Culverts Characteristics

Prepared By:

NajlaJasimYaseen

Civil Engineer

Table of Contents:

Corrosion

Abrasion

Soil and WaterConditions thatAffectCulverts

pH Extremes

Electrical Resistivity

Soil Characteristics

Culvert ProtectiveSystems

Extra Thickness

Bituminous Coating

Bituminous PavedInverts

Introduction

A culvert is a structure designed hydraulically to take advantage of submergenceto increase water carrying capacity. Culverts, as distinguished from bridges, areusually covered with embankment and are composed of structural material aroundthe entire perimeter, with thestreambed serving as the bottom of the culvert.

Additionally, a culvert in the event of a failure usuallyrepresents much less of a safety hazard. However failure of a major culvert may be both costly and hazardous. Like bridges, culverts should be inspected regularly to identify potential safetyproblems and maintenance needs to minimize property damage due to improperhydraulic functioning.

Figure ١ Culvert Structure

Culvert Requirements:

Structural Integrity - The failure of major culverts can present a lifethreatening safety hazard. The identification of potential structural andmaterial problems requires a careful evaluation of indirect evidence ofstructural distress as well as actual deterioration and distress in the culvertmaterial.

Hydraulic Performance - When a culvert's hydraulic performance isinadequate, potential safety hazards may result. The flooding of adjacentproperties from unexpected headwater depth may occur. Downstreamareas may be flooded by failure of the embankment. The roadwayembankment or culvert may be damaged because of erosion.

Roadside Compatibility - Many culverts, like older bridges, presentroadside hazards. Headwalls and wingwalls higher than the road orembankment surface may constitute a fixed obstacle hazard. Abrupt dropoffsover the end of a culvert or steep embankments may representrollover hazards to vehicles that leave the roadway.

Maintenance Needs:

Lack of maintenance is a prime cause of improper functioning in culverts andother drainage structures. Regular periodic inspections allow minor problems to bespotted and corrected before they become serious.

DifferentiationBetween Culvertsand Bridges

Traditional definitions of culverts are based on the span length rather than functionor structure type. For example, "...structures over ٢٠ feet in span parallel to the roadway are usually calledbridges; and structures less than ٢٠ feet in span are called culverts even though
they support traffic loads directly."
A few of the more significant differences between bridges and culvertsare:
Hydraulic Culverts are usually designed to operate at peak flows with a submerged inlet to
improve hydraulic efficiency. The culvert constricts the flow of the stream to causeponding at the upstream or inlet end. The resulting rise in elevation of the watersurface produces a head at the inlet that increases the hydraulic capacity of theculvert. Bridges may constrict flow to increase hydraulic efficiency or be designedto permit water to flow over the bridge or approach roadways during peak flows.However, bridges are generally not designed to take advantage of inletsubmergence to the degree that is commonly used for culverts.
Structural Culverts are usually covered by embankment material. Culverts must be designed
to support the dead load of the soil over the culvert as well as live loads of traffic.Either live loads or dead loads may be the most significant load element dependingon the type of culvert, type and depth of cover, and amount of live load. However,live loads on culverts are generally not as significant as the dead load unless thecover is shallow.
In most culvert designs the soil or embankment material surrounding the culvertplays an important structural role. Lateral soil pressures enhance the culvertstability to support vertical loads. The stability of the surrounding soil is importantto the structural performance of most culverts.
Maintenance Because culverts usually constrict flow there is an increased potential forwaterway blockage by debris and sediment, especially for culverts subject toseasonal flow. Multiple barrel culverts

may also be particularly susceptible todebris accumulation. Scour caused by high outlet velocity and turbulence at inletend is a concern.
Traffic Safety A significant safety advantage of many culverts is the elimination of bridgeparapets and railings. Culverts can usually be extended so that the standardroadway cross section can be carried over the culvert to provide a vehicle recoveryarea. However, when ends are located near traffic lanes or adjacent to shoulders,guardrails may be used to protect the traffic.
Construction Careful attention to construction details such as bedding, compaction, and trenchwidth during installation is important to the structural integrity of the culvert. Poorcompaction or poor quality backfill around culverts may result in unevensettlement over the culvert and possibly structural distress of the culvert.
Durability : Durability of material is a significant problem in culverts and other drainagestructures. In very hostile environments such as acid mine drainage and chemicaldischarge, corrosion and abrasion can cause deterioration of all commonlyavailable culvert materials.
Inspection The inspection and assessment of the structural condition of culverts requires anevaluation of not only actual distress but circumstantial evidence such as roadwaysettlement, pavement patches, and embankment condition.

