Standard Operating Procedure for Kansas Natural Resources Conservation Service Public Law 566 Construction

Surveys

Surveys for design and geologic investigation will be conducted according to Section KS650.180 of the National Engineering Handbook Part 650 (NEH 650), *Engineering Field Handbook*.

Construction stakeout for project dams and other complex structures generally involves basic staking of the embankment and excavations. The amount of basic staking required is dependant on the site conditions.

A stakeout schedule should be developed for each individual item that is part of the basic staking. The stakeout schedule will generally include the following information in a table form:

- Station
- Planned elevation
- Planned slope or grade
- Description - The description should indicate why that location is being staked such as an elevation change, cross section change, or similar item.

The stakeout schedule will serve as a guide to the field surveyors to ensure that all required locations are staked to provide adequate information to the contractor and obtain accurate information for quantity computations.

The schedule can be developed using the plan view and baseline profile. Each full station should be shown on the schedule along with partial stations required for changes in elevation or cross section. Other locations that must be found in the field can be estimated from the drawings and labeled with a "±" before the station. Structures with curved baselines should be staked every 25 or 50 feet depending on the radius of the curve.

The size of stakes and hubs given in the following instructions are recommendations only. Other sizes can be used at the discretion of the field personnel.

Embankment Stakeout - This stakeout can be aided by developing stakeout tables showing the toe distance for various elevations or feet of fill. It is recommended to use elevations if the total station or survey grade Global Positioning System (GPS) is utilized for stakeout. The Embankment Stakeout Tables spreadsheet can be used to develop stakeout tables.

The embankment will be staked at all full (100-foot) stations and at all grade breaks and changes in cross section of the embankment or cutoff trench. Distance between stations will not exceed 100 feet.

(a) The centerline at each station will be located with a flag.

(b) Interior toes (such as the Zone I or 3:1 toe and the cutoff trench toe) will be located during initial stakeout and recorded in the notes but not marked until after stripping, and then they will be marked with a flag only.

(c) Exterior toes will be marked with a fluorescent pink flag and anchored by a 1-inch x 2-inch stake at full (100-foot) stations only (unless warranted at intermediate stations). Otherwise, intermediate station toes shall be flagged only.

(d) Offsets will be marked by a 2-inch x 2-inch hub set with a pink flag. The hubs will be driven flush and normally set 20 feet beyond the toes. A 1-inch x 2-inch witness stake will be set directly behind the hub. The station will be marked on the back. The fill to the top of the dam from the top of the hub will be marked on the front. The distance to the centerline will be marked below the fill, and the offset distance will be marked at the bottom and encircled. Offsets at intermediate stations are optional.

Auxiliary Spillway Stakeout - Stakeout tables similar to the embankment stakeout tables can be developed if desired for large spillways. This stakeout will normally be part of the contractor's construction survey requirements unless the excavation is a payment item.

(a) No cut-no fill points (for example, inside dike) will be marked with a white flag anchored by a stake and set to finish grade distance. Outside toes of dikes will be marked with a fluorescent pink flag only.

(b) Offsets will be marked by a 2-inch x 2-inch hub set with a fluorescent pink flag. The hubs will be driven flush and normally set 10 feet beyond the toes. A 1-inch x 2-inch witness stake will be set directly behind the hub. The station will be marked on the back. The cut to the finish grade and the distance to the centerline of the spillway will be marked on the front. The fill to the dikes can be added (if needed). Offset distance will be marked at the bottom and encircled. The cut or fill will be from the top of the hub to the finish grade of the spillway floor or dike.

Cutoff Trench and Principal Spillway Trench General Procedure -

(a) Determine the location of the toes and record in the notes but do not stake during embankment stakeout. For quantity computations, use these locations if actual stripping is greater than 1.0 foot.

(b) Stake the toes after stripping has been completed by the contractor. For quantity computations, use these locations if actual stripping is less than 1.0 foot.

Cutoff Trench Stakeout -

(a) Toes will be marked with a white flag.

(b) A 1-inch x 2-inch offset with white flag will normally be set 5 to 10 feet beyond the toe on 1 side. The stake will be marked with the station on the back. The cut from the top of the stake and the distance to the centerline will be marked on the front.

Principal Spillway Stakeout -

(a) The pipe trench will be staked the same as the cutoff trench--except offsets will be marked with a yellow flag.

(b) The approach channel, stilling basin, and outlet channel will be staked with white flags at the toes and 2-inch x 2-inch offset stakes with a 1-inch x 2-inch witness stake normally set 5 to 10 feet beyond the toes. A flag will be set with the stake and marked in the same manner as in the auxiliary spillway.

(c) 2-inch x 2-inch hubs will be driven to the nearest 0.01 foot for pipe bedding grade at each joint. A brush will be set with the hubs.

Drain Stakeout -

(a) Centerline of drains will be marked with a white flag on 50-foot (minimum) intervals.

(b) A 1-inch x 2-inch stake will be driven to 1 side at a convenient distance and marked with the station and cut to the bottom of the trench at 100-foot intervals, grade breaks, and horizontal deflection points.

Excavated Borrow -

A topographic map of the excavated borrow will be made where possible. The survey can be completed with a total station or the survey grade GPS unit. Completed borrow areas that are subject to filling from ground water may have to be surveyed prior to completion of the structure to get an accurate topographic map.

Permanent Bench Marks -

(a) Set at least 2 permanent bench marks in line with the centerline of the dam where possible. On dams with points of intersection (PIs), additional bench marks may be required.

(b) Set the location on an even station or foot if possible, near the boundary fence, or in an area where little disturbance will occur and where no settlement is expected.

(c) Use the survey grade GPS unit to reference all permanent bench mark locations to Kansas state plane coordinates using metric units for horizontal control.

(d) Set the elevations of the cap to the nearest 0.01 foot by running a bench level circuit through the bench marks.

(e) Mark the aluminum cap with the site number and bench mark number (for example 12-1 or 12-20).

Plots and Quantity Computations

(a) Plots will be made of all embankment and cutoff trench stations.

(b) The embankment and cutoff trench will be plotted on the same cross section--except “cutoff-only” stations.

(c) Plots of other excavation areas are optional and will be made if needed to visualize cross sections to compute quantities.

(d) Stripping shots will be plotted “as is” to actual stripping depth. This lower limit of actual stripping, as well as common excavation, will be drawn in red.

(e) A blue line 1.0 foot below natural ground will be plotted where actual stripping exceeds 1.0 foot. A notation will explain where overstripping was approved for payment (for example “approved” or “not approved” can be shown in footnotes for each page and referenced on plots with symbols such as “*” and “**”). Similar notations should be documented in the field books.

