Failing Culverts – Solution Options

with special attention to the option of replacement by tunneling

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Introduction

Since corrugated metal pipe (CMP) was first introduced for culvert applications, untold miles of CMP have been installed across the country. These original (and more recent) culvert installations are now failing at an alarming rate and any failure can cause untold damage. State DOT's (Department of Transportation) are increasingly facing the challenges of deteriorating culverts, both concrete and CMP. DOT officials and maintenance engineers face a daunting task of maintaining failing infrastructure. The inconvenience to the public must be as minimal as possible during replacement or rehabilitation. The long-term interests of the public sector must be balanced between the immediate cost and the longest design life materials. This paper will discuss: first create a list of options for a failing culvert and second look closely at the option of complete replacement with same size or larger size pipe. This paper deals primarily with failing CMP, however the options and the replacement methods and materials can be used for other failing materials as well as square, rectangular or oval shaped structures.

Methods of Failure

The first step in deciding on a solution is determining the reasons for failure of the culvert. Several questions have to be answered:

- Is the existing culvert sized appropriately or is more capacity needed?
- Is the culvert invert damaged?
- Has the pipe diameter or shape changed in any way?
- Has the bedding material immediately adjacent to the pipe retained its structural integrity?
- Is there flow outside and around the culvert?
- Is there any settlement or pavement distress apparent at the ground surface above the culvert?

Normally as a CMP deteriorates the protective galvanized coating corrodes/erodes leaving the steel pipe, which over time rusts away as shown in Figure 1. This commonly occurs at the pipe invert. As the invert deteriorates a phenomenon occurs where the surrounding soil pressure forces the pipe to turn inward at the invert and "close up". This is sometimes known as "buckling". This effectively reduces the pipe circumference.

These conditions have a negative impact on the pipe bedding material, which loses structural integrity as it erodes under the damaged invert and around the damaged pipe. Hydrostatic pressure at the upstream end of the culvert can also cause ground water to flow through the bedding. This can wash the bedding material out from around the culvert's circumference. These conditions can also occur at the pipe seams as is shown in Figure 2. Settlement will occur above the culvert as the bedding material erodes. Figure 3 on the next page, shows extreme local settlement over a culvert under a roadway.

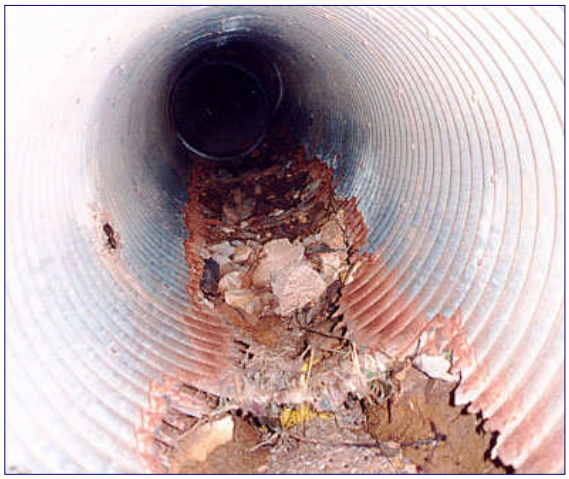

Fig 1. Deteriorating Corrugated Metal Pipe (CMP).

Fig 2. Corrugate Metal Pipe (CMP) coming apart at the seams.

Settlement is not always a slow and gradual process. Sometimes long heavy rains or other causes of extreme flow cause catastrophic failure of the culvert. Figure 4 shows just such a case.

Figure 3. Extreme Settlement Over a Culvert.

Figure 4. Sudden Catastrophic Failure of a Culvert.

Other Important Considerations

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The rehabilitation process relies on improved hydraulics to improve the storm drain capacity whereas as tunnel reconstruction relies on a larger cross sectional area. The capacity of the storm drain pipe may be an issue if FEMA requires the storm drain to be upsized from a 25- or 50-year flood event to a 100-year flood event. This in not an uncommon reaquirement when using Federal money or on Federal related projects.

The Agency that owns the culvert or their engineer must consider several possible environmental events when selecting a carrier pipe material. Some of these events are wildfire, traffic accidents, and flooding. These considerations should include addressing the the structures required to protect the upstream and down stream ends, Some pipe materials may burn in a fire and others may float is a flood, with both events causing a failure of the storm drain

Solution Options

Figure 5 presents solution options for failing culverts. Situations for which open cut replacement is an option exist but are rare. More often trenchless methods are employed to either replace or rehabilitate the deteriorating line. The trenchless options are lining, sliplining, and replacement with standard tunneling methods.

