CRADLES

Earth Dam Design

Association of State Dam Safety Officials

Outlet Works Technology Committee

Subcommittee on Use of Cradles

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Introduction

Penetrations through earthen embankment dams are one of the leading causes of failure. Unfortunately, conduits or pipes associated with principal spillways, or low-level outlets, are routinely constructed in earthen embankment dams as a cost effective and efficient means of discharging water from the impounded reservoir. Limiting or controlling water along the exterior of the penetration is critical to the long-term performance of the conduit, and thus the embankment.

Conduits through embankment dams present a series of issues to both the design engineer and to the construction contractor if not properly addressed. These issues include, but are not limited to:

- Discontinuity that increases potential for uncontrolled seepage
- Discontinuity that impedes 'normal' abutment to abutment placement of fill

The design of conduits through embankment dams must consider structural integrity, settlement, joint integrity, and seepage along the interface of the conduit and the embankment fill materials. Additionally, other region specific issues, such as the pH of surface water, must be considered.

The Association of State Dam Safety Officials (ASDSO) created an Outlet Works Technology Committee to develop an overview of industry standards pertaining to the use of cradles to control seepage along pre-cast or pre-constructed conduit penetrations through earthen embankment dams. This overview, which includes a brief history of measures to control seepage along conduits, as well as cradle types, locations, dimensions, and jointing, is presented herein. For the purposes of this white paper, the discussion will be limited to pre-cast conduits in earthen embankment dams having maximum heights of generally not more than 150 feet as measured from the crest of the dam to the floodplain. This 'white paper' discusses the issues related to the design of conduits as the design pertains to controlling seepage and the migration of soils from the interior of the dam. Secondary benefits from the design may include improved contractor operations or construction methodologies.

History of Seepage Control Measures

The design of measures to control seepage and associated migration of soils has, like design considerations in many engineering disciplines, evolved as a result of the experiences of past engineers and the success or failure of past projects. The first design methodology for pipe penetrations through embankment dams consisted of little more than placing a conduit on the natural ground surface and placing fill (compacted or not) adjacent to and over the conduit.

The propensity for uncontrolled seepage along these conduits and associated migration of soils led designers to include anti-seep collars or 'fins' projecting from the conduit into the fill and foundation to increase the seepage path, or length, that the water would have to travel before exiting at the downstream toe of the dam. The anti-seep collars, when designed and installed properly, increase the length of the seepage path a sufficient distance to reduce the gradient, or head loss, divided by distance, to a value sufficiently low enough to prevent the migration of embankment materials. While the design of the anti-seep collars is relatively simple, installation/construction of the collars in general accordance with the required design, is not. Construction of anti-seep collars is time consuming and requires significant amounts of manual labor from both an installation and backfilling point of view. Backfilling around/adjacent to anti-seep collars is expensive, and the level of compaction varies greatly due to the intensive hand labor required.