent specified or as otherwise directed by the engineer
- surveys to quantify the amount of dispersive, collapsible, and soluble materials are completed
- documentation is obtained as necessary to compensate the contractor for added work caused by removal of dispersive, collapsible, and soluble materials

### (6) Compaction and moisture control

Uniform densities of foundation material for dams and concrete structures are required to reduce the potential for differential settlement. Compaction of the foundation for earthfills and structures is generally required to obtain uniform densities, especially when fine-grained soils predominate. Compaction should be delayed until the earthfill or structure placement is

ready to start. The specified moisture content of the foundation is generally similar to the requirements for earthfill. Tests to verify the moisture and density of foundation materials are generally the same as those for earthfill. Moisture and density tests are described in section 645.0702 and in more detail in this handbook in Chapter 8, Earthfill and Rockfill.

Equipment provided for compaction of the foundation should completely traverse the foundation area with a sufficient number of trips to result in acceptable densities. The number and location of moisture/density tests should be adequate to assure that the moisture and density of the entire foundation meets or exceeds the specified requirements. Particular attention should be given to areas where the process of incorporating water and compacting foundation materials may be hindered. Such an area would be near an abutment or structure where there is limited room for maneuvering large compaction equipment, making it necessary to alter the normal process. Moisture density tests should always be performed in these areas as well as areas where there is ample room for the larger production equipment to process and compact foundation materials.

Compaction of some types of saturated soils in wet foundation areas may do more harm than good. When it is not feasible to completely dewater such areas, it may be necessary to place a thick initial lift of earthfill to permit compaction equipment to operate without disturbing the foundation soil. The compactive effort of equipment operating on the initial lift must be reduced and progressively increased as successive lifts are placed. This procedure should not be performed for foundation areas under earthfill dams unless specifically permitted by the plans and specifications or approved by the responsible engineer.

The inspector's responsibilities related to compaction and moisture control include verifying:

- the moisture and density of the foundation meets or exceeds the specified requirements
- adequate numbers of moisture/density tests are taken to document that specification requirements are met
- the responsible engineer is consulted if it is necessary to deviate from the specification requirements

### **(7) Preparing rock foundations**

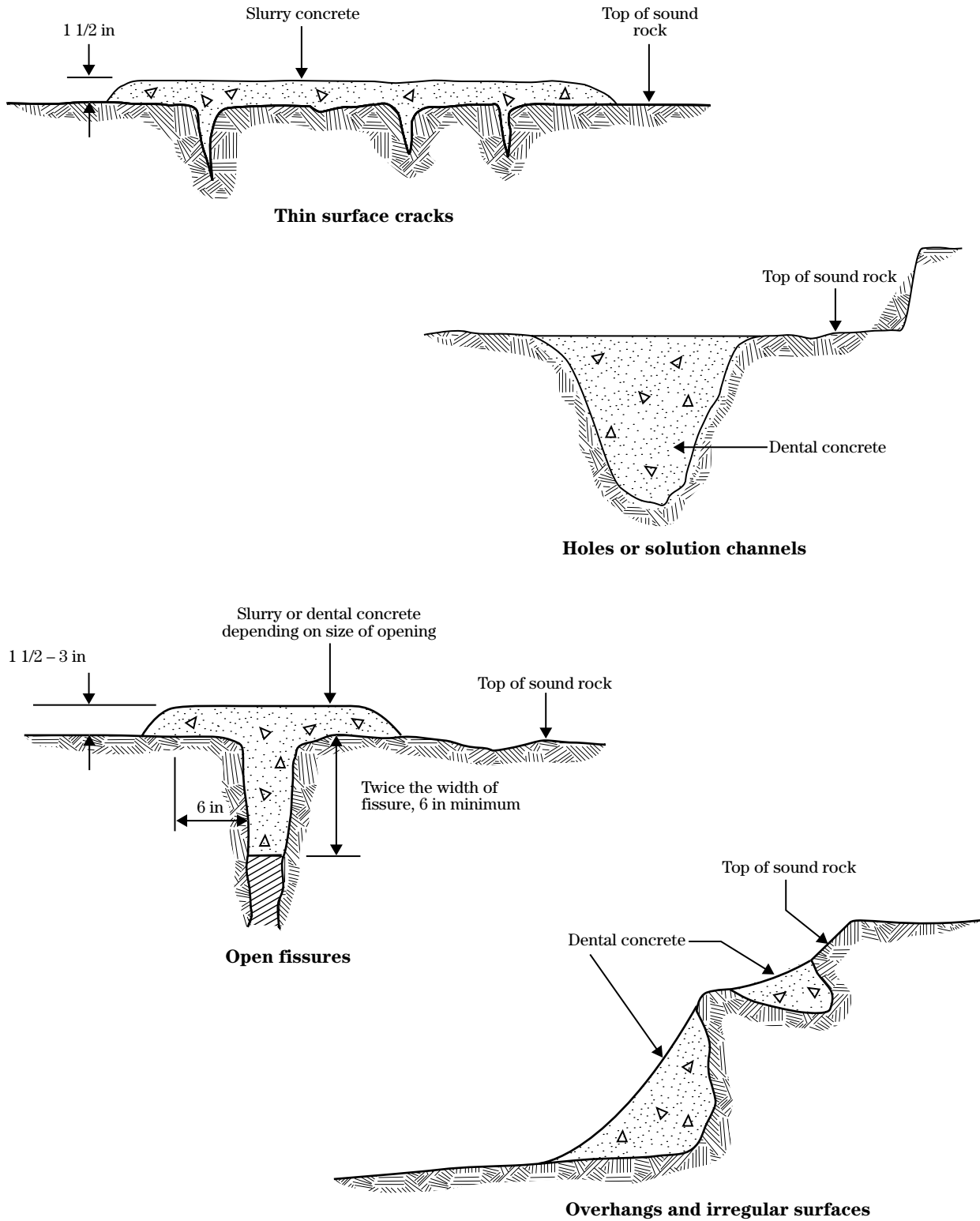
Blasting may be required to remove rock to the specified depth. This is often required in dam construction to slope a steep abutment or excavate a core trench into a rock abutment. Blasting may be employed to excavate an auxiliary spillway in a rock abutment. Care must be taken to avoid over-blasting and damage to rock below the specified lower limit of excavation. Blasting is a dangerous operation and should only be performed by experienced contractors who have the required license for handling and using explosives. See section 645.0701(c) for more on blasting.

Rock foundations must be cleaned to permit bonding with the materials to be placed. Earth, loose rock, and loose, weathered material should be removed from the surface and from any cracks or crevices. Washing and brooming may be necessary, particularly in locations where concrete is to be placed. Overhanging rock should be removed or the volume beneath the overhanging rock filled with dental concrete so that all materials can be placed on a positive slope (fig 7-3). Dental concrete is used to fill holes and to contour surfaces. Slurry concrete is used to fill clean cracks and crevices in rock. Rock, such as shale, that can break down when exposed should be left covered or protected from the elements until just before being covered with earthfill, concrete, or other construction materials.

Grouting is often required to fill subsurface voids in the foundation. The location and depth of subsurface grouting should be detailed on the drawings and in the specifications. Each location may present a distinct problem, and modifications may be required as the work progresses. Where subsurface grouting is required, a geologist should assist in verifying the adequacy of and recommending deviations from the specified location, depth, and treatment.

The performance of the completed structure is often reflected in the thoroughness with which procedures for preparing rock foundations are undertaken. This is particularly true for any dam or dike designed to retain water. Few dams are constructed without finding some undesirable foundation conditions that were not discovered in the geologic investigation for design. Most discrepancies between design and field construction occur in this portion of the work. The inspector must be aware of undesirable foundation conditions and be especially vigilant during this phase of the work

**Figure 7-3** Treatment of rock surfaces



to see that changes from the expected design conditions are documented and reported to the responsible engineer. Undesirable conditions in rock foundations may include zones of weathered or fractured rock; cavities; soft soil areas; abandoned pipes or drains; or abandoned stream channels filled with clay, silt, sand, or gravel.

It is often difficult and sometimes impossible to correct foundation and abutment deficiencies that show up after construction is well underway or completed. Therefore, earthfills or other structural materials must not be placed until it can be documented that the specification requirements for preparing rock foundations have been met. Documentation of foundation preparation measures and procedures should contain details that might be useful in negotiating a modification, settling a dispute or claim, or investigating the cause of an engineering deficiency. Such details might include:

- a description of the foundation surface
- the location of grout injection points
- the location where grout is gravity fed into the foundation
- increases or decreases in the volume or rate of grout flow into the foundation
- changes in the contractor's equipment or methods of drilling, grouting, or otherwise preparing the foundation
- conversations with the contractor and those of the contractor's crew concerning drilling, grouting, equipment, and methods of performing specific aspects of foundation preparation

The inspector should consult with the geologist and the responsible engineer to determine the full extent of documentation that is needed.

The inspector's responsibilities related to preparing rock foundations include verifying:

- all loose undesirable materials are removed and the foundation surface is cleaned as specified
- all cracks, crevices, and overhangs are cleaned and concreted or grouted and there are no

negative slopes or overhangs remaining on the foundation surface

- no weathered materials exist on the foundation surface
- subsurface grouting is performed as specified
- the responsible engineer is notified whenever discrepancies between design and field conditions occur
- the geologist and the responsible engineer are consulted to determine the full extent of documentation needed to adequately document foundation preparation measures and procedures

### (8) Cutoff trench

A cutoff trench, sometimes referred to as a "keyway" or "core trench," is normally required for dams and dikes that are designed to impound water. The cutoff trench is a trench filled with relatively impervious material installed at the specified moisture content and compacted to the specified density. The trench extends from the foundation surface to a specified depth and is intended to act as a barrier to prevent or hinder the flow of water under the dam or dike.

When estimating the depth of the cutoff trench, the design engineer takes into account the various earth materials in the foundation. A profile of the cutoff trench is plotted on a sheet that shows the geologist's estimation of various layers of soil and rock underneath the dam. It is common to design the cutoff trench to extend into a specific layer of material. The final depth of the cutoff trench will vary with the actual depth of this specific layer of material which can only be determined during cutoff trench excavation.

The inspector must verify that the cutoff trench is staked at the specified location and that, before excavation begins, quantity surveys have been attained to record the upper foundation excavation limits. To excavate to a specific layer of material, overexcavation may be required. Conversely, if the cutoff trench is designed to extend to rock and the rock is encountered before the specified lower limits of excavation are reached, underexcavation may be in order. The inspector must be able to determine if overexcavation is warranted or if underexcavation is allowed. The inspector should discuss substantial changes in the lower limits of the cutoff trench with the responsible engineer. The

inspector must document any changes in the cutoff trench and verify that quantity surveys of the lower limits are attained before backfilling begins.

The inspector must verify that the moisture content and density of the cutoff trench foundation materials is as specified prior to backfilling the trench. The materials used for backfilling the cutoff trench and the moisture and density at which those materials are installed must comply with what is specified on the drawings and in the specifications. Testing is required to document that the foundation and backfill materials are at the specified moisture and density.

The inspector's responsibilities related to the cutoff trench include verifying:

- the cutoff trench is staked at the specified location and quantity surveys have been attained to define the upper limits
- the trench is excavated to the specified or modified limits
- the trench extends to or into the specific layer of material shown on the drawings
- changes to the lower limits are documented and approved by the responsible engineer
- lower limits are surveyed for quantity computations
- foundation materials are at the specified moisture and density at the time of backfill placement
- only specified materials are placed in the cutoff trench
- materials are placed at the specified moisture and compacted to the specified density

### (9) Foundation drains

Drains are often installed in a dam foundation to intercept and filter water that might otherwise cause uplift pressures or piping. Damage from water flowing under a dam can be eliminated if the water is intercepted and filtered through an adequately designed and properly installed filter and drainage system. A typical foundation drain will consist of sand and gravel in a trench located between the cutoff trench and the downstream toe of the dam. Other types of foundation drains

include blanket drains, relief wells, and geocomposite drains.

Drains that are installed in the dam are often tied into foundation drains. When embankment and foundation drains are to be tied together, it is important to maintain a means of locating the foundation drain should it be covered with earthfill. Otherwise, it will be difficult to determine where to excavate when tying the embankment drain into the foundation drain. Drains are described in detail in chapter 11 of this handbook.

The inspector's responsibilities related to foundation drains include verifying:

- foundation drains are staked and quantity surveys needed to compute drainfill quantities are attained
- foundation drains are constructed to the specified limits
- segregation of drainfill materials is prevented
- internal perforated pipes are undamaged, clear of obstructions, and placed at the proper location
- materials are compacted to meet specification requirements

### (10) Final preparation

Final preparation of a foundation refers to items that are required immediately prior to placing of earthfill. At this point all of the clearing and grubbing, stripping, removal of unsuitable materials, and filling of depressions should be completed. Foundation drains should also be in place. Immediately prior to placing cutoff trench and embankment fill, the water content and density of the foundation must be adjusted to meet specification requirements, the compacted surface scarified, and large rocks and other unsuitable materials removed.

