UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2021
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SECTION 35 73 13

EMBANKMENT FOR EARTH AND ROCKFILL DAMS
11/18

****
NOTES: This guide specification covers the requirements for preparing the embankment and blanket foundations and placing and compacting all permanent fills and backfills for earth and rock fill dams. This section was originally developed for USACE Civil Works projects.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

This guide specification has removed paragraphs for related construction activities that have their own UFGS Guide Specifications. These include Section 31 23 00.00 20 EXCAVATION AND FILL, Section 31 00 00 EARTHWORK, Section 31 66 10 ROCK FOUNDATION PREPARATION and Section 31 11 00 CLEARING AND GRUBBING among others. Those Guide Specifications should be included and referenced as is appropriate..

REMOVE INFORMATION AND REQUIREMENTS NOT REQUIRED IN RESPECTIVE PROJECT, WHETHER OR NOT BRACKETS ARE PRESENT.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).
****

PART 1 GENERAL

****
NOTE: This guide specification provides for furnishing all plant, labor, and equipment, and performing all operations in connection with the

placement of embankment materials for earthen or rockfill dams.

The requirements for rock as prescribed herein are intended to be used on embankments involving rock fill sections. Where rock for slope protection is specified, Section 35 31 19 STONE, CHANNEL. SHORELINE/COASTAL PROTECTION FOR STRUCTURES should be used.

****

This specification provides for furnishing all materials, labor, and equipment, and performing all operations in connection with the placement of embankment materials for construction of the [earthen][rockfill] dam.

1.1 UNIT PRICES

****

NOTE: If Section 01 20 00 PRICE AND PAYMENT PROCEDURES is included in the project specifications, this paragraph title (UNIT PRICES) should be deleted from this section and the remaining appropriately edited subparagraphs below should be inserted into Section 01 20 00 as appropriate.

****

1.1.1 Compacted Fill, [Impervious][Pervious][Random]

****

NOTE: Include separate paragraphs for each type of compacted fill material that will be required for the construction of the dam, and select the appropriate bracketed description for each.

****

1.1.1.1 Payment

Payment will be made for costs associated with placement of compacted [impervious] [pervious] [random] fill embankment; spreading, harrowing, moisture control, compacting, removing objectionable materials; and all other incidental work required for the construction, protection, and maintenance of the dam embankment. [This payment is separate to any payment for excavating and transporting of material as specified in Section 31 00 00 EARTHWORK.] Payment for preparation of foundations to receive compacted [impervious] [pervious] [random] fill will be made in accordance with Section 31 66 10 ROCK FOUNDATION PREPARATION.

1.1.1.2 Measurement of Fill Material

Compacted [impervious][pervious][random] fill will be measured for payment in place based upon the established limit lines and the payment lines shown on the plans or as otherwise established. Limit lines will be established by the volume between the foundation lines as determined on the basis of a survey made from excavation [including the cut-off trench] and[accomplishment of foundation preparation (except scarifying)] and the lines, grades and slopes of the accepted embankment.

1.1.1.3 Unit of Measure

Unit of measure: cubic meter yard.

1.1.2 Backfill, [Impervious][Pervious][Random]

****
NOTE: Include separate paragraphs for each type of backfill material that will be required for the construction of the dam, and select the appropriate bracketed description for each.
****

1.1.2.1 Payment

Payment will be made for costs associated with preparation of contacting surfaces, including the spreading, compacting, moisture control, and all other operations incidental to the placement of [impervious] [pervious] [random] backfill. [This payment is in addition to any payment for excavating and transporting of the material as specified in Section 31 00 00 EARTHWORK.] Payment for preparation of rock foundations to receive [impervious] [pervious] [random] backfill will be done in accordance with Section 31 66 10 ROCK FOUNDATION PREPARATION.

1.1.2.2 Measurement

Backfill, [impervious][pervious][random], will be measured for payment in place based upon the established limit lines and the payment lines indicated on the cross sections shown on the plans or as otherwise established. Limit lines will be established by the volume between the foundation lines as determined on the basis of a survey made from excavation [and accomplishment of foundation preparation (except scarifying)]and the lines, grades and slopes of the accepted embankment.

1.1.2.3 Unit of Measure

Unit of measure: cubic meter yard.

1.1.3 Filter [Sand][Gravel][Rock]

****
NOTE: If several classes of material are to be used to include transition zones or a multi-stage filter, a separate pay item should be included for each class.
****

1.1.3.1 Payment

Payment will be made for costs associated with obtaining filter [sand] [gravel] [rock], [transportation to the site (whether from required excavation, borrow, or commercial source),] mixing the materials to the required gradation, spreading, moisture control, compacting, removing objectionable materials, and all other incidental work required for the construction, protection, and maintenance of the filter. This payment is in addition to any payment for excavation (from required excavation or borrow) of the material as specified in Section 31 00 00 EARTHWORK.

1.1.3.2 Measurement

Filter [sand][gravel][rock] will be measured for payment in place based upon the established limit lines and the payment lines indicated on the cross sections shown on the plans or as otherwise established. Limit lines will be established by the volume between the foundation lines as determined on the basis of a survey made from excavation and [accomplishment of foundation preparation (except scarifying)] and the lines, grades and slopes of the accepted embankment.

1.1.3.3 Unit of Measure

Unit of measure: cubic meter yard.

1.1.4 Rock Fill

****

NOTE: If several classes of rock fill material are used, a separate pay item should be included for each class of material.

****

1.1.4.1 Payment

Payment will be made for costs associated with rock fill, including all operations with excavation, quarrying, stockpiling, hauling, placing, moisture conditioning, removing objectionable material, and all other operations incidental to the placement of the rock fill.

1.1.4.2 Measurement

Rock fill will be measured for payment in place based upon the established limit lines and the payment lines indicated on the cross sections shown on the plans or as otherwise established. Limit lines will be established by the volume between the foundation lines as determined on the basis of a survey made from excavation [and accomplishment of foundation preparation (except scarifying)]and the lines, grades and slopes of the accepted embankment.

1.1.4.3 Unit of Measure

Unit of measure: cubic meter yard.

[1.1.5 Additional Rolling for Compaction

****

NOTE: If an end result (production) specification is used for compaction in section COMPACTION, delete this item.

****

1.1.5.1 Payment

Payment will be made for costs associated with additional rolling for compaction.

1.1.5.2 Measurement

****

NOTE: Delete the bracketed reference to Section 35 73 13 if this paragraph is not moved to Section 01 20 00.

****

Additional rolling for compaction will be measured for payment on the basis of the number of roller hours the compaction equipment is operated in accomplishing the compaction specified in [Section 35 73 13 EMBANKMENT FOR EARTH DAMS,]paragraph COMPACTION.

1.1.5.3 Unit of Measure

Unit of measure: hour.

]1.1.6 Instrumentation [Piezometer][Settlement Gage][Survey Marker]

****

NOTE: The installation of instrumentation is not strictly speaking an activity of construction of an embankment dam. This activity should be placed within its own specification division as an item of SPECIAL CONSTRUCTION. There is presently no UFGS guide specification for this item. The specification writer should consider the use of a section for SPECIAL CONSTRUCTION, and if so, delete the following paragraphs.

Include paragraphs for all types of instruments as may be utilized.

****

1.1.6.1 Payment

Payment will be made for costs associated with furnishing, installing, [monitoring] and maintaining the [piezometers] [settlement gages] [survey markers] during construction as specified[in Section 35 73 13 EMBANKMENT FOR EARTH DAMS] during construction, including measurements required to be made by the Contractor.

1.1.6.2 Measurement

[Piezometers] [Settlement gages] [Survey markers] to be installed will be measured for payment on the basis of the number specified[in Section 35 73 13 EMBANKMENT FOR EARTH DAMS].

1.1.6.3 Unit of Measure

Unit of measure: each.

