"When History Needs a Helping Hand from the Present"

An Overview of the Preservation of a Historic Façade in London

By Graeme Jones and George Ballard

Hoare's Bank is situated on Fleet Street, London, which for centuries has been the center of both England's legal profession and national press. As a Grade 2 (in England's Historical Building rating system) listed building, it has significant historical status.

Historical Context

The oldest surviving independent bank in Britain, Hoare's was established in 1672 by Richard Hoare, a goldsmith who rose to become Lord Mayor of London and Member of Parliment for the city. In 1704, he was knighted by Queen Anne. Today the bank is owned and run by members of the 10th and 11th generations of the Hoare family, all of whom are direct descendants of Richard Hoare.

Famous clients have included the poet Lord Byron, the society painter Thomas Gainsborough, the diarist Samuel Pepys, and the novelist Jane Austen, as well as two Prime Ministers: Lord Palmerston and the Earl of Liverpool.

Fleet Street has been the bank's home since 1690. But by the late 1820s, the business had outgrown its original premises. Therefore, in 1829-30, the bank was razed and replaced by the present building. One of the earliest purpose-built banks in England, Hoare's retains its dual role of private dwelling house and banking facility.

Fig. 1: 19th century representation of the bank's front façade

Repairs Necessary

The façade on Fleet Street is formed from honey-colored ashlar sandy limestone, as full-depth, load-bearing masonry at the basement and ground floor levels, and ashlar facings over brickwork above. The mortar jointing between the blocks is remarkably fine, with a system of wrought iron cramps and pins used to prevent movement of the stone during construction.

These metal fixtures remain in position some 4 in. (100 mm) deep within the stone but, like all iron-based components, are prone to corrosion with the effects of time. Deeper components were identified that had been set in lead which also shielded them; these were, not surprisingly, in near pristine condition even after 180 years.

As moisture (and urban contaminants which can accelerate the process) enters the stone, it diffuses to the shallower iron surfaces where corrosion is initiated. The effects of expansion of the corrosion products then begin.

The visual effect of the expansion of the iron component is to cause cracking of the stone with eventual fragmentation of the cover to the iron and loss of stone cover. This will continue to allow the environment to perpetuate the corrosion problem until the iron has corroded completely.

The expansive force also pushes the mortar beds apart and opens up the joint. When one cramp starts to corrode, it puts the adjacent cramps immediately at risk. It is common, therefore, for a building that has survived well for an extended period to develop a sudden corrosion problem, with the façade passing from relatively unblemished to badly deteriorated in a period of as little as 5 to 10 years.

Well ahead of that are the aesthetic degradation of the façade and the unacceptable appearance of the building, coupled with the attendant risk of falling pieces of stone.

Fig. 2: Aesthetic deterioration caused by the unsightliness of cracking of the stonework. Note the crack developing from a previous repair where all the iron was not removed

Fig. 3: Hoare's Bank in 2006 prior to the remediation work commencing

Over the past 20 years, the building has been the subject of localized repairs where the iron component is often (but not always) removed and a stone patch replaces the breakout area that was necessary to remove the ironwork. These areas were both the precursor and the warning of an accelerating problem caused by the corrosion of the iron.

The owner was conscious of the historical significance of the façade both as a National Landmark and as an emblem of durability of the Bank itself, but had little idea of the quantity of the iron components or how many areas were vulnerable to damage. Nor was he confident in the future aesthetic appearance of the façade after a program of reactive repairs over an extended period of time.

They faced a dilemma: should they continue the piecemeal approach that was already creating a patchwork of stone inserts across the façade or attempt a major dismantling operation to remove all the offending cramps?

A further dilemma arose. The limestone had weathered to a mellow bronze, which was part of the conservable patina of age. Intervention might disrupt this, an effect obvious from the fresh color of the repaired inserts.

An extensive assessment program was viewed as essential to put some substance to quantifying the problem and to make recommendations on the holistic approach to solve the developing corrosion problem.

Condition Assessment of the Iron Components within the Stonework

With such a peculiar problem, it was unlikely that conventional techniques would provide the depth of information that was necessary to resolve the owner's dilemma. The techniques adopted, therefore, employed, as far as possible, nondestructive techniques based on technological advances. These included metal detection to locate near surface ironwork, radar to locate deeper ironwork and structural arrangements, magnetic mass probe to help identify the extent of corrosion, and infra-red thermography surveys to map moisture retention in the façade. All this could be undertaken from street level with access using a cherry-picker.