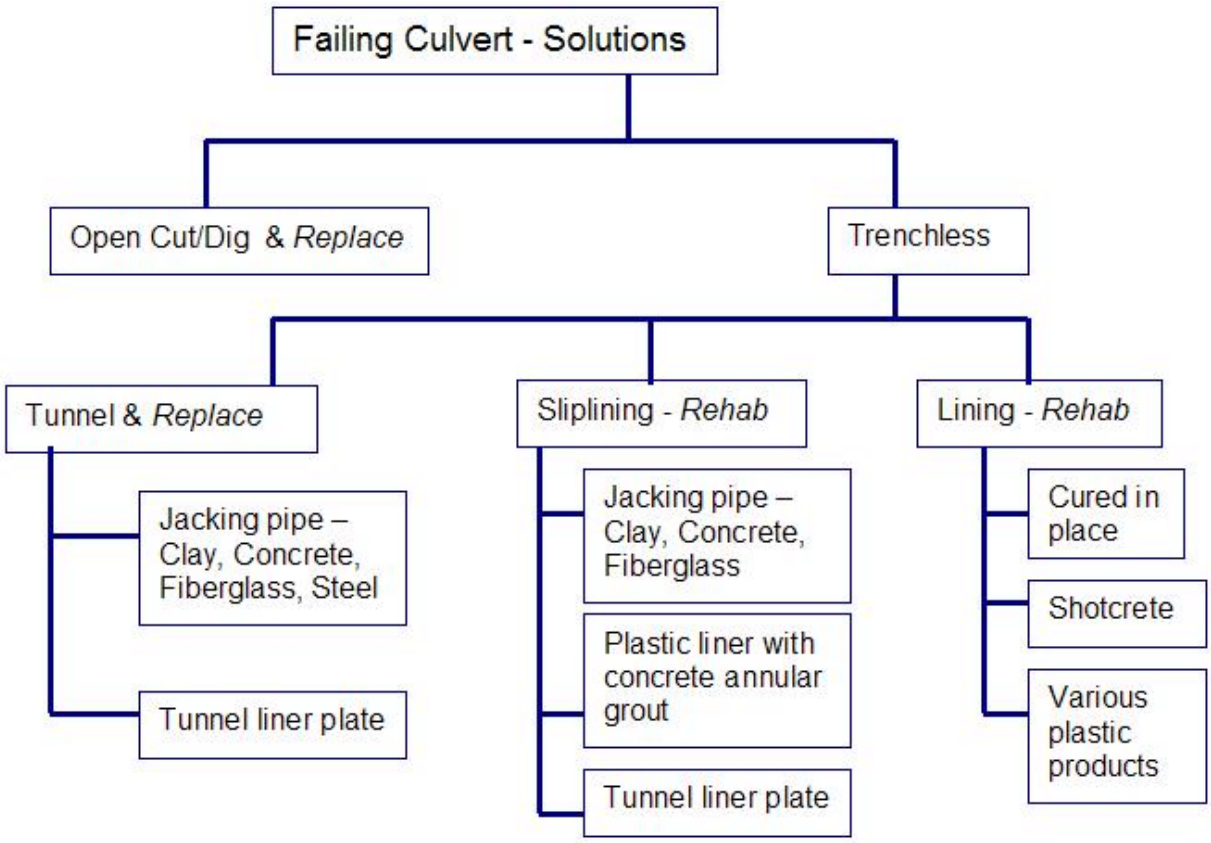

Figure 5.

Lining – Lining is a trenchless *rehabilitation* method. The North American Society for Trenchless Technology defines lining as – "A rehabilitation process where a length of material is introduced to extend the life of the existing sewer. The lining may or may not utilize some structural strength from the existing sewer; and it may or may not function as a structural enhancement".

Sliplining – Sliplining is a trenchless *rehabilitation* method. The North American Society for Trenchless Technology defines sliplining as – "A rehabilitation technique covering the insertion of one pipe inside an existing pipe." When sliplining, the annular space between the old pipe and the new pipe will always be grouted. When a thick annular space grout is required, care must be taken to ensure that the new pipe does not float up in the host pipe. Care must also be taken to ensure that 1) the new pipe does not collapse under the pressure that is developed when grouting and 2) the heat of hydration of the grout does not cause deformation of the new sliplining pipe.

