ABSTRACT

In the United States alone, drainage culverts protect more than 150,000 miles of mainline rail routes from the powerfully erosive force of water on their rail bed substructures. Many of the culverts have outlived their life expectancy and are now failing or in jeopardy of failing.

The pipe ramming technique causes little to no soil displacement, is capable of large diameter replacement or new installation, and has been in use to install steel casing for more than thirty years. It is also the most cost-effective alternative to other methods such as auger boring, open cutting and micro-tunneling. Typically work can be completed without disrupting rail traffic patterns and consequent loss of revenue during the replacement or installation process.

This paper will discuss the pipe ramming process and challenges related to the installation or replacement of culvert drainage pipes under railroad beds. In addition, case studies will be presented including a project in Cairo, Illinois, completed by Hurk Underground of Grinnell, Iowa.

INTRODUCTION

According to the American Association of Railroads, U.S. railroads move more than four times as much freight as all of Western Europe's freight railroads combined (1). This critical part of the U.S. transportation infrastructure is currently facing great challenges to replace and/or upgrade its railways’ compromised culverts. The reduced capacity of collapsing and failed culverts to direct water away from rail bed substructures requires an urgent remedy. Customer dependence upon the railways excludes any method that would shut down the line, such as open trenching. Further, any method that might threaten the integrity of the substructure and its overlying road bed due with post-restoration subsidence must be ruled out.

Given the technique used to create the original culvert, pipe ramming and project designs that include any of the various pipe ramming forms often prove to be ideal solutions.

Basic Pipe Ramming

Pipe and casing installed by pipe ramming is usually open ended with spoil entering the pipe as it is rammed into place with a pneumatic hammer (Figure 1). Spoil is cleaned out afterward with auger flighting, water jetting, compressed air, pipe pigs, or hand digging.

Figure 1: Basic pipe ramming method. Casing is installed open ended and cleaned out after installation is complete without disturbing surrounding railway substructure.
Replacing culverts with pipe ramming technique begins with excavation of two pits: the insertion pit and the receiving pit. An appropriately sized pneumatic ramming tool is attached to the rear of a steel pipe in the entry pit. Once properly aligned, the front of the steel pipe, which remains open-ended, is driven into the ground with repeated percussive blows from the hammer similar to the way vertical piles are driven.

The pipe can be installed as an entire length or, to accommodate confined spaces and restrictive ground conditions, it may be installed in shorter segments connected one at a time in a series of rams. Each time a shorter pipe segment has been rammed its full length into the ground, the hammer is returned to its initial position behind a new pipe segment, which has been welded or mechanically attached to those already driven into the ground.

The same tools used to clean old culvert prior to inspections can be utilized to remove spoils during installations. Such techniques include directional drilling fitted with auger flighting, augering, using compressed air, and water jetting (Figure 2). As soon as installation is complete, the pipe is immediately ready for use.

Pipe ramming typically is prescribed for relatively short runs up to approximately 150 feet or less for pipe in diameters up to 60 inches. However, ramming installations of more than 300 feet have been successfully completed, and pipes as large as 120 inches have been put in place with the ramming process (2). With the recent increase in hammer sizes such as a 34-inch hammer introduced this last year, culverts up to 180 inches in diameter are now possible.

Suitable Pipe Ramming Conditions

Length of run and size of pipe feasible for a pipe ramming project depend on soil conditions and rammer selections. The most suitable soil conditions for pipe ramming are soft to very soft clays, silts and organic deposits, all loose to-dense sands above the water table, and soils with cobble, boulders and other obstacles of significant size but smaller than pipe diameter.

However, casing installations can also be made in extremely wet conditions, even with running water present, in difficult, medium to dense sands below the water table, and in firmly cemented soils, hard and stiff clays (Figure 3). It can be used in remarkably constricted working spaces with limited access and challenging installation requirements (3).

