

Chapter 8-Construction and Fabrication .....	<a href="#">1</a>
Construction Specifications for Field Joints and bands .....	<a href="#">4</a>
Proposed Specifications for Coupling Bands .....	<a href="#">5</a>
Bedding and backfilling of Culverts with Weirs or baffles .....	<a href="#">7</a>
Concreting under Haunches .....	<a href="#">7</a>
Piping around or under Culvert .....	<a href="#">9</a>
Excavation into solid rock and reducing boulders .....	<a href="#">10</a>
Removal and Wasting of Unsatisfactory Excavation .....	<a href="#">10</a>
Weak or Soft Base under Culvert .....	<a href="#">11</a>
De-watering of construction site .....	<a href="#">13</a>

# Chapter 8-Construction and Fabrication

## Pipe-Arch Joint Connection System

Pipe-arches are fabricated by first constructing a circular pipe then deforming it to form the pipe-arch shape. Because of manufacturing limitations, the pipes are deformed in relatively short sections (less than 30 feet). Ideally, the sections will match each other, but in practice this seldom happens. Culverts are constructed with allowable tolerances that often leave gaps between sections. We have worked around these gaps filling them with concrete, caulking, and manhole sealer. Joining pipes would often take hours and lead to numerous contract concerns over quality of products. An alternative connection system for pipe-arches was developed and is presented below. The connection system includes an interior coupling flange that is used to bolt the sections together. 24" wide flat band couplers are used in combination with the bolted and gasketed flange connection. Arches installed with this system are easily assembled and meet the watertightness required for fish passage.

The connection system uses metal coupling plates welded to the two ends of the pipe sections. The plates are gasketed and bolted together to form a watertight connection between the two end sections. A construction detail of the joint connection is included in the drawings at the end of this chapter. The system includes the following elements.

1. The pipe-arches are first fabricated with baffles and/or weirs (when required) welded in the pipe sections.
2. The pipe sections are aligned and trimmed. The pipe section lengths are determined by the manufacture from the construction drawings, considering the weir or baffle spacing.
3. A minimum 4 inch wide, 10 gage galvanized flange plate is welded to the ends of the pipe.
4. The ends of the pipes are then factory aligned and clamped together. Circular holes are cut into the pipe by plasma cutting or drilling to ensure correct fit of the bolts. One-half inch diameter bolts will be used to bolt the two ends together using those holes.
5. The pipes are then match-marked, and delivered with flat bands and gaskets.
6. During field assembly, a gasket is placed between the connecting flanges for water-tightness, and under the band for soil-tightness.

Connecting flange welded to outside edge of pipe.



The connecting flange is designed to come up to the top of the haunches or spring line of the arch. During final assembly, a gasket is placed between the flanges for water-tightness. The flanges do not significantly reduce the flow capacity of the pipe. A small v-notch is often cut into the center of the coupling flange after the fill is installed to facilitate fish passage.





The bolted flange connection allows the use of flat bands as shown in the photo above. The bands need to be a minimum of 24" wide.



## Construction Specifications for Field Joints and bands

The following are typical specifications and a commentary on their use with the pipe arch coupling system.

### *“3.02 INSTALLATION:*

- A. *Pipe culverts shall be placed on prepared beds starting at the downstream end with the inside circumferential laps (if any) pointing downstream and with longitudinal laps at the side or quarter points. Coupling bands meeting manufacturers’ specifications shall be installed so as to provide the circumferential and longitudinal strength necessary to preserve the pipe alignment, prevent separation of pipe sections, and minimize infiltration of fill material.”*

A Spiral pipe has no circumferential or longitudinal laps. The above is an outdated specification intended for annular riveted pipes, which are seldom seen.

Flat bands are acceptable with this specification if the site does not require a “special “joint. A special joint is required in AASHTO for adverse requirements such as the need to withstand soil movements, resist disjoining forces and for unusual conditions as in poor foundation conditions. Under “ special joint” design conditions the design engineer should document his approval of this baffled flange connection.