(f) The embankment quantity will be figured separately from the cutoff trench and will include actual stripping that is less than or equal to 1.0 foot. The cutoff trench and any approved overstripping will also be figured separately.

(g) Cutoff trench overexcavation that was not directed will be plotted in blue, and a notation will explain that it was not approved for payment.

(h) Before plots are made, the book will be checked. Plots will be checked against the book before quantities are figured. Quantities will be checked before entering in the quantities folder. The quantities folder write-off will then be checked.

Job Diaries

(a) Fill out the title page, bid schedule, and material certification record. Bid schedule and material certification record are optional after Job Diary Book No. 1.

(b) Keep the equipment operating record current and accurate.

(c) For the cutoff trench, the foundation drain, and the blanket drains, record the bottom of the trench/drain elevation plus the soil classification on Page 95.

(d) If water use is measured through a meter, record water use data on Page 98.

(e) For concrete placement data, record the following on Page 100:
- Report number
- Date
- Air
- Slump
- Temperature
- Location of placement
- Cylinder number
- Time started and stopped

Field Books

(a) Field surveys will be entered in books according to the following format:
- An index will be placed on Page 2.
- Bench mark elevations and descriptions will be entered on Pages 3 and 4.
- The stakeout schedule, if developed, will be entered starting on Page 5
- Notes will have headings that include the following:
  - Survey
  - Title
  - Date
  - Weather
  - Party
  - Duties
- Each level circuit will be closed out.
- Red figures and red figure checkout will be initialed and dated. Note and initial surveys that have been plotted also.
- Cutoff and drain checkouts will include classification of the soil at the bottom of the trench.

(b) Surveys to be entered in Books A, A-1, A-2, etc.:
- Bench mark schedule
- Stakeout schedule
- Stakeout tables
- Stakeout of the following:
  - Embankment
  - Additional berm upstream
  - Local berm upstream
  - Local berm downstream
  - Cutoff trench
- Checkout of the cutoff trench
- After stripping cross sections

(c) Surveys to be entered in Books B, B-1, B-2, etc.:
- Bench mark schedule
- Stakeout schedule
- Stakeout tables
- Stakeout of the following:
  - Auxiliary spillway and wing dikes
  - Diversions
  - Waterways
- Checkout of auxiliary spillway sub-grade

(d) Surveys to be entered in Books C, C-1, C-2, etc.:
- Bench mark schedule
- Stakeout schedule
- Stakeout and checkout of principal spillway trench and filter diaphragm
- Approach channel and outlet channel
- Principal spillway pipe elevations and joint gap measurements
- Backfill to bedding grade in pipe trench
- Stilling basin
- Stakeout and checkout of foundation drain, blanket drain, and special drains
- Drain pipe elevations

(e) Surveys to be entered in Books D, D-1, D-2, etc.
- Bench mark schedule
- Partial pay cross sections
- Permanent bench mark circuit and elevations
- Permanent bench mark horizontal coordinates from GPS
- Final checkout of the following:
  - Embankment
  - Wing dikes and auxiliary spillway
  - Local berm downstream over pipe
  - Diversions
  - Waterways
  - Final clearing line

(f) Surveys to be entered in Books E, E-1, E-2, etc. ("Miscellaneous"):
- Bench mark circuit
- Stakeout of clearing line
- Construction surveys (all items)
- Contractor surveys
- Final grade stakes

One-Point Family of Curves Method for Determining Moisture-Density Values

The purpose of the "One-Point Family of Curves Method" is to quickly determine the optimum moisture and maximum density values for a specific earthfill test sample. The method is particularly useful when borrow areas contain materials of varying weight and texture as is often the case in an alluvium flood plain from which earthen dams are frequently built.

The method has been used in state highway and Natural Resources Conservation Service (NRCS) (formerly Soil Conservation Service) construction for several years at locations in several states. It has been found to be reasonably accurate in predicting the optimum moisture-maximum density values that would be obtained by completing the compaction test curve as described for Method A compaction in American Society for Testing and Materials (ASTM) D 698. The method is also useful for Methods B, C, and D described in the ASTM.

The method is outlined in the following steps:

Step 1. Construct a Family of Curves
A family of curves is developed from compaction test data compiled on soil samples tested in accordance with the procedure as set forth in ASTM D 698.

The compaction test curve data used to develop a family of curves should be from tests made on soil materials taken from the specific construction site and from other compaction test curves available from nearby sites with similar soils.

It is suggested that the family of curves be developed on 8-inch x 11-inch sheets of cross section paper with a scale of 5% moisture to the inch on the abscissa (x-value) and 5 pounds per cubic foot (pcf) to the inch on the ordinate (y-value).

The first step in developing the family of curves is to plot the optimum moisture-maximum density values available from each of the compaction test curves

on the cross section paper. The points will fall into a slightly scattered pattern covering the range of soils represented. A smooth curve is then drawn through these points that will represent the average optimum moisture-maximum density values of the soils tested.

This smooth curve forms a reference line and is the base line from which the family of curves is developed. Soils with optimum moisture contents more than two points from the reference line should be specifically identified for further testing according to ASTM D 698.

All compaction test curves used in plotting the points above, except those identified for special testing and handling, are then plotted to scale on the reference line. The plotting is accomplished by first shifting the moisture values of each compaction test curve either to the right or to the left by an amount and direction required to shift the maximum density value from its plotted position to the newly established reference line for the family of curves. These curves when plotted in this shifted position on the reference line will serve to guide the shape of the family of curves to be drawn.

It is suggested that the family of curves be completed with a curve plotted at each two-pound maximum density interval beginning at selected points on the reference line. Each curve of the family of curves is then drawn as guided by the compaction test data curves previously plotted. Care should be taken to evenly space each curve in relation to adjacent curves of the family and to prevent overlapping, even though the compaction test data curves may overlap at their extremities. All curves of the family of curves are not likely to assume the same shape; therefore, they should be drawn with an even transition as well as kept evenly spaced. The family of curves consists of these newly drawn curves and the reference line. It can be lifted from the worksheet used in developing it to a new sheet of cross section paper for field use.

The family of curves is a working tool to be used with a plotted point representing a specific soil sample as determined by the moisture-density values of a one-point compaction test (ASTM D 698). A compaction curve representing the specific soil sample is drawn through the one point and completed as guided by the family of curves. The optimum moisture and maximum density values of the soil sample are determined at the reference line.

Plot the zero air voids curve for the specific gravity of the materials being used for the compacted fill. See Table KS2-1, Points for curve of complete saturation (zero air void curve points). This table is from the Earth Manual, U.S. Department of Interior, Bureau of Reclamation, and is a convenient tool for use in plotting the zero air voids curve.

