Guidelines for Pipe Ramming

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Preface

Although pipe ramming is an established and widely used trenchless method for installation of steel pipes and casings, especially under railway and road embankments, it has not been covered adequately with guidelines and standards. The need for guidelines in this area was demonstrated in a study *Identification of Needs for User Guidance in Trenchless Technology Applications,* which was prepared by the Waterways Experiment Station (WES) (now Engineering Research and Development Center - ERDC) with the assistance of the Trenchless Technology Center (TTC) in 1998. The study surveyed existing guidelines and standards, as well as those under development by various organizations in the USA and abroad, and identified pipe bursting, pipe ramming and impact moling as areas of trenchless technology with priority needs for guidance development.

These guidelines are based on information obtained from manufacturers' literature, technical papers and other related information, and from comments and reviews made by industry experts. The following industry representatives are especially thanked for their reviews and advice:

- Mr. Frank Oursler, Middlecreek Mining Company, Peabody, KS
- Mr. Mike Argent, Permalok Corporation, St. Louis, MO
- Mr. Herbert K. Quigley, Vermeer/Earth Tool Co, Oconomowoc, WI

Executive Summary

These guidelines have been prepared to assist owners, designers and contractors involved in new pipe installation projects to evaluate capabilities of pipe ramming for such projects and to design and carry out pipe ramming jobs effectively and safely, in conformance with project requirements and site conditions. The objective of the guidelines is to give a clear understanding of the method, outline important design and construction considerations, identify potential problems and prevention measures and thus to engender confidence in the appropriate use of the method.

Pipe ramming is a trenchless method for installation of steel pipes and casings over distances usually up to 150 ft up long and up to 55-inches in diameter, although the method can be used for much longer and larger installations. The method is the most useful for shallow installations under railways and roads, where other trenchless methods could cause surface settlement or heave. The majority of installations are horizontal, although the method can be applied for vertical installations as well.

The method is pneumatic, i.e. it uses pneumatic percussive blows to drive the pipe into the ground. The leading edge of the pipe is almost always open, and is typically closed only when smaller pipes are being installed. Its shape has to allow a small overcut (to reduce friction between the pipe and soil and improve load conditions on the pipe) and to direct the soil into the pipe interior instead of compacting it outside the pipe. These objectives are usually achieved by attaching a soil-cutting shoe or special bands to the pipe. Further reduction of friction is typically achieved with lubrication, and different types of bentonite and/or polymers can be used (as in horizontal directional drilling) for this purpose. Spoil removal from the pipe can be done after the whole pipe is in the ground (shorter installations), or, if the pipe with the spoil becomes too heavy before the installation is completed, the ramming can be interrupted and the pipe cleaned (longer installations). Spoil can be removed by auger, compressed air or water jetting.

Repeated dynamic loading from the ramming tool on the pipe does not typically damage the pipe. However, when gas pipes are being rammed, it is recommended to place a short reusable impact pipe (approximately 5 feet long) between the installation pipe and the horizontal ram for protection.

1 Introduction

Pipe ramming is a trenchless method for installation of steel pipes or casings, in which a pneumatic tool is used to hammer the pipe or the casing into the ground while the excess soil from creating the borehole is removed to the surface. The method is frequently used under railway and road embankments. When casings are installed, pipes of other types for distribution of sewerage, water or gas, or electrical or telecommunication cables are subsequently inserted. The method is non-steerable.

Compared to other trenchless methods such as augering and directional drilling, pipe ramming can save both total installation time and costs under favorable conditions. Installation time can often be nearly 40% shorter than in augering because required width and depth of pits are smaller and actual installation is faster (40 to 60 feet sections can be rammed in half an hour while auger boring the same distance requires half a day). Directional drilling is generally better suited for long bores, however, pipe ramming is often superior for installations in the 5 to 60 feet range.

The method is most valuable for installing larger pipes over shorter distances and for installations at shallower depths. It is suitable for all ground conditions except solid rock, and is often safe where some other trenchless methods can lead to unacceptable surface settling (open-face augering in loose soils can cause unacceptable road settling or railroad tracks collapsing on the surface above the installation.)

A further application of pipe ramming is the installation of steel pipes to form a roof support for tunnel construction beneath existing infrastructure [15] such as railroad tracks [40]. In addition to new installations, pipe ramming can be combined with directional drilling and used to free the product pipe during pullback (or the drill pipe during pilot hole boring or reaming) if it gets stuck due to hydrolock or differential pressure sticking. The ramming tool is attached to the end of the product pipe when pullback slows down or stops, and the percussive action of the rammer helps to keep pipe moving through a difficult section [5].

Pipe ramming is typically used for horizontal installations, but can also be applied for vertical projects, such as piling driving or micro-piling. An example of vertical application is an installation of vertical supporting piles from a bridge through a body of water, when the bridge cannot support the weight of a crane necessary in a traditional method of installation of such piles [19].

1.1 Method Description

In a pipe ramming operation, a ramming tool attached to the rear of a steel pipe drives the pipe into the ground with repeated percussive blows. The method typically requires excavation of two pits. Before ramming, both the pipe and the ramming tool are placed into the insertion pit and lined up in the desired direction. Alternatively, the ramming can be launched without an insertion pit, if the ram is designed to start at the side of a slope. In contrast to pipe jacking, thrust plates or blocks in the insertion pit are not required.

The ramming action can be carried out either for the entire pipe length or as a series of shorter rams. The choice depends on the available space for an insertion pit setup and ground conditions. When shorter pipe segments are rammed, the ramming tool drives each pipe segment for its length through the ground, and then returns back to the tool's original position for the new segment that is to be welded or mechanically attached to the previous segment already in the ground.

The installed pipe usually has an open end that allows the soil to enter the pipe during the installation. The spoils inside the pipe can be removed either during or after the installation, by auger, compressed air or water jetting. The installed pipe can also have a closed end, but this option is usually selected only for installation of small diameter pipes or specific ground conditions (see section 3.4).

