TRENCHLESS CULVERT REPLACEMENT UNDER RAILWAYS WITH THE PIPE RAMMING METHOD

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ABSTRACT

The pipe ramming process has been successfully used to install steel casing in close proximity to sensitive structures for more than thirty years. When project specifications call for little to no soil displacement, as is the case for railway culverts, pipe ramming is the cost-effective alternative to other methods such as auger boring, open cutting and micro-tunneling.

Drainage culverts throughout North America are currently an urgent concern, no less for railroads than for state and local transportation agencies. More than 168,000 miles of mainline railway in the United States is operated by its seven Class 1 railroad companies, not counting their many spurs, sidings or yard tracks (1). All of these railways have one thing in common: they have culverts that currently need repair or replacement or will need it in the near future.

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, a recent case study will demonstrate pipe ramming to be the preferred method of culvert replacement.

INTRODUCTION

United States rail system is a critical part of the transportation infrastructure. According to data compiled in a 2012 report by the Association of American Railroads, all seven Class I U.S. railroad companies are continuing to develop their infrastructure: “Even during the economic downturn, railroads have continued making record investments ... to grow and modernize the national rail network” (2). Of the four largest U.S. freight railroads, each spends more on its infrastructure every year than most states spend on their highways. Unlike state highway agencies, however, the railroads themselves bear the full costs of maintaining infrastructure. The AAR has estimated that during the 20-year period from 1980 to 2000, railroads spent 40% of their total revenue—more than $480 billion—on maintaining and upgrading their railways (2).

One of the largest concerns for maintaining current rail routes in the United States is remediation of outdated and failing culverts. As Perrin and Jhaveri noted in a 2004 presentation before the Transportation Research Board, a recent rash of culvert failures in North America has raised concern about culvert degradation throughout the continent’s infrastructure (3). Neglected
culverts can lead to subgrade failure, sinkholes, flooding, claims for property damage, derailments and loss of life. Having a limited useful life expectancy, all drainage culverts are maintenance concerns. They are either currently in need of replacement, repair or upgrade or they soon will be, as flow capacity becomes inadequate either from changes in the environment that may now require greater capacity or from pipe deformity or collapse that reduce capacity.

The pipe ramming method often provides the most cost-effective and least intrusive means of replacing or relocating these culverts. It is generally less expensive as it entails fewer personnel to complete, yet it can be completed in a fraction of the time of open cut technique. It requires less setup and restoration time, avoiding their consequent costs.

Additionally, pipe ramming preserves revenue generated by rail traffic, since pipe ramming operations most often can be conducted without shutting down the railway or disrupting its traffic schedules.

For these reasons pipe ramming can be considered the preferred method for installing or replacing drainage culverts in the sensitive structures of railway roadbeds.

**PIPE RAMMING CULVERT INSTALLATION AND REPLACEMENT**

**Installation of New Pipe**

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.

Figure 1: Pipe Ramming is an excellent, cost efficient method for placing steel casing under roads, railroads, finished landscapes and structures. The casing is installed open ended and cleaned out after installation is complete.
The installed pipe usually has an open end that allows the soil to enter the pipe during the installation. The spoils that accumulate inside the pipe can be removed either during or after the installation. 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. As soon as installation is complete, the pipe is immediately ready for use.

**Compared to other trenchless techniques**

Compared to other trenchless methods such as auger boring and horizontal directional drilling, pipe ramming can save up to 40% on total installation time and costs under favorable conditions (4). 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 pit that is created to precisely match the grade and flow of the intended culvert. In contrast, grade and flow in the 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 usually needs only to be deep enough below the pipe’s intended grade to accommodate these hydraulic cradles, which might be only 18”.

In contrast to pipe jacking method, there is no need for thrust plates or blocks in the 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.

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 (4).

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.

**Culvert Replacement Through Trenchless Swallowing Technique**

Culvert replacement operations are much like the process for new installation, except that a larger diameter casing is rammed over an existing culvert. The existing culvert is swallowed along with the spoils. Once the larger diameter pipe has been rammed into place, the old culvert and remaining spoils can be removed from within using a variety of equipment.

Over the past decade the technique has proven successful even for replacing large culverts with steel pipes over 144" in diameter. With the recent increase in hammer sizes such as a 34” hammer announced earlier this year, culverts up to 180” in diameter are within range.

**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. 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.

**CASE STUDY EXAMPLE**

When CN Rail Line Culvert 71.30 near Askum, Ill., failed, it led to acres of flooding that threatened roadbed integrity. The inlet and outlet were completely concealed by rip rap, blocking both from view. This made...
pipe-swallowing technique impractical in this case.

Instead, in 2012 Hurk Underground of Pella, Ia., a contractor that specializes in culvert cleaning and restoration, was assigned the task of replacing the failed 36” culvert with two new 90 ft long, 60” diameter smooth wall steel pipes. The center line of each new 60” culvert would be located 6 ft to either side of the failed 36” culvert center line at a grade of 1.1%. Further, Hurk would decommission the failed culvert, backfilling it with CLSM (control low strength material cement).