Application Versatility

Although ramming is generally considered inappropriate for solid rock conditions, its versatility is well-documented. Pipe ramming can be combined with other underground techniques such as pilot tube boring to manage accuracy in
varying ground conditions over the installation path. Pipe ramming can be used to increase the range of culvert replacement and installation projects that qualify for trenchless design, while achieving greater overall economy (4).

Pipe ramming can even be called upon to complete installations initiated by other techniques such as augering and pipe jacking that encounter unanticipated changes in conditions they cannot overcome (5).

**Pipe Swallowing Replacement Method**

Culvert replacement operations with pipe swallowing method are much like the process for new installation, except that a larger diameter casing is rammed over an existing culvert.

Once the larger diameter pipe has been rammed into place, the old culvert is removed with the spoil (Figure 4).

**Slick Boring Method**

When project specifications call for little to no impact on carrier pipe weldments, the slick boring method is commonly used. This method is executed by installing a steel carrier casing using the conventional pipe ramming technique.

Once the carrier casing has been installed, additional pipe is pulled into place by changing the direction of the ram and pulling the new casing in place (Figure 5).

**Longer Culvert Installation or Replacement**

Although steel casings have been installed using the pipe ramming method in distances of up to 400 feet and longer, typical ramming projects range from 50 to 200 feet. Soil conditions, pipe size, distance and rammer selection determine the typical ramming project plan. When projects call for longer distances, proper planning and use of the telescoping method can help (Figure 6).

This method begins by ramming an oversized pipe over the existing culvert as a carrier pipe. Once the pipe has been installed to its maximum distance, the pipe’s interior is cleaned out. Incrementally smaller pipes are rammed in succession, each one extending farther toward the exit pit. Each one is cleaned out as it is completed until finally, the smallest diameter pipe has been installed the entire distance, from entrance to exit pit.

**Advantages over Other Underground Trenchless Techniques**

Traditional underground trenchless culvert rehabilitation methods include slip lining, fold and form, inversion processes, and other relining systems. However, these methods sacrifice internal diameter. Pipe ramming can increase diameter and capacity of existing culverts in place when requirements increase for load, seismic design specifications, or maximum flood event scenarios (6).
Compared to auger boring and horizontal directional drilling installation techniques, pipe ramming can save up to 40 percent on total installation time and costs under favorable conditions (2). This is usually due to preparation and restoration times, as the pits required for pipe ramming are smaller and require less precision than other techniques.

Auger boring, for instance, generally requires a working pit precisely created to match the grade and flow of the intended culvert. In contrast, grade and flow in pipe ramming technique are controlled by aligning the pipe with hydraulic pipe cradles or Pipe Mules, so a precision pit is not necessary. In some applications such as with an elevated rail bed’s berm, if any excavation is required, it only needs to be deep enough below the pipe’s intended grade to accommodate these hydraulic cradles, which might be only 18 inches.

In contrast to pipe jacking method, there is no need for thrust plates or blocks in a pipe ramming insertion pit.

The auger boring and jack and bore methods may even require a poured concrete floor to work from in wet or loose soil conditions. Time and expense to pour a concrete pad prior to installation and then to remove it at the end of the project can generally be avoided with pipe ramming technique. In fact, a pipe ramming project designed to start in the side of an unobstructed slope, as is the case for many rail bed culverts, does not require an insertion pit at all (Figure 7).

Any directional drilling or auger boring method used under free-floating sand or unstable/loose materials could lead to surface settling and/or formation of voids. Yet in the same conditions, pipe ramming technique excels. It presents no risk of soil displacement and is suitable for all ground conditions with the exception of solid rock (2).

Actual progression of pipe during installation is also faster in pipe ramming, which contributes to pipe ramming’s advantage over other methods in shorter installations.

CASE STUDY

A recent railroad culvert installation in southern Illinois demonstrates several capabilities of pipe ramming technique in a single application. The contractor was required to install two large-diameter steel casings to upgrade a failing drainage system. The jobsite was in extremely wet ground conditions and was difficult to access. The contractor encountered several unexpected obstacles, each overcome for ultimate project success.

