REHABILITATION OF
FAILED CORRUGATED METAL PIPE SPILLWAYS

PRESENTED AT JUNE 1996 REGIONAL CONFERENCE
MID-ATLANTIC COUNCIL FOR SAFE DAMS

by
Harald W. Van Aller, PE
Geotechnical Engineer,
Maryland Dam Safety Division

ABSTRACT

Many small to medium size dams constructed in the 1960s and 1970s in Maryland utilized corrugated metal pipe conduits for the principal spillway. Many of these structures have reached the end of their useful life because of deterioration of the pipes by corrosion. This paper presents case histories for some dams in Maryland with deteriorated pipes that were recently rehabilitated. Of special interest is the use of polyethylene pipe for sliplining existing spillways.

INTRODUCTION

Since the 1960s many small dams in Maryland have been constructed with corrugated metal pipe (CMP) spillways. Farm ponds that were once located in the middle of agricultural land have become focal points of new communities, often without benefit of needed renovation. In addition, many engineers have specified CMP conduits in the design of small-to-medium (less than 20 feet high) stormwater management ponds following guidelines published by various government agencies. These deteriorating CMP spillways are now presenting a costly dilemma for the current owners, which are often homeowner associations with little or no financial resources.

Removal and Replacement. Conventional removal of the old conduit and replacement with a new pipe is expensive and time consuming. For a dam of medium size (20 to 30 feet high) the estimated cost for pipe replacement, including design and construction, is about $100,000. Thus, there is a need to evaluate less costly alternative repair methods.

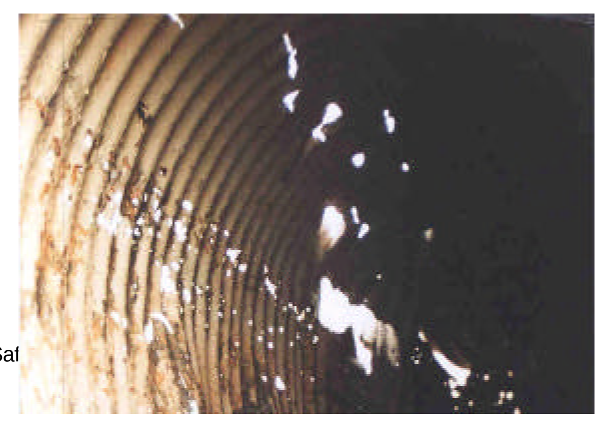
Sliplining. An obvious alternative to replacement of the pipe is "sliplining" where a smaller pipe is inserted into the existing pipe and grouted into place. The procedure has been used on a large Soil Conservation Service flood control dam in New York (Lake, 1987) and at several state forest service dams in Kansas (Austin, 1996). At first glance it seems that sliplining should be straightforward. However, there are many factors that need to be evaluated before attempting the procedure, including the condition of the pipe and embankment, effects of a smaller pipe on spillway capacity, liner structural design, and grouting techniques.

Other alternatives. One recently proposed alternative for rehabilitation of failing CMP spillways on small dams is installation of a new PVC siphon pipe near the top of the dam. The existing pipe is abandoned by completely filling it with grout. (ASDSO 1995). If the existing pipe is structurally sound, but leakage into the conduit creates a potential for "piping", then repair by injection of chemical grout into the soil outside the pipe through holes drilled through the pipe walls may be adequate. Grouting to remediate "piping" through leaking joints has also been performed successfully through borings drilled from the surface of the dam using cement grouts. (ASDSO 1995)

CASE HISTORIES OF REPLACED/REPAIRED CMP SPILLWAYS IN MARYLAND

Several dams in Maryland have recently required major repairs as a result of deteriorating CMP conduits. A few are listed here.