The final preparation of almost all rock foundations requires hand labor for cleaning and examining the finished surface for "drummy" rock (rock that sounds hollow when struck with a steel hammer or bar). The use of heavy or tracked vehicles on the final rock foundation should be avoided, especially if the rock is thinly bedded or badly jointed. Blasting to remove knobs or overhanging rock may prove to be more harmful than helpful, and extreme caution must be

exercised to prevent the opening of cracks or displacement of rock that would otherwise be adequate for foundation material. Care must be exercised not to damage previously placed concrete work or dental grout. It is generally desirable to place concrete fill beneath or around projections if, by so doing, blasting can be avoided. Where dental concrete and/or slurry concrete are used, materials and procedures should be directed towards ensuring good concrete/rock bond, and subsequent fill operations should avoid dislocating the concrete. Washing the hard rock surface with water under high pressure and dry brooming or air blowing to remove loose residue are generally the last steps in foundation preparation.

The inspector's responsibilities related to the final preparation of the foundation include verifying:

- all unsuitable materials have been removed
- the cutoff trench is installed
- drainage features are installed
- just prior to placing earthfill, the moisture content and density of the foundation meet specification requirements
- all subsurface grouting has been completed
- all rock surfaces are cleaned and grouted
- all loose and drummy rock has been removed from the surface
- all negative slopes have been corrected

## (b) Removal of water

Removal of surface and/or groundwater may be necessary for the performance of the specified work, especially where the construction is near or in a lake, stream, or area subjected to frequent or periodic inundation or flow of surface water. If removal of water is needed, it is generally required prior to any significant excavation and backfill operations and will likely be required when preparing the foundation.

Removal of water includes impoundment or diversion of surface runoff, exclusion of groundwater or impounded surface water, and removal of groundwater or surface water by gravity drainage and/or pumping. Removal of water involves furnishing and installing temporary works, such as water containment facili-

ties, channels, diversions, wells or wellpoints, pumps, piping, pollution control measures, and other facilities and equipment, that must be monitored and maintained until no longer required.

Methods for controlling water will vary with site condition and location. Unless otherwise specified, the contractor is responsible for designing and constructing the works needed for the removal of water. The contractor must provide and operate all equipment needed to keep foundations, structures, and borrow areas free of excess water. When required, the contractor must furnish, in writing, a plan for removal of water before beginning any construction activities. The plan should include an explanation of all permits required to be obtained by the contractor to conduct work in a stream or near a wetland, including permits to divert water as applicable. This plan is usually reviewed and approved by the responsible engineer who provides a copy and any approval documents to the inspector. The inspector must verify that the plan for removal of water is fully implemented, including the acquisition of permits prior to beginning work. Plan performance should be documented in the diary throughout the construction period. The inspector should discuss with the contractor any concerns of inadequate removal of water efforts. The responsible engineer should be consulted when contractor's efforts fail to adequately remove the water so that the work may be performed as specified or when the quality of work is jeopardized due to wet conditions at the site.

The methods and equipment used to divert streamflow or to dewater the site can affect the stability of the foundation and excavated slopes. These methods can also result in surface erosion, which can lead to further instability of slopes or pollution of surface water or groundwater. The inspector should monitor the foundation and excavated slopes for signs of instability and monitor diversions and dewatering operations for signs of pollution of surface water and groundwater. Make the contractor aware of related concerns, and document these concerns and any conversations with the contractor concerning removal of water.

The various plant and animal species that make up the stream ecosystem can be adversely affected by construction activities such as diversion of surface water. The potential for such impacts must be addressed in the design, and the inspector must be familiar with potential and planned measures to mitigate adverse

environmental impacts. The inspector should verify that precautions are taken to protect against adverse environmental impacts.

Removal of water is paid for as a standalone contract item or made subsidiary to another item of work such as excavation. If it is a standalone item, it is paid for as a lump sum item and progress payment amounts are generally prorated so that equal amounts are paid on each progress payment throughout the performance period. It may be set up to pay more up front to fund the cost of furnishing and installing the equipment devoted to removal of water.

Separate payment may be made under a contract item for pumping water with the amount of water pumped paid on the basis of 1,000 gallon units measured by meter at the pump discharge. The inspector must be aware of the method of payment and document performance of the work for verifying invoiced amounts for each progress payment. Details of the equipment installation should be documented in the job diary.

When payment for pumping is based on the amount of water pumped, quantity of water pumped should be recorded daily in the diary to show amount pumped that day and the cumulative amount. It is required that the contractor verify that any meter used for measuring pumped water is accurate within the specified percent of true quantity (generally 3% unless otherwise specified). Once the meter is checked and verified to be accurate within specification requirements, the inspector should check that the meter continues to give accurate readings. This is done by recording the beginning and ending meter reading over a period of elapsed time. If the pump speed remains relatively constant and the pump is in good working order, the amount of water pumped over a specific time period will be relatively constant from day to day. The inspector can record the value shown on the meter at the beginning and end of a period of time and compare the difference with that pumped during the same amount of time on the day the pump was tested and verified as meeting specification requirements for accuracy.

When removal of water is no longer needed, all temporary works should be completely removed so as not to inadvertently be left embedded in the earthfill or foundation and disposed of in a manner that does not adversely impact the permanent structure or the environment.

As the work progresses the inspector must verify:

- the accepted plan for removal of water is implemented
- required permits have been obtained prior to beginning work in or around streams or wetlands
- details of equipment installation and performance of plan are documented in the diary
- removal of water efforts are adequate to allow the performance of the work as specified
- contractor is made aware of inadequate removal of water efforts
- removal of water efforts does not adversely affect the stability of slopes or the foundation
- neither surface nor groundwater is being polluted by removal of water efforts
- precautions are taken to protect the environmental aspects of the stream or wetlands, including required pollution control measures
- contractor is made aware of concerns of instability and pollution and related discussions with contractor are well documented
- responsible engineer is consulted when contractor's removal of water efforts is inadequate or result in slope instability or pollution
- invoiced amounts for removal of water are consistent with documented performance of work
- quantity of pumped water is documented in the diary for each reporting period
- when payment is based on quantity of water pumped, pump accuracy is verified by the contractor and is checked periodically or when accuracy is suspect
- all temporary works for the removal of water are removed and disposed of in a manner that does not adversely impact the permanent structure or the environment

### (1) Controlling surface water

Many conservation engineering measures are constructed in a stream or flood-prone area where perennial or intermittent surface flows must be controlled to allow the work to be performed in a relatively dry



environment. The means for controlling surface water are generally left up to the contractor who may rely on limited measures in an effort to reduce costs.

Even though the contractor may be able to work in areas that are not well protected from surface runoff, the conditions may be such that the quality of work performed in these areas may suffer. Thus, the inspector should monitor site conditions and discuss concerns with the contractor if it appears there is a lack of adequate temporary works or maintenance of such works resulting in poor conditions for construction. Examples of poor conditions are those where:

- the foundation or earthfill becomes soft, rutted, or otherwise will not support equipment
- equipment traction is compromised
- concrete foundations are muddy or standing water
- excavations for belowground structures, such as concrete foundation beams and sills, are filled with water
- concrete reinforcement cannot be adequately supported
- reinforcement becomes contaminated with mud
- installed geotextile materials are covered with mud or silt
- drainage materials (sand and gravel) are contaminated
- material storage areas become inundated

The responsible engineer should be notified if the inspector feels the contractor is not responsive to these concerns. If the engineer sees the need for the contractor to improve surface water control measures, there may be cause to involve the owner or contracting officer, as applicable, to enforce contract requirements or add work to improve surface water control efforts.

The work area must remain dry enough to construct the specified permanent works in a quality manner. Sometimes it is prudent to postpone work until a dryer time of year. When work cannot be postponed, the plan for controlling surface water should include details for installing, maintaining, and continuously operating all cofferdams, channels, flumes, sumps, and

all other diversion and protective works needed to divert surface water through or around the construction site including borrow areas where applicable.

Water diverted around an area typically must be directed back into its original drainage long before leaving the site. It is generally against regulations for water to cross a property line at a different location than the point it crossed the line before being diverted. The plan for diverting surface water must include measures for directing the water back into its original drainage way in a nonerosive manner, and the inspector should verify compliance with this requirement.

**Dewatering of borrow areas** is required to allow borrowed materials to be excavated and processed in an efficient and timely manner. It is normally more efficient to remove excess water from borrow materials prior to hauling them to the fill surface than to dry them on the fill surface. Otherwise, the equipment that is placing, processing, and compacting the materials will have to stand idle while the process of drying wet borrow materials is taking place on the fill surface.

Borrow areas may have to be protected by diversions and dikes or worked by utilizing dikes and drainage channels. When borrow operations below a planned permanent pool are completed, any diversions or dikes below the pool should be knocked down to avoid leaving shallow areas within the pool that could be a boating hazard. This should be done as the work progresses because of the potential for the borrow area to be inundated or otherwise saturated to the point that operating equipment in the borrow area and removal of dikes and diversions is difficult.

**Stream diversions** are normally required when building new dams and rehabilitating existing dams. They may also be necessary when performing channel improvement work and other construction work in and around streams. It is important for inspectors to become familiar with the significant features of stream diversions and check that appropriate measures for diverting water have been implemented.

The principal factors that determine methods of stream control are the hydrology of the stream, topography and geology of the site, and the sequence of work. The construction of a diversion is often the most practical means of diverting streamflow around a construction area. If the diversion cannot be routed

to completely bypass the construction area, a partial diversion of the streamflow may be adequate. A partial diversion is one that would divert streamflow from the immediate work area through a portion of the construction area where work is not being done.

When building a dam, it is common to divert the stream to one side of the valley until the principal spillway and a portion of the embankment is completed. When the principal spillway conduit and the lower portion of the inlet structure have been constructed, this partial diversion can be removed and streamflow diverted through the new principal spillway so that the remaining foundation work can be completed. The embankment is then brought up to a uniform height as rapidly as possible to allow flow to spread and not concentrate in one area should the dam be overtopped. In the final construction phase, the entire dam is completed to full height.

**Emergency outlets** are sometimes provided when building a dam to reduce the probability of overtopping of the incomplete embankment when floods exceed the capacity of the principal spillway. As the dam is raised, the probability of overtopping gradually decreases as a result of increased principal spillway discharge capacity and reservoir storage. At some point, as the probability of overtopping decreases, emergency outlets may no longer be needed.

These emergency outlets should only be located in an abutment containing material that is stable enough to withstand the flow. The inspector should verify they are not located so that their function would result in flow being concentrated over any part of the dam. In most cases in NRCS dam construction, the cost of providing emergency outlets with sufficient flow capacity to avoid overtopping becomes excessive, and it is more appropriate to maintain the earthfill level to avoid concentrating the flow in any one area should the partially completed dam be overtopped. Construction Specification 23, Earthfill requires that the embankment be maintained approximately level during construction. The inspector should enforce compliance with this requirement and document discussions with the contractor and actions taken by the contractor to comply with the requirement.

**Cofferdams** are occasionally built upstream from the immediate work area to halt the flow of water and

allow it to be pumped or otherwise diverted around the work area. In no case should the contractor be allowed to repeatedly breach and rebuild the cofferdam to empty the stored water and allow it to flow through the worksite. Doing so will compromise the stability of the foundation and possibly lead to failure from hydraulic pressures that build up behind partially completed work.

**Protecting internal drainage systems** of structures, such as concrete channel liners, is critical due their limited capacity for relieving hydrostatic pressures. Surface runoff can inundate such structures, and the unprotected drainage system could become overcharged. As the water recedes, hydrostatic pressure can cause uplift forces resulting in extensive damage to the structure. The work must be protected at all times so that surface water does not overcharge the drainage system. Any openings in a structure that would allow water to enter the drainage system, except those installed for drainage outlets, should be sealed at all times during the construction period. Such openings include edges of a concrete-lined channel, any openings or block outs where items such as fence posts are to be installed, the upstream edge of a concrete liner, or any other avenue for surface water to enter an internal drainage system.

It is prudent for the designer to include flap gates or one-way flow devices at the outlet end of all drainage outlets that could become inundated. They should be installed as the work progresses to reduce the potential for overcharging the drainage system.