The experienced pipe ramming contractor said this is the most difficult ram the company has performed, both due to the size and length of the ram and the complications of subzero temperatures, inundated ground conditions, and obstacles inside the railway substructure. It is unlikely that any other technique would have successfully completed this installation.

Job Specifications

HURK Unground Technologies of Grinnell, Iowa, was contracted to install two 180-foot-long 60-inch-diameter culverts with pipe ramming method beneath a railway for the CN Rail Line on mile marker 359.7 in Cairo, Illinois. The culverts were new installations to relieve an existing, partially collapsed, 48-inch steel culvert with reduced capacity. The casing consisted of 30-foot lengths of 0.875-inch smooth wall steel pipe rammed and welded on one at a time. The new culverts were installed 2 feet apart from each other at an elevation 40 feet below the rail bed. Work began in November 2013.
Equipment

In addition to a 350-series excavator used to create the working pit, HURK brought to the jobsite a mini excavator, track loader, horizontal drilling machine with 48-inch-diameter posthole auger, 1,300 cfm air compressor, adjustable pipe stands, and 24-inch pipe ramming hammer and appropriate tooling for 60-inch pipe.

Site Preparation

The surface of the road bed was about 40 feet above the level of the culvert insertion point. This jobsite scenario, known as high fill or deep cut, is difficult to survey. Both sides of the roadbed were wetland areas. The only feasible approach was a mile-long drive across cropland described by HURK employees as “soupy,” to a location at the railway substructure that allowed HURK to stage their equipment just above water. The company’s trucks required assistance from their tracked equipment through the field to make it to and from the jobsite most days.

The soggy ground conditions presented a second obstacle once the jobsite was selected. As the four-person HURK crew tried to dig a 60-foot-long, 30-foot-wide working pit to 10 feet vertical depth at the toe of the railway berm, the pit’s sides would repeatedly collapse, filling the excavation with mud.

After several attempts, HURK found it possible to dig half of the working pit 3 feet lower than the intended working grade and immediately backfill the excavation with 3-inch rock, setting sump baskets in the backfill. Diesel-powered pumps in the sump baskets dewatered the ground sufficiently for the crew to finish the pit. Once pumping operations started, six 190 gph pumps ran 24 hours a day continuously for four months to project completion, including weekends and the Thanksgiving and Christmas work breaks. Overcoming complications at this location took the crew a week longer than usual to make the working pit.

Ramming Process

Both culverts were rammed from one working pit, one at a time. The HURK crew rammed and welded each of the first culvert’s first three lengths of pipe without problem. Each piece required them to attach the hammer to the pipe, ram it into the berm at about a 2 percent grade, detach the hammer, weld on the next pipe, reattach the hammer and continue ramming. Two welders could complete the root weld and fill passes on the large-diameter pipe to industry specification usually in less than five hours. Ramming progressed at about 6 inches per minute while the hammer was operating.

Obstacles: Tree Stump and Piers

HURK’s Jason Pollock, who directed pipe ramming operations on this project, said that whenever pipe ramming progress drops to less than 1 inch per minute, he believes the pipe is cutting through tree roots or rock, or is pushing an obstacle out of the way. Therefore, having rammed at 90 feet for approximately 30 minutes without progress on the fourth length of pipe, he suspected the pipe had met an obstacle that could not be cut or moved aside. Further ramming might damage the pipe or hammer.

The crew stopped pipe ramming operations to detach the hammer and auger out the spoils in the pipe.

The pipe diameter permitted the crew to physically inspect the obstacle, which was discovered to be a 5-foot-wide tree stump (Figure 8).

The crew concluded that the tree had been felled to make way for the railway, but its stump had been covered over during berm construction rather than completely
removed. Burial at this depth had preserved the wood remarkably well. The crew used small, electric chain saws to clear the stump, and pipe ramming continued.