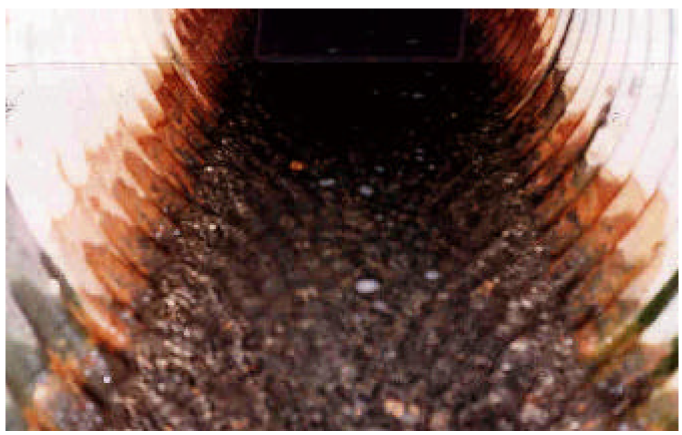
Priestford Hills. The Priestford Hills Dam is an earthen dam about 25 feet high which was constructed in 1974. It impounds a lake that serves as a focal point of a small community. By 1992, the 36-inch CMP conduit had deteriorated to the point where hundreds of holes (see Figure 1) were observed in the pipe invert and sidewalls, subjecting the underlying soil to erosion, which could potentially lead to a "piping" failure. The Dam Safety Division determined that the dam was unsafe and ordered the lake drained. The pipe was deemed "not repairable" and was there completely removed and replaced with concrete pressure pipe (ASTM C-361) using conventional excavation techniques. Cost was about $100,000 and the lake was drained for three years while the owner could secure financing.



Shores of Calvert (Lower Dam). This dam is about 15 feet high and was built in the mid-1970's for recreation. In 1992 an inspection of the dam noted that the pipe had settled due to undermining of the outfall, the pipe was deteriorating because of corrosion, and a small "sinkhole" was observed in the embankment adjacent to the pipe. Although the owner retained an engineer to inspect the structure and prepare remedial plans, no work on the dam was done. In 1994 the structure was reinspected and deemed unsafe because the sinkhole had enlarged considerably and one section of the pipe (10 to 15 feet long) at the downstream end was missing. Complete removal of the conduit and replacement with reinforced concrete pressure pipe was completed in 1995 at a cost of about $80,000.

Elk Neck State Forest Dam. This 22-foot high dam was constructed in 1959 with a 36-inch CMP spillway barrel. In the late 1980s an inspection of the dam revealed that the outlet pipe barrel was in good condition, but the base of the riser had deteriorated to the point where collapse was imminent. The owner of the dam (a state agency) performed temporary repairs to the riser base with concrete, and requested funds for spillway replacement. In 1990 a specialty contractor (Insituform) was contacted regarding the feasibility of completely relining the pipe and riser with a cured-in-place resin impregnated tube. The estimated cost at that time was about $60,000. This exceeded the funds set aside by the owner, and no work was done. In early 1996 the riser collapsed (see Figure 2) and plugged the spillway. The situation developed into an emergency condition during a heavy storm and the dam owner immediately drained the lake and breached the dam.

Campus Hills. The Campus Hills Dam is an earthen dam about 30 feet high which was constructed in 1969 for a recreational lake. An inspection of the pipe in 1992 showed that the 24-inch CMP conduit was beginning to show signs of deterioration, as the invert was severely corroded, but no holes were observed. However, the inspecting engineer was able to penetrate the pipe completely with a small blow by a blunt tool. Because the pipe did not show signs of leakage and the embankment showed no signs of "piping," the Dam Safety Division allowed the owner to investigate sliplining of the conduit as an alternative to conventional removal and replacement. A local engineering firm was retained by the owner to develop the design. A 22-inch, smooth-walled polyethylene (HDPE, type PE3408) pipe with a Standard Dimension Ratio (SDR) of 26 was selected as the slipliner material. The required lengths of pipe were "fusion welded" into a single length on the crest of the dam and then inserted into the conduit from the downstream end. A 36-inch SDR 26 HDPE pipe was inserted vertically into the CMP riser and joined to the barrel with 24-inch and 34-inch flanges field welded (PE extrusion) into the base. The annular space between the new and old pipes was filled with cement grout. The entire process took less than one week and the pool was lowered slightly, but not drained. The total project cost, including design and construction, was about $50,000.