1.2 REFERENCES

****

NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM C33/C33M	(2018) Standard Specification for Concrete Aggregates
ASTM C136/C136M	(2019) Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM D422	(1963; R 2007; E 2014; E 2014) Particle-Size Analysis of Soils
ASTM D698	(2012; E 2014; E 2015) Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/cu. ft. (600 kN-m/cu. m.))
ASTM D1140	(2017) Standard Test Methods for Determining the Amount of Material Finer than 75-µm (No. 200) Sieve in Soils by Washing
ASTM D1556/D1556M	(2015; E 2016) Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method
ASTM D1557	(2012; E 2015) Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft3) (2700 kN-m/m3)
ASTM D2167	(2015) Density and Unit Weight of Soil in Place by the Rubber Balloon Method
ASTM D2216	(2019) Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
ASTM D2487	(2017; E 2020) Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

ASTM D2937	(2017; E 2017; E 2018) Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method
ASTM D4253	(2016; E 2019) Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table
ASTM D4254	(2016) Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density
ASTM D4318	(2017; E 2018) Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D4643	(2017) Standard Test Method for Determination of Water Content of Soil and Rock by Microwave Oven Heating
ASTM D5195	(2014) Density of Soil and Rock In-Place at Depths Below the Surface by Nuclear Methods
ASTM D6938	(2017a) Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

1.3 DEFINITIONS

****
NOTE: Add applicable definitions as appropriate for the project.
****

1.3.1 Embankment

Embankment, as used in these specifications, is defined as the earth [and rock]fill portions of the dam structure and includes all types of earth [and rock]fill and filter materials for the dam [and cut-off trench,]and all other specified or directed earth and rock fills within the limits of the dam[, excepting those stone and filter materials used for slope protection in accordance with Section 35 31 19 STONE, CHANNEL, SHORELINE/COASTAL PROTECTION FOR STRUCTURES].

1.3.2 Compacted Fill

Compacted fill includes all fill, except backfill and rock fill, deposited in layers and compacted by rolling or tamping. The types of compacted earth fill are:

a. Impervious fill for the [cut-off trench][, horizontal and inclined impervious blankets,][and]impervious section of the embankment;

b. Random fill where indicated on the plans;

c. Pervious fill forming the upstream and downstream sections of the embankment or where indicated on the plans, and

d. Filter drainage layers forming the horizontal [and/or vertical or inclined] pervious drainage blankets.

1.3.3 Uncompacted Fill

All fill, deposited in layers but not compacted except by the controlled movement of hauling and spreading equipment.

1.3.4 Backfill

Backfill, as used in these specifications, is defined as that excavation refill which cannot be placed around or adjacent to a structure until the structure is completed and reached a specified concrete strength, requires special compaction efforts, and is defined by limits indicated on the plans and specifications.

1.3.5 Filter Materials

Filter materials are defined as material used as drainage or transition zones between various types of fill and backfill (impervious, pervious, random, and rock fill).

1.3.6 Rock Fill

Those portions of the embankment where rock is used as embankment fill.

1.3.7 Unsatisfactory Materials

****

NOTE: Unsatisfactory material will be defined in accordance with ASTM D2487. This paragraph should be edited as appropriate to delete inapplicable materials.

****

[Materials which do not comply with the requirements for satisfactory materials are unsatisfactory.] [Materials unsatisfactory for use as fill and backfill are those earth and earth mixtures that classify by ASTM D2487 as [CH], [MH], OL, OH, and PT. In addition all topsoil, organics, roots and other organic matter, biodegradable materials, debris, trash, rubble and contaminated soil is unsatisfactory for use as embankment, backfill or engineered fills. Unsatisfactory materials or processes are not in compliance with these specifications.] Notify the Contracting Officer when encountering any contaminated materials.

1.3.8 Unsatisfactory vs Satisfactory

The use of the terms satisfactory and unsatisfactory in this section is in reference to the Contract requirements. Satisfactory materials or processes are in full compliance with these specifications and unsatisfactory materials or processes are not in compliance with these specifications.

1.4 SYSTEM DESCRIPTION

1.4.1 Haul Roads

****

NOTES: Where roads are to be used by other Contractors, the limits of responsibility should be stated in the specifications.

With reference to the coverage in this paragraph, it has been found advantageous to establish a project traffic pattern for jobs of considerable scope and to indicate on the plans acceptable haul road locations and to specify maximum grades and minimum road widths which are considered suitable. Where project operations are varied and the use of haul roads by other Contractors is required, the specifications should so indicate. Detailed requirements for haul roads should be based upon the anticipated length of time the roads will be in use, traffic load and probable types of hauling equipment applicable to the specific project. This paragraph should be modified as necessary to clarify the requirements of the particular project.

****

Haul roads must be [located as indicated and][located and] constructed as approved. Design haul roads to maintain the intended traffic, to be free draining and maintain good condition throughout the contract period, unless otherwise directed. Remove haul roads within the area of contact between the embankment and its foundation and abutments and treat the area as specified in paragraph PREPARATION OF FOUNDATION, PARTIAL FILL SURFACE, AND ABUTMENTS.

Submit a Plan of Operations for approval thirty days prior to commencement of haul road construction or placing embankment and backfill, whichever is earlier, for accomplishing all embankment and backfill construction and for the location and construction of haul roads.

1.4.2 Stockpiling from [Approved Borrow Sources][Required Excavations]

When the excavation from [approved borrow sources][or required excavations] progresses at a faster rate than placement in the fill is being accomplished, stockpile excavated material at approved locations adjacent to the work until its use is authorized. No payment will be made for such stockpiling nor for the reloading and hauling of this material to its final position in the embankment.

1.5 SUBMITTALS

****

NOTE: Review Submittal Description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a “G” to an item if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Plan of Operations; G, DO

30 days prior to commencement of haul road construction or placing embankment and backfill, whichever is earlier, submit for approval a Plan of Operations for accomplishing all embankment and backfill construction and for the location and construction of haul roads. This plan must include, but not be limited to, the proposed sequence of construction for embankment and backfill items, and methods and types of equipment to be utilized for all embankment and backfill operations, including transporting, placing, and compaction. Also include the names and addresses of the commercial testing labs which will perform the soil testing and inspection and describe how all required soils testing will be performed in this plan.

Embankment and Backfill Materials; G, DO

At least 30 days prior to delivery of any Contractor-furnished material to the site of the work, submit soil classification test results, moisture-density curves, gradation curves, and laboratory results of the required tests of the proposed material.

SD-06 Test Reports

Foundation Inspection; G, DO

Provide a foundation inspection report, certified by a registered

Professional Geotechnical Engineer or Geologist, documenting the inspection. The report must include, at a minimum, a description of each geologic stratum encountered along the slopes and excavation bottom, laboratory testing results if any tests were performed, and other pertinent information. The report's main body must be a color copy submitted to the Government within four calendar days of completion of the inspection by the Contractor's geologist. Include figures, tables and photographs as necessary.

Measurement of Fill Material; G, RO

Submit a copy of the records of each compliance survey the next work day following the survey.

Testing; G, RO

Within 24 hours of conclusion of physical tests, three copies of test results, including calibration curves and results of calibration tests.

SD-07 Certificates

Testing; G, RO

Qualifications of the [USACE validated] [validate] commercial testing laboratory or the Contractor's validated testing facilities.

Nuclear Density; G, RO

Use nuclear density testing equipment in accordance with ASTM D6938. In addition, the following conditions are applicable:

a. Prior to using the nuclear density testing equipment on the site, submit to the Contracting Officer a certification that the operator has completed a training course approved by the nuclear density testing equipment manufacturer, the most recent data sheet from the manufacturer's calibration, and a copy of the most recent statistical check of the standard count precision.

b. Provide nuclear density testing equipment capable of extending a probe a minimum of 12 inches down into a hole.

c. Field density reports must include the laboratory density reports applicable to the field data presented.

PART 2 PRODUCTS

2.1 MATERIALS

****
NOTE: This paragraph may be modified to specify soils for various types of fill in accordance with the Unified Soil Classification System. When this is done, the optional sentence should be selected.
****

[Classification of soils will be in accordance with ASTM D2487.]

2.1.1 General

The origin of any fill material in no way determines where it may be used in the embankment. Obtain materials for embankment fills from required excavations, from the borrow areas indicated, or from off-site commercial sources as required. The intention is to use the most suitable materials obtainable from these sources. Material to be wasted will be specifically designated at the time the material is excavated. Materials containing brush, roots, sod, organics or other perishable materials will not be considered suitable. The suitability of the materials are subject to approval and their disposition in the embankment will be as directed. Excavate in the borrow areas in the location determined by the Contracting Officer, whenever such control is necessary to obtain the type of material required for the embankment. Use borrow pits in accordance with Section 31 00 00 EARTHWORK paragraph SELECTION OF BORROW MATERIAL and paragraph OPENING AND DRAINAGE OF EXCAVATION AND BORROW PITS. Mixing of materials during the excavating process at the borrow area may be required.

****

NOTE: The designer may choose to limit the definition of impervious with restriction on liquid limit, plasticity index, or fines content. If so, those restrictions should be added to paragraph 2.1.2.

