

501 PIPE CULVERT AND STORM DRAINS

501-1 Description

Several types of pipe are used for storm drain and culvert applications. They are:

- Precast Concrete Pipe
 - Includes:
 - RCP or RGRCP - (Rubber Gasket) Reinforced Concrete Pipe
 - NRCP- Non-Reinforced Concrete Pipe (up to 24")
 - HERCP- Horizontal Elliptical Reinforced Concrete Pipe
 - RCB- Reinforced Concrete Box
- Corrugated Metal Pipe (CMP)
 - Includes:
 - Corrugated Steel Pipe (CSP)
 - Corrugated Aluminum Pipe (CAP)
 - Plate Arch (see section 502)
 - Slotted drains and perforated pipes
- Black Steel Pipe (BSP)
- Corrugated High Density Polyethylene Plastic Pipe (CHDPEPP)
- Non-Reinforced Cast-In-Place Concrete Pipe (NRCI PCP)

The pipe summary sheets in the Project Plans will indicate which type of pipe may be used for each pipe run. The contractor may have an option on the type of pipe to use, pipe types not shown as an option shall not be used. At each location where a pipe is to be installed, the project plans will specify the size and approximate length along with the requirements for each approved option at that location, such as the wall thickness, corrugation configuration, coatings, linings, class, and strength. At each such specified location, pipe of one kind and material shall be selected by the contractor from the options shown. All contiguous pipe and all metal pipe in close proximity shall be of the same kind and material.

Each proposed pipe installation should be carefully reviewed to ensure that the planned location, skew angle, and length are proper to meet ultimate configuration of the street or roadway. The grade of the channel, both upstream and downstream from the pipe, should be checked to determine the proper elevation for each end of the pipe. Often, changes in excavation or embankment limits needed to meet field conditions cause changes in pipe lengths, grades, elevations and alignments. The length of each pipe run should be checked before the Contractor orders the material. Significant changes made to pipe lengths, grades, and elevation should be discussed with the Project Designer before installation. This will allow the Designer to analyze any changes in the hydraulic or structural capacity of the pipe.

Other factors to consider before installation include:

- Blue Stake notification and the marking of all existing underground utilities and structures, including those belonging to ADOT
- OSHA safety requirements for trenching and confined space entry, including preparation of a shoring plan
- Notification of utility companies affected by trenching and pipe installation, including coordination for possible shutdowns or temporary interruptions
- Protection of existing utilities and structures
- Securing any necessary local permits
- Locations of benches and other survey monuments

When there are changes to pipe run lengths and grades, the Contractor may ask for additional compensation beyond the bid unit price. Extra costs may include additional excavation and backfill because of a deeper trench or a restocking fee for quantities of pipe not needed. The Resident Engineer must keep

in mind that changes in pipe lengths needed just to meet field conditions does not necessarily justify unit price adjustments and extra costs. Only when the site differs materially from what is represented in the Project Plans (see Subsection 104.02), or when the Department makes design changes that significantly impact pipe runs, should additional compensation be considered.

On longer pipe runs, ADOT will have a soils report that is available to the Contractor. The Resident Engineer or Project Supervisor should review this soils report before construction with the intention of anticipating any installation or safety problems that may occur.

The specifications require the contractor to submit a written trenching plan prior to constructing trenches deeper than 5 feet. In most types of soil it is necessary to provide shoring, or to slope the ground beyond the neat lines shown in the Project Plans or Standard Drawings to avoid caving. Side slopes should conform to the Occupational Safety and Health Administration (OSHA) standards. See section 501-3 of this manual for more detail about OSHA requirements.

501-2 Materials

The Contractor should carefully unload, store, and handle all pipe sections (joints). Careful handling of coated pipe is necessary to keep coating scars and repairs to a minimum. The Inspector shall examine each pipe joint before it is placed in the trench.

The Inspector should check for:

- Correct diameter and material Standard Specifications including wall thickness
- Spalls, dents or chips around the ends of each pipe segment
- Cracks; both on the interior and exterior of the pipe
- Fabrication date stamped on precast concrete pipe
- For precast pipe:
 - Check the class or D-load, plant ID, and type of reinforcement (elliptical or quadrant)
 - Verify from pipe summary sheets whether pipe will be used for trench or non-trench condition
- Identification marks on the pipe indicating the same lot or production number as shown on the certificate of compliance
- Certificate of Compliance for the pipe, gaskets, banding material, and hardware
- Water tightness requirements stated on the Certificate of Compliance; when water tight joints are specified in the Project Plans or Special Provisions.

Inspectors may reject any pipe damaged during handling and storage, even if there is an ADOT stamp on it and certifications have been submitted.

Corrugated Metal Pipe (CMP)

Make an additional check on CMP being delivered to your projects for the proper markings and diameters. According to AASHTO M 218, Section 12, the following are the criteria for markings on CMPs.

Each two to five feet of sheet in coils or cut lengths shall be identified by showing the following:

- Name of sheet manufacturer
- Brand name
- Specified thickness
- Specified weight of coating
- Identification symbols relating to a specific heat number and coating lot number
- The 12.1.6 AASHTO designation number

When control tests do not show conformance to this specification, the brand will be removed, obliterated, or re-branded: "Non-Specification Material" on each 2 to 5 feet of material in a lot or heat.

Any corrugated metal pipe delivered on a project should have the above information stamped on it at the required locations.

Verify that the information on the pipe matches the information on the certifications.

According to AASHTO M 36, the following are criteria for pipe dimensions:

- 8.1.1 "The average inside diameter of circular (helical and annular corrugated) pipe and pipe to be reformed into pipe-arches shall not vary more than one percent or one-half inch, whichever is greater, from the nominal diameter when measured on the inside crest of the corrugations." (For example, a 36-inch pipe that measures 35-3/8 inches inside is not acceptable).
- For helical and annular corrugated pipe, two inside measurements are taken at 90 degrees to each other (usually horizontally and vertically) and the results are averaged. There is an alternative for measuring annular corrugated pipe. (An annular corrugation closes on itself). The minimum outside circumference can be measured in accordance with Table 6, which is shown in Exhibit 500-2-1. Measurement on the outside is on the sag of the corrugations.

