

PART 4 – PROCEDURES FOR DETERMINING COMPACTED ROCKFILL LIFT THICKNESS AND COMPACTIVE EFFORT IN LARGE SCALE TEST FILLS

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Part 1 summarized rockfill placement and compaction guidelines for mine structures, including dams and structure foundations. Part 2 provided an historical perspective to rockfill dam construction. Part 3 defined the difference between rockfill rock fragments versus earthfill soil particles. Part 4 for this article describes procedures for determining the compacted rockfill lift thickness and compactive effort in large scale test fills. The test fill procedures are similar to Corps of Engineers procedures developed in the early 1960's for rockfill dams.

Large scale test fills are generally conducted for rockfill dam construction at the startup of rockfill placement using fill construction equipment at the site. The test fills confirm design guidelines for rock quality, moisture control, lift placement and compaction requirements using the locally available rock quarry borrow materials. Additional test fills are conducted during construction, depending on any changes in rock quarry borrow materials or construction equipment for placement and compaction.

INTRODUCTION

Modern day rockfill dam construction must rely heavily on past experiences for guidance pertaining to the placement and compaction of large rock fragments in a compacted fill structure. Special rock equipment and procedures are required for rock borrow development, hauling, placing, and compacting to produce a stable and acceptable engineered fill structure. The conventional earthfill test methods for controlling lift thickness, gradation, moisture content, and compaction are not applicable to rockfills and must be modified to a site specific compactive effort specification using test fills and large vibratory roller compactors.

This article includes a summary discussion of large scale test fill procedures used for compacted rockfill dam construction, including related rock borrow selection, development, moisture conditioning, fill placement and compactive effort. The acceptable lift thickness and compactive effort can be quickly determined by surveyed measurements of test fill lift settlement versus roller pass performance. Typical rockfill placement operations and test fill survey control locations are shown on Photos 1 to 8.

A suggested minimum test fill layout for measurement of rockfill compactive effort is shown on Figure 1. A typical example format and plot of surveyed settlement versus roller pass test results are shown on Figures 2 and 3.

ROCK BORROW SELECTION

The large scale test fill procedures for determining acceptable rockfill lift thickness and compactive effort depend on the available rock borrow source and planned selection and development as rockfill material. Borrow selection for rockfills is generally based on economics. In the mining industry large quantities of mine waste rock material (non-ore overburden) is generally available from open pit mine cuts for use in water storage and tailing impoundment embankment fills. The mine waste rock, already blasted or ripped and loaded into rock haul trucks, can be economically hauled and placed in embankment fills several miles from the open pit mine for less cost than local borrow development within the upstream reservoir or impoundment limits.

The additional storage volume gained from on site impoundment borrow cuts is offset by raising the dam embankment crest to a higher level with offsite mine waste rockfill to achieve the same impoundment storage capacity. Other sources of rock borrow may include required dam excavations associated with any foundation bedrock keyway, spillway, or diversion tunnel structures.

In the case of water storage dams, the exterior shells are typically constructed with more coarse granular earthfill or rockfill on both sides of the less coarse low permeability core material with more than 70 percent of the coarse dam materials placed in the exterior shells. In the case of rockfill tailing dams, a relatively thin low permeability core and transitional filter drain material is placed near the upstream slope so that about 85 to 90 percent of the dam is constructed with mine waste rockfill. Modern day concrete-faced or impervious geomembrane-faced water storage dams can be designed for more than 95 percent rockfill materials.

Rockfills for earth-rock water storage embankments generally include rock slope protection on the upstream face, upstream and downstream rock shells, and oversized rock placed for erosion protection on the downstream face and in rock-lined spillway channels and outlet pools. The more competent and durable rock materials are placed on the outer slope with finer rock materials placed in the interior for filter drains and transition near the core.

Selection of the more durable rocks is sometimes limited by the higher cost to excavate, transport, place, and compact hard rock materials. Special rock loading, hauling, and placement equipment may be required because of the higher wear and tear on conventional earth-moving equipment. The more durable rock sources are generally selected for riprap erosion protection and concrete aggregate materials.

ROCK BORROW DEVELOPMENT

Rock borrow development generally will require ripping or blasting. Where ripping is possible in weathered or highly fractured rock, a dozer with a single or multiple ripper shank loosens the rock to typically 3 ft (0.9 m) deep for wetting by large rubber-tired water wagons with spray bars, if needed. The loosened rock materials are excavated using large loaders and haul trucks or conventional earthwork scrapers, depending on the rock size and hardness.

