

### COMPUTATION OF JOINT EXTENSIBILITY REQUIREMENTS

This technical release presents the procedure and working tools required for the computation of the joint extensibility that may be required in a drop inlet barrel constructed of articulated segments which are essentially free to move with the adjacent parts of the embankment or earth foundation. The discussion and procedures that are established for determining the depth "d" in which foundation compression occurs, the average foundation shear strength "s" as used to compute foundation stress ratio, and the corresponding foundation settlement "δ" relate only to the computation of the required joint extensibility of conduits on yielding foundations. The foundation is considered as a body and conduit cuts or pads are not considered as influencing the total foundation deformations. These procedures do not necessarily apply to situations involving a determination of total foundation settlement.

An explanation of the strains produced at or near the interface of an earth dam embankment and its compressible foundation is contained in two reports. They are (1) "Report on Investigation of Deformations in Foundations of Earth Embankments Containing Concrete Pressure Pipe Conduits" by Moran, Proctor, Mueser and Rutledge, Consulting Engineers, dated September 1960 and (2) "Report on Study of Movements of Articulated Conduits Under Earth Dams on Compressible Foundations" by Mueser, Rutledge, Wentworth and Johnston, Consulting Engineers, dated June 1968. These reports provide the basic data and procedure which are used herein to estimate joint extensibility requirements.

The depth of the compressible foundation, d, will be obvious in some cases but in others it may be obscure until consolidation computations based on proper evaluation of foundation conditions and laboratory tests indicate the depth below which consolidation may be neglected. When the compressive unit strain in feet per foot in any stratum under the center of the embankment and at a depth of about 0.25H or more becomes less than 10 percent of the compressive unit strain of the strata above, and strata with a higher compressive unit strain do not exist below the stratum in question, it may be assumed that the depth of the compressible foundation has been attained. Obviously judgment is required in estimating d and the consolidation potential of the foundation. Relatively large consolidation can be expected on loessial soils which have not been preloaded, medium stiff residual soils or special fine grained material such as glacial lake deposits whereas relatively low or insignificant consolidation should be anticipated from ordinary SCS dams on glacial till, stream terraces, or alluvial coarse sands and gravels.









$L$  = length of a monolithic section of conduit in feet

$P$  = preconsolidation stress in pounds per square foot

$p$  =  $H\gamma_m$  = maximum vertical pressure at the interface in pounds per square foot

$\bar{p}$  = average effective stress on stratum at depth  $y$  in pounds per square foot

$R_1$  = theoretical ratio of maximum unit horizontal strain to average unit vertical strain,  $\delta \div d$

$R_2$  = a correction factor for the effect of the foundation stress ratio on  $R_1$  (see equation 3)

$s$  = average consolidated undrained foundation shear strength at the condition of completion of the embankment in pounds per square foot

$S$  = safety margin in inches (see equation 8)

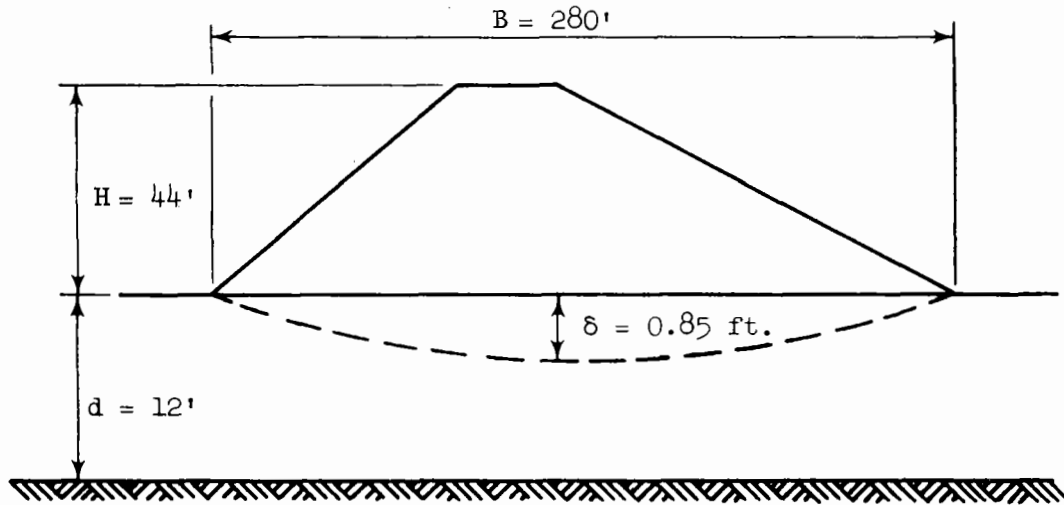
$y$  = depth into the foundation from the embankment-foundation interface to the stratum in question in feet

