Installation of Culverts by Pipe Ramming

By Steven Werner

Public Works Engineer

Montana Rail Link, Inc.

P.O. Box 16390
Missoula, Montana 59808

Phone Number: 406-523-1551
Fax Number: 406-523-1529
swerner@montanarail.com
ABSTRACT

In March of 2000 the Montana Department of Transportation (MDT) approached Montana Rail Link with a project to install ten new culverts beneath its track. These culverts were required to accommodate future reconstruction of a state highway adjacent to the railroad’s mainline track. Montana Rail Link was asked to administer the design and installation of these culverts with funding provided by MDT. This paper will discuss some aspects of the culvert design, but will primarily review the pipe ramming procedure utilized to install the culverts in 2002.

Key Words: culverts, installation, pipe ramming
INTRODUCTION

In the spring of 2000, the Montana Department of Transportation (MDT) approached Montana Rail Link (MRL) with a need to install ten new drainage culverts beneath its mainline track in Western Montana. By the summer of 2002 MRL had assumed complete administrative responsibility for this project including both design and installation. The somewhat new practice of pipe ramming was used to install these culverts after an extensive investigation of the site’s surface and subsurface conditions. The factors that dictated the use of pipe ramming will be described along with a discussion of the obstacles that were encountered, both anticipated and unanticipated.

THE PROJECT

Two miles west of Weeksville, Montana the railroad’s mainline track and US Highway 200 are crowded between the Clark Fork River and a large rock hillside for a distance of just over one mile. With no room to shift the highway centerline the only choice for MDT was to propose elevating the highway approximately 30 feet above the existing profile grade. This raise of grade would significantly change the local drainage patterns. This plan required MDT to propose that additional culverts be installed beneath MRL’s mainline track. To eliminate the possibility of any construction related train delay, MRL established the requirement that these culverts would have to be installed using trenchless technology, i.e. no open cutting of the track.
The railroad maintains a rock “slide fence” within the 20-foot wide gap between the railroad and the highway. When struck by rocks this slide fence activates a signal indication to warn approaching trains of obstructions on the track. Unfortunately this fence also eliminates any type of off-rail access to the railroad from the highway for a distance of almost three miles. For most of these three miles the railroad’s embankment drops sharply to the Clark Fork River. There is a small shelf of ground between the railroad and the river, no more than 22 feet wide, for a distance of approximately 2,000 feet. Five of the ten culverts were proposed within this shelf area. For the purposes of this paper it is important to appreciate the extremely limited off-rail access and small construction workspace available at five of the ten culvert locations.

MONTANA RAIL LINK ASSUMES PROJECT CONTROL

During all of 2000 and early into 2001, MRL attempted to convince MDT of the seriousness of these considerations. We felt this culvert project had the potential of seriously disrupting our operations and possibly delaying trains during construction. While MDT expressed concern with these issues, we did not believe they truly appreciated the seriousness of our concerns. In early 2001 a proposal to completely separate the installation of culverts beneath the railroad from the highway project was advanced as a solution to MRL’s concerns. The project would still be funded with federal and state highway funds but would be administered by MRL with MDT oversight. Project administration would include designing the culverts, preparation of bid documents, selecting a contractor, construction inspection and general
supervision. This approach would allow the railroad to select a contractor with experience in trenchless culvert installation. It would also allow installation of the railroad culverts years ahead of the highway reconstruction.

**SUBSURFACE EXPLORATION**

Orion Engineering (Orion), a local engineering firm, had been selected by MRL to assist in the culvert design and project administration. Both Orion and MRL felt that the bid package should include accurate subsurface information for each culvert location. The most difficult challenge in obtaining subsurface information was in overcoming the lack of off-rail access to each site. To conform to our goal of little, if any, impact on the normal operations of the railroad it was important that the drilling rig used in the subsoil testing be easily moved on the rail and easily removed from the rail when required to clear for trains. As none of the culverts were to be excessively deep, being only 9 to 12 feet below the tie, a large drill rig was not required. Orion had a Burley 2400 drill rig mounted on a highway trailer that appeared to be well suited for this application. The idea of placing this drill rig on a railroad push car solved our need for easy on-rail mobility.

