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7-1 Drains

7-1.1 Roadway Subdrainage

Underground streams and seepage zones which require installation of water collection systems may be encountered in roadway excavation. The gradation of gravel used in water interception channels is of prime importance. Gravel backfill for drains has been developed for this use. This drain material is an open graded gravel which will become plugged with infiltered fines if not protected with a filter. It should always be used with a filter cloth which has proven effective in inhibiting the infiltration of fines.

When installing perforated drain pipe, the perforations should be in the lower half of the pipe. This will minimize infiltration of fine material and ensure longer service.

Where a subdrain installation is intended to pick up flow from intermittent seepage zones, nonperforated pipe should be used between the seepage areas to avoid possible loss of water into otherwise dry areas. In some cases, it may be necessary to supplement the pickup system with a carrier pipe system.

The Project Engineer's attention is directed to the fact that control of water during construction is the responsibility of the Contractor. See Chapter 2-3.4 of this manual for temporary water pollution/erosion control.

7-1.2 Installation of Drains

Most of the instructions for the installation of culverts covered in Chapter 7-2.4 of this manual are equally applicable to the installation of drains.

7-1.3 Measurement and Payment

Measurement and payment for structure excavation is covered in Sections 2-09.4 and 2-09.5 of the *Standard Specifications*. Measurement and payment for drain pipe and gravel backfill for drains is covered in Sections 7-01.4 and 7-01.5 of the *Standard Specifications*.

7-2 Culverts

7-2.1 General Instructions

The life of the roadway depends largely upon proper drainage, and it is essential to give diligent attention to adequacy as well as to quality of construction. In addition to providing for the passage of existing natural drainage channels through the project, a highway drainage system must provide for the collection and disposal to natural drainage channels of all rainfall on the right of way and of all ground water flow that may be intercepted during roadway construction.

It is attempted during location and planning to provide for necessary drainage systems, however, particularly with respect to underground water flow, it is impossible to foresee all drainage problems that may result from the construction of the highway. It is the responsibility of the Project Engineer to evaluate the sufficiency of the provided drainage systems and to initiate action for changes or additions where necessary.

The Project Engineer should carefully review all provisions of the applicable Environmental Impact Statement, right of way agreements, and other commitments made by the Washington State Department of Transportation (WSDOT) which have direct bearing on the project. Many of these commitments involve drainage matters. Although such elements should have been incorporated into the design, in some cases, they have been overlooked or require revision. Such a lack of oversight which directly affects adjacent property or individuals is sure to trigger an immediate negative response reflecting on WSDOT integrity.

The Project Engineer should go over the project, particularly during severe storms, closely observing the quantity and action of the storm water runoff to determine the sufficiency of openings and ditches or the need for larger openings and ditches than those contemplated, reporting the results of this observation to the Regional Office. Any changes made in the size of drainage openings must be approved by the Regional Office before the Contractor is advised of the change.

Tables showing the allowable heights of embankments over the various types of pipes are in the *Standard Specifications* and the *Hydraulics Manual*. Quite often, upon locating culverts to fit the drainage conditions, the height of embankment is more than was anticipated during the location work. After the culverts are staked, a check should be made to see that the allowable embankment height for the particular type of pipe is not exceeded.

Pipe arches shall not be constructed until the site has been investigated by the Regional Materials Engineer and the materials and methods for the construction have been approved by the Regional Materials Engineer.

7-2.2 Roadway Surface Drainage

Curb and gutter systems must be constructed in such a manner that water will not pond on the roadway or flow at random over fill slopes. Manholes, catch basins, and spillways should be checked for location, size, and number to ensure efficient removal of collected water. Controlled drainage should be carried to a point beyond the roadway to where damage to the roadway cannot occur.

Water pockets are very apt to be formed in superelevation transitions and roadway width transitions, especially where the roadway grade line is quite flat. It is necessary that the Project Engineer investigate these areas to be sure that proper drainage is installed.

In placing the grates for catch basins and gutter inlets, it is imperative that they are placed at the proper elevation. If they are placed too low, they constitute a traffic hazard and if they are placed too high, they will not intercept the water. In keeping with design safety requirements, many culvert entrance structures utilize catch basins or grate inlet facilities. Such installations are particularly susceptible to deciduous debris and roadside trash. Grate opening size allowing passage of such debris is very critical in rural and mountainous locations.

