Asset Reinvestment Review Working Group

Line Reinvestment Process

April 2022

Public

Purpose

The purpose of this document is to provide a high-level overview of the process that Powerlink applies to identify and assess the need to take corrective action on its transmission lines. In particular, this includes where we undertake line reinvestment.

Introduction

Powerlink transmission lines use three structure types: lattice steel, concrete pole or steel pole. The network includes approximately 22,000 lattice steel structures, 2,000 steel poles and 1,000 concrete poles. The dominant cause for defects and failure for transmission line components at Powerlink (if not addressed in an appropriate timeframe) is corrosion.

Lattice steel structures are composed of galvanised steel members (categorised as heavy or light depending on their size) as well as fixtures and fittings (including nuts and bolts). Structure sizes can vary markedly with the larger structures containing up to approximately 600 members and 3000 nuts and bolts.

Having to manage more than 25,000 structures, it is not efficient or practical to regularly monitor individual structure condition. Therefore a fleet maintenance approach is required using sampling techniques.

Overview of Powerlink line reinvestment process

The processes and systems which Powerlink use to determine the most appropriate timing for aged transmission line reinvestment can be viewed at different levels of detail. At a summary level, Powerlink uses a Health Index (HI) system to record condition against individual structures (where information is available) and the overall line, and forecasts the point in time at which individual structures will transition from acceptable to unacceptable condition (primarily due to corrosion). Structure condition HI scores are aggregated to give an overall Asset Health Index (AHI) for the transmission line, and the point at which the overall line will exceed a threshold AHI value of 8 is deemed to be the need date for some form of action to ensure the ongoing security, reliability and performance of the line (explained further below).

Depending on a number of factors including the size and location of the transmission line, the adequacy in terms of long term capacity, the criticality, and the availability of outages, a number of options may be available to address condition issues.

A capital project is undertaken for a significant life extension (a refit). A refit typically extends life by 10 to 20 years. The scope of work carried out typically includes rectification of all condition issues which are likely to lead to a failure within the life extension period (i.e. to achieve a minimum condition), and the update of any aspects of the line which are considered to be a requirement under safety or any other legislation. For safety related work all structures are generally included in the scope of work where a cost effective solution is available. The range of options including project solutions increased maintenance and a “do nothing” option, are compared using NPV and economic modelling to ensure the most cost effective, compliant solution is selected.

Process in greater detail

At a more detailed level, the process for line reinvestment described above requires and contains a large number of sub-processes in order to:

1. Collect regular detailed condition data from transmission lines, particularly for structures
2. Process and analyse large quantities of data to produce meaningful aggregated scores for individual structures and lines
3. Determine and monitor rates of deterioration so that condition forecasts will be accurate
4. Monitor risk and identify emerging risks as a result of the coincidence of deteriorating condition and risk exposures
5. Visualise and communicate future needs, and carry out additional actions to initiate a project or the collection of additional information to minimise uncertainty
6. Develop the project options and associated scopes of work to ensure that all required work (due to either condition or legislative requirement) is included, while identifying sections where no work is necessary.
7. Evaluation of all options to determine the lowest long-run, compliant cost option.

Each of these sub-processes can also be broken into discrete steps, as described below.

1. Collect condition data from transmission lines, particularly for structures

Condition information from transmission structures and lines is collected by various inspection means including ground patrols, aerial (helicopter) patrols, climbing inspections, and unmanned aerial vehicle (UAV) inspections. This level of detailed inspection is additional to patrols which identify short term defects (for example a damaged tower leg from collision with a tractor) and are intended to identify intermediate and developing issues.

Inspections typically record corrosion levels (in four categories G1 to G4) on all parts of structures, as well as the condition of insulators, hardware and earth wires, on a sample basis (5%), starting from expected half-life (around 20 to 25 years old). Details are found in Appendix 1 of this document. The system used for detailed structure and line inspection is called the Lines Asset Measurement Point (LAMP) system, as data is transferred into Powerlink's SAP database in a semi-automated process and is stored as a series of Measurement Points.

2. Process and analyse large quantities of data to produce meaningful aggregated scores of individual structures and lines

Structure corrosion level data and other component condition data collected by field inspections as described above and recorded as Measurement Points in the SAP database is processed by a separate application using in-house developed algorithms to condense approximately 50 Measurement Points for any one structure, into a HI score for the structure body, foundations, insulators (including hardware), and the earth wire. Once calculated these HI scores can be visualised on mapping and dashboard platforms, and analytics and data metrics systems used to identify trends. While HI scores are calculated for other components, the examples used in this overview are mainly for structures, which are more important for determination of capital intervention need timing.

