# Chapter 4 - Drainage

## *2-400 General*

This chapter covers the construction and reconstruction of culverts, catch basins and drop inlets, manholes, underdrains, and ditches and channels. The chapter includes more design material than most of the chapters in the *Manual* because of the responsibility of project personnel to identify where plans need to be modified to improve drainage.

Water causes or contributes to most highway failures. In addition, damage to private or public property can be caused by a drainage structure that is not the right size or is not installed at the right location or elevation. Ideally, potential problems with a project's drainage system should be resolved during design. Unfortunately, actual drainage conditions often are not discovered until after construction starts. The Department must rely on the Chief Inspector and other project personnel to recognize potential drainage problems and request reviews of the design when necessary.

After design problems are resolved, drainage systems should be installed carefully and accurately so that the intentions of the design are realized in the finished construction.

## *2-401 Purpose*

Drainage installations can function in three ways:

- to convey the free flow of natural water courses through highway property,
- to collect surface runoff to prevent flooding and the erosion of the shoulders or slopes, and
- to control subsurface flow to maintain the stability of the roadway.

A highway drainage system accommodates surface runoff, free ground water, or both. Removing surface runoff is relatively simple if compared with removing free ground water that flows or percolates through the pores in soil, holes created by decayed matter, insects, worms, and frost action. The porosity of soil controls the rate of underground channeling, if the slope is sufficient and the flow is not hemmed in by rock or impervious soils.

The subbase is meant to carry away ground water, but it sometimes brings in unwanted water to the subgrade instead, usually in cuts. If the water is not controlled, it removes the fine-grain components of the subbase gravel and causes a loss of the bearing power of the pavement. “Pumping” occurs at the joints and cracks of concrete pavement, caused when the flexing of the pavement under heavy wheel loads results in the movement of the free water. If the lateral movement of the water is restricted by curb footings on impervious material, the flow carries the water and fine grains through the joints, creating voids under the pavement. The loss of support and continuing heavy loads combine to crack the pavement and further the cycle of deterioration.

Capillary flow occurs in fine-grained soils; the force of gravity is overcome, and water can move in any direction. This flow is normal, and the resulting moisture can act as a binder for the soil particles. However, the moisture can become a lubricant if it is in the form of free water. In silt or clay, water can rise about 9 ft. (3 m) and about 18 in. (450 mm) above free-water level in sand. The amount of capillary water held in the soil depends on the characteristics of the soil, the supply of free water that replenishes the capillary water, and the extent of evaporation.

Frost heaves and boils are the result of the formation of ice crystals from the water supplied by capillary action. When water freezes, it increases approximately 9 percent in volume. The resulting expansion force is about 30,000 lbs. (133 kN) or 15 tons/sq. in. (207 000 kPa). With the first frost, the ice crystals fill the voids near the surface. Capillary water continues to feed the ice crystals, layer on layer, building up pressure until the surface ruptures or the slab is heaved. In the spring, the upper layers of ice thaw during the first warm spell. The thawed areas, when surrounded by frozen ground, develop into water traps that promote softening of the roadbed.

The depth, gradation and proper compaction of the subbase all tend to reduce capillary movement, improve the supporting qualities, and decrease the depth of frost penetration, but the subbase must also be drained to hold capillary action to a minimum. Surface and subsurface drainage installations are used to control free water movement through the subbase.

### *2-402 Outlets*

The status of drainage outlets, the right to discharge water into private property, and the Department's related obligations for maintenance are below.

### *2-403 Natural Water Course*

A natural water course is a channel within highway limits that is available for the discharge of runoff within a definite drainage area, conforming to the original ground contours. A diversion of runoff from another area by the constructed drainage system requires additional rights from the downstream owner. The State is responsible for the free flow of all streams through highway property but does not assume any obligation for the maintenance or improvement of streams on private property. Construction activities are often the source of claims by adjoining owners due to erosion of the channels or sedimentation of ponds. The Inspector should remain aware of the possibility of a claim both prior to and during construction.

### *2-404 Drainage Right-of-Way*

A drainage right-of-way is a deeded easement for the installation and future maintenance of a pipe or ditch through private property, to provide a more suitable outlet. It is preferably located adjacent to the boundary line as a lease encumbrance to the property and varies in width from 10 to 20 ft. (3 to 6 m), depending on the size of the installation. The landowner retains the limited use of the easement area; however, any improvements, such as piping the ditch or extending the outlet, are at the landowner's expense and subject to Department permit requirements.

### *2-405 Right-to-Drain*

A right-to-drain is a deeded right to discharge runoff over land into adjoining property at a specific location. It generally is limited to open land. Future improvements are at the owner's expense.

### *2-406 Adverse Rights*

This type of outlet is not considered in new construction; however, it is the most common cross-culvert installation in rural areas. By statute, the State acquires a right-to-drain after 15 years of continuous use. The problem to property owners has been recognized, and the Department normally cooperates to the extent of installing a maximum of 200 ft. (60 m) of pipe furnished by the owner. The Department installs the structure and maintains the system in exchange for a definite drainage right-of-way.

### *2-407 Agreements*

Outlets into existing town systems are by agreement covering construction and maintenance.

On completion of a project, the Department receives requests for outlets into its systems by private owners, developers or towns. Connections for cellar drains, roof leaders, etc., are allowed subject to a drainage agreement and permit requirements. The discharge of contaminated water from septic tanks or commercial processing is not permitted. Outlets for town improvements or developments also are allowed, assuming that the highway drainage system is adequate and Department rights are not jeopardized. Because circumstances vary, all requests for connections should be referred to the District Drainage Engineer for investigation.

### *2-408 Runoff Design*

State highway drainage systems are typically designed for a 25 year frequency storm, which is the magnitude of one storm expected or experienced every 25 years. Systems at underpasses, depressed roadways, and culverts enclosing natural watercourses are at a 50 year frequency.

Highway and urban land area runoff is computed by the rational formula:

$$Q = \frac{A\ I\ R}{360}\ (Q = A\ I\ R)$$

Q = quantity of water in cubic feet (cubic meters) per second

A = drainage area in acres (hectares)

I = percentage of imperviousness of the area, from 0.2 to 0.9

R = maximum average rate of rainfall over the entire drainage area in inches (millimeters) per hour that may occur over the design frequency

Rural land area drainage is computed by the Izzard method. The factors of design are somewhat similar to the rational formula but are for larger areas and use charts adapted for Connecticut conditions.

## *2-409 Trench Excavation*

### *2-409A General*

Trench excavation is covered in Article 2.05 of the *Standard Specifications*. There are several pay items for trench excavation, differentiated by the depth of the excavation and whether rock is excavated. Regardless, pay items cover the removal and disposal of material and excavation and backfilling for the following.

- Constructing pipe culverts, endwalls, catch basins, drop inlets, manholes, underdrains and outlets, sewers and service pipes.
- Removing drainage structures and appurtenances beyond the limits of roadway and structure excavation.
- Removing miscellaneous items, such as abandoned underground tanks, pipelines, etc.

Trench excavation is paid for in accordance with the *Standard Specifications* or special provisions. The Inspector should become knowledgeable in the current OSHA standards regarding trenching and advise the contractor to meet the standards, with copies of the advisements sent to the District.

It is not always possible to judge subsurface drainage requirements accurately when a preliminary subsurface investigation is made. During excavation operations, the Chief Inspector must notify the Project Engineer immediately on encountering any wet condition that is not provided for in the design. The Project Engineer must arrange to have proper drainage features installed with as little delay as practicable.

### *2-409B Rock Excavation*

If ledge rock is encountered in trench excavation, the Chief Inspector must measure and record the amount to be removed. Extreme care should be used in recording the quantity of rock in the trench to state whether or not the quantity is to be deducted from the quantity of trench excavation of the applicable depth. Failure to make such notation may result in either overpayment or underpayment of the items involved.