Suppliers may furnish arch pipe shaped by deforming a circular pipe rather than actually machine forming an arch. The vertical dimension from the invert to the line through the widest horizontal dimension should be checked for compliance with AASHTO-M-36. It is not unusual that an arch pipe will not meet M-36 requirements. Arch pipe made with crimped spiral joints often tends to warp longitudinally and has ends that do not match well. Great care is needed in making joints to ensure a good match of abutting sections and tight joints. It may be necessary for the Contractor to replace pieces to get a good joint. Since the supplier is responsible for supplying matching pieces, the Inspector or Project Supervisor should insist that the Contractor provide nothing but quality joints.

Nominal Inside Diameter		Corrugation Sizes ^A					Minimum Outside Circumference ^B	
in.	mm	-1/2 by 1/4 in. 38 by 6.5 mm	2-2/3 by 1/2 in. 68 by 13 mm	3 by 1 in. 75 by 25 mm	5 by 1 in. 125 by 25 mm	Ribbed Pipe ^C	in.	mm
4	100	X					11.4	284
6	150	X					17.7	441
8	200	X					24.0	598
10	250	X					30.2	755
12	300	X	X				36.5	912
15	400	X	X				46.0	1,226
18	450	X	X			X	55.4	1,383
21	500		X			X	64.8	1,540
24	600		X			X	74.2	1,854
---	700		X			X	---	2,169
30	800		X			X	93.1	2,483
36	900		X	X	X	X	111.9	2,797
42	1,000		X	X	X	X	130.8	3,111
48	1,200		X	X	X	X	149.6	3,739
54	1,400		X	X	X	X	168.4	4,364
60	---		X	X	X	X	187.0	---
---	1,600		X	X	X	X	---	4,987
66	---		X	X	X	X	205.7	---
72	1,800		X	X	X	X	224.3	5,609
78	2,000		X	X	X	X	243.0	6,231
84	2,200		X	X	X	X	261.7	6,853
90	---			X	X	X	280.3	---
96	2,400			X	X	X	299.0	7,475
102	---			X	X	X	317.6	---
108	2,700			X	X	X	336.3	8,408
114	---			X	X		355.0	---
120	3,000			X	X		373.6	9,341
---	3,300			X	X		---	10,274
---	3,600			X	X		---	11,207

- ^A An "X" indicates standard corrugation sizes for each nominal diameter of pipe.
- ^B Measured in valley of annular corrugations. Not applicable to helically corrugated pipe.
- ^C Rib sizes 3/4 x 3/4 x 7 1/2 in. [19 x 19 x 190mm] and 3/4 x 1 x 11 1/2 in. [19 x 25 x 292mm].

Source:

Standard Specification for Corrugated Steel pipe, Metallic-Coated, for Sewers and Drains

AASHTO Designation: M 36 [M 36M]

ASTM Designation: A 760 [A 760M]

Precast Concrete Pipe

ADOT's Materials Group inspects precast concrete pipe at the manufacturing plant. When the precast pipe arrives at the project site the Inspector shall obtain the casting dates stamped on each pipe joint. The Inspector shall then inform the materials laboratory coordinator for the project of these casting dates. In turn, the materials laboratory coordinator shall contact ADOT Materials Group (Structural Materials Testing Section) who will verify that the precasting plant was inspected and materials used for the pipe were tested on those casting dates. Pipe that was made during days where plant inspection and testing were not performed is unacceptable and shall be rejected by the Inspector.

Pipe inspected at the plant can still be rejected at any time; poor handling and latent defects are often the cause of damage that shows up later. The Inspector should encourage the Contractor to inspect the deliveries, since any damage appearing after installation is cause for rejection and may interrupt the installation process.

501-3 Construction Requirements

Contractor Quality Control

Special Provisions may contain Contractor Quality Control requirements for pipe if the project includes any of the following:

- 60-inch diameter, or greater pipe
- Total of more than 600 feet of pipe
- Contractor Quality Control for earthwork

Salvaged Bedding Material

The Special Provisions may contain requirements for pipe bedding material composed wholly or in part of salvaged asphaltic concrete or Portland cement concrete material.

Safety

Trench safety and confined space entry are the two major safety concerns for any pipe installation operation. OSHA has strict standards to which Contractors must adhere for anyone inside a trench or a confined space.

Subpart P of the OSHA regulations (29 CFR 1926.650 - 652) applies to excavation safety. The first section of Subpart S (29 CFR 1926.800) applies to confined space entry. Each ADOT Field Office should have a copy of these standards as part of the collection of all the OSHA safety standards related to construction.

Although OSHA requirements apply to trenches of any depth, the standards become quite involved for excavations 5 feet and deeper. The flow chart in Exhibit 501-3-1, which is reproduced from the OSHA standards, summarizes the safety evaluation process. The full set of subpart P standards should be consulted when investigating a safety concern.

Special attention should be given to trench side wall stability during periods of changing moisture content.

The following figures are a graphic summary of the requirements contained in subpart P for excavations 20 feet or less in depth. Protective systems for use in excavations more than 20 feet in depth must be designed by a registered professional engineer in accordance with *1926.652(b) and (c).