****

2.1.2 Impervious Fill

Provide material for compacted impervious fill consisting of [GC SC ML CL MH CH clays, silty clays, or clayey silts] classified as cohesive materials in accordance with ASTM D4318, ASTM C136/C136M and ASTM D1140 obtained from the designated borrow areas [or required excavation] [or off-site commercial sources].

2.1.3 Random Fill

Provide material for compacted random fill consisting of any or all types of satisfactory material which are suitable for use in the dam embankment.

2.1.4 Pervious Fill

Material for compacted pervious fill must be clean, free draining sand or sand and gravel obtained from natural deposits [within borrow areas and from designated excavations][or][from sources designated]. Provide particles of material that are free from any objectionable coating and not more than [_____] percent of the material, by weight, and passing a 0.075 mm No. 200 sieve.

2.1.5 Uncompacted Fill

Except as otherwise [indicated or]required, material for uncompacted fill may consist of any or all types of material available from required excavations and designated borrow areas with the exception of material that is considered unsatisfactory as defined in Unsatisfactory Materials.

2.1.6 Backfill

Provide backfill consisting of material of a type and quality conforming to that specified for the contiguous embankment fill material, unless

otherwise directed.

2.1.7 Filter Drainage Layers

Filter materials must meet the quality requirements of ASTM C33/C33M concrete aggregate except as stated herein. Filter materials must consist of sand, gravel, or crushed stone composed of tough, durable, angular particles; must be free from thin, flat and elongated pieces, and must contain no organic matter or soft, friable particles. The material must be washed with clean water such that the final product has no visible soil, soil slurry, or objectionable coatings.

Gradation of the material must be determined in accordance with ASTM D2487, ASTM D422, ASTM D1140, and ASTM D4318. All points on individual grading curves obtained from representative samples of filter material must lie between the boundary limits as defined by smooth curves drawn through the tabulated grading limits plotted on a mechanical analysis diagram. The individual grading curves within these limits must not exhibit abrupt changes in slope denoting skip grading, scalping of certain sizes or other irregularities which would be detrimental to the proper functioning of the filter; and will be well-graded between the limits specified below:.

SIEVE SIZE	PERCENT BY WEIGHT PASSING
[_____]	[_____]
[_____]	[_____]
[_____]	[_____]

2.1.8 Rock Fill

2.1.8.1 Rock

Stone classed as "rock" must be sound; well graded and free draining.[The presence of rock meeting the requirements of slope protection, Section 35 31 19 STONE, CHANNEL, SHORELINE/COASTAL PROTECTION FOR STRUCTURES, will not be objectionable.] Obtain rock from required excavation[and from already existing stockpiles][and from designated quarries]. Shales, mudstone and other rock and excavated material unsuitable for use as rock fill, will be wasted in designated spoil areas.

PART 3 EXECUTION

3.1 CONSTRUCTION

3.1.1 Lines and Grades

****
NOTE: If settlement of the foundation is expected during construction, install settlement gages as detailed in 3.9.2 and 1.1.11.
****

Construct the embankment to the lines, grades and cross sections indicated, unless otherwise directed. The Government reserves the right to increase or decrease the foundation widths or the embankment slopes or make such other changes in the embankment sections as may be deemed necessary to produce a safe structure. Increases in height of section,

made to compensate for shrinkage or consolidation of the embankment material or foundation during construction of the embankment, will not exceed five percent of the height above the foundation indicated without the approval of the Contracting Officer. The end slopes and side slopes of partial fill sections must not be steeper than[one vertical on [_____] horizontal][those shown].

3.1.2 Conduct on the Work

Maintain and protect the embankment in a satisfactory condition at all times until final completion and acceptance of all work under the contract. At all times protect pervious fills, filters, and drainage layers from erosion, runoff, and contamination from different soils or other materials. These materials must be uncontaminated for minimum dimensions shown on the plans. Minimize equipment travel on these zones to prevent segregation, contamination, and breakdown of materials.

If in the opinion of the Contracting Officer the hauling equipment causes horizontal shears or slickensides, rutting, quaking, heaving, cracking or excessive deformation of the embankment, limit the type, load or travel speed of the hauling equipment on the embankment. Replace any embankment material rendered unsuitable after being placed in the embankment and before final acceptance of the work in a satisfactory manner and no additional payment will be made therefor. Excavate and remove from the embankment any material which the Contracting Officer considers objectionable, dispose of such material, and refill the excavated area as directed, all at no cost to the Government. Do not place unsatisfactory materials in the embankment. The Contractor may be required to remove, without additional payment, any embankment material placed outside of prescribed slope lines.

3.2 PREPARATION OF FOUNDATION, PARTIAL FILL SURFACES AND ABUTMENTS

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NOTE: General preparation of the foundation for dam construction should be addressed in Section 31 66 10 ROCK FOUNDATION PREPARATION. The following paragraphs may be deleted or modified as appropriate to provide explicit direction to preparation of surfaces for placement of embankment fill.

****

3.2.1 Earth

After excavation or stripping of the embankment foundation[and excavation of the cut-off trench] to the extent indicated or otherwise required, break down the sides of stump holes, test pits, and other similar cavities or depressions where so directed to flatten out the slopes, and scarify the sides of the cut or hole to provide bond between the foundation material and the fill.[Scarify the slopes and bottom of the cut-off trench as directed.] Unless otherwise directed, fill each depression with either pervious, random, or impervious[, or rockfill] material dependent upon the type of material which is to be placed immediately above the foundation. Place the fill in layers; moisten and compact in accordance with the applicable provisions of paragraphs PLACEMENT, MOISTURE CONTROL, and COMPACTION. Spread materials which cannot be compacted by roller equipment because of inadequate clearances in [_____]-mm-inch layers and compact with power tampers to an extent equal to that of the contiguous embankment fill material. After filling of depressions[and cut-off

trench] and immediately prior to placement of compacted fill in any section of the embankment, loosen the foundation of such section thoroughly by scarifying, plowing, discing or harrowing to a minimum depth of [_____] mm [_____] inches, and adjust the moisture content to the amount specified in paragraph MOISTURE CONTROL for the appropriate type of material, except in areas where this requirement is waived by the Contracting Officer. After removal of roots or other debris turned up in the process of loosening, compact the entire surface of the embankment foundation area [by [_____] complete coverages of the compaction equipment as specified for the appropriate type of fill in accordance with paragraph COMPACTION.] [compacted to a density of [_____] percent in accordance with paragraph COMPACTION.][Proof roll foundation areas in accordance with Section 31 00 00 EARTHWORK paragraph PROOF ROLLING.]

Prior to placement of compacted fill on or against the surfaces of any partial fill section, remove all soft or loose material, all material containing cracks or gullies, and all material that does not conform with the specified zoning of the embankment. Loosen the remaining surface of the partial fill by scarifying, plowing, discing or harrowing to a minimum depth of 150 mm 6 inches, and adjust the moisture content as specified in paragraph MOISTURE CONTROL for the appropriate type of material. Compact the surface of the partial fill section upon which fill is to be placed as specified in paragraph COMPACTION for the appropriate type of fill. No separate payment will be made for loosening and rolling the foundation area, the abutment area, or the surfaces of partial fill sections, but include the entire cost in the applicable contract price for fill.

3.2.2 Rock

Claen all rock surfaces upon which or against which embankment materials are to be placed in accordance with the applicable provisions of Section 31 00 00 EARTHWORK and Section 31 66 10 ROCK FOUNDATION PREPARATION.[Prior to the placement of embankment material upon or against a rock surface, fill all open joints and cracks in that surface with mortar to the depths cleaned. Fill those portions of such rock surfaces where, in the opinion of the Contracting Officer, the compaction of the embankment materials cannot be accomplished satisfactorily with power tampers or other specified compaction equipment with mortar or concrete as directed to the extent necessary to permit satisfactory use of the compaction equipment. Do no leave a thin coat of mortar on smooth, intact rock surfaces. Remove large rock overhangs and protrusions by pre-splitting or line drilling techniques in such a manner as to minimize damage to the underlying rock, or the spaces beneath overhangs and fill around protrusions with consolidated concrete so that satisfactory compaction of embankment materials can be accomplished. Provide vertical surfaces that are no more than [_____] meters [_____] feet in height, and provide benches of sufficient width as necessary so that the average slope of any rock face is not steeper than [_____] vertical on [_____] horizontal. Provide mortar and concrete, including forming as necessary, conforming with the applicable provisions of Section [03 30 53 MISCELLANEOUS CAST-IN-PLACE CONCRETE][03 30 00 CAST-IN-PLACE CONCRETE][_____].]