### *2-409C Backfilling*

Material used to backfill a drainage structure must be suitable for the purpose intended. Varved clay, rock, clay-silts, loam or organic soils are not acceptable backfill materials. Any material used for backfill should be compactable, have minimum void contents, be free of large stones, and provide for uniform load distribution and adequate structural support.

The material should be placed in layers of not more than 6 in. (150 mm) after compaction. Mechanical rammers, mechanical vibrators or pneumatic tampers should be used. Hand tampers can be used only with written permission of the Engineer. Consolidation by puddling or jetting should not be allowed because it produces an unstable and unevenly compacted condition.

## *2-410 Foundations*

In general, the life of a drainage unit can be cut short by water seepage, rock breakage, water traps, and damage from uneven settlement or foundation bearing. Paved ditches, paved channels, catch basins, drop inlets and manholes located in rock-cut areas require special consideration of the need for granular cushion material. Information about foundations for specific types of drainage structures is included in the remainder of the chapter.

## *2-411 Culverts*

The most commonly used drainage structure is the culvert, which either passes water from one side of the highway to the other, or (in connection with catch basins) carries highway runoff to a satisfactory place of disposal. The water must be confined to the culverts to prevent erosion and instability of the roadbed.

Article 6.51 of the *Standard Specifications* covers the installation of new and the re-laying of existing culverts. Article 6.52 covers both reinforced concrete and metal culvert ends. Article 5.06 includes endwalls. Bedding material is a separate item under Article 6.51.

## *2-412 Types of Culverts*

### *2-412A Corrugated Metal Pipe*

Corrugated metal culverts are sometimes called "flexible" pipe structures. The strength of a metal pipe depends on its size, shape, gage, bedding and backfill. The steel sheets or plates used in the pipe are corrugated to provide high flexural strength. Most metal pipe used for highway purposes is coated with a tough, semi resilient, waterproof bituminous material. Invert areas are paved with durable bituminous material. A typical invert covers about 25 percent of the interior circumference of a pipe. It is paved to protect the flow line from abrasion and to improve the flow characteristics of the pipe. See Figure 2-4.1.

A corrugated metal pipe or pipe arch is manufactured from corrugated sections that are riveted together along the longitudinal and circumferential seams. Generally, the sections are riveted together in multiples of 24 in. (600 mm), but pipe is available in lengths that are not multiples of 24 in. (600 mm). Manufactured lengths seldom exceed 20 ft. (6 m) because of handling and transportation restrictions.

### *2-412B Plate Pipes and Arches*

Structural plate pipe, plate-pipe arches and plate arches are usually field assembled from precurved, corrugated metal plates.

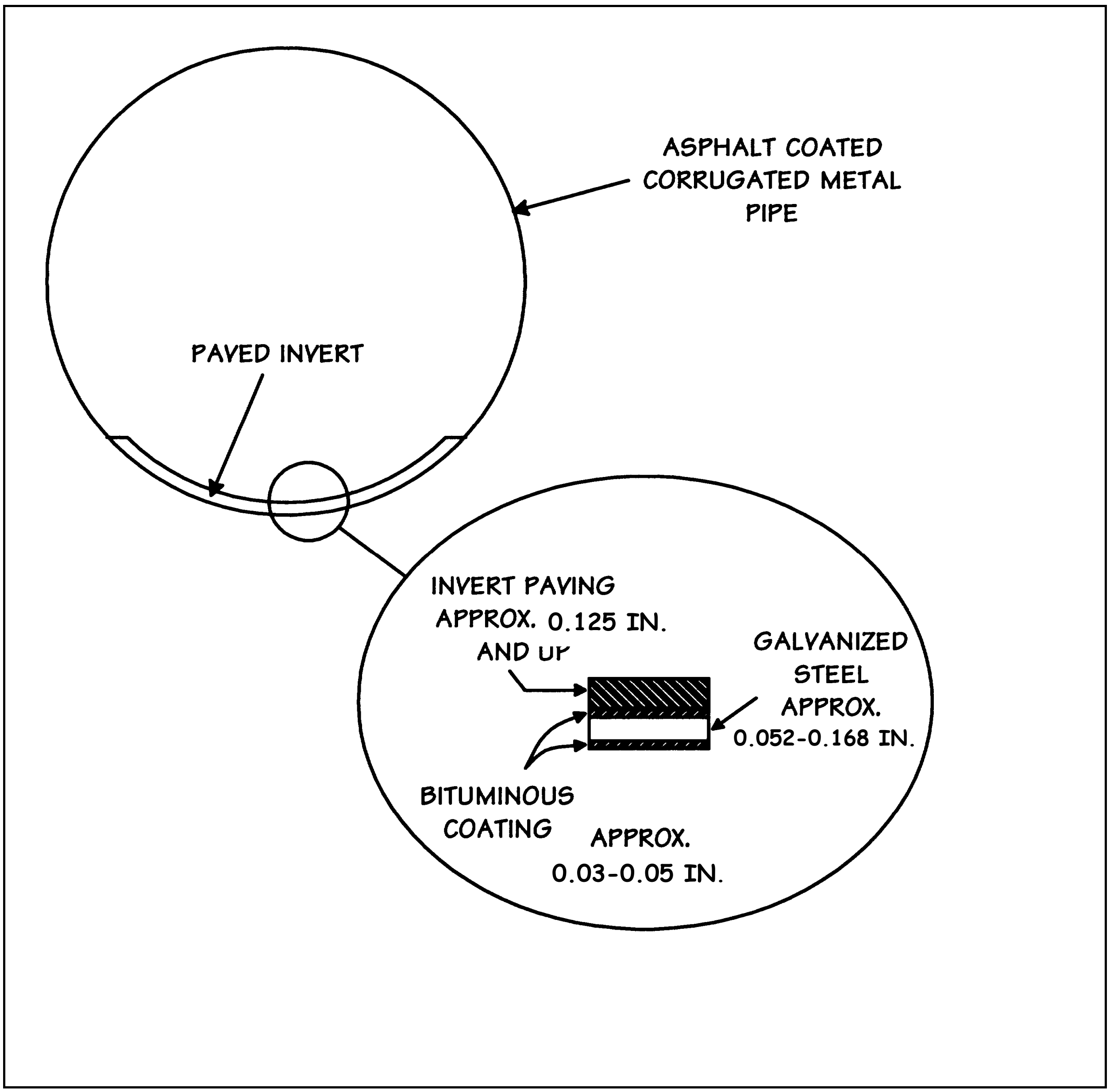
### *2-412C Concrete Pipe*

Concrete pipes are commercially produced up to a diameter of 108 in. (2 700 mm). Most of the concrete pipes used for highway purposes have diameters between 12 and 72 in. (300 and 1 800 mm). Pipes of the same size may be made of concrete that has different strengths. Strength is indicated as "pipe class." There are five classes, Class I through Class V. A higher pipe class indicates a higher strength.

Pipe in one pipe class may be manufactured with different wall thicknesses. Wall thickness is denoted as Wall A, Wall B, or Wall C. Wall A is the thinnest wall. The pipe-wall designation reflects the minimum wall thickness in inches (millimeters), the reinforcement requirement, and the minimum concrete strength (the same for each class of pipe). Circular pipe is reinforced with circular reinforcement, and elliptical pipe is reinforced with elliptical reinforcement.

Improvements and refinements in the manufacturing process and the development of high-strength, low-slump concrete

**Figure 2-4.1 Paved Invert**



mixes have enabled pipe manufacturers to produce pipe that conforms to rigid specifications.

### *2-413 Pipe Selection*

Since 1959, design standards for drainage have been revised with a general increase in pipe sizing to provide for more extreme conditions. The design for each drainage area considers the slope, ground cover, soil, and future development that may affect runoff characteristics. Pipes are sized by the Manning formula, with special attention to outlet conditions and critical slopes.