There will be openings and avenues for surface water entry in those areas where work is being performed, such as at the leading edge of a concrete channel where construction is progressing upstream. The contractor must plan to protect these areas during runoff events that could result in surface flow or inundation at the opening. This should be a part of the contractor's removal of water plan. The inspector must verify that all avenues for surface water to enter an internal drainage system are sealed as the work progress. And verify that areas which remain unsealed to facilitate construction are sealed anytime surface flow or inundation is expected.

The inspector's responsibilities related to controlling surface water include verifying:

- dewatering and drainage control systems are correctly installed according to the removal of water plan
- dewatering and drainage control systems are maintained and functioning to allow work to be performed as specified
- if water pumped from dewatering systems is muddy or contains fine sand, wells are sealed and wellpoints with an adequate filter system are installed
- backup power and standby pumps are immediately available
- diversion outlets empty in a nonerosive manner into the same drainage way that the water would have reached had it not been diverted
- dikes and mounds of soil in the borrow area are graded as the work progresses to blend in and avoid leaving shallow areas within the pool
- when a dam is being constructed, the top of the dam is maintained as near level as possible to allow flow to uniformly spread across the full width of the dam should the uncompleted dam be overtopped
- cofferdams are maintained and not repeatedly emptied by breaching and allowing water to flow through the worksite
- compliance with requirements that diverted surface water must be returned to its original drainage way before leaving the site or owner's property
- borrow areas are maintained as the work progresses so that dikes are knocked down to avoid leaving shallow areas within the pool
- emergency outlets are located so that their function will not result in flow being concentrated over any part of the dam
- embankment is maintained approximately level during construction
- all avenues for surface water to enter an internal drainage system are sealed as the work progresses, and those that must remain unsealed to facilitate construction are sealed when it appears eminent that a runoff event could result in surface flow or inundation at the opening

## (2) Controlling groundwater

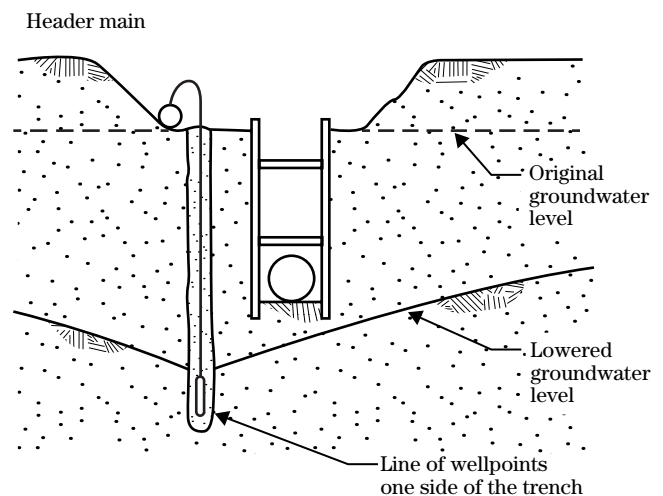
**Borrow areas** sometimes have a high groundwater table that must be lowered to facilitate excavation and aid in drying the borrow material before it is transported to the fill area. This may be accomplished by digging a series of ditches that gravity drain to a sump where the water is pumped from the borrow area.

Wellpoints may be used to lower the groundwater table in the borrow area; however, other methods are normally pursued to avoid the expense of wellpoints for the borrow operation.

**Foundations** that are wet usually require dewatering. In certain groundwater situations, it may be necessary to pump the water from the surrounding earth to lower the water table below the level of the excavation or to erect a watertight barrier, such as sheet piling, around the excavation to keep the groundwater outside the excavation. Pits or sumps at the bottom of the excavation are commonly used to collect any water that gets through or under the impermeable barrier.

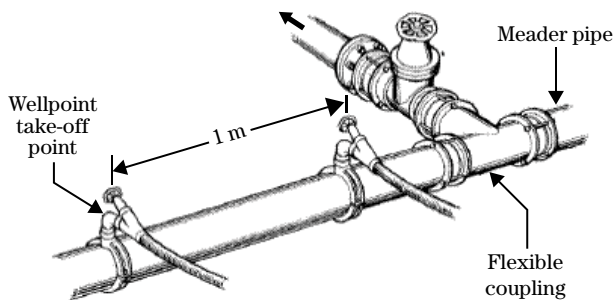
When an excessive volume of groundwater occurs in excavations, wellpoints are commonly used to lower the water table in the immediate area of construction. Wellpoints are a series of closely spaced, small diameter water extraction wells containing 1- to 2-foot sections of perforated pipe connected to a nonperforated pipe. The top of the perforated pipe is set at or below the desired groundwater surface elevation. The non-

**Figure 7-4** Wellpoint connect to header or manifold pipe

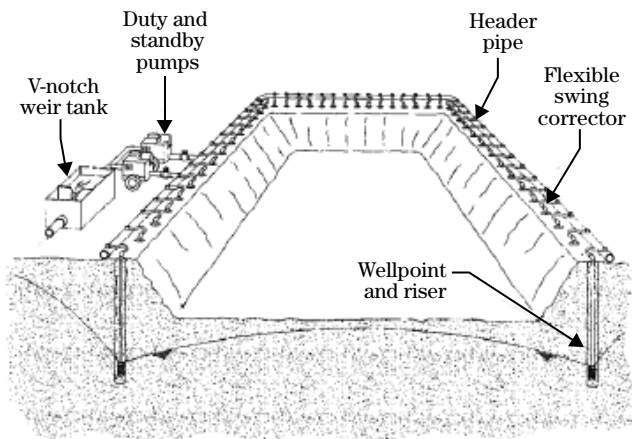


perforated pipe extends from the perforated pipe to the ground surface and is connected to a manifold or header main pipe (fig. 7-4). The manifold pipe is connected to the suction side of a suitable pump (fig. 7-5). Wellpoints should be screened at the bottom to allow the entrance of water, but keep out the soil. Wellpoints are installed in the soil around the excavation (fig. 7-6) or on the water-bearing side of the excavation if subsurface water is flowing through the foundation from one direction (fig. 7-4). They work especially well in free-draining materials, but not so well in less pervious materials.

**Figure 7-5** Header or manifold pipe



**Figure 7-6** Wellpoints surrounding an excavation



Inspectors must verify that groundwater control systems are functioning properly. A system that is not functioning properly can often be detected in early stages by visual observation of:

- increased seepage flow
- erosion of material from the foundation or slopes
- development of soft wet areas
- uplift of excavated surfaces
- lateral movement of slopes or other slope failure
- muddy or sandy discharge being pumped from the system
- a rise in groundwater even as pumping is continued

Water pumped from dewatering systems must be frequently observed at the discharge outlet. If the discharge water is muddy or contains fine sand, fine-grained materials are being removed from the foundation. The removal of materials from the foundation can be detrimental to any structure that may be built on that foundation. If this occurs, it is crucial that proper filtering be installed to prevent the removal of fine-grained materials. Wells or wellpoints from which fines are being discharged must be abandoned, sealed, and replaced with wells with an adequate filter system.

Failure of a dewatering system can result in extensive and costly remedial work. In excavations bottoming on impervious material, artesian pressures from groundwater in underlying pervious strata can cause heaving of the excavation bottom. If the impervious stratum ruptures under these pressures, boils will develop, causing the loss of the underlying foundation material and thereby endangering the entire structure. Failure of excavation slopes may also occur because of excessive artesian pressures.

Excessive artesian pressures may occur if the dewatering system becomes clogged or pumping ceases. Consequently, all power sources should have standby gas or diesel-powered pumping or generating equipment, and standby pumps should be available. These are items that should be mentioned in the dewatering plan and verified to be working and on ready standby at the site.

When an excavation, such as a cutoff trench, is extended to rock or to an impervious stratum, there will likely be some water seeping into the excavation and “wet spots” in the bottom of the excavation. Water seeping into the excavation from the upstream and downstream slopes of a cutoff trench can usually be captured by narrow, longitudinal ditches or drainage trenches located along the toe of the slope. These trenches may be excavated in the bottom of the cutoff trench or by forming such trenches with sandbags. Sumps will be needed for pumping the water out if gravity drainage is inadequate. If the bottom of the excavation will still not dry out, smaller ditches can be cut through the problem areas and sloped to drain to the side trenches.

Concrete structures should be installed only on a firm subgrade. One way to test the firmness of the subgrade is to drive a loaded dump truck or concrete truck over it. The subgrade is considered firm if the truck tires make only a slight indentation and there is no pumping or rutting of the surface. Control of water, excavation of saturated soils, and backfill with drainfill or other materials are often required to construct a firm subgrade for concrete structures. All concrete should be placed on a relatively dry foundation with only the foundation surface being moist enough to avoid wicking water out of the fresh concrete. No standing or flowing water should come in contact with the concrete until it has achieved its initial set.

The inspector’s responsibilities related to controlling groundwater include verifying:

- dewatering and drainage control systems are correctly installed according to the removal of water plan
- dewatering and drainage control systems are maintained and functioning to allow work to be performed as specified
- if water pumped from dewatering systems is muddy or contains fine sand, wells are sealed and wellpoints with an adequate filter system are installed
- backup power and standby pumps are immediately available
- concrete is not placed on a wet foundation

- standing or flowing water does not come in contact with concrete until it has achieved its initial set

### **(3) Erosion, pollution control, and removal of temporary works**

Removal of water from the construction site, including the borrow areas, should be accomplished in a manner that will minimize erosion and the transport of sediment and other pollutants from the site. Dewatering activities must be accomplished in a manner such that water quality downstream of the site is not impacted. The U.S. Army Corps of Engineers (USACE) Section 404 permit is required when working in streams, and a U.S. Environmental Protection Agency (EPA) or State stormwater permit is required for most construction sites.

Special precautions should be taken to protect streams that might be particularly sensitive to diversions and associated construction activities. Surface erosion may present problems on slopes excavated in silts, fine sands, and lean clays. Eroded material will wash down and partially fill in the excavation below the slope. The slope will be left deeply scoured and rutted, making it necessary for costly smoothing operations to be performed before fill can be placed.

One effective way to combat surface erosion of temporary excavation slopes is to backfill as soon as possible, thus cutting down on exposure time. When this cannot be done, it becomes necessary to employ other measures. Temporary vegetative cover on the slopes is a good means of preventing surface erosion if it can be readily established and if the slopes are to remain open for an extended period. Mulching or protective erosion control blankets can also be used. Other slope protection measures such as riprap, asphaltic treatment, or shotcrete are rarely justified for construction slopes, but may be an option.

While most slopes can withstand rain falling directly on them with only minor sloughing or erosion, concentrated flows from above the slope can cause severe damage. Diverting the water at the top of the slope with ditches or berms to carry it to a nonerosive outlet is the most common method of protection. Diversion terraces may be needed at several elevations on excavated slopes to retard the flow of surface water. Since ponding water on or above slopes could cause instabil-

ity, diversions should be designed and constructed so that ponding water on or above slopes is avoided.

Dewatering system filter components, such as sediment and debris basins, are designed to trap sediment, debris, and other pollutants to keep them from being discharged from the site. The contractor must exercise care when removing these components to avoid the loss of this trapped sediment, debris, and pollutants. For more on erosion and pollution control see chapter 6 of this handbook.

With respect to removal of water, the inspector's responsibilities related to erosion, pollution control, and removal of temporary works includes verifying:

- required permits have been obtained and, when required, copies are available on the jobsite prior to beginning work in or around streams or wetlands, including the USACE Section 404 permit and EPA or State stormwater permit
- best management practices (BMPs) are installed and maintained as required by the Stormwater Pollution Prevention Plan (SWPPP)
- precautions are taken to protect environmentally sensitive streams during stream diversion and associated construction activities
- water is diverted from slopes, and slopes are protected to reduce erosion
- care is exercised when removing dewatering system filter components to minimize the loss of trapped sediment, debris, and other pollutants

### (c) Excavation

On some projects, such as construction of an excavated pond or a cropland waterway, excavation is the primary item of work. On other projects, excavation is only a part of the work to accomplish items such as preparing the foundation or obtaining material (borrow) to be used for earthfill.

#### (1) Excavation safety

The qualifications of equipment operators and the conditions of the excavating equipment must comply with safety regulations. In addition to concerns about safe excavating equipment and equipment operation, there

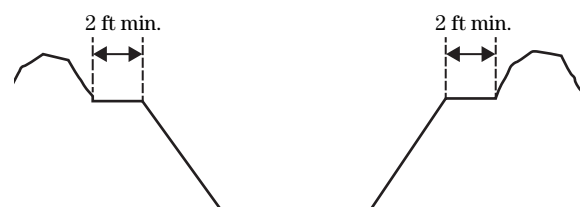
are specific items of safety associated with excavation that must be addressed. See chapter 4 of this handbook for guidance concerning excavation safety.