### *603.06 joining pipes*

*Pipes shall be firmly joined by form fitting coupling bands. End sections shall be attached to pipe by connecting bands or other measure as recommended by the manufacturer. Gaskets shall be installed at each joint to form a watertight connection when SHOWN ON THE DRAWINGS. Dimpled bands shall not be used when the slope of the pipe is greater than 15%.*

*The Coupling bands shall meet the strength requirements of field joints for Non-Erodable Soil Conditions–Special Joint Type according to Division II, Section 23 of the Standard Specification for Highway Bridges by AASHTO.*

This specification implies the use of annular or spiral bands. These should not be used on 3 x1 pipe-arches for a variety of reasons. Manufacturing problems, resulting from re-corrugating the pipe ends and arching, cause the re-corrugations to diverge, and the integrated band couplers do not seat properly or provide reliable mechanical engagement. These integrated bands should not be relied upon to meet the tensile requirements for Special Joint types in AASHTO.

The specification above references an AASHTO specification that has divided joint properties into six categories. The Special Joint category differs significantly from a Standard Joint Category. See table below from AASHTO. The AASHTO specifications include a commentary on how to apply this table and the applicability of Standard or Special Construction joints. When special

joints are required, the design engineer should design bolting or welding details, for field attaching the band coupler to the pipe that will satisfy the **special joint** requirements. With the approval of the design engineer, the bolted or welded connection can be used. Pipes on steep gradient of 15% or more, as noted above, should have a separate analysis for pullout forces on the joints. A special backfill requirement may be required for steep slope pipe joint connections.

Category of Pipe Joints taken from Table 26.4 of AASHTO

	Standard Joint in non-erodable soils	Special Joint in non-erodable soils
Shear: as a percent of the calculated shear strength of the pipe on a transverse cross section remote from the joint.	2%	5%
Moment: as a percent of the calculated moment capacity of the pipe on a transverse cross section remote from the joint.	5% or meet minimum joint requirement noted below.	15%
Tensile 0- 42"	0	5000 lbs
Tensile 48" - 84"	-	10000 lbs
Joint overlap	10-1/2"	N/A

### Proposed Specifications for Coupling Bands

1. Coupling bands shall be either one, two, or three piece construction and shall be of the same material as the pipe. Coupling Bands for pipes larger than 42 inches shall be of two or three piece construction.
2. Steel coupling bands shall be formed metal not more than three standard culvert gauges lighter than that of the pipe to be connected, but shall not be less than 0.052 inches or more than 0.109 inches thick unless otherwise shown ON THE DRAWINGS. Coupling Bands for corrugated aluminum pipes may also be up to three gauges lighter than the pipe, but not less than .060 inches thick.
3. The minimum width of the coupling bands for pipe ends shall be AS SHOWN ON THE DRAWINGS.
4. The installed distance between pipe ends shall be no greater than 1-1/2 inches and the maximum difference in diameter between the pipe ends to be joined shall be 1/2 inch for pipe sizes 48 inches or less, and one-percent (or less) of the diameter for larger pipe sizes.

5. When required by the Plans or the Specifications, watertight joints shall be provided by the use of approved sealant or gasket material. These materials shall be neoprene expanded rubber or sheet rubber gaskets, "O" ring rubber gaskets, butyl rubber, base joint sealant, or other approved materials. Sheet rubber gaskets shall be at least 7 inches wide and 3/8 inches thick and shall conform to the requirements of ASTM D 1056 with Grades 41 to 43 inclusive, unless otherwise specified. "O" ring shall conform to ASTM C 443 and shall not be used on helical corrugations.

6. To prevent galvanic action when unlike metals are connected, the connecting band shall be coated with asphalt or other insulating material as approved by the engineer. Galvanized and Aluminized Type 2 steel are not considered to be "unlike" materials

## Bedding and backfilling of Culverts with Weirs or baffles

Construction of weirs or baffles into pipes affects the bedding and backfill of the pipes. With three-dimensional structures as baffles or weirs, the structure becomes semi-rigid. Good quality backfill materials and methods are essential to prevent deflection and possibly tearing of the welds. If the pipe is improperly installed, the welds may tear along the edge of the welded baffles.