After completing the installation, the pipe is ready for use or other pipes or cables can be inserted through it.

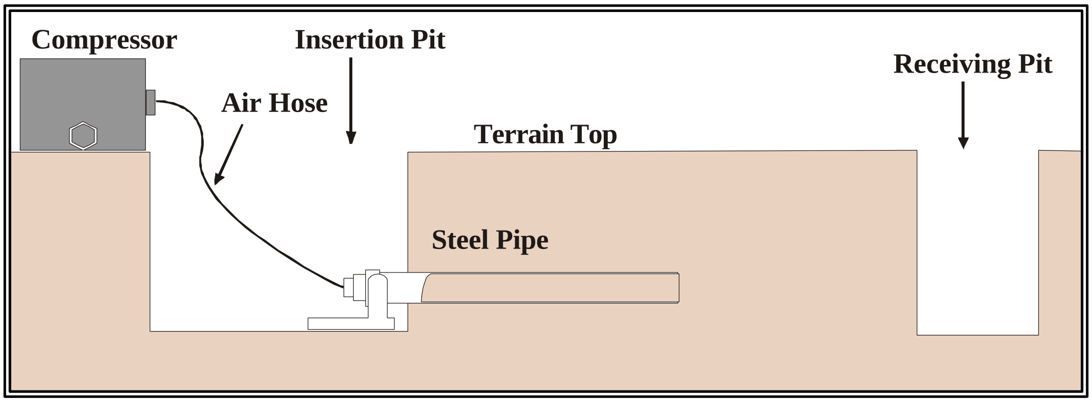

Figure 1-1: Typical pipe ramming setup

1.2 Applicability and Limitations

1.2.1 Installation Lengths and Pipe Sizes

Pipe ramming is typically used for pipe installation over relatively short distances, usually up to 150 feet [17], but installations longer than 300 feet have been successfully accomplished [4], [5], [7], [33], [44]. The method is mostly used on pipes between 4 and 55 inches in diameter, although much larger pipes can be successfully rammed in the right ground conditions. Some examples of large-diameter casings installation show that pipe ramming can be applied to 120 and 138 inch pipes [1].

1.2.2 Ground Conditions

Although pipe ramming can be applied in a wide variety of soils, some soils are better suited for this method than the others. The most suitable soil conditions for pipe ramming are soft to very soft clays, silts and organic deposits, all sands (very loose to dense) above the water table, and soils with cobbles, boulders and other obstacles of significant size but smaller than pipe diameter (soils with cobbles can be in extremely wet conditions, even with running water). Pipe ramming is a little more difficult in medium to dense sands below the water table, medium to very stiff clays, hard clays, highly weathered shale, soft or highly fractured rocks, marls, chalks, and firmly cemented soils. The only soil conditions that pipe ramming is completely unsuitable for is solid rock. However, in rocky ground conditions, a pneumatic tool can be used to punch the pilot hole first and the pipe can be rammed afterwards.

Compared to auger boring and directional drilling, pipe ramming can be used where these two methods are not efficient or effective. This applies especially to relatively short runs in soils with loose rock and cobble, or extremely fine sands because, in such soils, both augers and drilling heads may get stuck.

Applicability is further promoted by the method's ability to be performed where only a tight space is available for setup and in locations that cannot support very heavy construction equipment involved in open cut or other trenchless pipe installation methods. (Pipe ramming equipment usually weighs between 400 and 10,000 lbs.)

1.2.3 Limitations

Limitations generally come from the economical, environmental or safety aspects of the process. Compared to other casing installation methods, pipe ramming can be cost beneficial to the user. However, depending on the specifics of the project, the method may be more expensive than open-cut installation or directional drilling. Other drawbacks include high noise levels, which are typical for pipe ramming (if no noise protection is used), and sometimes a significant soil disturbance that can happen if a blockage is created at the end of the installed pipe.

1.3 Effects from Pipe Ramming on the Pipe and the Surrounding Environment

1.3.1 Ground Vibrations

Under each dynamic application of the force by the pipe ramming equipment, the pipe vibrates and the generated vibrations are transferred from the pipe to the soil particles. Ground vibrations associated with pipe ramming have not been studied so far. However, an extensive study of vibrational ground movement was carried out by the TTC for pipe bursting in pipe sizes ranging from 8 to 16 inches in diameter [26]. With respect to the ground vibrations, typical open-end pipe ramming is comparable to size-for-size pneumatic pipe bursting, because, in both methods, the equipment operates using a similar number of blows per minute (between 180 and 580) and the surrounding soil is not being compacted (due to displacing a volume of soil, although some compaction can occur in unconsolidated soils due to vibrations). In pipe bursting, ground vibrations are rapidly attenuated with the distance from the source and are not likely to be damaging to nearby underground objects, except at very close distances from the origin of vibrations, i.e. two to three pipe diameters of a pipe being burst for buried pipes and approximately eight pipe diameters for surface structures. Thus, ground vibrations from pipe ramming are not expected to damage nearby objects at similar distances. It should be noted, however, that increases in diameter and power, or the presence of rock may cause high levels of vibration at much greater distances.

1.3.2 Surface Disruption

Surface disruption associated with pipe ramming happens rarely because a solid, steel pipe is in the ground all the time and the soil within the pipe is not removed until later in the process. As a result, the creation of voids during construction or post-project settlement are drastically reduced. However, pavement sags or humps occur occasionally on the surface above an installation. The type and extent of surface disruption depend on the soil conditions, type of pipe ramming (open-end pipe vs. closed-end pipe), and the depth of installation.

Surface settlement or loss of support to adjacent pipelines can happen during ramming in sandy, cohesionless soils due to a loss of ground ahead of the cutting edge, as the soil flows into the pipe [18]. The vibrations from ramming operation can further consolidate such soils around the pipe. The selection of a closed-end pipe may be considered to prevent surface settlement, although such a measure would increase the required ramming force and is not practical for installation of larger casings.