#### (2) Trench excavation

Trench excavation refers to any excavation with vertical or near vertical walls and is a major safety concern in any earthwork construction operation due to the potential for sloughing and poor air quality in confined working conditions. Trench excavation must comply with Occupational Safety and Health Administration (OSHA) regulations, and the contractor's plan to comply with these regulations should be reviewed and discussed with all employees. Trenching operations should be supervised by a competent person. Material removed from the trench should be placed a safe distance from the excavation (a minimum distance of 2 ft is recommended) to prevent excessive loading on the trench walls (fig. 7-7). To reduce excavation hazard potential, limit the amount of excavation to no more than can be maintained.

Excavated slopes that are steep or unsupported and vertical trench walls are prone to sloughing and cave-ins. Fluctuations in soil moisture can cause an otherwise stable excavation to cave in. In cold weather, freezing and thawing of the ground can result in excavation instability. Placing a surcharge load, such as spoil material, on the bank above an excavation can lead to the collapse of the excavated slopes. Material that falls into the excavation from a surcharge pile could strike an employee. Equipment operating in or near excavations can also cause surcharge loads or ground vibration that may contribute to slope failures. Any change to soil conditions, spoil locations, and location of equipment operations should be monitored by a competent person and necessary measures taken to immediately reduce hazard potential.

**Figure 7-7** Minimum distance from surcharge load to edge of trench



The contractor should have an excavation safety plan that identifies the hazards and provides for a means to protect workers. The plan should be reviewed and discussed with all employees. The plan must include emergency action items made known to all employees. OSHA requires that workers operating in excavations greater than 5 feet deep be protected from sloughing or cave-in by a system designed by a qualified engineer. OSHA offers guidelines for sloping, shoring, and worker protection that may be used in lieu of a custom-designed system. For more on excavation safety, see chapter 4 of this handbook and OSHA Part 1926.

The inspector's responsibilities related to excavation safety and trench excavation include verifying:

- qualifications of equipment operators and the conditions of the excavating equipment comply with safety regulations
- the contractor's excavation safety plan is reviewed and discussed with all employees
- all employees have been informed of what to do in emergency situations
- contractor operations comply with OSHA regulations related to excavations
- trenching operations are supervised by a competent person
- spoil materials are placed a safe distance (2 ft minimum) from top of excavated slopes
- confined space air quality is considered where applicable
- the amount of trench excavated at any one time is limited to no more than can be maintained
- shoring, trench boxes, and trench access ladders are installed per OSHA requirements
- consideration is given to changing soil conditions of moisture and freeze/thaw, surcharge loads, equipment operation, and other conditions that may cause excavations to be unstable

### (3) Buried utilities

NRCS policy states that employees are to check with the landowner, operator, or sponsoring organization to determine if there are underground utilities in the work area and to check records of known utilities on file in the field office. Particular attention should be

given to utility markers set in fence lines or elsewhere. These checks should be made during the design phase and again prior to beginning excavation. Excavation should not begin until all buried utilities in the area to be excavated have been marked or otherwise identified.

Contracts normally require the contractor to check for the presence of buried utilities within the work area. Many States have a "one-call phone number" to assist with the location of buried utilities, and the contractor is required to call this number prior to any excavation on a project. Some utilities, such as municipal utility companies, military facilities, and others, may not participate in the one-call system, so calling this number should not be the only action taken to determine if there are utilities on the site.

If buried utilities are known to be in the vicinity of proposed work, the responsible party should complete, sign, and return the postcard Form NRCS-ENG-005 (see appendix B of this handbook) to certify that specific actions concerning buried utilities have been taken. Failure to return the completed postcard will result in termination of NRCS assistance.

The inspector must complete Form NRCS-ENG-006 (see appendix B of this handbook) to document action taken pertaining to work in the vicinity of buried utilities. The completed NRCS-ENG-005 and 006 should be filed in the local field office or contract file.

The inspector's responsibilities related to buried utilities include verifying:

- an NRCS employee has checked with the landowner, operator, or sponsoring organization to determine if there are underground utilities known to be in the work area
- an NRCS employee has checked for records of known utilities on file in the field office
- the landowner, operator, sponsoring organization, or prime contractor:
  - called the State one-call number to ascertain the presence of utilities
  - notified the utility owner of the time, place, and type of work to be done

- requested that the buried utility be located and marked by the utility owner
- requested that a representative of the utility owner be present during excavation operations
- notified the excavation contractor of the location of known utilities
- completed, signed, and returned the NRCS-ENG-005 to the NRCS
- NRCS-ENG-005 and 006 are completed and filed in the local field office or contract file.

#### (4) Materials to be excavated

Various types of excavation are required to install conservation measures. These include foundation, borrow, and auxiliary spillway excavation to name a few. The inspector must be able to identify: the type of excavation, the class of excavation, and the various classes of soils being excavated. Additionally, payment for excavation will likely be based on type and class of excavation making it necessary for the inspector to monitor changes in excavation limits for the various types and class of excavations.

**Type of excavation**—Excavation is further classified according to the purpose or type of excavation. Common types of excavation for conservation measures are:

- foundation excavation with or without stripping
- core trench
- pipeline or other trench
- cutoff, keyway, or core trench excavation for a dam or dike
- channel excavation
- structure excavation for concrete
- auxiliary spillway excavation for a dam
- site grading excavation
- borrow excavation

All types of excavation, other than borrow excavation, will have specified lower and upper limits. The lateral limits are defined by the intersection of the lower and upper limits. The specified lower limits are generally

set at a desired finished grade or some depth below finished grade to allow for earthfill, topsoil, concrete, building supports, or rock placement on top of the excavated surface. The lower limits of a foundation or core trench excavation for a dam or dike will typically be specified to extend to or into a specific soil or rock strata.

It is rarely possible to conduct so extensive a site investigation as to fully define all of the existing geologic detail during the project design phase. This, coupled with the variability of most geologic deposits and formations, almost ensures that the lower limits of excavation will change from that specified. For example, a rock stratum may be located higher or lower than originally thought. Consequently, if the lower limits of excavation are planned to be at the top of the rock, either less or more excavation quantities will be required.

As excavation nears the specified lower limits, the inspector must verify that the excavation extends to or into the specified horizon. All changes to excavation limits should be documented in the diary and on the as-built plans. Excavation quantities for payment must be adjusted when excavation limits change. Surveys will be needed to define the limits needed for adjusting the payment quantities.

Minor changes in excavation limits that result in quantity variations that do not exceed the variations allowed by the contract's quantity variation clause should be anticipated by the contractor and do not warrant a contract modification. These changes generally only require a minor variation in payment quantities. If the change in excavation limits results in a significant change in the scope of work or a significant increase or decrease in the amount of excavation, a contract modification will likely be in order. The inspector should notify the responsible engineer when a significant change in the work is anticipated. Detailed documentation of the change, including a record of equipment and individuals employed by the contractor to accomplish significant added work, should be recorded in the job diary.

**The class of excavation** is listed in NRCS Construction Specification 21, Excavation, as one of three classes: common, rock, or unclassified. The designer specifies unclassified excavation when the materials to be excavated cannot clearly be classified as common



or rock excavation at the time of design. Rock or common excavation is specified when the designer is more confident, during the design phase, in knowing that the material is indeed rock or soil.

Construction Specification 21 defines common and rock excavation according to the equipment required to excavate the material. For example, common excavation is defined as excavation that can be accomplished with a 250 flywheel horsepower track-type tractor with a rear-mounted heavy duty single-tooth ripping attachment. If larger equipment or blasting is required for the excavation, the classification changes to rock excavation.

Classifying excavation requires judgment of the capabilities and limitations of the contractor's equipment. The contractor should select adequate equipment and machinery based on the type of soil, site conditions, and equipment availability. The inspector is not authorized to require specific methods or equipment be used unless they are specified in the contract; however, concerns about operation inefficiency should be documented and made known to the contractor. To do otherwise might infer that the inspector agrees with inefficient methods and procedures. If the contractor continues to operate in an inefficient manner, the inspector should elevate concerns to the responsible engineer and document the facts related to the inefficient operation and all related conversations with the contractor and the engineer.

When there is a change in the excavation class from what was bid, measurements needed to accurately quantify each excavation class are required. The inspector should be keenly aware of any change in the material being excavated so as to identify and document any change in the class of excavation. For example, if rock is encountered in an excavation that has been classified by the designer as being common excavation, it is necessary to quantify the amount of rock excavated so as to compensate the contractor for the added excavation effort. Conversely, if the excavation is classified by the designer as rock excavation, it is necessary to quantify any significant portion of the excavation within the specified rock excavation limits that only requires a common excavation effort. The inspector must recognize these changes so that these measurements can be made in a timely manner before the limits of one class of excavation is destroyed by further excavation or covered by earthfill.

### ***The Unified Soil Classification System***

**(USCS)**—The USCS is used by engineers to identify soils based on particle size and degree of plasticity as these properties relate to the soil's performance in engineering applications. ASTM D2487, Standard Practice for Classification of Soils for Engineering Purposes (USCS) is used by soil mechanics laboratories to classify soils. After classifying the soils, the lab conducts tests for engineering properties such as strength and permeability. The designer uses this information to specify where each class of excavated soil can best be used as foundation material or in earthfill.

ASTM D2487 is a precise method for classifying soils in the laboratory, but it is not very handy for use in the field. Since it is necessary to classify soils in the field as they are being excavated, a less precise procedure was developed for field use. This field procedure is described in ASTM D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). Worksheet WS 7.1 located in appendix B of this handbook can be used when classifying soils per ASTM D2488. Inspectors must be able to classify soils using the method described in ASTM D2488.

When laboratory classifications are available, the inspector should compare their field classifications to that of laboratory classifications of soils in the area. This will serve as a check of the accuracy of the field classification and help to improve the inspector's skill and ability to field classify soils according to the USCS.

The USCS classifies soils in two major types: course and fine. Course soils are further separated into two types: sands and gravels. Fine soils used in construction are separated into two types: silts and clays. Highly organic soil is a third fine soil, but it is not suitable for foundations or construction. Figure 7-8 illustrates the difference between the major types of soil as they are classified by grain or particle size.

Each basic type of soil (gravel, sand, or fine) is further categorized by the USCS. Gravels and sands may be poorly graded or well graded, and fines may be plastic or nonplastic. Soils seldom exist separately as basic types, but rather as various combinations of gravel, sand, and fines. Thus, the USCS further classifies soils as combinations of the basic types with variations within the basic types. For example, the USCS classification "clayey gravel," or "GC," is a combination of gravel and fines, and the fines are further classified as

clay. For a complete listing and description of the various USGS classifications, see ASTM D2487 or D2488.

Designs are based on detailed geologic investigations that contain limited soil data. Only the soils sampled in a bore hole or pit at a specific sample location can be known for sure. Thus, soils encountered during excavation and foundation preparation will differ to some degree from that assumed by the designer. Additionally, many conservation measures are designed without detailed soil mechanics information, and decisions must be made during excavation as to the suitability of materials for the application. Thus, inspectors must observe soils as they are being unearthed and be aware of the engineering characteristics of various soil groups and the suitability of each group for a construction material. Table 7-1 describes characteristics and uses for various soil groups.

The NRCS provides soil mechanics training courses and modules for engineers and inspectors. It is recommended that inspectors take advantage of these and

other available resources for improving knowledge, skills, and abilities in understanding engineering characteristics of various soil groups and how they can best be used in construction of conservation measures.