### *2-413A General Guidelines*

A designer is guided in the selection of the type of pipe (metal or concrete) and the cross section to use by the following considerations.

- *General.* Reinforced concrete pipe is used if water is not corrosive, cover is adequate, and the height of fill is limited. Asphalt-coated corrugated metal pipe (ACCMP) or pipe arches are used if clearances are limited, in high fills, for grades over 10 percent, and where uneven ground support is expected.
- *Depth of Fill.* For fills in excess of 25 to 30 ft. (7.5 to 9 m), ACCMP usually is used. Reinforced concrete pipe is used if the height of fill is not over 25 ft. (7.5 m) or not over 20 ft. (6 m) for pipe 36 in. (900 mm) or larger.
- *Flow-Line Gradient.* ACCMP usually is used if the flow-line grades are in excess of 10 percent. Corrugated metal pipe frequently is used as slope pipe to connect roadbed drainage units to drainage outlets. Corrugated-metal pipe elbows usually are installed in the run of slope pipe along the toe of a slope to provide for flow-line gradient adjustment, additional cover over the pipe, and an improved outlet or endwall connection to the end of the slope pipe.
- *Hydrology Criteria.* To satisfy flow requirements and installation restrictions, pipes having arch-shaped sections may need to be used instead of round pipe.

The gage or wall thickness of culverts varies with the size of the structure and the height of fill over the installation. Availability also plays a role in pipe selection.

### *2-413B Available Metal Pipe*

Most of the metal pipe culverts used in Connecticut are of the following types and sizes.

- *Asphalt-Coated Corrugated Metal Pipe*. 12 in. to 72 in. (300 to 1800 mm) diameter, gage variable.
- *ACCMP Arch*. 17 × 13 in. (450 × 340 mm) to 71 × 47 in. (1 800 × 1 190 mm) size, gage variable.
- *Corrugated Structural Plate Pipe*. Size and gage are variable.
- *Corrugated Structural Plate Arch*. Size and gage are variable.
- *Corrugated Structural Plate-Pipe Arch*. Size and gage are variable.

### *2-413C Concrete Pipe Strength*

The strength or class of concrete pipe required for a location depends on the pipe's size, height of the fill, foundation conditions, depth and width of trench, bedding, and backfill. Generally, reinforced concrete pipe must conform to

AASHTO M170. Class IV, Wall B meets strength requirements for pipe from 12 in. (300 mm) diameter through 72 in. (1 800 mm) diameter. Class IV, Wall C meets strength requirements from 78 in. (1 950 mm) through 84 in. (2 100 mm) diameter. If the culvert is installed by jacking, extra strength pipe or pipe of a higher class usually is used.

### *2-413D Loading*

General principles for the loads carried by pipes are below.

- For conditions that produce a maximum load on the pipe, the weight of the fill is carried partly by the pipe and partly by friction against the sides of the trench.
- The width of the trench at the top of the pipe has a definite effect on the load to be carried by the pipe. The load is greater for wide trenches than for narrow trenches if the width is kept constant. Sloping the side of the trench has little effect on the load on the pipe.
- The load on a pipe due to the weight of the fill increases with the depth, but at a diminishing rate. After the depth of the fill is approximately ten times the width of the trench at the top of the pipe, there is practically no increase in the load for greater depths of fill.
- The maximum load due to the fill on the pipe usually occurs at the first thorough flooding of the trench fill after construction. The general effect of a lapse of time after the backfill has been compacted is to decrease the load on the pipe.

### *2-414 Materials Inspection*

Culvert materials are tested and inspected by personnel from the Department's Materials Testing Laboratory and are inspected by project personnel.

### *2-414A Corrugated Metal Pipe*

Laboratory personnel perform a general field inspection of the pipe when it is delivered to the job site and collect samples for testing. For ACCM pipes and arches, the inspection and tests check that the following items meet specifications:

- the variation between actual inside dimensions and nominal dimensions,
- the variation between the dimensions of abutting pipe ends,
- the type and thickness of the metal,
- the types of seams,
- the spacing of rivets and the distances from the rivets to the edge of the metal,
- the thickness of the asphalt coating, and
- the width and thickness of the paved invert.

Coupling bands are checked for dimensions and the presence of asphalt coating (no minimum thickness is specified). Pipe elbows are checked for the same items as pipes and arches and for the width of the coupling bands. Culvert ends are checked for the presence of asphalt or tar-based coating and for the configuration of the attachment system.

Project inspection personnel should inspect the material for damage that affects the pipe shape or dimensions, for bent ends that affect coupling, and for damage to the asphalt coating. The inspections should be conducted when the material is delivered to the job site, when it is transported to the installation site, and after it has been installed.

### *2-414B Concrete Pipe*

The Laboratory inspects and approves the materials and the construction methods employed when the pipe is manufactured. Samples of the cured pipe are inspected for surface defects and size variations and are tested by the three-edge bearing test for quality and strength and by the absorption test. Precast materials delivered to the site must be accompanied by a PC-1 Form that verifies Laboratory approval. An example form is shown in Figure 2-4.2.

All pipe used on a project must be inspected and approved by the Laboratory. Laboratory personnel place a stencil on all approved pipe. As with ACCMP, project personnel should inspect the pipe when it is delivered to the job site, when it is transported to the installation site, and after it has been installed. Some inspection guidelines are as follows.

- Each section of pipe should be clearly marked with the pipe class, date of manufacture, and name or trademark of the manufacturer. Note: The stenciled date should match the date given on the PC-1 Form.
- Pipe must have no fractures or cracks passing through the shell, except for a single end crack that does not exceed the width of the joint.
- Pipe must not have any defects that indicate imperfect proportioning, mixing or molding or that indicate honeycombed or open texture.
- Pipe must have no damaged or cracked ends that would prevent making a satisfactory joint.

**Figure 2-4.2 Certification of Precast Concrete Products (Form PC-1)**

**CERTIFICATION OF PRECAST CONCRETE PRODUCTS**
**MAT-314 (PC-1)**
REV. 11/03

STATE OF CONNECTICUT
*Department of Transportation*
**Division of Materials Testing**
280 West Street , Rocky Hill CT 06067-3502

DATE OF SHIPMENT

Project Personnel: Submit with Request for Test ***AFTER*** visual inspection on project site.

*List one type of product per cast date per line*
**DISTRIBUTION**: Original to Lab, Copy to Project Engineer, Copy to be kept by Manufacturer

| MANUFACTURER | LOCATION |
|---|---|
| | |

| SHIPPED TO: (Contractor's Name) | PROJECT NO. or PURCHASE ORDER NO. |
|---|---|
| | |

| Description of Products | Cast Date | Quantity |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

Remarks

This document certifies that all the products listed above conform to all applicable Department and project specifications

| Authorized Agent of Manufacturer | |
|---|---|
| Signed: | DATE |

- Pipe must have no exposed circumferential reinforcement, which indicates misalignment of the reinforcement.
- Pipe must not have any continuous crack having a surface width of 0.01 in. (0.25 mm) or more and extending for a length of 12 in. (300 mm) or more, regardless of the position in the wall of the pipe.

Pipe may be repaired, if necessary, because of accidental injury during handling. The pipe is acceptable if the repairs are sound and properly finished and cured, and the repaired pipe conforms to the requirements of the specifications. The exposure of the ends of the longitudinal steel, stirrups, or spacers that have been used to position cages during the manufacturing process are not cause for rejection.

### *2-415 Culvert and Endwall Layout*

Except in specifically designated instances, the Inspector must have the endwalls constructed parallel to the highway tangent, or when on curves, perpendicular to the radius passing through the centerline or the culvert, with the top plane longitudinally parallel to the gradient of the road.