Where blasting is required in more competent rock borrow areas or in required rock excavations, a dozer and large rock loader or backhoe excavator are generally used to muck and load blasted rock fragments into large rock trucks for hauling to the fill area. Blasting depths are generally associated with controlled bench cuts, and the borrow cuts advance into the blasted rock area by developing an active vertical cut face at typically 20 to 40 ft (9 to 12 m) in thickness.

Where rockfill borrow becomes too coarse for placement and compaction by available or specified equipment, borrow operations are adjusted or new areas located for producing acceptable rockfill sizes. Blast hole patterns, type and amount of explosives, and delayed blast timing plan can be adjusted to produce the desired rock gradation sizes. Oversized rocks can be selectively removed during borrow excavation and "grizzly" screening, or during fill placement by dozing the oversized rock fragments to the downstream embankment slope.

The geologic rock structure, degree of weathering, and natural fracture patterns of rock borrow sources often dictate the rock fragment sizes that can be produced from ripping or blasting for the test fill pad.

MOISTURE CONDITIONING

Moisture conditioning of rock borrow materials typically involves wetting of loosened or excavated rock materials that are generally located above the natural ground water level and in a dry condition. Moisture conditioning of rockfill borrow materials is not as critical as for earthfill borrow materials to achieve acceptable compaction density.

Moisture conditioning can be accomplished in either the borrow area or on the fill surface. Clean durable rockfill materials require significantly less water for compaction compared to rockfills containing some dry earthfill materials in the rock matrix or more weathered rock fragments that weaken and consolidate with wetting. Weathered rock fragments that break down to earthfill sizes during excavation, moisture conditioning, placement and compaction are not considered rockfill material, as defined in Part 3.

The importance of moisture conditioning in rock borrow areas versus fill areas is realized by the additional mixing and blending action of loading, dumping, and spreading of the rockfill prior to compaction. However, water truck access to rock borrow surface areas for development and moisture conditioning is generally rugged and may restrict conventional water truck application to the fill areas to reduce equipment wear and tear.

Wetting is generally accomplished in the borrow area with the use of high pressure spraying from a water truck hose onto the blasted borrow surface or active cut face. A dozer may feed rock materials to the loading equipment in stockpiles, which can also be wetted by pressure spray before loading. Rock borrow materials that are rippable can usually be wetted in-place before and after ripping using conventional large rubber-tired water trucks with front or back spray bars.

Wetting is easier to accomplish on rockfill surface areas, where the dumped rockfill materials can be leveled by dozer blade for access by conventional rubber-tired water trucks with spray bars. Excessive rock fragment sizes are dozed to the outside slope of the fill during placement operations for a less rugged loose rockfill surface compared to a ripper loosened rock borrow surface. Subsequent vibratory smooth steel drum roller compaction provides a relatively smooth surface for light and heavy construction equipment access. The compacted rockfill surface can be lightly wetted with water truck spray bars in preparation for placement of the next loose rockfill lift.

Excessive wetting is generally not a problem in most rockfills, except prior to fill compaction. Clean rockfills can rapidly drain, and therefore compaction can start immediately. However, an overly wetted rockfill with some earthfill materials intermixed in the rock matrix will dampen the dynamic forces of vibratory compaction and reduce compaction efficiency or cause rutting under heavy haul truck tire loads. Abundant wetting is strongly encouraged in the borrow cut and in the fill area for clean rockfills with less than 5 percent earthfill fines (silt and clay sizes). Less clean rockfills should target moisture conditioning to near the earthfill optimum moisture content for the minus $\frac{3}{4}$ inch (19 mm) earthfill fraction.

TEST FILL PLACEMENT AND COMPACTION

General

Suggested test fill procedures for rockfills discussed herein are fashioned after procedures established by the Corps of Engineers (Pope 1966 and COE 1994). After rock borrow selection, development and moisture conditioning procedures have been determined, the next step is to determine test fill procedures for acceptable rockfill lift thickness and compactive effort with the specified or available onsite construction roller equipment. The established rockfill placement and compaction procedures from test fill performance are subsequently verified by in-place density and gradation test results in the rockfill structure, which will be discussed in Part 5 of this series of rockfill articles.