**Equipment**

Ramming equipment consisted of a 24” ram, or *hammer* as it is often called, with a 60” collar to fit it to the pipe. A 1,600 cfm compressor provided ample air for the pneumatic ram. Cradling supports called Pipe Mules helped the Hurk Underground crew to keep the pipe aligned on course and at the designated 1.1% grade. A 24,000 lb horizontal directional drill was used to remove spoils during the installation process.

**Complicating Conditions**

The railway above the culvert consisted of a main line and siding lying alongside each other. The surface of the road bed was about 15 ft above the level of the culvert insertion point, presenting a jobsite scenario known as *high fill* or *deep cut*, which is difficult to survey. Buried utilities and fiber optic cable were located and protected throughout the installation without having to disconnect service.

Wet weather further complicated ramming operations, making surfaces difficult for personnel and equipment to work from. Hurk created a rock base and ran dewatering pumps in the entry pit continuously throughout the project due to the rain and standing ground water.
A paved state road and associated Illinois Department of Transportation culvert only 30 feet away limited working space at the pipe ramming entry pit. Potentially, if the pipe’s progress were to stop due to spoils buildup while it was extending too far from its entry point, the horizontal directional drill would not have enough room to set up for spoils removal.

**Installation Process**

Installation was performed in two separate 90 ft runs, each consisting of 20 ft sections of pipe connected and rammed in succession. After each section was driven to its full length, its spoils were removed with the horizontal directional drill. A new section was set in place, welded to the previously installed pipe, and then rammed to its full length.

Completed installation of each 90 ft culvert was within a couple inches of the 1.1% targeted grade, meeting CN Rail’s operating specifications.

After both of the new culvert pipes were installed, the existing culvert was filled with concrete. The new culverts have eliminated the flooding.

**CONCLUSION**

Though wet conditions nearly doubled the time anticipated to complete the pipe ramming project, it was still completed in three weeks, start to finish. It was done without interfering with rail traffic, which continued even as the pipe ramming process was underway. This meant the railroad lost no revenue during the project. Nor did pipe ramming interfere with utility services, with fiber optic cable service or with vehicle traffic on the nearby road.

Not only was the installation itself cost-effective, but no restoration measures were necessary to the roadbed or berm other than adding rip rap to the new inlets and outlets after backfilling the decommissioned culvert. Furthermore, the only restoration required in the right of way and drainage channel was to backfill the entry pit excavation and reseed the worksite’s disturbed grassy areas.

For these reasons pipe ramming can be considered a superior and cost-effective method for installing or replacing drainage culverts beneath railway roadbeds.
REFERENCES


TRENCHLESS CULVERT REPLACEMENT UNDER RAILWAYS WITH THE PIPE RAMMING METHOD

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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

Problems aren’t limited to rail

- 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.

Band failures and sink holes

- Pinney Mountain Road Washout
- Chelshill Flood July 13, 2000
- Orange County Emergency Management
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

- Barrel Reamer w/HDD
- Push Bucket w/HDD
- Push Bucket w/HDD

Cleaning Methods

- Pull Bucket w/HDD
- Brush w/HDD
- Similar tooling specifically designed for box structures can be used.

Cleaning Methods

- Vacuum Truck

Regular Inspection/Maintenance

- Its 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
- CMP Pipe
- Concrete Pipe

Liner Repair Method
- Large 78 inch diameter welded section liners being put into position
- Liner being pushed into place and then the annular space is grouted

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

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Length</th>
<th>Number</th>
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</thead>
<tbody>
<tr>
<td>6&quot;</td>
<td></td>
<td></td>
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<tr>
<td>8&quot;</td>
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<tr>
<td>10&quot;</td>
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Note: Follow local regulations for sloping or shoring of pits.

**SITE PREP: CASING PLACEMENT**

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

Lubrication

Supplies lubricating fluid to OD and ID of casing during installation.

Soil Shoe

External Shoe

Reinforces lead casing and provides an annulus for lubrication.

Collets and Rammer

Install Pushing Collets/Collars

Install Rammer

Collets and Collars help to distribute the ramming force to the face of the pipe. The collets also lock the rammer into place.

The rammer is locked into the collets when the tool is started.

Spoil Removal

Spoil removal <30” Casing

Manual excavation, HDD culvert cleaning tools, jet washing, auger boring wherever applicable.

Spoil removal for >30” and/or large spoil culverts

Air and/or water pressure. Seal kit for air pressure removal.

Pipe Ramming Case Studies

Trenchless Culvert Replacement Under Railways with the Pipe Ramming Method

Askum, Illinois

- Culvert failure near Askum, IL leading to acres of flooding and threatened the railbed integrity.
- 36” culvert replaced with two new 90’ long, 60” dia steel pipes at 1.1% grade.
September 29 – October 2, 2013
Indianapolis, IN

**Product/Footage**
- Telescoping Method, Alaska
  - Collapsed 7’ casing, 164 feet long

**Equipment**
- 24” Rammer

**Replacement of 84” dia. culvert drain**
- 96” steel casing, 164 feet.

**Swallowing and removing sections.**

**Trenchless replacement of pipe.**

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**Thank You**

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