TECHNICAL PAPER

Geosynthetic Portable Coffer Dams for Civil Construction Applications

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ABSTRACT

Geosynthetic cofferdams are increasingly utilized for civil construction applications including dewatering, flood control and sediment control. This paper describes one of the more commonly used geosynthetic dam system which was developed in the early 1990's and has been used extensively in North America as a portable cofferdam. It is a water control structure designed to source water directly from the stream, river or pond to control, contain and divert the flow of water. It is used in applications such as dewatering for bridge foundation work, dam repair, pipeline crossing, canal liner repair and shoreline construction and restoration. Geosynthetic dams provide an economical and modular alternative to conventional construction of earth dikes and mechanical sheet piling in these applications.

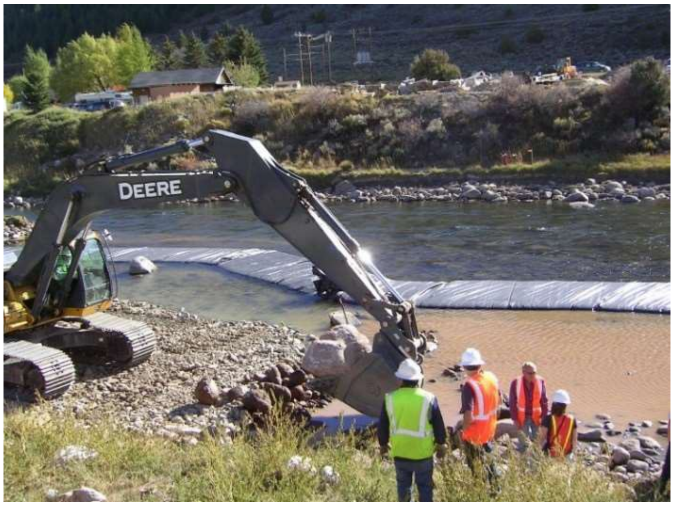

Figure 1. Installation of 6' Cofferdams - Eagle River, CO

This paper highlights a recently installed 1,400 lineal foot (427 m) project to control sediment during the excavation of a new channel during bridge construction in Kilisut Harbor, Washington. The North Olympic Salmon Coalition (NOSC) and the Washington State Department of Transportation (WSDOT) were looking to restore the historic tidal channels and fish runs between southern Kilisut Harbor and Oak Bay in Jefferson County, Washington. This challenging tidal application required the portable geosynthetic dams be installed in various heights up to 12 feet (3.66 m) to isolate the channel for dewatering and sediment removal using excavators and dump trucks.

INTRODUCTION

Cofferdams by definition are an enclosure built within or across a body of water to allow the enclosed area to be dewatered. This creates a dry working environment so that construction can be carried out properly and safely. Typical cofferdams are welded

Figure 2. USACE 10' & 8' Cofferdam - Baytown, TX

steel structures consisting of sheet piles, wales or cross braces and are normally dismantled after construction. However new portable or temporary geosynthetic cofferdam systems provide an effective alternative. These systems come in a variety of different designs, materials and installation methods and provide a more economical solution for temporary site dewatering versus conventional structural cofferdams. Portable geosynthetic cofferdams are typically lighter weight modular systems produced from geomembrane and geotextile fabrics. They limit the impact of construction generated silt and sedimentation when excavating in submerged or dredging areas, which lessens the environmental impact. Most systems are also modular in design allowing for bends and turns in the project waterway. They can also be installed and removed quicker than standard structural cofferdams which makes them more cost-effective. Properly handled, these dams can also be drained and re-used, eliminating the need to purchase a new dam for different projects in some instances. Common applications for the geosynthetic portable cofferdams include dewatering for bridge foundations, dam repairs, pipeline crossing, irrigation canal repair and shoreline construction and restoration. Smaller diameter geosynthetic dams are also used extensively for flood control barriers. Figure 1 and 2 above show the installation and applications of the geosynthetic cofferdams.

