CULVERT TYPE EVALUATION

LRRB
LOCAL ROAD RESEARCH BOARD

Report # 2023RIC06

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The TAP would also like to thank the following for providing valuable information:

- Minnesota Concrete Pipe Association (MnCPA)
- National Corrugated Steel Pipe Associations - North Central Region
- Plastic Pipe Institute

Introduction

There are three commonly used culvert types in Minnesota: concrete, corrugated steel pipe (CSP) and plastic. The latter is relatively newer. Therefore, Minnesota local agencies requested more insight on how to select a culvert type.

A literature search was conducted, and although there are several technical resources, most of them focused on design vs culvert selection. This report summarizes three areas to assist with culvert selection:

- A summary of culvert use/experience by Minnesota local agencies,
- input from industry representatives providing recommended use, and
- a list of resources and design guides for each culvert type.

The intent of this synthesis is NOT to provide recommendations, but to provide Minnesota cities and counties information, including links to resources, so that an agency can make their own decision on which culvert type is best for their context.

Summary of Minnesota Local Agency Use/Experience

A survey was conducted via State Aid to all Minnesota cities and counties in April 2022. The following information is provided as insight to the use, experience and opinions of Minnesota cities and counties with the various culvert types. **It is not intended as a recommendation.**

Attribute	Concrete	CSP	Plastic
Average Use (past 5 years) **Cities** **Counties**	54% 77% 47%	39% 21% 50%	7% 11% 11%
Reported performance	63% reported met/exceeded expectation	51% reported met/exceeded expectation 8% did NOT meet **Issues:** rusting/corrosive soils, shorter serviceable life	27% reported met/exceeded expectation 9% did NOT meet **Issues:** lack of strength/ crushed, joints, conflicts w/ utilities, ends damaged (mowing, grass fire),
Opinion on when to use	• At centerline/underneath paved roadways; especially high ADT • When needing "long lasting" pipe • Where cost to replace is high (deep) • Under heavy loads (minimal cover)	• Approaches • Gravel/secondary roads • Under driveways/trails/ parks • Shorter term installations • Clay soils	• When more than 2-feet of cover exists • Lower volumes roadways • Possibly in driveways/approaches • Non-ROW areas/green spaces • Drain tile/storm drainage
Opinions on when NOT to use	• Due to higher cost, low volume, non-paved areas, driveways/approaches, short term/temp situations • Areas of shifting soils (concerns w/joints) • Steep slopes (subject to scour) • Poorer soils (where heaviness will cause settlement)	• Under centerline/paved roads • Underwater, continually flowing water • Within corrosive soils • Areas of heavy loadings/ traffic • Deeper fills/cover areas	• Under centerline/paved roads • Shallow installations (less than 2-feet) • Where ditch burning occurs
Design process/ specification	MnDOT Spec 2501.503 MnDOT Drainage Manual MnDOT Concrete Manual CEAM HydroCAD	MnDOT Spec 2501.503 CEAM	MnDOT Technical Memorandum No. 22-04-B-02
Reported average cost	Relatively 2x CSP	Relatively ½ Concrete pipe	Little data, more than CSP, less than concrete
Lessons learned/ advice	• Install a clay plug under the inlet apron to block water from flowing under the culvert. • Tie, seal and wrap joints.	• Install sand/granular material around pipe. • Use newer coatings.	• Requires specific bedding (granular) and compaction as part of the pipe structure installation. • New (gray) materials perform better than older black materials.

Input from Industry/Vendor Representatives

Locations/situations for material consideration	Concrete	CSP	Plastic	Condensed Comments *(See following pages for full comments)*
Paved roads	●	●	●	
Gravel/secondary/low volume roads	●	●	●	
Approaches/under driveways	⊙	●	●	Concrete pipe is appropriate where heavy vehicles are present; may not be cost effective if only light loads.
Trails/parks	⊙	●	●	Concrete pipe is appropriate where heavier vehicles operate or where there are buoyancy concerns due to low cover.
Storm sewer (multi-node system, not just a catch basin and outlet)	●	⊙	●	Corrugation and coatings of CSP should be considered to optimize performance.
Under heavy loads Continuous heavy commercial truck/ag hauling and < 2 ft of cover	●	●	⊙	Consult with plastic pipe manufacturer representatives for guidance.
Deep fill/cover areas > 10-ft (high cost to repair/replace)	●	●	●	
Shallow installations < 2-ft of cover				See comment below.
Short term/temporary situations	⊙	●	●	Concrete pipe may be used effectively but may not be cost effective.
Underwater continually flowing or submerged	⊙	⊙	⊙	See comment below.
Corrosive soils (high alkaline)	●	⊙	●	CSP requires proper coating.
Clay soils (concerns w/shifting/ joints)	●	●	⊙	Recommend imported backfill material to be placed and compacted around plastic pipe.
Weak/poorer soils (pipe weight may cause settlement)	●	●	⊙	Engineers and manufacturers should be consulted for installations of plastic pipe in these conditions.
Where ditch burning occurs	●	●	●	Plastic pipes should not daylight into areas known to be fire prone. Non-plastic end sections are often placed to diminish the ignition potential.