Figure 1. Preliminary Decisions

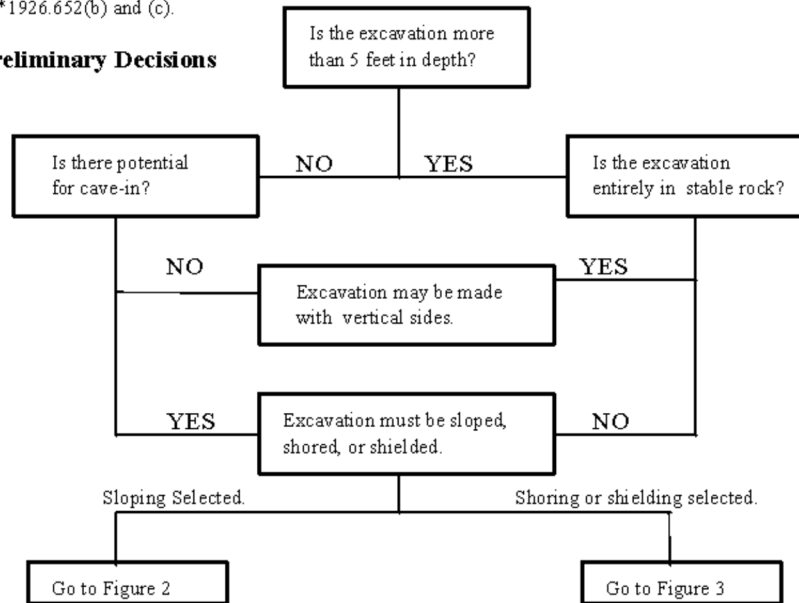
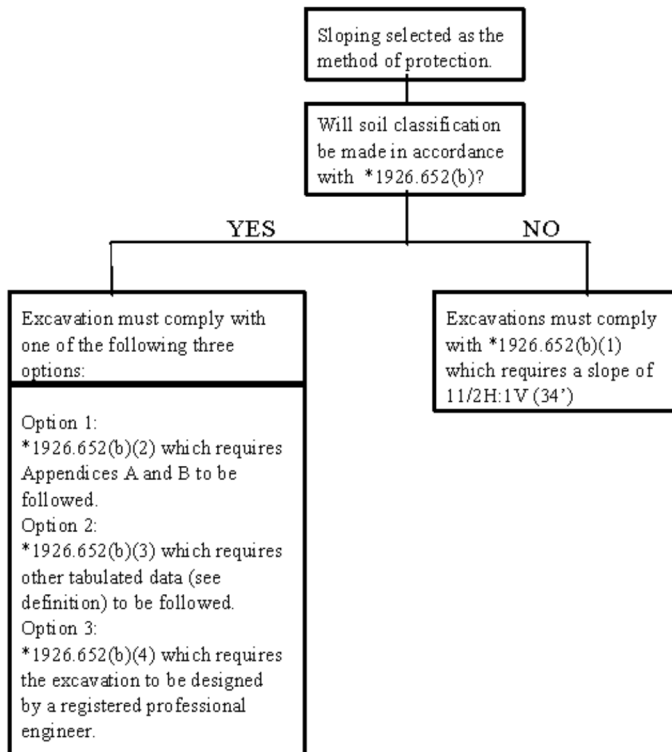


Figure 2. Sloping Options



EXCAVATION STANDARD

Figure 3. Shoring and Shielding Options

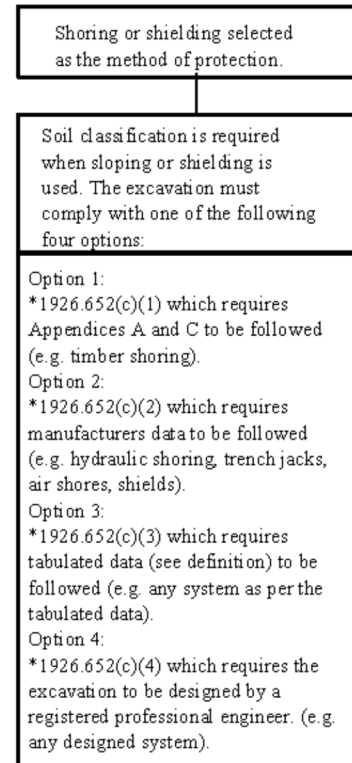


Exhibit 501-3-1. Excavation Safety Requirements

Some important highlights of the OSHA excavation safety standards:

- The Contractor must have a competent person on the job site whose duties include:
 - Classifying soil and rock deposits
 - Evaluating the potential for cave-ins when excavations are less than 5 feet
 - Removing exposed employees found in hazardous conditions
 - Making daily inspections of excavations
 - Monitoring dewatering equipment
- The Resident Engineer should ensure that the Contractor's designated competent person does meet OSHA's definition of a "competent" person (see section 1926.650(b)). In reviewing the individual qualifications, the Resident Engineer should check for demonstrated experience or ability in:
 - Classifying and investigating soils
 - Selecting, installing and inspecting trench protection systems
 - Installing and operating dewatering equipment
 - Recognizing situations that may present atmospheric hazard (oxygen deficiency or The presence of toxic gasses)
 - Having monitoring and rescue equipment readily available
- A Professional Engineer must be used for slope, shoring and shield designs when trench depths are greater than 20 feet in accordance with §1926.652(b) and (c). A Professional Engineer is also needed to determine that nearby structures are not affected by the excavation.
- Soils are classified as a stable rock or type A, B, or C soil. The soil classifications must include manual testing (gradation, soil strength, etc.) as well as visual testing of the soil. Sloping, shoring, and shielding requirements are based on the soil type.
- The competent person must evaluate the effect of spoil piles near the trench on its stability.
- For excavations less than 5 feet, a competent person must decide if there is a potential for cave-in, and either slope, shield, or shore the trench walls if the potential for a cave-in exists.

ADOT's Standard Specifications require the Resident Engineer to review the sloping, shoring, or shielding the Contractor proposes to use for trenches 5 feet or deeper. For trench sloping, the Resident Engineer should verify that the Contractor has identified the soil correctly and selected the appropriate slope rate. If the Contractor proposes to use a trench shield, then all the Resident Engineer needs to do is ensure that the shield has been certified by a Professional Engineer for the type of soils expected in the trench. When the Contractor elects to shore the trench, the Resident Engineer should check that the Contractor's proposed shoring method meets the requirements of OSHA.