[3.2.3 Foundation Inspection and Mapping Procedures

Foundation means any area of the excavation to receive concrete, backfill, or embankment, including the entire excavation bottom and side slopes.

Inspections to determine the adequacy of the foundations will be performed by the Contracting Officer in all foundation areas between completion of

the surface preparation and placement of Embankment Fill, Filter Material, Mud Mat, or concrete. The Contractor will cooperate to the extent necessary to assist in the inspection. This will include having equipment and personnel available to assist excavating, compacting, proof rolling, cleaning, etc. The Contractor must coordinate his schedule for foundation preparation and final cleanup with the Contracting Officer to ensure that the cleanup and inspection proceed in an orderly manner.

][3.2.4 Foundation Condition Evaluation

[Government will perform foundation condition inspection of the completed foundation after final cleanup, dental treatment (if required) and mapping/documentation are complete. Notify the Contracting Officer at least seven days before foundation cleanup will be completed and ready for inspection by the Government. Maintain the foundation in a cleaned condition for a period of at least [_____] [days] [hours] for Government foundation inspection. The [____] [days][hours] for Government evaluation starts after the Contracting Officer receives notification from the Contractor that the foundation is completed and ready for mapping and inspection. Government will evaluate excavation surfaces to receive backfill or structures. As used in this Section, evaluation means inspection, testing, mapping, exploratory test pits, interpretation, and decision making. Government will perform inspection of excavated foundation subgrade and cut slopes at each site to obtain a geologic record.

][Proof roll the earth foundation by a fully loaded dump truck or approved roller to detect and eliminate soft spots in the foundation.

][During inspection, following cleanup for geologic mapping, if the Contracting Officer determines that additional excavation is required to improve foundation conditions, perform additional excavation as directed. Clean the areas of additional excavation. The Government will map and inspect the surfaces of additional excavation.

]][3.2.5 Excavation and Foundation Mapping

Foundation mapping will be performed by Government personnel throughout excavation, foundation cleanup, and foundation acceptance inspection. Permit and facilitate safe access to the excavation by Government personnel for geologic mapping, sampling, inspection, and testing of surfaces exposed during construction.

a. Keep traffic and equipment away from test areas during testing to ensure personnel safety and to prevent ground vibrations;

b. Keep traffic and equipment away from personnel performing mapping to ensure personnel safety;

c. Provide support, such as excavating equipment, to permit proper inspection.

Foundation mapping will require excavated surfaces to be closely inspected and documented. The Government will require surfaces to be cleaned by the Contractor to facilitate mapping. Cleaning will require cutting of fresh surface on the excavation bottom and on excavated slopes, and excavation of test pits on excavated slopes and excavation bottom. The Contractor must provide Government personnel access to the excavation bottom for a period of [_____] [days] [hours] after final cleanup and foundation

preparation, and before dental treatment. During excavation and foundation mapping, remove any temporary ramps covering side slopes such that the excavation side slopes can be documented and mapped by the Government. The Contractor must provide equipment to perform test pits as deemed necessary by the Government geologist and engineers performing the excavation mapping.

][3.2.6 Equipment for Foundation Excavation and Mapping

The Contractor must have on site and make available to Government personnel performing mapping and inspection the following equipment with equipment operators to aid in performing excavations for test pits, sampling, inspection and cutting fresh surfaces for inspection and mapping:

a. Excavating equipment - Backhoe with smooth edge bucket and bulldozer.

b. Proof roller - Fully loaded dump truck.

c. Hand tools - Shovels, bars, picks, wedges, and brooms.

d. Water jet - A water jet consists of a high flow nozzle with a supply hose connected to a suitable source of water. Provide a system capable of delivering up to 24 gpm. The flow rate must be controllable at the nozzle.

]3.3 PLACEMENT

3.3.1 General

Do not place fill on any part of the embankment foundation until such areas have been inspected and approved by the Contracting Officer in writing. The gradation and distribution of materials throughout the compacted earth fill section of the dam must be such that the embankment will be free from lenses, pockets, streaks, and layers of material differing substantially in texture or gradation from surrounding material of the same classification. Dump successive loads of material at locations on the fill as directed or approved. Do not place fill upon a frozen surface, nor shall snow, ice, or frozen earth be incorporated in the embankment. Fill will not be placed on or against any dry surface, but against a surface that is moist or damp.

3.3.2 Frozen Material

Do not place embankment on frozen material, or on material which has been subjected to freeze-thaw action. This prohibition encompasses natural ground, all prepared subgrades, whether in an excavation or on an embankment, and all layers of previously placed and compacted earth fill upon which successive layers of embankment fill will be placed. Remove all material that freezes or has been subjected to freeze-thaw action during the construction work, or during periods of temporary shutdowns, such as, but not limited to, nights, holidays, weekends, or winter shutdowns or earthwork operations, to a depth that is acceptable to the Contracting Officer and replace with new material. Alternatively, the material must be thawed, dried, reworked, and recompacted to the specified criteria before additional material is placed. The Contracting Officer will determine when placement of fill must cease due to cold weather. Embankment material containing frozen clumps of soil, snow, or ice is not acceptable.

3.3.3 Rate of Placement

****

NOTE: If construction of the embankment involves a closure section, the following considerations should be taken into account and specified by the designer, if required.

Placement of rock fill in the closure section may be delayed until completion of the compacted fill to elevation [_____] meters feet m.s.l. The rate of placement of materials in the embankment closure section will be such that this section will be completed to elevation [_____] meters feet m.s.l. within a period of [_____] calendar days from the authorized date of diversion, but in no event will the rate of placement in this section be faster than required to construct the embankment to elevation [_____] meters feet m.s.l. within [_____] days from the beginning of fill operations. Subsequent to completion of the embankment closure section to elevation [_____] meters feet m.s.l. and prior to the beginning of topping operations a period of [_____] calendar days will elapse, unless this provision is waived in writing by the Contracting Officer at the time of construction.

Rate of placement of clay fill materials should be governed by the potential for development of high pore pressures in the fill that could lead to instability of the embankment slopes. Appropriate paragraphs should be included to identify elevations where placement may need to cease until pore pressures have dissipated sufficiently to prevent slides or failure of the embankment.

****

Unless otherwise directed, maintain the embankment at approximately the same level regardless of the number of types of materials being placed,[except place rock fills and the adjoining filter blankets with sufficient lag to prevent mixture of embankment and filter blanket and/or rock materials].

3.3.4 Impervious Fill

Place impervious fill in the impervious section of the embankment as shown on the plans[, cut-off trench,][and impervious blanket].

3.3.5 Random Fill

Place random fill in the random sections of the embankment as shown on the plans.

Except as specified below, limits of random sections shown indicate the maximum extent of random material. In general, place the finer grained random material toward the impervious section or blanket and place the coarser-grained random material toward the outer edge of the random section so that a transition in permeability is effected from the

impervious section to the [pervious section][outer portions of the embankment].

3.3.6 Pervious Fill

Place pervious fill in the pervious sections of the embankment as shown on the plans.

3.3.7 Filter Drainage Layers

****
NOTE: Where there are vertical or inclined filters and horizontal filters, a different tolerance may be indicated for each.
****

Place [sand filters][, gravel filters,][and][sand and gravel filters] in the embankment in the manner described and to the lines and grades indicated. Tolerance of plus or minus [_____] mm inches will be allowed.

3.3.8 Rockfill

Construct the [upstream][,][and][downstream][and rock drain] sections of the embankment of quarry run sizes of durable rock dumped and bulldozed into place in not greater than [_____] mm foot lifts to the lines and grades shown, or as staked in the field, and in such manner as to produce a reasonably well graded mass with no objectionable pockets of small stones or clusters of larger stones. A tolerance of plus 300 mm 12 inches and minus 150 mm 6 inches from the slope lines and grades shown will be allowed in the finished surfaces of the rock fills, except that the extreme minus tolerance must not be continuous over an area greater than 20 square meters 200 square feet. All bridging in rock fills shall be broken as well as all slabs and slabby rock. Stone having a length to thickness ratio greater than 3:1 are considered flat, elongated, or flat and elongated and will be rejected. Special care must be exercised in placing rock fill in all areas within 1 m 3 feet of structures to avoid damage to such structures.