StructuralCharacteristics ofCulverts

Loads on Culverts In addition to their hydraulic functions, culverts must also support the weight ofthe embankment or fill covering the culvert and any load on the embankment.
There are two types of loads that must be carried by culverts: dead loadsand live loads.
Dead Loads
Dead loads include the earth load or weight of the soil over the culvert and anyadded surcharge loads such as buildings or additional earth fill placed over anexisting culvert. If the actual weight of earth is not known, ١٩٢٠ kilograms percubic meter (١٢٠ pounds per cubic foot) is generally assumed.
Live Loads
The live loads on a culvert include the loads and forces, which act upon the culvertdue to vehicular or pedestrian traffic. The highway wheel loads generally used foranalysis are shown in Figure.٢. The effect of live loads decreases as the heightof cover over the culvert increases. When the cover is more than two feet,concentrated loads may be considered as being spread uniformly over a squarewith sides ١.٧٥ times the depth of cover. This concept is illustrated in Figure.٣and.٤. In fact, for single

spans, if the height of earth fill is more than ٢.٤meters (٨ feet) and exceeds the span length, the effects of live loads can be ignoredall together. (AASHTO)

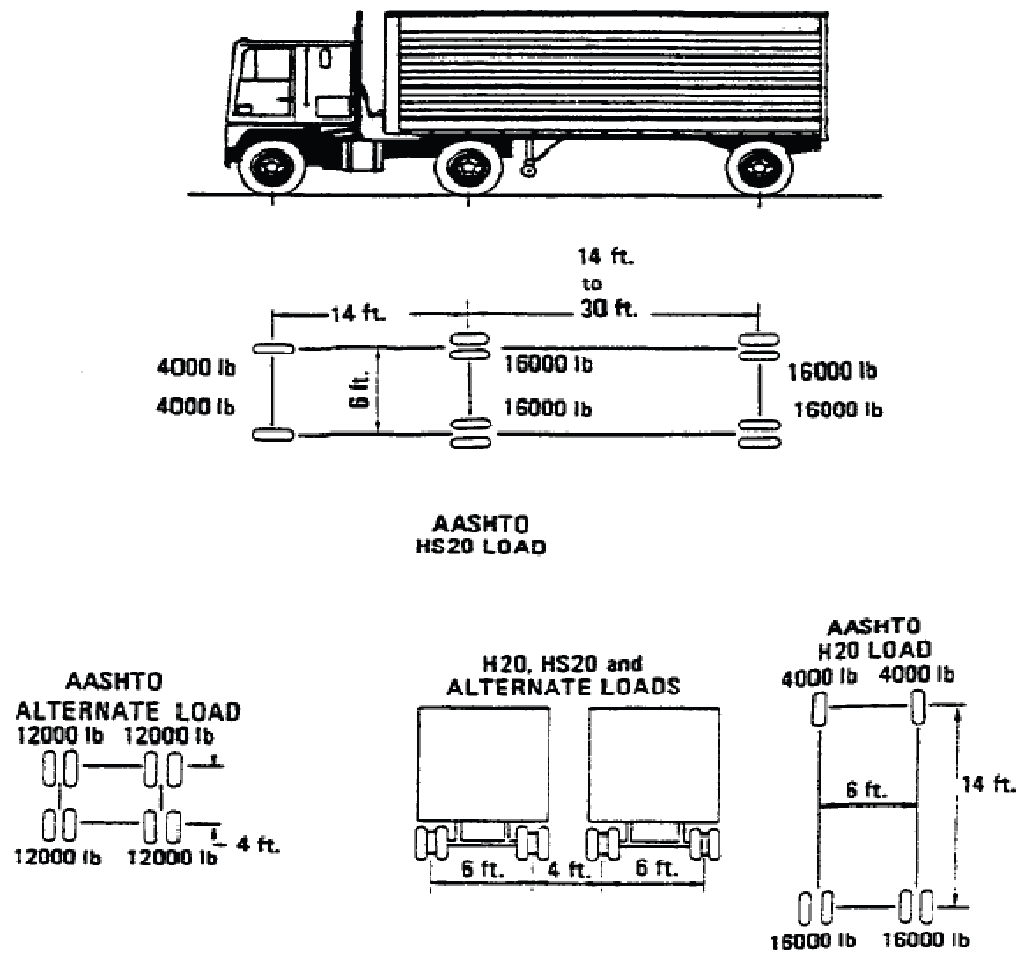
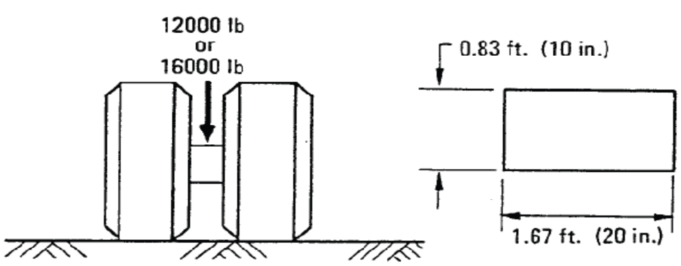