$e_{h m}$  = maximum unit horizontal strain

$\delta$  = maximum anticipated settlement of the foundation surface in the vicinity of the conduit in feet

$\gamma_m$  = moist weight of the embankment as built in pounds per cubic foot

$\gamma_f'$  = average submerged weight of foundation material above depth  $y$  in pounds per cubic foot

Example No. 1

Given:  $B = 280. \text{ ft.}; H = 44. \text{ ft.}; d = 12. \text{ ft.}; \delta = 0.85 \text{ ft.}$

$\gamma_m = 115. \text{ lb./ft.}^3; s = 1800. \text{ lb./ft.}^2; L = 16. \text{ ft.}; D = 48. \text{ in.}$

$D_o = 54. \text{ in.};$  class (a) dam;

Find: Required joint extensibility

Procedure:

Step 1. Compute  $\frac{B}{d} = \frac{280}{12} = 23.3; \frac{B}{H} = \frac{280}{44} = 6.4; \frac{\delta}{d} = \frac{0.85}{12} = 0.071;$

$p = H\gamma_m = (44)(115) = 5060. \text{ lb./ft.}^2;$

$\frac{2pd}{sB} = \frac{(2)(5060)(12)}{(1800)(280)} = 0.24$

Step 2. From ES-146 for  $\frac{B}{d} = 23.3$  and  $\frac{B}{H} = 6.4$  read  $R_1 = 0.123$

Step 3.  $R_2 = 0.24 + 0.10 = 0.34$

Step 4.  $e_{hm} = (0.123)(0.34)(0.071) = 0.00297$

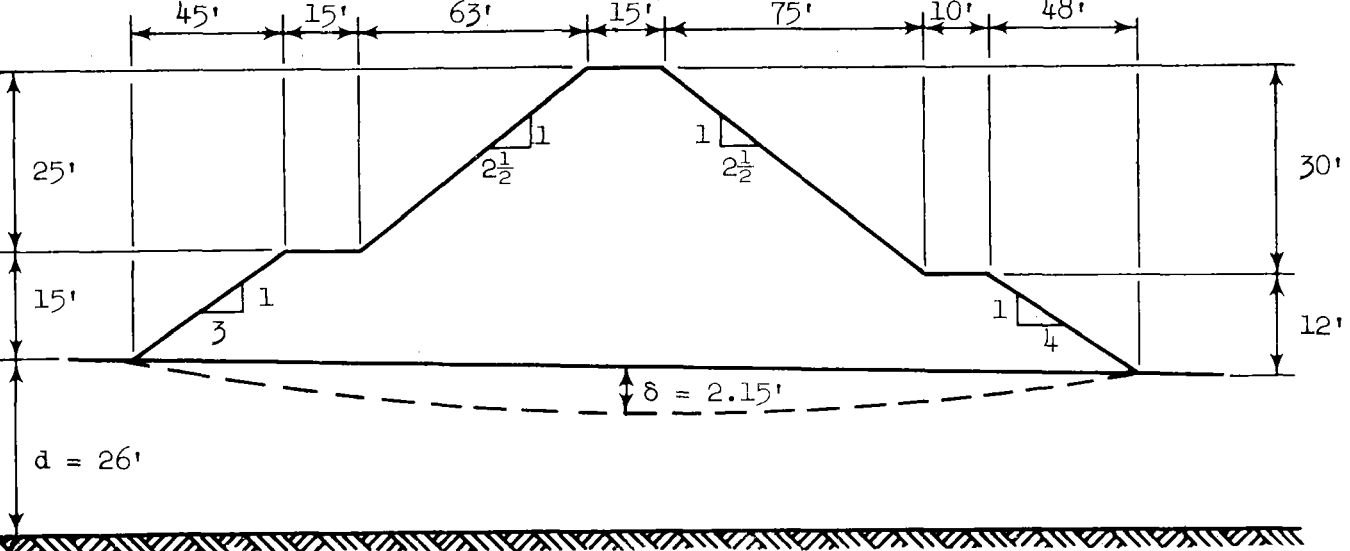
Step 5.  $g_s = (0.00297)(12)(16) = 0.57 \text{ inch}$

