Use of Concrete Pressure Pipe in Dams and Levees

Completed NRCS dam with concrete emergency spillway built over concrete pressure pipe principal spillway installed through the dam.

Perhaps unknown to most of the non-governmental engineering community, Concrete Pressure Pipe has been used for decades in medium to critical service for dam outfalls and levees.

Likely the most common designer for such applications anywhere has been the Natural Resources Conservation Service, (NRCS, formerly the Soil Conservation Service or SCS), a division of the U.S. Department of Agriculture. The most common designer of applications for levees in the United States is the U.S. Army Corps of Engineers. Engineers in both agencies utilize a similar approach for pipe installation analysis and pipe design. Most often for pressure applications, prestressed concrete cylinder pipe (AWWA C301) is the pipe of choice. The NRCS allows use of either a traditional D-load design curve or the design procedure presented in AWWA C304 for the design of prestressed concrete cylinder pipe, while the Corps of Engineers uses the AWWA C304 design procedure exclusively when designing prestressed concrete cylinder pipe.

PROVEN PERFORMANCE OF CONCRETE PRESSURE PIPE

In the 80+ years since NRCS and its predecessor agencies have been building dams, more than 29,000 dams have been built across the United States for flood control and soil erosion mitigation. This does not include smaller farm pond structures. Construction of larger SCS/NRCS dams began in 1948, with a higher volume of dam construction sparked by passage of the Watershed Protection and Flood Prevention Act of 1954.

Of those larger dams, approximately 7300 are big enough to utilize concrete pressure pipe for the principal spillway. The tallest SCS/NRCS dam to date is in Arkansas at 134 feet tall. The largest principal spillway made of concrete pressure pipe is 84 inches in diameter; there are larger monolithic box spillways in other dams. In total, approximately 295 miles of concrete pressure pipe

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Principal spillway of concrete pressure pipe laid to grade, with forming for vertical intake structure in background.

continues to serve as dam spillways in SCS/NRCS dams, and new and rehabilitated dams with concrete pressure pipe spillways continue to be designed and built to this day. Corps of Engineer dams and levees also utilize an additional amount of concrete pressure pipe.

DESIGN CONCERNS FOR PIPELINES IN DAMS AND LEVEES

Given that the purpose for the dam or levee is to contain and redirect the flow of water, the first priority of the pipeline installation is that there are no leaks either in the pipe, at the pipe joints, or around the pipe installation. This requirement dictates that through the water retention zone of the embankment the pipe is embedded in selected low permeability soils that are well compacted at the specified moisture content to reduce the likelihood of water flowing along the length and outside of the pipeline. A concrete cradle is required under the pipe for support and to achieve adequate compaction under the haunches of the pipe. Historically, concrete "water stop" walls that extended away from the pipe into the impervious fill were frequently used to reduce the potential for flow along the length and outside of the pipeline. For new and rehabilitated dams, this discontinued practice has been replaced by a filter envelop around the pipe that extends some distance in all directions from the pipe. This filter diaphragm may be a part of a more extensive filter and drainage system, and is made of select materials and designed to filter out any soil being carried by water that is flowing along the pipe or near the pipe in order to prevent internal erosion of the dam or foundation.

The effect of the weight of the dam or levee on its foundation materials must also be considered. The material of the structure itself will settle, and any compressible material on which the dam or levee is built will consolidate under the new structure's weight. The result will be for the centerline of a pipeline placed under the structure to sag from its original installed location. The effects of the sagging must be accommodated.

One effect of the sagging is that low spots in the middle of the pipeline could result. Low spots can be avoided by laying the pipeline in a slight upward camber, so that the future settlement of the arched pipeline will result in a near-straight pipe centerline, slightly angled down in the direction of intended water flow.