Health Indices for a single structure can theoretically range from 0 to 16, although the normal operating range is from 0 to 10. New structures have no corrosion (HI of 0), and over time the extent and intensity of corrosion develops from minor superficial (G2) to more significant G3 corrosion (indicating loss of zinc) and ultimately loss of metal (G4). Typical bolt corrosion development with time is shown in Figure 1 for a single lattice steel structure in a C3 Corrosion Region.

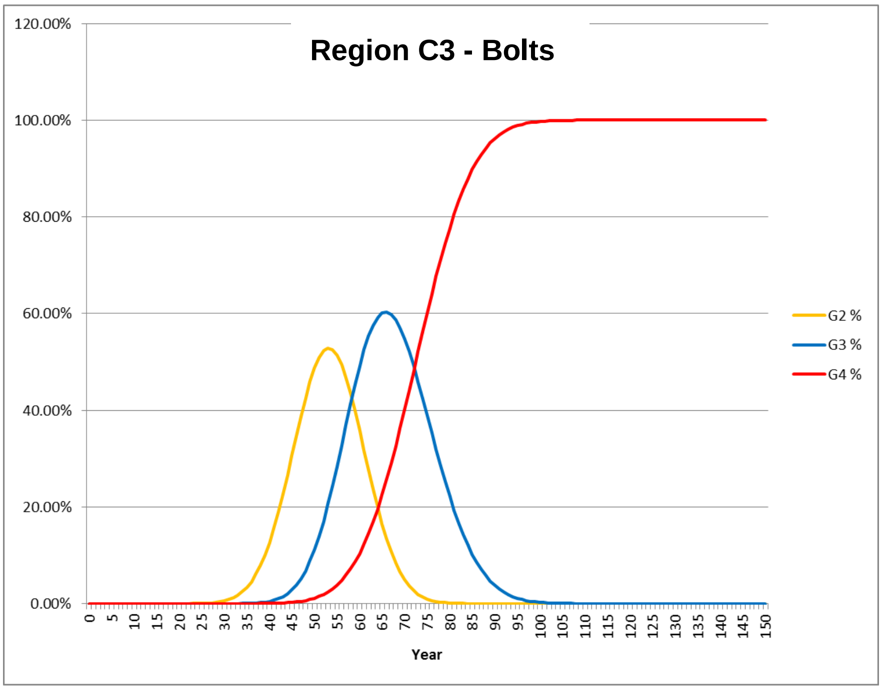
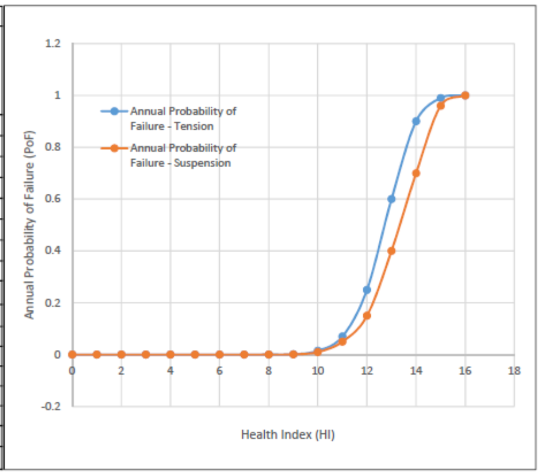


Figure 1 - Development of corrosion on a single Lattice steel Structure bolts

The presence of corrosion Grades 1, 2 and 3 on a structure do not constitute a loss of strength, or any increase in risk of failure. Only Grade 4 corrosion signals a reduction in strength, and the presence of a very small number of bolts which have just reached G4 is unlikely to materially affect strength. However, higher levels of advanced G4 corrosion correspond to a higher probability of structure failure, typically in high wind conditions. The structure Health Index values and curves used by Powerlink to estimate structure probabilities of failure are shown in **Error! Reference source not found.**.