This section includes a discussion of the suggested guidelines for test fill layout, lift thickness, lift placement and roller type for determining the test fill performance of the selected rockfill loose lift thickness versus the number of required compaction equipment roller passes.

Test Fill Layout

Test fills are generally incorporated within the rockfill structure, because of the large quantities of rockfill materials required for single or multiple test fill lifts and for any experimental changes in the test fill lift thickness. The test fill is located in a level and firm foundation subgrade area within or outside of the planned rockfill limits. The foundation area is typically compacted by ten passes of the vibratory steel drum compactor or heavy rubber-tired roller planned for use in the test fill to minimize the effect of subsequent roller pass settlements in the test fill subgrade.

In some cases large loaded haul trucks are used as the compaction equipment. These types of concentrated tire load rollers require sufficient lateral test fill width to stagger the tire tracks for 100 percent coverage of the lift surface, in addition to sufficient width along the fill slope edges for lateral bearing capacity fill support. A typical test fill layout for a vibratory compaction roller is shown on Figure 1.

The test fill limits are determined by the size of the construction equipment and the number of lifts to be used for testing rockfill placement and compaction. The minimum width of the test fill subgrade area is generally set at three times the width of the compaction roller and three times the height of the final test fill surface above the base level, as shown in Equation 1. The same test fill width is suggested for loaded haul trucks, due to the potential for lateral spreading of the rockfill along the exterior slopes of the test fill pad from the more concentrated and dynamic haul truck tire loads.

$$\text{Test Fill Minimum Base Width} = (W \times 3) + (N \times T \times 3) \quad (\text{Eq. 1})$$

Where:

W = Roller drum width,

N = Number of lifts to be placed, and

T = Planned loose lift thickness.

A typical 10-ton vibratory roller with a drum width of 7 ft (2.1 m) and say two test fill lifts of 1.5 ft (0.46 m) each should have a 30 ft (9.1m) minimum test fill subgrade base width, as shown in Equation 2. Assuming approximate 1 ft (0.3 m) side overlaps in the steel drum roller passes for ideal 100 percent pass coverage, this base width spacing allows the steel drum roller compactor to stay about 1 ft (0.3 m) away from the edges of the final lift fill level for support purposes. Loaded rubber-tired haul trucks would have approximately half the truck width of lateral spacing from the edge of the final test pad lift level, as the tire tracks are staggered across the center of the test pad area for 100 percent tire pass coverage.

$$\text{Test Fill Minimum Base Width} = (7 \text{ ft} \times 3) + (2 \text{ lifts} \times 1.5 \text{ ft} \times 3) = 30 \text{ ft} (9.1 \text{ m}) \quad (\text{Eq. 2})$$

The compactor length dictates how much level fill surface length is required between the ramp and test area for level compaction across the test section. The test fill length is generally at least two times the width to allow the vibratory compaction operator to set

and adjust his speed and vibration controls before crossing the planned control area on a level test fill surface. Ramps are used at both ends of the test fill as needed to place, spread, and compact each lift horizontally; similar to planned operations.

In the example above for the steel drum roller, the minimum length at the base of the test fill pad would be about 60 ft (18 m), depending on the time required to set compaction controls. Shorter test fill lengths are possible when the operator does the machine adjustments outside of the test fill limits before reaching the ramp to the level test fill surface.

Lift Thickness

The maximum loose lift allowable for design depends on the purpose of the engineered rockfill (ie: critical structure such as a high water storage dam versus a less critical small diversion dam), as well as the site specific test fill materials, equipment and performance. The rockfill lift thickness for design is generally determined by past experience with the specified vibratory or heavy roller compaction equipment, and subsequently adjusted during construction based on the gradation, maximum rock size, and frequency of maximum rock size produced from the borrow area.

The 8 to 15 ton (static drum weight) smooth steel drum vibratory compaction rollers generally have an effective rockfill compaction lift thickness of between 1.5 to 3 ft (0.5 to 1 m) in about 4 roller passes on moistened rockfill. The 20 ton (static drum weight) smooth steel drum vibratory compaction rollers generally have a deeper effective rockfill compaction lift thickness of between 3 to 5 ft (1 to 1.5 m) in about 4 passes on moistened rockfill. The vibratory compaction roller weight versus general rockfill lift thickness estimates on moistened rockfill are approximate, based on visual observations and recorded field densities by this author in large hand excavated test pits at several dam sites. The definition of moistened rockfill for this discussion is minus $\frac{3}{4}$ inch (19 mm) earthfill materials within a range of 2 percent dry to 2 percent wet of optimum moisture content.