Figure ٢ AASHTO Live Load Spacing for Highway Structures



Source: Concrete Pipe Handbook
American Concrete Pipe Association

Figure ٣ Surface Contact Area for Single Dual Wheel

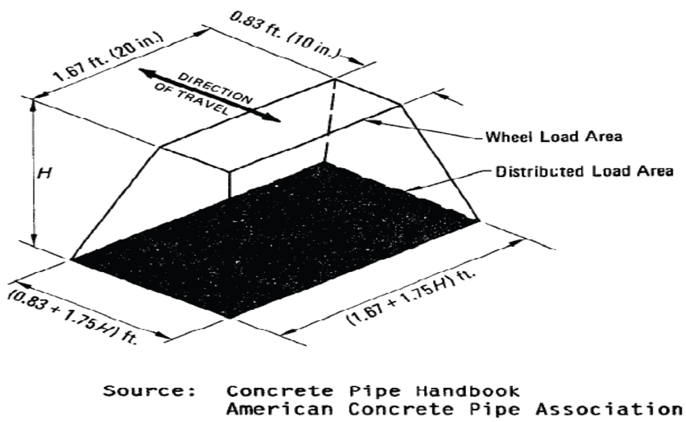


Figure ٤ Distribution of Live Load (Single Dual Wheel) for Depth of cover

Categories of StructuralMaterials

Based upon material type, culverts can be divided into two broad structuralcategories: rigid and flexible.

- Rigid Culverts

Culverts made from materials such as reinforced concrete and stone masonry arevery stiff and do not deflect appreciably. The culvert material itself provides theneeded stiffness to resist loads. In doing this, zones of tension and compressionare created. The culvert material is designed to resist the corresponding stresses.

- Flexible culverts

Flexible culverts are commonly made from steel or aluminum. In some statescomposite materials are used. Flexible culverts rely on thesurrounding backfill material to maintain their structural shape. Since they areflexible, they can be deformed significantly with no cracks occurring.

As vertical loads are applied, a flexible culvert will deflect if the surrounding fillmaterial is loose. The vertical diameter decreases while the horizontal diameter increases. Soil pressures resist the increase in horizontal diameter.For flexible culverts with large openings, sometimes longitudinal and/orcircumferential stiffeners are used to prevent excessive deflection.Circumferential stiffeners are usually metal ribs bolted around the circumferenceof the culvert. Longitudinal stiffeners may be metal or reinforced concrete. Thistype of stiffener is sometimes called a thrust beam.

Figure ٥ Flexible Culvert

Construction and Installation Requirements

The structural behavior of flexible and rigid culverts is often dependent on construction practices during installation . Items, which requireparticular attention during construction, are discussed briefly in the following text.

□Compaction and Side Support - Good backfill material and adequatecompaction are of critical importance to flexible culverts. A wellcompactedsoil envelope is needed to develop the lateral pressuresrequired to maintain the shape of flexible culverts. Well-compacted
backfill is also important to the performance of rigid culverts. Poorlycompacted soils do not provide the intended lateral support.

□Trench Width - Trench width can significantly affect the earth loads onrigid culverts. It is therefore important that trench widths be specified onthe plans.

□Foundations and Bedding - A foundation capable of providing uniformand stable support is important for both flexible and rigid culverts. Thefoundation must be able to support the structure at the proposed grade andelevation without concentration of foundation pressures. Foundationsshould be relatively yielding when compared to side fill. Establishing asuitable foundation requires removal and replacement of any hard spots orsoft spots. Bedding is needed to level out any irregularities in thefoundation and to insure uniform support. When using flexible culverts,bedding should be shaped to a sufficient width to permit compaction of theremainder of the backfill, and enough loose material should be placed ontop of the bedding to fill the corrugations. When using rigid culverts, thebedding should conform to the bedding conditions specified in the plans .Adequate support is critical inrigid pipe installations, or shear stress may become a problem.

Construction Loads - Culverts are generally designed for the loads theymust carry after construction is completed. Construction loads may exceeddesign loads. These heavy loads can cause damage if constructionequipment crosses over the culvert installation before adequate fill hasbeen placed or moves too close to the walls, creating unbalanced loading.

Additional protective fill may be needed for equipment crossing points.

Camber - In high fills the center of the embankment tends to settle morethan the areas under the embankment side slopes. In such cases it may benecessary to camber the foundation slightly. This should be accomplishedby using a flat grade on the upstream half of the culvert and a steepergrade on the downstream half of the culvert. The initial grades should notcause water to pond or pocket.

Culvert Shapes :

A wide variety of standard shapes and sizes are available for most culvertmaterials. Since equivalent openings can be provided by a number of standardshapes, the selection of shape may not be critical in terms of hydraulicperformance. Shape selection is often governed by factors such as depth of coveror limited headwater elevation. In such cases a low profile shape may be needed.Other factors such as the potential for clogging by debris, the need for a naturalstream bottom, or structural and hydraulic requirements may influence theselection of culvert shape.

Circular:

The circular shape is the most common shape manufactured for pipe culverts .It is hydraulically and structurally efficient under most conditions.Possible hydraulic drawbacks are that circular pipe generally causes somereduction in stream width during low flows. It may also be more prone to cloggingthan some other shapes due to the diminishing free surface as the pipe fills beyond the midpoint. With very large diameter corrugated metal pipes, the flexibility ofthe sidewalls dictates that special care be taken during backfill construction tomaintain uniform curvature. See Figure ٥.

