Modeling stray current and its influence on corrosion of steel sheet piling

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Abstract
Stray currents are known to promote corrosion of nearby metallic structures. Electrolysis is the responsible phenomenon. Where currents enter the metallic structure, the latter is protected. The construction corrodes at the location where currents exit through the ground to be collected by the substation.
The extent of such corrosion has until now been hardly predictable and quantified. Thus, authorities are extremely reluctant to accept the use of steel piling solutions in the vicinity of DC-operated systems (railways, tramways, cathodic protection, HVDC lines...).
The influence of stray currents on sheet piling structures was assessed using Elsyca's software CatPro® and CPMaster® initially dedicated to the pipeline and cathodic protection industries. Various steel piling designs were modelled meanwhile parameters such as wall/track distance, soil type, soil stratification, number and position of trains, anchors and track position were varied.
Corrosion rates obtained on different piling designs were considerably lower than expected. Moreover, zones of potential corrosion risk could be identified, thus cost-effective and practical countermeasures can be resorted to.
A first phase of a common TNO - ArcelorMittal project did present the same trend. Current collaboration with TNO and a consortium of other Dutch companies allows installation of a pilot steel piling project (2009) to put modelling results to test.

Keywords: sheet pile, piling products, stray current, corrosion, electrochemical modelling.

1. Introduction

Natural soil corrosion is generally not considered as highly damaging for steel piling solutions, but stray currents is believed to be a major issue for structures located close to DC power systems. Stray current corrosion was studied using modelling on various steel piling designs. Corrosion rates obtained were considerably lower than expected. Moreover zones of potential corrosion risk could be identified; cost-effective and practical countermeasures were thus clearly highlighted.

Figure 1. Sheet piling structures (underground car parks, tunnels, open-cuts, ...)

Stray currents are known to promote corrosion of close metallic structures. The extent of corrosion has until now been hardly predictable and quantified. Thus, authorities are extremely reluctant to accept the use of steel piling solutions in the vicinity of DC-operated systems. Corrosion induced by stray currents occurs through electrolysis. Where (cathodic negative) currents enter, metallic structure is protected. The latter corrodes at the location where (anodic positive) currents exit through the ground to be collected by the substation.

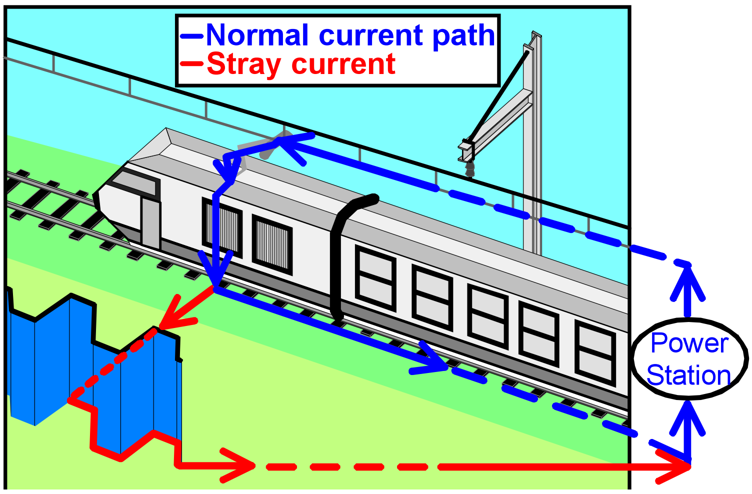

Figure 2. Origin and path of stray currents through a sheet pile wall

Faraday's law yields that a current density of 1A/m^2 (applied during one year on a steel structure) corresponds approximately to a thickness loss of 1mm.

2. Stray currents modelling work

The influence of stray currents on sheet piling structures was modeled using Elsyca's software CatPro® and CPMaster® dedicated initially to the pipeline and cathodic protection industries. A preliminary development phase required to adapt them to sheet piles. Elsyca was main partner in the global study.
In this article, few results for one reference case are reported. Electrical DC network comprises a 20km long track. Two substations, providing 3300V, are located at both ends of the track. The 15m long sheet pile wall is located at an equal distance from both substations.
The track-to-earth resistance was limited to 2.0 Ω.km with a maximum traction current of 2200A. Initial position of the train is in the middle of the wall.
Cases A, B, C (below) were also considered but not reported here.