The specialist survey team assessed the entire surface of the façade over a number of visits to the site to accommodate street access restrictions

Fig. 4: Accessing from the street for surveying

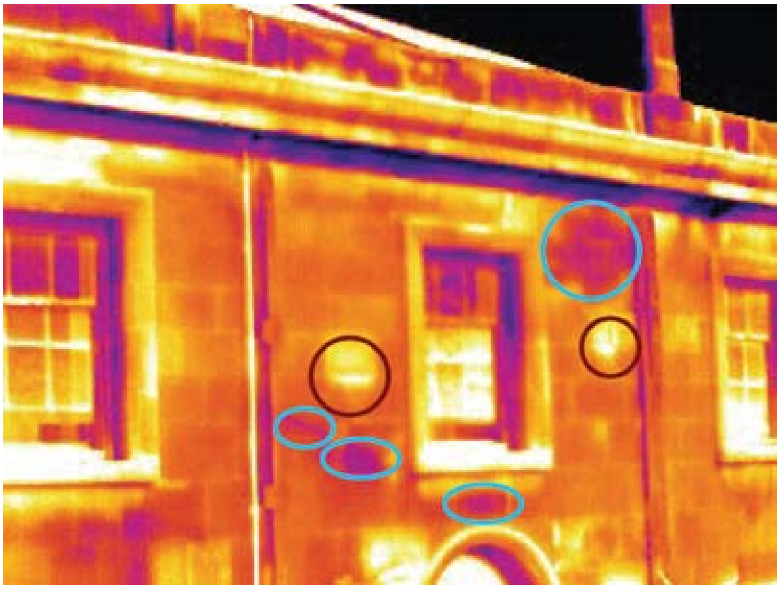

Fig. 5: Thermography output showing areas of moisture retention, circled in blue, and previous spalls and repairs, circled in brown

Fig. 7: Iron cramp exposed during preview to show condition; this agreed with a position that was deemed high risk by the condition survey. Note the end of the dog cramp to the left shows the emergence of a crack developing from the tip

Fig. 6: CAD representation of iron component positions including color-coding of corrosion risk assessment. Note that the red-shaded area was the location chosen for the ICCP preview study. The blue-shaded area was to test surface-applied corrosion inhibitors that did not take place

imposed by the city of London and the nature of working in such a busy thoroughfare.

Infra-red thermography was used to assess the retained moisture profile of the façade as this is inextricably linked to the vulnerability pattern of the iron within the stone. Where moisture is retained, it is likely that the ironwork in that location would be prone to corrosion initiating and propagating. It also identified areas of damage where corrosion had already corrupted the stone.

While this provides a risk assessment of vulnerability, however, it does not allow assessment of current condition; to this end, a mixed use of standard metal detection and state-of-the-art magnetic mass probe and radar techniques were adopted.

Magnetic mass probe is an evolution of pulse induction techniques developed by GB Geotechnics Ltd. to work in parallel with radar assessment of stone damage to identify the departure of any cramp relative to an assumed healthy condition and dimension. Iron components were graded as low, medium, and high risk, depending on the combined results of the survey techniques. A CAD drawing was produced that showed the precise location and apparent condition of all detectable iron components.

This was used as the basis of assessment of the next phase that considered the best approach to provide a durable and long-term solution—one that would allow more control over the problem without radically changing the appearance of the building.

Providing a Durable and Controllable Solution

The owner's prospect of replacing—in a piecemeal fashion—all of the iron components was not only a daunting one but one that would cause unacceptable and continual disruption to the operation of its business. The other problem was that any preventative solutions were largely

