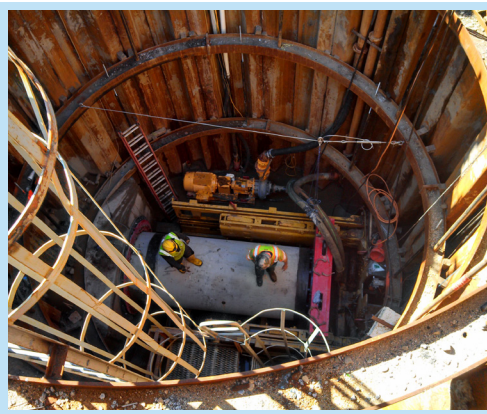


JACKING AWWA C300 AND C302 CONCRETE PRESSURE PIPE



Jacking, including microtunneling, allows installation of pipe in deep covers, under existing infrastructure or in areas that might otherwise be nearly inaccessible, such as narrow streets or alleys. Since the integrity of pipe in such installations is critical, the strength, durability, corrosion resistance, and water-tight joint integrity of concrete pressure pipe make it the ideal choice. Unlike flexible pipe, concrete pressure pipe will not collapse due to external pressure, and unlike some types of plastic and fiberglass pipe, concrete pressure pipe will not compress longitudinally. Due to its strength and leak-free design, concrete pressure pipe is also an excellent choice for casing applications.

Additionally, and more importantly, the strength and integrity of concrete pressure pipe makes single-pass installations of jacked pressure pipe water lines possible and reliable. If a protective PVC or HDPE liner is factory-installed in the concrete pressure pipe for sewer or force main applications, the pipe can still be jacked into place and the interior plastic liner joints melt-welded after the pipe has been placed in its final position. Such installation designs eliminate the cost and additional time needed to first jack a casing pipe in place, and then install the pressure-carrier or effluent pipe. Concrete pressure pipe is structurally sufficient to handle the installation loads, final external loads, and safely contain the finished pipeline internal pressure, without need of casing pipe installation.

WATER-TIGHTNESS IS CRITICAL

In many instances, installation of pressure pipe is only allowed under existing infrastructure such as railroads and highways with a pre-installed tunnel, while gravity "storm sewer" pipe is allowed to be installed without the tunnel encasement. That design philosophy assumes that a leaking pressure pipe will leak

continuously, and the encasing tunnel pipe will safely convey the leaking fluid out from under the infrastructure, while the intermittent flows in gravity pipe installations will not cause significant damage to the above infrastructure. For short-term exposures, that design expectation is likely true. For long-term applications, leak-proof joints are needed on both pressure and gravity pipe to avoid continuing soil migration causing undercutting and eventual collapse.

Jacking or microtunneling should be performed only by experienced contractors to assure pipe water-tightness is maintained by proper pipe alignment and assuring the pipe is not overstressed.

Water-tightness of all jacked installations should be tested to assure the installed joints do not leak. This can be accomplished either by a zero-leakage tolerance hydrostatic test following pipe installation, using a feeler gauge or joint tester on single gasket joints, using an infiltration test, or by using double-gasket joints with air tests between the gaskets to assure no leakage at every individual joint. Welded joints on concrete pressure pipe with steel joint rings can also be used and tested by vacuum boxes, dye penetrant, or magnetic particle tests.

APPLICABLE TYPES OF CONCRETE PRESSURE PIPE FOR JACKING

Jacked pipe must move longitudinally through the soil to its final position. To minimize pipe-to-soil friction and reduce the potential for damage to the pipe reinforcement steel's cover during jacking, types of concrete pressure pipe without mortar coating are most often used for jacking. These include reinforced concrete cylinder pipe type AWWA C300 for applications with higher internal working pressures, and reinforced concrete non-cylinder pipe type AWWA C302 for applications with a maximum working pressure of 55 psi. The exterior of both types of pipe are manufactured by wet-casting and curing concrete within smooth steel forms, resulting in smooth and tightly controlled exterior diameters and roundness.

If pipe with mortar coatings are to be used for jacked installation, the coating should be screeded or otherwise manufactured with tight controls for smoothness, consistent thickness, and dimensional accuracy.

DESIGN OF CONCRETE PRESSURE PIPE FOR JACKING

Pipe for jacking differs from that installed by open cut in that jacked pipe are subject to axial loadings from the applied jacking forces in addition to the external loads

and internal pressures. Rigid concrete pressure pipe, by virtue of its thick walls and high compressive strength, is ideally suited to carry these applied loads.

Additional information on jacked pipe design is available in the AWWA Manual M9, "Concrete Pressure Pipe", and ASCE 27, "Standard Practice for Direct Design of Precast Concrete Pipe for Jacking in Trenchless Construction".