Surface heave happens rarely because the volume of the displaced soil in the area of the cutting shoe is usually small. Heave can sometimes happen in dilatant soils such as granular and heavily over-consolidated soils that tend to expand when disturbed. However, the cutting action at the leading edge usually forms an earthen plug near the edge and a positive pressure that compacts the soil, thus preventing excessive soil loosening.

1.3.3 Effects on the Pipe

Pipes used for ramming are subjected to a dynamic (impact) force that is repeated a large number of times during the ramming operation. Under each dynamic application of the force, kinetic energy is transferred from the ramming tool to the pipe and the soil. Thus, in addition to the calculations of required jacking force, minimum pipe dimensioning and buckling safety of the pipe (done in conventional pipe jacking), a consideration needs to be given to the effects of kinetic energy on the material structure of the pipe and on the earth pressure.

These effects were studied in the research conducted in Germany by the Ingenieurburo Prof. Dr.-Ing. Stein & Partner, Bochum, the Institute for Sewer Technology at the University of Bochum, and a manufacturer of horizontal rams Tracto-Technik, Lennestadt, on behalf of Ruhrgas AG [8], [r14].

In the first phase of the research, measurements of expansion and acceleration were performed on several pipes during pipe ramming, and the amount of strain caused by the impact power was determined. The results revealed that the ramming method does not damage the pipe and that it is not necessary to add further design loads or adjustment to the values for the calculation of the installation pipes. Protection of the pipe is recommended only for gas pipes by placing a reusable impact pipe, approximately 5 feet long, between the installation pipe and the horizontal ram.

This research has also indicated that, compared to conventional pipe jacking, pipe ramming creates considerably more favorable load conditions (both during construction and afterwards from ground and traffic loads). In the second phase of the research, large-scale model tests and modeling with finite element method were used to further evaluate the influence of pipe ramming on the load conditions. Both experimental and theoretical results confirmed an activation of an arch-like supporting behavior in the ground. The results showed that, as the pipe is being rammed into the ground, loads on the pipe and stresses in the soil change and that, in any cross-section along the line of installation, the following characteristic stages can be distinguished:

- as the pipe leading edge (cutting shoe) is approaching the cross-section, both horizontal and vertical earth pressure are slightly increased due to soil compaction as the result of dynamic load initiation
- when the pipe leading edge reaches the cross-section, the pressure in the ground surrounding the pipe clearly redistributes creating an arch-like supporting effect of the soil above the pipe – the vertical earth pressure load drops significantly above the pipe and increases in the pipe abutment areas
- as the pipe is jacked a little further, the load on the pipe increases due to reorientation of soil against the pipe wall
- finally, at some distance behind the pipe leading edge, a stable final state is attained with a distinctly smaller earth pressure load on the pipe and increased vertical stress in the soil at both sides

In all the tests, the pipe leading edge had conical shape in the direction of pipe interior (yielding the soil into the pipe instead of displacing it outside the pipe) and an offset shape at the outer pipe contour (creating an overcut of $^{3}/_{16}$ inch which corresponds to the maximum value in accordance with German standard ATV-A 125 for driving pipes under German railway installations).

The research concluded that the external earth pressure stress of dynamically driven pipes is considerably less than the comparative values for pipes installed by conventional pipe jacking, and also lower than the earth pressures in the ground for the primary stress state (before pipe installation).

2 Applicable References

American Standards

American standards do not cover the process of pipe ramming, but they cover the steel pipes used for ramming. Applicable are standards by the American Society for Testing and Materials (ASTM) and the American Petroleum Institute (API).

The most appropriate pipe specification for pipe ramming is:

ASTM A139-00	Standard Specification for Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over) (Grade B pipe)

Note: No hydrostatic test is required for this pipe if it is not used for encasement.

Similar and also acceptable pipe specifications are:

ASTM A53/A53M-01	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless (Grade B pipe)
API 5L	Specification for Line Pipe (41st edition 1995) (Grade X or B pipe)
ASTM A106-99e1	Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service (Grade B pipe)

German Standards

ATV-A 161E	Structural Calculation of Driven Pipes (January, 1990)

3 Design Considerations

3.1 Route Layout

The pipe ramming method is non-steerable and pipelines installed by this method are laid straight. In the design phase, it is important to lay the route at a safe distance from existing utilities and other underground objects and protect them from being directly hit or damaged from vibrations.

The safe distance required to prevent direct hitting is determined by the installation accuracy of the method, which is, under normal circumstances, expected to be 1%, both vertically and horizontally. However, with good initial alignment of the first rammed pipe section, the accuracy of the method is often higher (between 0.1 and 0.5%). With respect to pneumatic vibrations, the recommended safe distance for pipe ramming in smaller diameters and in softer to medium compact soils can be adopted from pipe bursting, i.e. at least 2½ feet or 2-3 pipe diameters from the existing utility lines, whichever is greater. If the bore has to be laid closer, utilities that interfere with or may be damaged should be located and exposed prior to the ramming.

Because the location of existing utilities may not be known precisely, especially if only mapped data are being used, it is wise to set a "tolerance box" around existing lines and plan the route layout from the tolerance boxes instead of the utility lines. The size of tolerance boxes depends on the degree of accuracy with which the locations of the existing lines are known.

3.2 Depth

Most pipe ramming jobs are designed at depths between 10 and 20 feet below road surface of railway tracks [28], but can be carried out at shallower depths, between 5 and 10 feet [29], or even, in extreme cases, at depths less than 18 inches from the surface. Extremely shallow installations should be designed without a soil shoe and, in the construction stage, the surface above the installation line should be monitored carefully to detect any disturbance due to ground movements. An example of extremely shallow installation was ramming at depth of only 15 inches below railroad tracks [47].

3.3 Pipe

Pipes used for ramming are made from steel. Typically, a new, smooth wall carbon steel pipe that conforms to ASTM Specifications A139, Grade B, should be used. The pipe should have a minimum yield strength of 35,000 psi [13]. The wall thickness of the pipe should be selected based on calculations to support the maximum anticipated loads on the pipe during the construction and in the operating state. As static thrust calculation used for conventional pipe jacking [31] generally gives slightly greater value for pipe wall thickness than is required for dynamically driven pipe [14]. In addition to minimum dimensioning, buckling safety of the pipe should be checked. Pipe lengths are typically determined by the contractor.