When excavations are greater than 20 feet, a Professional Engineer must design, sign, and seal the method of stabilizing the trench walls (sloping, shielding, or shoring). ADOT's Geotechnical Operations Section or Bridge Design Section can assist in reviewing these designs. The Project Designers will have staff who can perform this type of review.

Adequate ventilation, and the monitoring of oxygen and methane gasses are the primary considerations for working in confined spaces. Usually, air monitors are placed in the pipe that measure oxygen levels and the amounts of methane and other explosive gasses. In many cases, certain types of gasses are heavier than air. Therefore, the oxygen levels in deep, narrow trenches should also be measured to ensure adequate ventilation. Manhole covers are usually removed upstream and downstream of the workers. Forced air is required when natural drafts through the pipeline are inadequate. See Section 1926.800 of OSHA Subpart S for more details.

All areas of the trench, which will contain one or more persons, must be inspected by a “competent” person (as defined by OSHA) prior to entry. If the Inspector is unsure about the safety of a particular section of trench, have the Contractor’s “competent” person inspect it. The Inspector shall escalate to the Engineer any unresolved concerns about the Contractor’s trenching and confined space safety procedures. ADOT’s Safety and Health Office is available upon request to assist with consulting any trench and confined space issues.

501-3.01 Preparation of Foundations, Trenches, and Embankments

The Inspector who is overseeing the pipe installation should review Subsections 203-5 & 10 of the Standard Specifications since both are applicable to pipe. City of Phoenix projects will have additional requirements in the Special Provisions.

Reinforced concrete pipes (RCP) are installed in either a trench or non-trench condition. The pipe summary sheet in the Project Plans will specify where pipes can be installed in a trench condition. A trench condition exists only when the Contractor limits the width of the trench to the dimensions shown in Standard Drawing C-13.15. When a trench condition is specified, the proper width must not be exceeded, or adequate side support will not be obtained. All other cases are considered a non-trench condition. Most pipes are installed in a non-trench condition.

If groundwater is encountered during excavation, the Contractor has several options to control groundwater. They include tight sheathing, trench drains, pumping, or a well point system. The selection of a dewatering system is up to the Contractor. However, the Resident Engineer should realize that dewatering might lead to greater trench instability. Lowering the water table may cause ground subsidence in the surrounding area affecting nearby structures and pavements. The Resident Engineer should ensure the Contractor takes precautions in accordance with OSHA requirements, and any additional Federal, State, and Local laws, if either of these situations is likely to occur.

Standard Drawing C-13.15 shows a minimum of 1 foot of material over the top of the pipe. The 1 foot of cover is to be increased when construction traffic will pass over the pipe. It is the Contractor's responsibility to protect the pipe during construction by placing additional material for a temporary construction ramp. The amount of extra cover depends on the weight of the vehicles, the types of vehicles, the type of material, the speed of the vehicles, and other factors under the Contractor's control. The Inspector or Resident Engineer should not establish the amount of cover, since it is the Contractor's responsibility to protect the work (see Subsection 105.04, 105.13 and 105.14).

The Inspector should pay attention to the trench widths obtained during excavation. The Standard Specifications have minimum widths allowed to the Contractor for pipe installed in a non-trench condition. Sufficient width is needed to allow bedding material to be easily placed and compacted around the pipe haunches. On the other hand, pipe installed in a trench condition limits how wide a trench can be so that the walls of the trench can be used to help support the pipe. In this case, a flowable fill is used to backfill around the pipe haunches.

It is important for the Inspector to examine and approve the pipe subgrade before any bedding material is placed. A firm subgrade free of any soft or unstable material is needed to adequately transfer the loads placed on the pipe. Soft yielding subgrades cause excessive shifting or settlement of the pipe. A rocky subgrade is just as undesirable as this would result in concentrating the loads at the very bottom of the pipe. This point loading of the pipe would cause cracking along the invert or crown, much like squashing an egg between two fingers.

When pipes are placed in embankments, it is important to have the embankment built before or at the same time the bedding is placed for the pipe. This will provide confinement for the bedding during compaction and result in a much more stable base for the pipe. Do not permit the Contractor to place the

bedding and pipe first then build the embankment around them. See Standard Drawing C-13.15 for further details.

501-3.03 Installation

After the bedding has been placed, graded, and compacted, the Inspector should spot check the profile and alignment of the trench for a uniform grade with no dips or high spots, and a pipe alignment free of any unnecessary bends. The Inspector should be free to use an ADOT survey crew if needed, although the Inspector should be skilled in using the Contractor's references and offset stakes as a check.

Suitable equipment must be provided for handling and lowering the sections of pipe. Unless otherwise permitted by the Resident Engineer, all pipes shall be laid upgrade. This helps seat each pipe joint since the mating force is applied in a downhill direction. It also helps prevent the joints from pulling apart from accidental movements of the pipe as the installation continues. It is important to ensure that the bell or groove (female) end of the pipe points upstream to reduce the chance of leakage through the pipe joints. The Inspector should review the Standard Specifications, read the Special Provisions, and obtain the manufacturer's recommendations on the procedures for joining pipes. This should include the recommended equipment and materials. Standard Specifications for CMP coupling bands are extensive and important. Leaky joints are a common problem with storm drains and culvert pipes. It is important for the Inspector to closely monitor jointing procedures. On occasion, Inspectors have had the pipe manufacturer's representative visit the site to clarify installation procedures.

Watertight and Water Resistant Joints

Before mortaring any joints, each joint should be washed clean with a wet brush. Immediately prior to placing the mortar, the ends shall be thoroughly wetted. Free water shall not be allowed to come in contact with the mortar until well after the initial set. (More than 1 day is recommended). The grout shall be protected from rapid moisture loss (cured), and grouting must be done far enough behind the placing operation to avoid movement of the joints. (Minimum of two pipe lengths is recommended).