The traditional method for culvert installation details specified adding **camber** in the grade under high fills to balance settlement. Camber **is not** recommended for culverts installed with weirs or baffles. In lieu of camber, the foundation of the culvert must be constructed with sufficient strength to prevent deflection.

Assuming the foundation of the pipe is placed on firm material the foundation needs to be totally compacted to at least 95% of T99 prior to placing the bedding materials. Grades are set with a laser level to achieve tolerances of +/- .02 feet.

## Placement of a flowable fill under the Haunches of Pipe-Arches

Concreting under Haunches

Pressure in the haunches of pipe-arches is particularly high because of the small radius of curvature of the conduit at those locations. The backfill at those points must meet design specifications for density or the pipe may deform. This concern is of particular importance if the pipe arch sections have structures welded in them such as weirs or baffles. Deformation of the pipe from settlement may cause the welds to break.

When installing welded plates, baffles, or weirs in pipe, I have typically specified that pipe-arches be backfilled with a “flowable fill” such as concrete slurry. The flowable fill should extend to the haunch level of the pipe. The slurry is typically a low strength, high slump concrete. Details and specifications are attached. The contractor is able to place the pipe and install the flow- able fill in a single day. The following day he can continue backfilling operations. The result is a high quality bedding for the pipe with only a minor increase in cost to the whole project. The simplicity of installation and savings in time for compaction of the pipe is often less expensive than trying to backfill and compact the culvert using conventional methods and granular backfill.

I recommend this procedure in lieu of manually compacting material around and under the haunches.

**Caution: If slurry is placed too quickly, the pipe can float or rise. This is a major concern, and the contractor must be aware of that possibility. Contractor should be required to place the slurry in thin lifts, such that the pipe does not float.**

## Inlet and Outlet Protection of Culverts

Large culverts are typically installed with riprap at the inlet to prevent scour and erosion of the back-slopes. The riprap is placed on a 1-1/2:1 slope and normally not grouted or concreted. Pipes are also step beveled at the inlet to improve their efficiency to handle debris flow during high events. Anchors are often added to secure the pipe arch when using concrete headwalls or grouted riprap. A typical anchor involves attaching the cut ends of the pipe to the head walls or ring beams with ¾-inch bolts spaced at about 18 inches O.C. (Ref 1, page 325). A more elaborate collar is detailed for large span structures and arches. Anchoring can be as simple as placing bolts into grouted riprap or as complex as constructing a concrete slope collar that ties the end walls to the foundation. The selection of the anchor type is a judgment of the design engineer. In making that selection, the engineer will consider the span of the pipe, potential debris load to the inlet, headwater to depth ratio, and stream dynamics at the site.

Grouting riprap with anchors is recommended for the following conditions:

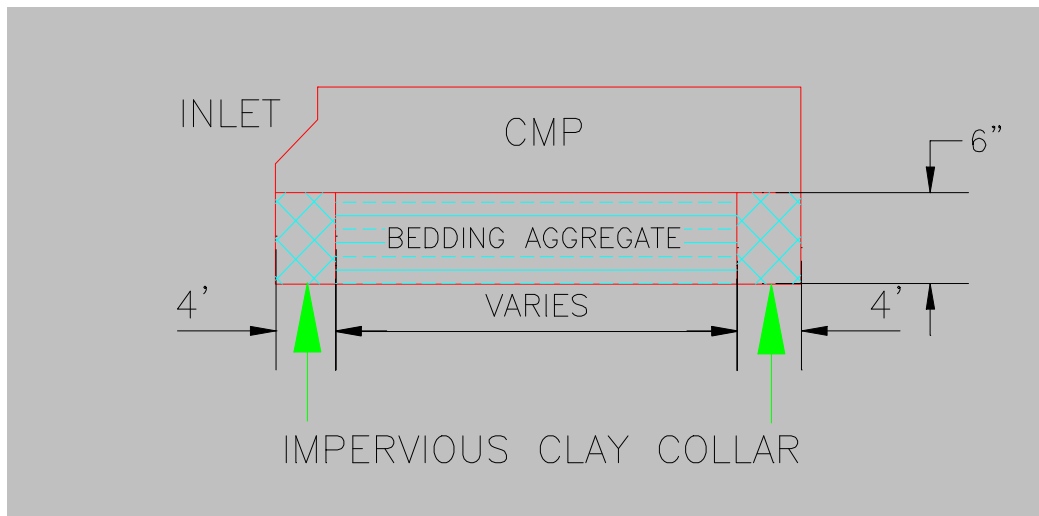
1. Use a collar or anchor when there is a potential for debris plugging the entrance to the culvert. A pipe-arch or arch is not the recommended structure for streams with high debris loads. Arch structures are easily damaged if the fills wash out and water flows directly over the pipes. An acceptable compromise is to place grouted riprap along the entire slope of the inlet and outlet. During high flows, debris will rise up on the slope and potentially even onto the road. These sites are often constructed with a paved roadway.
2. The steel drainage handbook gives limits for beveled or skewed pipes beyond which a collar or anchored structure is required. Figure 4.22 in the handbook compares spans to skews and the need for an anchored sidewall. Table 4.7 in the handbook does the same for gage, corrugation type, and span. Always anchor the pipe when the skew exceeds 15 degrees or the bevel exceeds 2:1.