Shortly after resuming pipe ramming, progress once again halted. The hammer was removed, the pipe was augered out, and the crew inspected the obstacle. This time they discovered the wooden post remnant of a pier (Figure 9). It was revealed that a bridge had once existed in this same location.

After removing the obstruction, pipe ramming again continued. From this point on the crew encountered a pier every 10 to 20 feet. Piers were encountered on both pipe runs.

**Lubrication Not Required**

Except for these two obstacles and the harsh working conditions, there were no other complications. Both culverts were competed to their 180-foot length.

Though pipe ramming was interrupted repeatedly not only to deal with complications such as cutting away obstacles by hand, but also for weekends and holidays, the hammer moved the pipe without hesitation each time ramming operations resumed.

Pollock said that on the first pipe he had rigged up the lubrication system lines and had a lubrication mix ready to use, but HURK did not inject the mix. After the first pipe he did not rig up a lubrication system for the others, since it proved unnecessary.

After installing the two culverts, the HURK crew grouted the failed 48-inch culvert, and restored the areas altered by the working pit and vehicle and equipment transportation (Figure 10). The project was completed in February 2014.

**CONCLUSION**

The obstacles HURK encountered doubled the time it took to complete the installation project. However, given the difficult environment of this location, an open cut culvert installation would still have increased project cost many times over. Additionally, open cut installation would have required rerouting rail traffic, closing this section of the line and preventing revenue from it for an extended period.

Further, rail bed restoration of open cut work is vulnerable to settling and consequent subsidence over time, requiring future maintenance and additional cost to repair the berm and rail bed at a later date.

Use of the pipe ramming method permitted rail service to continue unimpeded throughout the entire four-month project. The ground conditions of the berm and the integrity of the overlying roadbed were not disturbed and are not subject to further settling.
REFERENCES


LIST OF FIGURES

Figure 1: Basic pipe ramming method. Casing is installed open ended and cleaned out after installation is complete without disturbing surrounding railway substructure.

Figure 2: Spoil is removed from this 60-inch railroad culvert with 48-inch-diameter auger flighting after installation.

Figure 3: The relatively compact, lightweight equipment used for pipe ramming method allows the contractor to operate in extremely wet locations. This site for a railroad customer near Cairo, Illinois, is accessible only through a mile-long drive over soggy cropland with the assistance of tracked machinery.

Figure 4: Pipe swallowing method.

Figure 5: Slick boring method.

Figure 6: The telescoping method makes longer ramming distances possible.

Figure 7: Pipe ramming work pits do not have strict requirements, allowing pipe ramming equipment to be set up in difficult conditions. Grade and direction of installation can be controlled with adjustable cradle-like Pipe Mules (upper right) set on the rock fill pit bottom.

Figure 8: Crew must remove a 5-foot-diameter tree stump buried during original construction of railway substructure.

Figure 9: Pieces of pier the crew repeatedly encounters during both 180-foot rams have to be removed each time manually before pipe ramming can continue.

Figure 10: Crew begins restoration of finished installation.
Pipe Ramming and the U.S. Rail System

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Facts About the United States Rail System

• Critical part of US transportation infrastructure.
• More than 150,000 miles of mainline rail routes.
• Moves more freight than any other rail system in any other country.
• SOURCE: American Association of Railroads

Drainage Problems

• Lack of maintenance
• Lack of inspection programs
• Lack of capacity/flow, flooding and liability
• Ponding of water causes pavement and sub grade deterioration and may lead to washout failures

Washout

• The failure rate has the potential to cause property damage and loss of life.
• Lack of maintenance and delays in repairs has translated into soaring construction expenditures.

Problems aren’t limited to rail

Band failures and sink holes
Solutions

- Well executed inspection programs
  - Clearing of debris prior to inspection
  - Determine condition of structure and implement repair/replace action plan.
- When necessary, installation of new or replacement of existing drainage culverts.