3.4 Pipe End and Overcut

Depending on the pipe size and ground conditions, the pipe can be planned to have open or closed end. Open-ended ramming is generally preferable, because it requires less ramming force and is less likely to cause pipe deflection or surface heaving. Closed end is typically reserved for smaller pipes with diameter up to 6 inch [20] or for ground conditions with insufficient self-support, in which the flow of soil into the open pipe could cause surface subsidence or loss of support to nearby utility lines [18].

The pipe leading edge design should allow slight overcut of the borehole to create a small soil clearance around the pipe. Overcut can be designed only on the outside of the pipe to reduce external friction between the pipe and soil and help maintain the designed pipe grade during installation. In addition, it can also be designed on the inside of the pipe to reduce internal friction between the pipe and the spoil, thus facilitating the spoil removal from the pipe. The typical overcut, both on the outside and inside of the pipe, is between ¼ and ¾ inch [28], but can go up to 1½ inch [18], depending on the diameter of the ramming tool, depth and ground conditions.

3.5 Lubrication

Lubrication with different types of bentonite or polymers is usually essential for the ramming operation. The purpose of lubrication is to reduce the friction between the pipe and the soil. It is recommended in all soil types except in gravels and cobbles, where it is not considered necessary, and in porous sandy soils, where it would dissipate into the soil without accomplishing its purpose. Lubrication is especially important in medium dense to dense sands above watertable, where the heating of the pipe during the installation causes the moisture in the soil to evaporate and the soil to become locally cemented and solid. This can disturb the designed line and grade of the pipe during the ramming, or prevent the ramming completely. [16]

The theoretical minimum required amount of lubrication can be calculated by multiplying the cross-sectional area of the overcut (in^2) with the expected speed of ramming (in/min), and dividing the result (in^3/min) by 231 in^3/gal to convert it into gal/min [44]. However, the actual required amount of lubrication is usually greater than this value because the lubricant will run towards the pneumatic tool and out of the borehole.

4 Construction Considerations

4.1 Area Requirements

The working area for a typical ramming project has to be large enough to accommodate an insertion and a receiving pit, a spoil stockpile, a ramming tool and a pipe, a power source, a welder (if used), lubrication equipment and a lubricant supply.

4.2 Excavations

The location of insertion and receiving pit is determined by the job requirements, right of way access, and regulations of the authorities with regulatory authority over the site.

The length of insertion pit can be calculated from the length of the pipe sections to be installed, adding approximately 10 feet to this length. (The ramming tools are usually between 6 and 10 feet long.) If the surface area is not confined, the insertion pit may be considerably longer thus allowing the pipe or casing to be installed in fewer sections. The typical width of the insertion pit is up to 10 feet, with about 3 feet of clearance on each side of the tool. The pit depth should be at least 4 feet, and the minimum clearance above the ramming tool should be between 5 and 7 feet.

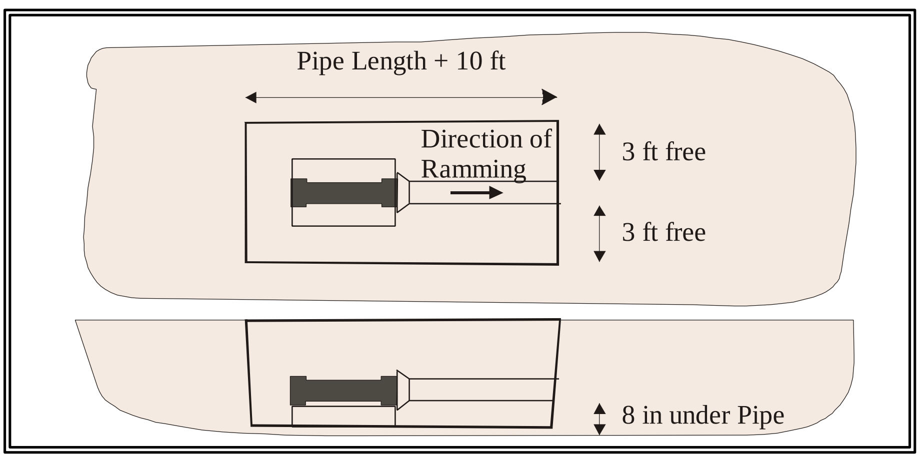

Figure 4-1: Insertion pit

The ramming operation requires that a solid base be established in the insertion pit. The floor of the insertion pit should be sloped and leveled to match the specific grade of the bore, and it should have a base of crushed rock at least 6 inches thick. It is further recommended to pour a concrete mat and install guide rails set to the line of the bore on the mat [18]. With the pipe to be rammed resting on them, such guide rails help ensure a level grade at the start of the ram. Concrete can also be poured over the guide rails [41]. Although such pit preparation prolongs the installation (it takes an extra day for the concrete to cure), the concrete supports are very helpful, especially when maintaining grade over longer rams. An alternative to guide rails is the use of adjustable bearing stands.

Figure 4-2: Adjustable bearing stands (TT Technologies)

The ramming can also be launched without an insertion pit, if the ram is designed to start at the side of a slope. The solid base for ramming should be prepared as for the insertion pit.

A receiving pit is excavated to get access to the end point of the installed pipe. The spoil may be extracted out of the pipe through this pit. Typically, it is smaller than the insertion pit.

Shoring of both pits should be carried to conform to local and national safety work codes.

4.3 Pipe Preparation

After the pits are excavated, the first length of pipe/casing should be prepared for insertion: the pipe leading edge is made ready and a lubrication pipe is attached to the main pipe.

Whenever possible, the pipe is driven in a continuous, single run, but if space is limited, the job has to be completed in a series of short ramming sections. Length of pipe sections should be selected based on available space for an insertion pit setup. A length between 10 and 60 feet is normally considered appropriate for pipe ramming, with the most commonly selected length being between 20 and 40 feet.