Gage of Pipe	2-x ½ Corrugations	3 x 1, 5 x 1, Corrugations	6x2 Corrugations
12	60	96	156
10	66	108	168
8	72	114	180

## Piping around or under Culvert

Culverts are typically placed on a 6-inch thick layer of bedding aggregate. A four lineal foot thick impervious clay collar is often placed at the inlet and outlet of the culvert to prevent piping. The clay collar may be omitted at the outlet at the discretion of the engineer. The goal is to prevent water from piping under the pipe from the inlet. See typical detail at the end of this report. If a spring or subsurface water flow is found in the excavation, add a French drain under the pipe below the base rock. Sub-excavating and installing a free draining layer below the pipe will also allow the ground water to move under the pipe without eroding the bedding material.

Pipes placed on steep grades must be bedded with an aggregate bedding to prevent scour of the bedding material. My personal preference is not to install culverts with a grade over a 5% without select granular borrow for backfill.



Drawings to an exaggerated scale

## **Excavation into solid rock and reducing boulders**

Pipes for stream simulation are designed to be bedded on a crushed rock base. If large rocks or bedrock is found in the excavation limits, it must be removed. Blasting or impact tools are typically required. Culverts for stream simulation and fish passage are designed with selected control points at the inlet and outlet changing the grade because of rock is not an acceptable solution. As a minimum the contractor should be advised to have a contingency plan for removal of rock if found in the excavation.

Contractually, many agencies define all material as “unclassified”. Any boulder reduction or blasting is then up to the contractor without a pay increase or modification. If materials are undefined or classified into types such as “common” or “rock”, removing the rock is then a contract change unless a separate pay item is included for that work. “Ordered work” outside the “neat lines” of the project is considered a change. Review these concerns at the pre-work conference to avoid confusion during the construction process.

## **Removal and Wasting of Unsatisfactory Excavation**

Locate all waste sites prior to advertising the contract. Include contingencies at the waste areas for erosion protection to include silt fences, or hay bales, mulching, etc. If temporary waste sites are requested on the site they need to have the same review as permanent ones and should be clearly defined.