Step 6.  $g_r = \frac{(2.5)(54)(0.85)}{280.} = 0.41$

Step 7.  $S = \left(\frac{1}{2}\right)(0.24) + 0 + 0 = 0.12 < 0.5$  hence use  $S = 0.5$

$J = 0.57 + 0.41 + 0.50 = \underline{1.48} \text{ inches}$

Example No. 2



Given: Cross section of earth dam embankment as shown;  $d = 26$ . ft.;  
 $\delta = 2.15$  ft.;  $\gamma_m = 125$ . lb./ft.<sup>3</sup>;  $s = 1000$ . lb./ft.<sup>2</sup>;  $L = 10$ . ft.;  
 $D_o = 35$ . in.;  $D = 30$ . in. class (c) dam.

Find: Effective  $B$  and  $H$  and  $J$   
 $H = 41$ . ft. by inspection

$$B = \frac{2 \text{ times cross-sectional area of dam}}{H} = \frac{(2)(5333)}{41} = 260 \text{ ft.}$$

Procedure:

Step 1.  $\frac{B}{d} = \frac{260}{26} = 10$ ;  $\frac{B}{H} = \frac{260}{41} = 6.3$ ;  $\frac{\delta}{d} = \frac{2.15}{26} = 0.083$

$$p = H\gamma_m = (125)(41) = 5125 \text{ lb. per ft.}^2$$

Foundation stress ratio,  $\frac{2pd}{sB} = \frac{(2)(5125)(26)}{(1000)(260)} = 1.03$

Step 2. From ES-146 for  $\frac{B}{d} = 10$  and  $\frac{B}{H} = 6.3$  read  $R_1 = 0.213$

Step 3.  $R_2 = 1.03 + 0.10 = 1.13$

Step 4.  $e_{hm} = (R_1)(R_2) \left(\frac{\delta}{d}\right) = (0.213)(1.13)(0.083) = 0.020$