When rubber gaskets are used, they shall be installed in the manner and at the time specified by the manufacturer. The Inspector should have the manufacturer's written recommendations on hand at the time of inspection.

Extending Existing Pipe

When an existing pipe is to be extended, the existing pipe end must be in such condition that the new pipe can be firmly joined. The "Pipe Extension Summary Sheet" may include removing a nominal 1 foot of existing pipe to ensure a good joint. The inspector must determine if the removal is necessary, or sufficient. If the existing pipe end is not damaged, and removal per the Pipe Summary is only 1 foot, then removal is not necessary. If the existing pipe end is damaged, then remove as much pipe as necessary to ensure a sound joint. The galvanized coating on CSP must be repaired after removal in accordance with Subsection 501-3.03(B)(1).

501-3.04 Backfilling and Compacting

Improper bedding, backfilling, and compaction of trenches are one of the major causes of roadway settlements and pavement damage.

There are three different classifications of granular materials used in pipeline construction. They are bedding, pipe backfill, and trench backfill. Standard Drawing C-13.15 illustrates the relative positions and limits of each in a typical trench.

Bedding and Flowable Fills (CDFs)

Pipe bedding starts at the bottom of the trench and ends at the pipe springline (halfway up the pipe). Two types of bedding materials are generally acceptable: an aggregate bedding material (which is similar to Class 2 AB), or a cement-treated slurry (known as controlled-density fill (CDF), controlled low-strength material (CLSM), or flowable fill). Bedding material and bedding placement must conform to the requirements of Subsection 501-3.02, as modified by the Special Provisions.

When pipes are 36" or greater in diameter, constructed in trenches, a cement-treated slurry bedding material must be used from the bottom of the pipe to the springline.

Bedding materials should be tested prior to use. However, acceptance sampling and testing is still done at the project site.

Aggregate bedding shall be tested for:

- Gradation
- PI
- pH
- Resistivity

The last two tests are important since bedding and backfill materials can promote pipe corrosion under certain conditions.

Aggregate bedding material can be compacted by either mechanical means, by jetting, or by placement as wet slurry (with no cement).

When the use of jetting is allowed on the project, the Inspector should check to see that the sides and bottom of the trench are free draining. Free draining is defined as having a coarse gradation of existing side and bottom trench material that allows water to drain through it rather than run along it. It is not acceptable to have the water flow along the bottom of the trench, since this removes fines from previously placed bedding.

Cement treated slurry bedding or flowable fill (CDF) is the same as aggregate bedding material, but a small amount of cement is added to help the material flow better. The improved flow characteristics reduce the likelihood of voids under the pipe haunches and eliminate the need for compaction or internal vibration; however, the Inspector may request the use of vibrators if the mixture is not sufficiently fluid enough to fill all the voids in the trench. A check of the slurry's slump can also be used to determine if the material is adequately flowable. Slump values for slurry bedding are shown in 501-3.02(A)(3).

CDF is required for pipe installed in the trench condition because the trench width is generally too narrow to allow proper placement and compaction by other means.

There are two major problems that can happen with CDFs. The first is with cement content. If too much cement is added, the material will be difficult, if not impossible, to excavate through in the future if the pipe ever needs to be serviced. On the other hand, too little cement does not improve the flow characteristics sufficiently to fill all the voids in the trench without some form of compaction. Inspectors should closely monitor CDFs for both flowability and cement content. Do not allow the Contractor to add more or less than the amount of cement specified in Subsection 501-3.02(A)(3). It is better to err on the side of having too little cement, and requiring the Contractor to vibrate rather than creating an impenetrable tomb for the pipe.

The second problem with CDFs can occur with their density. The flowability characteristics of the slurry make it behave more like a liquid than a granular material. The denser this liquid, the more buoyant force it exerts on the pipe. When these materials have been used as trench backfill, there have been cases, especially with plastic pipes, where buoyant forces have caused the pipe to float in the backfill. When the

Contractor intends to use a CDF as backfill, the Contractor should consider the buoyant forces expected on the pipe. When the buoyant force is greater than the weight of the pipe, then floating may become a problem, and the pipe may need to be anchored prior to backfilling. This is especially the case when using CDFs with flexible pipes CMPs and CHDPEPP.

Regardless of the type of bedding material used, it is imperative that the material under the pipe haunches is properly compacted and free of voids. Most structural failures of pipe have been attributed to poor consolidation and compaction of the bedding material under and around the pipe.

Pipe and Trench Backfill

After the pipe has been laid, and before pipe backfill is placed, the remaining bedding material is to be placed up to the pipe springline and compacted. The Inspector (and Contractor's Quality Control Representative where applicable) should make visual spot checks and perform density tests on the completed bedding material. Once the Inspector has approved the bedding, then the Contractor may proceed with the pipe backfill. Pipe backfill has similar material requirements to structure backfill, and are used interchangeably when pH and resistivity requirements are met. The material shall be sampled and tested for gradation, pH, resistivity, and PI. As an alternative, the Contractor may use pipe bedding materials as pipe backfill. Pipe backfill does provide additional rigidity and load carrying capabilities to flexible pipes such as CMPs and CHDPEPPs. The Inspector should be as careful as how pipe backfill is sampled, placed, compacted, and tested, as with pipe bedding.

Trench backfill is typically the native material removed from the trench. However, the Contractor is free to use pipe bedding or backfill materials as trench backfill. Sometimes the Contractor will elect to do this when these materials can be placed more quickly and more efficiently.

Heavy vibratory equipment should not be allowed to operate directly over the pipe until there is a least 3 feet of cover. Excessive vibration can cause the pipe to crack and shift in the bedding, thus, opening up the joints. Pipe or trench backfill should not be placed on top of any flowable fill until it has at least 24 hours to cure and develop some cohesiveness.