The rockfill lifts will have high compaction density at the lift surface with moderate compaction density at the bottom of the lift. The overall effective compaction lift thickness is determined by the engineer to meet acceptable design stability and settlement requirements.

The size of mine haul trucks has been increasing in recent years to where some mine rockfill structures use the loaded haul trucks as roller compaction equipment. Large 240 ton (218 tonne) loaded rubber-tired haul trucks can provide moderate compaction to the 8 ft (2.4 m) depth with up to 100 truck passes on dry run-of-mine rockfill (Uhrie and Koons, 2001). The moistened rockfill compaction depth is greater than for dry rockfill conditions and may approach 10 ft (3 m) in depth with one or more passes. The greater depth of rockfill compaction for these more massive rubber-tired compaction rollers requires better control of moisture conditioning in the borrow areas and follow up large

scale density tests with depth to determine the effective compaction lift thickness and number of required passes compared to conventional vibratory compactor rollers.

Using the historic dam construction rockfill lift thicknesses versus the selected type and size of conventional vibratory compactor rollers as a guideline, the test fill loose lift thickness is adjusted to a thickness greater than the maximum rock quarry size for efficient rockfill compaction. A good rule of thumb for maximum rock size in the fill is typically set at two thirds of the loose lift thickness for ease in dozer leveling and compaction. For example, a rock borrow material with typically 18 inch (0.45 m) square mesh maximum rock fragment sizes with occasional rock fragment sizes greater than 18 inch (0.45 m) could be placed in 24 inch (0.6 m) maximum loose lifts for test fill compaction by a 15 ton (static drum weight) vibratory roller. The occasional rock fragment sizes above the 18 inch (0.45 m) mesh size in this example would be allowable within the lift, provided they do not protrude above the leveled lift surface to impede compaction.

Dozer equipment spreading the loose lifts will sometimes track over the larger rocks to crush oversized rock fragments down to acceptable rockfill sizes or rake the oversized rock to the outside slope of the rockfill. The more rugged rockfills containing the larger oversized rock materials can be selectively placed in the downstream shell of a dam embankment with a transition to smaller sized rockfill materials in the interior next to the embankment filter and drain earthfills. The rockfill loose lift thickness is adjusted accordingly to suit the differing embankment zones of rockfill material sizes, as needed.

Lift Placement

Placement of a level rockfill lift close to the desired lift thickness is difficult to achieve by operators without some practice and adjustments in fill procedures. For rock haul truck operations, a load is end dumped in a pile and dozers spread the pile forward to the desired lift thickness.

Careful control of the loose lift thickness is important for test fill evaluations. Toe stakes are generally set on both sides of the test fill limits as a visual guide. A person stands next to the test fill area with a stake marked with the planned loose lift height. The person indicates to the dozer operator to increase or decrease the lift with his dozer blade, as the loose rockfill material is being spread across the test fill area.

Spreading operations by the dozer are kept to the same amount of work accomplished on a regular fill operation. Excessive dozer traffic from spreading and leveling may distort the test fill results.

Roller Type

Experience indicates the most efficient rockfill compactors are large vibratory steel drum rollers. The heavy 50 to 100 ton pneumatic rubber-tired rollers used in early Corps of Engineers test fills in the 1960's achieved lower compaction densities and generally

cannot take the wear and tear of compacting and turning on a rugged rockfill surface compared to the smaller and more mobile 8 to 20 ton vibratory steel drum rollers.

Test fill information and visual observations of rockfill test pits indicate the steel drum vibration range is most efficient at 1,200 to 1,500 vibrations per minute (vpm) at a roller speed of about 2 mph (3.2 km/h). This roller speed is equivalent to a casual walk by a person across level ground. The rockfill surface is generally not uniform in rock fragment distribution so that the natural resonance of the rockfill can be somewhat variable, when measured with a vibration meter.