Another effect of the settlement is the toes of the dam are forced outward which can induce longitudinal friction on the pipe and elongate the pipeline. Lateral spreading of the embankment can also result from earthquake shaking. Under extreme conditions, these forces can be sufficient to either pull the gasketed joints apart, or to induce cracking in the pipe wall concrete, or both. These problems are addressed by designing the pipe with extra-deep joints that will accommodate additional extensibility without losing water tightness, and requiring the steel cylinders in the pipe to be of the thickness needed to assure that the pipe cylinder can adequately withstand the tensile force applied and attendant stress to the pipe by soil friction from the settling dam.

The uniformity of the foundation soil must also be considered. Building a dam or levee over variable foundation conditions, such as a rock substrate for some distance, and compressible soil for the remainder, will cause a change in support under the pipe at the boundary between the rock and soil. In the past, similar discontinuous support would occur at locations of the "water stop" concrete walls previously placed around the pipe. The pipe crossing locations of foundation compressibility may need to be either reinforced with additional thickness cylinder or provided with additional flexible joints if the calculated bending force on the pipe at such locations exceeds the standard pipe wall bending force limits. The concrete cradle placed under the pipe can also be tailored in these areas to provide a more uniform bedding.

A BRIEF HISTORY OF THE GOVERNMENT AGENCIES

U.S. Army Corps of Engineers. George Washington appointed the first engineer officers of the Army on June 16, 1775, during the American Revolution, and engineers have served in combat in all subsequent American wars. The Army established the Corps of Engineers as a separate, permanent branch on March 16, 1802, and gave the engineers responsibility for founding and operating the U.S. Military Academy at West Point.

Since then the U.S. Army Corps of Engineers has responded to changing defense requirements and played an integral part in the development of the country. In the 20th century, the Corps became the lead federal flood control agency and significantly expanded its civil works activities. Its role in responding to natural disasters also grew dramatically.

The Corps became a leading environmental preservation and restoration agency in the late 1960's. It now carries out natural and cultural resource management programs at its water resources projects and regulates activities in the Nation's wetlands. In addition, the Corps assists the military services in environmental management and restoration at former and current military installations.

For more information on the history of the U.S. Army Corps of Engineers, see http://www.usace.army.mil/About/History/Brief-History-of-the-Corps/Introduction/

Natural Resources Conservation Service. American scientists began to recognize the detrimental effects of soil depletion and erosion in the early 1900s. Following the presidential election of Franklin Roosevelt, leaders in the federal government recommended federal support for soil conservation measures, including crop rotations, contour plowing, strip cropping, grassed waterways, and "terraces" to retard or prevent soil erosion. This effort was originally assigned in 1933 to the Soil Erosion Service, an agency under the U.S. Department of the Interior. The Soil Erosion Service was moved to the U.S. Department of Agriculture at President Roosevelt's direction in March,1935, and an act of Congress on April 27, 1935, created the Soil Conservation Service (SCS). The SCS worked through engineers in each state, who in turn worked with landowners to evaluate potential dam sites and subsidize the design and construction of dams. In 1994, SCS's name was changed to the Natural Resources Conservation Service to better reflect the broadened scope of the agency's concerns.

For more information regarding the Natural Resources Conservation Service, see http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044444.pdf

SUMMARY

Design of Concrete Pressure Pipe for installations in dams and levees requires a thorough geotechnical analysis of the substrate upon which the structure is to be built so as to best estimate the tension and bending forces that are typically caused by both the settling of the structure and the consolidation of the substrate. Pipe joints must provide a watertight seal, and be sized to accommodate joint extension. Pipe bedding must be provided to achieve adequate earthfill compaction under the haunches of the pipe to reduce potential for seepage along the pipe. A filter diaphragm must be provided to intercept any seepage that may occur adjacent to or in the vicinity of the pipe. Proven analysis and responsive design have resulted in thousands of successful Concrete Pressure Pipe spillway and levee installations across the country providing many decades of continuous service.

LEARN MORE

For more information about design of Concrete Pressure Pipe for installations in dams or levees, speak with your Concrete Pressure Pipe supplier, or contact the American Concrete Pressure Pipe Association at 714.801.0298 or www.acppa.org.

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