When a pipe is placed under a roadway or other structure, the Inspector must carefully monitor the backfill operation to ensure that the material is both placed in proper lifts and adequately compacted. There have been many pavement failures over pipe trenches. Strict enforcement of the backfill and compaction specifications is necessary on the Inspector's part.

Slope plating material is required around all pipe culvert inlets and outlets according to Standard Drawing C-13.10. This includes pipe with end sections. Slope plating material is not required when:

- Headwalls are installed
- Some other type of protection is specified (such as dumped rip-rap)
- The slopes will be plated with 2 feet of topsoil

The plating material must meet the material requirements of 501-3.04(A)(3). It is important that this material is both cohesive enough and compacted well enough to keep water from moving around the pipe and into the pipe backfill. The end sections are provided for scour and erosion protection.

Pipe should be inspected during and after any earthwork operation, or any heavy hauling over the pipe to detect any distortion or cracking of the pipe. Contractors must provide adequate cover over all pipes to avoid damage from heavy loads during construction. Section 105.14 provides guidance on enforcement of load restrictions.

The Inspector should perform a final inspection on the pipe checking for:

- Debris or obstructions
- Cracks exceeding specified widths and/or depths

- Properly sealed joints (especially around manholes)
- Pipe invert free of sags or high points
- Pipe ends or stubs properly plugged
- Connections and hookups properly made
- Catch basins, inlets, and drains connected properly
- Manhole frame and covers properly installed
- Patching and crack repairs completed

501-3.07 Non-Reinforced Cast-In-Place Concrete Pipe (NRCI PCP)

(A) General Requirements

Only Contractors or Subcontractors with previous experience in cast-in-place pipe should be allowed to use this option over other allowable pipe options such as RCP or CMP. If the Resident Engineer doubts the ability of the Contractor to perform the work adequately, then request the Contractor to submit a list of the proposed equipment and personnel including their experience on similar projects. The Resident Engineer is encouraged to visit these past projects and talk to the agency personnel. The intent is to get an idea of the level of skill and the quality of the workmanship to expect with this Contractor. Any decision not to allow the Contractor to use the proposed cast-in-place pipe crew or equipment should be discussed first with the District Engineer.

The Contractor will be required to have a Quality Control Administrator who will oversee the Contractor's quality control (QC) efforts and complete the "NRCI PCP Daily Observation Report" (see blank forms for this chapter). The Resident Engineer shall verify the qualifications of the proposed Quality Control Administrator.

Shoring plans are also required for NRI PCP if personnel are expected to enter trenches deeper than 5 feet. Although the operation might not be designed for this, the Engineer should be aware that personnel do enter the trench for such things as anchoring the deadman, cleaning the trench bottom of sloughed material, pulling the forms, and digging out the joint collar.

Inspectors should oversee the Quality Control Administrator's completion of the "Daily Observations Report". Ensure the Administrator is there to witness or perform the various quality control activities shown on the form. The Administrator should turn in a copy of the form the following day. The completed original form should be turned in after that section of pipe has been cored and accepted.

(B) Excavation

In the construction of cast-in-place pipe, the walls and bottom of the trench serve as forms and permanent bedding. The trench must be in stable soil that will retain its slope during the casting operation. When excessive sloughing occurs, the trench is filled with pipe backfill, compacted, and re-excavated to the exact pipe slope. The pipe must be cast against solid ground. For safety reasons, the length of an open trench should be limited to 1,600 feet. However, to prevent excessive drying and sloughing of the subgrade material, it is recommended that the amount of open trench be kept to a minimum.

If unsuitable material is encountered, it must be removed and replaced with pipe backfill compacted in lifts to 95% of the maximum density. The newly compacted material will then be excavated in the same way as the original material.

The trench is dug with a round bottom bucket having the same dimensions as the outside diameter of the pipe. Bucket teeth need to be sharp to cut a trench to the proper shape and grade. Over excavation will require extra concrete; which will result in uncompensated expenses for the Contractor. If the Contractor inadvertently over-excavates, only approved pipe backfill shall be used to refill the trench.

A trench that is too narrow or shallow may cause the casting machine to wedge in or to decrease wall thickness. Thin-walled areas may result in added expense to the Contractor for removing concrete, reshaping the trench, and recasting the removed pipe.

Smooth trench alignment, both horizontal and vertical, is needed to maintain the minimum wall thickness and a uniform flowline. The Contractor shall use laser guided alignment instruments to control line and grade. The inspector should measure (via straightedge, smart level, survey level, ADOT Survey, etc.) variation in grade, alignment, and degree of pipe support at 10 feet intervals to verify conformance with the Standard Specifications.

(C) Concrete Placement

The casting machine fits the shape of the trench. A winch with its cable attached to some fixed object propels the casting machine.

It is intended that the casting machine will have been specifically designed for constructing cast-in-place concrete pipe. The equipment must be acceptable to the Engineer. As a part of the proof-of-performance, the Contractor can be required to furnish certified load tests and hydrostatic test data.

The casting machine must be designed to continuously maintain minimum wall thickness and to distribute, tamp, vibrate, or consolidate the concrete resulting in concrete free of rock pockets and well bonded to the trench walls.

The Inspector should watch for sloughed material in the trench bottom caused by unstable materials and workers and equipment beside the trench. If the machine does not push this loose material ahead of it, the Contractor must clean it out ahead of the machine.

Two types of casting machines are usually used. One uses an inflatable tube ("balloon") form inside the pipe, and the other connects thin metal forms along the top 270 degrees of the pipe's interior as the pipe casting work progresses.