Step 2. Make a One-Point Compaction Test Specimen from Soil Material to Represent the Test Sample

The one-point compaction test specimen shall be made in accordance with the procedure described in ASTM D 698. It shall be made from a part of the earthfill test sample or from the same soil mixture taken from the side of the test hole or under the nuclear gage test site. It is important that the soil moisture of the material used for the one-point compaction test specimen be adjusted to optimum--or a few (1-2) percentage points below optimum--as experience has shown that points in this range can be projected on the family of curves with the most reliable accuracy. One-point compaction tests that fall above the optimum moisture value should not be used to project optimum values for the test sample.

Step 3. Plot the Moisture and Density Test Values and Draw a New Compaction Curve

The one-point compaction test identifies one point on a standard compaction curve in accordance with ASTM D 698. When the one point is plotted on the family of curves, it will identify the location of a new curve representing the material sample. The new curve is then drawn through this point and shaped to conform to the adjacent curves of the family.

Step 4. Locate the Optimum Moisture-Maximum Density Point Determined by the Newly Drawn Curve

The optimum moisture-maximum density values for a specific soil sample is determined by reading the values directly from the family of curves at the peak point of the newly drawn curve which is the point of intersection of the newly drawn curve and the reference line.

Step 5. Record the Optimum Moisture-Maximum Density Values to Represent the Specific Soil Material

The optimum moisture-maximum density values are then recorded for use in determining moisture and density values required for a specific soil sample tested.

Example No. 1

(a) Embankment moisture and density test results
- Dry Density = 109.0 pcf
- Percent Moisture = 18.2%

(b) Using sample of same material as embankment moisture and density test, make one point of Proctor test by ASTM D 698.
- Find Dry Density = 110.6 pcf
- Percent Moisture = 16.1%

(c) Plot on curve and project to locus line using same shape curve projection as shown by family of curves.
- Read - maximum dry density 111.0 pcf
- Read - optimum moisture 16.7%

(d) Compute % compaction using

$$\frac{\text{Dry Density Item (a) 109.0 pcf}}{\text{Maximum Dry Density Item (c) 111.0 pcf}} = 98\%$$

(e) Moisture is 1.5% above optimum found in Item (c).

Example No. 2

(a) Embankment moisture and density test results
- Dry Density = 101.5 pcf
- Percent Moisture = 21.2%

(b) Using sample of same material as embankment moisture and density test, make one point of Proctor test by ASTM D 698
- Dry Density = 105.0 pcf
- Percent Moisture = 21.2%

(c) Plot on curve--Item (a). This is on the right side of locus line and should not be used. Use field judgment or complete a test to determine that the moisture of the one-point sample is reduced below optimum. Then repeat Item (b) at the new moisture content.
- Dry Density = 106.5 pcf
- Percent Moisture = 18.5%

(d) Plot on curve and project to locus line--Item (b) above--and read as follows:
- Maximum Dry Density 106.8 pcf
- Percent Moisture = 18.5%

(e) Compute % compaction using

$$\frac{\text{Dry Density (field) Item (a) 101.5 pcf}}{\text{Maximum Dry Density Item (d) 106.8 pcf}} = 95\%$$

(f) Moisture is 2.2% above optimum.

