Solutions to Failing Culverts

Written by Jennifer Harrell, PE, American Concrete Pipe Association, in conjunction with her presentation at the 2022 Pipe School's Poster Session. See Jennifer's poster here.

Some recent failures have been catastrophic as highways, local roads, and life-saving evacuation routes collapse without warning. With today's economic realities, it is more important than ever to closely evaluate these failures and develop long term, cost effective, site appropriate, sustainable, and resilient solutions. To do this it is necessary to consider the fundamental modes of culvert failures, considerations with each failure and how to choose the best solution.

First, let us look at why culverts deteriorate and fail. For all installed structures, culverts have a given lifespan starting at their time of installation depending on the condition when installed, the material it is made of, if it was accurately designed and installed based on the type of culvert, environmental factors and of course, if it was constructed correctly based on the engineering design and requirements for the particular culvert. Below are a few reasons a culvert could fail:

- Dead and live loading on a culvert more than the design capacity of the structure or increased loading due to increased amount of soil or groundwater elevations causing cracks greater than 0.10" or slabbing in RCP culverts
- Improper bedding or cover can also cause slabbing in RCP
- Deflections in flexible pipe can be caused by dead and live loads exceeding the pipe material and engineered structural soil envelope design capacity, increased loading due to increase in the amount of soil placed on top of culvert or increase in groundwater elevations. Construction equipment loading during construction. Improper installation of haunching, backfill and compaction. Loss of soil through joints or walls of pipe and loss of materials around the culvert.
- Environmental factors which cause deterioration and corrosion of inverts include stream bed loads, abrasive materials and chemicals entering the system, pH of the water, pH of surrounding soils
- Improper homing and seating of culvert joints during installation, movement of culvert due to slope erosion, improper or lack of proper end sections and treatments, settlement, structural degradation, deflection, and buoyancy can cause joint separation and infiltration of soil.
- Culverts damaged during installation by equipment or rock indirect contact with culvert, environmental stress and material break down in strength due to aging causing cracks or fractures in flexible culverts
- Another cause is fire damage or incineration due to fire.

These reasons should be considered when observing the deteriorated or failed culvert and can be used to assist in observation and decisions to rehabilitate, repair or replace the culvert. Observations should be well documented when evaluating a deteriorating culvert. Potential evaluation considerations:

- Is it a squatted pipe and what is causing it to deflect.
- Are there circumferential changes, buckling or collapse of the culvert
- Has it lost its capacity or function.
- Has it lost its structural strength either in the rigid structure or if flexible is the structural soil envelope failing and why
- Is there a sag in the system that is causing it to not function properly.

- Is the backfill/bedding eroded.
- Are there any environmental factors affecting the system.
- Will there be any impact on hydraulics and or velocities if a liner is used.
- Are the existing system currently undersized or other factors affecting the system that was not there when initially designed. Changes in land use, precipitation rates, water elevations
- What axial thrust/jacking forces will there be and the effects on the system.
- Any joint separation or holes in the walls
- Other utilities installed through the culvert or causing damage to the culvert
- Has the invert eroded and losing its capacity to discharge water effectively.
- Has the water entering the culvert able to penetrate the bedding and backfill under and around the culvert.
- Has the material in and around the culvert dislodged, undermined or washout occurred

Choosing a solution should be site specific. Culvert characteristics may point to one repair method, but hydraulic updates, changes and needs may direct you to another solution. The keys are to first understand the conditions leading to the deterioration or failure of the existing culvert and secondly observations and considerations affecting the culvert in its present stage. It is also important to determine the most cost effect culvert repair method. Several factors need to be considered including design capacity, design life, environmental impact, increased structural integrity, adaptability, resilience and sustainable, construction time, permitting & regulatory issues, contractor availability, cost to the community and total estimated cost of the project.

One solution has always been the open cut method of digging up the old structure and roadway, removing the damaged culvert and replacing with a new more resilient structure. This method typically does take more time, requires road closures and detours that has a social cost for disrupting people's lives. A trenchless repair options is tunneling where Jacking Pipe would be used to tunnel around the failed culvert with a larger diameter pipe resulting in an increased hydraulic capacity and new structural integrity. Other trenchless options would be rehabbing the culvert with either lining, cured in place or spiral wound liner or sliplining just to name a few.

This article has shown there are several elements or mechanisms of culvert failure that work in concert to affect the total failure of the culvert. Flexible culvert system replacement must address the complete structure including pipe and supporting structural material. Ultimately failure of culverts is due to corrosion and the degradation of the structural soil envelope. The solution to a failing culvert that is reliant on the structural soil envelope is replacement of the failed structural soil envelope. If we are determined not to repeat history, including being the most economical regarding life cycle costs, the culvert needs to be replaced with a long design life culvert that does not depend on the structural soil envelope for strength. Many culverts, whether they are federal, state, or local, and located in high traffic areas or in deeper fills. Rehabilitation of these culverts has become a national problem, as there are few alternatives that do not impact traffic flow. Traditional tunneling methods have been found to be an effective and economical method of removal and replacement of failing culverts. They address both the damaged surrounding structural soil envelope and the culvert material and also allows the owner to upsize the existing capacity. Tunnelling allows for the replacement of the existing pipe and can be a solution to utility conflicts that open cut methods might have. Tunneling creates a new structure with a new long design life material and a very long-life expectancy.