Welding the pipe segments during ramming can significantly contribute to the total installation time and steel casings with an interlocking pipe joining system (Permalok) can be selected instead. These casings have mechanical press fit joints that provide a strong and quick connection without welding, allowing an increase in the production rate. The use of Permalok joints can save 8-10 hours per connection of 60-in diameter casing [25].

If pipe segments are welded, the connections need to be strong enough to withstand the dynamic force from the percussive ramming. Full-penetration welded connections are recommended to prevent cracking or breaking of field welded connections.

4.3.1 Pipe Leading Edge

In open-end ramming, either a prefabricated soil-cutting shoe is attached to the front of the pipe leading edge (Figure 4.2-left) or a special band is welded around the outside or inside edge of the pipe (Figure 4.2-right). Both options reinforce the pipe edge and slightly overcut the hole in the soil, thus reducing internal and external friction between the pipe and soil.

When special bands are used, their design can be adjusted to the soil conditions to optimize the system's performance. In most soil types, the bands are two rings (one inside and the other outside the pipe) attached around the whole pipe circumference. In soft clays, however, the bottom 6 to 10 inches around the pipe invert may be left out to prevent pipe ebbing during the installation. The rings are usually 3 to 4 inches wide and attached directly at the pipe end, but in stiff clays they may be wider (between 10 and 14 inches) and attached at some distance from the pipe end (about 12 to 18 inches back within the pipe). This design allows the rings to enlarge the hole in the ground after the pipe leading edge has already cut into the ground. [16] In gravels and cobbles, the bands can be beveled to help rocks enter into the pipe, as well as to help in splitting or fracturing the rocks. In cemented soils, which are the toughest soils for pipe ramming, rings with a beveled edge should be used and combined with auger or drilling teeth welded around the pipe.

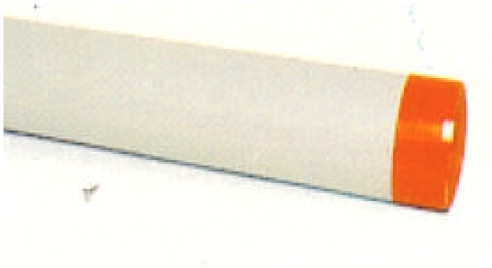

Figure 4-3: Left: Soil-cutting shoe (TT Technologies). Right: Special band for overcutting

With closed-end pipes, an attachment shaped as a cone can be welded or threaded to the front of the pipe. The purpose of such a cone is to compress the soil around the pipe face as the pipe is being rammed, and the ramming process resembles an action of a smaller piercing tool.

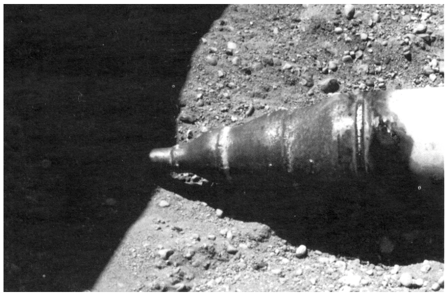

Figure 4-4: Left: Open-end pipe (TT Technologies). Right: Closed-end pipe on an 8-in pipe using multiple reducers (Vermeer)

4.3.2 Lubrication Pipe

The lubrication pipe is a small diameter pipe used to supply lubricant into the borehole near the leading edge of the pipe. Usually a ½-in steel schedule 80 pipe is selected and welded on top of the casing [29], [34]. When more lubrication is required, a 1-in steel pipe can be selected instead, and, for even larger quantities, two lubrication pipes can be used.

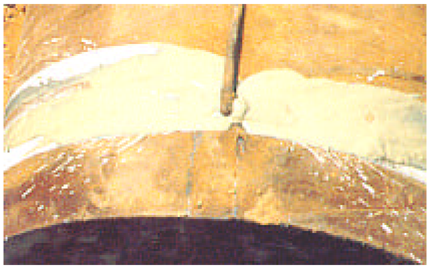

Figure 4-5: "Lubrication pipe" (TT Technologies)

The lubrication pipe can be designed to direct the drilling fluids along only the outside of the pipe being installed (usually in soft clays, silts and organic deposits), or both inside and outside the pipe (generally in medium-stiff to hard clays and in sands). If the lubricant is to be pumped inside the pipe, the lubrication pipe is fed through a small hole near the front of the leading edge.

4.3.3 Pipe-Tool Connection

After the pipe has been provided with adequate support, it is rigidly connected to the ramming tool and special cone adapters are typically used for this purpose. [16]. When the tool has much smaller diameter than the pipe, a series of adapters can be used. [21]

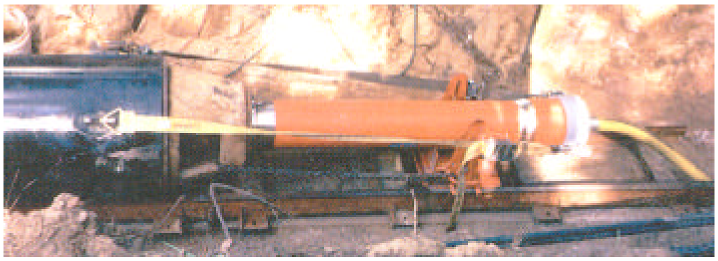

Figure 4-6: A combination of segmented rams, tapered ram cones, and a soil removal adapter used to link 10 inch ramming tool and 30 inch pipe [21]

4.4 Ramming below Groundwater Table

Pipe ramming below the groundwater table, especially in sands, can cause a problem of flooding, because groundwater can easily flow through spoils in the pipe and enter the insertion pit. The amount of water and sand entering the pipe can be reduced with the installation of plugs at the front end of the pipe. The plug can be created by either filling approximately 8-10 feet of the pipe with sandbags or by leaving the spoil in the front section of the pipe (approximately 20 feet) and cleaning the spoil only from behind the plug [43]. Such plugs also may optionally be used in medium to dense sands when ramming above the groundwater table.