Pipe Arch and EllipticalShapes:

Pipe arch and elliptical shapes are often used instead of circular pipe when thedistance from channel invert to pavement surface is limited or when a widersection is desirable for low flow levels (see Figure .٦). These shapes may alsobe prone to clogging as the depth of flow increases and the free surface diminishes.Pipe arch and elliptical shapes are not as structurally efficient as a circular shape.

Arches:
Arch culverts offer less of an obstruction to the waterway than pipe arches and canbe used to provide a natural stream bottom where the stream bottom is naturallyerosion resistant (see Figure ٧). Foundation conditions must be adequate tosupport the footings. Riprap is frequently used for scour protection.

Figure٦Pipe Arch Culvert

Figure ٧ Arch Culvert

Box Sections:
Rectangular cross-section culverts are easily adaptable to a wide range of siteconditions including sites that require low profile structures. Due to the flat sidesand top, rectangular shapes are not as structurally efficient as

other culvert shapes(see Figure .٨). In addition, box sections have an integral floor.

Figure ٨Concrete Box Culvert

Multiple Barrels :
Multiple barrels are used to obtain adequate hydraulic capacity under lowembankments or for wide waterways (see Figure .٩). In some locations theymay be prone to clogging as the area between the barrels tends to catch debris andsediment. When a channel is artificially widened, multiple barrels placed beyondthe dominant channel are subject to excessive sedimentation. The span or openinglength of multiple barrel culverts includes the distance between barrels as long asthat distance is less than half the opening length of the adjacent barrels.

Figure.٩Multiple Cell Concrete Culvert

Frame Culverts:

Frame culverts are constructed of cast-in-place (see Figure ١٠) or pre-castreinforced concrete. This type of culvert has no floor (concrete bottom) and fillmaterial is placed over the structure.

Figure ١٠Frame Culvert

Culvert Materials

Precast Concrete
Precast concrete culverts are manufactured in six standard shapes:
□Circular, □Pipe arch, □Horizontal elliptical, □Vertical elliptical, □Rectangular,Arch
With the exception of box culverts, concrete culvert pipe is manufactured in up tofive standard strength classifications. Box culverts are designed for various depths of cover and liveloads. All of the standard shapes are manufactured in a wide range of sizes.
Circular and elliptical pipes are available with standard sizes as large as ٣.٧ m in diameter, with larger sizes available as special designs. Standard boxsections are also available with spans as large as ٣.٧ m. Precastconcrete arches on cast-in-place footings are available with spans up to ١٢.٥ m.

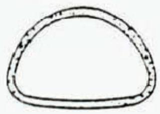
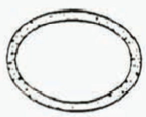
SHAPE	RANGE OF SIZES	COMMON USES
CIRCULAR 	12 to 180 inches reinforced 4 to 36 inches non-reinforced	Culverts, storm drains, and sewers.
PIPE ARCH 	15 to 132 inches equivalent diameter	Culverts, storm drains, and sewers. Used where head is limited.
HORIZONTAL ELLIPSE 	Span x Rise 18 to 144 inches equivalent diameter	Culverts, storm drains, and sewers. Used where head is limited.
VERTICAL ELLIPSE 	Span x Rise 36 to 144 inches equivalent diameter	Culverts, storm drains, and sewers. Used where lateral clearance is limited.
RECTANGULAR (box sections) 	Span 3ft to 12ft	Culverts, storm drains, and sewers. Used for wide openings with limited head.

Figure ١١ Standard Concrete Pipe Shapes

Cast-in-Place Concrete Culverts that are reinforced cast-in-place concrete are typically either rectangularor arch-shaped. The rectangular shape is more common and is usually constructedwith multiple cells (barrels) to accommodate longer spans. One advantage of castin-place construction is that the culvert can be designed to meet the specificrequirements of a site. Due to the long construction time of cast-in-place culverts,pre-cast concrete or corrugated metal culverts are sometimes selected. However, inmany areas, cast-in-place culverts are more practical and represent a significantnumber of installations.

Metal Culverts Flexible culverts are typically either steel or aluminum and are constructed fromfactory-made corrugated metal pipe or field assembled from structural plates.
Structural plate products are available as plate pipes, box culverts, or long spanstructures (see Figure ١٢). Several factors such as span length, vertical andhorizontal clearance, peak stream flow and terrain determine which flexible culvertshape is used.