Design for External Load. The earth load for which the pipe must be designed is always less, and usually considerably less, than the load from an equal depth in an open cut installation. The design for resisting the external earth load is not related to the design of the pipe's axial strength to resist jacking forces, which is covered later herein. The earth load on concrete pressure pipe installed by jacking is a function of the following:

1. The (downward) weight of the prism of earth directly above the bore;
2. The (upward) shear force between the prism of earth above the bore and the adjacent soil;
3. Cohesion of the soil along the periphery of the soil prism over the bore which reduces the effective downward load.

The magnitude of the earth load is:

$$W_t = C_t w B_t^2 - 2c C_t B_t$$

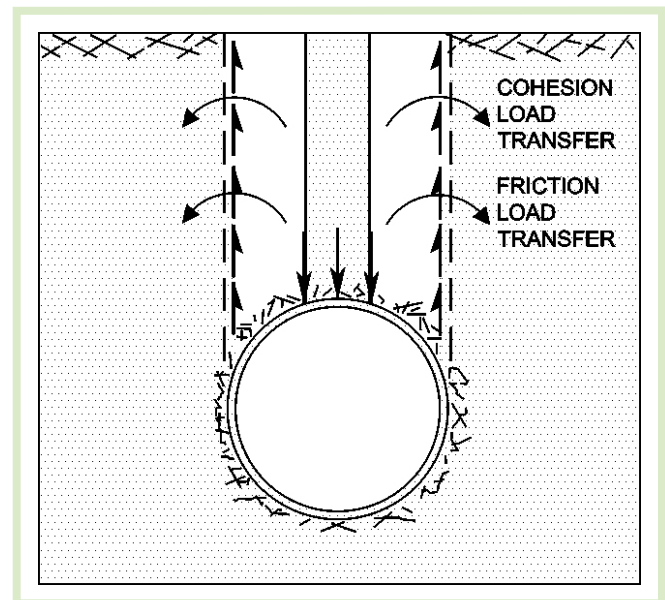


Figure 1. Forces Affecting External Load on Rigid Jacked Pipe

where:

W_t = earth load in pounds per linear foot of pipe

w = unit soil weight in pounds per cubic foot

B_t = width of the bore in feet

c = coefficient of soil cohesion in pounds per square foot, (see Table 1)

C_t = load coefficient for jacked pipe, as follows.

$$C_t = \frac{1 - e^{-2K\mu'H/Bt}}{2K\mu'}$$

where:

K = ratio of active lateral soil pressure to vertical pressure

μ' = coefficient of friction between material over the bore and adjacent earth

H = height of cover over the pipe in feet

Procedures for determining pipe reinforcement should be based upon use of a load factor of 3 or a design bedding angle of 150 degrees.

DESIGN FOR JACKING LOADS

The pipe and joints are to be designed for all anticipated axial loads. The magnitude of these loads is a function of many factors including installation technique, total length of jack (or length between intermediate stations), pipe skin friction, pipe diameter, cutting head resistance and whether the pipe will be jacked through a curve.

Table 1. Design Values of Coefficient of Cohesion

Type of Soil	Values of c (lb/sf)	
Clay	Soft	40
	Medium	250
	Hard	1,000
Sand	Loose Dry	0
	Silty	100
	Dense	300
Top Soil	Saturated	100

The rated jacking force (R_{js}) of concrete pressure pipe is dependent on several primary factors, including:

- the cross sectional area of the pipe at contact surface with the joint, A_j
- the compressive strength of concrete, f'_c
- an appropriate factor of safety, SF

Additionally, with some joint designs, or when jacking through a curve, longitudinal bending due to eccentricity of the load on the joint face should be evaluated.

Direct Compression Force. The rated jacking force (R_{js}) conforms to the following equation:

$$R_{js} = A_j \times f'_c / SF$$

A minimum recommended concrete strength of 5000 psi and minimum safety factor of 3.0 are commonly used.

Longitudinal Bending Strength. In general, the entire pipe remains in compression, despite minor bending due to eccentricity between the center of the joint face and the gross wall section beyond the joint. With some joint designs, however, the resultant force is acting considerably off the centerline of the wall, (see Figure 2), creating a net tensile stress. In such cases, the tensile stress should be limited to $3 \times f'_c^{1/2}$.

TYPES OF JACKING PIPE JOINTS

Jacking pipe joints may be either all steel, using Carnegie spigots and bells, or a combination of a concrete spigot with a steel bell sleeve. Steel joint surfaces are typically coated during pipe manufacture with either zinc or epoxy coatings for corrosion protection. No additional joint protection is required to be applied in the field. Experience has shown that due to the lack of oxygen replenishment around pipe installed by jacking, exterior joints do not need mortar coating for corrosion protection.