The early vibratory rollers were operated by a gas-powered motor and were pulled by dozer tractors. The vibrations were produced by a rotating eccentric shaft in a fixed direction for maximum downward force at a slight angle from the vertical in the forward direction of the roller. Ballast was added by filling the drum with a mixture of sand and water or antifreeze during winter operations. Weights were sometimes added to the pulling frame for additional compaction weight. Changing direction and compacting along abutments was generally slow, and tight corners were difficult to compact.

Modern day self-propelled vibratory compactors have improved considerably over the early day vibratory compactors. The steel drum compactor rollers can be single or double drum, and generally can reverse the rotating shaft for maximum vibratory compaction in the forward or reverse direction without having to turn around at the end of each pass. Sufficient steel weight is included in the drums, eliminating the need to add ballast and measure or calculate the operating static weight of the drum.

Equipment manufacturer specifications typically list a total operating weight with ballast and maximum dynamic or centrifugal drum force for the steel-drum compactor rollers. The operating static weight for self-propelled single drum rollers may include the total weight of the roller equipment on level ground and not the weight of the roller drum itself. The single roller drum static weight is typically not more than 90 percent of the total operating weight. Double drum self-propelled compactors have each drum weight at 50 percent of the total static operating weight. The maximum dynamic or centrifugal drum force is generally achieved at high throttle with the vibrations in resonance with the fill surface. Depending on the compactor, a lighter static drum weight with higher dynamic drum force can sometimes be more effective at compaction compared to a heavier static drum weight with lower dynamic force.

As a general rule of thumb for loose rockfill lifts up to 1.5 ft (0.5 m) in thickness, the static drum weight should be at least 8 tons (7.3 tonnes) on level ground with a minimum dynamic drum force of 15 tons (13.6 tonnes) for a moistened and well compacted rockfill. Heavy vibratory steel drum rollers of the order of 10 to 20 tons (9.1 to 18.2 tonnes) static drum weight and 20 tons (18.2 tonnes) minimum dynamic force have been used to compact thicker lifts. Variable densities occur in the thicker lifts, primarily because of a reduction in effective compaction with depth and some rock segregation for loose lifts approaching 3 ft (1 m) or more in thickness. The maximum

effective compaction depth for the heavier vibratory compactor rollers is about 5 ft (1.5 m) for moderate rockfill compaction.

Roller Passes

After the loose lift is placed, an initial survey of the lift surface can be conducted by spray painting a cross pattern with a test point number at each control point to be surveyed. Occasional rock protrusions in the selected control point areas are removed and filled in with smaller rock or the fill surface is proof-rolled by a single pass of the smooth drum roller without vibration to seat the rock for initial survey readings. The technique selected for the test fill is dependent on the degree of surface roughness prior to compaction. The cross pattern is generally spray painted again following the first roller pass due to the initial movement and seating of surface rock materials.

The control points are surveyed for elevation (settlement) readings versus roller passes using a conventional survey gun, rod, and minimum 12 inch (0.3 m) square plate having a cross pattern and center mark. The cross pattern on the plate is lined up to match the control point cross pattern on the fill surface for consistent survey readings at the exact same location on the rocky surface.

A minimum of five control points for each lift can be analyzed for acceptable test fill control. The control points are laid out in a pattern for the central portion of the roller drum to pass over the control points with about 1 ft (0.3 m) of side overlap for each pass. For a roller drum width of 7 ft (2.1 m), as an example, the control points would be spaced as shown on Figure 1. An example format and test results for recording and plotting each elevation reading at increments of two passes by the compaction equipment are shown on Figures 2 and 3.

Typically the survey control points for measuring settlement versus roller passes show the influence of additional dozer tracking in the direction of fill placement and dozer leveling with the leading edge of the test fill showing the most settlement. In the example test plot of surveyed test fill data shown on Figure 3, Control Points 1 and 2 were located on the leading edge of the test fill and showed more settlement compared to Control Points 4 and 5. Control Point 3, located in the center of the test fill limits, showed measured settlement close to the overall average settlement of the 5 control points.

A total of eight passes in two-pass increments are made for each test fill lift to evaluate settlement versus roller passes and determine the required number of passes acceptable for rockfill placement. In general, the required number of passes is set at 80 percent of the total settlement in eight passes or a maximum of six passes. Excessive passes on rockfills with large or heavy roller equipment tend to pulverize and crush the surficial 6 to 12 inches (0.15 to 0.3 m) of rockfill without significantly improving the density of the lower portion of the lift. The engineered test fill survey control work to determine acceptable roller passes on active rockfill placement areas can be conducted

over a period of less than one hour for each lift (marked survey readings on the active lift after each two-pass increment).