**Photo1 – Drill Rig**

Caption – Drill being removed to clear for train
This drill rig proved to be very efficient. In the two days it took to complete these sample borings, the maximum available work window between trains was two hours. One test bore was drilled at the center of the track over each proposed culvert location to a maximum depth of 15.5 feet. The sampling process consisted of drilling with a hollow-stem continuous flight auger into each soil layer and then performing Standard Penetration Tests using a split-barrel sampler to determine in-situ conditions of the subsurface materials. Soil boring logs were provided to each prospective bidder as part of the bid documents.

Subsurface conditions varied greatly at each of the ten proposed culvert locations. These conditions included both loose and dense, silt, sand, gravel, cobbles and even “talus” sized rock.

ACCESS CONSIDERATIONS

Having decided to provide subsurface information in the bid documents, both MRL and Orion felt it important to also include a discussion of the limitations of vehicle and equipment access at each location.

To overcome the obstacle of the slide fence, MRL installed a gate in the fence and an approach off of Highway 200 leading to a temporary at-grade railroad crossing. This gate looked like a standard railroad farm gate but had a circuit wire with a removable plug running the length of the gate. When the gate was closed and plug joined, the gate could maintain the
electrical continuity through the slide fence. When the plug was disconnected and the gate opened, the adjacent intermediate railroad signals indicated a restriction to trains mandating movement at a restricted speed. The gate and plug were under the exclusive control of a railroad flagman who was told, that unless an emergency situation developed, to open the gate and disconnect the plug only when all trains were outside the view of the intermediate signals.

The contractors where specifically informed in the bid process that access through the slide fence was planned but would be limited by the movement of trains. The contractors were also required to provide highway flagging which conformed to current MDT requirements when using the temporary approach and at-grade railroad crossing.

MRL and Orion also prepared a map showing the location of each proposed culvert relative to nearby roads, highways, streams, and rivers. The map specifically indicated the available access to each location. This map was supplied as part of the bid documents.

**SELECTION OF A CONTRACTOR AND AN INSTALLATION METHOD**

By the summer of 2002, Orion had completed its design of the culverts and had developed a final set of plans and specifications for the project, which included soil boring logs and access map. On July 2\textsuperscript{nd}, 2002 a mandatory pre-bid site visit was held with the prospective bidders. All of the bidders had been prequalified as having experience in trenchless pipe installation. MRL did not specify a specific trenchless method, believing it better to let the bidders make
that decision based on their experience, the subsurface reports, and specific site conditions. For this type of culvert installation the choices for trenchless construction were mainly between the better known auger boring method and the newer pipe ramming technology.

An auger boring machine consists of a section of the steel pipe or casing with an internal rotating auger that cuts and removes soil from the bore ahead of the pipe. This machine must have a thrust block or frame to allow force to be applied to the machine to advance the pipe and auger. Once a section of pipe is installed, the power supply is retracted to allow attachment of the next section of pipe and additional auger sections. The reason auger boring was not used in this project was this need for a thrust block or frame, i.e. something to push against to advance the auger. With the limited area available at our construction site, building a thrust frame would have required construction of a platform extending into the nearby river. All of the contractors quickly eliminated the idea of encroachment into the river as being too costly and too difficult to permit with regulatory agencies.

Auger boring works best in compacted, uniform soils. In loose sand, gravel, cobbles, and any unstable mixed soil including those with large rocks, auger boring has been known to cause serious damage to roads, streets and embankments. In these loose soils it is difficult to maintain the integrity of the bore opening above the exposed auger. While half of the locations in this project had soil suitable to auger boring, the problem of constructing a thrust frame made pipe ramming the more logical choice for this work. We simply did not have enough room to dig an auger bore entry pit at the five most difficult culvert locations.
PIPE RAMMING

