Mill scale on historic wrought iron: impact on corrosion and coating performance

Nicola Emmerson, Eric Nordgren & David Watkinson, Cardiff University, Cardiff, United Kingdom

Mill scale, the oxide layer formed on the surface of iron and steel during hot rolling and forging, is well understood for modern steels but less so for ancient and historic ferrous material. Recent studies on atmospheric corrosion of historic wrought iron reinforcements in French gothic cathedrals identified surviving mill scale in corrosion layers and studied its effect on corrosion processes. Anecdotal evidence from conservators working on heritage iron also attests to the presence of mill scale and they report that it has a protective effect on the wrought iron substrate. Better understanding of the properties of mill scale will lead to improved conservation rationales and the design of evidence based procedures. Determining whether mill scale represents the original surface of corroded ironwork, if it survives only as fragmented layers and whether its presence influences corrosion rate will develop this understanding, as will determining its impact on the adhesion of protective coatings applied over it.

Surface preparation advice from coating and steel manufacturers and the use of industrial standards conflict with the experience of heritage ironworkers and conservation ethics. Removing all oxide layers to 'optimise' performance of protective coating systems inevitably leads to complete loss of the information contained therein, yet the evidence that removal of oxide layers reduces post coating corrosion rates is limited.

Work at Cardiff University aims to characterise mill scale on wrought iron and mild steel samples and assess how its removal impacts on corrosion rates and the adhesion of coatings. The morphology and composition of mill scale on 2nd century AD archaeological forged nails, mid/late 19th century rolled wrought iron bar and plate and modern mild steel samples have been investigated. Location and thickness of 'mill scale' layers and their degree of continuity have been determined using optical microscopy and SEM-EDS. X-ray diffraction has been used to characterise mill scale in the context of the corrosion profiles on un-cleaned, cleaned to mill scale, and cleaned to bright metal samples. The results give insight into the nature of mill scale on archaeological and historic wrought iron produced using differing technologies.

The corrosion behaviour of these samples is being investigated using Electrochemical impedance spectroscopy and corrosion rates derived by measuring oxygen consumption of samples sealed in controlled high relative humidity environments. Effect of mill scale retention on adhesion of coating systems to samples cleaned to mill scale and bright metal is tested using a standard hydraulic pull-off rig. The decision whether to remove or retain mill scale during a conservation process can now be made with an enhanced understanding of its impact on corrosion rate and coating performance.