Technical Information Paper

Assessment & Treatment Options for Regent Street Disease

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Most people would agree that prevention is better than cure, but in some instances prevention is impossible, leaving the cure as the only option. This is the situation with so-called Regent Street disease (RSD).

The problem however is not confined to London’s Regent Street; in Manchester it is known as Deansgate disorder and it is also to be found riddling the skyscrapers of Chicago in the US. It occurs in buildings constructed using a steel frame covered in facing stone – in the case of Regent Street, Portland stone - but also in other materials such as brick or terracotta.

The use of such an emotive term, akin to ‘concrete cancer’ for reinforced concrete structures, indicates the concern that is generated by these problems. As with human medical conditions, the sooner the symptoms are recognised, the faster and more effectively an appropriate treatment can be initiated. Designers today, aware of the disease, build in mechanisms such as cathodic prevention to steel frame structures (i.e. the Broadgate development in the City of London) to inhibit any occurrence in the future.

THE DISEASE

Corrosion problems associated with early 20th century masonry clad steel frame buildings have become increasingly evident over the past few decades.

Buildings affected by corrosion were generally constructed during the first half of the 20th century and many are now listed or designated within conservation areas. These buildings often have ornate stone or masonry facades which provides the impression of traditional solid load bearing construction.

The problems of corrosion in early 20th century steel framed buildings are related to the original designs. Unlike modern buildings utilising cavity wall construction techniques, these buildings have thick masonry or stone units tightly built about the structural steel frame.

As the facing masonry and masonry in-fill materials are often porous this method of construction allows moisture entering the structure to come into contact with the steelwork. Sufficient levels of moisture for corrosion can enter the structure through a variety of routes the more common of which include: open joints, cracks, directly through porous masonry facings, or through inadequate or poorly maintained rainwater protection details.
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Detailing may inadvertently trap inborne rain against the steelwork, so that once any original paint or other applied protection has broken down, corrosion can take place with no outside evidence - or at least initially. A similar problem can occur with hard bricks, and with terra cotta and faience, compounded by the inability of moisture to 'breathe' out through these non-porous materials once it has entered the fabric.

Within a given local environment, corrosion rates can vary markedly, due to the effects of sheltering and prevailing winds etc. It is therefore the 'micro-climate' immediately surrounding the structure which determines corrosion rates for particular processes.

Typically the volume change is a 5 to 10 times enlargement and since most elements have a flattish surface it follows that rusting tends to 'grow' outwards forming a surface layer.

Evidence of such corrosion can include vertical cracking at column positions and outward displacement of stonework in front of a member. Such stones may eventually become dangerous if they are dislodged and fall.

Cast iron has a generally good resistance to corrosion as-cast, as silica in the moulding sand or loam fuses and coats the surface of the casting and forms a barrier to oxygen. Cut or fractured surfaces however will corrode quite rapidly. Wrought iron has a reasonable corrosion resistance, generally agreed to be somewhat better than that of carbon steel.

In unprotected and unrestrained conditions, iron and steel typically corrode at about 0.1mm/year in a damp clean atmosphere. In a marine, abrasive, or other aggressive environments the corrosion rate will be much greater.

When investigating structures for appraisal it will often be necessary to assess the residual section where corrosion has occurred. Iron and steel that is embedded in masonry or encased in concrete may present particular difficulties for appraisal.

Firstly, it is generally inaccessible, both for routine inspection and maintenance during its previous life, and for examination now. Secondly, it may be exposed to damp conditions, with an adequacy of oxygen but no significant air movement to remove the moisture. Altering this environment to prevent further corrosion, or applying corrosion protection, may be difficult.

Original Construction Protection Measures

Embedded steel frames in masonry were rarely adequately protected against corrosion. The 1930 London Building Act requirement in this respect was:

“All structural metalwork comprised in the skeleton framework of a building shall be clean of all scale, dust and loose rust, and be thoroughly coated with one coat of boiled oil, tar or paint before erection, and after erection shall receive at least one additional coat. Where such metalwork is to be embedded or encased in brickwork, terracotta, concrete, stone, tiles or other incombustible materials one coat of Portland cement wash of adequate consistency applied after erection may be used in lieu of coats of oil, tar or paint.”

In practice, it is found that steel in such construction has received only one coat of 'paint' (typically red lead), or even none, before being embedded in masonry. This paint is, after over half a century or more, unlikely to provide protection now or in the future.