The balloon form is a heavy inflatable bag approximately 600 feet long made of canvas-like material. Normally, there is no need for hand finishing when using the balloon. The outside top portion of the pipe is finished smooth and free of rock pockets and cracks. The air pressure in the balloon must be monitored and kept uniform so that the form will stay firmly in place until the concrete attains initial set. After the concrete has set, the form is deflated and moved ahead for the next run.

The extruded method uses steel forms 4 feet long and shaped to the curvature of the inside of the pipe. The sections are installed manually by a worker "feeding" the sections into the machine and hooking them onto the previously placed section. A brace is then set to support the forms until the concrete sets, usually in 2 to 6 hours. After the concrete has its initial set, the forms are dropped, removed, cleaned, and reset. Workers finish the bottom inside and the top outside surfaces of the pipe during the pour.

It is important for the Inspector to ensure that the sides of the trench are kept moist during casting. This will help to prevent dry shrinkage cracking, which is a common problem with cast-in-place pipe.

When balloon forms are used, it is impossible to see if concrete is being adequately placed around the pipe invert. One way to check is by tracking the yield of the placed concrete. The Contractor should estimate in advance how many cubic meters of concrete will be placed for every linear meter of pipe. The actual quantities of concrete placed should be compared to the estimated quantities. The Inspector should spot check the Contractor's calculations. Any underrun in yield (actual quantities less than estimated) should be a cause for concern.

Whenever the placing operation is stopped long enough that the concrete will set, a construction joint must be made as described in the Standard Specifications. The Inspector will make the determination of when the concrete has set, to the extent that a construction joint is needed. This joint will be of the rebar dowel

or collar type. Before approving the pipe operation, the Engineer should come to an understanding with the Contractor as to when joints will be made. The Inspector should insist that the Contractor has the tools and materials at the site necessary for making unplanned construction joints.

When reinforcing dowels are required, they must be placed while the concrete is still plastic. With the stiff mix used for this operation, the Inspector should be aware that the bars would not be fully surrounded by concrete unless the Contractor applies some means of tamping or vibration.

When the Contractor resumes work at the construction joint, the Inspector should carefully inspect the condition of the joint and have it cleaned or trimmed, as may be necessary. The Standard Specifications call for standard construction joint cleaning. The collar around the joint must bear on firm ground and shaped to the full dimensions called for in the Standard Specifications. Note that the Standard Specifications call for a "collar" and not a "cap." The difference in labor and time is significant, and the Inspector must enforce this requirement.

Construction joints and joints for manholes, risers, and pipe junctions are constructed differently. The Engineer and Inspectors must have a detailed submittal for this operation. The submittal will include dimensions, rebar, time lapses, and curing.

(D) Finishing

With the "balloon" form, only the outside top section needs to be finished. When using steel forms, the inside bottom section and the outside top are finished. The finisher should use the laser to obtain a smooth flowing invert free of depressions that would hold standing water.

(E) Curing

Curing should be applied within 15 minutes following concrete placement. The top of the pipe is sprayed with curing compound, or in hot weather, covered with a polyethylene film and covered entirely with up to 6 inches of loose, moist dirt. Many of the pipe casting machines are equipped with fixtures for dispensing polyethylene film. In addition to keeping the cover dirt moist, it is important to close the ends of the pipe to keep a high humidity condition inside the pipe during the 7 day curing period. The Contractor should close the ends of the pipe in a manner that prevents air drafts through the pipe that would cause rapid drying. However, manholes and other openings should be left uncovered to dissipate any build-up of heat. Ventilation has to be provided when work is being done inside the pipe. The length of time that the pipe is left open shall be kept to a minimum. Standing water trapped in the pipe invert can also be used when excessive drying or heat build-up is anticipated.

(F) Backfilling

Backfilling may be done after the concrete attains 2500 psi, which may take about 48 hours. The usual procedure in these cases is to fabricate "field cured" cylinders for breaking before allowing backfilling.

Native material may be used, if acceptable, for backfill. Layer placing and compaction is the same as is required for the other types of pipe. Care is needed to keep heavy loads away from the pipe during backfilling. Also, excessive water should not be allowed to saturate the backfill.

(G) Pipe Repair

Patching rock pockets and voids should be done as soon as possible with an approved patching material. Typically, a non-shrink grout is used that will not pop out once the pipe is in service. ADOT's Material Testing Section can be helpful in approving patching materials. It is not unusual to have to patch honeycombs and rough areas between form sections. Occasionally, the Contractor will run into a wet portion of a load and the concrete will not set up as well as anticipated. If possible, an Inspector should be present during any form-pulling operation to look for top areas that drop when the support is lost. Patching

should be used as a means to remediate isolated imperfections and not as a repair method to correct improperly constructed CIPCP.

An important part of the quality control for CIPCP is the check for cracking inside the pipe. This should be done after all other repairs are completed and the pipe will no longer be subjected to any more loads from the Contractor's heavy equipment. This inspection is usually done near the end of the project or when a partial acceptance is requested. The Standard Specifications set down detailed criteria on what cracks are acceptable. Generally, regardless of the length of a crack, when it fails to meet the depth and width specifications at any location, the entire section of pipe between the nearest transverse cracks is rejected. Transverse cracks 0.05 inches or more in width will be filled with an elastomeric sealant, however there are three conditions noted in the Standard Specifications to reject pipe having longitudinal cracks. The Resident Engineer, after consulting with ADOT Materials Section and the District Engineer, may allow the rejected pipe to remain in place. The contractor in such a case will be required to epoxy inject the full depth at his expense. Generally, when a deficiency is discovered, it is the contractor's responsibility to propose to the Resident Engineer the repair method, and materials to be used, or remove the pipe. The Resident Engineer will either approve or reject the proposal.

(H) Pipe Wall Thickness

The contractor has complete responsibility for quality checks to ensure adequate wall thickness is achieved. These checks will be determined at the pipe invert and crown at a minimum of 25-foot intervals, and recorded on the Daily Observation Report (see blank forms for chapter V). Since there is no tolerance provided in the Standard Specifications, the contractor needs to target above the minimum wall thickness to ensure variations during the casting operation will not cause thin areas, possible rejection, and removal.