Figure KS2-1 - Family of curves - plotted dry densities

Note: F.C. and L.C. designate field curves and laboratory curves

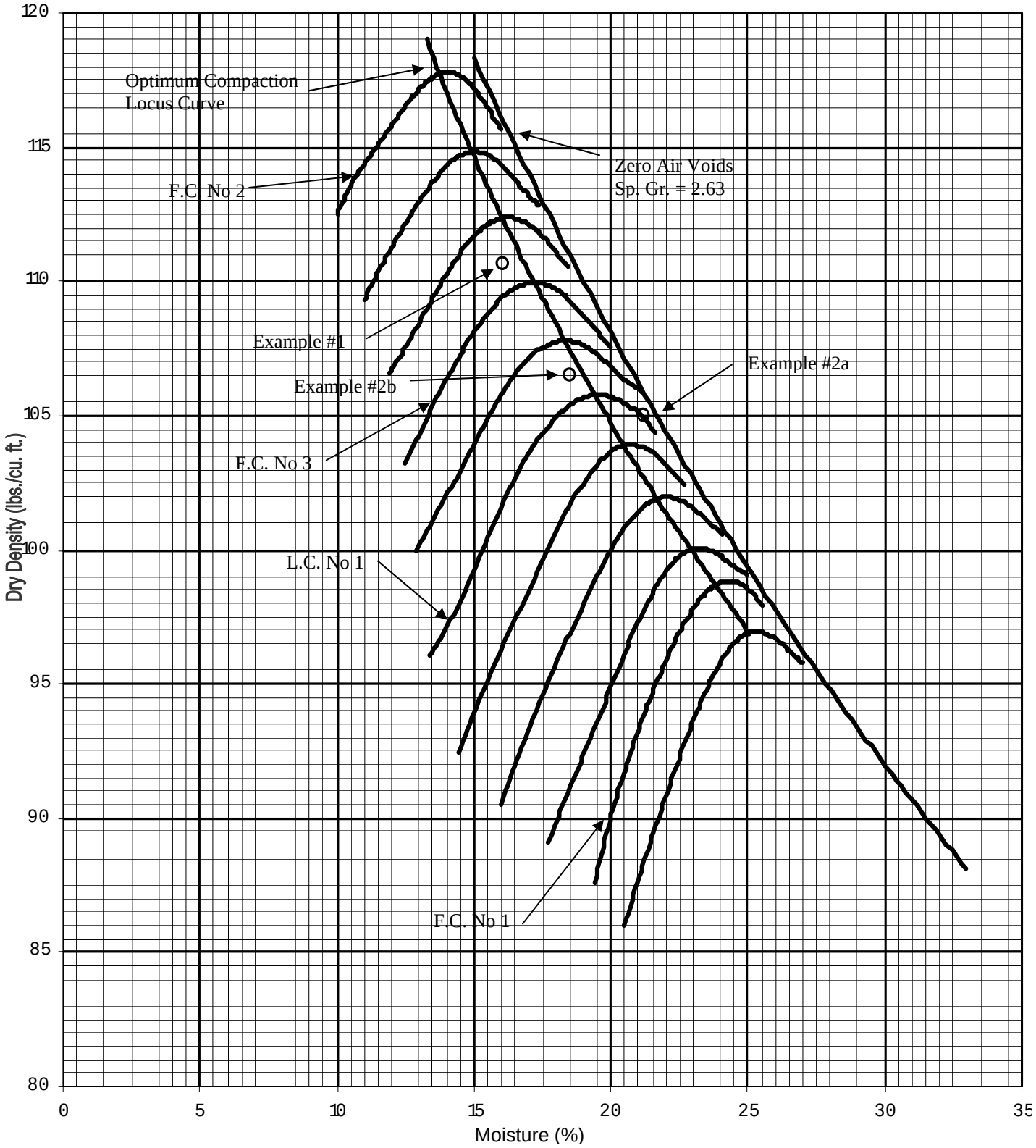


Table KS2-1 Points for curve of complete saturation

Percent voids	10	15	20	25	30	35	40	45	50	55	60
Specific gravity	Dry density in pounds per cubic foot Water content in percent										
2.46 ----------	138.3	130.6	122.8	115.2	107.5	99.8	92.2	84.6	76.8	69.2	61.5
	4.5	7.2	10.2	13.5	17.4	21.9	27.1	33.2	40.7	49.6	60.9
2.47 ----------	138.9	131.2	123.5	115.7	108.0	100.4	92.6	84.9	77.2	69.4	61.7
	4.5	7.1	10.1	13.5	17.3	21.8	27.0	33.1	40.5	49.5	60.7
2.48 ----------	139.5	131.6	124.0	116.2	108.5	100.7	93.0	85.2	77.5	69.7	62.0
	4.5	7.1	10.1	13.4	17.3	21.7	26.9	33.0	40.3	49.3	60.4
2.49 ----------	140.0	132.2	124.4	116.6	108.9	101.1	93.3	85.6	77.8	70.0	62.2
	4.5	7.1	10.1	13.4	17.2	21.6	26.8	32.8	40.2	49.2	60.3
2.50 ----------	140.4	132.6	124.8	117.0	109.2	101.4	93.6	85.9	78.1	70.2	62.4
	4.4	7.1	10.0	13.3	17.1	21.5	26.7	32.7	40.0	48.9	60.0
2.51 ----------	141.0	133.2	125.4	117.5	109.7	101.9	94.1	86.3	78.2	70.6	62.7
	4.4	7.0	10.0	13.3	17.1	21.4	26.5	32.6	39.9	48.7	59.8
2.52 ----------	141.6	133.8	125.9	118.1	110.2	102.4	94.4	86.6	78.7	70.8	63.0
	4.4	7.0	9.9	13.2	17.0	21.4	26.5	32.4	39.7	48.5	59.5
2.53 ----------	142.2	134.4	126.3	118.5	110.5	102.7	94.7	86.9	79.0	71.2	63.2
	4.4	7.0	9.9	13.2	16.9	21.3	26.3	32.3	39.5	48.3	59.3
2.54 ----------	142.8	134.9	126.9	119.0	111.1	103.1	95.2	87.2	79.3	71.4	63.4
	4.4	6.9	9.9	13.1	16.8	21.2	26.2	32.2	39.4	48.1	59.1
2.55 ----------	143.2	135.3	127.3	119.4	111.4	103.4	95.5	87.5	79.6	71.6	63.6
	4.4	6.9	9.8	13.1	16.8	21.1	26.2	32.1	39.2	47.9	58.9
2.56 ----------	143.8	135.8	127.8	119.8	111.8	103.8	95.8	87.9	79.9	71.9	63.9
	4.3	6.9	9.8	13.0	16.8	21.1	26.1	32.0	39.1	47.7	58.6
2.57 ----------	144.3	136.3	128.3	120.3	112.3	104.2	96.2	88.2	80.2	72.2	64.1
	4.3	6.9	9.7	13.0	16.7	21.0	26.0	31.8	38.9	47.5	58.4
2.58 ----------	144.9	136.8	128.8	120.7	112.7	104.6	96.6	88.5	80.5	72.4	64.4
	4.3	6.8	9.7	12.9	16.7	20.9	25.9	31.7	38.8	47.4	58.1
2.59 ----------	145.5	137.4	129.3	121.2	113.1	105.1	97.0	88.9	80.8	72.7	64.6
	4.3	6.8	9.7	12.9	16.6	20.8	25.6	31.6	38.6	47.2	57.9
2.60 ----------	146.0	137.9	129.8	121.7	113.6	105.5	97.3	89.2	81.1	73.0	64.9
	4.3	6.8	9.6	12.9	16.5	20.7	25.7	31.5	38.5	47.0	57.7
2.61 ----------	146.6	138.4	130.3	122.2	114.0	105.9	97.7	89.6	81.4	73.3	65.1
	4.3	6.7	9.6	12.8	16.4	20.6	25.6	31.3	38.3	46.8	57.5
2.62 ----------	147.2	138.9	130.8	122.6	114.5	106.3	98.1	89.9	81.8	73.6	65.4
	4.2	6.7	9.6	12.7	16.4	20.6	25.5	31.2	38.2	46.6	57.3
2.63 ----------	147.7	139.5	131.3	123.1	114.9	106.7	98.5	90.3	82.1	73.8	65.6
	4.2	6.7	9.5	12.7	16.3	20.5	25.4	31.1	38.0	46.5	57.1
2.64 ----------	148.3	140.0	131.8	123.6	115.3	107.1	98.9	90.6	82.4	74.1	65.9
	4.2	6.7	9.5	12.6	16.3	20.4	25.3	31.0	37.9	46.3	56.8
2.65 ----------	148.8	140.6	132.3	124.0	115.8	107.5	99.2	91.0	82.7	74.4	66.1
	4.2	6.6	9.4	12.6	16.2	20.3	25.2	30.8	37.7	46.1	56.6
2.66 ----------	149.4	141.1	132.8	124.5	116.2	107.9	99.6	91.3	83.0	74.7	66.4
	4.2	6.6	9.4	12.5	16.1	20.3	25.1	30.8	37.6	45.9	56.4
2.67 ----------	150.0	141.6	133.3	125.0	116.6	108.3	100.0	91.6	83.3	75.0	66.6
	4.2	6.6	9.4	12.5	16.1	20.2	25.0	30.7	37.5	45.7	56.2
2.68 ----------	150.5	142.2	133.8	125.4	117.1	108.7	100.3	92.0	83.6	75.3	66.9
	4.1	6.6	9.3	12.4	16.0	20.1	24.9	30.5	37.3	45.6	56.0
2.69 ----------	151.1	142.7	134.3	125.9	117.5	109.1	100.7	92.3	83.9	75.5	67.1
	4.1	6.6	9.3	12.4	16.0	20.0	24.8	30.4	37.2	45.5	55.8
2.70 ----------	151.6	143.2	134.8	126.4	117.9	109.5	101.1	92.7	84.2	75.8	67.4
	4.1	6.5	9.3	12.3	15.9	19.9	24.7	30.3	37.0	45.3	55.6
2.71 ----------	152.2	143.7	135.3	126.8	118.4	109.9	101.5	93.0	84.6	76.1	67.6
	4.1	6.5	9.2	12.3	15.8	19.9	24.6	30.2	36.9	45.1	55.4
2.72 ----------	152.8	144.3	135.8	127.3	118.8	110.3	101.8	93.4	84.9	76.4	67.9
	4.1	6.5	9.2	12.3	15.8	19.8	24.6	30.1	36.8	44.9	55.2
2.73 ----------	153.3	144.8	136.3	127.8	119.3	110.7	102.2	93.7	85.2	76.7	68.1
	4.1	6.4	9.2	12.2	15.7	19.7	24.4	29.9	36.6	44.7	55.0
2.74 ----------	153.9	145.3	136.8	128.2	119.7	111.1	102.6	94.0	85.5	76.9	68.4
	4.1	6.4	9.1	12.2	15.7	19.7	24.4	29.9	36.5	44.6	54.8
2.75 ----------	154.4	145.9	137.3	128.7	120.1	111.5	103.0	94.4	85.8	77.2	68.6
	4.0	6.4	9.1	12.1	15.6	19.6	24.3	29.8	36.4	44.4	54.6
2.76 ----------	155.0	146.5	137.8	129.1	120.6	111.9	103.3	94.7	86.2	77.5	68.9
	4.0	6.4	9.1	12.1	15.7	19.5	24.2	29.7	36.2	44.3	54.4
2.77 ----------	155.6	147.0	138.3	129.6	121.0	112.4	103.7	95.1	86.5	77.8	69.2
	4.0	6.4	9.0	12.0	15.5	19.4	24.0	29.5	36.2	44.2	54.2
2.78 ----------	156.1	147.5	138.8	130.1	121.4	112.8	104.1	95.4	86.8	78.1	69.4
	4.0	6.4	9.0	12.0	15.4	19.4	23.9	29.4	36.0	44.0	54.0
2.79 ----------	156.8	148.1	139.3	130.6	121.9	113.2	104.5	95.8	87.1	78.4	69.7
	4.0	6.3	9.0	12.0	15.3	19.3	23.8	29.3	35.9	43.8	53.8