Corrosion damage in such cases is very variable and often depends on location and on detailing. Thus a roof level beam immediately below a defective and poorly maintained gutter, or one under a limestone window sill, may be severely corroded, whereas an immediately adjacent structure appears quite sound. Because of this, it is difficult to be sure that corrosion is absent without 100% investigation - a daunting and potentially disruptive and expensive task.
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Today there are two repair options available to address this problem.

1. Removal of external stone/masonry to repair steelwork
2. Cathodic protection

1. REMOVAL OF EXTERNAL STONE/MASONRY CLADDING

to undertake repair to the corroding steelwork,

This process involves cleaning the exposed steelwork to remove the surface rust by either sand blasting or needle gunning and treating the exposed surface with an appropriate site applied protective paint coating.

Normally the treatment is limited to the external face of the embedded steelwork as this is most at risk from moisture migrating inwards. However, damaged and or faulty buried rainwater goods can cause more general corrosion to steel members buried within the elevation. Parapets and cornices can also be more vulnerable to more extensive corrosion.

Unless all of the steelwork is treated there is a residual risk of ongoing future corrosion. However, it may not be practically possible to expose the steelwork without seriously impacting the external envelope and causing significant disruption to the occupant.

Locally deconstructing comice stones can prove technically challenging bearing in mind that they may rely on the dead weight of the façade over to stabilise them. Furthermore, the resulting widespread destruction of the decorative stone details may prove sensitive with the planners, particularly if the building is listed or within a conservation area, and if the repair detail involves a man-made moulding to replicate the original detail.

Whilst taking the stone off and treating the steelwork is more expensive and time consuming the owner (and/or tenant on a FRI lease) has the peace of mind of physically seeing the work being done. It also offers the structural engineer the opportunity to assess the structural adequacy of the corroded members and strengthen as necessary.

2. CATHODIC PROTECTION (CP)

When the disease first emerged in the 1970s, the only option for treatment was to remove the masonry to access the steel frame, treat and/or remove and replace the steel and finally replace the masonry. Clearly this was not only costly, but also highly disruptive to the daily business of a building.

CP relies on the passage of a DC current from the environment into the protected metal surface to reverse the direction of electric currents associated with the corrosion process. It does not make good previous corrosion but suppresses the continuation of the process. Iron usually dissolves (rusts) to form positive ions and the damage caused by corrosion occurs at locations (termed the anode of the corrosion cell) where a positive current leaves the surface.

In reversing the direction of this current flow the cathodic protection system shifts the metal potential in the negative direction. As unlike charges attract more negative steel potentials provide a barrier to iron dissolution. Thus, the performance of a CP system may be monitored by determining the metal potential shift using an independent reference electrode.

The above description applies to all CP systems. The main difference between systems comes from the components used to distribute the current to the protected steelwork. It should be noted that CP requires the instillation of an electrical system with all its associated components.

The most important of these is termed the anode. There are primarily four anode systems available:

Conductive paint
Titanium mesh with a cementitious overlay
Conductive cementitious overlay
Discrete anodes
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For steel framed buildings it is appropriate to use discrete anodes and for reinforced concrete buildings, either conductive paint or discrete anodes.

The positive terminal of the DC power (the anode) is connected to the conductive material (the masonry). The negative terminal is connected to the steel (the cathode). The anodic reaction occurs in the embedded anode which is design to resist deterioration over the design life of the system.

The feasibility study should include a site visit, an examination of as-built drawings and all available reports. Various technical parameters are also considered such as electrical continuity, substrate conditions, presence of other embedded metals and fixings and any possible adverse side effects. If such information is not available then a site survey and testing may be required.

The site visit will also involve undertaking targeted key hole opening up of the structure to assess the general extent of corrosion and highlight any concerns regarding the structural integrity of the corroding steelwork. It is not unusual to find in the more vulnerable areas of the external envelope that local strengthening and/or replacement of steel members is also required as the CP scheme ca not address such matters, it will only prevent future deterioration.

Before deciding on which system to use i.e. galvanic (sacrificial) system or impressed-current system fundamental design decisions must be made to select the type of system and the most suitable type of anode appropriate to that system. Also required, is the determination of the size and number of the power sources, or sacrificial anodes, and their distribution on the structure.

Before concluding that CP is a viable option for a steel framed building it is essential that the following factors are assessed.

1. **Continuity of the steel frame, fixings and other metallic elements**

Failure to ensure the electrical continuity of all metallic elements in a steel framed building can result in stray current interactions between the various elements of the structure, resulting in the accelerated corrosion of the discontinuous elements. CP designers and engineers involved with steel framed buildings should always be fully acquainted with all common design details, historical methods of construction and testing and inspection methods for identification of discontinuous metallic elements.