Figure ١٢ Metal Culvert

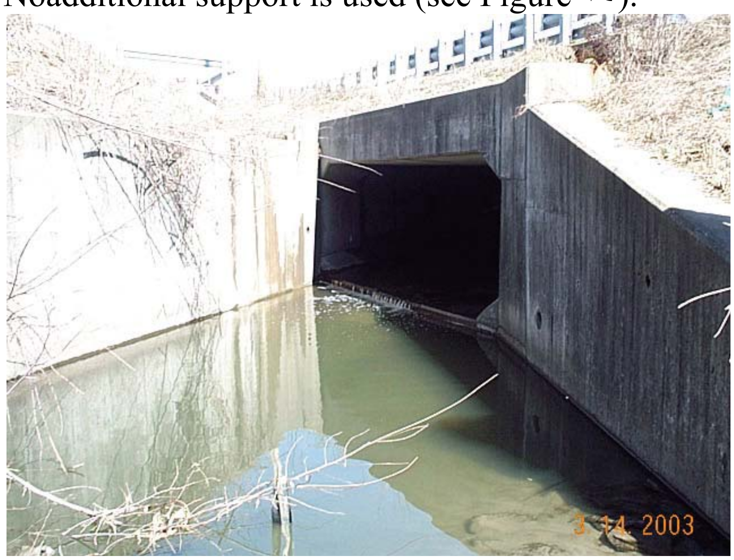
Masonry Stone and brick are durable, low maintenance materials. Currentlystone and brick are seldom used for constructing culvert barrels. Stone is usedoccasionally for this purpose in locations which have very acidic runoff, but the most common use of stone is for headwalls where a rustic or scenic appearance isdesired. A stone masonry arch culvert is shown in Figure ١٣.

Figure ١٣ Stone Culvert

Timber
Timber culverts are generally box culverts and are constructed from individualtimbers similar to railroad ties. Timber culverts are also analogous to a short spantimber bridge on timber abutments .

Other Materials Aluminum, steel, concrete, and stone masonry are the most commonly foundmaterials for existing culverts. There are several other materials which may beencountered during culvert inspections, including cast iron, stainless steel, terracotta, asbestos cement, and plastic. These materials are not commonly foundbecause they are either relatively new (plastic), labor intensive (terra cotta), orused for specialized situations (stainless steel and cast iron).

Culvert EndTreatments
Culverts may have end treatments or end structures. End structures are used tocontrol scour, support backfill, retain the embankment, improve hydraulicefficiency, protect the culvert barrel, and provide additional stability to the culvertends.
The most common types of end treatments are:
- Projecting - The barrel simply extends beyond the embankment. Noadditional support is used (see Figure ١٤).



- Mitered - The end of the culvert is cut to match the slope of theembankment. This type of treatment is also referred to as beveling and iscommonly used when the embankment has some sort of slope paving (seeFigure ١٥).

Figure ١٥ Culvert Mitered End

□Skewed - Culverts, which are not perpendicular to the roadway, may havetheir ends cut parallel to the roadway.

□Pipe end section - A section of pipe is added to the ends of the culvertbarrel. These are typically used on relatively smaller culverts.
□Headwalls - Used along with wingwalls to retain the fill, resist scour, andimprove the hydraulic capacity of the culvert. Headwalls are usuallyreinforced concrete (see Figure ١٦), but can be constructed of masonry. Metal headwalls are usually found on metal box culverts.

Figure ١٦ Culvert Headwall

Miscellaneous Appurtenance Structures may also be used with end treatments toimprove hydraulic efficiency and reduce scour. Typical appurtenances are:
Aprons - Used to reduce streambed scour at the inlets and outlets of culverts. Aprons are typically concrete slabs, but they may also be rip-rap. Most aprons include an upstream cutoff wall toprotect against undermining.
Energy Dissipaters - Used when outlet velocities are likely to causestreambed scour downstream from the culvert. Stilling basins, riprap orother devices that reduce flow velocity can be considered energydissipaters (see Figure ١٧).

Figure ١٧ Energy Dissipaters

Hydraulics ofCulverts

Culverts are primarily constructed to convey water under a highway, railroad, orother embankment. A culvert which does not perform this function properly mayjeopardize the throughway, cause excessive property damage, or even loss of life.The hydraulic requirements of a culvert usually determine the size, shape, slope,and inlet and outlet treatments. Culvert hydraulics can be divided into two generaldesign elements:
- Hydrologic Analysis
- Hydraulic Analysis

A hydrologic analysis is the evaluation of the watershed area for a stream and isused to determine the design discharge or the amount of runoff the culvert shouldbe designed to convey.A hydraulic analysis is used to select a culvert, or evaluate whether an existing
culvert is capable of adequately conveying the design discharge.

Hydrologic Analysis Most culverts are designed to carry the surface runoff from a specific drainagearea. While the selection and use of appropriate methods of estimating runoffrequires a person experienced in hydrologic analysis. Climatic andtopographic factors are briefly discussed in the following sections.

Climatic Factors: Climatic factors that may influence the amount of runoff include:
Rainfall intensity, Storm duration ,Rainfall distribution within the drainage area
Soil moisture, Snow melt, Rain-on-snow, Rain-hail, Other factors.

Topographic Factors
Topographic factors that may influence runoff include:
The land use within the drainage area,The size, shape, and slope of the drainage area.
Other factors such as the type of soil, elevation, and orientation of the areaLand use is the most likely characteristic to change significantly during the servicelife of a culvert. Changes in land use may have a considerable effect on the amountand type of runoff. Some surface types will permit more infiltration than othersurface types. Practically all of the rain falling on paved surfaces will drain offwhile much less runoff will result from undeveloped land.
If changes in land usewere not planned during the design of a culvert, increased runoff may exceed thecapacity of an existing culvert when the land use does change.
The size, shape, and slope of a culvert's drainage area influence the amount ofrunoff that may be collected and the speed with which it will reach the culvert. Theamount of time required for water to flow to the culvert from the most remote partof a drainage area is referred to as the time of concentration. Changes within thedrainage area may influence the time of concentration.
Land use changes may also decrease time of concentration sincewater will flow more quickly over paved surfaces. Since higher rainfall intensitiesoccur for shorter storm durations, changes in time of

concentration can have asignificant impact on runoff. Drainage areas are sometimes altered and flowdiverted from one watershed to another.