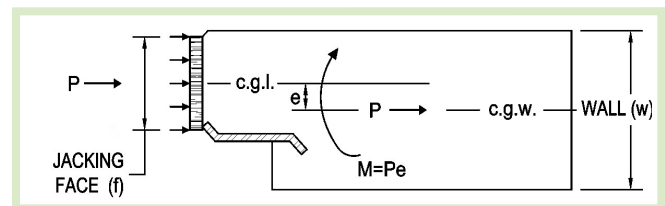


Figure 2. Jacking Strength – Longitudinal Bending Force Diagram

Some example joint configurations are shown in Figures 3 through 5.

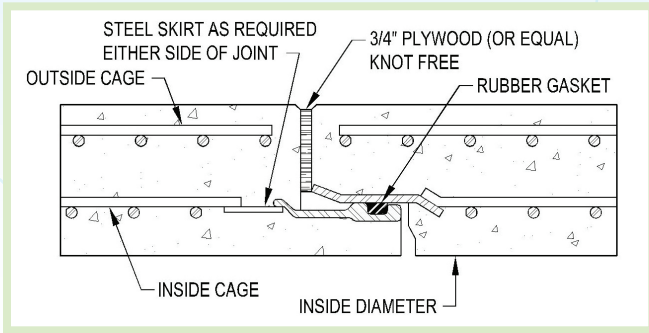


Figure 3. AWWA C302 Non-Cylinder Pipe with Steel Joint Rings

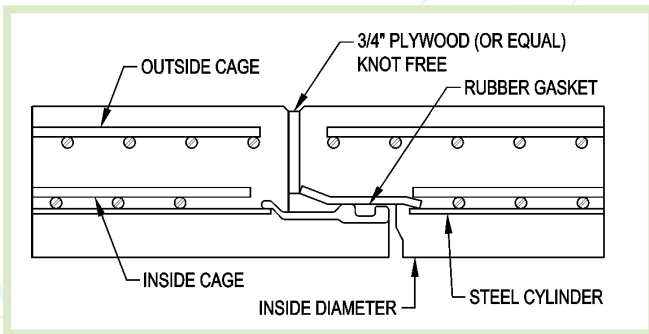


Figure 4. Steel Joint on Reinforced Concrete Cylinder Pipe

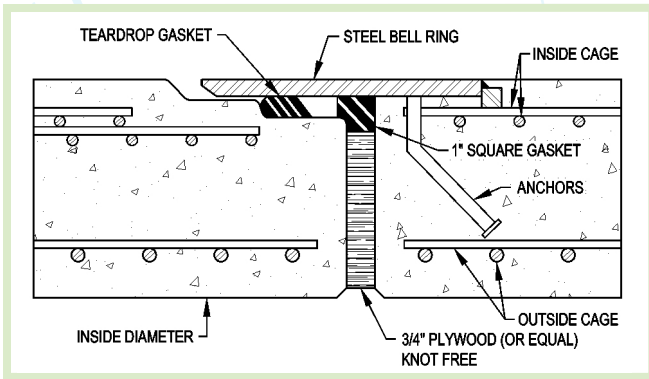


Figure 5. Concrete and Steel Joint on Non-Cylinder Reinforced Concrete Pipe

INTERMEDIATE JACKING STATIONS

To accommodate increasing jack lengths without detrimentally increasing jacking forces, intermediate jacking stations are used. The jacking stations have steel shells with the same outside diameter as the pipe, inside which hydraulic jacks are mounted and designed to bear against thick steel plate and/or thrust transfer rings.

The long end of the shell is designed to extend axially as the intermediate jacks are activated, thereby allowing intermediate reaches of the pipeline to be jacked independently of other reaches. After completion of the entire jacking run, the intermediate jacks are removed, and the gap is closed by activation of the adjacent intermediate jacking station or main station jacks.

QUALITY ASSURANCE AND TESTING

The higher degree of sophistication used with modern jacking equipment has allowed substantially longer distances to be jacked under areas of ever increasing sensitivity. Both the increased demands on concrete pressure pipe performance and the potential liabilities for failure have mandated exacting jacking pipe manufacturing quality assurance.