Generic structure collapse curves - Tension and Suspension				
Structure Health Index	%G4 bolts	Annual Probability of Failure - Tension	Annual Probability of Failure - Suspension	Note
0	0	0.00004	0.00004	Long term average failure rate (due to wind). New
1	0	0.00004	0.00004	Weathered
2	0	0.00004	0.00004	Weathered, ZCP
3	0	0.00004	0.00004	Initial to moderate G2 corrosion
4	0	0.00004	0.00004	Widespread G2 corrosion
5	0	0.00004	0.00004	Initial to moderate G3 corrosion
6	0	0.00004	0.00004	Widespread G2 corrosion
7	1	0.00005	0.00005	Initial G4, Limit of normal operational range
8	4	0.000150	0.000100	Project completion date set by quantity @ HI8
9	9	0.001500	0.001000	Developing G4, small reduction in strength
10	20	0.015000	0.010000	Reduction in strength becoming significant.
11	37	0.070000	0.050000	High level of risk
12	57	0.250000	0.150000	>5% of bolts provide no strength. Likely to fail
13	75	0.600000	0.400000	
14	88	0.900000	0.700000	>10% of bolts provide no strength. Very likely to fail
15	95	0.990000	0.960000	
16	98.5	1.000000	1.000000	>20% bolts provide no strength. Almost certainly will fail



Non-operational area

Figure 2 - Structure Health Index to Generic Structure Probability of Failure

The selection of AHI of 8.0 as a trigger for project initiation is selected as a prudent trade-off between risk management and cost. Figure 2 shows the expected failure rates for structures with an AHI of 8 and while the rates of annual probabilities of failure of 0.015% for tension and 0.010% for suspension towers are relatively low they are theoretical and averaged. The real risk would need to be determined for each tower by the position of the compromised bolts and nuts on the structure, the corrosivity of the local environment, the likelihood of a high wind event and the severity of the G4 corrosion.

In practice operational risk assessment is managed by Operational Staff and while the worst risk is be mitigated under corrective maintenance, the large population of structures necessitates a fleet management approach. From a strategic point of view 4% of G4 corrosion on a transmission line (particularly a longer line) indicates that the condition of the asset requires more frequent monitoring, assessment, prioritisation and replacement that can stretch maintenance resources becoming an inefficient and repetitive process.

In addition, from an economic point of view, if an asset is 'sweated' to a more degraded condition with higher probability of failure (PoF) rates before taking action, the project becomes much more expensive. This is due to the need for additional preparation and painting of more members or the need to replace members (including heavily loaded members which are expensive to replace). This can also compromise crew safety when climbing and attaching to the structure, requiring increased use of elevated working platforms and cranes that would typically need access track improvements and benching around the towers.

The rate of development of corrosion on any structure depends on the corrosivity of its location. Structures near windswept beaches and in humid tropical or industrial areas corrode much faster than dry inland locations, well away from salt or any industrial pollution. As such, a suite of corrosion curves is used to reflect the differing rates of corrosion development. The curves used by Powerlink to assign rates of corrosion and forecast future corrosion to a structure, are shown in Figure 3.