Hydraulic Capacity The factors affecting capacity may include headwater depth, tailwater depth, inletgeometry, the slope of the culvert barrel, and the roughness of the culvert barrel.
The various combinations of the factors affecting flow can be grouped into twotypes of conditions in culverts:

- Inlet control
- Outlet control

Inlet Control Under inlet control the discharge from the culvert is controlled at the entrance ofthe culvert by headwater depth and inlet geometry (see Figure ١٨). Inletgeometry includes the cross-sectional area, shape, and type of inlet edge. Inletcontrol governs the discharge as long as water can flow out of the culvert fasterthan it can enter the culvert.

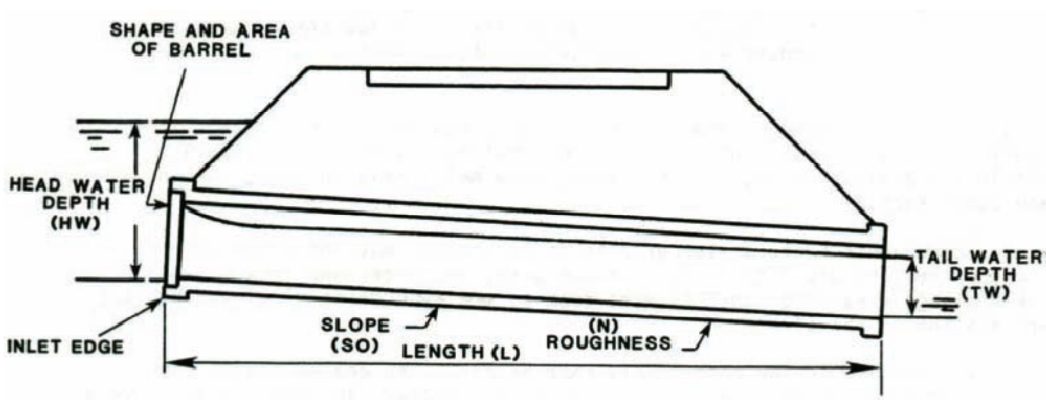


Figure ١٨ Factors Affecting Culvert Discharge

Most culverts, except those in flat terrain, are designed to operate under inletcontrol during peak flows. Since the entrance characteristics govern, minormodifications at the culvert inlet can significantly affect hydraulic capacity. Forexample, change in the approach alignment of the stream may reduce capacity,while the improvement of the inlet edge condition, or addition of properlydesigned headwalls and wingwalls, may increase the capacity.

Outlet Control Under outlet control water can enter the culvert faster than water can flow throughthe culvert. The discharge is influenced by the same factors as inlet control plus
the tailwater depth and barrel characteristics (slope, length, and roughness).Culverts operating with outlet control usually lie on flat slopes or have high tail water.When culverts are operating with outlet control,

changes in barrel characteristicsor tailwater depth may affect capacity. For example, increased tailwater depth ordebris in the culvert barrel may reduce the capacity.

Special HydraulicConsiderations

Inlet and Outlet Protection
The inlets and outlets of culverts may require protection to withstand the hydraulicforces exerted during peak flows. Inlet ends of flexible pipe culverts, which are notadequately protected or anchored, may be subject to entrance failures due tobuoyant forces. The outlet may require energy dissipaters to control erosion andscour and to protect downstream properties. High outlet velocities may cause scourwhich undermines the endwall, wingwalls, and culvert barrel. This erosion cancause end-section drop-off in rigid sectional pipe culverts.
Protection against PipingSeepage along the outside of the culvert barrel may remove supporting material.This process is referred to as “piping”, since a hollow cavity similar to a pipe isoften formed. Piping can also occur through open joints. Piping is controlled by
Reducingthe amount and velocity of water seeping along the outside of the culvertbarrel.

Factors AffectingCulvertPerformance

Some of the common factors that can affect the performance of a culvert includethe following:
- Construction Techniques - Specifically, how well the foundation wasprepared, the bedding placed, and the backfill compacted.
- The characteristics of the stream flow - water depth, velocity, turbulence.
- Structural Integrity - how well the structure can withstand the loads towhich it is subjected, especially after experiencing substantialdeterioration and section loss.
- Suitability of the Foundation - Can the foundation material provideadequate support?
- Stability of the embankment in relationship to other structures on theupstream or downstream side.
- Hydraulic capacity - if the culvert cross section is insufficient for flow,upstream ponding could result and damage the embankment.
- The presence of vegetation - can greatly affect the means and efficiency ofthe flow through the culvert.
- The possibility of abrasion and corrosion caused by substances in thewater, the surrounding soil or atmosphere.