### *2-415A General Method*

To attain statewide uniformity, the Inspector uses the following method to verify the layout of culverts and endwalls by the contractor:

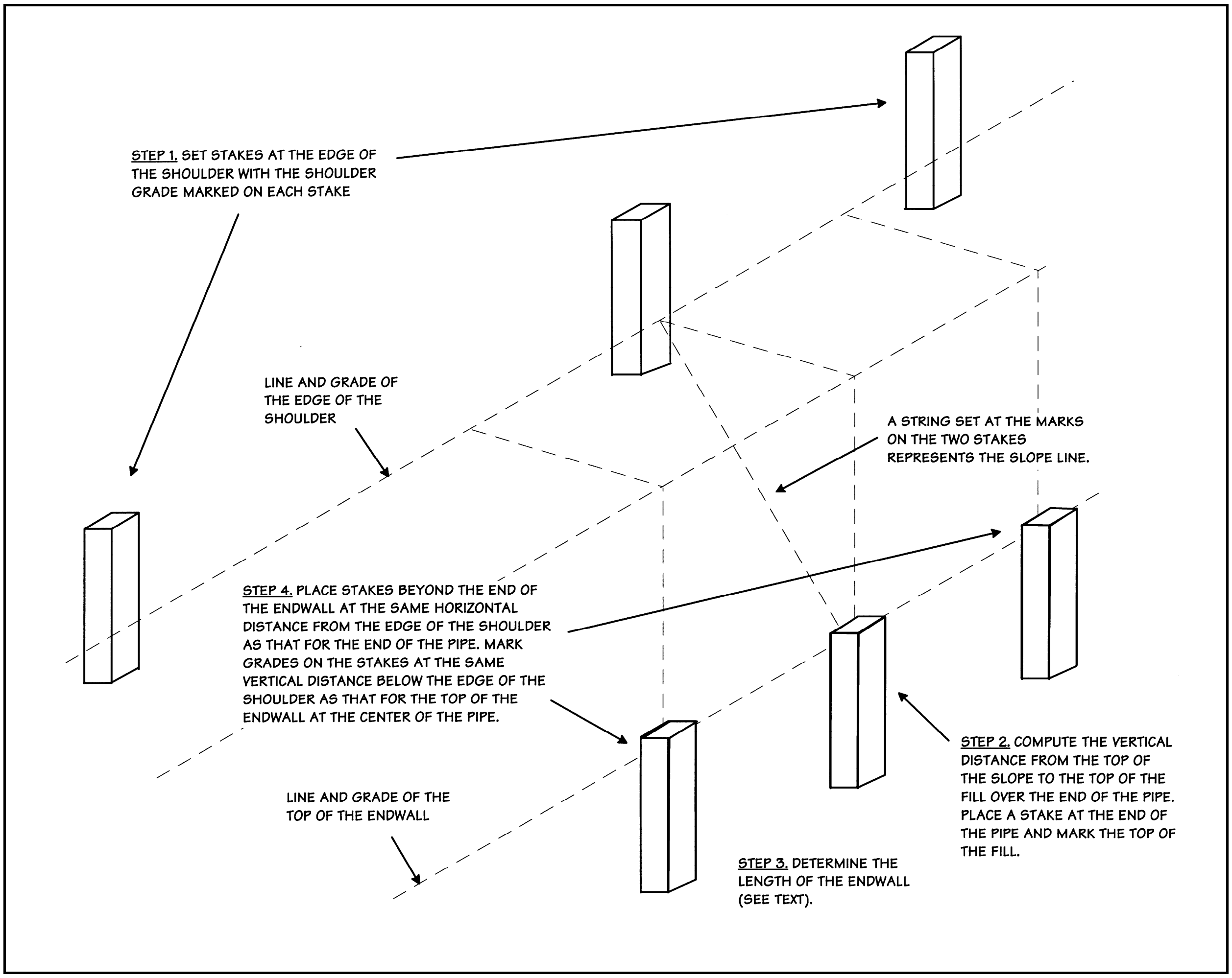
- Determine the station and distance from the centerline to both ends of the pipe.
- Determine the elevation at the edge of the shoulder, by applying the crown or superelevation for the pavement to the pavement centerline elevation.
- Compute the elevation of the embankment 12 in. (300 mm) back from the end of the pipe, using the known rate of slope. The endwall should be a minimum of 7 in. (175 mm) higher for 1.5:1, 2:1, and 4:1 slopes and 3 in. (75 mm) higher if it is at or close to the edge of the shoulder.

The endwall is staked parallel to the edge of the shoulder and on the same grade, except that at the foot of deep fills the endwall may be staked with a level grade. The ideal location for the end of the pipe is such that the embankment slope coincides with the top of the end of the pipe.

### *2-415B Field Method*

One method of verifying the layout in the field is depicted in Figure 2-4.3. Set stakes at the regular 20 m (66 ft.) station on both sides of the pipe, with the grade of the edge of the shoulder marked on the stakes. Stretch a string between the two stakes and measure the distance at right angles from the edge of the shoulder to the end of the pipe. Compute the vertical distance from the top of the slope to the top of the fill over the pipe and mark it on a stake at the end of the pipe. A string carried from the mark to the edge of the shoulder represents the finished slope line.

**Figure 2-4.3 Endwall Layout**




Check the height above the flow line of the pipe with the length of the endwall to be sure that material spilling around the ends of the endwall does not block the drainage way. The relationship between the height and length of a straight endwall is given by the equation:

$$L = 3S + D \ \ (L = 3S + D)$$

L = Length of the endwall in feet (meters)

S =Height from the flow line of the pipe to the intersection of the slope line and the face of endwall (minimum = D + 2 in. (50 mm))

D = Nominal diameter of the pipe in inches (millimeters)

Fill material that spills around the ends of an L- or U-shaped endwall forms cones. The wall must be of sufficient length to prevent spillage from blocking the inlet or outlet channel or ditch.

After the length of the endwall is determined, place stakes beyond the ends of the endwall at the same horizontal distance from the edge of the shoulder as for the end of the pipe. Mark grades on the stakes at the same vertical distance below the edge of the shoulder as was determined for the top of the endwall at the center of the pipe. This procedure will result in the endwall being parallel to the roadway in both line and grade.

### *2-416 Trench Excavation*

If a pipe is to be laid in a cut section, the bottom of the trench is graded to match the bottom of the bedding material or to afford a uniform, firm bearing for the length of the pipe. If rock is encountered, it must be excavated to at least 12 in. (300 mm) below the bottom of the pipe, and the excavation must be filled with bedding material and tamped.

If pipe is laid in a fill area, the embankment is placed and compacted to 12 in. (300 mm) above the elevation of the top of the pipe. Then the trench is excavated.

### *2-417 Foundations*

All new or relaid pipe culverts are installed in pipe bedding. Pipes with an internal diameter of less than 48 in. (1 200 mm) are installed in Type I installations, and larger pipes are installed in Type II installations.

A Type I installation consists of installing the pipe or pipe arch in bedding material with a thickness directly under the pipe of 4 in. (100 mm) and preshaped to a height of 10 percent of the total height of the pipe. After the pipe has been installed, the trench is backfilled with bedding material to a height of 25 percent of the total height of the pipe.

A Type II installation consists of installing the pipe or pipe arch in bedding material with a thickness directly under the pipe of 4 in. (100 mm) and preshaped to a height of 10 percent of the total height of the pipe. After the pipe has been installed, the trench is backfilled with bedding material to a height of 12 in. (300 mm) above the top of the pipe.

All poor foundation conditions must be corrected. If the supporting soil has nonuniform load bearing capacity (hard and soft spots), the excavation should be carried below the bedding line and granular fill used as the replacement material. Soft, unstable material in small pockets should be completely removed. Soft, unstable material encountered at the bedding level should be excavated below the designated grade, to the depth specified by the Engineer, and backfilled with granular fill. In unusually wet conditions, the Engineer may direct that crushed stone with a geotextile cover be substituted for the granular fill.