As with lining, sliplining reduces the flow capacity of the culvert. The degree of under sizing depends upon the condition of the culvert. Partially collapsed culverts will have to be severely undersized to accommodate the collapse.

Tunnel and Replace – Normally when the method of tunneling is mentioned, the expectation is that it will be the most expensive option. This is often not the case. Tunneling through an existing pipe requires less material removal and therefore less time.

The replacement may be with conventional jacking pipe materials – such as clay, steel casing, polymer concrete pipe, or concrete pipe (see Figure 8) – or the replacement may be with tunnel liner plate. In either case it is always possible to replace the existing pipe with the same size culvert or a larger culvert of greater flow capacity. The deteriorating culvert is replaced as the tunnel is excavated. Figure 11 shows the removed culvert of a typical tunnel and replace job.

Figure 8. Tunneling with Concrete Pipe.

Figure 9

Before **After**

Figure 10

The extent of the deterioration can be seen in some of the pipe laying on the ground in the picture to the right. The existing pipe was cut and then pulled out as the new pipe was advancing through the tunnel.

Figure 11. Culvert Removed From a Typical Tunnel and Replace Job.

It is important to compare the two different tunneling methods: replacement with jacking pipe and replacement with tunnel liner plate. Jacking pipe is appropriate when the job can accommodate a jacking pit. Since many culverts start at ground level on both the upstream and downstream ends, the use of liner plate is appropriate when a jacking pit is not available.

The following is a brief comparison of the two solutions. (Jacking pipe below and liner plate on the next page).

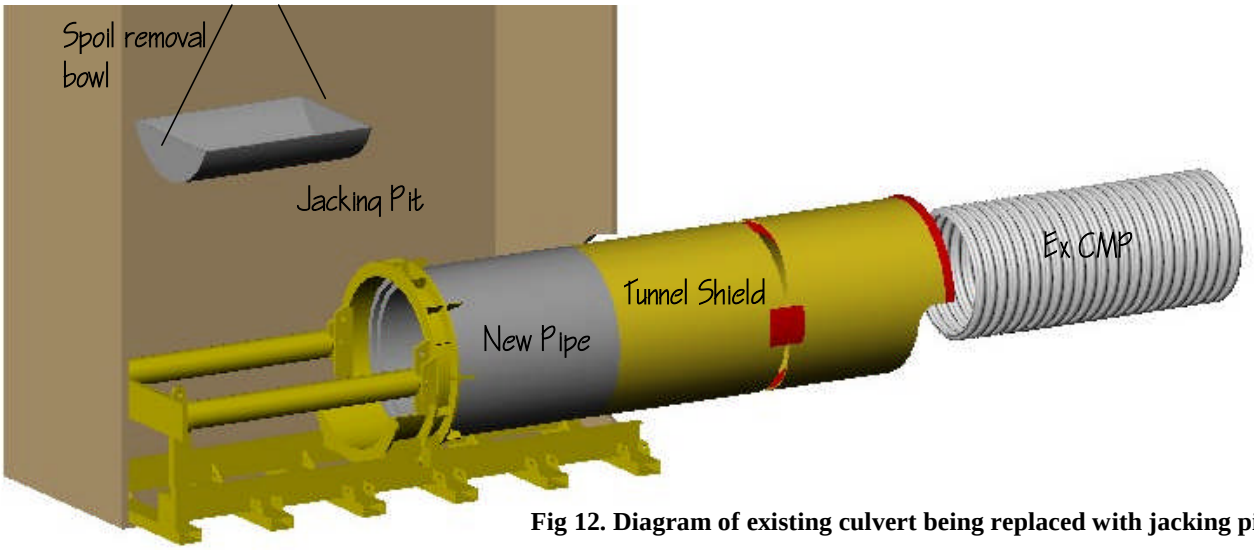

Fig 12. Diagram of existing culvert being replaced with jacking pipe.

The following details characterize conventional tunneling with jacking pipe:

- New pipe is jacked segment by segment as the men remove the existing culvert in pieces and excavate any face material, both within a protective shield,
- The shield has steering capability to maintain grade,
- The jacking unit is substantial and requires a sizeable work pit, - see Fig 12 above.
- The jacking unit must have a stable backstop to push against,
- Jacking a pipe column requires the use of a lubricant. This lubricant will help in reducing the skin friction that the column will generate. The longer the column of new pipe, the more important the use of lubricant becomes.
- When the new pipe is in place – the annular space must be grouted.
- The Jacking pipe materials available for this option include – clay, polymer concrete, concrete and steel.