SUMMARY

The primary purpose of large scale test fills for compacted rockfills is to establish the lift thickness and compactive effort requirements to meet the intent of design. Rockfill moisture conditioning depends on the distribution and amount of earthfill soil particles contained within the rockfill fragment matrix and any rock fragments that weaken from wetting.

The large scale test fill procedures for determining acceptable rockfill lift thickness and compactive effort depend on the available rock borrow source and planned selection and development as rockfill material. The geologic rock structure, degree of weathering, and natural fracture patterns of rock borrow sources often dictate the rock fragment sizes that can be produced from ripping or blasting for the test fill pad.

Test fill operations begin with rock borrow development. Rock borrow materials, selected as representative of the rockfill after blasting, ripping, or screening, are removed from the borrow area, placed in the test fill, and compacted using the same equipment and procedures as planned for the rockfill construction. This includes borrow development, loading, hauling, dumping, spreading, and compacting. Moisture conditioning, where required, can be done in the borrow area or on the fill.

Moisture conditioning of rockfill borrow materials is not as critical as for earthfill materials to achieve acceptable compaction density. Moisture conditioning is encouraged in the rock borrow areas as much as practical. However, rock borrow surface development is rugged and may restrict conventional water truck application to the fill areas.

Test fills are generally conducted in rockfills during construction to suit available rock borrow and site conditions. The test fills are conducted to determine specific acceptable procedures for placement and compaction including moisture conditioning, loose lift thickness, rock type and gradation, compaction equipment, and number of passes by the specified compactor. Some limitations are initially set during design concerning the specified rock types, maximum rock sizes, lift thickness, and compaction equipment requirements. The design specifications can be modified by the engineer to suit site specific conditions, based on the quality and quantity of available rock borrow materials and the test fill performance during construction.

The test fills are generally incorporated within the rockfill structure, because of the large quantities of rockfill materials required for single and multiple lifts and variations in loose lift placement in the test fills. Test fill performance is measured with surveyed control points (settlement versus roller passes) for each lift, as well as subsequent verification of compacted in-place density and gradation testing discussed in Part 5 of this series of rockfill articles.

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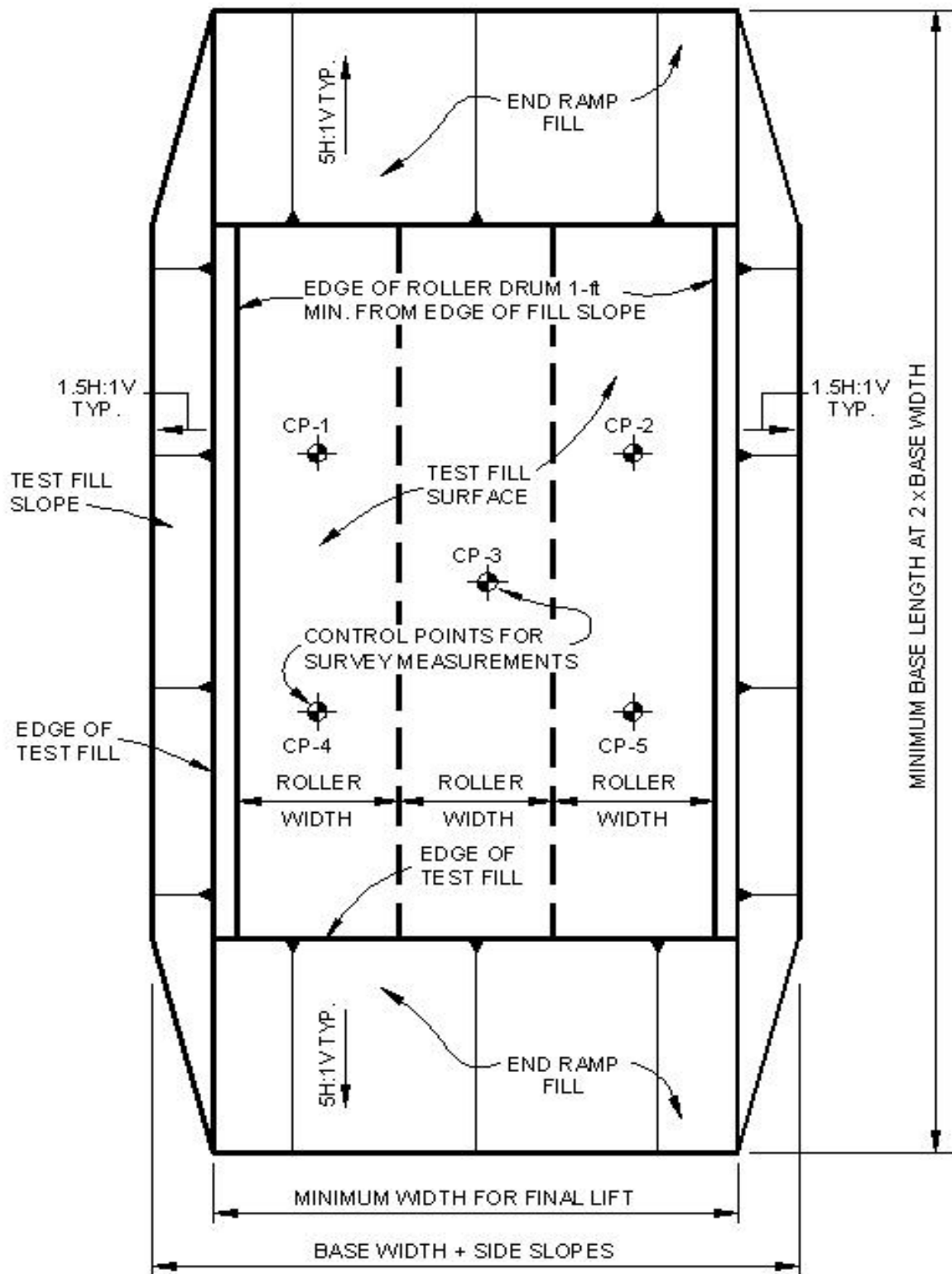