## Weak or Soft Base under Culvert

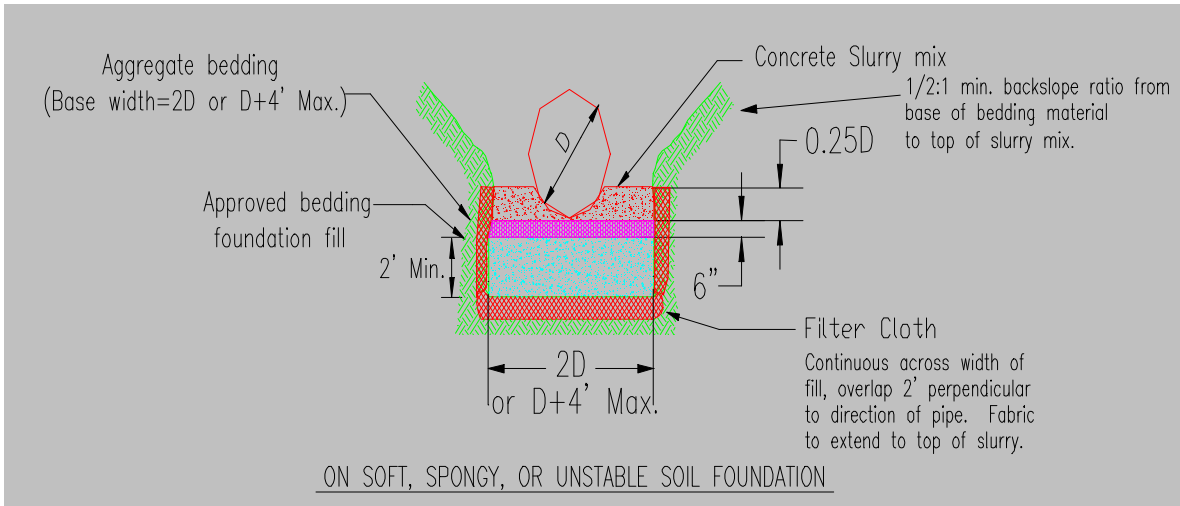
The accepted solution for a weak or soft base is to sub-excavate the site, place drainage fabric around the hole, and than backfill with free draining angular rock. That solution has been modified slightly to take advantage of higher strength fabrics now on the market. Revised typical details are included for installing culverts on weak and very weak soils. The details incorporate a high-strength fabric, two or three feet of free draining rock, and additional width of excavation.

The proposed fabric is a high-strength, woven drain fabric. Along the bottom it prevents the rock from sinking into the soft material and provides tensile reinforcement. Along the sidewalls the fabric allows water to drain into the free draining rock below in addition to providing additional anchoring to the fabric along the bottom. The fabric is overlapped a minimum of two feet and extends along the sidewalls to at least the level of the haunches.

The sub-base rock is specified as a free draining angular riprap. The goal is to have a rock that will act both as a French drain and as a high strength base that will distribute the fill to the full width of the trench. The width of the trench is increased three feet the same as the depth of the sub-base rock. The desired phi angle for this rock is 45 degrees or better. See Leslie Crossing Project for details and photos.

### CONSIDERATIONS

1. The fabric specified is a heavy drainage fabric not readily available. The contractor or contracting agency must have the fabric on hand at the site prior to any work beginning. Consider having a roll of heavy drain fabric available as a government furnished item.
2. Identify the source of the base rock early in the contract. Pay for the rock separately as an optional item when “directed in writing”.
3. The foundations of major pipes are approved by the contracting agency prior to placing the pipe. Coordinate with contractors to insure engineers are available at crucial times.
4. The additional excavation below the pipe is a changed site condition unless a pay item and method of measurement is defined in the contract for that work. A convenient procedure is to define the sub-excavation limits in terms of “neat lines”. Payment for the additional excavation will then be limited to work only inside those “neat lines” without affecting the other excavation at the site. A pay item for sub-excavation is then included in the contract when “ordered by the engineer” in writing.



## De-watering of construction site

De-watering of sites historically was left to the contractor with general guidelines on sedimentation limits. An emphasis on water quality now requires that construction sites have a plan for diverting water. This is often a minor issue on coastal streams where the flow is very small during the construction periods. A typical de-watering plan should include the following:

1. A settlement pond upstream of the inlet, outside the construction area.
2. A pipe from that pond through the project, or around it diverting the water from the site.
3. The outlet pipe will be in a pool or placed so as to not erode soil into the stream.
4. For large streams a pump is often installed in the pond. These ponds are often lined with a plastic liner. Construct the pond with clay or impermeable material to prevent leakage. A small amount of bentonite, well mixed with the natural soil, will often prevent leakage. The pond is normally constructed from materials in the channel. Removal can be accomplished by breaching the dike at the end of the project. This results in a short-term increase in turbidity and movement of rocks into the culvert structure

Local and state regulations often have permit requirements for Dewatering sites. The designer needs to review those regulations. See photo below of a pump basin used for dewatering a construction site.