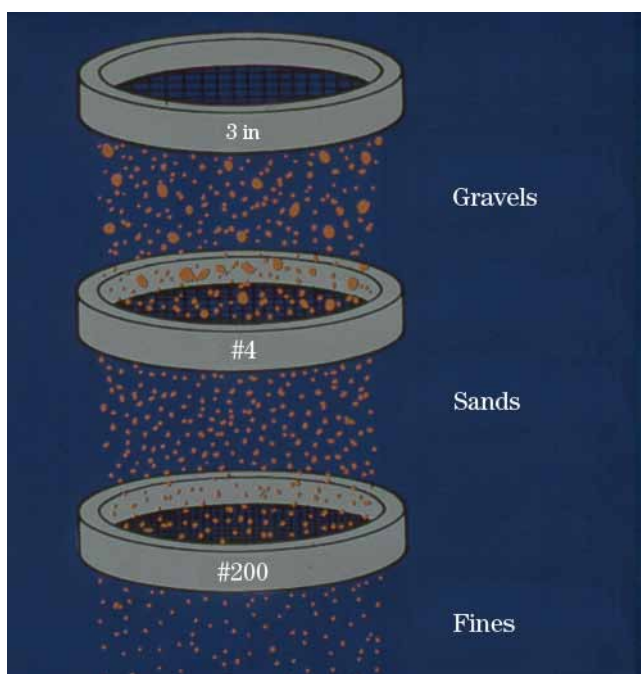
The inspector's responsibilities related to excavated materials include:

- identifying the type of excavation, the class of excavation, and the various USCS classes of soils being excavated
- having an awareness of the engineering characteristics of various soil groups including the suitability of each group for a construction material
- observing soils for suitability for a construction material as they are being unearthed
- when required, separating and stockpiling topsoil
- being keenly aware of any change in excavation limits or class of excavation
- documenting and elevating to the engineer any concerns about excavation operation inefficiency
- notifying the engineer when it is anticipated that a change in materials will result in a significant change in the quantity or scope of work
- recording details and related conversations in the job diary of any change or added work related to materials
- verifying surveys are made to define the excavation or material class limits needed for adjusting payment quantities
- verifying excavation extends to the specified limits
- documenting all changes to excavation limits on as-built plans

### (5) Blasting

Blasting is often required as a means of excavating and shaping rock to the specified line and grade. The transportation, handling, storage, and use of explosives should be directed and supervised by a licensed blaster of proven experience and ability to conduct blasting operations. Storage of explosives is very

**Figure 7-8** Major types of soils based on grain size



**Table 7-1** Soil identification and engineering properties

Field identification procedures										Suitability for embankments										
Coarse-grained soils	More than half of material (by weight) is of individual grains not visible to the naked eye	Clean, little or no fines	For visual classification the 1/4 in sieve may be used as equivalent to the No. 4 sieve size	Gravels (more than 50% passing larger than #4)	Wide range in grain size and substantial amounts of all intermediate particle size					Very stable: pervious shells of dikes or dams										
					Predominantly one size or range of sizes with some intermediate sizes missing					Reasonably stable: pervious shells of dikes and dams										
		Will not leave a dirt stain on a wet palm		Sands (more than 50% smaller than #4)	Wide range in grain size and substantial amounts of all intermediate particle size					Very stable: pervious sections, slope protection required										
					Predominantly one size or range of sizes with some intermediate sizes missing					Reasonably stable: pervious sections with slope protection										
		With appreciable fines (more than 12%)		With plastic fines	Gravel with plastic fines (For identification of fines, see characteristics of CL and CH below)					Fairly stable: May be suitable for impervious core										
					Sand with plastic fines (For identification of fines, see characteristics of CL and CH below)					Fairly stable: impervious core, flood control structures										
		Will leave a dirt stain on a wet palm		With nonplastic fines	Gravel with nonplastic fines or fines with low plasticity (For identification of fines, see characteristics of ML and MH below)					Reasonably stable: Limited use for impervious core or blankets										
					Sand with nonplastic fines or fines with low plasticity (For identification of fines, see characteristics of ML and MH below)					Fairly stable: not particularly suited to shells, limited use for impervious cores or dikes										
		Fine-grained soils		More than half of material (by weight) is of individual grains not visible to the naked eye	Silts and clays (low plastic)	Odor	Slight	Dry crushing strength	Rapid	Dilatancy (shake) reaction	Low to none	Ribbons (near the P.L.)	None	Shine (Near the P.L.)	Dull	Poor stability: may be used for embankments with proper design and control in placing				
							High		Medium to slow		Medium		Weak		Slight to shiny	Stable: impervious cores and blankets				
Medium	Slow to none		Low to none		None		Dull to slight		Not suitable for embankments											
Medium	Very slow to none		Medium		Weak		Slight to shiny		Poor stability: not desirable in core rolled fill embankments											
Very high	None		High		Strong		Shiny		Fair stability with flat slopes, thin ores, blankets, and dikes											
High	None		Low to medium		Weak		Dull to slight		Not suitable for embankments											
Silts and clays (highly plastic)	Medium		None		High		None		None		None		None		None	None	None	None	None	
																				None
Highly organic soil											Readily identified by color, odor, spongy feel and frequently by fibrous texture		Do not use for construction							

**Table 7-1** Soil identification and engineering properties—continued

Value for foundation (seepage control)	Typical names	Unit dry weight (lb/ft <sup>3</sup> ) (ASTM D698)	Compaction characteristics	Suggested compaction equipment	Unified soil classes
Good bearing value (Requires positive cut- off)	Well-graded gravels, gravel-sand mixtures, little or no fines	125–135	Good	Tractors, rubber-tired equipment. Vibrating compactors or grid-type rollers	GW
Good bearing value (Requires positive cut- off)	Poorly graded gravels, gravel-sand mixtures, little or no fines	115–125	Good	Tractors, rubber-tired equipment. Vibrating compactors or grid-type rollers	GP
Good bearing value Upstream blanket and toe drains	Well-graded sands, gravelly sands, little or no fines	110–130	Good	Tractors, rubber-tired equipment. Vibrating compactors or grid-type rollers	SW
Good to poor: depends on density (Blankets and toe drains)	Poorly graded sands, gravelly sands, little or no fines	100–120	Good	Tractors, rubber-tired equipment. Vibrating compactors or grid-type rollers	SP
Good bearing value (None)	Clayey gravels, gravels- sand-clay mixtures	115–130	Fair	Rubber-tired, sheepsfoot or grid rollers	GC
Good to poor (None)	Clayey sands, sand-clay mixtures	105–125	Fair	Sheepsfoot or rubber- tired rollers	SC
Good bearing value (Toe trench to none)	Silty gravels, gravel- sand-silt mixtures	120–135	Good - with close control	Rubber-tired, sheepsfoot or grid rollers, vibrating compactors	GM
Good to poor bearing value depending on density (Upstream blanket and toe drainage)	Silty sands, sand-silt mixtures	110–125	Good - with close control	Rubber-tired, sheepsfoot or grid rollers, vibrating compactors	SM
Fair to very poor: suscep- tible to liquefaction (Toe drainage to none)	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	95–120	Good to poor	Rubber-tired or sheeps- foot rollers	ML
Good to poor (None)	Inorganic clays of low to medium plasticity, grav- elly clays, sandy clays, silty clays, lean clays	95–120	Fair to good	Sheepsfoot or rubber- tired rollers	CL
Fair to poor bearing, excessive settlement may result (None)	Organic silts and organic silty clays of low plas- ticity	80–100	Fair to poor	—————	OL
Poor bearing (None)	Inorganic silts, mica- ceous or diamataceous fine sandy or silty soils, elastic silts	70–95	Fair to very poor	Sheepsfoot roller	MH

**Table 7-1** Soil identification and engineering properties—continued

Value for foundation (seepage control)	Typical names	Unit dry weight (lb/ft <sup>3</sup> ) (ASTM D698)	Compaction characteristics	Suggested compaction equipment	Unified soil classes
Fair to poor bearing (None)	Inorganic clays of high plasticity, fat clays	75–105	Fair to poor	Sheepsfoot roller	CH
Very poor bearing (None)	Organic clays of medium to high plasticity, organic silts	65–100	Poor to very poor	—————	OH
Remove from foundations	Peat and other highly organic soils	—————	Compaction not practical	—————	Pt

important to manage correctly. Security provisions against theft and precautions to avoid the risk of fire must be implemented. Special provisions regarding the transportation of explosives must also be met. As with all construction activities, attention to safety is paramount when conducting blasting operations (see chapter 4 of this handbook on safety).

**Blasting plan**—The contractor is required to submit a blasting plan to the engineer prior to beginning blasting operations. Blasting operations begin with the transportation of blasting materials to the site. Thus, the plan must be provided prior to transporting blasting materials to the site.

Designs of earlier blasts used for similar excavations are usually referenced when developing a blasting plan. The blasting plan must be flexible so that adjustments can be made if the desired results are not being attained. The plan should show the:

- name and address of the blasting company
- name and license number of the blaster and onsite person who is responsible for blasting
- how transportation, storage, and handling of blasting materials will comply with safety regulations, local codes, and permit requirements
- types of explosives to be used
- type of material to be blasted (i.e., limestone, shale, sandstone, etc.)
- powder factor
- diameter of boreholes
- layout of the blasting area with sketches showing the planned depth, direction, and spacing of boreholes
- burden/spacing ratio used to determine the hole layout
- method of initiation (i.e., electric or nonelectric)
- delay types
- type of circuit if electric initiation is used
- maximum number of holes per delay
- maximum weight of explosives per delay
- proximity to structures or utilities that might be adversely affected by blasting
- if required, monitoring plan including equipment to monitor air blast and ground motion, planned location of equipment, name of person taking equipment readings, and name of person or firm who will analyze the readings

The blasting plan should be reviewed by the engineer and inspector and any concerns resolved with the contractor prior to beginning blasting operations. Since blasting is a hazardous operation, the inspector must be especially diligent in verifying that the contractor transports, stores, and handles blasting materials in accordance with the blasting plan.

**Blasting process**—The blasting process begins by drilling holes in the rock that is to be excavated. An explosive material and igniter (detonator) is loaded into each hole. Stemming material, such as sand, is placed on top of the explosive to help direct most of

the blast energy into the rock and limit the amount of energy exiting the hole. Figure 7-9 shows two blasting holes with the weight of blasting agent in each hole (13 and 15 lb Anfo), the type of detonator (1/4 by 12 Emulex), and the height of stemming (5 1/2 and 7 ft).

The contractor is responsible for designing the blast so that the rock is broken up to the desired particle size and can be excavated with available equipment. The factors affecting the breakage of rock are:

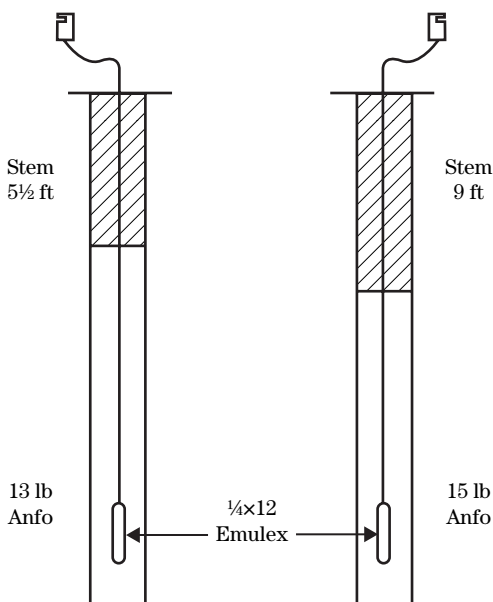
- properties of the explosive
- properties of the rock
- geometry of the free faces
- number, position, and sizes of charges
- type, positions, and amounts of stemming material
- accuracy of drilling, loading, and stemming
- timing between detonations and its accuracy

In many cases, the contractor is responsible for designing the blast so that the finished grade of the excavated surface is within a specified tolerance. For

example, this would be the case if rock is being excavated to expose the crest of an auxiliary spillway. The holes are drilled to a depth that will result in the removal of rock down to the planned lower limits of excavation. For sloped surfaces such as the cut slope of a spillway, a line of holes may be drilled at an angle oriented along a line corresponding to the planned sloped surface. In this case, charges are ignited in these holes first to “pre-split” the rock along the planned slope just milliseconds prior to igniting the charges in the remaining holes. As seen in figure 7-10, pre-splitting can produce a relatively uniform slope

**Sequential blasting**—Structures near the blast can be damaged from ground vibration, air blast, or fly rock. The amount of ground vibration, air blast, and fly rock can be controlled by limiting the maximum weight of explosives per delay. Sequential blasting is a technique used to limit the maximum weight of explosives per delay. This technique is illustrated in figure 7-11, which shows the general location and layout of boreholes. Each borehole is numbered beginning with number 1 in the top left corner of the sketch. The point of ignition (P.O.I) is on the right end of the middle row at hole 47. The number below each borehole is the elapsed time in milliseconds (ms) from the ignition of

**Figure 7-9** Sketch of loaded boreholes



**Figure 7-10** Presplitting in the bypass and auxiliary spillway at Hughes River Dam in West Virginia



the P.O.I. to the ignition of the explosive in the borehole.