For this paper, the cofferdam system produced by the manufacturer consists of two geomembrane tubes contained by a high strength woven textile outer tube. The two inner tubes are filled with water which creates a stable, non-rolling water-controlled structure. A center baffle curtain is installed for stability, reducing movement or tipping as a result of hydrodynamic loading. The local water source is normally used to fill the inner tubes of the dam. This cofferdam dam system was first introduced in the early 1990's and is constructed in a range of sizes from 4' diameter to 16' diameter in standard 100' and 200' lengths. Special connecting collars are used to join the dams during installation. Standard fill and drain ports are installed into each dam. Installation of the dams requires trained technicians and equipment and can be far more difficult in moving water applications versus slow or still water projects. Special patch kits and repair techniques are used in the event the dams are punctured during the installation or in application. Figure 3 below shows the modular capabilities of the portable cofferdams.

Figure 3. 6' Geosynthetic cofferdams for pipeline repair in Manitoba, Canada

DESIGN & ENGINEERING

This section summarizes the system stability and engineering needs of the water filled manufacturers dams. System stability is critical to the successful use and installation of the portable cofferdams. The basic principle behind the water filled dam system incorporates a dual inner tube system with a center baffle to stabilize the entire structure. This is shown in figure 4 below. The safety factor against sliding depends greatly on the coefficient of friction of the material that the dam is sitting on. In this case where it is sitting on a wet grass surface, the coefficient of friction used is 0.20 (Noon, 1994). The factor of safety against sliding is 1.33 when 24" (0.61 m) of water is being held back.

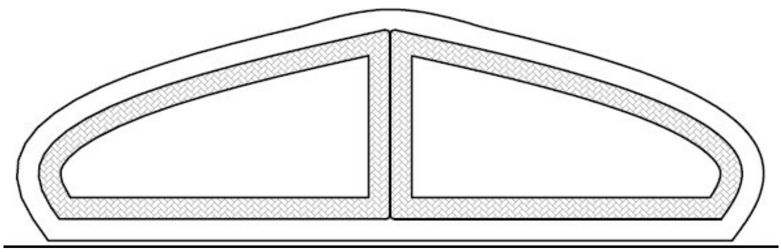

Figure 4. Schematic of water filled dam with inner tubes

As the water builds on one side of the dam, the inner tubes prevent rolling and the dam behaves as a solid barrier as shown in figure 5.

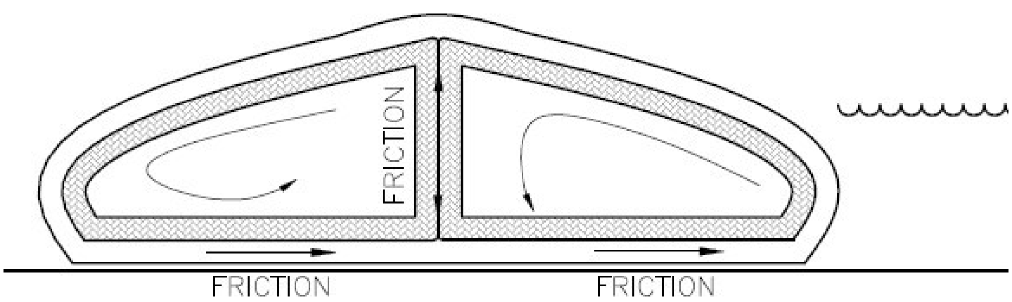

Figure 5. Stability of water filled dam to hydrodynamic loading

Engineering designs with proper calculated safety factors are required based on individual manufactured systems and project specific site conditions. Under hydrodynamic loads the portable dams need to be designed to resist sliding, tipping, and overturning. In order for the manufacturers dam to move as a result of the pressure exerted on one side, it must either be tipped over or slide across the surface on which it rests. In order to tip, the water pressure must lift the first inner tube up and over the second. The following calculation verifies the dam's resistance to tipping:

Assumptions:

The inner tubes are assumed rectangular when filled to facilitate the calculations. The water level on one side will assumed to have reached the top of the Aqua Dam to simulate the worst-case scenario.

P = Pressure
h = water depth
D = width of Aqua Dam l = length of Aqua Dam
Þ = mass density of water
g = gravitational acceleration y = specific weight of water
F = Force exerted on the face of the Aqua Dam due to pressure (P) A = area of the side face of the Aqua Dam
W = weight of water in the inner tube V = Volume of the inner tube
P = Þgh = yh Pavg = y(h/2) A = hl
F = PA = Pavg A W = yV

The force exerted on the side of the water structure is defined as: $F=\gamma\frac{h}{2}hl$