In addition, a mechanical seal, usually composed of a rubber flange, can be mounted to the wall of an insertion pit to guard against groundwater flooding. Such seal also prevents an inflow of drilling fluids into the insertion pit during the ramming operation, and is therefore an option even for ramming above the groundwater table.

4.5 Spoil Removal

Spoils can be removed from inside the pipe either after the whole pipe is rammed into the ground (usually on shorter rams, up to 80 feet long), or periodically during the ramming, to lessen the drag and weight of the spoil accumulating in the pipe [18]. When pipe ramming is performed in soils containing large and tough cobbles and boulders, cleaning of the spoil from inside the pipe may be needed rather frequently.

Generally, the spoil is extracted from the pipe by either compressed air (when ramming smaller diameter pipes) or by augers (usually for larger diameter pipes). In addition, the spoil can also be removed using a "fabricated pipe shovel" (Fig. 4-9).

If the spoil contains large boulders (12 inches or more), the spoil removal can be more challenging than the ramming. With such spoil, augers typically do not work, and other types of equipment are applied, such as a mini skid steer (a small machine with a little bucket, cleaning the spoil out bucket by bucket) [24]. If the boulders are exceptionally large, they may need to be hauled out with a winch. In such cases, pneumatic air drills may be used to puncture the rock inside the pipe and drill in eyebolts, then the winch cables are attached to the eyebolts and the rocks hauled out with a winch [46]. For very large pipe diameters, excavators can be used to clean the spoil out.

Sometimes the spoil inside the pipe may need to be hand-mined with air-spades before removal. Any use of explosives requires that the tunnel is properly ventilated and monitored for oxygen.

Once the casing reaches the receiving pit, a plug or a pipe pig is inserted into the pipe on one end, usually in the insertion pit, and a seal-off plate installed. The air compressor that powered the ramming tool is used to build the pressure behind the plug or the pig, and extract the spoils out through the other pipe end.

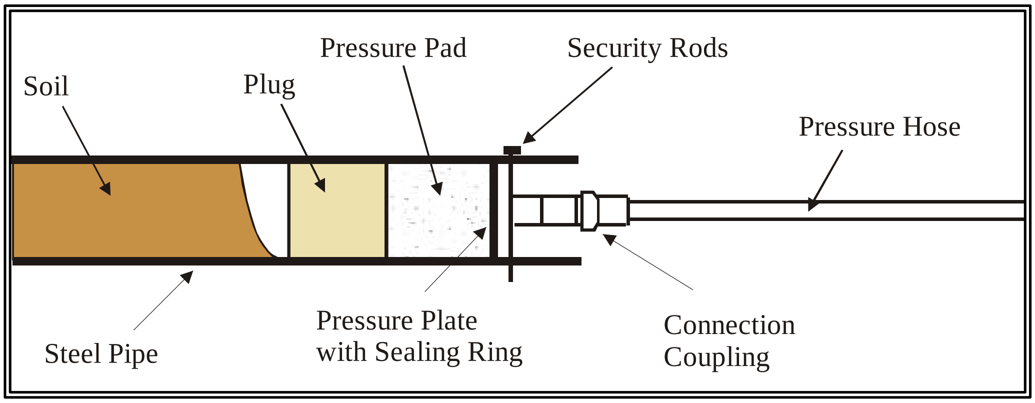

Figure 4-7: Spoil removal with compressed air (Mole Engineering, UK)

To remove the spoil from a pipe that has been only partly rammed in place, the ramming has to be stopped and the ramming tool removed from the pit. The spoil is then cleared out through the insertion pit. If the compressed air is used, a seal-off plate with an opening for the spoil can be attached to the rear of the pipe (Figure 4.8 - right). Another possibility is to cut a blow hole about 15 feet from the rear end of the casing and insert pressure hoses into the pipe to blow the spoil back through the hole into the pit. All members of the crew need to be removed from the area before this operation is commenced. If an auger is used, it is temporarily positioned in the pit replacing the ramming tool for the duration of the spoil removal.

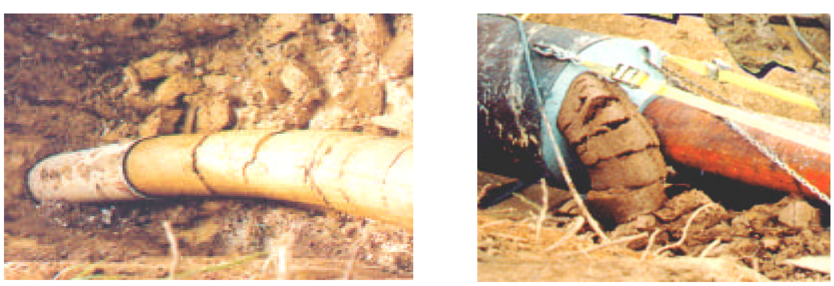

Figure 4-8: Left: Spoil exiting through front end of the pipe in the receiving pit (TT Technologies). Right: Spoil exiting the pipe through the seal plate on the rear of the pipe in the insertion pit.

The use of a "pipe shovel" is a simple alternative to other spoil removal methods. An approximately 10-ft long pipe segment with a diameter roughly 6in smaller than the rammed pipe is cut out on the front 7 ft to resemble a shovel. The shovel is then attached to a 4-in to 5¾-in impact mole (which drives the pipe shovel into the rammed pipe) and to a cable or chain (which is used to retrieve the shovel loaded with spoil from the pipe). The shovel is repeatedly driven into the pipe until all the spoil is removed.