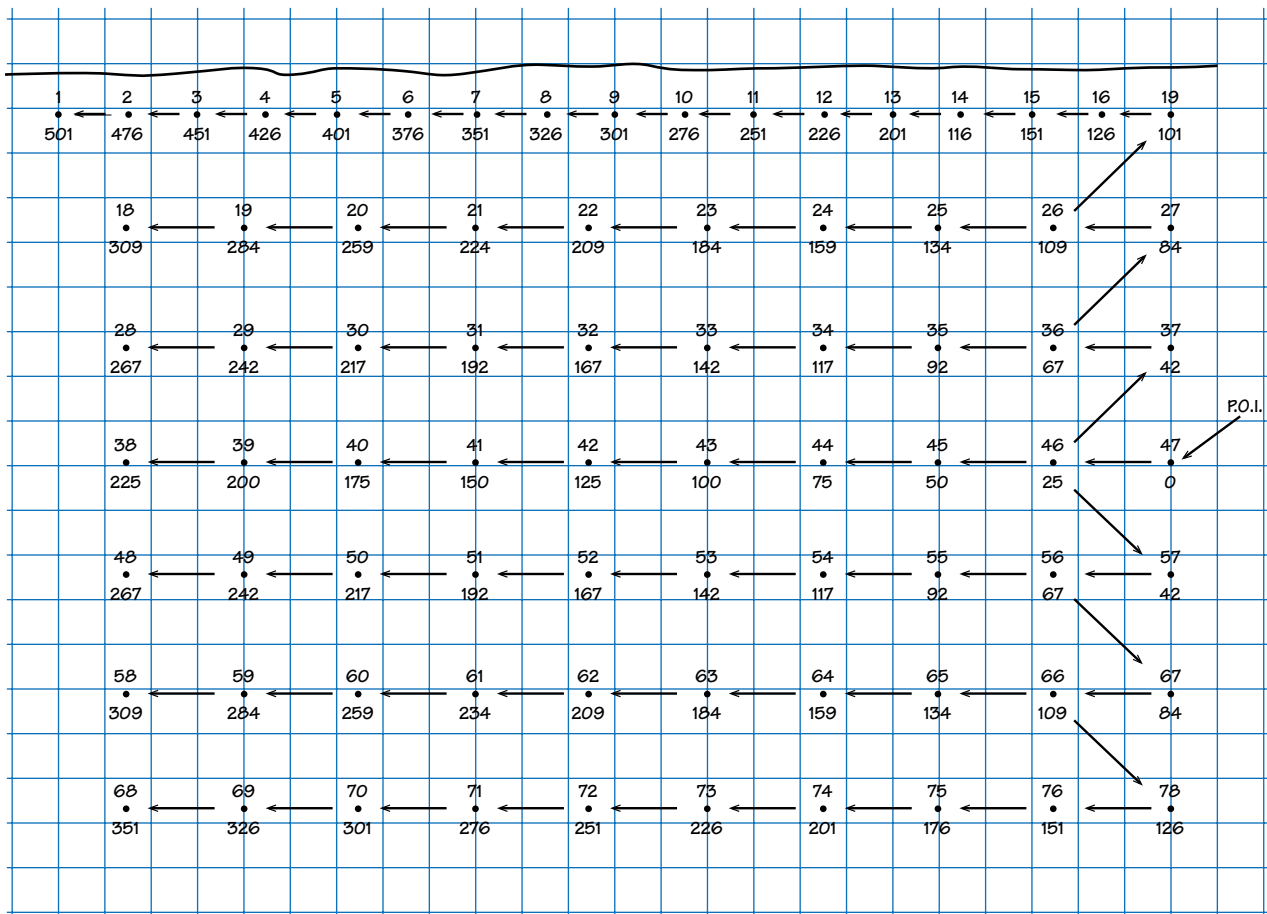
The delay period between the ignition of hole 47 and the next hole that is detonated (number 46) is 25 milliseconds. As hole 46 is detonated the charge is transmitted from hole 46 to holes 45, 37 and 57. The delay from 46 to 45 is 25 milliseconds; the delay from 46 to holes 37 and 57 is 17 milliseconds. Thus, the minimum delay period is 8 milliseconds (i.e., 25 ms - 17 ms = 8 ms).

The maximum weight of explosives per delay is determined by multiplying the maximum weight of explosive material(s) in each borehole by the maximum number of holes detonated at any one time. Using the

plan illustrated in figure 7-11, if a maximum of two holes are detonated at any one time and the maximum weight of explosive material(s) per hole is 31 pounds, the maximum weight of explosives per delay would be 62 pounds (i.e., 2 holes per delay × 31 pounds per hole = 62 pounds per delay). The inspector should verify that the maximum weight of explosives per delay does not exceed the maximum allowed in the blasting plan.

**Overblasting** or blasting operations that loosen or damage rock beyond the planned grade or specified slope lines is generally objectionable and should be avoided. Although the depths of drill holes are frequently extended a short distance below the specified lower limits of excavation, the blasting of areas much below grade or the overloading of explosives will

**Figure 7-11** General location and layout of boreholes for sequential blasting



result in overblasting. Figure 7–12 shows an auxiliary spillway that was overblasted.

The time and expense associated with overblasting can be avoided with good quality control to ensure the drill hole depth and weight of explosive(s) per delay comply with the blasting plan. The inspector should check the contractor's operations against the blasting plan by plotting depth, direction, and spacing of the holes on cross sections to be sure the holes do not extend below the planned grades.

The desired results are being attained when the materials can be excavated to the planned line and grade with minimal overblasting and with no damage to the materials that remain in place.

**Blast monitoring** is generally specified when blasting near buildings, structures, or utilities that could be damaged from blast-induced ground vibrations or air blast. The need for blast monitoring may either be specified or left up to the contractor. If there are buildings, structures, or utilities that may be damaged from blast-induced ground vibrations or air blast, pre-blast conditions of these should be documented regardless of whether blast monitoring is implemented. Photo documentation is very valuable to access conditions before and after blasting.

When blast monitoring is specified, the party that performs monitoring and analyzes the results should be separate and apart from the construction contractor or

blaster. It is not uncommon for the blast to be monitored by one party and the results analyzed by another.

Monitoring involves instrumentation to measure ground vibrations in terms of peak particle velocity (ppv) and may include instrumentation to measure air blast (sometimes called overpressure) in terms of decibels (dB) or pounds per square inch (lb/in<sup>2</sup>). Air blast or overpressure may cause window breakage or some other minor damage, but it is the ground vibration that causes the most damage. Documented experience has shown that vibration of the ground below certain threshold values is acceptable to avoid damage to structures. These vibrations can be estimated and the blast designed for a maximum weight of explosives per delay to avoid damage to structures.

The inspector is not responsible for estimating ground vibrations or the adequacy of the blasting design to avoid damage to structures. This is the responsibility of the engineer. The inspector is responsible for verifying that the blast monitoring complies with the blasting design after it has been accepted by the responsible engineer.

**Documentation** of blasting operations is required. The inspector should note blasting operations in the job diary and complete WS 7.3, Report of Blasting Operations (see appendix B of this handbook). Photos of pre- and post-blast conditions of buildings, structures, or utilities should be referenced in the job diary and in the comments section on WS 7.3.

The inspector's responsibilities related to blasting include verifying:

- the contractor has submitted a blasting plan, and it is accepted by the responsible engineer prior to transporting blasting materials to the site
- the blaster has obtained a blasting permit if required
- blasting operations comply with the accepted blasting plan as follows:
  - operations are directed and supervised by the person(s) listed in the blasting plan
  - materials are stored, transported, and handled in accordance with the blasting plan

**Figure 7–12** Results of overblasting in an auxiliary spillway





- safety measures are implemented according to the blasting plan
- the depth, direction, spacing, and loading of the holes are consistent with the blasting plan
- adjustments are made in the blasting plan to prevent overblasting and to attain the desired results
- pre-blast conditions of potentially affected buildings, structures, or are well documented
- monitoring is implemented when specified or planned
- photo documentation of pre- and post-blast conditions are referenced in the job diary and on WS 7.3
- all blasting operations and related activities are documented in the job diary and on WS 7.3

### (6) Disposal of excavated materials

To the extent specified, all suitable excavated materials are to be used in construction of earth or rock fills. If specified, the topsoil must be salvaged and stockpiled in designated locations. Unsuitable or surplus excavated materials must be disposed of at the specified locations. Usually, waste or surplus materials are spread uniformly with consideration for drainage and appearance. Wet materials that are otherwise suitable can be stockpiled to be used after drying. The inspector must routinely check to verify the removal and proper disposal of unsuitable materials.

The inspector's responsibilities related to disposal of excavated materials include verifying:

- all suitable materials are used as specified
- where specified, top soil is salvaged and stockpiled in designated locations
- excavated unsuitable or surplus materials are disposed of as specified in specified locations
- no unsuitable materials remain in areas from which they are to be removed

### (7) Borrow excavation

When the quantities of suitable material obtained from specified excavations are insufficient to construct the specified earthfills and earth backfills, additional material must

be obtained from the designated borrow areas. Borrow areas are normally selected in the design phase of the project. Their locations are shown on the drawings unless the contractor is responsible for locating and furnishing the borrow material from an offsite source. All borrow areas should be staked or otherwise delineated in the field. If the borrow excavation is included as a pay item, surveys may be required before and after removal to determine the actual quantity of borrow material excavated. The specification may require the upper limit of excavation to be determined after the topsoil has been removed.

Borrow areas should initially be prepared in a similar fashion to the foundation. The borrow area should first be cleared, stripped, and grubbed. Topsoil should be salvaged to later be placed on exposed earthfills and cut slopes.

**Adequacy of borrow areas**—Determining the adequacy of the borrow area to produce the needed materials is usually an ongoing job. As borrow excavation progresses, the inspector should verify that borrow materials have similar properties to those assumed in the design. USCS field classification of borrow materials can be compared to the classification of materials specified to be placed in the various zones. Materials that do not conform to specification requirements should not be used unless they are approved by the responsible engineer. The inspector must immediately advise the responsible engineer when borrow quantities appear inadequate.

**Adjusting soil moisture**—If the soil is too wet, adequate drainage, pumping, and aeration may be considered as a solution to reduce the water content. Conversely, if the soil is too dry for the borrow materials to be used for earthfill, irrigation may be required to raise soil moisture in the borrow area. It is often helpful to estimate the amount of water needed to raise the moisture content of dry borrow soils to within the specified range. This can be accomplished with equation 7-1.

$$\text{Water (gal/yd}^3\text{)} = \frac{\text{w\%increase}}{30.9} \times \gamma_{\text{dry}} \quad \text{eq. 7-1}$$

where:

water (gal/yd<sup>3</sup>) = gallons of water required to raise the moisture of a cubic yard of compacted earthfill to the specified moisture content

$w\%$  increase = desired percent moisture—percent field moisture  
 $\gamma_{\text{dry}}$  = specified dry density of compacted earthfill

**Example:** Borrow material is being transported to a dam where it is to be compacted to a dry density of 104.5 pounds per cubic foot at a moisture content ranging from 20 percent to 24 percent. The moisture content of the material in the borrow area is 12.4 percent. Estimate the number of gallons of water required per cubic yard of compacted fill to comply with the specification for moisture content at the time of compaction.

$$\text{Water} = \frac{(20\% - 12.4\%)}{30.9} \times 104.5 \text{ lb/ft}^3 = \text{gal/yd}^3$$

Chapter 8 of this handbook contains a graphical solution for estimating the amount of water needed to raise soil moisture content. If the specified dry density is known, the graph entitled “Water Requirement for Compaction” will estimate the gallons of water needed to raise the moisture content 1 percent.

**Sloping and grading**—Borrow areas need to be sloped to drain during excavation. When they are no longer needed as a source of fill material they should be sloped and graded as specified. Where the borrow area will be permanently inundated, it must be smoothed and piles of materials cut down to eliminate shallow areas within the pool that could be a boating hazard. Borrow areas that will not be permanently inundated should be left in a condition that they can be vegetated or otherwise stabilized. Placement of topsoil on areas that will be vegetated may also be required.

The inspector’s responsibilities related to borrow areas include verifying:

- borrow areas have been staked or otherwise delineated in the field
- borrow areas have been cleared as specified
- provisions are made to dispose of unsuitable materials
- the responsible engineer is notified if it appears borrow area will be inadequate
- where applicable, surveys are obtained for borrow quantity computations

- the water content of borrow materials is adjusted, as needed, prior to transporting materials to the fill area
- borrow areas are smoothed and piles of materials cut down to eliminate shallow areas within the pool that could be a boating hazard
- borrow areas are sloped and graded as specified
- borrow areas that will not be permanently inundated are covered with topsoil and vegetated or otherwise stabilized as specified

### (8) Grading

Grading is the final cut and fill needed to shape the earthfill or excavation to the specified line and grade. On some projects, such as land leveling for irrigation and drainage, grading is the primary item of work. On other projects, grading puts the final touches on a much more extensive excavation or earthfill.

Grade stakes are normally provided to guide where the excavation or fill is to be placed and how much excavation is to be completed. Regular grade checks must be made by the inspector during construction to ensure compliance with the plans and specifications. Final grading may require additional staking depending on the type of work involved. This staking is often called blue topping.

With blue topping, stakes are set so that the tops of the stakes correspond to the specified final project lines and grades. Stake tops were historically painted blue to make them more visible. Modern blue topping stakes have a flexible plastic whisker stapled to the stake that extends above the top of the stake. These whiskers are available in various bright colors that allow the location of the stake to be identified even when it is covered with a few inches of soil. When the soil surface is graded so that it corresponds with the top of the stake the final line and grade has been attained.