3.3.9 Spreading

After dumping, spread the materials by bulldozers or other approved means in approximately horizontal layers over the entire fill areas. Unless otherwise directed, the thickness of these layers before compaction with tamping type rollers must not be more than [_____] mm inches for impervious materials, nor more than [_____] mm inches for other embankment materials, except backfill which must be spread in accordance with paragraph BACKFILL. Unless otherwise directed, the thickness of layers before compaction with rubber-tired rollers must not be more than [_____] mm inches for impervious materials, nor more than [_____] mm inches for other embankment materials except backfill. Spread pervious fill and filters in layers not more than [_____] mm inches in thickness. As soon as practicable after commencement of construction of any section of the embankment, raise or crown the [central portion thereof][area adjacent to the inclined or vertical filter drain] with grades not to exceed [_____] percent so that the surface of the fill will drain freely and maintain throughout construction. Filter material placement should lead the placement of adjacent material to avoid contamination of the filter material. If the compacted surface of any layer of material, exclusive of filter material[and rock fill], is determined to be too smooth to bond

properly with the succeeding layers, loosen it by harrowing, or by any other approved method, before the succeeding layer is placed. At all times during the dumping and spreading processes, maintain a force of men adequate to remove all roots and debris from all embankment materials and all stones of greater than [_____] mm inches in maximum dimension from impervious materials and greater than [_____] mm inches in maximum dimension from pervious materials, except filters. Remove stone, roots, and debris from the embankment and dispose of in an approved manner. Maintain the entire surface of any section of the embankment under construction in such condition that construction equipment can travel on any part of any one section. Remove ruts in the surface of any layer by scarifying before placing and compacting additional material.

3.4 MOISTURE CONTROL

Provide materials in each layer of the fill containing the amount of moisture, within the limits, specified below or as directed, necessary to obtain the specified compaction. Rework material that is not within the specified limits after compaction regardless of density.

3.4.1 Impervious Sections

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NOTE: It is preferable to moisture condition the impervious fill material either at the excavation site, borrow site, or another area that is not on the embankment itself.

****

The moisture content after compaction must be uniform throughout any one layer of impervious materials placed. The moisture content after compaction as determined by ASTM D2216 must be within the limits of [_____] percentage points above optimum and [_____] percentage points below optimum moisture content.

Process material such that the moisture content is within [_____] percent of the specified range prior to placing the material on the embankment. This may require material processing either at the borrow/excavation site or other location near the embankment. Harrowing, or other approved methods may be required ensure a uniform distribution of moisture.

Accurately control the amount of water applied on a layer of fill such that free water does not appear on the surface during spreading and rolling. Should too much water be added to any part of the embankment, so that the material is too wet to obtain the specified compaction, the rolling on that section of the embankment will be delayed until the moisture content of the material is reduced to an amount within the specified limits. Material that is too wet may be worked by discing or harrowing, if necessary, until the moisture content is reduced to an amount within the specified limits. Wet material may also be blended with drier material to produce a product that meets the moisture requirements of this specification.

If, in the opinion of the Contracting Officer, the top or contact surfaces of the partial fill section become too dry to permit suitable bond with the succeeding lift, the Contractor will be required to moisture condition the materials on the fill. The Contractor will loosen the dried materials by scarifying or discing to such depths as may be directed by the COR, dampen the loosened material to an acceptable moisture content, and

compact this layer in accordance with the applicable requirements of paragraph COMPACTION, subparagraph IMPERVIOUS FILL.

3.4.2 Random Sections

****

NOTE: The designer should determine if specified control of the moisture content of the random portions of the embankment is important. In many cases, the density is the only consideration and the random sections may be specified to achieve a certain density regardless of moisture content.

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The upper and lower limits of moisture content, and the moisture control procedures for random materials must be [the same as that specified for impervious material, or pervious material, dependent upon which of these types it most nearly resembles][such that the specified density can be achieved].

3.4.3 Pervious Section

Wet pervious material by sprinkling after spreading on the embankment and [maintain the moisture content of each layer at the optimum for compaction] [keep each layer in an approximately saturated condition] during rolling. Prewetting of pervious material at the sources of excavation or borrow will not be required. Sprinkle with hoses connected to header pipes along the faces of the embankment, by water trucks with pressure spray bars, or by any other approved method. All connections in the water supply system, including the hose connections to the header pipes, must be watertight. Do not direct jets at the embankment with such force that the finer materials will be washed out. Provide capacities of pumps and sizes of header pipes sufficient to supply the required amount of water at all times.

3.4.4 Filter Drainage Layers

Moisture control of graded gravel filter and bedding layers will not be required and sluicing will not be permitted. Moisture control of filters containing a predominate amount of sand particles will be as required to achieve the density specified in paragraph COMPACTION.

3.4.5 Rock Fill

[No moisture control will be necessary on rock fills.][The moisture content of the rock fill must be reasonably uniform throughout each layer of material placed prior to and during compaction. Add water in an amount equal to [15][_____] percent of the volume of the fill to the material on the embankment prior to compaction by uniform spraying from a water truck. The required water amount may be modified based on results of a test fill, as approved by the Contracting Officer.]

3.5 COMPACTION

3.5.1 Equipment

****

NOTES: In determining the use of a method specification versus an end-result (production)

specification, the following should be considered:

a. The use of a method specification involving restrictions on material type, lift thickness, moisture content, and a specified number of passes with approved compaction equipment, a test fill should be required at the start of embankment work, to include foundation preparation. This will allow for the evaluation of the results achieved for particular efforts prior to the beginning of production work.

b. If the designer chooses an end-result (production) specification which would specify material type, lift thickness, moisture content, and in-place density, the requirements of COMPACTION EQUIPMENT and ADDITIONAL ROLLING FOR COMPACTION may be either removed or tailored to fit the project requirements.

With reference to the use of compaction equipment in this paragraph, the following precautions should be noted:

a.The following paragraphs are provided as examples of the information that should be provided within the specifications to describe the selection of equipment to perform construction. Specifications should be written to ensure that the type of compaction equipment will be used which, in the judgment of the designer and Contracting Officer, is best suited to obtain the desired compaction of the material being utilized. Consideration must be given to soil type, lift thickness and placement location. A requirement should be included in the specifications for the performance evaluation of each type of compaction equipment conforming with the specifications and intended for use by the Contractor at an early stage of embankment construction. This equipment evaluation should be accomplished through analysis of test fill areas that are carefully constructed under representative working conditions with materials and moisture contents as specified. Test fill areas may either be separate or part of the permanent work, and for clarity to prospective bidders, payment under a separate item is recommended to equitably cover costs of required variations in equipment coverages, possible changes in equipment loading or foot sizes, as well as intensified field soils testing.

b. For tamping rollers that are either towed or self-propelled, with drums capable of being ballasted with fluid, the provision for a pressure relief valve and safety head should be included. Over-pressurization of fluid ballasted compaction drums to the level of a safety hazard has been rare, but has occurred on several occasions at locations of high elevation and temperature.

c. In compacting materials consisting of shales, sandstones, weathered rock and similar random materials, consideration should be given to specifying sheepfoot-type tamping equipment that has been modified by replacing the standard feet with "chisel" point tamper feet generally referred to as "shale breakers". The end areas of these modified tamper feet tend to break up weathered rock to prevent the bridling effect sometimes created by large rock particles.

d. For compaction of sand and gravel fills or filter and drainage layers, equipment characteristics for both a large and small vibratory roller have been provided for optional selection by the designer, depending upon location, selected lift thickness, gradation, grain shape, and durability properties of the materials. The smaller roller should be specified for materials which exhibit degradation under compaction. Other options, based on construction experience may also be exercised. For example, it has been found that improved trafficability can often be achieved when compacting clean, fine grained, uniform sands by specifying a drum driven self-propelled vibratory roller.

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Provide compaction equipment conforming to the following requirements and use as prescribed in subsequent paragraphs.

3.5.1.1 Tamping Rollers

3.5.1.1.1 Towed

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NOTE: Towed rollers are generally obsolete and seldom used in modern construction. The specification writer should delete this section unless there is an expectation that towed roller will be used.