Cleaning Methods

- Push Bucket w/HD
- Barrel Reamer w/HD
- Pull Bucket w/HD
- Brush w/HD

- Similar tooling specifically designed for box structures can be used.

Cleaning Methods

- Vacuum Truck

Regular Inspection/Maintenance

- It's evident that cleaning is necessary to determine the condition of this culvert.
- A regular maintenance schedule can prevent systems from getting to this point.
Examples of repairable structures

Just one year later…and getting worse

Major Joint Separations

Liner Repair Method

Liner being pushed into place and then the annular space is grouted

Large 78 inch diameter welded section liners being put into position

Pipe Ramming Method

A pneumatic hammer installs an open ended steel casing that is cleaned out during and after completion of pipe installation.

Pipe Ramming for Culvert Replacement

Trenchless Culvert Replacement Under Railways with the Pipe Ramming Method
Trenchless Advantage

- Able to swallow anything that is smaller than the diameter of the casing.
- Minimizes and/or eliminates voids in sub-grade.
- Reduced soil compaction.

Culvert “Swallowing” Replacement Method

An oversized casing is rammed over existing culvert. After installation is complete, old culvert and spoil is removed. Steel casing can serve as the drainage culvert or as a carrier pipe for another pipe inserted within.

Telescoping Method for Longer Distances

An oversized pipe is rammed over the existing culvert until production ceases and is cleaned out. Further progress is made with smaller casings installed within the oversized pipe in the same manner.

Method Implementation

Trenchless Culvert Replacement Under Railways with the Pipe Ramming Method

Ram Site Layout

SITE PREP: CASING PLACEMENT

Rail system  I-beam  Pipe Mule® Leveling System
Steel Casing Prep

- Lubrication Soil Shoe
  - Reinforces lead casing and provides an annulus for lubrication.
  - Supplies lubricating fluid to OD and ID of casing during installation.

Collets and Rammer

- Install Pushing Collars/Collars
  - Collets and collars help to distribute the ramming force to the face of the pipe. The collets also lock the rammer into place.
- Install Rammer
  - The rammer is locked into the collets when the tool is started.

Spoil Removal

- Spoil removal <30” Casing
  - Air and/or water pressure. Seat in for air pressure removal.
- Spoil removal for >30” and/or large spoils/culverts
  - Manual excavation, HURK culvert cleaning tools, jet flushing, auger boring and horizontal drilling where applicable.

Case Study

Cairo, Illinois

Problem

- Partially collapsed 48” steel culvert with reduced capacity

New Installation/Equipment

- 2-60”, 180’ long new culverts installed using pipe ramming method.
- Installation to be 2 feet apart, 40 feet below rail bed.

- In addition to a 350-series excavator used to create the working pit, HURK brought to the jobsite a mini excavator, track loader, horizontal drilling machine with 48-inch diameter posthole auger, 1,300 cfm air compressor, adjustable pipe stands, and 24-inch pipe ramming hammer and appropriate tooling for 60-inch pipe.
Site Prep

Pipe ramming work pits do not have strict requirements, allowing pipe ramming equipment to be set up in difficult conditions. Grade and direction of installation can be controlled with adjustable cradle-like Pipe Mules set on the rock fill of the pit’s bottom.

“Toughest Project Experienced”

- Long distance rams
- Subzero temperatures
- Inundated ground conditions
- Obstacles encountered under railway substructure

“It is unlikely that any other technique would have successfully completed this installation.”

-Jason Pollock, Hurk Underground

Subzero Temperatures

Buried Tree Trunk

During the ram, they encountered a five foot diameter tree stump that was buried in the original fill.

Buried Wood Bridge Piers

“Soupy” soil conditions.
Pipe Cleanout

Auger flighting attached to a directional drill was used to clean out the new pipe installed.

Installation of pipes completed.

- Crew begins restoration of finished installation.

Questions?

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