Surface ditches may be necessary above cut slopes to prevent water from flowing over the cut face. Roadside ditches at the ends of cut sections should be diverted well away from the adjacent embankment to avoid erosion of the fill material.

7-2.3 Design of Culverts

Present standard design practice permits the Contractor to select the type of culvert and drain pipe to be installed except in those instances where a specific type is called for in the plans. Approved types are detailed in the contract plans and specifications.

When changes or additions are determined necessary by the Project Engineer, consideration must be given to the type of pipe being furnished to the project. Specific types should be required only when engineering considerations substantiate that preference should be given to one type or another.

Corrugated metal pipe arches fill a need where headroom above the invert is restricted and where more capacity and wider clearance for discharge of debris is required than would be afforded by a multiple pipe installation. Due to the method of forming the pipe arches, it is usually more difficult to obtain a well-fitting joint. The construction of the joints must receive careful attention when the installation is in material susceptible to erosion.

7-2.4 Installation of Culverts

The ability of the culvert to withstand the height of cover as shown in the tables is based on the culvert being constructed in accordance with the *Standard Specifications* and the *Standard Plans*. All phases of culvert installation should receive thorough attention and inspection to achieve that end.

7-2.4A Grade and Flow Line

Unless shown otherwise in the plans, the flow line grade of a culvert should match the stream channel which it replaces. Where the flow line grade of a culvert is relatively steep, debris and sediments tend to pass more easily through the culvert, but increased abrasion in the invert and increased erosion potential at the outlet can be expected. Where the flow line grade is relatively flat, sediment deposition within the culvert can become a problem. This is especially true with culverts that are placed on a flatter grade than the existing stream channel.

When necessary to construct an inlet channel to the culvert, the channel shall provide a smooth transition into the culvert without constricting the flow.

The destruction of vegetation, and rip rap resulting from the modification of culverts will lead to an increase in erosion around the culvert. The outlet side of the culvert is particularly susceptible to increased damage, even under normal flow. If you disturb or change either the culvert inlets or outlets during construction, consideration needs to be given to providing protection. This protection should extent upstream or downstream as needed. At the completion of the work all culvert inlets, outlets, and the channels leading to and from them shall present a neat and workmanlike appearance. At the completion of the contract, they shall be open and ready for operation.

7-2.4B Foundation

Care must be taken to ensure that the ground upon which pipes are to be laid has sufficient stability to support the pipe without excessive or nonuniform settlement. Where the underlying soil is soft or spongy, or subject to excessive consolidation under load, adequate support shall be obtained by excavating and removing the unstable soil and replacing it with satisfactory (usually granular) material, provided this procedure is feasible. In some cases, installation of the pipe should also be laid with a slight camber to overcome anticipated settlement. Where the unstable foundation soil is of such depth that the above procedure is not practical, other means must be used. This may involve the use of partial backfill of granular material to spread the load, placement of a timber or brush mat, the construction of a pile and timber cradle, or other such means. Before selecting a method, the Regional Materials Engineer should be consulted.

Uniformity of support is essential to successful installations. Where transition is made from foundation soils that may consolidate to firm, unyielding ground, special consideration should be given to the transition zone.

7-2.4C Bedding

Where pipe is laid on existing ground, care must be taken to ensure full, uniform support along the barrel of the pipe. Hand shaping and checking with a template may be necessary. When placing concrete pipe with bell-type joints, depressions must be constructed to receive the bell so that full barrel support is achieved. Isolated stones or boulders which may cause point bearing must be removed.

When granular bedding material is used (as is usually the case in trench construction or where rock soils exist), workers sometimes become careless on the assumption that the bedding material will in itself ensure adequate support. Inspection should ensure that proper depth is used and that the pipe is seated in the bedding material to provide full, uniform barrel support.

Care must be exercised in placing pipe in rock fills or where solid rock, hardpan, or cemented gravel is encountered. Pipe installed on these hard materials must be bedded on a cushion of suitable earth, fine gravel, or sand at least 6 inches (150 millimeters) in depth to eliminate concentrated points of loading.

Gravel having sizes larger than 1 inch (25 millimeters) should not be used for bedding material. The importance of good quality material and good installation practices cannot be overstressed. The load supporting capacity of the pipe is directly affected by the quality of the bedding.