Types andLocations ofCulvert Distress

Types of Distress

The combination of high earth loads, long pipe-like structures and running watertends to produce the following types of distress:

Shear or bending failure - High embankments may impose very high loadson all sides of a culvert and can cause shear or bending failure.

Foundation failure - Either a smooth sag or differential verticaldisplacement at construction or expansion joints (settlement).Tipping ofwingwalls. Lateral movement of precast or cast-in-place box sections (seeFigure ١٩).

Figure ١٩ Cracking of Culvert End Treatment Due to Foundation Settlement

Hydraulic failure - Full flow design conditions result in accelerated scourand undermining at culvert ends as well as at any irregularities within theculvert due to foundation problems (see Figure ٢٠).

Figure ٢٠ Scour and Undermining at Culvert Inlet

Debris accumulation - Branches, sediment and trash can often be trappedat the culvert entrance restricting the channel flow and causing scour (seeFigure.٢١).

Figure ٢١ Debris and Sediment Buildup

Inspection Locations A logical sequence for inspecting culverts helps ensure that a thorough andcomplete inspection will be conducted. In addition to the culvert components, theinspector should also look for highwater marks, changes in the drainage area, andother indications of potential problems. In this regard, the inspection of culverts issimilar to the inspection of bridges.For typical installations, it is usually convenient to begin the field inspection withgeneral observations of the overall condition of the structure and inspection of theapproach roadway. The inspector should select one end of the culvert and inspectthe embankment, waterway, headwalls, wingwalls, and culvert barrel.

Approach Roadway andEmbankment

Inspection of the approach roadway and embankment includes an evaluation of thefunctional adequacy .The approach roadway and embankment should also be inspected for the followingfunctional requirements:

Signing, Alignment, Clearances, Adequate shoulder profile, Safety features

Defects in the approach roadway and embankment may be indicators of possible
structural or hydraulic problems in the culvert. The approach roadway andembankment should be inspected for the following conditions:

Sag in roadway or guardrail, Cracks in pavement, Pavement patches or evidence that roadway has settled, Erosion or failure of side slopes

Approach roadways should be examined for sudden dips, cracks, and sags in thepavement . These usually indicate excessive deflection of theculvert or inadequate compaction of the backfill material.
New pavement can temporarily hide approach problems. It is advisable for theinspector to have previous inspection reports that may indicate the age of thepresent overlay.It is important to note that not all defects in the approach roadways have an adverse effect on the culvert. Deterioration of the pavement may be due toexcessive traffic and no other reason.
Embankment The embankment around the culvert entrance and exit should be inspected for slidefailures in the fill around the box. Check for debris at the inletand outlet and within the culvert. Also note if vegetation is obstructing the ends.
End Treatments
The most common types of box culvert end treatments are:
Skewed Ends, Headwalls, both end treatment types use wingwalls to retain the embankment around theopening.Wingwalls should be inspected to ensure they are in proper vertical alignment. Wingwalls may be tilted due to settlement, slides or scour.
Skewed Ends - Skewing the end of a culvert has nearly the same effect onstructural capacity as does mitering. Stresses increase becausea full box shape is not present at the end.
Headwalls – Headwalls and wingwalls should be inspected for undermining andsettlement. Cracking, tipping or separation of culvert barrel from the headwall andwingwalls is usually good evidence of undermining.
Appurtenance Structures Typical appurtenance structures are:
Aprons, Energy Dissipaters
Aprons – should be checked for any undermining or settlement. The jointsbetween the apron and headwalls should be inspected to see if it is watertight.
Energy Dissipaters – are used when outlet velocities are likely to cause streambedscour downstream from the culvert. Energy dissipaters mayinclude stilling basins, riprap or other devices. Energy dissipaters should beinspected for material defects and overall effectiveness.
Culvert Barrel The full length of the culvert should be inspected from the inside. All componentsof the culvert barrel should be visually examined, including walls, floor, top slab,
and joints. The concrete should be sounded by tapping with a hammer particularlyaround cracks and other defects. It is important to time the inspection so that waterlevels are low. Culverts with small diameters can be inspected by looking through the culvert from both ends or by using a small movable camera. For concrete box culverts, the culvert barrels

should be inspected primarily fordefects such as misalignment, joint defects, cracking, spalling, and other materialdefects.

Durability Although the structural condition is a very important element in the performanceof culverts, durability problems are probably the most frequent cause of replacement. Culverts are more likely to "wear away" than fail structurally.Durability is affected by two mechanisms: corrosion and abrasion.