● Strongly recommend, no concerns
⊙ OK to use, advise working with supplier
● Not recommended, explore other alternatives

Detailed Comments

(Industry/vendors were asked to supply comments when recommendation was ⊙ or ●)

Approaches/Under driveways

Concrete. Appropriate for approaches and driveways/entrances when heavy vehicles (e.g. construction vehicles or farm equipment in rural settings) utilize the entrance, especially when cover over the pipe is limited. However, designers may use a lower-cost pipe material if light duty loading is anticipated (assumes local soils are not problematic for a flexible pipe structure).

Trails/parks

Concrete. Appropriate for approaches and driveways/entrances when heavy vehicles (e.g. construction vehicles or farm equipment in rural settings) utilize the entrance, especially when cover over the pipe is limited. However, designers may see an opportunity to economize with use of a lower-cost pipe material if light duty loading is anticipated (assumes local soils aren't problematic for a flexible pipe structure) or where heavy equipment access may be limited.

Storm Sewer

CSP. Corrugation and coatings need to be considered to optimize performance.

Under heavy loads

Plastic. Corrugated plastic pipe can be used beneath heavy loads (AASHTO HL-93) with two feet of cover. Highway traffic loads (AASHTO HL-93) can also be accommodated with less than two feet of cover. As discussed under "Shallow installations" (below). Loads greater than HL-93 can often be accommodated with two inch or more additional temporary cover. For circumstances with heavy haul loads greater than HL-93, consult with manufacturer representatives for guidance.

Shallow installations

Each of the vendor's responses indicated cover depths lower than that recommended in the MnDOT Tech Memos (see below); when using culverts in shallow installations, it is recommended to work closely with the manufacturer. The following are MnDOT's Tech Memos for concrete and plastic culverts (none are found for CSP):

MnDOT Technical Memorandum No. 20-05-B-01 – Reinforced Concrete Pipe Load Tables

MnDOT Technical Memorandum No. 22-04-B-02 - Use of Plastic Pipe for Storm Sewer and Culverts on Trunk Highways

Short term/temporary situations

Concrete. May be used effectively in temporary installations where shallow cover, heavy traffic and construction loads are anticipated (e.g. temporary roads/detours built on or near the jobsite to circumvent a road repair). However, a designer may be inclined to use a lower-cost pipe to save money due to the temporary nature of this situation. NOTE: RCP may be a more financially viable option if the sections can be carefully removed and utilized elsewhere after their initial use.

Underwater

Concrete. This situation is not ideal for any pipe material as it is difficult to obtain proper grade, joint performance, soil placement, and compaction around the pipe. However, concrete pipe can be designed accordingly to account for lack of soil support. At the same time, it should be noted that for other apparent reasons, installation in these conditions should be avoided if it is possible.

CSP. Total submerged conditions would prompt an aluminized or polymer coated CSP.

Plastic. Dewatering would be necessary to achieve and confirm appropriate compaction density of backfill material. If adequately dewatered for installation, corrugated plastic pipe can be installed in high water applications. Review and input from manufacturers are recommended when considering equalizer pipes or configurations that may result in significant hydraulic pressure changes.

Corrosive soils

Concrete. Extremely durable in high alkali soils. Durability regarding alkali–silica reaction (ASR) and sulfate soils should be considered if there is a concern, although these aren't common in Minnesota.

CSP. Proper coating type needs to be selected to achieve optimal service life.

Clay soils

Plastic. To achieve the desired compaction densities with clay soils, often the moisture content must be monitored, and the lift heights must be smaller. Therefore, clay soils are not typically recommended for backfilling around corrugated plastic pipe unless needed for short stretches as a water barrier, and then with appropriate care. When the native soils are clay, this typically results in a well-formed trench and allows for the installation of an imported backfill material to be placed and compacted around the pipe.

Weak/poorer soils

Plastic. These materials are never appropriate for backfill around corrugated plastic pipe. When the native soils are weak or poorer, it is likely difficult to achieve a stable foundation or well-formed sidewall within an excavated trench. If corrugated plastic pipe must be installed in these conditions, typical industry practices include over excavation and fill with select granular materials or the use of geotextile products to enhance soil stabilization and bearing capacity. Engineers and manufacturers should be consulted for any buried structure installations in these conditions.