Field Density and Moisture Content Tests - Nuclear Gauge Method

General

The nuclear moisture-density gauges can be used to determine the density and moisture content of all soil and soil and rock mixtures commonly used in earthfill and structural backfill. The wet or total density is directly determined by this method. Dry density is then determined from the wet density and the moisture content.

Equipment

The nuclear gauge must be capable of direct transmission measurements for density by the use of a source probe that is inserted in the ground. The gauge must be capable of accurately measuring wet density and moisture content with a simple correction procedure for moisture measurements. A standard count is run at the beginning of each day the instrument is used. The count is run with the gauge sitting on a reference standard supplied by the manufacturer. The reference standard should be placed on a concrete or asphalt surface if possible. A concrete block at least 4 inches thick is also acceptable.

Calibration for Moisture Correction (Offset)

Before the gauge is used in soil density and moisture control, it must be calibrated to determine the moisture correction or offset for each specific soil type that will be tested. The offset (k) factor is determined by comparing the moisture content of a laboratory sample with the moisture content determined by a gauge reading. Take moisture content readings at 5 different locations in the same soil using the gauge with no correction applied.

The formula for the k factor is as follows:

$$k = \frac{\%M_{\text{oven dry}} - \%m_{\text{gauge}} \quad x\ 1000}{100 + \%M}$$

Use Form KS-ENG-13, Nuclear Gauge Calibration, to determine the k factor to use based on the average moisture values from at least 4 tests. An example of a completed Form KS-ENG-13 is shown on Figure KS2-2.

Field Density and Moisture Testing

A standard count should be taken as recommended by the manufacturer prior to making any moisture or density field tests. The gauge should be firmly seated on the reference block and the reference block should be placed on a dry, flat surface at least 10 feet from any structure. A concrete block at least 4 inches thick is acceptable for use as the flat surface. The moisture and density standard counts should be recorded in the log book kept with the gauge and compared with the previous 4 readings to determine acceptable limits of variability. The acceptable limits for the gauge are given in the operator's manual.

Set the k factor to the value determined using Form KS-ENG-13. All field density and moisture tests should be done with the probe set at a depth of 6 inches and the count time set for 4 minutes.

Select the location for the test and smooth a surface prior to testing. Use the scraper plate to mark the location and do final smoothing of the test area. A small amount of filler (either native soil or fine sand) may be used to fill small voids in the soil surface below the gauge. Hammer the drill rod into the soil through the rod guide while standing on the scraper plate. The drill rod must be set at least 2 inches deeper than the test depth, and it is marked accordingly. Remove the drill rod by pulling straight up and twisting the extraction tool. Avoid distortion of the hole by hammering on the side of the drill rod. Mark the sides of the scraper plate as a guide for gauge placement.

Place the gauge on the marked location and carefully insert the source rod into the hole made by the drill rod. **Use care when inserting the source rod, trying not to disturb the soil around the hole.** Lock the source rod into the correct position by releasing the trigger. Gently slide the gauge toward the keypad so the source rod makes contact with the wall of the hole. Take measurements by pressing "start/enter."

Record the wet density, dry density, moisture (%), source rod depth, count time, k factor, density standard count, and moisture standard count on Form KS-ENG-63, Moisure-Density Determination, in the appropriate locations. An example of a completed KS-ENG-63 is shown on Figure KS2-3.

After the gauge is removed and stored, determine the elevation and location of the test. The location should be identified by station and offset. Record this information on Form KS-ENG-63. Dig out a part of the test area to determine the uniformity of

the material and to run a one-point proctor test if needed to place the material on the family of curves. A one-point proctor test should be done whenever the visual observation indicates different material from previous tests or when different borrow material is being used. A one-point proctor test is required for every five density tests as a minimum.

The maximum dry density and optimum moisture of the material should be determined using the family of curves or moisture-density compaction curves for the site. Record this information on Form KS-ENG-63 and determine the allowable ranges for moisture and density from the construction documents.

Correcting Moisture-Density Relationships for Rock Fractions

This is the procedure for determining a practical value for field density of a material containing soil and rock when that material is being controlled in the field by recommended compaction methods. The standard density test method described in ASTM D 698 is used to determine a maximum density and optimum moisture content for use in controlling earthfill compaction. The test procedures limit the maximum particle size of the test material to 4.76 millimeter (mm) (#4 sieve). The materials used in earthfill often contain particles larger than the specified maximum size. These large particles must be removed to perform the standard tests. The material larger than the maximum size will be referred to as "rock" or "oversize rock." The material remaining after the oversize particles have been removed will be referred to as "the soil fraction."