RECOMMENDATIONS FOR SLIPLINER REHABILITATION

1. Evaluation of Existing Pipe. A thorough inspection of the existing pipe is required. (Remember that spillway conduits may be subject to regulations restricting personnel access in "confined spaces"). The condition of the pipe, amount of deflection, and evidence of leakage or piping should be determined. Excessive leakage at poor joints or holes in the pipe may result in piping of embankment material into the conduit. Sliplining of the pipe may not be economical if extensive grouting of large voids along the outside of the pipe will be required prior to inserting the liner pipe.

2. Hydraulic Adequacy. The effect of a smaller pipe on spillway hydraulics must be evaluated. Typically, a new, smaller plastic pipe will have a hydraulic capacity equal to or greater than the original conduit because it is smoother than the pipe into which it is inserted. (The reported Manning s "n" value for smooth wall HDPE pipe is 0.009, HDPE profile wall pipe is listed as 0.010 to 0.012, and other sliplining products have similar hydraulic properties.) Thus, a slipliner design that maintains at least 85 percent of the original cross-sectional area will likely have about the same capacity as the existing pipe, although this depends on the type of pipe used originally.

3. Slipliner Selection. Many new products that may be suitable for sliplining have appeared on the market in recent years with the interest in “trenchless technology” for underground utility repairs. These include smooth wall, high density polyethylene (HDPE or PE), reinforced plastic mortar (RPM or fiber glass), polyvinyl chloride composite (PVC) and resin-tube inversion (or cured-in-place pipe). HPDE products include smooth wall (Phillips DriscoPipe) and profile wall (ConTech Culvert Renew). Fiberglass products (such as Hobas) have been used to rehabilitate pipe spillways. Inversion tube techniques (Insituform and InLiner), typically used for rehabilitation of sanitary sewers, are relatively expensive for large pipe diameters and may not be cost-effective for repair of dam spillways.

4. Slipliner Structural Adequacy. Although some support will likely be provided by the old pipe, the slipliner should be strong enough to support the dam embankment on its own in the event that the old pipe continues to deteriorate after remediation. This requires that the annular space between the old pipe and the slipliner be fully grouted so that the new pipe is properly supported. As an example of the importance of complete grouting, the Phillips DriscoPipe design manual states that the maximum external pressure differential on unsupported HDPE SDR 26 pipe for a service life of 50 years is 9 feet of water head. However, when the same pipe is properly grouted into an existing pipe, it can withstand 36 feet of head. Thus, it is imperative that the grouting of the annular space between the pipes be continuous with no voids (a few small voids can be tolerated) to achieve the improved structural support. (Phillips DriscoPipe, 1991)

   Recommended design procedure for non-pressure HDPE pipe (after PPI, 1993):

   a. Select a slipliner diameter. Use the largest possible size based on the size and condition of the existing conduit.

   b. Assume a thickness for the pipe liner and compute the critical buckling pressure for the unsupported pipe (Love’s Equation). Compare the buckling load to the maximum anticipated external hydrostatic pressure. Revise the assumed wall thickness until a factor of safety of at least 2 is obtained. (A more detailed evaluation is needed if the pipe will be subjected to internal pressure.)

   c. Analyze the hydraulic capacity.

5. Joint type. Each slipliner product has its own joint design. Joints must be watertight. Heat fusion is a tried and true method for joining sections of smooth wall HDPE pipe. A special machine is used to trim the ends of the pipes to be fused, heat the plastic to about 500 F, and force them together under pressure. The simple, foolproof procedure results in a joint that is as strong as the pipe material itself. (A small “bead” is formed where the melted material is extruded from the joint. Whle it has a negligible impact on the pipe hydraulics, the bead can be easily removed with a special tool with no effect on the strength of the joint PPI, 1985). Mechanical joints are also possible, and many prefabricated fittings such as elbows, bends and tees can be fusion welded to the pipe in the field. Extrusion gun welding with PE rods has been used with limited success for some low pressure fabrications. However, it is not recommended for general use (Phillips DriscoPipe, 1991). Some HDPE products have integral threads (ConTech ThreadLock) that allow sections to be easily joined without special equipment. Other types of pipe typically use gasketed or glued bell and spigot joints.