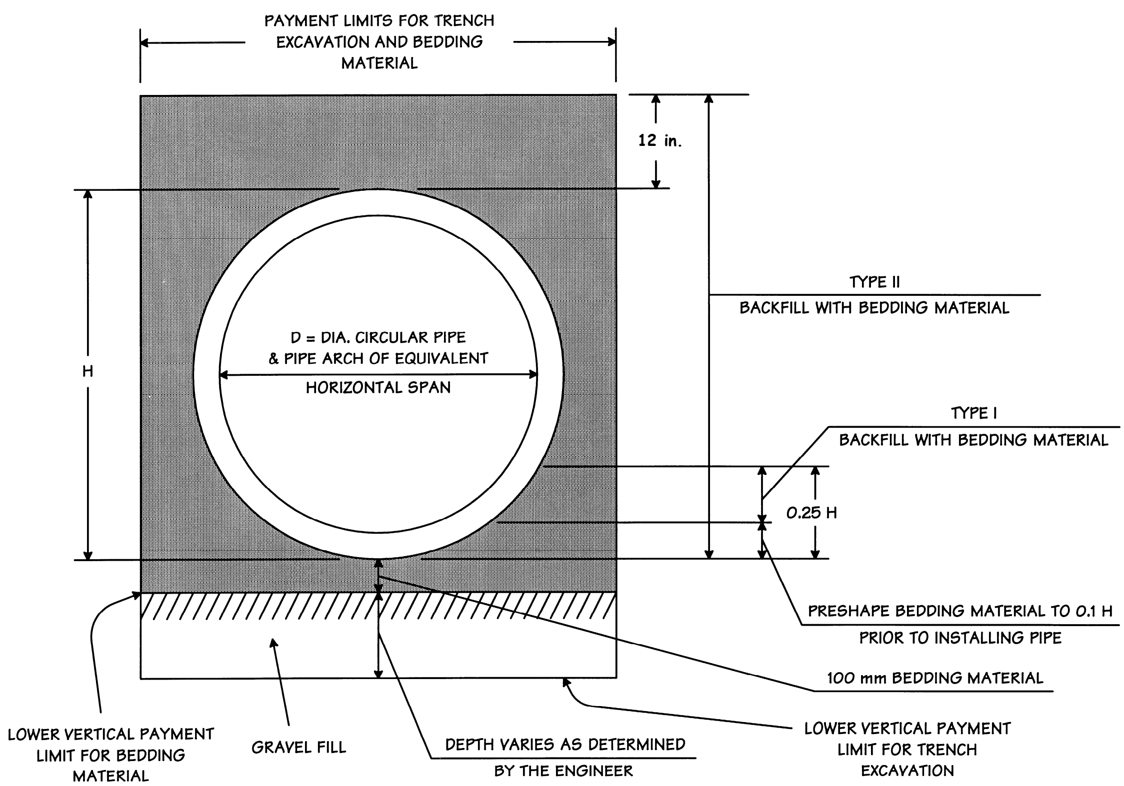
Figure 2-4.4 shows both Type I and II installations when gravel fill is used. Figure 2-4.5 shows the installations when gravel is not used.

### *2-418 Culvert Installation*

When culverts are being installed, the following recommendations should be followed.

- Check the foundation, and if the underlying material is unsuitable, remove and replace it with granular fill.
- Install a minimum of 12 in. (300 mm) of bedding material or granular fill under cross culverts where ledge is encountered. The bed for the pipe should be formed true to line and grade and fully compacted so that it is unnecessary to place additional material under the pipe after laying it.

**Figure 2-4.4 Pipe Installations with Gravel Fill**



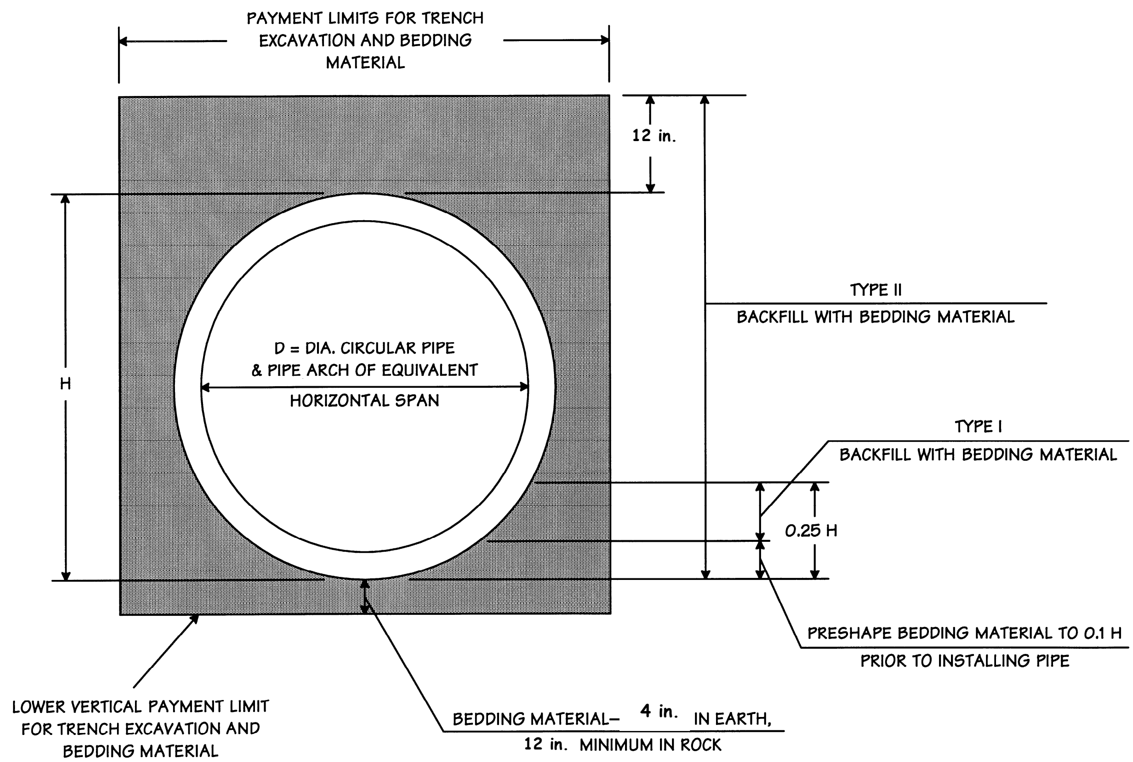

- Start laying the pipe from the outlet end of the culvert and place the pipe with the bell ends, if any, up grade.
- Place cold-applied bituminous sealer, preformed plastic gaskets or flexible watertight rubber gaskets in the invert of the bell of each concrete pipe before entering the spigot of the succeeding pipe.
- Wipe the joint on the inside of the pipe clean and smooth.
- Bring up the backfill equally on both sides of the pipe and tamp each successive 6 in. (150 mm) layer.
- Place at least 12 in. (300 mm) of cover over the pipe before allowing equipment to pass over it. The contractor is responsible for damage to culverts caused by equipment, regardless of cover.

In fills with depths of 15 ft. (4.5 m) or over, metal pipes of 48 in. (1 200 mm) or greater diameter are shored up on the inside while the embankment is being formed to prevent the weight of the fill and the impact of equipment from deflecting the pipe.

## *2-418A Corrugated Metal Pipe*

Pipe lengths are jointed on the job site with connecting bands that are made of the same steel as the pipe. All pipe should be installed with the inside laps downstream and the longitudinal laps toward a side of the trench. Bands are corrugated and should be lapped equally over adjoining ends of pipe sections. The diameter of the pipe determines the width of a band, the number of corrugations it will have, and whether it is a one-piece or two-piece unit. Satisfactory connections are easily made if the pipes are properly aligned, the band and pipe corrugations are carefully matched, the

**Figure 2-4.5 Pipe Installations without Gravel Fill**




band is tapped with a mallet after preliminary tightening of the bolts, and all bolts are tightened uniformly. One-piece bands should be placed around the diameter of the pipe with the bolts in a vertical position. Each band, in meshing with the corrugations of the pipe, separates the two sections of pipe by the width of one corrugation.