Having determined the force on the side of the Aqua Dam, the tendency of the Aqua Dam to tip can be evaluated. Point A is assumed the pivot point and moments are calculated about this point. The moment created by each force, is a measure of how much the force contributes to rotating the first column of water around point A. The two formulas are shown below:

$$\sum M_A = W\frac{1}{2}D - F\frac{n}{3} = 0$$

Equation 2. Formula for calculating tipping forces

$$\sum M_A = \rho h\frac{D}{2}l\frac{D}{2} - \rho\frac{h^2}{2}l\frac{h}{3} = 0$$

Equation 1. Optional formula for calculating tipping forces

Simplifying the expression, it is observed that the stability of the dam is dependent on the relationship between its width (D) and the depth of water it must resist. The relationship above indicates the minimum width of the dam to prevent it from tipping when resisting water with a depth (h) equal to the height of the dam itself. The design height for the water structures to prevent tipping would be described as: D> (.82) h

In order to quantify the stability of the dam, the actual dimensions of the standard dam for D and h are substituted into the equation above. The results are expressed in terms of a safety factor. The safety factor indicates how many times greater the water pressure or water depth must be in order to roll the dam.

Based on the current dam designs, the safety factor against tipping when water levels are to the top of the structure as per table 1 below:

B	Inflated Width (in inches)	Safety Factor Against Tipping
36”	68	2.30
48”	120	3.48
72”	186	3.15
84”	282	4.12

Table 1. Design Factor of Safety for Water Level at Top of Manufacturers Dams

Additional site-specific details and risk assessment must also be predetermined for each project. This is done by completing a detailed site assessment prior to installation. Important criteria required for this assessment includes the water body type (lake, river, stream, ocean), anticipated water depth, historical water depths, water flow rates, freeboard level, and ground surface conditions. Site specific project assessment forms are required by the manufacturer for each project estimate.

PROJECT PROFILE – KILISUT HARBOR

In 2019, the North Olympic Salmon Coalition and the Washington State Department of Transportation needed to restore the historic tidal channels and fish runs between southern Kilisut Harbor and Oak Bay in Jefferson, County Washington. This included removing the outdated culverts and installing a new elevated bridge which replaced a causeway as part of creating 2,300 acres of productive fish habitat in the Puget Sound region. The first phase of this project included restoration of the channel on the north side of the highway in a sensitive marine environment. Figure 6 shows the cofferdams being deployed during tide out conditions.

Figure 6. Kilisut Cofferdams being deployed in low tide

PROJECT SCOPE

As part of the new bridge construction, the project scope required the contractor to excavate and dewater a large channel in a very environmentally sensitive region for the protection of salmon stocks and their migration. To address these environmental concerns, silts and sedimentation from construction had to be tightly controlled. Based on the project constraints, the engineer and contractor chose a temporary portable coffer dam. Layfield USA Corporation's modular cofferdam system was chosen for the project.   The project scope including the manufacturing and installation support of 1,400 feet (427 m) of multiple sizes dams in sizes of 4', 6', 8', and 12' (1.22, 1.83, 2.44, 3.66 m) in heights. The installation started in September 2019 with a crew of seven field technicians.

Figure 7. Kilisut Harbor Cofferdams

PROJECT CHALLENGES

The project faced a number of unique challenges. One of the main challenges was working in tidal conditions which required the installation of the dams to only take place during low tide cycles. The contractor was also not allowed to operate equipment on the majority of the site in order to protect the pickle grass and wetlands area. This required many of the dams to be unrolled and positioned manually. With the multiple size dams, special fabricated collars were manufactured to connect the different sizes on site.

Figure 8. Aerial view of completed Kilisut Cofferdam installation.

Figure 9. 8' Cofferdams being installed - Toppenish, WA

CONCLUSION

The installation of the modular dams took 7 days to complete and were drained and removed in January 2020. The dams performed successfully with the contractor being able to complete solids removal from the channel in dry conditions. This was a significantly faster method versus if they had had to rely on a vacuum dredge. The use of the temporary cofferdams was a key component in providing an environmentally safe and successful installation. It also provided major cost savings to the contractor and project owner.

Civil engineers and contractors are increasing the use of portable geosynthetic cofferdams to help control water in a variety of excavation and dewatering applications. While there are numerous systems available, each system should be individually reviewed and engineered for each application in order to reduce the risk of failure and ensure safe work conditions. When properly designed and installed, portable geosynthetic cofferdams can provide numerous economic and environmental advantages when used to control water.

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