When suitable material is not readily available on the project for bedding the pipe, Gravel Backfill for Pipe Zone Bedding should be used. Normally, this material is to be used only from 6 inches (150 millimeters) below the pipe to the limits shown on the *Standard Plans*. In areas of rock embankment, where there is only fragmentary rock material available on the jobsite to backfill the pipe installation, gravel backfill for pipe zone bedding should be used for the backfill within 12 inches (300 millimeters) of the sides and top of the pipe. If it is necessary to remove the material under the pipe excavation zone to produce a firm foundation, this void should be backfilled with Gravel Backfill for Foundations which is more stable than Gravel Backfill for Pipe Zone Bedding.

If the Engineer deems it desirable or necessary to construct part of the embankment prior to construction of the culvert, the embankment shall be constructed at least 5 diameters of the culvert each side of the installation and compacted to 95 percent of the maximum density of the material. The embankment shall be constructed to a minimum height above the pipe invert elevation of at least one half the diameter of the pipe, more if equipment is to be routed over the pipe installation. No tractors or other heavy equipment shall be operated over the top of the pipe until the backfill has reached a height of 2 feet (0.6 meters) above the top of the pipe. If the Contractor elects to construct the embankment to final grade, shoring will be required for embankments more than 4 feet (1.22 meters) in height above the bottom of the trench. The upper limit for measurement of structure excavation is a maximum of 4 feet (1.22 meters) above the invert of the pipe as specified in Section 2-09.4 of the *Standard Specifications*.

Concrete pipe must be laid with the bell or groove end up grade. Metal pipe with riveted or resistance spot welded seams must be laid with the outside laps of circumferential joints pointing up grade and with the longitudinal laps positioned other than in the invert.

It is important that concrete pipe with elliptical reinforcement, fabricated to form an elliptical section, be installed with the “top” or “bottom” position as marked on the pipe exactly on the vertical axis. There are special cases, such as on side-hill installations, where the imposed load will be at some angle other than vertical. In these cases, the pipe should be tilted to meet the direction of load. Theoretically, a small departure from the correct position does not greatly affect the supporting strength of the pipe, as the reinforcement cages may not be shaped to true ellipses, or they may not remain in the true shape during placing of the concrete. Practically, the steel may be in such a position that a large percentage of its effectiveness is lost a short distance away from the vertical axis. Elliptically reinforced concrete pipe is manufactured with lift holes in the top of the pipe or is clearly marked to simplify true positioning. Many culvert pipe failures have resulted because of carelessness in installation with respect to position of the vertical axis.

7-2.4D Backfill

The load supporting strength of any pipe is directly affected by the condition of the material around and above the pipe as well as the bedding material under the pipe. In general, the higher the degree of compaction of the fill or backfill under the haunches and along the sides of the pipe, the less the pipe will deform under load. Also, the higher the compaction, the less the material along side the pipe will consolidate. Consolidation can result in an increased transfer of embankment load onto the pipe. For these reasons, the backfill or embankment material adjacent to the pipe should be selected material free from large rocks and lumps, containing sufficient fines so that it will compact to a relatively impervious mass and it must be compacted to a density and width not less than that required by the *Standard Specifications* or *Standard Plans*.

Care must be taken to obtain proper compaction under the haunches of the pipe and to place and compact the backfill uniformly on both sides of the culvert. Firm support must be obtained. Caution shall be used to avoid over-tamping to the extent that the pipe is lifted out of position.

Many failures of culvert pipe in the past could have been avoided by proper backfilling. No type of pipe can withstand heavy embankment loads unless the backfilling is performed in strict accordance with the *Standard Plans* for Pipe Zone Bedding and Backfill and the *Standard Specifications*.

7-2.4E Placement of Fill Over Culverts

The load that will be imposed on a culvert pipe is affected largely by the manner in which the embankment around and above the culvert is constructed. The maximum height of fill allowable over various sizes and types of pipe and pipe arch culvert is dependent upon backfilling and constructing the embankment over the culvert in strict compliance with the *Standard Plans* and the *Standard Specifications*. Careful attention shall be given to constructing pipe installations in accordance with the appropriate standard except as modified by special provisions.

Equipment shall not be permitted to operate across the culvert until the embankment has been constructed 2 feet (600 millimeters) above the culvert. The operation of equipment over the culvert installation shall be in accordance with Section 1-07.7 of the *Standard Specifications*.