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Provide tamping rollers consisting of two or more non-vibratory roller drums mounted side-by-side in a suitable frame and towed by either a crawler-type or rubber tired tractor having sufficient power to pull the roller satisfactorily when the drums are fully ballasted. Each drum must be free to pivot about an axis parallel to the direction of travel. Control rollers operating in tandem sets in a manner such that the prints produced by the tamping feet of the tandem units are staggered. Each drum of a roller must have an outside diameter of not less than [_____] m [_____] feet and must be not less than [_____] m [_____] feet in length. The space between two adjacent drums, when on a level surface, must not be less than [_____] m [_____] feet nor more than [_____] m [_____] feet. [Equip each drum ballasted with fluid with at least one pressure-relief valve and with at least one safety head. The safety head must be equal to union-type safety heads equipped with rupture discs suitable for rupturing pressures between 350 and 500 kPa50 and 75 psi. The pressure relief valve is a manually operated valve and must be opened periodically. Instruct

personnel responsible for opening pressure-relief valves periodically to ascertain that valve openings are free from plugging to assure that any pressure developed in roller drums is released at each inspection.] Provide at least one tamping foot for each [_____] square mm[_____] square feet of drum surface. The length of each tamping foot from the outside surface of the drum must be not more than [_____] mm [_____] inches and must be maintained at not less than [_____] mm [_____] inches. The bearing surface of each tamping foot must be flat with a surface area not less than [_____] mm [_____] inches nor more than [_____] mm [_____] inches. During the operation of rolling, the spaces between the tamping feet must be maintained clear of materials which would impair the effectiveness of the tamping rollers. The weight of a roller when fully loaded must be not less than [_____] N/m[_____] pounds per foot of drum length, and the weight of a roller empty must be not more than [_____] N/m[_____] pounds per foot of drum length. The bearing surface, tamping foot size, the drum loading, and the operation of the rollers must be as required to obtain the desired compaction. If more than one roller is used on any one layer of fill, all rollers so used must be of the same type and essentially of the same dimensions. Draw rollers by crawler-type or rubber-tired tractors at a speed not to exceed [_____] km/h[_____] mph. Discontinue the use of rubber-tired towing equipment if the tires leave ruts that prevent uniform compaction by the tamping roller, and the substitution of crawler-type towing equipment may be directed.

3.5.1.1.2 Self-propelled

The use of self-propelled non-vibratory tamping rollers conforming with the following specification will be permitted, and their design and operation will be subject to approval, and subject to the right, at any time during the prosecution of the work, to direct such modifications to the tamping feet or variations in roller drum weight where applicable, as may be found necessary to secure optimum compaction of the earth fill materials. If use of self-propelled tamping rollers causes shearing of the fill, laminations in the fill, or results in inadequate compaction, the Contracting Officer may direct that such rollers be removed from the fill and that appropriate towed tamping rollers be used. Two-or three-drum side-by-side units that are either in drive position or drawn by separate power equipment must have a clearance between adjacent drums not less than [_____] mm[_____] inches nor more than [_____] mm[_____] inches. Two-drum or four-drum equipment separated by cab and differential and arranged in tandem must have its static weight equally distributed to all compaction drums and must have the tandem drums positioned such that the prints of the tamping feet produced by the tandem drums are staggered. The surface on which the tamping feet are mounted must have a minimum outside diameter of [_____] mm[_____] feet and at least one tamping foot for each [_____] square mm[_____] square feet of drum surface. The distance between the centers of any two adjacent tamping feet must be not less than [_____] mm[_____] inches. The length of each tamping foot from the outside mounting surface of the drum must be not more than [_____] mm[_____] inches and must be maintained at not less than [_____] mm [_____] inches. The bearing surface of each tamping foot must be flat and have a surface area not less than [_____] square mm[_____] square inches nor more than [_____] square mm[_____] square inches. Cupped recesses within the bearing surface of each tamping foot will be permitted but must not exceed [_____] mm[_____] inches in depth. During rolling operations, keep the spaces between the tamping feet clear of materials which would impair the effectiveness of the tamping roller. The weight of all roller drums during compaction of fill materials must be maintained uniform and with the weight per foot of drum length not less

than [_____] N[_____] pounds. [For self-propelled rollers with drums capable of being ballasted with fluid, equip each drum with at least one pressure-relief valve and with at least one safety head. The safety head must be equal to union type safety heads equipped with rupture discs suitable for rupturing pressures between 350 and 500 kPa50 and 75 psi. The pressure relief valve is a manually operated valve and must be opened periodically. Instruct personnel responsible for opening pressure-relief valves periodically to ascertain that valve openings are free from plugging to assure that any pressure developed in roller drums is released at each inspection.] For self-propelled rollers in which steering is accomplished through the use of rubber-tired wheels, the tire pressure must not exceed [_____] kPa[_____] psi. Discontinue use of the compactor if the tires leave ruts that prevent uniform compaction by the tamping roller and the substitution of appropriate towed tamping rollers may be directed. When a self-propelled roller is provided with a dozer blade, do not count coverages made with the blade in operation as compaction coverages. Operate self-propelled rollers at a speed not to exceed [_____] km/h[_____] mph.

3.5.1.2 Vibratory Rollers

Equip vibratory rollers for compacting rock fills, pervious sand and gravel fills, or filter and transition drainage layers with a smooth steel compaction drum and operate at a frequency of vibration during compaction operations between 1100 and 1500 vibrations per minute (vpm). Provide vibratory rollers that are either towed or self-propelled and that have an unsprung drum weight that is a minimum of 60 percent of the rollers' static weight. Provide towed rollers that have at least 90 percent of their weight transmitted to the ground through the compaction drum when the roller is standing in a level position hitched to the towing vehicle. Rollers for compacting rock fill, [sand and gravel fills, or filter and drainage layers] must have a minimum static weight of [_____] kN [_____] pounds, a minimum dynamic force of [_____] kN [_____] pounds when operating at 1400 vpm, and an applied force not less than [_____] kN/m [_____] pounds per foot of compaction drum length. [Rollers for compacting sand and gravel fills or filter and drainage layers must have a minimum static weight of [_____] kN [_____] pounds, a minimum dynamic force of [_____] kN [_____] pounds when operating at 1400 vpm, and an applied force not less than [_____] kN [_____] pounds nor greater than [_____] kN/m [_____] pounds per foot of compaction drum length.] The level of amplitude and vibration frequency during compaction will be maintained uniform throughout the embankment zone within which it is operating. Operate rollers at speeds not to exceed [_____] km/h [_____] mph.

3.5.1.3 Rubber-tired Rollers

Provide rubber-tired rollers that have a minimum of four wheels equipped with pneumatic tires. The tires must be of such size and ply to maintain tire pressures between [_____] and [_____] kPa [_____] and [_____] psi for a [_____] kN [_____] pound wheel load during rolling operations. Locate the roller wheels abreast and design so that each wheel will carry approximately equal load in traversing uneven ground. The spacing of the wheels will be such that the distance between the nearest edges of adjacent tires will be greater than 50 percent of the tire width of a single tire at the operating pressure for a [_____] kN [_____] pound wheel load. Provide the roller with a body suitable for ballast loading such that the load per wheel may be varied, from [_____] to [_____] kN [_____] to [_____] pounds. Tow roller at speeds not to exceed [_____] km/h

[_____] mph. The character and efficiency of this equipment will be subject to approval.

3.5.1.4 Power Tampers

Perform compaction of material, in areas where it is impracticable to use a roller or tractor, as provided in paragraph EARTHWORK, by the use of approved power tampers.

3.5.2 Impervious Fill

After a layer of impervious fill material has been dumped and spread, harrow it if required, to break up and blend the fill materials, to remove laminations, ruts or smooth surfaces to enhance bonding between layers. Perform harrowing to the full depth of the layer.

When the moisture content and the condition of the layer is satisfactory, compact the lift [to at least [_____] percent of maximum dry density as determined by ASTM D698, prior to placement of the next layer. Determination of in-place density must be in accordance with ASTM D1556/D1556M and ASTM D6938.][by [not less than][[_____] complete coverages of the tampering roller][[_____] complete coverages of the rubber-tired roller].][Provide complete coverage consisting of the coverage of the entire lift to be compacted with the roller specified.][A complete coverage must consist of the application of compactive effort to the entire lift to be compacted with a single roller drum having the characteristics as specified in paragraph SELF-PROPELLED. The use of four-drum self-propelled equipment that is laterally separated by operator's cab and differential may be used; however, two complete coverages of the lift to be compacted will be achieved by a subsequent offset trip of the roller for coverage of the previously uncompacted central portion of the roller path.] Place portions of the fill which are not accessible to the roller [_____] mm inch layers loose measurement and compacted with power tampers to a degree equal to that obtained on the other portions of the compacted fill by rolling as specified in accordance with paragraph BACKFILL. Dumping, spreading, sprinkling, and compacting may be performed at the same time at different points along a section when there is sufficient area to permit these operations to proceed simultaneously.