Corrosion: Corrosion affects all metals and alloys, although the rates can vary widely depending both upon the chemical and physical properties of the metal and uponthe environmental condition to which it is exposed. When a metal corrodes a verylow voltage electrical current is established between two parts of a metal surfacethat have different voltage potential. The difference in voltage potential may becaused by slight variations in the material, changes in surface condition, or thepresence of foreign materials. The current removes metallic ions from one locationand deposits them at another location, causing corrosion. The chemicals present inthe water greatly influence its effectiveness as an electrolyte.Corrosion is the deterioration of culvert materials by chemical or electrochemical re-action to the environment. Culvert corrosion may occur in many different soilsand waters. These soils and waters may contain acids, alkalis, dissolved salts,organics, industrial wastes or other chemicals, mine drainage, sanitary effluents,and dissolved or free gases. However, culvert corrosion is generally related towater and the chemicals that have reacted to, become dissolved in, or beentransported by the water. Corrosion can attack the inside or outside of the culvert barrel. The chemicals indrainage water can attack the material on the interior of the culvert. Culvertssubject to continuous flows or standing water with aggressive chemicals are morelikely to be damaged than those with intermittent flows. The exterior of culvertscan be attacked by chemicals in the ground water which can originate in the soil,be introduced through contaminates in the backfill soil, or be transported bysubsurface flow.Although less common than with metal pipe, corrosion can occur in concreteculverts. Metallic corrosion can take place in the reinforcing steel when it isexposed to cracking or spalling, when the concrete cover is inadequate or whenthe concrete is porous enough to allow water to contact the reinforcing steel.If the steel corrodes, the corrosion products expand and may cause spalling of theconcrete. Corrosion can also take place in the concrete itself. It is not, however, thesame type of electrochemical reaction that occurs in metal.

Abrasion: Abrasion is the process of wearing down or grinding away surface material as
water laden with sand, gravel, or stones flows through a culvert. Abrasive forcesincrease as the velocity of the water flowing through a culvert increases; forexample, doubling the velocity of a stream flow can cause the abrasive power tobecome approximately four-fold.

Soil and WaterConditions thatAffectCulverts

Certain soil and water conditions have been found to have a strong relationship toaccelerated culvert deterioration. These conditions are referred to as "aggressive"or "hostile." The most significant conditions of this type are:

pH Extremes: pH is a measure of the relative acidity or alkalinity of water. A pH of ٧.٠ is
neutral; values of less than ٧.٠ are acid, and values of more than ٧.٠ are are strongly acid andthose of ٨.٥ or more are strongly alkaline.Acid water stems from two sources, mineral and organic. Mineral acidity comesfrom sulfurous wells and springs, and drainage from coal mines. These sources contain dissolved sulfur and iron sulfide which may form sulfurous and sulfuricacids. Mineral acidity as strong as pH ٢.٣ has been encountered. Organic acidityusually found in swampy land and barnyards rarely produces a pH of less than ٤.٠.Alkalinity in water is caused by strong alkali-forming minerals and from limed andfertilized fields. Acid water (low pH) is more common to wet climates and alkalinewater (high pH) is more common to dry climates. As the pH of water in contactwith culvert materials, either internally or externally, deviates from neutral, ٧.٠, itgenerally becomes more hostile.

Electrical Resistivity: This measurement depends largely on the nature and amount of dissolved salts inthe soil. Thegreater the resistance the less the flow of electrical current associatedwith corrosion. High moisture content and temperature lower the resistivity andincrease the potential for corrosion. Soil resistivity generally decreases as thedepth increases. The use of granular backfill around the entire pipe will increaseelectrical resistivity and will reduce the potential for galvanic corrosion. The collection ofpH and electrical resistivity data during culvert inspections can provide valuableinformation for developing local guidelines.

Soil Characteristics The chemical and physical characteristics of the soil, which will come into contactwith a culvert, can be analyzed to determine the potential for corrosion. The
presence of base-farming and acid-forming chemicals is important. Chlorides andother dissolved salts increase electrical conductivity and promote the flow ofcorrosion currents. Sulfate soils and water can be

erosive to metals and harmful toconcrete. The permeability of soil to water and to oxygen is another variable in thecorrosion process.

Culvert ProtectiveSystems

There are several protective measures that can be taken to increase the durabilityof culverts. The more commonly used measures are:

Extra Thickness For some aggressive environments, it may be economical to provide extrathickness of concrete or metal.

Bituminous Coating This is the most common protective measure used on corrugated steel pipe. Thisprocedure can increase the resistance of metal pipe to acidic conditions if the coating is properly applied and remains in place. Careful handling duringtransportation, storage, and placement is required to avoid damage to the coating.Bituminous coatings can also be damaged by abrasion. Field repairs should bemade when bare metal has been exposed. Fiber binding is sometimes used toimprove the adherence of bituminous material to the metallic-coated pipe.

Bituminous PavedInverts

Paving the inverts of corrugated metal culverts to provide a smooth flow and toprotect the metal has sometimes been an effective protection from particularlyabrasive and corrosive environments. Bituminous paving is usually at least ٣ mm(١/٨-inch) thick over the inner crest of the corrugations. Generally only the lowerquadrant of the pipe interior is paved. Fiber binding is sometimes used to improvethe adherence of bituminous material to the metallic-coated pipe.

Other Coatings There are several other coating materials that are being used to some degree.

Polymeric, epoxy, fiberglass, clay, and concrete fieldpaving, have all been used as protection against corrosion. Galvanizing is the mostcommon of the metallic coatings used for steel. It involves the application of a thinlayer of zinc on the metal culvert. Other metallic coatings used to protect steelculverts are aluminum and aluminum-zinc.