FIGURE 1 – TEST FILL LAYOUT FOR 7 FT SMOOTH DRUM ROLLER WIDTH

TEST FILL #: _____ PROJECT NAME: _____

LIFT #: _____ PROJECT #: _____

LIFT THICKNESS: _____ DATE: _____

ROLLER TYPE: _____ BY: _____

ROLLER DRUM WIDTH (FT): _____

ROLLER DRUM STATIC/DYNAMIC FORCE (TONS): _____ / _____

ROLLER SPEED (MPH): _____

ROLLER VIBRATION (VPM): _____

PLACEMENT EQUIPMENT AND PROCEDURES: _____

# OF ROLLER PASSES	CONTROL POINT # AND SETTLEMENT READINGS (FT)					AVERAGE SETTLEMENT (FT)
	1	2	3	4	5	
0						
2						
4						
6						
8						
80% OF AVERAGE SETTLEMENT IN 8 ROLLER PASSES =						

FIGURE 2 – ROCKFILL SETTLEMENT VERSUS ROLLER PASS DATA SHEET

# OF ROLLER PASSES	CONTROL POINT # AND SETTLEMENT READINGS (FT)					AVERAGE SETTLEMENT (FT)
	1	2	3	4	5	
0	100.50	100.40	100.50	100.60	100.50	0.000
2	100.73	100.58	100.66	100.71	100.62	0.160
4	100.80	100.63	100.70	100.75	100.67	0.210
6	100.83	100.66	100.73	100.78	100.69	0.238
8	100.84	100.67	100.74	100.78	100.70	0.246
80% OF AVERAGE SETTLEMENT IN 8 ROLLER PASSES =						0.197