**CATHODIC PROTECTION : PRACTICAL CONSIDERATIONS**

Making CP work in practice is a specialist skill. As a first step a feasibility study is normally carried out to assess the suitability of CP for the structure.
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2. Level of contact between the steel and masonry facing
The CP of steel framed buildings is possible since the protective current can be passed through the stonework or masonry to the steel via the mortar/masonry contact. Knowledge of the connection between the two elements is not always easy to ascertain. In some cases infill is completely absent. Expert knowledge of steel frame construction is required to make an accurate risk assessment on voidage.

For the system to be effective, large voids may need to be grouted. Identification and filling any voids around the steelwork with a suitable material is an important part of the CP design and installation. Once the voids around the steel are eliminated if the CP system fails the risk of masonry cracking is increased as a small amount of corrosion can cause it.

3. Current distribution
(controlled by mortar and stone resistivity)
The electrical resistivity’s of most masonry materials are in a suitable range for the application of CP when containing more than 2% moisture by weight. However as with any porous material it is important to understand the behavior of moisture content on resistivity.

The external cladding material should be carefully considered. Particular care is required when materials such as terracotta, faience and glazed bricks where the glazing or fire skin layer acts as an insulator making it difficult to distribute protective currents to the steel surface. However, protection is possible in the majority of cases if, for example, the anode materials are in contact with the underlying porous material beyond the surface layer.

4. The impact of anode location and type
With regard to steel framed buildings, there are two main choices of anode:
- mixed metal oxide coated expanded titanium mesh ribbon anode
- discreet rod anodes

Expanded mixed metal oxide coated anodes have several distinct advantages:
i. The anodes are not visible in mortar joints
ii. The anodes can be installed using standard masonry pointing techniques
iii. The anodes can often be installed parallel to beams & columns
iv. They cause minimal internal disturbance

Discreet rod anodes can be installed externally; however, careful consideration is required in relation to their positioning and resultant disturbance on the facade. However, they have the following advantages:
i. They can be installed internally and require no external access
ii. Anodes can be placed deep within the structure making them less susceptible to wetting and drying cycles on the building surface.

5. Aesthetic considerations
Cables can be installed in mortar bed joints with no noticeable visual effects on the front façade.

ECONOMIC DECISIONS
At the design stage of a CP scheme, a decision must be made as to whether the scheme will be a galvanic or impressed-current system. In specific circumstances, the use of both types of systems may be appropriate, but care is required to avoid interaction between them.

Galvanic systems have the advantage of being
- simple to install
- independent of a source of external electric power
- suitable for localised protection
- less liable to cause interaction on neighbouring structures
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However, the current output available from the practical size and weight of galvanic anodes is relatively small and depends principally on the electrical resistivity of the electrolyte.

The current from the anodes is not normally controllable; thus changes in the structure that causes an increase in protection current demand, may necessitate the instillation of further sacrificial anodes to maintain protection.

Impressed current installations have the advantage of being
- able to supply a relatively large current
- able to provide high DC driving voltages enabling it to be used in most types of electrolytes (environments)
- able to provide a flexible output that may accommodate changes in, and additions to, the structure being protected

Generally, however, care must be taken in the design to minimise interaction on other structures and, if no AC supply is available, an alternative power source (solar, diesel, etc.), is required. Impress current systems require regular maintenance and monitoring and may be connected up to the BMS or remotely monitored via the phone line.

For badly corroded steelwork direct intervention in the form of physical repart and strengthening to the steelwork may be the only protractible solution.

Prior to installation of a CP system a pilot study should first be undertaken to assess its suitability

MONITORING

The effectiveness of a CP system is assessed in accordance with a number of nationally and internationally verified and accepted criteria. These criteria are based on electrochemical parameters that can be measured and on-going monitoring and adjustment is required on a regular basis.

Time to first maintenance is determined by the life of the anodes which should provide at least 25 years service.

A well designed, installed, operated and inspected CP system should not require any major maintenance throughout its design life. An impressed anode CP system could last between 10 and 120 years depending on the type of anode CP system. Any electrical components and cabling would be expected to be renewed after about 30 years.

The major risk with CP systems in commercial buildings is that its electrical distribution infrastructure is accidentally damaged by tenants when undertaking fit-out works. Hopefully this is picked up in the monitoring of the system and within the facility management procedures.

It is good practice to inform all building owners of CP systems and infrastructures in the area of influence of any new CP systems, or of significant changes to existing systems, so that their effect on these facilities may be assessed.