ADOT has the responsibility for the acceptance of pipe wall thickness through a process of marking hole locations to be drilled by the contractor. Holes should be marked at the invert and springline, plus other locations if directed by the Resident Engineer. The contractor will drill the holes a minimum diameter of $\frac{3}{4}$ -inch. The inspector will use a gauge or measuring tape to determine the pipe wall thickness. If less than the minimum thickness is measured, then 3-inch diameter, or larger, cores will be taken adjacent to the drilled hole and isolated per the Standard Specifications. Repair procedure for drill or core holes shall be as approved by the Engineer.

Jack and Bore

Pipe Installation

Jack and bore is a form of trenchless pipe construction that requires the contractor to tunnel/bore underneath an existing roadway/railway/structure/etc., which cannot be closed or otherwise disturbed, in order to install storm drain or utility pipes. As a broad synopsis, a contractor will either use an auger-boring machine or manpower to tunnel underground, excavating and removing earthen material, and then insert/"push" a casing pipe, using a hydraulic-powered jacking system, to support the surrounding soil. After the casing pipe has been fully inserted, a carrier pipe will typically be inserted inside of the casing for use as the storm drain pipe or utility conduit.

Preconstruction Considerations

Jack and bore is an atypical form of construction that requires additional design considerations to be taken. ADOT Geotechnical Services should be consulted in the design and specification development for the work, and the ADOT Geotechnical Project Development Manual outlines additional requirements for subsurface exploration.

Factors to be mindful of when designing for jack and bore include:

- Percentage of rock cobbles that may be encountered

- Cohesiveness of the soil to be bored through

While these factors and design considerations will need to be addressed prior to construction beginning on the project, the Inspection team should be aware of said considerations and should take care in monitoring the soil being removed from the boring operation. A change in soil type may require the contractor to amend their means and methods so as to keep either loose soil from collapsing into the bore hole or the line and grade of the pipe from being thrown off due to the presence of large rocks.

Contractors performing this type of work are expected to provide a work résumé of previous projects within which they performed work of this nature. The Special Provisions should have experience requirements for both the company and key personnel on the crew.

On projects in which the casing pipe (most often made of steel) will also act as the carrier pipe, further considerations will need to be taken regarding the design of the jack and bore. This includes whether more stringent steel properties/cathodic protection/pipe coating will need to be specified. Additionally, as with all pipe construction, maintenance access will need to be considered and addressed. Careful consideration needs to be given to this access, for it follows that, if the pipe run was difficult to initially install (requiring jack and bore), it would be just as difficult, if not more so, to reinstall.

Pre-Activity Meeting

Prior to the work commencing, a pre-activity meeting should be held with the Department's Inspection team, prime contractor personnel, and subcontractor personnel. If the work is for a utility or other third-party, a representative should be present at the meeting as well. At the meeting, an overview of the activity and sequence of work should take place.

Topics to cover include:

- Pipe jacking and tunnel boring method and equipment
- Pipe profile and alignment quality control and verification
- Safety considerations
- Staging locations and site access
- Use of lower-tier subcontractors to perform the work
- Contingency plans if conditions change
- Contractor's working hours and schedule

An example of a pre-activity meeting agenda can be found in the "Forms" section of this chapter.

Safety Precautions and Considerations

As with other types of trenchless pipe construction, the work area for jack and bore may be within some pretty tight quarters. Due to this, many of the jacking/receiving pits, let alone the pipe tunnel, will be considered a "confined space," thereby introducing a myriad of safety requirements in performing and inspecting the work. In spite of the safety requirements, some of which may keep the Inspection team from performing their duties hands-on, the contractor needs to be reminded that the Inspection team shall have either have access to, or have information furnished of, the work activity as it progresses, per Section 105.12 of the Standard Specifications.

Depending on the size and depth of the jacking and receiving pits, shoring may be required. In instances when engineered shoring is required, the contractor will need to submit their shoring design for the Department's review prior to installation. Once cleared for use, as with any shoring plan, a copy should be provided to the Inspection team for their use and record.

Construction Procedure

As stated previously in this section, jack and bore is a form of trenchless pipe construction that requires the contractor to tunnel/bore underneath an existing roadway/railway/structure/etc. The tunneling operation is typically performed using an auger-boring machine. In rare instances, when the soil conditions are either non-cohesive or contains higher amounts of rock cobbles, the contractor may elect to perform the work via hand-tunneling, which entails having contractor personnel hand-excavate the soil inside the casing pipe. Whether excavation is performed via auger or hand-excavation, neither method should advance outside the end of the casing pipe, so as to help protect any personnel in the pipe and help minimize the risk of soil collapsing during the tunneling operation.

As the excavation advances along the pipe's line and grade, the contractor will then push/jack the casing pipe into the soil, providing the support for the surrounding soil. This jacking operation will continue until the pipe run is completed and the casing pipe outlets into the receiving pit. During the jacking process, care should be taken so as to not create excessive voids outside of the casing. Unless described in the Special Provisions, the contractor should be tasked with how voids outside of the casing will be both minimized and repaired. In many instances, this is completed by pressure-grouting outside of the casing, through pre-drilled grout ports at the top of the casing, once the casing's installation is complete.

After the casing has been installed, if specified, the carrier pipe will be installed. The carrier pipe is typically installed by being slid in on rails installed inside the casing pipe. Care should be taken to not damage the carrier pipe during installation. After installation is completed, the space between the outside of the carrier pipe and inside of the casing pipe, otherwise known as the "annular space," will be filled with pea gravel.

Once the jack and bore operation has been completed, including the collection and furnishing of the surveyed pipe profile and video inspection record, the jacking and receiving pits are to be backfilled per the project specifications.