Laser grade control is an alternative to blue topping. Laser grade control employs a tripod-mounted laser that rotates and projects a plane of laser light to receivers mounted on the earthmoving or grading equipment. The operator raises or lowers the equipment blade in response to a display that shows up or down arrows whenever the receiver is above or below

the laser light plane. This control system may also be configured so that the blade or other earthmoving device automatically raises and lowers without the need for operator input. Laser grade control is common on equipment used for land leveling, trenching, channel grading, levees, border terracing, and other practices where precision grade control is specified.

Final grading of some excavations may be difficult in some soil or weather conditions and may have to be delayed to achieve the required finished tolerances. Many fine-grained soils are difficult to grade unless the moisture content is within a narrow range that allows the soil to be cut without damage to the surface. Overexcavation in these fine-grained soils during final grading must be avoided because thin fills to correct overexcavation will likely result in an unstable laminated surface. Soil that is wet or frozen must dry or thaw before grading can be accomplished without damage to the surface.

The inspector's responsibilities related to final grading include verifying:

- grade stakes are accurately placed and regular grade checks are made
- where applicable, topsoil is placed to the specified depth before final grading
- final grading is made to the specified lines and grades
- overexcavation is avoided
- grading is avoided when the soil is too wet, too dry, or frozen

## 645.0702 Sampling and testing

Sampling and testing of foundation materials and other excavated materials are required to verify specification compliance and to verify that materials found during excavation are of the nature and quality anticipated by the designer. Testing of materials is a six-step process:

- Step 1* Select the test location.
- Step 2* Properly sample the materials.
- Step 3* Properly perform the test.
- Step 4* Evaluate the test results.
- Step 5* Accurately record test results and sample location including elevation and depth below-ground where the sample was obtained.
- Step 6* Determine the necessary frequency of testing.

### Step 1 Select the test location.

**Field control tests** (also known as reference standard tests) are used to determine values of soil moisture and density of soil compacted with a standard or modified compaction effort. They must be developed and matched to the soil prior to taking field control tests. They may have been developed from geologic investigation samples and included in the soil mechanics report. Regardless of whether they are obtained from the soil mechanics report or developed by the inspector during construction, they must be verified and supplemented during excavation, foundation preparation, and borrow operations. The moisture and density of the soil, as it is being processed and compacted, will then be compared to the specified field control test values to determine specification compliance.

Note the field control test (ASTM D698) listed in the third column of the materials placement data table in figure 7-13. Either ASTM test standard D698 or D1557 will be specified as the field control test for earthfill. These are the ASTM test standards for developing Proctor curves. Test D698 is conducted to develop the more commonly specified standard Proctor curve; D1557 is conducted to develop the less commonly specified modified Proctor curve. See chapter 8 of this handbook for a detailed description of Proctor's principal and the field tests related to this principal.

**Figure 7-13** A materials placement data table and corresponding cross section for a zoned embankment

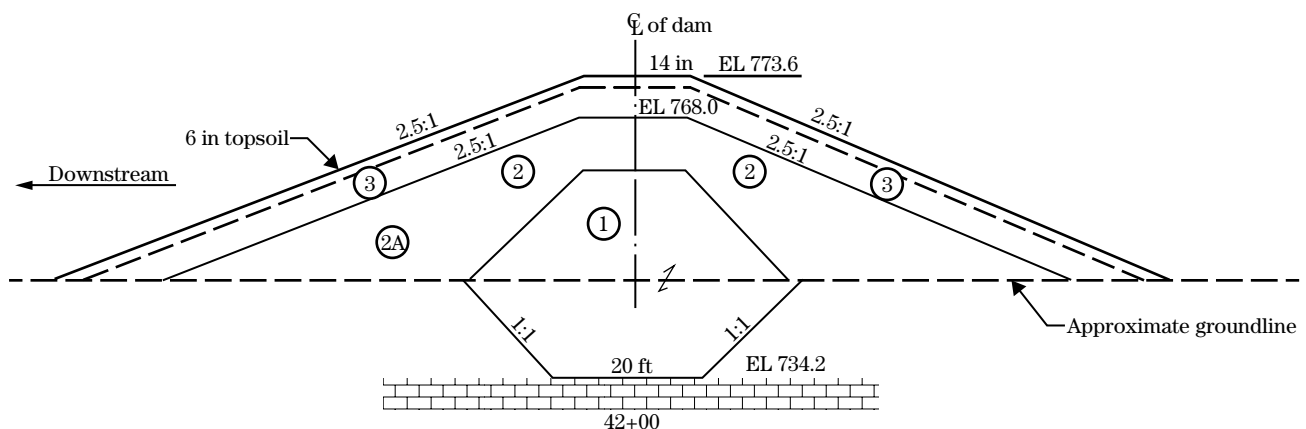
**Zoned embankment data**

Materials placement data									
Embankment zone <sup>1/</sup>	Type or unified classification	Field control test		Placement and confirmation requirements					
		ASTM test		Maximum allowable particle size	Maximum uncompacted layer thickness	Specified compaction class	Min. dry density percent of field test max. dry density	Moisture limits relative to field test optimum percent	
								From	To
①	CH: Highly plastic, silty clay	D698	A	6 in	9 in	A	95	-1	UP
②	GC: Clayey, sandy gravel with moderately plastic fines	D698 <sup>3/</sup>	A	9 in	15 in	C <sup>2/</sup>	95	OPT.	UP
②A	Shale: Breaks down to a highly plastic clay (CH)	D698	A	6 in	9 in	A	95	-1	UP
③	CL, GC: Weathered limestone, low to medium plasticity fines	D698 <sup>3/</sup>	A	9 in	15 in	C <sup>2/</sup>	95	OPT.	UP

1/ The zone boundaries shown in the sections are approximate. They may be varied as permitted to allow the use of all suitable and needed materials from the required excavations.

2/ Class C compaction shall be required for this type of material and shall be accomplished by a minimum of 6 passes per layer of a tamping roller weighing not less than 1,200 pounds per foot of roller width at a towing or traveling speed of 2 mi/h or greater. Rock fragments greater than 9 inches shall be removed from the fill material either at the borrow source or after being placed on designated fill area. Oversized rock shall be wasted in a location designated by the engineer.

3/ A Standard Proctor D698 procedure shall be run on materials passing the No. 4 sieve for determination of placement moisture only.



As an example of how field control tests are used, consider the soil to be placed in embankment zone 1 in figure 7-13. This soil is classified as a CH material. When being compacted, the soil moisture content must be above -1 percent of the optimum moisture determined by conducting ASTM D698. It must be compacted to a density that is at least 95 percent of the maximum dry density, which is also determined by ASTM D698. Thus, to verify compliance with the compaction requirements, the Standard Proctor Test values must be known before testing the compacted soil.

For this example, assume the optimum moisture obtained from the standard Proctor curve shown in figure 7-14 is 28 percent and the maximum dry density is 100 pounds per cubic foot. With this information, the inspector can test the soil after or as it is being compacted. If the soil moisture at the time of compaction is at least 27 percent and the density at least 95 pounds per cubic foot, it meets the minimum requirements for moisture and density.

A common error in testing compacted soils for compliance with moisture and density requirements is the selection of the Proctor curve that represents the soil. If a site-specific soil mechanics report is available, it will include Proctor curves that were developed in the soil mechanics lab from samples obtained during the geologic investigation of the site. The number of Proctor curves available in the soil mechanics report

will depend on the number of different soils sampled during the investigation. The soils will differ in USCS classification with each class of soil having different compaction characteristics. The inspector must be able to match each Proctor curve to the soil it represents.

In the above example, the soil to be placed in embankment zone 1 was a CH soil. The inspector must verify that the soil being transported to zone 1 is indeed a CH soil and that the Proctor curve used for field control matches the CH soil being transported to zone 1. The sampling and testing required to match each Proctor curve to the soil it represents is described in chapter 8, section 645.0802(d) of this handbook.

#### **Tests of compacted earthfill and foundation materials**

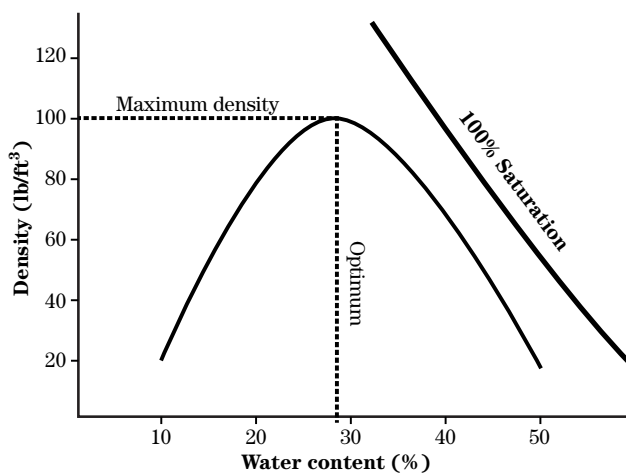
Selecting the location of a test is based on two areas of concern. The first is a random test of the materials representative of all like material in an area. The second is testing specific areas that may be weaker (less dense) than the majority of the fill. Both kinds of testing are needed to adequately verify and document the quality of the material being tested. As the test site is being prepared, close observations must be made to estimate the uniformity of foundation moisture and density. When apparent differences in density or moisture are observed, some testing should be located in the apparent weaker portions.

Weaker portions of the fill may not be apparent by visual observation. The inspector should consider some areas to be inherently weaker than others because of the difficulty of controlling moisture and performing compaction in specific areas. Such areas are those that are confined or have restricted access. Areas near an embedded conduit or at an abutment are examples of areas where weaker portions of the fill may be located. Any fill that Construction Specification 23 defines as "backfill" is, by definition, suspect to being weaker than that defined as earthfill. Chapter 8 of this handbook describes testing of compacted materials in more detail, but it is mentioned here because this testing is conducted during the foundation preparation phase to verify moisture and density of foundation soils comply with specification requirements.

#### **Step 2 Properly sample the materials.**

Sampling of materials to be tested and maintaining the integrity of the sampled materials are critical steps in obtaining test results that accurately represent

**Figure 7-14** Proctor curve



the materials being tested. All of the in-place density methods, with the exception of the nuclear method, require the removal of a soil sample from the test area. Soils sampled for testing should be sampled and protected according to ASTM D5220. In most cases, the main concern is that the sampled soil be protected from moisture loss prior to testing. It should be placed in a plastic storage bag or other air-tight container immediately after sampling and remain there until the moisture content value is obtained. See chapter 8 of this handbook for more soil sampling.

Gravels and sands that are used in filter and drainage systems must be graded within specified limits, thus it is important that any sample of these materials used for a mechanical sieve analysis be obtained from a nonsegregated portion of the material stockpile. See chapter 11 of this handbook for more on sampling and testing gravels and sands.

ASTM D4220 contains four different procedures for sampling and protecting soil samples identified as Group A, Group B, Group C, and Group D. Applicability of each procedure is dependent on the purpose of the sample. Samples of foundation materials obtained for the purpose of determining the presence of collapsible soils must remain intact prior to testing. ASTM D4220 Group C or Group D shall be employed for obtaining and protecting these samples.

### Step 3 Properly perform the test.

Testing during foundation preparation and borrow operations includes some tests that are the same tests performed during other operations. For example, density and moisture tests are covered extensively in chapter 8 of this handbook, so they are only mentioned here even though in-place density and moisture content of foundation soils must be tested as well as fill materials. Common tests that are related to soil moisture and density are listed in table 7-2 along with the ASTM test designation, the title of the test method, its applicability, and the chapter in this handbook where it is described most.

Tests to identify collapsible soils, dispersive clays, and soluble materials are described below as they are more commonly conducted during foundation preparation and borrow operations.

**Collapsible soils** may be identified visually (see figs. 7-1 and 7-2 and by comparing the in situ density of foundation soils to that of the same soil after it has been compacted. The density of collapsible soils is generally less than 90 pounds per cubic foot and their moisture content is generally less than 10 percent.

A nuclear moisture density meter (ASTM D6938) may be used to test the density of collapsible soil by direct transmission provided the soil does not collapse when driving in the pin to make the hole for the probe. Testing the density in backscatter mode may be more appropriate for checking the density of suspect soils with the nuclear gauge, but the results will only represent the soils near the surface. One of the better methods for determining the moisture and density of an undisturbed sample of collapsible soil is ASTM D7263, Laboratory Determination of Density (Unit Weight) of Soil Specimens (Method A—Water Displacement), commonly referred to as the “clod test.” This method determines the density of an irregularly shaped clod.