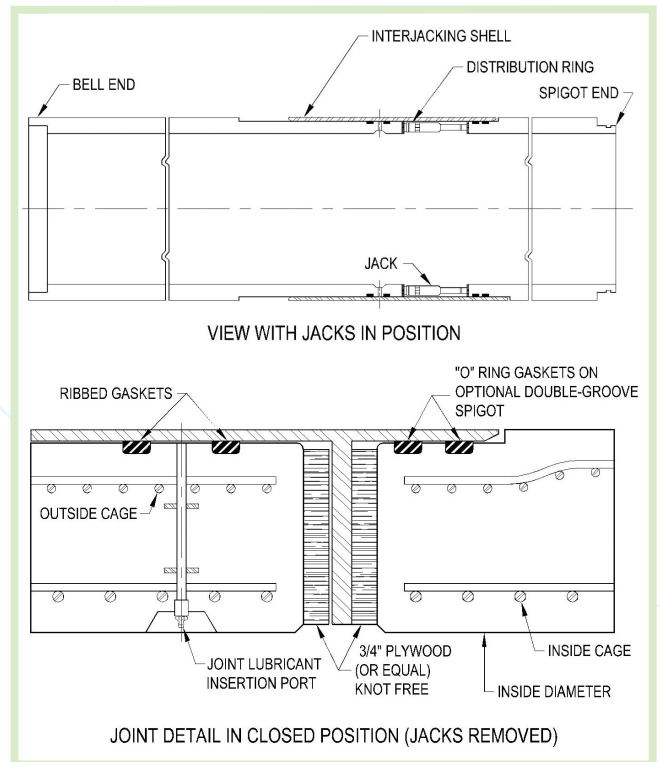


Figure 6. Intermediate Jacking Station Joint Detail for Non-Cylinder Concrete Pipe

Quality Assurance. Quality assurance of concrete pressure pipe for jacking focuses on several major areas, including:

- dimensional accuracy
- pipe strength confirmation
- core finish
- joint watertightness

Dimensional Accuracy. For a jacking pipe to perform as intended, it is important that the geometry of the wall, joint and pipe as a whole be accurate and consistent. Specific checks should include:

- Wall thickness in the joint and barrel to ensure that the intended axial strength is achieved. A tolerance of +/- 3 percent of the wall thickness with a maximum deviation of 3/16 in. is recommended.
- Outside diameter conformance to ensure pipe follows bore with minimum interference. A tolerance of +1/32 – 1/16 in. per ft of inside diameter, with a maximum tolerance of +/- 3/8 in., is recommended.
- Squareness of pipe ensures uniform load transfer. For this purpose, dual checks are made – length of opposite sides and end squareness.
 - For length of opposite sides, (measuring pipe length 180 degrees apart) a tolerance of 1/4 in. for pipe up to 48 in. is recommended, and for larger sizes, a tolerance of 3/8 in.
 - For end squareness, diagonals are measured 180 degrees apart, and the same tolerance as for length of opposite sides is recommended.
- Normality of the joint face helps ensure a uniform stress transfer across the joint during jacking. A maximum deviation of +/-1 degree from true perpendicular is recommended.

Pipe Strength Confirmation. As previously discussed, the rated jacking strength of a pipe is a function of its compressive strength. Compressive strength is generally determined by testing 6 x 12 in. concrete cylinders made from the same batch and with the same curing as the pipe, at predetermined intervals up to and including 28 days. In general, this procedure works well, but may fail to identify a pipe which may not meet strength due to a deficiency in concrete placement or curing.

As a second check, in situ concrete strength is often estimated on the pipe ends using a Schmidt rebound hammer. In this test, ten readings are made on the joint faces of each pipe, averaged, and compared to a predetermined value which correlates the hammer reading to concrete strength. In this manner, independent confirmation is made that the concrete in each individual pipe meets design strength.

Core Finish. One of the major factors influencing field jacking loads is the skin friction of the piping material being jacked. To ensure that this value is being minimized, limits should be placed on exterior surface irregularities such as “bugholes” and gate offsets. To this end, it is recommended that excessive irregularities and gate offsets greater than 1/8 in. be repaired.

Many projects now utilize a “Q/A” manifest for each length of jacking pipe. Under such a system, each pipe is assigned a unique number, and a Q/A report documenting all tests, checks and strength are recorded to assure completion.

Lubrication Ports. Small-diameter outlets are generally provided on jacking pipe for the purpose of injecting bentonite or other lubricant between the pipe and the hole in the soil. Determining the number and placement of such outlets is typically the installation contractor’s responsibility and is based upon the length of drive, type of soil, and other considerations.

Testing. In all other respects, jacking pipe is subject to the same product testing as pipe installed by open cut. Occasionally, testing may be done to confirm that the rated jacking strength is achieved. This is especially true when developing a new or modified type of jacking pipe.

CONCLUSION

As America's cities and towns continue to mature, jacking and microtunneling promise to become more a method of choice, eliminating the problems of traffic jams, road restoration, loss of commerce, and quality of life typically associated with open cut installations. Microtunneling has made rapid improvements in the last decades, both in accuracy and length of installations. As this technology continues to evolve, concrete pressure pipe will be designed to meet the ever-increasing demand for excellence in jacked pipe.

LEARN MORE

For more information on flow friction characteristics, speak with your Concrete Pressure Pipe supplier, or contact the American Concrete Pressure Pipe Association at **714.801.0298** or **www.acppa.org**.



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