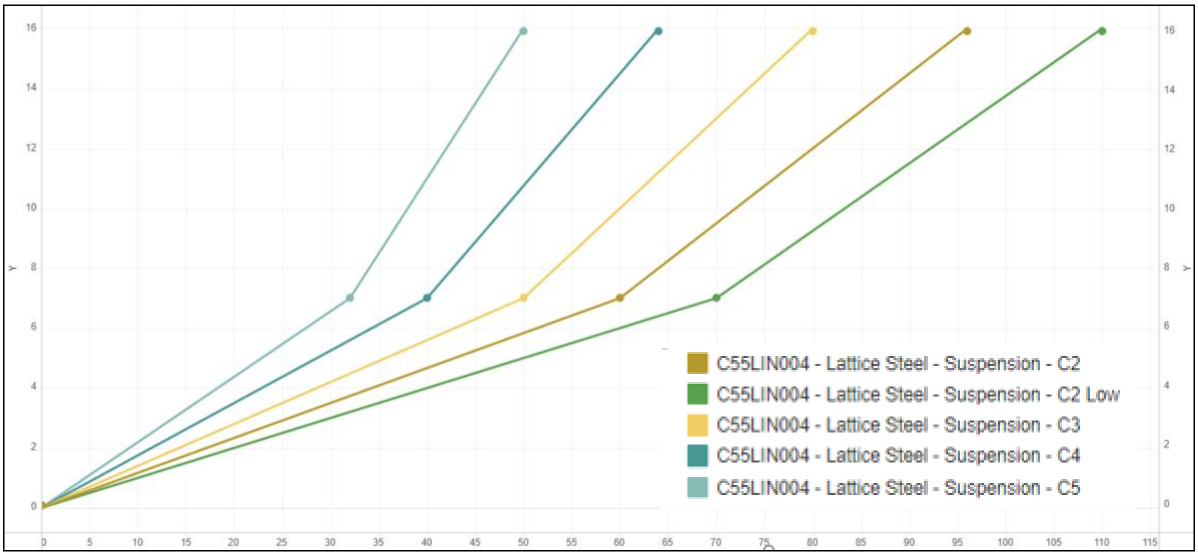


Figure 3 - Powerlink Corrosion Region Curves

The geographical spread of structure corrosion classifications is shown for the Powerlink network in Figure 4.

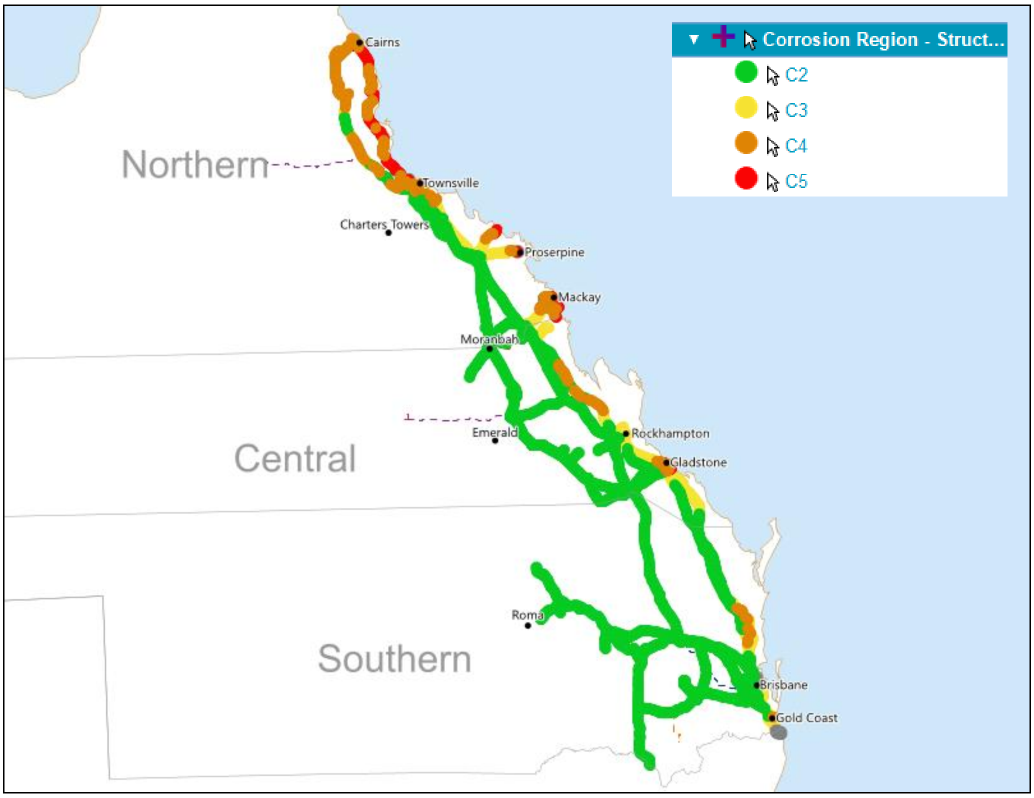


Figure 4 - Geographical Distribution of Powerlink Structure Corrosion Classifications

Once sufficient quantities of up to date data have been collected for the individual structures on a particular transmission line, it is possible to determine an overall Health Index for the entire built section. This is called the Asset Health Index (AHI) in line with Powerlink's accounting processes where the asset is considered to be a built section of transmission line.

Some built sections are homogenous in that condition is very similar on all structures along the length of the built section. However, some built sections transition through very different environments (e.g. over mountain tops and through heavily vegetated, tropical areas) which leads to non-homogenous corrosion performance, leading to a wide variance in the condition of individual structures.