The clod test can be run in the field. The scale must be adapted so the clod can be measured as it is suspended in air or in water. A container of water and melted wax are also needed. A common crock pot can be used for melting the wax. The steps for the procedure are listed and illustrated.

*Step 1* Tie a string around an undisturbed clod of soil.



*Step 2* Weigh the clod.



*Step 4* Weigh wax-coated clod submerged in water.



*Step 5* Obtain a sample of the clod without wax.

*Step 3* Coat the clod with wax.



*Step 6* Weigh the sample.*Step 7* Oven-dry the sample and weigh it again.*Step 8* Compute the moisture content and dry density. See appendix B, WS 7.2 for a sample calculation using the clod method to determine soil moisture content and density.

**Dispersive clays** may be identified by one of three tests. ASTM D4221, Test Method for Dispersive Characteristics of Clay Soil by Double Hydrometer, can be conducted in the field, but is not commonly considered a laboratory test in NRCS work. ASTM D4647, Test Method for Identification and Classification of Dispersive Clay Soils by the Pinhole Test, has rarely been conducted in the field on NRCS jobs, but has been used when the crumb test failed to identify dispersive soils that were identified as dispersive by the pinhole test. The most common field test for identifying dispersive soils in the field is ASTM D6572, Standard Test Methods for Determining Dispersive Characteristics of Clayey Soils by the crumb test. The crumb test is commonly conducted on NRCS construction sites and thus warrants further description. It is a simple test that should be conducted if there is a potential for the presence of dispersive soils that would adversely impact the project.

The crumb test consists of placing a small clod of soil in distilled water. The clod is allowed to remain undisturbed in the distilled water as the turbidity of the water is visually observed at 2-minute, 1-hour, and 6-hour time intervals. Figure 7-15 shows typical ratings of the crumb test. Crumb test reactions of 3 or 4 indicate a high likelihood the soils are dispersive. The

responsible engineer must be notified whenever dispersive soils are found onsite.

**Soluble materials**, such as gypsum and common salts, can dissolve and create voids that cause collapse or lead to piping of foundation or earthfill soils. The inspector should report, to the engineer, any suspicion of soluble materials in the foundation or materials to be used for fill.

Gypsum particles are opaque to white in color and can often be seen with the naked eye in soils that contain appreciable amounts of gypsum. In areas where gypsum laden soils are common, the inspector should be on the lookout for these particles.

A white film of salt on the soil surface is a good indicator that soluble salts are present. An electroconductivity (EC) meter can be used to measure the EC of soil and give the results in microsiemens per centimeter ( $\mu\text{S}/\text{cm}$ ) or millimho per centimeter ( $\text{mmho}/\text{cm}$ ). EC meters are handheld devices that are well suited for field use; they are commonly used in the NRCS for measuring salinity in cropland. Problems may occur in foundation or earthfill soils that have an EC greater than  $300 \mu\text{S}/\text{cm}$  or  $0.3 \text{ mmho}/\text{cm}$ .

**Frequency of testing**

Whenever Construction Specification 94, Contractor Quality Control, is included in the specification package, a testing frequency is generally specified. For example, moisture and density testing of in-place earthfill may be specified for every 500 cubic yards of earthfill. The specified testing frequency is an estimated amount that is specified for bidding purposes. The actual frequency of testing will vary during the course of the work and should be adequate to document compliance with the specification for moisture and density of the foundation or compacted fill.

For compaction, more frequent testing is needed near the beginning of the work to determine the compactive effort required to compact the various soils to the specified density. Once the process has been established, testing may become less frequent as needed to verify specification compliance. Anytime the equipment or process changes, testing frequency will likely increase until confidence in the process is established. The quality control inspector is responsible for meeting specification requirements for the number of tests

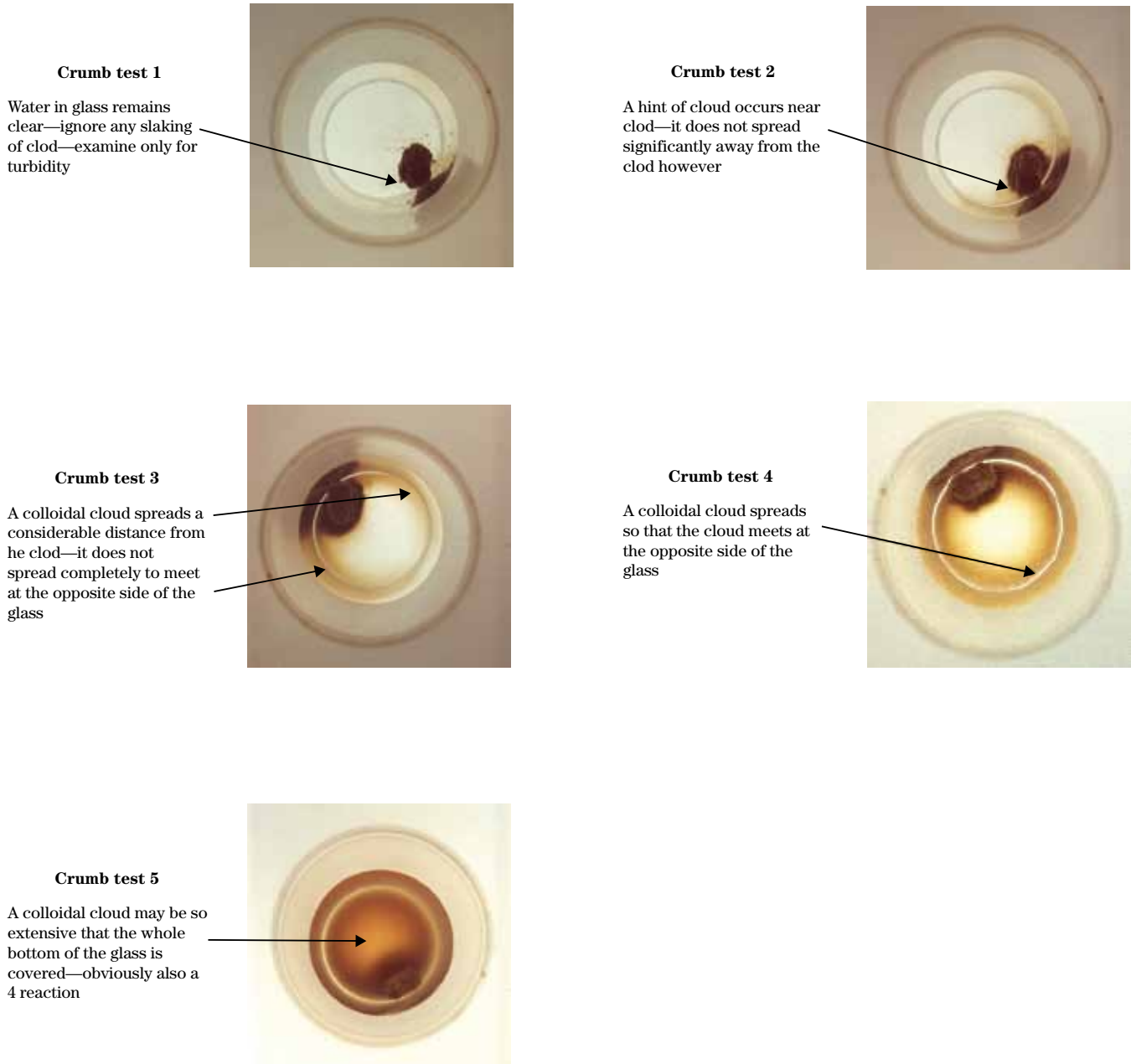


**Table 7-2** Application of and chapter reference for common tests and practices related to soil moisture and density testing

ASTM designation	Standard test methods for:	Applies to		Refer to chapter
		Soil foundations and earthfill	Drainfill and filters	
D698	Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft <sup>3</sup> (600 kN-m/m <sup>3</sup> )) (also known as Standard Proctor)	√	√ <sup>1/</sup>	8
D1556	Density and Unit Weight of Soil in Place by Sand-Cone Method	√		8
D1557	Laboratory Compaction Characteristics of Soil Using Modified Efforts (56,000 ft-lbf/ft <sup>3</sup> (2,700 kN-m/m <sup>3</sup> )) (also known as Modified Proctor)	√		8
D2167	Density and Unit Weight of Soil in Place by the Rubber Balloon Method	√		8
D2216	Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass	√	√	8
D2937	Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method	√		8
D4220	Standard Practices for Preserving and Transporting Soil Samples	√		8
D4253	Maximum Index Density and Unit Weight of Soils Using a Vibratory Table		√	11
D4254	Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density		√	11
D4643	Determination of Water (Moisture) Content of Soil by Microwave Oven Heating	√	√	8
D4944	Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester	√	√	8
D4959	Test Method for Determination of Water (Moisture) Content of Soil By Direct Heating	√	√	8
D6938	In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)	√	√	8
D7263	Laboratory Determination of Density (Unit Weight) of Soil Specimens (also known as the Clod Test)	√		7

1/ ASTM D698 modified for determining density on an oven-dry sample of filter sand (also known as the one-point method)

**Figure 7-15** Crumb test ratings



required and also for conducting an adequate number of tests to verify compliance.

The quality assurance inspector should also conduct tests to verify that quality control is being maintained. The quality assurance plan, when provided, will generally list the required minimum frequency of QA testing. This minimum frequency is often estimated at one QA test for every 10 QC tests, but should be increased if the QA inspector needs to conduct more tests to verify and document QC compliance.

## 645.0703 Records and reports

All test results must be accompanied by a complete description of the test location. For example, record the horizontal location and elevation at the test site of any foundation surface and the elevation of the test location (i.e., foundation surface elevation minus depth at which material is tested).

ASTM and other test standards include a report section that lists all of the items to be reported. It is important to report all of the items listed in the report section of the test standard because the answers may be interpreted differently depending on the information that is available. Also, if all of the information required by the test standard is not recorded, the integrity of the test, tester, and results are less defensible should the test be scrutinized in a contract claim.

Most construction disputes and claims are based on foundation preparation, dewatering, and excavation activities. For this reason, the inspector should be actively monitoring and documenting these activities. In addition, many failures are directly related to foundation preparation, dewatering, and excavation activities and thorough documentation of these items can prove invaluable in an investigation to determine the cause of a failure. Most of this documentation can be handled by making entries in the job diary.

In addition to the standard job diary items of equipment, workforce, weather conditions, and quantities accomplished; there are certain items related to foundation preparation, dewatering, and excavation that must be documented. It is not possible to anticipate and list all items that could later be of value when negotiating a contract modification, defending a claim, or investigating a failure; however, a partial list is provided.

- time of beginning and ending of all surveys including identification of surveyors
- conditions of the worksite during day to day activities
- delays in work, including the cause of the delay and efforts taken to resolve issues

- time of submittal and approval of contractor's dewatering plan
- each stage of the implementation of the dewatering plan
- discussions, deficiencies, and actions related to removal of water
- discussions, deficiencies, and actions related to safety
- materials encountered, especially when they differ from anticipated
- time when groundwater is encountered and contractor's related actions
- facts concerning extent of groundwater impact on construction operations
- conversations related to changes and actions taken
- details related to changes in the limits of excavation and reasons for doing so
- reference to pictures taken and their significance to the diary discussion at hand
- results of or reference to moisture or density tests values that document foundation conditions

Photo documentation should show materials encountered, especially when those materials differ from what was anticipated. Any item that might be valuable in defense against a contract claim or during a deficiency investigation should be documented by a photo. Photos should always be made of groundwater issues including those showing deficiencies in the contractor's dewatering operation. Remember that foundation work will eventually be covered up and photos may be the investigator's only chance to really get a feel for what is there.

Since the job diary is the official record of activities on the site, it is the document that is most thoroughly researched when processing a claim or studying a deficiency. Thus, significant photos that could be valuable in defense of a contract claim or in a deficiency investigation should always be referenced in the job diary.

It may also be helpful to reference a particular photo on the as-built drawings to illustrate the exact location

or item in the photo. The vantage point from which the photo was taken should also be indicated.

The following records and reports are related to excavation, dewatering and foundation preparation:

- Job diary
- WS 7.1—Materials Testing Report: Visual Soil Classification
- WS 7.2—Field Density and Water Content by the Clod Method
- WS 7.3—Report of Blasting Operation
- NRCS-ENG-005 postcard for certifying actions concerning buried utilities
- NRCS-ENG-006 Utility Check Sheet

Samples of job diary entries related to foundation preparation, removal of water, and excavation are included in appendix C of this handbook. The worksheets and forms are included in appendix B along with sample entries to illustrate the use of these.

Additionally, the checklists for foundation preparation, removal of water, and excavation may be completed, kept onsite, and ultimately submitted to the responsible engineer to be filed with contract documents to document accomplished work at various times throughout the performance of the work.

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**645.0704 References**

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