## *2-418B Plate Pipe and Arches*

Erection should be in accordance with the manufacturer's assembly instruction. Multiplate structures should be assembled with as few bolts as possible until all the plates are in place. Three or four loose bolts installed near the center of each plate along the longitudinal and circumferential seams are usually sufficient. After several complete sections have been assembled, the remaining bolts can be loosely installed, always working from the center of a plate toward the corner of the plate. Corner bolts should not be installed until all others are in place and tightened.

All bolts must be well tightened. Final tightening should be carried from one end of the structure to the other after all the plates are assembled. The operation should be repeated to ensure that all nuts are tightened evenly. Any damage to the bituminous coating on the inside or outside of the assembled unit must be repaired before the placement of the backfill material. Inverts are to be paved in accordance with the requirements of the plans and specifications for the item.

### *2-418C Concrete Pipe*

Elliptical and circular pipe should be installed such that the manufacturer's marks designating the top or bottom of the pipe are not more than 5 degrees from the vertical plane through the longitudinal axis of the pipe. Pickup holes should be sealed with mortar or precast plugs, grouted in place. Stones should not be used to plug the holes.

### *2-419 Backfilling*

Special consideration must be given to the placement and compaction of material under the bottoms of pipe arches and under the haunches of pipes. The bedding material should be in intimate contact with the bottom or haunch of the structure and extend to the undisturbed wall of the trench or to the payment width used for trench excavation, whichever is less. If culverts under embankments are constructed prior to filling operations, the embankment fill should be placed and compacted in conjunction with the structure backfill.

Material placed around pipes should be placed evenly, at approximately the same elevation on both sides of the structure. In fill areas, the embankment is placed and compacted to an elevation 12 in. (300 mm) above the top of the proposed pipe. Then the trench excavation is made and the pipe is installed. The cover over the pipe should be increased if it is anticipated that heavy hauling will traverse the pipe.

During the backfilling operation, large-diameter metal pipes usually are strutted. Corrugated metal pipe usually is strutted along the horizontal diameter with wires or steel rods and turnbuckles or along the vertical diameter with timbers, so that the pipe section is changed from circular to elliptical during installation, backfilling and completion of the embankment. Corrugated metal pipe structures deflect under load. Changing the section during installation is necessary so that allowance can be made for deflections resulting from the overlying embankment, and the pipe can return to a full round shape. The resultant changes in diameter lengths enable the pipe to compress the backfill and build up increasing side support for the structure.

Corrugated metal pipe usually is strutted at the time of manufacture in accordance with standardized elongation requirements for various fill heights and pipe sizes. When the pipe is placed on the prepared grade, check the horizontal and vertical diameter at each strut. Excessive elongation differences are adjusted before any backfill is placed. All struts should be slowly and carefully released after embankment placement and consolidation have been completed. To minimize the danger of the pipe bending at the struts, the pipe must be permitted to deflect slowly as the load is applied.

### *2-420 Drainage Structures*

### *2-420A Materials Inspection of Precast Units*

Precast units are accepted on the basis of the manufacturer's certification. The Laboratory inspects the manufacturer's facilities, fabrication procedures and materials tests, similar to its inspection for concrete pipe. However, final approval of individual precast units is the responsibility of the District. All precast units received on the construction site must be inspected by District inspection personnel. Individual units may be rejected for any of the following conditions:

- Units that do not bear proper identification, such as manufacturer's name or trademark or date of manufacture.
- Catch-basin or drop-inlet tops and sumps that are cracked, show evidence of honeycomb, or have patched areas in excess of 30 sq. in. (19 350 $mm^2$) on exposed surfaces.
- Manhole riser sections, bases and appurtenances, catch basins, or drop inlets that exhibit the following:
    - Fractures or cracks passing through the wall, except for a single end crack that does not exceed the depth of the joint.
    - Defects that indicate imperfect proportioning, mixing and molding.

- Surface defects indicating honeycomb or open texture.
- Damaged or cracked ends if the damage prevents making satisfactory joints.
- Any continuous crack having a surface width of 0.01 in. (0.25 mm) or more and extending for a length of 12 in. (300 mm) or more, regardless of the position in the section wall.

Damage to precast units resulting from accidents in handling may be repaired, if necessary, and will be accepted if the repairs are sound and properly finished and cured, and if the repaired unit conforms with the requirements of the specifications.

Each precast unit should be clearly marked by the manufacturer with the date of manufacture and the name or trademark of the manufacturer. This information, together with the DOT stencil number on the steel frames and grates for catch-basin or drop-inlet tops, is obtained by District personnel from each precast unit delivered to the project and is submitted to the Laboratory on the Request for Test form (Form MAT-100, see Figure 1-4.1), with one copy of the Certification of Precast Concrete Products (Form PC-1, see Figure 2-4.2) furnished with each shipment by the manufacturer. On receipt of the required information and Certification, the Laboratory issues a test report documenting acceptance of the precast units.

### *2-420B Culvert End Treatment*

#### *2-420B.1 Endwalls*

Endwalls are constructed of Class A concrete at the entrance and outlet of culverts to retain the slopes adjacent to the entrance and outlet, to prevent water from undercutting or bypassing the culvert, to prevent erosion, and to direct the flow of water into the culvert. The Inspector should compare the designed structures with actual field conditions to ensure that the endwalls function as intended. The Inspector should refer any condition that is in need of correction to the Project Engineer.

#### *2-420B.2 End Sections*

Current design practice requires the use of culvert ends, instead of endwalls, if feasible. Culvert ends are placed on a prepared bed of the existing ground or a bed of compacted granular fill. After the attachment of the culvert end to the culvert, backfill is placed around both sides of the unit to the prescribed surface, exercising caution to avoid displacement or deformation of the unit.

#### *2-420B.3 Endwall Improvements*

Endwalls may have to be removed or splash pads built during rehabilitation projects. The work must be performed in accordance with the plans and specifications for the project.

When an endwall is removed, a section of the pipe, back to its next joint, must also be removed. An allowance for replacing this portion of pipe may not have been included in the estimated quantities for that pipe item. If this is the case, an overrun in quantity of that size pipe may be unavoidable.

During the replacement of an endwall with a flared end section and splash pad, the Inspector may observe that the elevations of the pipe invert and the splash pad are below existing ground level. The difference in elevation is usually caused by sedimentation from storm and snow runoff in the years since the original work was done. Only the amount of excavation necessary to remove the endwall and install the flared end section and splash pad should be made. Any further excavation violates the DEP permit requirements. The Inspector should make a note of the area and forward it to DOT Maintenance for its records and possible correction.

## 2-420C Box Culverts

Small stream crossings are frequently most economically achieved by using culverts of a special design instead of a bridge structure. Inspection procedures for reinforced-concrete box culverts are the same as for bridge structures. Volume 2, Chapter Eight, "Structures," includes bridge inspection procedures. All work relating to excavation, foundation preparation, reinforcement and concrete placement, waterproofing and backfilling operations must be carefully and diligently performed in full compliance with the shop drawings and specifications. Special attention should be given to foundation preparation and settlement or camber allowance. Concrete culverts usually are constructed in sections, and it is required that all joints be clean, properly sealed, and watertight.

## 2-420D Catch Basins and Drop Inlets

### 2-420D.1 New Construction

Catch basins and drop inlets are roadway-level intercepter units constructed in shoulder or gutter areas to remove surface runoff. Basin depths vary according to the flow line elevation of the outlet pipe. The depth of sumps must be a minimum of 24 in. (600 mm). Excavation for the structures is payable as trench excavation. Catch basins and inlets are covered in Article 5.07 of the *Standard Specifications*. A typical catch basin (Type CL) is shown in Figure 2-4.6.

