Developing Free-Surface Inception Point for Stepped Chutes with Multiple Sections of Surface Roughness along the Chute Floor

Sherry L. Hunt, Ph.D., E.I.T., USDA-Agricultural Research Service Hydraulic Engineering Research Unit

Kem C. Kadavy, USDA-Agricultural Research Service Hydraulic Engineering Research Unit

Aging embankment dams are commonly rehabilitated with roller compacted concrete stepped chutes in the U.S. These aging embankment dams typically range in height from 9.1 m to 30 m (30 ft to 100 ft) with downstream slopes of 10Â° â‰¤Î¸ â‰¤ 30Â°. Safety is sometimes cited as a concern around these structures as the training walls may be significantly tall and the steps may be easily climbed. While fencing if often used to secure the site, alternative safe, economic measures to these structures are often sought by the dam safety community and construction industries. Scientists with the USDA-Agricultural Research Service (ARS) Hydraulic Engineering Research Unit found the free-surface inception point is a key parameter in determining flow depth, mean air concentration, and energy coefficient used in design of stepped spillways applied to embankment dams. To improve knowledge in the performance of these structures with consideration of discouraging climbers on these structures, scientists expanded research to examine the effect changing the chute floor surface roughness (e.g. smooth to stepped) has on the developing free-surface inception point. With a broad-crested weir entrance, a 3(H):1(V) 1.8 m (6 ft) wide concrete flume with 5.5 m (18 ft) vertical drop was used for testing. The upper 20% section of the test flume consisted of a smooth chute bottom surface with an equivalent step height of 0.15 mm (0.006 inches) or a bottom surface with step heights equal to 19 mm (0.75 inches) in the upper 20% of the chute. For the remaining 80% of the flume, the step heights were 19, 38, 76, or 152 mm (0.75, 1.5, 3, or 6 inches). Research results indicated when the larger steps occupy a minimum of 65 to 75% of the distance from the downstream edge of the broad-crested weir to the free-surface inception point, then one may assume the larger step height for calculating this distance. If the smaller step is assumed to dominate in this scenario one could expect 15 to 65% error in the prediction of the distance from the downstream edge of the weir to the free-surface inception point. Accounting for the different step heights and assuming a constant rate of boundary layer development for each step height allows the error to be reduced to Â±10% for stepped chutes with two different roughness height sections. This research is intended to provide alternative design considerations when considering safety around these structures.