Where ditch burning occurs

Plastic. Generally, corrugated plastic pipes should not daylight into areas known to be fire prone. Proper design and maintenance reduce the potential harm to corrugated plastic pipes in fire prone areas. Dissimilar material end sections are often placed on corrugated plastic pipes to diminish the ignition potential. Regular maintenance is encouraged in fire prone areas to remove the collection of ignitable debris from the pipe end or end treatment.

When installing 24-inch diameter culverts, what equipment is needed (besides haul truck and backhoe)?

Culvert Type	Equipment
Concrete	Sling/straps for lifting the pipe with backhoe. Laser for maintaining line and grade during installation. Pipe puller (optional) to assist with pulling joints together. Mechanical compactor (aka "wacker packer") or similar equipment for compaction of the outer bedding and haunch area up to the concrete pipe's spring line.
CSP	Compaction equipment, socket or wrench and possibly a pry bar
Plastic	Push piece or sling to home pipe. Gasket lubrication for homing. Hand-compaction equipment (jumping jack, walk behind roller, plate compactor) where required. Knifing or spading clean crush rock can often achieve desired compaction levels.

When installing 24-inch diameter culverts, what crew size and skill is necessary?

Culvert Type	Crew Size	Skill
Concrete	2 min but 3-4 is typical for a 24-inch pipe install.	Experienced backhoe operator. Basic pipe laying skills for those in the trench (laying grade, installing joints, operating compactor, etc.)
CSP	2-3	backhoe operator, pipe layer and top man
Plastic	2 Laborers & Operator/ Foreman	Excavator operation, line & grade checks, joint prep and assembly, compaction techniques, trench safety

Under normal conditions, what is the estimated design life of a typical culvert?

Culvert Type	Estimated Design Life
Concrete	100 years
CSP	Galvanized 50 years, Aluminized 75 years and Poly-Coated 100 year
Plastic	75-100 years

Recommendations from the CSP Industry regarding uses of:

Pipe Material	Use
Poly-coated pipe	Suitable for highly aggressive environments.
Aluminized pipe	Storm sewer applications, longer design service life applications, corrosive soil situations, underground storm-water management systems. Suitable soil conditions for aluminized CSP are when the soil or water pH is between 5 to 9 and resistivity of 1,500 ohm-cm or greater.
Galvanized pipe	County road crossings, temporary by-passes, driveway entrances and where the expectation for soil or water pH is between 7 to 10 and resistivity of 2,000 ohm-cm or greater.

List of Resources and Design Guides

	Resource	Description	Type
Concrete	MnDOT's Tech Memo Reinforced Concrete Pipe Load Tables	Guidance on required strength class of concrete pipe for culverts and storm sewers	T
	American Concrete Pipe Association's LRFD Fill Height Tables	Was adopted by MnDOT into their Tech Memo - Reinforced Concrete Pipe Load Tables:	T
	Minnesota Concrete Pipe Association (MnCPA)	MnCPA assists with designs and construction specs; also provides seminars	PO
	MnDOT's Standard Specifications for Construction	Concrete pipe installation guidance – Section 2501 Culverts – Section 2503 Storm Sewers	T
	MnDOT's Pavement Design Manual – Chapter 3	Standard trench details for: – concrete pipe culverts (pages 25-27) – concrete pipe storm sewers (page 29):	T
	ASTM C1479 "Standard Practice for Installation of Precast Concrete Sewer, Storm Drain, and Culvert Pipe Using Standard Installations	Provides installation guidance for concrete pipe culverts and storm sewers	T
	Concrete Pipe and Box Culvert Installation Manual	American Concrete Pipe Association (ACPA) -ebook	PO
CSP	Corrugated Steel Pipe Design Manual	Design manual for corrugated steel pipe	PO
	NCSPA Installation Manual for Corrugated Steel Pipe	Installation manual for corrugated steel pipe	P0
	National Corrugated Steel Pipe Association	Website with resources/calculators	PO
	Contech Engineered Solutions – web resources	Interactive brochures Knowledge Center – design guides/webinars	V
Plastic	Corrugated Plastic Pipe Handbook	Drainage handbook from the Plastics Pipe Institute	PO
	Advanced Drainage Solutions – web resources	Engineering resources	V
	Prinsco -web resources	Culvert Installation Guide Stormwater installation Guide Structures Design Guide	V

T – Technical Resource

PO – Professional or National Organization

V – Vendor Provider

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