Pipe ramming, as used in this project, basically consists of using powerful percussive blows to drive open-ended pipe through the ground. As the pipe is driven it encases soil, rocks and even boulders that are later removed with an auger, high-pressure air or water, or even hand tools. The pipe was driven by a ramming tool, powered by an air compressor, hammering on series of cones placed in the end of the pipe. After the pipe was rammed, an auger was used to remove the soil and rock from the pipe. Since ramming does not create a void in advance of the pipe, a problem in auger boring, the risk of cave-ins is eliminated. For this reason, pipe ramming is much better suited for working in loose gravel, cobbles and unstable mixed soils. In this project five of the ten locations had soils more suitable to ramming than for use of an auger, but the principal advantage to ramming the culverts was the ability to perform this operation in the very limited available workspace.

Pipe ramming is normally used in non-grade sensitive applications. Where controlled grade is a requirement, such as in this project, consideration of the allowable variation between the inlet and outlet design elevations and what can be accepted should be discussed before a contract is signed. In our project we asked MDT to give us an allowable variation in elevations which would be compatible with the hydraulic design of the highway. Where you start the pipe ramming process can be very accurately set for elevation and starting grade. As these railroad culverts were to be connected to future highway culverts at the railroad
culvert’s inlet, the inlet elevations were the more critical control. This being the case, you normally would want to dig the entry pit at the railroad culvert’s inlet side. Unfortunately in our project eight of the ten locations, including all of the locations with the most difficult soil conditions, would have to be rammed from the outlet side due to a complete lack of workspace between the railroad and the highway. MDT required that no final inlet elevation be more than two inches higher or four inches lower than the design values. The outlet elevations were less critical and the final elevation could be up to sixteen inches lower than the design values. The contractor accepted these as appropriate and all parties executed the contract.

At each of the ten locations a Sprint fiber optic cable had been installed between the river and the railroad. Before excavation could begin at a given location, hand methods were used to expose the Sprint line to determine its exact location and depth. Keeping this excavation open during the pipe ramming allowed the onsite Sprint inspector to monitor this fiber optic cable throughout the process. The process continued with the contractor digging an entry pit and installing a 20-foot long trench box to support the walls of the entry pit. The contractor then set the elevation and grade of the floor of each entry pit to conform to the MDT design values for elevation and grade. The trench box allowed ramming of pipe in lengths of no more than 20 feet. A track made of steel rails was set on the floor of the entry pit to guide the pipe at the selected grade. A length of smooth steel pipe was then lowered onto the track and ramming collets were place on the end of the pipe to distribute the percussive force of the ramming tool
to the pipe. The ramming tool was then placed into the collets and connected to the air compressor.

Photo 2 - Ramming Tool
Caption – Ramming tool attached to pipe

At this point the tool was ready to begin the ramming process. The rate of progress of the pipe while being hammered varied greatly depending on the soil types. This progress rate varied from 1.5 feet per hour to 15 feet per hour with the average rate being approximately 5 feet per hour. This included the time required to weld new pipe sections on the culvert as it advanced. Due to the limited length of the entry pit, a new section of pipe was added after no more than 20 feet, but more commonly 15 feet, of pipe had been rammed.

The total length of culvert rammed at each location varied in length from 33 feet to 50 feet. The diameter of the culvert at all locations was 36 inches with a thickness of 0.5 inches. This wall thickness conformed to MRL structural requirements and was the minimum recommended by our contractor for this diameter of culvert in a ramming operation. Orion tested the corrosive potential for the soils at all locations and determined that additional wall thickness to offset future corrosion was not required. At most locations the entire length of the culvert would be rammed before the tool was removed and the auger installed to clean the spoils from
the pipe. At two locations boulders and large rocks were encountered during the ramming and the auger was used to clean to the boulders so they could be removed using hand methods.

After the smooth steel pipe was rammed at eight of the locations, corrugated steel culverts were joined at the outlet end of the smooth steel pipe with a coupling band. These corrugated extensions along with rock riprap provided a path for the anticipated culvert discharge to enter the river or drainage ditch with minimal concerns for turbulence or erosion. The cost of ramming the 36-inch, smooth steel pipe, in 2002 dollars, was $850.00 per foot of length. While this cost did not include mobilization by the contractor it should be viewed from the perspective of difficult soil and access considerations.