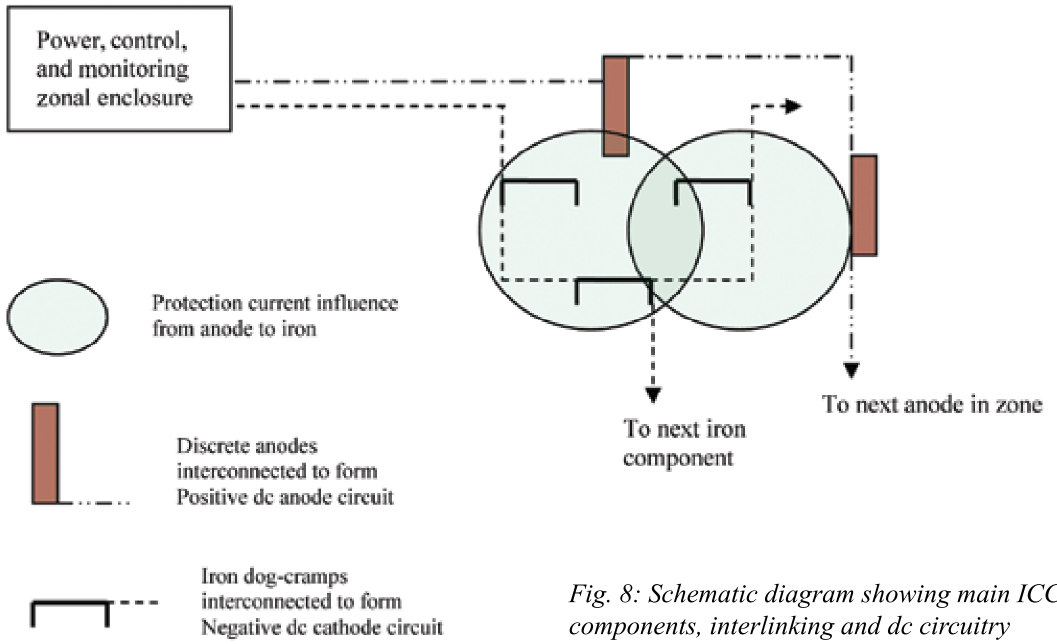

Fig. 8: Schematic diagram showing main ICCP components, interlinking and dc circuitry

untested in this type of environment. A number of electrochemical solutions were considered using either surface-applied or drilled-in capsule corrosion inhibitors or a cathodic protection system, whether passive galvanic or an active impressed current system.

Inhibitors were likely to require frequent retreatment/replacement as frequently as every 10 to 15 years, which did not compare with the historical longevity of the building. A simple passive galvanic cathodic protection system might have a somewhat longer life, but there would again be a need for future replacement, which was unwanted by the bank.

This left impressed current (ICCP) as the only feasible option. However, with only limited feasibility testing having been performed previously on this type of application, (e.g., Inigo Jones Chiswick House Gate, Buckingham Palace, Trinity College Dublin), the owner was facing an innovative development of known technology.

The iron components identified during the condition assessment numbered over 500 isolated and, therefore, electrically discontinuous dog-cramps and pins. Every one of these would need to be included within the system, or there was a risk that a stray disconnected object would be driven anodic of the rest, resulting in a rapid sacrificial corrosion regime.

The principle is simple: all the iron objects to be protected are connected together and held at potential at which they are cathodic to a distributed anodic zone by passing a current between the two. The current supplied is remotely controlled from a network management system.

The task of discretely positioning anodes was relatively simple in comparison with the intricacies of ensuring interconnection of all iron components to make a fully continuous cathode, while also avoiding the risk of short-circuits by the cross-pathing of cathode interconnecting wire with the titanium wire of the anode circuits.

Moreover, any end system would require the internal routing of the cabling and positioning of power, control, and monitoring units. The internal features of the building were also covered by the historical Grade 2 status of the building and had recently undergone renovation; therefore, they could not be touched. Facing these barriers, the feasibility of employing an ICCP solution to the building appeared to be difficult to achieve.

However, the owners agreed to Phase 2 of the project, which consisted of installing a preview (feasibility) study of the proposed ICCP installation and to temporarily power-up to ensure not only that the correct potentials could be achieved but also that the operation would correct imbalances. This stage would also be used to convince the city's conservation specialists that a full-scale scheme could be employed.

Conservation policy favors the principle of minimum intervention, whereby any repairs should preserve the historically important features of the architecture and, wherever possible, should be reversible. The choice of anode technology and its method for discrete installation in harmony with the establishment of the cathode in a single rather than disparate entity was therefore the key to achieving an acceptable way forward.

In terms of cathodic protection performance, its use in this environment does not coincide entirely with the principles of either the NACE RP02:90 recommended practice or European BS EN 12696: 2000 standard relating to ICCP use in reinforced concrete. The anode types relevant to this application were likely to be the same as those employed in that sector.

The absence of alkalinity in the substrate relative to a concrete application and, therefore, the presence of a more neutral environment meant that performance criteria, especially associated with performance criterion such as potential decay, were less relevant. This would also extend to the use of the technology in transitional steel frame applications where voiding in the mason's mortar in-fills is sporadic.

These issues will no doubt evolve to new criteria in the future as organizations, such as ICRI, develop documents such as the guideline ICRI's Masonry Committee is currently drafting.