Figure 13. The photo above shows steel casing being used.

Figure 14. The photo above shows concrete jacking pipe being used.

Tunnel Liner Plate

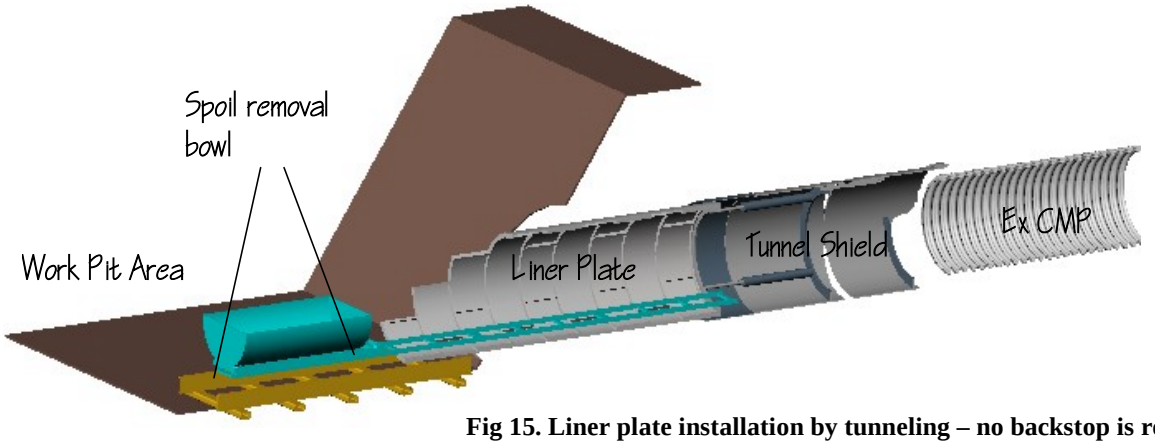

Fig 15. Liner plate installation by tunneling – no backstop is required.

The following details characterize a replacement with tunnel liner plate:

- The new liner plate is installed one ring (typically 16" long) at a time as the tunnel is advanced,
- The crew removes the culvert in pieces and excavates as necessary, both within a protective shield,
- The shield is advanced by hydraulic cylinders located in the shield that push off the most recently assembled liner plate ring,
- The shield has steering capability to maintain grade,
- Installation does not require a jacking unit,
- The work area must be long enough to launch the shield and to allow for the safe entrance and exit of the men and materials,
- Liner plate installation does not require a lubricant.
- The installed liner plate must be grouted at the end of each shift or workday.

Liner plate can be as thick as three eights of an inch. It can be galvanized and coated with different coatings such as coal tar epoxy. In areas where a concrete pipe is needed the liner plate tunnel can be large enough to accommodate the insertion of concrete "carrier pipe".

There is one other option worth noting here – the finished liner plate tunnel can be lined with reinforcing steel or mesh and then shotcreted with a concrete liner so as to create a continuous concrete pipe.

Figure 16. The photo above shows two rings of liner plate assembled on the launch track, ready to be lowered into the pit. This short assembly will be used for the initial launch of the shield.

Figure 17. Here we see a tunnel underway with 48" liner plate.

A word about other materials and non-circular shapes.

When the existing culvert is reinforced concrete pipe or reinforced concrete box culvert, the same tunneling options apply. The old pipe material must be removed and the hole excavated as necessary to allow the new pipe or box structure to be jacked into place. New box culvert suitable for jacking is available in both reinforced concrete and polymer concrete.

If there is no jacking pit available - liner plate can be used, as it is available in horseshoe shaped configurations.

The jacking equipment and /or shield can easily be configured to accommodate the material and shape chosen.

Conclusion

With the new economic realities that we all face, it is now even more important that the public sector maintain the infrastructure. Now more than ever, there is not enough money to replace the road because the pipe under it has failed. While the public is less willing to pay more in taxes or user fees, the public is even less willing to see the infrastructure fail.

Since corrugated metal pipe (CMP) was first introduced for culvert applications, untold miles of CMP have been installed across the country. These original - and more recent - culvert installations are now failing at an alarming rate and threaten our nation's roads. State DOT's, counties, as well as local cities and towns are increasingly facing the challenges of deteriorating culverts, both concrete and CMP.

We have tried to show that there are a number of appropriate options available. We have tried to give special attention to the replacement option.

If you have any questions or would like to discuss any of the material presented here, please contact us at

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