PROBLEMS ENCOUNTERED DURING PIPE RAMMING

At eight of the ten locations the pipe ramming was generally uneventful. At these locations the variations in inlet elevations were from one to four inches lower than the design values. The outlet elevations were generally 2 to 3 inches lower than the design values. These values are all within MDT’s allowable variation.

There were difficulties encountered at two of the locations. At one location the boring log indicated a large layer of “talus” type rock. A sinkhole developed after ramming only ten feet into this embankment. We assumed that since there was no evidence of any bulging in the
railroad’s embankment that this extremely rocky material was full of voids and theorized that
the ramming process, with its inherent vibration, was vibrating finer material near the surface
of the embankment into these large subsurface voids. This sinkhole was directly under the
Sprint line and appeared to be capable of endangering the track if ramming continued and due
to this concern, we halted the operation. After reviewing the situation with MDT’s
representative, it was decided to try a new ramming location approximately 300 feet west of
the design location. A new entry pit was dug and the ramming began anew. Unfortunately
the exact same type of material was encountered and a sinkhole again developed. At this
point MDT reviewed their hydraulic design and concluded that rather continue with the
ramming, they felt this location could be eliminated from the project. They modified their
design to divert flows planned for this culvert to the nearby culverts using a larger ditch
section.

The other difficult location was more of surprise in that the soil-boring log showed a uniform
soft to dense sand that should be very suitable for ramming pipes. After ramming over 30 feet
of smooth pipe the end of pipe appeared to hit a single large boulder, causing the pipe to
deflect upward into the surrounding sand. It is possible in the ramming process to attempt to
steer the pipe if it is obviously tracking off grade. By cutting notches and bending sections at
the leading edge of the pipe as it is rammed, the pipe can be somewhat “steered” and brought
back on grade. This procedure was used at this location to reduce the upward deflection and
prevented the culvert from further adverse deflection. Even with the attempted steering, the
outlet elevation for this culvert was almost two inches above MDT’s allowable elevation and
the grade of the pipe was measured at less than 0.5%. While this was not an optimal situation, MDT ruled that the culvert as installed would be accepted, as they believed the overall lack of grade in the culvert would not cause any significant problems.

In this project all of the culverts installed by ramming were designed to act as carrier pipe for drainage off of the highway. But if MDT desired the rammed culverts could be used as casing pipe allowing insertion of a carrier pipe at the time of the highway’s reconstruction. This is especially true understanding that MDT’s hydraulic analysis had only required culverts with a 24-inch diameter. The 36-inch diameter size that was used, was more an accommodation for construction and future maintenance. It was likely that workers would be required to enter the pipe during its installation and manually remove boulders lodged in the pipe and after installation clean debris from the culvert. We simply felt it would be much easier for workers to work within a 36-inch opening when compared to that of 24 inches.

PROJECT SUMMARY

The use of an experienced contractor utilizing pipe ramming technology allowed Montana Rail Link to administer the installation of nine culverts beneath its track for the Montana Department of Transportation with no impact whatsoever on the normal operation of trains through the construction zone. This was accomplished in spite of the challenges of extremely limited access and very difficult subsoil conditions. The railroad’s requirement of trenchless installation along with the problem of a very small workspace made pipe ramming the
preferred method of culvert installation. While pipe ramming did prove to be a useful technique, the problems encountered reinforce the need to perform extensive subsurface testing and exploration before embarking on a trenchless, grade sensitive culvert installation beneath any active railroad track. After acquiring an appreciation for its merits and limitations in this project, Montana Rail Link will consider pipe ramming for future projects requiring trenchless installation of culverts on its system and will view pipe ramming as a viable alternative to installation of culverts by open cutting.

Photo 1 – Drill Rig Installation of Culverts by Pipe Ramming
Photo 2 – Ramming Tool Installation of Culverts by Pipe Ramming