In-place density tests that determine the density and moisture content of the total mass, including the oversize rock and the soil fraction, will be referred to as "mass density" tests. They are generally easier and, in some cases, the only practical tests to use. In-place densities and moisture contents determined by using a nuclear gauge are always on a mass density basis.

When mass density tests are used and the oversize rock is greater than 5%, some corrections to the standard density test are necessary to allow for a proper comparison. Adding rock to a soil affects the moisture-density relationship of the soil in two ways: (1) the addition of material of higher density than the soil produces a mixture whose unit weight is greater than the unit weight of the soil fraction alone and (2) the added rock absorbs no appreciable amount of moisture so the moisture content of a soil and rock mixture as compared to soil alone is reduced in proportion to the amount of rock present. The following procedure should be used to correct the standard test results so that a proper comparison can be made with a field mass density test on materials with 5% to 40% rock. **The standard tests and in-place density tests referred to are not applicable for soils containing more than 40% rock.**

Correction Procedure

The changes in unit weight and moisture content of soil resulting from the addition of rock can be calculated by the following equations. The derivation of the equations for W_{rs} and M_{rs} may be found in "Laboratory Procedure for Testing Earth Materials for Foundation Construction Purposes" prepared by the Bureau of Reclamation.

$$W_{rs} = (W_s \times W_r) / ((1 - P)\, W_r + (P \times W_s))$$

and

$$M_{rs} = M_s(1 - P) + (M_r \times P)$$

Where:

W_{rs} = Dry density of soil and rock mixture (in pounds per cubic foot [pcf])
W_s = Maximum dry density of soil fraction (in pcf)
W_r = Dry density of rock (in pcf)
P = Percent by weight of rock expressed as a decimal
M_{rs} = Moisture in soil and rock mixture expressed as % of dry weight of mixture
M_s = Moisture in the soil fraction expressed as % of dry weight
M_r = Moisture in rock expressed as % of dry weight of rock

The necessary data for making density and moisture corrections for rock are as follows:

- The maximum density (W_s) and moisture content (M_s) of the compacted soil fraction (from standard density tests)
- The dry density (W_r) and moisture content (M_r) of the rock fraction
- The percent (P) that the rock fraction is of the total dry weight of the mixture expressed as a decimal

The unit weight and percent moisture of the rock should be determined by laboratory procedure for the particular rock in question. When no laboratory values of these quantities are available, 165 pcf and 2% moisture are close approximations for most rocks. Use Page 2 of Form KS-ENG-63 to assist in the required calculations to correct moisture-density relationships for rock fractions.

Examples of this are shown in Figures KS2-4 and KS2-5 for a soil and rock mixture that is a sandy clay (SC) material containing 40% fines, 43% sand, and 17% gravel. The gravel portion was retained on the #4 sieve, and all of the gravel is smaller than 1½ inches. Considering only the soil fraction of this material, there is 48% fines and 52% sand. Specific gravity of the soil solids is 2.68, and the unit weight of the rock is 165 pcf. Moisture in the rock is 2%. The material is to be placed according to the following specifications:

The dry density is to be at least 95% of the standard maximum dry density determined by ASTM D 698, Method A, and the moisture is to be controlled between 2 percentage points below (dry side) and 1 percentage point above (wet side) the optimum moisture content. Figure KS2-6 is an example of Form SCS-ENG-352, Material Testing Report, and shows the standard compaction curve, penetration resistance, and total saturation curves for the soil fraction of the material.

95% maximum density = 0.95 x 115.0 = 109.2 lb/cu. ft (pcf)

Optimum moisture - 2.0 = 13.2 - 2.0 = 11.2% (minimum moisture)

Optimum moisture + 1.0 = 13.2 + 1.0 = 14.2% (maximum moisture)

Locate the 11.2% moisture and the 14.2% moisture intersections with the 109.2 density line. Using M_s = 11.2 and W_s = 109.2, compute corrections for 10%, 20%, 30%, and 40% rock as shown on Figure KS2-5. Plot the corrected density and moisture points and draw the “Lower Moisture Limit” curve.

Using M_s = 14.2 and W_s = 109.2, compute corrections for 10%, 20%, 30%, and 40% rock as shown on the completed worksheet. Plot the corrected density and moisture points and draw the “Upper Moisture Limit” curve. For any percent rock from 0 to 40 determined in the field, interpolate into the percent-of-rock scale on the left and project horizontally to connect lower and upper moisture limit curves.

For 20% rock, minimum placement dry density is 117.2 pcf, the lower moisture limit is 9.3%, and the upper moisture limit is 11.6%. The shaded area defines the acceptable range of moisture-density values for 20% rock.

Density and moisture for any other percentage of rock may be determined by the same procedure. If no upper moisture limit is specified, then any moisture-density point above 117.2 pcf and to the right of 9.3% moisture would be acceptable for 20% rock.

Figure KS2-2 Example of Form KS-ENG-13

USDA
NRCS

Nuclear Gauge Calibration 1/

KS-ENG-13
Rev. 2/04

Location: North Black Vermillion Site 4 Date: November, 2005

Gauge Serial No.: Troxler 3430, SN 23841 Recorded by: Joe Inspector

Checked by: Robert Engineer

Moisture Correction - NRCS Construction Note 2					
Sample No.	%M Oven Dry	%M Gauge	Difference 2/	K Value	K^2 Value
1	18.2	15.9	2.3	19.8	393.81
2	19.5	16.6	2.9	24.9	618.58
3	20	18.8	1.2	10.1	102.03
4	19.4	17.1	2.3	19.6	385.78
5	17.9	15.3	2.6	22.5	508.50
6	20.2	17.0	3.2	27.4	748.05
Average	19.2	16.78333333	2.4		

$$\text{Average K Value} = \frac{\text{Average difference}}{\text{Average \%M Gauge} + 100} \times 1000 = \boxed{20.7}$$

Use the average K value as the moisture correction factor. Dial it into the moisture correction switches paying attention to the algebraic sign if it meets the statistical criteria below:

Compute the K value for each sample and check the following before using it as the moisture correction factor:

$$\text{standard deviation } (\delta) = \sqrt{\frac{\Sigma K^2 - \frac{(\Sigma K)^2}{n}}{n - 1}}$$

$$\frac{\delta}{\bar{K}} = \boxed{0.29}$$

Must be $\leq \pm 0.3$; otherwise, eliminate the test that has the K value with the greatest difference from the "Average K Value"

$\bar{K}$ = Average K value

n = Number of samples used (A minimum of 4 are required.)