6. Installation. Sufficient work area must be available at the downstream toe of the dam for insertion of the slipliner. At the Campus Hills project, the smooth wall HDPE pipe was fabricated into one long section on the crest of the dam and transported to the toe (the fabricated weight was about 3000 pounds). The pipe is then inserted into the downstream end of the spillway conduit and simply pushed upstream. To prevent flotation of the pipe during grouting it is recommended that the pipe be filled with water.

7. Grout design and Inspection. Careful grouting of the annular void between the old pipe and the slipliner is essential for a permanent repair. This can be a complex process and requires the experience of a qualified contractor to assure that no voids remain. In addition, the design engineer must be familiar with this type of work in order to prepare an appropriate procedure. The following guideline are taken from a recent article in “No-Dig Engineering” magazine discusses mix design for “annular backfill,” grouting methods, inspection and testing. (Stephens, P.J., 1996)

   d. The grout mix must remain fluid and not thicken for a period of at least two hours. Premature thickening of the grout will result in high injection pressures, inadequate support of the liner, and will require the contractor to drill intermediate grout injection holes to locate and fill any remaining voids. The grout should be tested in accordance with ASTM C939 and API Specification 10, or by taking a bucket of the proposed grout and pouring it into another bucket at 30-minute intervals.

   5. The grouting equipment must be capable of mixing and delivering the grout at a rate that will allow the annular space to be entirely filled in a continuous operation. It is strongly recommended that the grouting be completed in within a period of two hours.

e. Grouts are susceptible to degradation by excessive water infiltration before the grout sets. This problem is aggravated by use of flyash, so flyash based lightweight grouts are not recommended for slipliner grouting.

f. If the existing pipe has deflected from a straight alignment, there is the possibility that trapped air will result in discontinuous grout.

g. The engineer should be familiar with grout design. The design should specify mix design, density, viscosity, maximum injection pressure, initial set time, 24-hour and 28-day compressive strength, shrinkage, stability, and "bleed" or fluid loss.

h. The grouting contractor must be experienced, well qualified and have dependable equipment of a size that will allow the work to be done quickly.

i. Grout injection should start at the upstream end of the pipe and progress toward the downstream end so as to more easily displace water and debris. Thus, suitable injection tubes must be inserted at the upstream end. Vent pipes installed at the downstream end should be 150 percent larger than injection tubes to minimize the potential for clogging.

j. In the field, every batch of grout should be tested for density and viscosity.

k. Dirty water and excess grout discharged from the downstream vent tube should be collected and disposed of properly.

l. Do not assume that the grout will flow into any voids that may exist in the embankment outside of the pipe. Any suspected voids in the dam embankment must be pressure grouted prior to inserting the slipliner.

8. Additional Considerations.

Some longitudinal shrinkage of HDPE should be anticipated because of thermal effects. For example, the Campus Hills pipe (120 feet long) was installed during hot weather in June 1995 and now shows longitudinal shrinkage of about two inches. This is consistent with the HDPE design manual that predicts about three inches of linear expansion/contraction per 100 feet of pipe for a 20-degree change in temperature.

The service life of the slipliner material should also be considered. For HDPE, the design life is a function of the stress history of the pipe. A typical design calls for a 50-year life.