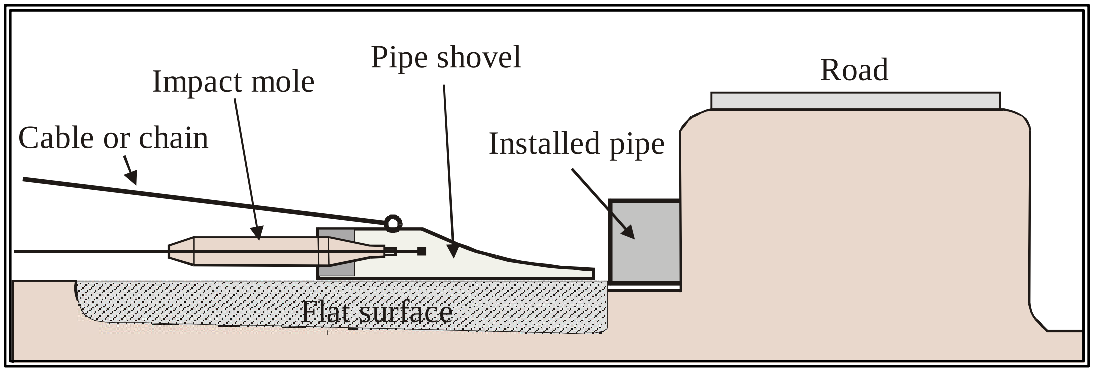

Figure 4-9: Spoil removal using a fabricated pipe shovel (Vermeer)

4.6 Ground Movements

During pipe ramming, ground movements associated with the work should be monitored and, if necessary, the construction method should be changed to control the ground movements and prevent damage to adjacent structures and pavement. Permissible tolerances with respect to the ground surface settlement and pipe alignment should not be exceeded.

5 Bid Documents

5.1 General

The bid documents are prepared by the owner/engineer, and should provide the contractor information needed to prepare competitive bids for construction. Bidding documents for pipe ramming projects typically include the following: Invitation for Bids, Scope of Work, Plans, Specifications, Site Investigation Report, Procedures for Protecting Existing Structures and Site Features, Inspection Procedures, Minimum Performance Requirements, and Performance Period.

Satisfactory evidence may be requested that the contractor has regularly engaged in furnishing products and performing construction work as proposed, and has the capital, labor, equipment, and material to execute the work required by contract documents.

5.2 Minimum Performance Requirements

Minimum performance requirements are established in the contract documents to ensure that the pipeline, as installed, will perform as designed. The criteria typically established for gauging performance include hydraulic characteristics, grade tolerances, water infiltration, internal pressure tests, and protection of adjacent structures. Other criteria may include allowable ground displacement, allowable work hours, and safety requirements.

5.3 List of Applicable References and Standards

A list of references and standards for equipment, materials, safety, etc. should be provided to the contractor for use in planning and bid presentation.

5.4 Site Investigation Report

Site investigation information, including existing utility network investigation, surface investigation and sub-surface investigation, allows the contractor to prepare a bid that is consistent with the probable soil conditions.

This information should be presented to the contractor prior to the bid, and the contractor should examine the project site on his own. Clauses transferring all responsibility for ground conditions to the contractor are not always accepted by the courts and, in addition, they also typically cause contractors to increase their bid price to cover the additional risk of unexpected ground conditions. On the other hand, failure to collect appropriate and reasonably available site information during the bid period may not relieve the contractor from responsibility for such investigations, interpretations, and proper use of information in preparation of his proposal.

5.5 Minimum Qualifications

To ensure a safe, efficient, high-quality project, the owner should present a list of minimum qualifications to the potential contractors. The minimum qualifications typically include a minimum number of pipe ramming projects successfully completed by the contractor (for example, five pipe ramming projects, or over 2,000 feet of steel pipe installed in the last four years, with at least one project in the past year and at least one project in similar ground conditions). Contractors that do not satisfy minimum qualifications may qualify if they provide assistance on site by a competent individual from the manufacturer, or local representative, or dealer of the manufacturer.

Financial data on the contractor and any subcontractors should also be furnished. The deadline for submittal of these qualifications should be clearly specified and should be prior to contract award.

5.6 Minimum Submittal Requirements (from Contractor to Owner)

To ensure compliance with the requirements of the specifications, a number of submittals should be required from the contractor. The specifications should clearly state the minimum submittal requirements for the contractor. The timing of the various submittals should be in accordance with the submittal schedule as presented in the contract. Submittals detailing the construction process, equipment, lubrication fluids, layout, and machinery set-up should be approved by the engineer prior to construction. Other submittals (e.g., as-built construction records) will be submitted throughout the construction process.

5.7 Requirements for Monitoring and Protecting Existing Utilities and Site Features

If of concern, the nearby utilities and structures should be monitored for displacement or damage, and the contract documents should clearly state the monitoring requirements. If the contractor disturbs the surrounding environment, existing utilities, or structures, the contractor should be required to restore them to their original condition.

When necessary, the owner should specify the level of noise, lighting, traffic interruption, and work hours that will be acceptable during construction.

5.8 Measurement and Payment

Ideally, the payment procedure should be fair and easily interpreted by the contractor and the owner. For small jobs or for a small component of larger projects, lump sum contracts are often preferred. However, for most pipe ramming projects, payment by the lineal foot of installed pipe of different diameters and/or upsizing is often preferable. Payment by the lineal foot allows the contractor to price each drive according to degree of difficulty, complexity of the site conditions, and anticipated competition. A combination of lump sum, lineal footage, or time and materials may be applicable when the specified project includes difficult ground conditions.

Special payment items for anticipated potential problems such as local excavations at an obstruction can help prevent arguments about the cost of such items at a later date (see section 5.9). The cost and number of these contingency items must be evaluated carefully to prevent problems with an unbalanced bid.

5.9 Remedial Action Requirements

During the ramming operation, if an obstruction is encountered such that the pipe gets stuck, an excavation may need to be made at the location of the obstruction to allow the installation to continue. In such cases, the contractor should inform the owner or the engineer and ask for direction. The bid documents should address such circumstances so that the contractor is aware, prior to bid, how these problems will be handled, including information on payment (whether the owner will pay on a time and materials basis, a lump sum basis, or whether the situation will be negotiated on a case-by-case basis).