1/ Material tested is to be at or near optimum moisture content.

2/ Difference = %M Oven Dry - %M Gauge

Figure KS2-3 Example of Form KS-ENG-63, page 1

USDA
NRCS

Moisture-Density Determination

KS-ENG-63
Rev. 3/08

Watershed: North Black Vermillion Site No.: 4

Test Number	21	22
Test Date	11-4-05	11-5-06
Location	Sta. 14+15, 80' Right	Sta. 15+60, 30' Right
Elevation	1239	1242
Construction Item	Embankment	Embankment

		Drive Mold		Nuclear Gauge		One-Point	
Test Number		21		22		21	22
Can Number		W-6				R-2	W-6
Tare Weight (grams)	[#1]	74.1				52.4	74.1
Wet Weight (grams)	[#2]	541.3				519.9	530.1
Dry Weight (grams)	[#3]	469.5				456	473.1
Moisture (%) (#2 - #3) / (#3 - #1)	[#4]	18.2%		21.5%		15.8%	14.3%
Weight of Mold and Sample (lb)	[#5]	4.37				8.56	8.28
Weight of Mold (lb)	[#6]	0.98				4.56	4.56
Weight of Sample (lb) (#5 - #6)	[#7]	3.39				4	3.72
Volume of Mold (cubic feet)	[#8]	0.027				0.033	0.033
Wet Density (pcf) (#7 / #8)	[#9]	125.6		123.5		121.2	112.7
Dry Density (pcf) (#9 x 100) / (100 + #4)	[#10]	106.3		101.6		104.6	98.6
Mode and Depth				Slow, 6"			
Offset (k) Factor				20.7			
Wet Density Correction							
Density Standard				2454			
Moisture Standard				663			
Source of Fill Material		Auxiliary spillway		Borrow area Sta. 15+00, 300' US			
Maximum Dry Density (pcf) [1/]	[#11]	107		105.5		107	105.5
Optimum Moisture (%) [1/]		18%		19%		18%	19%
Compaction (%) (#10 / #11)		99%		96%			
Specified Density Range (pcf) [2/]		**101.6+**		**100.2+**			
Specified Moisture Range (%) [2/]		**15-21%**		**17-22.5%**			

[1/] From the family of curves or moisture-density compaction curves
[2/] From the construction plan

Tested by	JBI		JBI		JBI	JBI

Checked by: Robert Engineer Date: 3/28/08

Figure KS2-4 Example of minimum allowable density and moisture corrections on Form KS-ENG-63, page 2

KS-ENG-63
Page 2

Correcting Moisture-Density Relationships for Rock Fractions

Column (Col.) A	*Col. B*	*Col. C*	*Col. D*	*Col. E*	*Col. F*	*Col. G*	*Col. H*	*Col. I*	*Col. J*	*Col. K*	*Col. L*	*Col. M*	*Col. N*	*Col. O*
				(Col. C x Col. D)		*(1 - Col. F)*	*(Col. G x Col. D)*	*(Col. F x Col. C)*	*(Col. H + Col. I)*	*(Col. E / Col. J)*	*(Col. B x Col. G)*		*(Col. M x Col. F)*	*(Col. L + Col. N)*
Percent Rock	**M_s [1/]**	**W_s [2/] (pcf)**	**W_r [3/] (pcf)**	**W_s x W_r**	**P [4/]**	**1 - P**	**(1 - P) x W_r**	**P x W_s**	**(1 - P) x W_r + P x W_s**	**W_{rs} [5/] (pcf)**	**M_s x (1 - P)**	**M_r [6/]**	**M_r x P**	**M_{rs} [7/]**
0%	11.2%	109.2								109.2				11.2%
10%	11.2%	109.2	165	18018	0.1	0.9	148.5	10.9	159.4	113.0	10.1	2.0%	0.2	10.3%
20%	11.2%	109.2	165	18018	0.2	0.8	132.0	21.8	153.8	117.1	9.0	2.0%	0.4	9.4%
30%	11.2%	109.2	165	18018	0.3	0.7	115.5	32.8	148.3	121.5	7.8	2.0%	0.6	8.4%
40%	11.2%	109.2	165	18018	0.4	0.6	99.0	43.7	142.7	126.3	6.7	2.0%	0.8	7.5%

[1/] M_s = Moisture in the soil fraction expressed as % of dry weight

[2/] W_s = Maximum dry density of soil fraction in pounds per cubic foot (pcf)

[3/] W_r = Dry density of rock in pcf (use 165 pcf or lab data if known) - Leave blank for 0% rock.

[4/] P = Percent by weight of rock expressed as a decimal

[5/] W_{rs} = Dry density of soil and rock mixture in pcf (corrected for rock fraction)

$(W_s \times W_r) / ((1 - P)\ W_r + (P \times W_s))$

[6/] M_r = Moisture in rock expressed as % of dry weight of rock (use 2% unless lab information is known)

[7/] M_{rs} = Moisture in soil and rock mixture expressed as % of dry weight of mixture (corrected for rock fraction)

$M_s (1 - P) + (M_r \times P)$

Figure KS2-5 Example of minimum allowable density and maximum allowable moisture corrections on Form KS-ENG-63, page 2

KS-ENG-63
Page 2

Correcting Moisture-Density Relationships for Rock Fractions

Column (Col.) A	*Col. B*	*Col. C*	*Col. D*	*Col. E*	*Col. F*	*Col. G*	*Col. H*	*Col. I*	*Col. J*	*Col. K*	*Col. L*	*Col. M*	*Col. N*	*Col. O*
				(Col. C x Col. D)		*(1 - Col. F)*	*(Col. G x Col. D)*	*(Col. F x Col. C)*	*(Col. H + Col. I)*	*(Col. E / Col. J)*	*(Col. B x Col. G)*		*(Col. M x Col. F)*	*(Col. L + Col. N)*
Percent Rock	**M_s [1/]**	**W_s [2/] (pcf)**	**W_r [3/] (pcf)**	**W_s x W_r**	**P [4/]**	**1 - P**	**(1 - P) x W_r**	**P x W_s**	**(1 - P) x W_r + P x W_s**	**W_{rs} [5/] (pcf)**	**M_s x (1 - P)**	**M_r [6/]**	**M_r x P**	**M_{rs} [7/]**
0%	14.2%	109.2								109.2				14.2%
10%	14.2%	109.2	165	18018	0.1	0.9	148.5	10.9	159.4	113.0	12.8	2.0%	0.2	13.0%
20%	14.2%	109.2	165	18018	0.2	0.8	132.0	21.8	153.8	117.1	11.4	2.0%	0.4	11.8%
30%	14.2%	109.2	165	18018	0.3	0.7	115.5	32.8	148.3	121.5	9.9	2.0%	0.6	10.5%
40%	14.2%	109.2	165	18018	0.4	0.6	99.0	43.7	142.7	126.3	8.5	2.0%	0.8	9.3%

[1/] M_s = Moisture in the soil fraction expressed as % of dry weight

[2/] W_s = Maximum dry density of soil fraction in pounds per cubic foot (pcf)

[3/] W_r = Dry density of rock in pcf (use 165 pcf or lab data if known) - Leave blank for 0% rock.