The connection of the barrel liner to the riser is somewhat difficult. At the Campus Hills project, a connection was custom fabricated by the contractor. (See Figure 3)

Inversion tube processes, in which a resin impregnated tube is cured in place, may not be suitable for sliplining bituminous coated CMP spillways unless they are prelined to prevent contamination of the resin by chemicals present in the asphalt coating. (Briver, 1990)

CONCLUSIONS

The use of slipliners to rehabilitate deteriorating CMP spillways is feasible and relatively economical. Grouting procedures should be prepared by an engineer experienced in trenchless technology. The work should be performed by a contractor experienced in sliplining projects.

REFERENCES

American Concrete Pipe Association, 1992, “Design Life Seminar-Buried Pipelines,” 8300 Boone Blvd., Vienna, VA 22182 (703) 821-1990.

American Society for Testing and Materials (ASTM), 1989, “Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of Resin Impregnated Tube (ASTM designation F 1216-89),” 100 Barr Harbor Drive, West Conshohocken, PA 19428, (610) 832-9500.

Austin, G., 1996, Kansas Dam Safety, State Board of Agriculture, Division of Water resources, Topeka, KS. Pesonal communication.

Association of State Dam Safety Officials (ASDSO), 1995, “Mid-Atlantic Regional Technical Seminar-Design and Construction Issues for Embankment Dams: Conduits through Earth Dams and Overtopping Protection,” 450 Old East Vine St, 2nd Floor, Lexington, KY 40507 (606) 257-5140, Section 7, page 11.

Bakeer, R.M. and Barber, M.E., 1996, “Use of Polyethylene Liners in Pipe Rehabilitation,” Geotechnical News, March 1996, Vol. 14 No.1, p 31-32.

Briver, E., 1990, “Culvert Repair at Enid Lake, Mississippi,” US Army Corps of Engineers, 3909 Halls Ferry Road, Vicksburg, MS 39180, REMR Bulletin Vol. 7, No. 1, p 1.

*ConTech Construction Products, Inc., 1994 “Culvert Renew HDPE Liner Pipe,” P O Box 800, Middletown, OH 45042.

*Hobas, Inc., “Fiberglass Reinforced Pipe for Sliplining”

*InLiner USA, 1996, “InLiner Resin Saver Design Guide for Cured In Place Pipes”, (800) 299-2477

*InsituForm East, Inc., 1990, “Pipeline Reconstruction without Disruption,” 3421 Pensy Drive, Landover, MD 20785, (301) 388-4100.

Lake, D., 1987, “Rehabilitation of Embankment Conduits,” presented at the 1987 ASDSO Annual Conference, Columbus, Ohio.

*Lamson-Vylon Pipe (21"-48" diameter), 1993, 25701 Science Park Drive, Cleveland, OH 44122 (800) 321-1970.

Lee, L., “Grouting Slip Liners: The New Inside Story,” 1990, ASCE Civil Engineering Magazine, September 1990, p 78-80 (See also follow-up editorial in February 1991 issue).

Maitland, N., 1991, “Rehab Roundup,” ASCE Civil Engineering Magazine, September 1991, p 46.

*National Corrugated Steel Pipe Association, 1988, “Rehabilitation of Corrugated Steel Pipe and Pipelines of Other Materials,” 2011 Eye Street NW, Washington, DC 20006 (202) 223-2217.

*Phillips Drisco Pipe, Inc., 1991, “Systems Design Manual,” P O Box 83-3866, Richardson, TX 75083 (800) 527-0662.

Plastics Pipe Institute (PPI), 1985, “Renewing Sewers with Polyolefin Pipe”, 1275 K Street, N.W., Suite 400, Washington, D.C. 20005, (202) 371-5306

Plastics Pipe Institute (PPI), 1993, “Pipeline Rehabilitation by Sliplining with Polyethelene Pipe”, 1275 K Street, N.W., Suite 400, Washington, D.C. 20005, (202) 371-5306

*Spirolite Corporation, 1989, “Renewing Sewers with Spirolite,” Chevron Chemical Company, Norcross, GA (404) 497-2309.

Stephens, P.J., 1996, “Project Guidelines for Slipline Grouting,” Trenchless Technology No-Dig Engineering, March/April 1996 issue.

* Manufacturers’ literature