Corrugated Metal Culverts – Durability in New Zealand Conditions

Corrugated steel pipes have been used for culverts in the United States since 1886 and aluminium pipes since the early 1960s. They have proven to be convenient, easy to install and generally more cost-efficient than concrete culverts. To improve the durability of metal culverts coatings like asphalt, concrete and - more recently, epoxy/polymers - have been applied. This summary introduces CSP Pacific's range of Multiplate structures and outlines the methods for predicting the service life of corrugated metal culverts (both uncoated and coated) in various environmental conditions - with a particular focus on the New Zealand experience.

Mechanisms of metal culvert deterioration

Environmental deterioration of metal culverts is, broadly speaking, caused by three mechanisms:

Soil-side corrosion which refers to the attack on the outside face of the buried culverts caused by soil contact. Both zinc and aluminium form protective films of oxides when exposed to corrosive conditions. These films will dissolve and re-form at a rate dependent on the nature and severity of the environmental attack. In a galvanised steel culvert, once the layer of zinc has been lost, the corrosion of the steel wall progresses more rapidly which is why aluminium culverts typically outlast galvanised steel in similar environmental conditions. The durability of the outside face of culverts can be extended by applying additional coatings. Cohesive or water-logged backfill material accelerates culvert corrosion.

Water-side corrosion affects the internal surface of the water-carrying metal culverts. Same as for the soil-side corrosion, aluminium tends to perform better than galvanised steel and additional coatings have been successfully used to extend the service life of culverts. The internal surface of culverts, above the water line, is typically less affected by corrosion than the section of walls in contact with water. The chemical composition of water flowing through the culvert affects the rate of water-side wall corrosion.

Invert abrasion is caused by the solid particles (typically gravel and rock) transported by water. Aluminium tends to have better abrasion resistance than galvanised steel because, being a softer metal, it tends to absorb the impact of aggregate without chipping. Also, the corrosion resistance of aluminium is in-depth while steel deteriorates quickly once the protective layer of zinc has been stripped by abrasion. Durable coating layers like asphalt paving, epoxy/polymers or concrete enhance the abrasion resistance of metal culvert walls.
The majority of culverts deteriorate starting from the invert, where water-side corrosion combines with abrasion to create a particularly aggressive combination of environmental conditions. For this reason invert coating is usually the most economical way of extending the service life of culverts.

Assessment of environmental corrosivity

The two main predictors of the severity of the environmental attack on metal culvert walls are the concentration of hydrogen ions pH and soil resistivity governed by the presence of chloride/sulfate ions. Other chemical elements affecting the durability of metal culverts are calcium (in the form of CaCO3), which slows the corrosion rate of steel, and heavy metals which are particularly detrimental for aluminium. Soil resistivity and pH index can be measured on site or in the laboratory to help designers specify the right product to achieve the required service life. Since abrasion greatly accelerates invert corrosion, it must also be taken into account.

The pH readings and soil resistivity can be combined into one graph to indicate the expected service life of metal culverts in any particular environmental conditions. In this approach the end-of-life is defined as either the loss of say 25% of the culvert wall thickness to corrosion or as local perforation. Alternatively, tabled information or formulae describing the rate of wall thickness loss can be used by designers.

‘Sacrificial wall thickness’ durability design

Strength checks in the AS/NZS 2041.1:2011 ‘**Buried corrugated metal structures’** standard are based on the residual thickness of the culvert wall at the end of design life. This means that some wall thickness can be lost to corrosion (sacrificed) without affecting the safety of the structure. The same approach is used in the design of other structural elements in soil contact such as steel piles or pipelines, but culverts showing surface corrosion are often viewed as failing. This perception is based on everyday experience with steel components painted for aesthetics. Culverts are different in that their appearance is secondary to function which is why ‘sacrificial wall thickness’ has been commonly adopted as the most cost-efficient design approach.

If aesthetics is a consideration, aluminium culverts are a better option than the galvanised steel product, as aluminium oxidation looks similar to metal so does not have a ‘rusty’ appearance.

CSP Pacific culvert durability design

To comply with the New Zealand legal framework and NZTA F3:2010 '**Specification for pipe culvert construction**' document CSP Pacific culverts are designed to AS/NZS2041.1:2011 'Buried corrugated metal structures' standard. This includes strength checks for the residual (end-of-life) culvert wall thickness as well as compliance with the material suitability and invert protection provisions in Table 3.4. For added protection, the CSP Pacific **Multiplate 100+** premium product range designed for corrosive environments features both the 'sacrificial wall thickness' code allowance and full epoxy/polymer coating on both faces.

CSP Pacific's NEW online culvert selection and pricing tool

To assist culvert designers in choosing the right product to meet the durability requirements of a particular project CSP Pacific has developed a convenient online design tool. Based on the environmental conditions on site (as assessed and input by the culvert designer) the tool selects the CSP Pacific culvert material and trim to achieve the required design life. The price generated by the online tool is indicative only and does not include non-standard features like bevels, skews, elbows, risers etc. **Cick here** to access CSP Pacific's culvert selection and pricing tool.

Bibliography:

1 NCSPA '**CSP Durability Guide'**, May 2000
2 NCSPA '**Invert Abrasion Testing of CSP Coatings'**, March 2002
3 California DOT '**Development of New Corrosion/Abrasion Guidelines for Selection of Culvert Pipe Materials**', November 2009
4 AS/NZS2041.1:2011 **'Buried Corrugate Metal Structures'** standard
5 NCSPA '**Pipe Selection Guide'**, 2010