The base area must be carefully graded and provide for uniform foundation support. Yielding material must be removed and replaced with granular material. In rock, a tamped granular base cushion is recommended. Side walls can be built of brick, Class A concrete, cement-rubble masonry or precast concrete units. The upper 24 in. (600 mm) of all basin sidewalls are corbelled to provide a satisfactory fit for the top. Corbelling must be in accordance with the details shown on the standard drawings.

Pervious material is used as the backfill material for the upper portion of the excavation down to the invert of the outlet pipe, with a maximum depth limit of 3 ft. (1 m) below the top of the structure. Drainage openings are formed in all walls at or immediately above the bottom of the pervious backfill. The inverts of drop-inlet bases must be carefully shaped to the required cross section.

The Inspector should check the location and grade stakes of all basins before the base is constructed. Accurate stakeout is required for proper basin location. The corbelling can be altered slightly to ensure a good fit on the top. The maximum corbel allowed is 3 in. (75 mm) per course of masonry. All pipes are to be cut flush with the face of the inside wall. In sandy soils, the interior wall faces shall be damp-proofed from the floor to the elevation of the outlet flow line.

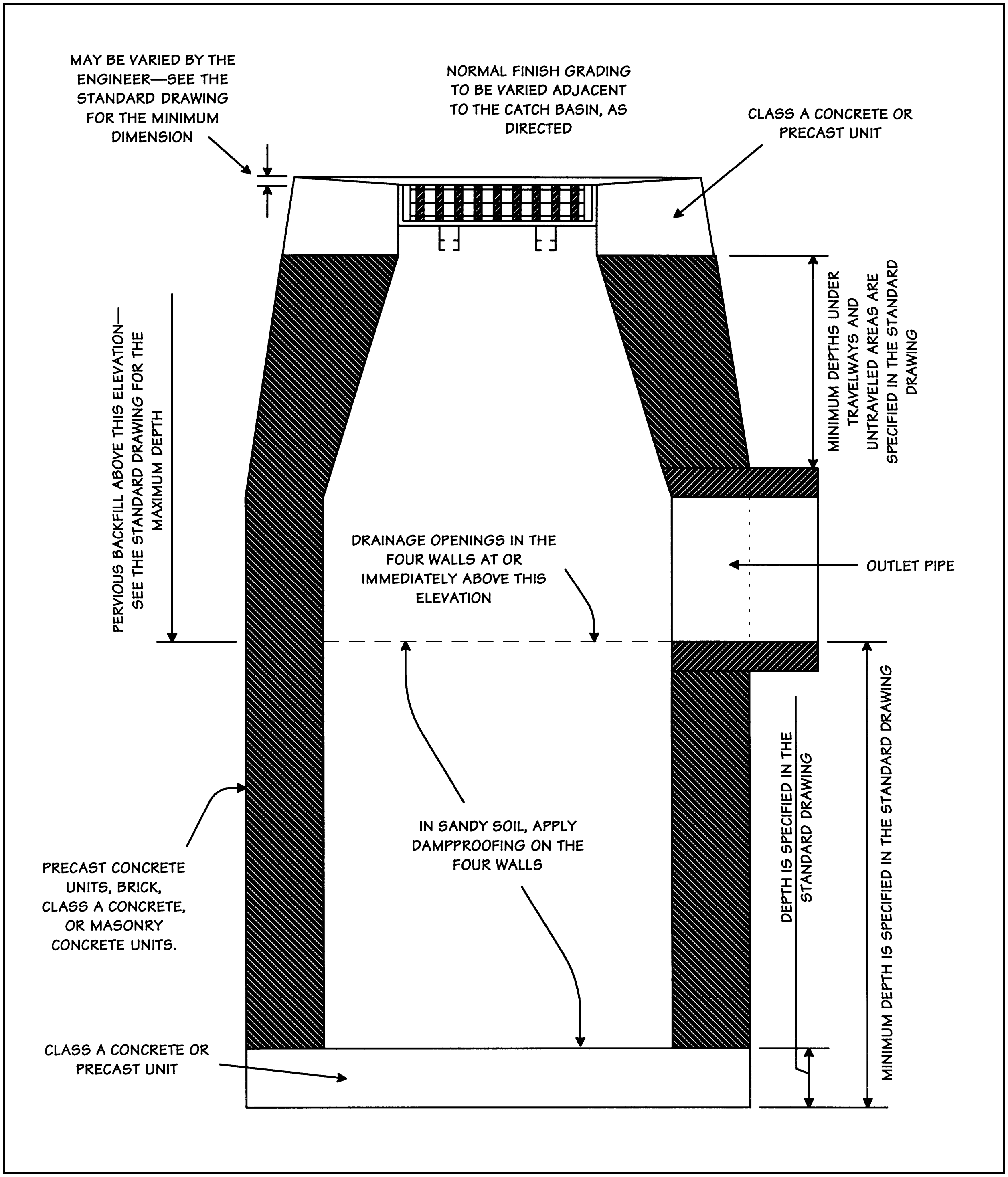
Top units may be precast or cast in place. Cast-in-place top units shall be given a 0.04 gal./sq. yd. (0.2 L/$m^2$) application of protective compound after the curing period. Precast units have the protective compound applied at the fabrication plant.

Cast-in-place tops must conform to the dimension and material requirements of the specifications. All tops must be depressed in accordance with the gutter strip details noted on the applicable standard sheet. All frames and grates must be galvanized.

### 2-420D.2 Resetting Catch Basins

Catch basins may need to be reset during rehabilitation projects to match a new pavement. The work is done in accordance with the plan and contract specifications and with the *Standard Specifications*.

**Figure 2-4.6 Catch Basin (Type CL)**



Inspect all catch basin tops and structures for structural soundness. If new tops are needed, or the structure needs rebuilding or replacement, a new item price agreed to with the contractor must be obtained as soon as possible. A Construction Order is necessary for approval of the additional work. The catch basin must be repaired or replaced before final paving can be done.

The catch basin must be set such that the top of the grate is flush with the pavement at its inside edge and the slope of the grate closely matches the cross slope of the gutter, if one is present. The gravel exposed around the catch basin must be compacted in accordance with the specifications before the bituminous concrete patch is placed.

### *2-420E Manholes*

Manholes are concrete brick, Class A concrete, or precast concrete units of variable depth, constructed over drainage lines to effect changes in pipe size, grade or alignment. Manhole foundations must provide for adequate structural support. Channels may be shaped in the concrete base of the manhole or formed of brick.

Manholes located in bituminous concrete pavement usually are set to grade after the binder course has been placed. Manholes located in concrete pavement should be set to grade after the forms are in place.

### *2-421 Underdrains*

Underdrains are designed either to intercept subsurface water from outside sources before it reaches the roadbed, to remove and dispose of free subsurface water from within the roadbed, or both. They are covered in Article 7.51 of the *Standard Specifications*. A typical installation is shown in Figure 2-4.7. Planned locations of underdrain installations are based on the findings of the soils survey.

If questionable subsurface drainage conditions are encountered, the Inspector should notify the Project Engineer. If a condition warrants expert technical advice, an engineer from Soils and Foundations may be contacted to determine the best method for its correction.