The performance expectations were therefore rooted in the ability of the power systems to provide a stable and continuous supply of controllable current and the ability of the iron over time to take advantage of the cathodic reaction of oxygen and water to produce new alkalinity locally to induce renewed passivation. This will take time, and the first stage is to ensure adequate polarization to the immunity level for the iron-water system.

The practicalities of the installation meant some intervention to the ironwork and, as such, the breakouts were made by a specialist masonry repair contractor who also had previous experiences with the application of ICCP to transitional steel frame buildings. Care was the watchword and the preview installation was highly successful. Data showed that the electrochemical condition could be altered and controlled and the end aesthetic passed the inspection by third-party conservation specialists. The project was ready to proceed to the full installation phase.

Fig. 9: Anode drilled and grouted into position with interconnection wire ready for retucking

Installation of the ICCP Components

A discrete anode was chosen that had the physical dimensions to minimally disturb the bed joints (these were only 0.04 in. [1 mm] in width but a 0.31 in. [8 mm] anode was viewed as acceptable). The interconnecting wire was 0.05 in. (1.2 mm) in diameter and therefore the amount of over-widening of the joints was constrained to very small discrete hole positions and only slight along the length of the bed joints.

The cathode interconnections were made using 0.05 in. (1.2 mm) steel wire and formed in joints on the opposite side (where possible) to the anode wire. Where crossover was a problem, the titanium anode wire was sleeved with a low diameter tubing to insulate the two wires.

The final installation is controlled in three zones (by building level) that are networked together internally and the cables managed within the floor space to avoid internal disruption. The performance is managed using remote access to data and Internet access to reporting and has been warrantied for a period of at least 25 years.

The end product for the owner is a repaired building that has, on the face of it, remained unchanged in physical appearance from its reconstruction of the building in 1827, but with a new lease of life that is protected and controlled for the foreseeable future.

The strategy to protect the iron cramps and pins

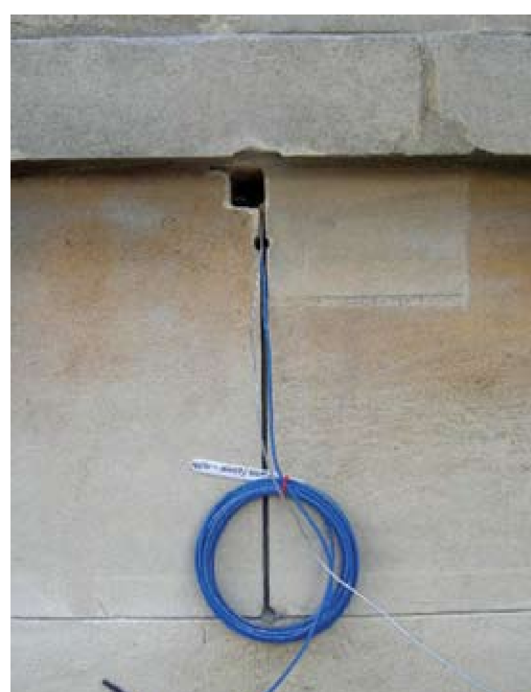

Fig. 10: Position showing discrete breakout for drill and tap steel connections and reference electrode monitoring installation

Fig. 11: A view of Hoare's Bank after the work was completed

within the front façade of this bank building was less likely to succeed than it was to fail on the outset. The formation of a specialist team that showed great care and diligence, however, achieved the objective with a beautiful end product. Special projects such as these are rarely achieved without close team effort; this project had that in abundance from the owner and his design team to the contractor and his team.

Acknowledgments

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__Graeme Jones__ is the founder of C-Probe Systems Limited and has over 20 years of experience (both academic and in industry) with corrosion and the protection of civil engineering and building structures. He is involved in the U.S. with ICRI and serves as Chair of ICRI's Corrosion Committee, and in Europe with the development of guidelines and standards for ICCP, inhibitors, and monitoring of corrosion of reinforced concrete and masonry structures.

__George Ballard__ has 30 years of specialist experience in the application of instrumentation and nondestructive testing to the structural investigation of engineered structures. Early research work in earthquake detection, engineering, and risk assessment as a Senior Assistant in Research in Earth Sciences at the University of Cambridge led to the formation of a private practice in geotechnical, geophysical, and structural assessments. Ballard has particular expertise in concrete technology, repair systems, tunnel construction methods, and historic building conservation. He also lectures at the University of Greenwich on nondestructive testing techniques and conservation, and in Master classes in Conservation at the University of York.