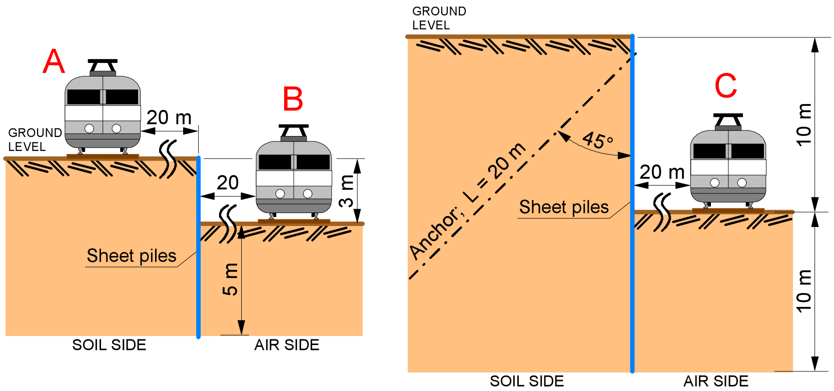

Figure 3. Modeled configurations – location of trains was different in cases A, B and C.

Parameters such as wall/track distance, soil type, soil stratification, number and position of trains, anchors and track position were varied.

3. Simulation results on piling structures

Depending on software, current densities are imported in Excel or mapped on the modeled structures.
To clarify, current path through the soils and sheet pile wall have been illustrated on the schematics below. Current exit (=corrosion) can be precisely located.

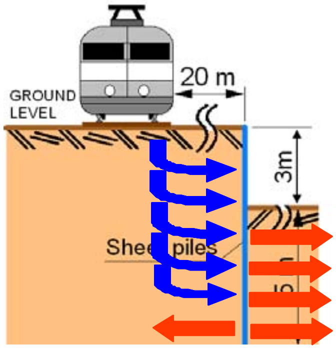

Figure 4. Case A Stray currents path through the sheet pile wall (blue arrows indicate currents entering the structure)

Quantitative effects could be assessed with the graph below for the same case. Current densities on the developed length of wall are reported at several depths.

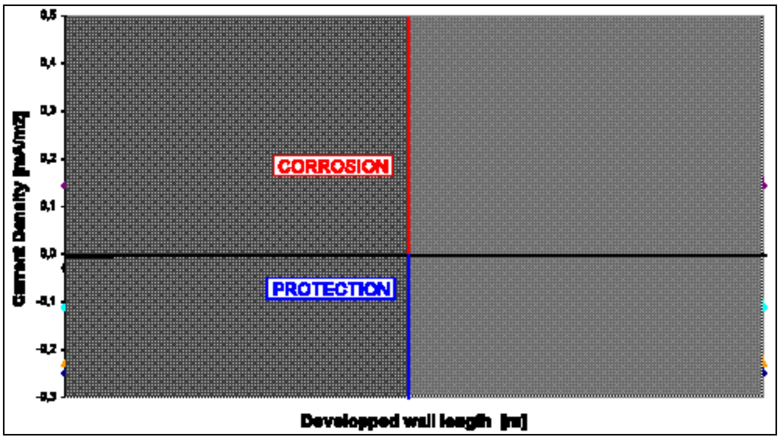

Figure 5. Case A: Current density distribution and intensity on developed wall length (two sides) - Positive current indicate corrosion

Current densities were limited to 0.45mA/m^2. Using Faraday's law and assuming the accelerating train remains one year there, the corrosion due to stray current would be maximum 0.45µm/y at a precise location.
EN 1993-5: 2007 prescribes 0.30mm thickness loss for 25 years in undisturbed natural soils (12µm/y considering a linear extrapolation).
Some parameters have direct impact on stray current corrosion, however low current densities were established in all cases.
This implies minor influence of stray current on the corrosion of steel sheet piles close to DC traction power systems in accordance with numerical modeling for the considered cases.
The modeling tools used make it possible to identify corrosion areas and define optimized cost-effective solutions.

4. Conclusion

This research enabled to estimate more accurately stray current intensity and distribution on sheet piling structures with electrochemical software adapted successfully.

Qualitative and parametric studies of stray current corrosion for general piling designs were carried out to be used by technical assistance. Moreover minor influence of stray current on corrosion of piling structures close to DC sources was highlighted.

Further outlook

A first phase of a common TNO - ArcelorMittal project did present the same trend. Further collaboration with TNO and a consortium of other Dutch companies allowed installation of a steel piling field experiment (2009) to put modelling results to test.

Acknowledgements

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[1] Elsyca is a service provider for the design, evaluation and optimization of cathodic protection systems, based on a unique and comprehensive platform for expert modeling.