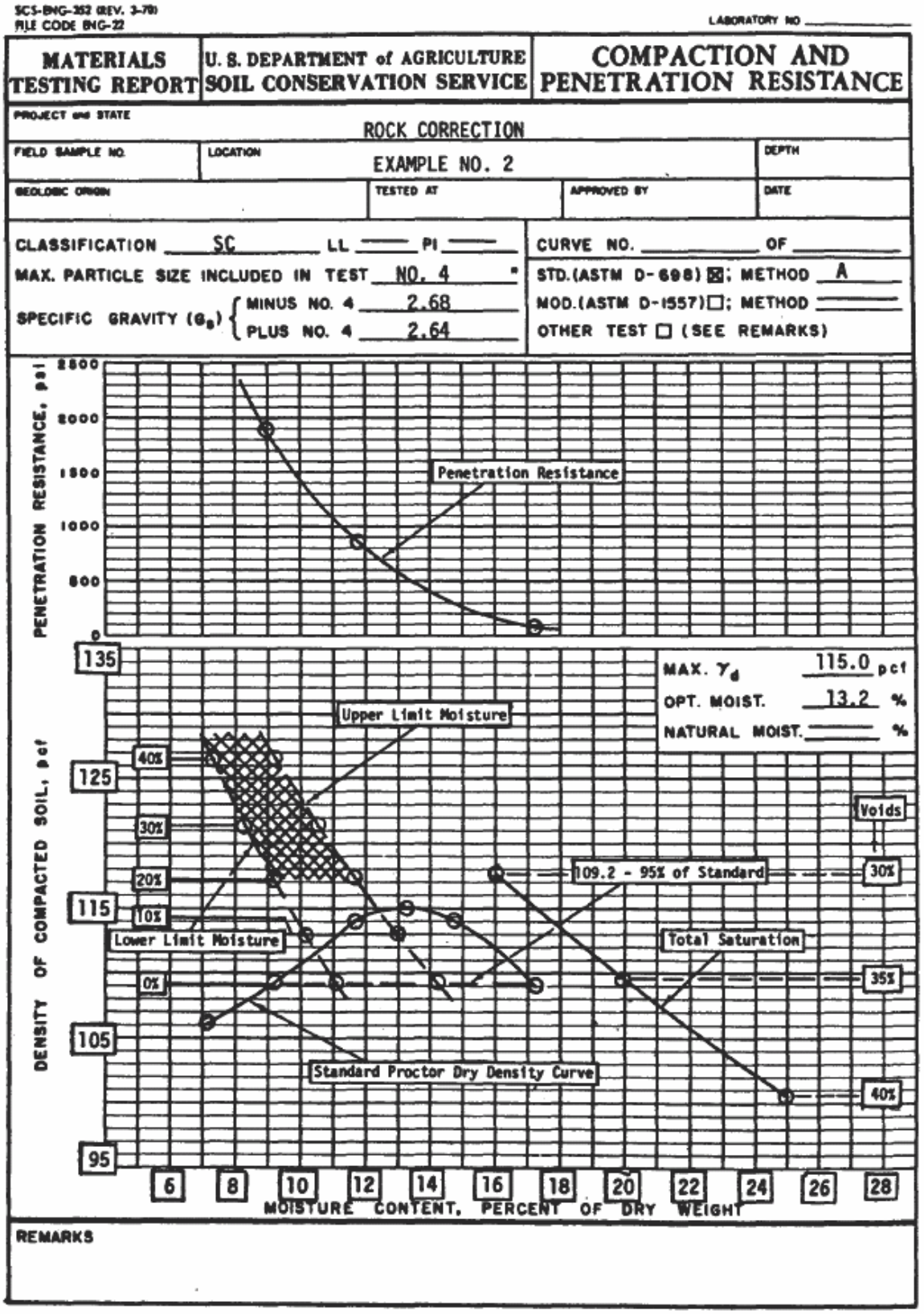
[4/] P = Percent by weight of rock expressed as a decimal

[5/] W_{rs} = Dry density of soil and rock mixture in pcf (corrected for rock fraction)
$(W_s \times W_r) / ((1 - P)\ W_r + (P \times W_s))$

[6/] M_r = Moisture in rock expressed as % of dry weight of rock (use 2% unless lab information is known)

[7/] M_{rs} = Moisture in soil and rock mixture expressed as % of dry weight of mixture (corrected for rock fraction)
$M_s (1 - P) + (M_r \times P)$

Figure KS2-6 Example of Form SCS-ENG-352



Testing Concrete

Frequency of Testing for Concrete Quality Assurance

Recommendations of Portland Cement Association - Frequency should depend on uniformity of materials and conditions such as aggregate moisture, organic impurities, and grading.

(a) Type of Test

(1) Air

- At point of delivery to assure proper air content for each sample that strength test specimens are taken

(2) Slump

- First batch of concrete each day
- For each sample that strength test specimens are taken

(3) Temperature

- Whenever air and slump tests are performed

(4) Strength Test Specimens

- Not less than once per day
- Not less than 1 set per 150 cubic yards
- Not less than 1 set per 5000 square feet of slab or wall area
- More often for more critical strength required

NRCS Recommendations - The following are minimum recommendations. More frequent testing may be justified.

(a) Type of Test

(1) Air

- First batch of day
- Follow-up tests only if needed to confirm questionable results
- For each load from which test cylinders are made

(2) Slump

- First batch of day
- Follow-up tests only if needed to confirm questionable results
- For each load from which test cylinders are made

(3) Temperature

- Whenever air and slump tests are performed

(4) Strength Test Specimens - Specification 31 and designated structures using Specification 32

- Two cylinders - 28-day
  - Not less than once per day
  - Not less than 1 set per 15 cubic yards
- Two cylinders - 7-day
  - First batch of concrete on each contract
  - First batch after new design mix is approved
  - Anytime that design mix strength results are suspect