3.5.3 Pervious Fill

After each layer of pervious material has been dumped and spread, and the moisture content is in accordance with the provisions of paragraph PERVIOUS SECTION, compact the entire surface of the layer [to an average of [_____] percent minimum relative density][by not less than [_____] complete coverages of [the rubber-tired roller][the vibratory roller]].

[3.5.4 Additional Rolling for Compaction

If, in the opinion of the Contracting Officer, the desired compaction of any portion of the embankment is not achieved by the minimum number of coverages specified, make additional complete coverages over the surface area of such designated portion until the desired compaction has been obtained.

]3.5.5 Filter and Transition Drainage Layers

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NOTE: The following paragraph for Transition Layers does not include bedding for riprap slope protection, which should be provided under Section 35 31 19 STONE, CHANNEL, SHORELINE/COASTAL PROTECTION.
****

Accomplish compaction of filter soil using the compaction equipment described in subparagraph VIBRATORY ROLLERS of paragraph COMPACTION above. The roller must make a minimum of two (2) passes, acting in vibratory mode, across the initial lift of filter material. Upon completion of these first 2 passes, check the density of the filter material. Make additional passes of the vibratory roller until a relative density between [_____] and [_____] percent is attained based on the maximum dry density obtained in accordance with ASTM D4253 and minimum dry density as determined by ASTM D4254. The number of passes required to achieve a relative compaction of [_____] percent must be the minimum required number of passes on subsequent lifts of filter material. Compaction equipment must be clean and free from other fill types or debris and must not result in contamination of the filter material. Slightly sope adjacent lifts of other fill types to drain away from the filter material. Remove and replace any contaminated filter material at no additional cost. Placement methods must not result in segregation of the filter material (such as but not limited to placement via conveyor of chute).

3.5.6 Rock Fill

After the rock fill has been dumped and spread to the thickness specified, compact the entire surface of the layer by not less than [_____] complete coverages of the vibratory roller specified in paragraph VIBRATORY ROLLERS. Provide a complete coverage consisting of the entire coverage of the area with one trip of the equipment specified. Each trip of the roller must overlap the adjacent trip not less than [_____] mm feet.

3.6 BACKFILL

3.6.1 General

Do not place embankment fill, filter soil or backfill against a concrete structure until the top of the structure has been completely placed, and has reached 80 percent of its design strength. Bring fill up in lifts evenly on both sides of structure and headwall structures with no more than [_____] m[_____] feet difference in elevation on opposing sides of the structure.

Subsequent to the concrete structure attaining 80 percent of design strength, backfill operations may be initiated but no rolling or hauling equipment will be permitted to pass over the structure, or within [_____] mm [_____] feet of any part of the structure. During this period, backfill may be placed against the sides of the structure and to a minimum thickness of [_____] mm [_____] feet over the top of the structure, if compaction is accomplished by power tampers as specified in paragraph POWER TAMPERS. Before passage of hauling and rolling equipment over the top of the conduit or other structure will be permitted, the depth of fill over the concrete must be sufficient to permit such passage without inducing harmful stresses or vibrations in the structure.

3.6.2 Placement

Place backfill in [_____] mm inch layers and thoroughly compact. Unless otherwise directed, the placing and compacting of all backfill material and the control of its moisture content must conform to the applicable provisions of paragraphs PLACEMENT, MOISTURE CONTROL, and COMPACTION. Keep fill in back of wing walls at approximately the same elevations as that of the backfill, gravel blankets, riprap, or derrick stone on the opposite side of the wall until placement has reached the maximum elevation of the materials to be placed on the toe of the wall. Keep drainage openings through walls open at all times.

3.7 FIELD QUALITY CONTROL

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NOTE: FAR Part 46.312 establishes a requirement for Contractor Quality Control (CQC) in construction contracts and ER 1180-1-6 requires that a CQC section based on Sections 01 45 00.00 10, 01 45 00.00 20, and 01 45 00.00 40 QUALITY CONTROL be included in contracts of $1,000,000 or more. Use of Section 01 45 00.00 10, 01 45 00.00 20 and 01 45 00.00 40 for contracts of less than $1,000,000 is discretionary. This part of the specifications must be consistent with the CQC section.

Use caution when applying nuclear gages for in-place density measurement of cohesive and cohesionless soils. Soils consisting of mica, halloysite, some other chemical composition, or oversize rocks and large voids would affect the measurement accuracy of wet density. Sand Cone or similar field density tests should be performed periodically at the same location as Nuclear Tests to assure nuclear testing is providing accurate information.

Specifier may desire the use of a tabular format for frequency of testing of materials.

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Establish and maintain field quality control for embankment and backfill operations to assure compliance with contract requirements and maintain detailed records of field quality control for all operations including but not limited to the following:

3.7.1 Materials Testing

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NOTE: Types of tests and frequency of testing should be detailed below. Types of tests and frequency of testing will be dependent upon the types of materials utilized, configuration of foundation and embankment, placement and compaction procedures required, moisture control requirements etc. Testing requirements are material type specific rather than embankment fill type specific. It is desirable to present the testing frequency and type in tabular form.

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Perform sufficient testing to ensure that the fill is being constructed as specified. The testing program specified below will be considered the minimum acceptable frequency of testing. This does not relieve the Contractor from the responsibility of performing additional testing, if required to ensure compliance with these specifications.

[3.7.1.1 Soil Classification Tests

Soil classification tests will be performed in accordance with ASTM D2487. One initial classification test will be required for each different classification of material to be utilized as embankment fill or backfill. As prescribed in ASTM D2487, grain size analyses in accordance with ASTM D422 and Atterberg limits in accordance with ASTM D4318 will be performed on each different classification. Submit additional tests for every [_____] cubic mcubic yards of embankment or backfill material. Soil classification tests will be performed on foundation material as required to determine the acceptability of the in-situ soils. Additional tests will be required if noticeable changes in the material occur.

]3.7.1.2 Cohesive Material Testing

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NOTE: Edit the following to comply with the method selected to determine the optimum properties (i.e., density and moisture content, LL, PL, PI).
****

3.7.1.3 Moisture Density Relationships

The moisture-density relations for each different classification of cohesive material utilized will be determined in accordance with [_____] [ASTM D698], [Method A] [Method B] [Method C].[Prior to placing any fill material containing cohesive material, a minimum of [_____] five-point [_____] compaction test will be performed on representative samples of the material to be used as fill.] During fill placement a minimum of one additional moisture-density test will be performed for every [_____] cubic mcubic yard placed. Additional tests will be required each time a new material is encountered.[The moisture-density curves will be compiled to form a family of curves which will be utilized to estimate optimum properties (maximum dry density and optimum moisture content) to be used with field density test.]

3.7.1.4 Water (Moisture) Content Tests

Determination of water content will be performed in accordance with ASTM D2216.[ASTM D4643 may be used when rapid moisture content results are needed. All rapid results obtained by ASTM D4643 will be confirmed by a test on a duplicate sample performed in accordance with ASTM D2216. In the event of disagreement between the results, ASTM D2216 will govern.] One water content test will be performed for each [_____] cubic mcubic yards of material placed [or each lift of material whichever is less].[These tests will be in addition to the water content tests performed in conjunction with in-place density tests.] Backfill and fills not meeting the required specifications for water content will be retested after corrective measures have been applied.

3.7.1.5 In-place Density Testing for Cohesive Materials

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NOTE: The designer should pick the method or methods of In-place density which are acceptable. If uncompacted fill is specified density control may not be required.

Use caution when applying nuclear gages for in-place density measurement of cohesive and cohesionless soils. Soils consisting of certain chemical composition, or oversize rocks and large voids would affect the measurement accuracy of wet density.