Powerlink uses only recently measured information to establish the distribution, including the mean performance and leading edge (where corrosion is worst). In practical terms, the use of the mean condition to determine a reinvestment or need date can lead to asset failure risk as a large quantity of good structures can hide a small quantity in very poor condition.

Equally, the use of the worst condition structure for need timing (the leading edge) for the whole line is over conservative, especially if the deterioration is caused by local environmental issues and deterioration can be addressed by maintenance activities.

As such a percentile value is then used to establish a suitable threshold value to determine the need timing for action to restore condition. This percentile threshold value is typically between the 65th percentile for short lines (up to 20km) and the 95th percentile for long lines (more than 100km), with the need timing said to be the year in which a structure at this percentile in the condition distribution reaches an AHI of 8. At this time the HI of a small number of structures (typically 10) will have exceeded a HI of 8, and potentially will require some level of maintenance intervention.

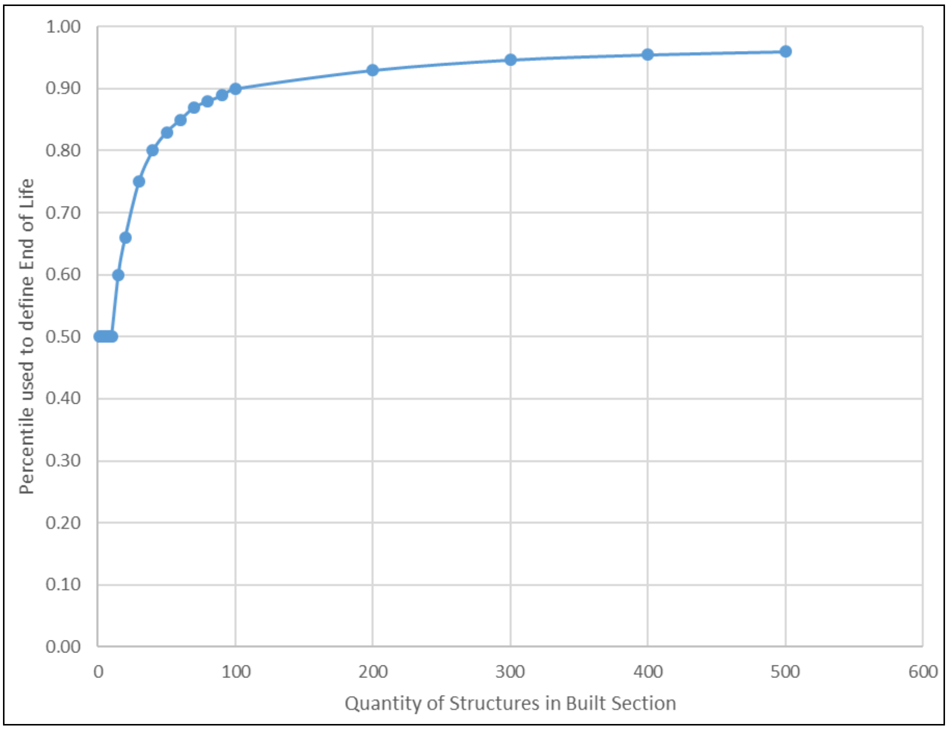


Figure 5 – Percentile Used for End of Life Timing

3. Determine rates of deterioration so that condition forecasts will be accurate

When the condition of structures at a point in time has been determined, and the rate of deterioration can be calculated, a projection of this rate of deterioration forward in time can be used to forecast the likely condition in the future (Figure 3). The future point in time when this deterioration is likely to result in reduced strength and an increased likelihood of asset failure can also be forecast i.e. when G4 corrosion is present in high quantities.

Curves used by Powerlink for asset deterioration are similar across many types of assets, which show strongly non-linear performance with condition deteriorating faster towards the end of the asset life cycle. Transmission lines also follow this pattern, primarily due to the very large difference in the rate of change of galvanised steel in comparison to un-galvanised steel (20 to 30 times). As such the curves shown in Figure 3 have a "knee-point" (change in slope) at HI7.

This model, in particular the underlying data, forms the basis of the system by which the condition of structures is forecast in time, and all structures are assigned to one of these curves. It is important to assign structures to the most appropriate curve, which is done by using inspection data to compare the expected performance with actual performance.