Mitered ends of metal and thermoplastic culverts may require some type of weighted protection to keep the end of the culvert from floating due to hydrostatic pressure. Usually concrete headwalls are specified for this purpose. Concrete headwalls must be constructed as soon as the embankment is constructed to the height of the headwall so the mitered ends of the culvert will be protected when the first storm is encountered.

7-2.5 Measurement and Payment

Measurement and payment for structure excavation is covered in Sections 2-09.4 and 2-09.5 of the *Standard Specifications*. There is no specific unit of measurement or payment for any bedding or backfill material placed in the pipe zone, as covered in Sections 7-08.4 and 7-08.5 of the *Standard Specifications*. All costs associated with furnishing and installing the bedding and backfill material within the pipe zone are included in the unit contract price for the pipe. Measurement and payment for pipe and end sections are covered in Sections 7-02.4 and 7-02.5 of the *Standard Specifications*.

It should be noted that if the Contractor constructs pipe in excess of the length designated by the Engineer, the excess length will not be measured or paid for. It is quite often undesirable to have culvert pipe constructed in excess of the necessary length from both hydraulic and aesthetic considerations thus the Engineer should have the excess removed at the contractor's expense when this occurs.

7-3 Structural Plate Pipe, Pipe Arch, Arch, and Underpass

7-3.1 General Instructions

Most of the instructions for the construction of culverts covered in Chapter 7-2 of this manual are equally applicable to the construction of structural plate pipes, pipe arches, arches, and underpasses.

In the construction of multi-plate structures, it is quite important that the bottom plates be correctly positioned for alignment and grade of their edges before the other plates of the section are bolted up so the completed structure will be in proper alignment. Manufacturers of multi-plate structures normally supply detailed assembly instructions with their multi-plates, which should be closely followed, as they will prevent creep or spiral. If the structure starts to creep or spiral, the only way to correct this condition is to remove the plates to where it is in correct alignment and reconstruct the structure.

High-strength bolts are used in bolting the plates together. In order for the connections to function as designed, the bolts must be tightened to the specified tension. Chapter 6-3.6B covers the instructions for construction and inspection of high tensile strength bolts. Impact wrenches must be calibrated as specified since overtightening may overstress the bolts and under-tightening will not give the connection the required strength. If more than one crew is assembling the structure, the impact wrenches must be calibrated to tighten the bolts to the same torque.

7-3.2 Measurement and Payment

Measurement and payment instructions are covered in Sections 7-03.4 and 7-03.5 of the *Standard Specifications*.

7-4 Storm Sewers

7-4.1 General Instructions

Most of the instructions for the construction of culverts covered in Chapter 7-2 of this manual are equally applicable to the construction of storm sewers.

The grade line that storm sewers are constructed on is rather critical since the capacity of the pipe is dependent on its flow line grade. The storm sewer system has been designed to carry the anticipated flow if it is constructed on the grade lines shown in the plans. It is quite important that the effect on the capacity of the pipe be checked whenever it becomes necessary to vary the flow line grade to avoid obstacles that may be encountered on construction.

Careful attention must be paid to the construction of the joints or the storm sewer line may not meet the tests that may be required in the contract.

7-4.2 Sewer Trench

Trenches shall be constructed as specified in Section 7-08.3(1)A of the *Standard Specifications*.

If the trench is 4 feet (1.22 meters) or more in depth, Shoring and Cribbing shall be constructed or the sides of the trench sloped as necessary to protect the workers in the trench. See Section 2-09.3(4) of the *Standard Specifications* and Chapter 2, Section 2-9.1, of this manual.

Backfilling will be in accordance with Section 7-08.3(3) of the *Standard Specifications*.

7-4.3 Measurement and Payment

Similar to culvert installations, measurement and payment for structure excavation is covered in Sections 2-09.4 and 2-09.5 of the *Standard Specifications*. There is no specific unit of measurement or payment for any bedding or backfill material placed in the pipe zone, as covered in Sections 7-08.4 and 7-08.5 of the *Standard Specifications*. All costs associated with furnishing and installing the bedding and backfill material within the pipe zone are included in the unit contract price for the pipe.

7-5 Manholes and Catch Basins

The instructions for this work are described in Section 7-05 of the *Standard Specifications*.

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