### *2-421A Subsurface Drainage Systems*

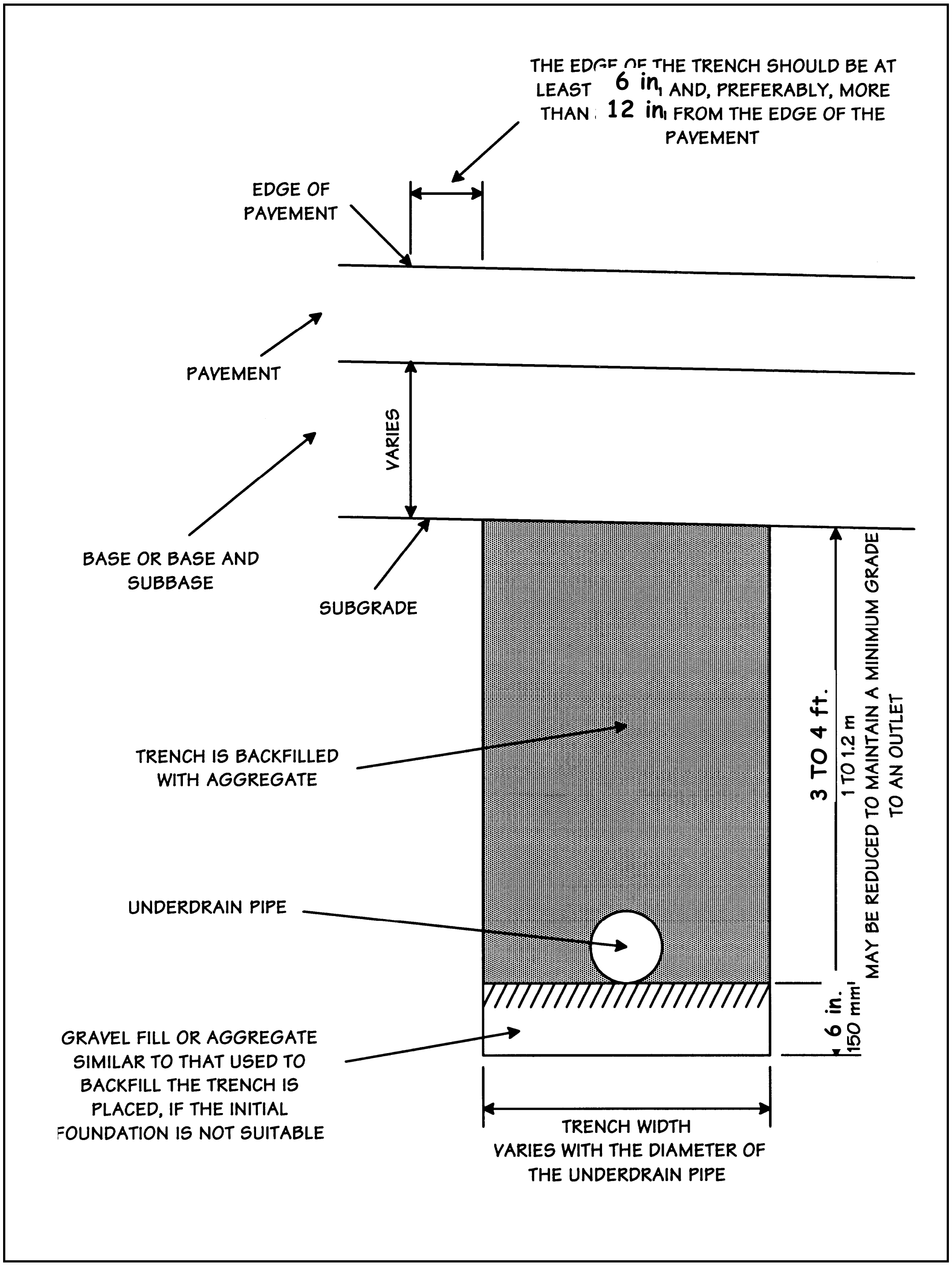
Subsurface drainage systems consist of interceptor and outlet pipes and are classified into these pay items: Underdrains, Foundation Underdrains, Slope Underdrains, Structure Underdrains, and Outlets for Underdrains. Perforated concrete pipe, cradle-invert clay pipe, perforated asphalt-coated corrugated metal pipe, perforated PVC pipe, or perforated aluminum pipe is specified as the type of pipe to be installed.

Underdrains generally are installed parallel to the roadway, 3 to 4 ft. (1 to 1.2 m) below the bottom of the subbase. Only in exceptional instances should the inside edge of the drain be located less than 12 in. (300 mm) from the outside edge of the pavement. When the objective of a proposed underdrain is to intercept seepage water before it reaches the highway, the Inspector should locate the underdrain as close to the bottom of the cut slope as practicable with the equipment used.

Foundation Underdrains are used to drain rock cuts, springs or pocketed basins under the road and subbase where long grades, depth changes, and superelevation about median areas results in potential water traps. Installation is 3 to 4 ft. (1 to 1.2 m) below the bottom of the pavement.

Outlets for Underdrains consist of standard pipe of the type specified, installed between the terminal end of the perforated pipe underdrain and the outlet drainage structure. Where practical, outlet pipes should be connected directly to other drainage structures. Independent outlets must be terminated with a standard underdrain outlet endwall.

**Figure 2-4.7 Underdrain**



### *2-421B Excavation and Installation*

The trench for underdrains is excavated the same as that for culverts. If the bottom of the trench is unstable or in rock, the trench is excavated 6 in. (150 mm) deeper. The extra excavation is filled with gravel fill or aggregate similar to that used to fill the trench.

Underdrains are bedded and installed as below.

- If a perforated pipe is used, and the perforations are to be at the bottom of the pipe, a bed is made with 3 inches (75 mm) of the aggregate used to fill the trench. The aggregate is tamped true to line and grade.
- If the pipe used has a bell, the pipe is installed with the bell up grade and the spigot end entered fully into the adjacent bell.
- If clay or concrete pipe is used, the joints do not have to be filled with a joint sealant or fitted with a gasket.
- If metal, bituminized fiber, plastic, polyethylene or asbestos cement pipe is used, the pipe must be carefully butted together and held by bands or other approved means to prevent displacement of the joint.

### *2-421C Backfilling*

After installation, aggregate is placed around and over the pipe to 12 in. (300 mm) above the top of the pipe. The remainder of the trench is filled with aggregate and tamped in layers as shown on the plans. If perforated pipe is used and the holes are upward or if sand is used instead of aggregate, a 3 in. (75 mm) layer of Size No. 8 (3/8-in.) aggregate is placed over the pipe and around all of the holes. Geotextile may be substituted for the 3 in. (75 mm) layer of aggregate. If geotextile is used, the entire length of the pipe is wrapped in the fabric. The fabric is lapped and welded or bonded. Where the seams of the fabric are not welded or bonded, the fabric must be lapped. For pipes 6 in. (150 mm) or larger, the lap must be equal to the diameter of the pipe. For smaller pipe, the lap must be at least 6 in. (150 mm).

In some instances, the Contractor's equipment may be of such capacity that the trench for the underdrain is wider than the designed width. The contractor may elect to fill the entire trench with aggregate. If the contractor elects to backfill the trench with earth to give the required cross section and place only the required amount of aggregate, the aggregate and earth must be separated by a layer of filter fabric. In either case, the earth or other material used as backfill outside the limits of the underdrain should be placed and compacted in the same manner as backfill for culverts.

If subbase material or gravel is to be placed over the underdrain, a 6 in. (150 mm) layer of the material must be placed immediately after the trench is filled.

Call Before You Dig regulations require the contractor to place warning tape 12 in. (300 mm) above an underdrain installation. The tape must be durable, designed to withstand extended underground exposure, green in color, and durably imprinted with an appropriate warning message. There is no additional pay for providing and placing the tape. Additional information about Call Before You Dig can be found in Volume 2, Chapter Three, "Excavation and Embankment."

### *2-422 Ditches and Channels*

Ditches and channels of the specified type and cross section are to be installed where noted on the plans or ordered by the Engineer. Unstable soil conditions encountered in the field prior to actual ditch or channel construction should be referred to the Project Engineer for resolution. Gravel wedges, gravel blankets, or riprap with geotextile have been used effectively to stabilize wet slopes.