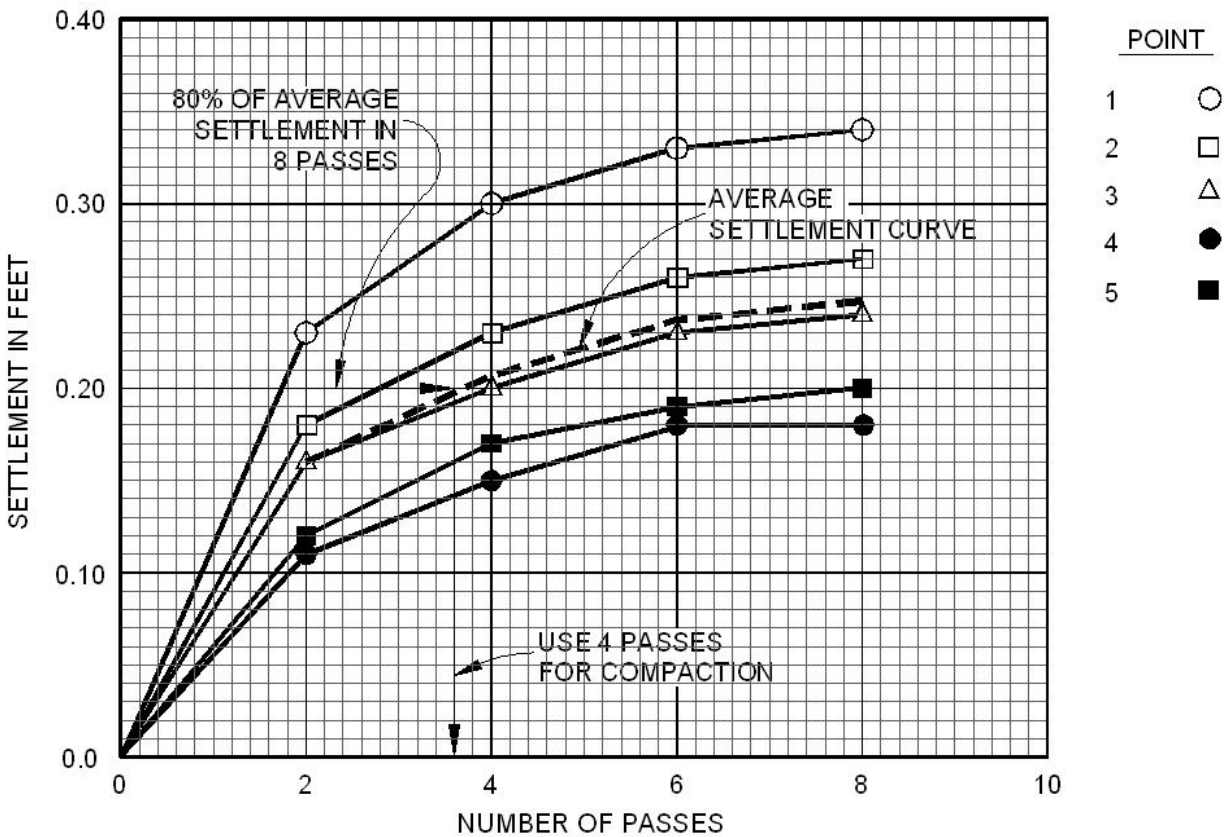


FIGURE 3 – EXAMPLE PLOT OF SETTLEMENT VERSUS ROLLER PASS DATA



PHOTO 1 – ROCKFILL DAM CONSTRUCTION IN SOUTHERN CALIFORNIA WITH 50 FT (15 M) DOWNSTREAM RAISE TO EXISTING DAM



PHOTO 2 – WETTING AND COMPACTING 2 FT (0.6 M) THICK LOOSE ROCKFILL LIFT WITH 20 TON VIBRATORY COMPACTOR ROLLER



PHOTO 3 – DOZER PREPARED TEST FILL SURFACE FOR CONTROLLED ROLLER PASS VERSUS SETTLEMENT MEASUREMENTS IN 2 FT LIFT



PHOTO 4 – INITIAL SURVEY MEASUREMENT OF LOOSE LIFT SURFACE ELEVATION IN TEST FILL (NOTE ROUGH ROCKFILL SURFACE)



PHOTO 5 – INITIAL ROUGH TEST FILL SURFACE BY DOZER MARKED FOR SURVEYED MEASUREMENT AT 5 LOCATIONS ON ROCKFILL SURFACE



PHOTO 6 – TEST FILL CONTROL POINTS CROSS-MARKED FOR SURVEY AND SPACED 1 ROLLER WIDTH APART FOR CENTERLINE COMPACTION



PHOTO 7 – TEST FILL SETTLEMENT POINTS ARE REMARKED FOR SURVEY AFTER 2 VIBRATORY COMPACTION ROLLER PASSES



PHOTO 8 – TEST FILL SURFACE BECOMES MORE LEVEL WITH EACH PASS OF THE VIBRATORY COMPACTION ROLLER