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The in-place density of the cohesive materials will be determined in accordance with [ASTM D1556/D1556M] [, ASTM D2167] [, ASTM D6938] [, ASTM D2937] [, or] [ASTM D5195]. At least one (1) in-place density test will be performed on [each lift of material or] every [_____] cubic mcubic yards of completed fill whichever is more frequent with the horizontal locations randomly staggered in the fill.[At each field density test location, soil samples will be obtained and one [one-point] [two-point] compaction test, one moisture content, [one grain size analysis,] [and one Atterberg limits test,] [if applicable,] will be performed on the sample.][The results of the [one-point] [two-point] compaction test and the moisture content test will be utilized to obtain the optimum properties to compare to the results of the in-place density test.][For use with the family of curves to determine the optimum properties of the material a [one-point] [two-point] compaction tests will be performed in conjunction with each in-place density. A portion of the soil from the in-place field density test and soil obtained immediately adjacent to the field density test location will be used for a [one-point] [two-point] compaction test. The minus 19 mm 3/4-inch portion of the soil will be subjected to [_____] compactive effort using a [150 mm][6-inch][_____] compaction mold in accordance with the procedures presented in ASTM D[_____] [ASTM D698] [ASTM D1557]]. Fill not meeting the required specifications for in-place density will be retested after additional compaction has been completed.[When nuclear method is used for in-place density testing according to ASTM D6938, the first test and every tenth test thereafter for each material type will include a sand cone correlation test in accordance with ASTM D1556/D1556M. The sand cone test will be performed adjacent to the location of the nuclear test, will include a nominal 150 mm6 inch diameter sand cone, and will include a minimum wet soil weight of 2.7 kg 6 pounds extracted from the hole. Nuclear density testing equipment will not be used during rain. The density correlations will be submitted with test results. Each transmittal including density test data will include a summary of all density correlations for the job neatly prepared on a summary sheet including at a minimum:

a. Test Identification Number.
b. Test location.
   Station.
   Coordinates.
c. Elevation of Lift.
d. Lift number (if appropriate).
e. Photo number (if appropriate).
f. Meter serial number and operators initials.
g. Standard count for each test.

h. Material type.
i. Probe depth.
j. Moisture content by each test method and the deviation.
k. Wet density by each test method and the deviation.
l. Pass/Fail.
m. Retest.
n. Comments.]

[3.7.1.6 Cohesionless Material Testing

3.7.1.6.1 Compaction Tests

Run not less than one relative density test for every [3,000] [_____] cubic m[3,900] [_____] cubic yards of cohesionless fill in accordance with ASTM D4253 and ASTM D4254.

[3.7.1.6.2 In-place Density Tests

The in-place density of the cohesionless materials will be determined in accordance with [ASTM D1556/D1556M] [, ASTM D2167] [, ASTM D6938] [, ASTM D2937] [, or] [ASTM D5195]. Run not less than one (1) field in-place density test on [each lift of material or] every [shift][day] [_____] cubic m cubic yards of completed embankment fill or backfill whichever is less. Horizontal locations will be randomly staggered in the fill. When nuclear method is used for in-place density testing according to ASTM D6938, the first test and every tenth test thereafter for each material type will include a sand cone correlation test in accordance with ASTM D1556/D1556M. The sand cone test will be performed adjacent to the location of the nuclear test, and will include a nominal 150 mm6 inch diameter sand cone, and will include a minimum wet soil weight of 2.7 kg6 pounds extracted from the hole. The density correlations will be submitted with test results. Each transmittal including density test data will include a summary of all density correlations for the job neatly prepared on a summary sheet including at a minimum:

a. Test Identification Number.
b. Test location.
   Station.
   Coordinates.
c. Elevation of Lift.
d. Lift number (if appropriate).
e. Photo number (if appropriate).
f. Meter serial number and operators initials.
g. Standard count for each test.
h. Material type.
i. Probe depth.
j. Moisture content by each test method and the deviation.
k. Wet density by each test method and the deviation.

][3.7.1.6.3 Water (Moisture) Content Tests

Determination of water content will be performed in accordance with ASTM D2216.[ASTM D4643 may be used when rapid moisture content results are needed. All rapid results obtained by ASTM D4643 will be confirmed by a test on a duplicate sample performed in accordance with ASTM D2216. In the event of disagreement between the results, ASTM D2216 will govern.] One water content test will be performed for each [_____] cubic mcubic yards of material placed[or each lift of material whichever is less].[These tests will be in addition to the water content tests performed in

conjunction with in-place density tests.] Backfill and fills not meeting the required specifications for water content will be retested after corrective measures have been applied.

][3.7.1.6.4 Additional Testing

The Contracting Officer may request additional tests if there is reason to doubt the adequacy of the compaction, or special compaction procedures are being used, or materials change, or if the Contracting Officer determines that the Contractor's testing is inadequate, or the Contractor is concentrating backfill and fill operations in a relatively small area.

]]3.7.1.7 Materials

Suitability of embankment and backfill materials.

3.7.1.8 Fill Placement

Layout, maintaining existing drainage, moisture control, thickness of layers, removal of oversized material, spreading and compaction for embankment and backfill.

3.7.1.9 Grade and Cross Section

Surveys to verify that the dimensions, slopes, lines and grades conform to those shown on the drawings.[Surveys to monitor settlement gages to measure foundation settlement.] [Surveys to locate core boring locations and elevations to determine foundation settlement.]

3.7.1.10 Testing by the Government

During the life of this contract, the Government [or its Contractors] will perform quality assurance tests. Make available to the Government [or its Contractors] the equipment to perform these test.

3.7.1.11 Reporting

On a daily basis, furnish the inspection records and all material testing results, [the quantity of fill placed,] as well as the records of corrective action taken, in accordance with Sections 01 45 00.00 10, 01 45 00.00 20, and 01 45 00.00 40 QUALITY CONTROL.

3.8 SLIDES

In the event of slides, in any part of the embankment prior to final acceptance of the work, remove material from the slide area, as directed, and rebuild such portion of the embankment. In case it is determined that the slide was caused through the fault of the Contractor, perform the removal and disposal of material and the rebuilding of the embankment without cost to the Government; otherwise this work will be paid for at the applicable contract unit prices for borrow excavation and compacted fill or backfill.

3.9 PIEZOMETERS, SETTLEMENT GAGES AND SURFACE REFERENCE MARKS

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NOTE: The installation of instrumentation is not strictly speaking an activity of construction of an embankment dam. This activity should be placed

within its own specification division as an item of SPECIAL CONSTRUCTION. There is presently no UFGS guide specification for this item. The specification writer should consider the use of a section for SPECIAL CONSTRUCTION, and if so, delete the following paragraphs.

Include paragraphs for all types of instruments to be utilized.

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[3.9.1 Government Installed Piezometers

A number of piezometers will be installed on the embankment foundations by the Government with its own forces. Connections and extensions of riser pipes must be made by the Contractor with materials furnished by the Contractor. Determine the elevation of the top of the riser pipe immediately before and immediately after each extension is added to the pipe. Keep the top of such pipes at least 600 mm 2 feet above the embankment surface. During construction, place a mound of fill around the riser pipes and compact to the same density and moisture content as the surrounding fill material. Conduct the required operations in such a manner that the devices will not be damaged. Place suitable markers and guard posts around the gages for protection. No separate payment will be made for such protection or for special measures required in connection with the installation of these devices; include all costs in the contract prices bid for related items of work.

][3.9.2 Location and Installation of Settlement Gages

Furnish and install settlement gages for determining foundation and embankment settlement during construction. Provide type, arrangement and location of gages as shown. The areas in which adjustment in quantities will be made as a result of foundation settlement are as indicated on the plans. Place the base plate on a level surface of well compacted foundation material. Determine the elevations of the base plates before placing fill material and again within 48 hours after completion of the embankment. Determine the elevation of the stem immediately before and immediately after each extension is added. These elevations will be verified by the Contracting Officer. Carefully install the stem plumb. Extend the stem in increments as the embankment rises with the top of the stem at a minimum of 600 mm 2 feet above the surface of the embankment. Conduct these operations in such a manner that the gages will not be damaged. Place suitable guard posts around the gages for protection. Compact fill around the stem to the same density and moisture content as the surrounding material. Restore or replace any settlement gage damaged or destroyed due to fault or negligence at no additional cost to the Government. No additional payment will be made for compaction of fill around and over the settlement gages or for interference with the Contractor's operations resulting from the settlement gage installations.

][3.9.3 Surface Reference Marks

Furnish and install surface reference marks as shown. Furnish the horizontal and vertical location of each reference mark with respect to established bench marks at the time of installation, and every [_____] calendar days thereafter until completion of the contract. Conduct these operations in such a manner that the reference marks will not be disturbed or damaged. Replace or repair any reference mark disturbed or damaged due

to negligence on the Contractor's part and furnish the correct horizontal and vertical locations the Contractor's expense.

] -- End of Section --