If an adjacent underground utility is damaged, the contractor must immediately notify that utility owner of the location and nature of damage. Also, the contractor must allow the utility owner a reasonable time to accomplish necessary repairs before continuing the ramming. In general, when a correctly marked and specified utility line is struck and damaged, the damage caused by the contractor will be repaired at his/her own expense. For damage to utility lines that are unmarked or incorrectly located, the owner or the other utility provider would be responsible. The accuracy of utility locations and the required clear space should be specified in bid documents provided to bidders.

Most contract documents cannot or do not cover all the problems that may occur on a project. The owner and engineer should strive to identify anticipated problems and should establish or request submittals detailing a course of action for the contractor to follow in the event that problems are encountered. These actions should as far as possible cover all anticipated problems.

6 Submittals from Contractor to Owner

6.1 General

Submittals requested by the owner from the contractor are to ensure compliance with the project specifications. In addition, they provide the basis for monitoring details of the project. These submittals, or portions of, can be provided at various points during the procurement and construction process. The submittals of interest will be discussed in this section.

6.2 Material

Submittals should include calculations showing that the selected pipe would support the maximum anticipated loads on the pipe during the construction and in the operating state. The enclosed calculations should also prove the buckling safety of the pipe. All Contractor's submittals requiring structural design should be signed by a registered professional civil or structural engineer.

Submittals should include shop drawings, catalog data, and manufacturers technical data showing complete information on material composition, physical properties, and dimensions of a pipe and fittings. A pipe certification of compliance with specifications for materials and pipe jointing method and details should be furnished. In addition, manufacturer's recommendations for handling, storage, and repair of pipe and damaged fittings should also be enclosed.

6.3 Construction Method

Submittals should include details of the proposed method of construction and the sequence of operations to be performed during the construction. This should include a detailed written description of the installation procedure and working drawings.

A methodology statement should explain the operation of the equipment. A manufacturer's description of the ramming system, and a certification by the manufacturer of the tool, condition, and operational characteristics of all equipment to be used, should be enclosed. The submittals should also include detailed description of projects on which the system has been successfully used, names, addresses and telephone numbers of owner's representatives for these projects, as well as length, diameter and pipe material used.

The submittals should also include location of working pits, and calculations and drawings indicating limits of access pits. A method of excavation and any ground support to be utilized should be clarified. This should include shoring and bracing appurtenance installation, and dewatering techniques to be used when anticipating unstable ground conditions. A groundwater stabilization scheme should include all calculations and detail drawings for methods of controlling groundwater.

If lubricant use is planned for the project, the contractor should submit information on the type of lubricant to be used and methods of spoil disposal.

Working drawings should include the following pages:
- layout of pipe ramming and ancillary equipment at each pit location
- shop drawings including configuration of pipe front edge (soil cutting shoe) and overcut
- spoil removal system details
- grade and alignment control system details
- ground water control provisions

Submittals should include material safety data sheets (MSDSs) on appropriate materials, a description of where the material will be used, and the purpose in the construction process.

6.4 Site Layout

Construction site layout information is important to the owner to verify that the operations do not infringe on personal property or unnecessarily interfere with any public or private operations. A sketch should be submitted indicating storage areas, equipment set-up areas, construction staging areas, and locations of all major supporting equipment.

6.5 Contractor Qualifications

The contractor should provide evidence of qualifications to the owner. Background information on key personnel should be furnished to the owner to ensure they have adequate experience. Complete names, affiliations, addresses, and telephone numbers should be provided to allow the owner to contact the references and verify a satisfactory prior performance. If defined in individual specifications, minimum time requirements for start-up operations and operator training should be met and documented. If the contractor does not have prior experience with pipe ramming, he should arrange assistance on site from a competent individual from the manufacturer, or local representative, or dealer of the manufacturer.

Supporting financial data on the company should also be submitted to ensure that the contractor and pipe supplier would be available to support the product in the long-term.

6.6 Quality Assurance/Control Plan

The submittals should clarify how the quality control requirements will be satisfied. To assure quality control for materials and equipment, a representative of pipe supplier or ramming system manufacturer may be present on the site to observe site conditions, installation, quality of workmanship, start-up of equipment, operator training, test, adjust, and balance of equipment as applicable, and to initiate operation.

Quality control for construction should include the following:
- preparatory inspection – Prior to the pipe installation the following should be done:
  - Pipes should be checked for conformance to approved certified tests. The pipes should have no mid seam welds, or if they exist, they should be certified.
  - Pipes should be checked for proper storage and handling. The pipes should be unloaded from trucks with a crane or a backhoe and not dropped off or pushed off.
  - Pipe installation procedure should be discussed and reviewed with construction manager.

- ✍ initial inspection – After completion of pipe installation, the following should be done:
  - ✍ Pipe depth and grade should be checked.
  - ✍ Pipe joints should be checked.
  - ✍ Pipe alignment should be checked. A straight run of pipe can be checked for gross deficiencies by holding a light at one end of the pipe; it should show an approximately full circle of light through the pipe when viewed from the opposite end of pipe.
  - ✍ If television inspection of the installed line is specified, the contractor is to provide continuous videotape over the entire length of the pipe.

6.7 Safety Plan

The safety plan is to ensure that the public and workers are protected from construction hazards. This safety plan should include a Contractor's safety plan for the ramming operations and appurtenance installation. The plan should include provisions for lightning and electrical safeguards.

6.8 Construction Records

During the construction process, a contractor has to monitor the project progress and to document how the work is carried out. Various submittals prepared during the construction should include the following:

- ✍ pre-construction survey reports, documented as-built conditions
- ✍ construction logs
- ✍ materials installed
- ✍ extent and causes of delays
- ✍ locations of affected areas
- ✍ unusual problems or conditions encountered

A construction log of the ramming operation should consist of the following:

- ✍ the position of the pipe in relation to the design line and grade
- ✍ the date, the starting time and the finishing time
- ✍ inclination
- ✍ advance rates
- ✍ hammer strokes per minute
- ✍ operating pressure
- ✍ muck quantities removed
- ✍ a separate hand log for tracking pipe lubricant, showing quantity and viscosity of lubricant and a pumping pressure

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