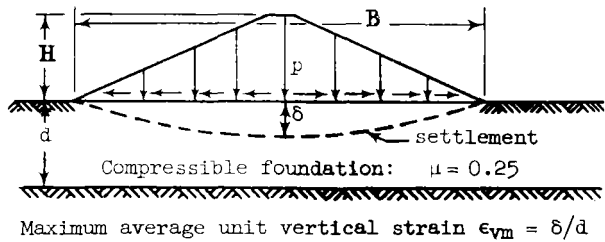
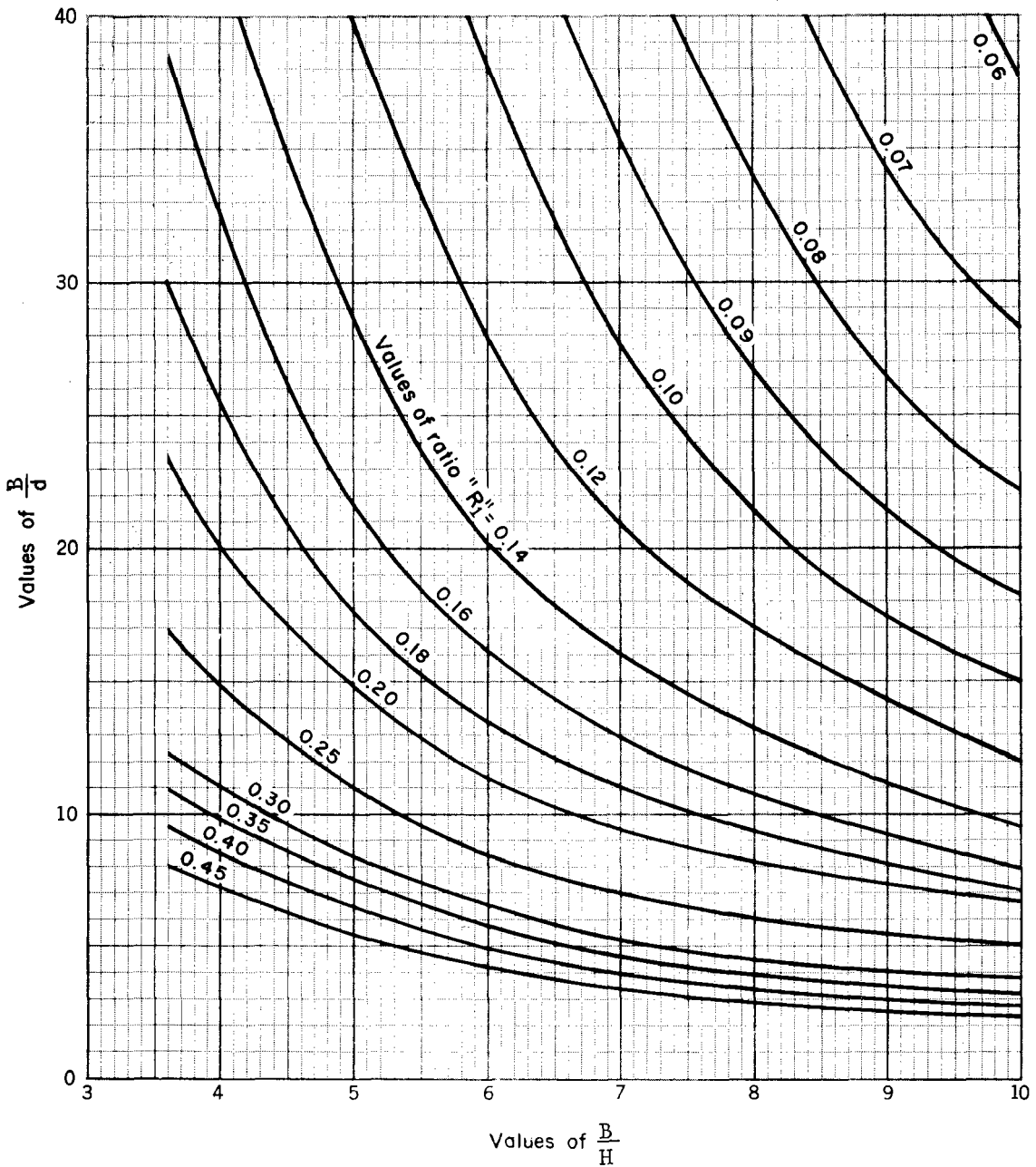
Step 5.  $g_s = (e_{hm})(L)(12) = (0.020)(10)(12) = 2.40$  inches

Step 6.  $g_r = \frac{2.5D_o \delta}{B} = \frac{(2.5)(35)(2.15)}{260} = 0.72$  inches

Step 7.  $S = \frac{1}{2} \cdot \frac{2pd}{sB} + C_H + C_D$   
 $= \left(\frac{1}{2}\right)(1.03) + 0 + 0 = 0.52 > 0.5$  use  $S = 0.52$



**SOIL MECHANICS:** Values of theoretical ratio of maximum unit horizontal strain to average unit vertical strain =  $R_1$   $\mu=0.25$



REFERENCE "Report on Investigation of Deformations in Foundations of Earth Embankments Containing Concrete Pressure Pipe Conduits" by Moran, Proctor, Mueser, and Rutledge.

U. S. DEPARTMENT OF AGRICULTURE  
SOIL CONSERVATION SERVICE  
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO. ES-146  
SHEET 1 of 1  
DATE 3-24-61

