Technical Note 11 – Effect of Pipe Linings and Patch Repairs on Seismic Performance

Contents

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1 Background

Many gravity pipelines and some pressure pipelines are lined to restore or improve performance in normal service. Local patch repairs may also be used in gravity pipelines.

The majority of lining and repair systems have different characteristics to those of the host pipe that has been lined. The lined system then behaves as a composite system. This paper explores the effect of linings and patch repairs on seismic performance of pipelines. The emphasis is primarily on gravity systems since these are most commonly lined or repaired, but some of the findings will also apply for pressure systems.

This note is largely theoretical as there are very few observed cases of lined pipelines being subjected to earthquakes and only limited testing has been conducted on lined pipeline systems.

2 Linings

Linings are typically installed from manhole to manhole to form a continuous new pipeline inside the existing (host) pipe. While they may be secured at the ends with a sealing adhesive, a lining will usually be secured mainly by frictional interaction with local surface irregularities, and by mechanical interlock over joints and lateral connections. However, as noted below, patches are usually strongly bonded to the host pipe.

The majority of linings used in gravity sewers are Cured In Place Pipe (CIPP) or Spiral Wound Pipe (SWP), although slip lining is sometimes used.

CIPP is usually formed from a felted or woven fabric tube that is impregnated with resin and then inserted into the cleaned host pipe. It is then pressurised with water or steam to force it against the inside of the host pipe and cured using heat (hot water or steam) or Ultraviolet lamps.

Spiral Wound linings are formed using one or more strips wound into a tube using a special winding machine. They are often grouted in place.

Sliplining requires a thermoplastic pipe (PVC or PE) to be inserted into the host pipe. Because sufficient clearance is needed to allow installation, slip-lining can substantially reduce carrying capacity. The gap between host pipe and lining pipe is usually grouted.

Close fit lining is a variant of slip lining in which the thermoplastic pipe is deformed to aid installation – usually by folding into a U or C shape to improve flexibility and reduce effective diameter. After installation, the deformed pipe is pressurised with cold water, hot water or steam to re-round it.

A close fit can also be obtained by stretching the pipe (die drawing or swagelining) or by compressing the pipe to temporarily reduce the diameter (rolldown), but these techniques are mostly intended for use in pressure systems are not currently used in New Zealand.

3 Patches

Repair patches are intended to make good localised damage, typically over a single pipe length. They are typically 1.2 or 2.4 metres long formed of a felted or woven fibre mat impregnated with resin. Because the (polyester, glass or carbon fibre)

Some are ambient cure, in which case the resin is intended to cure without any additional heat input, but they may be heat or UV cured. Heat and UV cure usually provides a more consistent end product but can be more demanding to install. Patch repairs are intended to be securely bonded to the inside of the repaired pipeline and the bond strength has to be high because the bonding length is relatively short.

4 Lined Systems

The typical lined pipeline system is concrete with frequent rubber-ring joints that have low resistance to tension and a typical deflection tolerance of around 0.5 to 1.0 degree per joint. In contrast, the lining system is a continuous flexible pipeline. A rigid segmented system is thus typically lined with a flexible continuous pipe to form a composite system.

4.1 Response in Tension

When put into tension, the segmented pipe joints separate, but the lining will either stretch or disconnect at one or both ends. This means that in some cases, a lined pipe will be more tolerant of tensile displacement during shaking and to permanent displacement than an unlined pipeline.

Since CIPP linings are usually only weakly bonded to the host pipe, and often only have localised bonding in places in conjunction with a friction fit at changes of section (eg laterals, joints, surface irregularities). If the bonding is weak, separation of a joint can be born across an extended length of lining, so the likelihood of a lined pipeline withstanding moderate displacements is increased.

Similar behaviour can be expected from a deformed thermoplastic lining, since they too are flexible and continuous and are weakly bonded t the host pipe.

The behaviour of SWP is less clear, since the behaviour of the joints between the strips could act as a potential weak point that could trigger extensive failure, much as is seen in lap welded steel pipes which can unzip along the lap weld.

Limited testing on small diameter PE service pipes indicates that under tension a grouted lining would most probably detach from the grout as it cracked and that the lining would then be free to deform.

However, the longer term stability of an intact lining may have been compromised since it is no longer fully supported by the host pipe, especially at any pulled joints.

4.2 Response in Compression

When the host pipe is put into compression, the joints will take up any available slack and then attempt to transfer displacement to the next joint. If the lining is not bonded to the inside of the host pipe, the host pipe may compress around it, which may result in the lining being partially displaced into one or both of the manholes it connects.

If displacement cannot be transferred down the line, either the spigot or socket will fracture. If the lining is a close fit with the host pipe, the lining will usually buckle, but could potentially transfer compressive displacement along its length, eventually causing displacement into the manhole. In some cases the buckled lining will remain substantially intact, meaning that the lined pipeline is more durable than the host pipe.

As in tension, a weakly bonded pipeline has greater capacity to accommodate any deformation in compression, so wrinkling or buckling can be expected.

4.3 Response in Bending

When a lined pipeline is placed into bending, the lining will experience tension and compression at different locations. Local buckling and deformation may occur but complete failure is less likely than in an unlined pipeline as the lining provides some ability to accommodate local deformation without failure.

5 Patch Repairs

5.1 Response in Tension

In most cases, patch repairs are restricted to a single pipe length or across one joint. If there is any separation of the repaired section, then assuming that the adhesive bond to the host pipe remains intact, any separation will be borne by a very small section of the patch. Failure by overstraining is likely in this case. If, however, the adhesive bond can be partially released, the displacement is accommodated in a longer load-bearing section. In the extreme case, full debonding would destroy the integrity of the patch.

Tightly bonded patches are therefore less accommodating of displacement than patches that can partially disbond over a moderate distance.

5.2 Response in Compression

Because the patch is relatively short, there is limited capacity to wrinkle or buckle in compression. If the pipe joint or repair section fails, debonding or buckling failure is likely. As with tension, partial debonding will increase the capacity to accommodate buckling by increasing the available load-bearing section, but full debonding will destroy the integrity of the patch.

5.3 Response in Bending

The patch will not normally experience bending when it is within the barrel of a pipe since the joint is more flexible than the pipe barrel and will move first. A patch across a joint could experience limited bending, but once the joint failed, the small scale of the patch would restrict its ability to accommodate resulting displacement.

5.4 Observed Behaviour

There are very few cases where the behaviour of patched and lined pipelines have been directly observed before and after a seismic event. There are reports that a CIPP lined brick sewer suffered partial collapse of a wall in one of the 2011 Christchurch events, but that the lining prevented complete collapse.

Large-scale physical testing at Cornell University has demonstrated that linings can accommodate some forms of lateral displacement and appear to provide seismic strengthening to lined pipelines.

6 Summary

CIPP linings have potential to improve the seismic resilience of segmented pipes and brick-barrelled pipes since the weak bonding allows tensile strains to be accommodated within a substantial length of lining. While they may buckle under compressions, failure is also unlikely because of the weak bonding with the host pipe.

Some other continuous lining systems have potential to improve the ability to accommodate tensile and compressive displacements,

In contrast, the relatively short length of the patch and tight bonding to the host pipe limit the ability to accommodate tensile and compressive strain. While partial debonding from the host pipe can increase this ability, excessive debonding can destroy patch integrity.

7 References

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