One further point to note is that structures tend to corrode in particular areas (e.g. coastal areas) and not in a way that is uniform across the structure. Often, the tops of structures including earth wire peaks and cross-arms are more exposed, and deteriorate faster. In other cases, the prevailing wind, an elevated location, a particular design of steelwork, poor galvanising, or dense vegetation can lead to localised deterioration on one side only. As such there is a degree of uncertainty in modelling and forecasting.

4. **Identify emerging risks as a result of the coincidence of deteriorating condition and risk exposures**

While structures and components remain at full strength, the risk of failure even in high winds is very low. When however, the strength of structures or components is reduced due to the loss of metal through corrosion or wear, there is an increasing likelihood of failure with time.

The geographic correlation of deteriorated structures and other components with risk exposure locations is carried out in the Portfolio Risk System, which automatically calculates risk based on the condition of all vulnerable lines components. For example the presence of buildings, roads, populated areas, distribution lines and other features is used to identify possible consequence scenarios, should the component fail and drop the conductor. This risk calculation system relies on forecasting when components will start to lose strength, and how quickly strength will be lost.

5. **Visualise and communicate future needs, and carry out additional actions to initiate a project or the collection of additional information to eliminate or minimise uncertainty**

Systems to forecast deteriorating condition of structures and other components across the network are important to identify when and where intervention will be required. This informs Powerlink's view of probable work within a 10 year outlook. The project initiation process describes the need, identifies and evaluates risk, provides options and associated scopes of work. Projects are formally created in the SAP database, connected to other electronic systems.

6. **Develop the scope of a project to ensure that all required work (due to either condition or legislative requirement) is included, while identifying sections where no work is necessary**

When longer term deteriorating line condition is detected at a level which is likely to lead to a project solution being more efficient and practical than a maintenance solution, a project is initiated to address the need. A number of options will be developed for comparison, with alternate scopes of work. Options may include capital investment or operational works, different life extension periods, differing start dates, and may consider non-network and alternative solutions. Projects with a credible option above the RIT-T threshold (currently $7 million) are also evaluated and consulted upon under the RIT-T process.

The inclusion of improved safety features in project scopes is an important matter. Older lines (pre 1990s) were not equipped with approved attachment points for climbing, and workers are required to make decisions on where to attach safety harnesses as they climb and work aloft. The introduction of rated attachment points integrated with step bolts ensures that climbing speed is optimised while assuring safety, and while it is clear that structures without rated attachment points can be climbed safely, these attachment points coupled with new step bolts appear to offer a higher level of safety.

Powerlink updates the safety and security aspects of all towers when capital life extensions are undertaken, particularly on transmission lines with a significant life extension period, even if the current condition of a specific tower is likely to reach the target life extension date. However, such works are considered on a case by case basis, for example, where a line is being life extended for 10 years, but is unlikely to be required in the long term due to capacity limitations, or a required change in network topography, it may be justifiable to avoid the safety (compliance) improvements for the wider built section.

7. Evaluation of all options to determine the lowest long-run cost option that is practical

Modelling and the process of comparing a range of options which provide differing life extensions, as well as benefits and disadvantages is carried out for all proposed projects. This analysis, involving Net Present value (NPV) calculations provides the opportunity to compare capital and operational options. It is important to ensure that the option undertaken provides the most efficient outcome to customers in the long run.

Evaluation on an economic basis only may result in an option being selected which is very difficult to implement, will take significantly longer to achieve, require more complex outages, have significant work approval or environmental implications, require more highly constrained internal labour or require multiple mobilisations with a greater impact to stakeholders.

These considerations need to be appropriately priced into the cost of the work to ensure the optimal outcome is achieved, and when included in the costing model highlight why a proposed capital project is preferred over multiple staged works. Uncertainty in condition at the time of scoping is inevitable and needs to be factored into the evaluation criteria, as well as consideration of climatic, seasonal and weather factors which are difficult to capture fully in an economic assessment. In many cases the more simple solution where less is likely to go wrong can provide the highest quality and most efficient outcome.

Appendix 1 – Powerlink corrosion grading system

The following corrosion grades for galvanised steel forms the basis of the Powerlink system:

- Grade 1 (G1) – no significant corrosion observed
- Grade 2 (G2) – galvanising layer starting to discolour/breakdown
- Grade 3 (G3) – loss of greater than 50% of the galvanising layer and in the worst cases unprotected carbon steel corrosion is about to commence
- Grade 4 (G4) – total loss of galvanising and the onset of unprotected carbon steel corrosion.