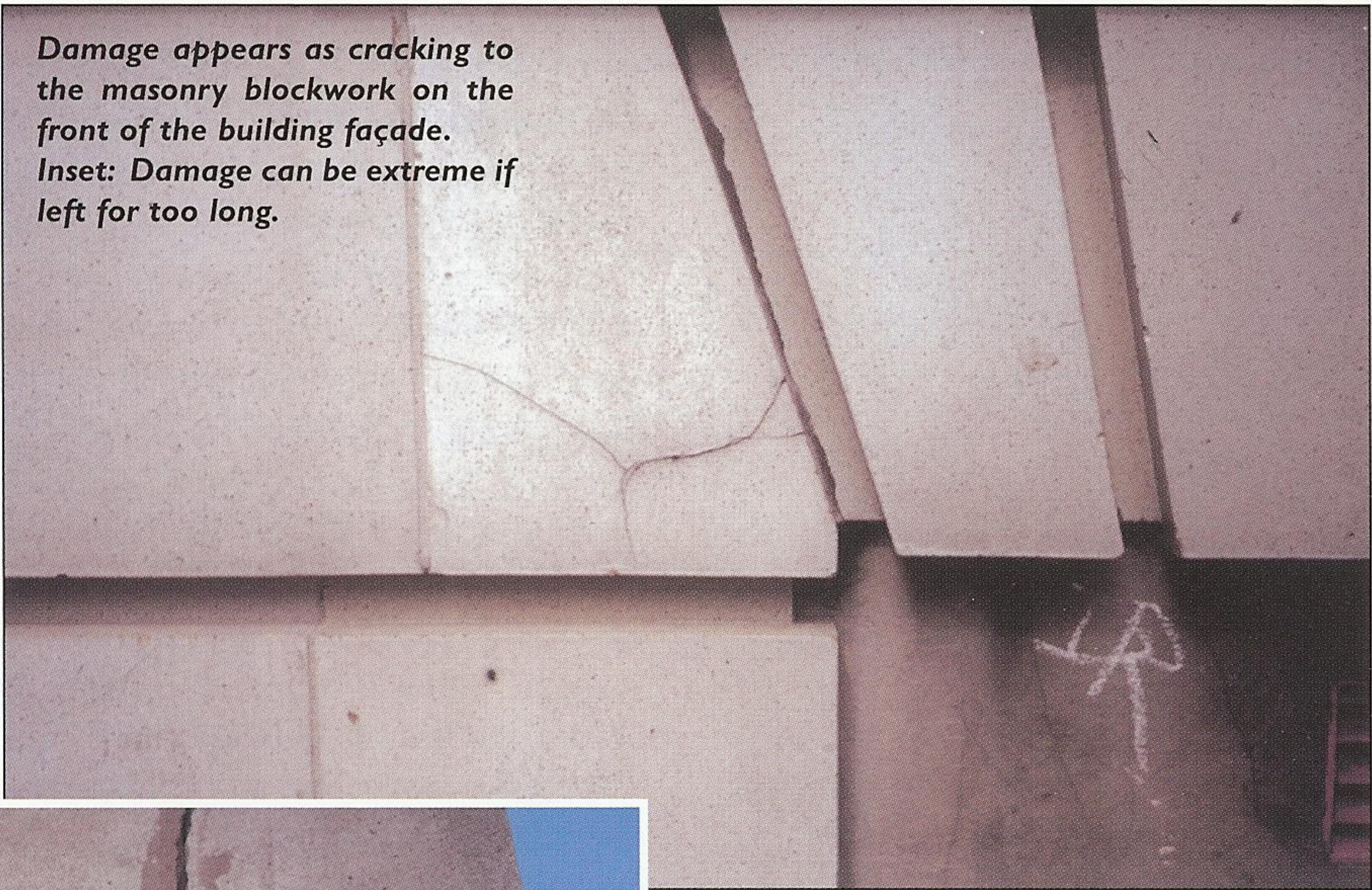


Hi-TECH HERITAGE

One of central Manchester's historic landmarks, Arkwright House, has been subjected to a novel form of cathodic protection to prevent further corrosion of its structural steel frame. Graeme Jones, C-Probe Technologies Limited, Paul Lambert, Mott MacDonald and Peter Bolton with Michael Robinson of Richard Ellis St. Quintin* discuss some of the attributes of this radical approach to sustaining and improving the service life of a precious city asset.



Damage appears as cracking to the masonry blockwork on the front of the building façade. Inset: Damage can be extreme if left for too long.



Table 1. Approximate distribution of repairs			
Elevation	'Major'	'Intermediate'	'Minor'
North	30%	5%	65%
South	30%	20%	50%
East	25%	10%	65%
West	30%	10%	60%
Penthouse	30%	10%	60%
Overall*	30%	10%	60%
*to nearest 5%			

Introduction

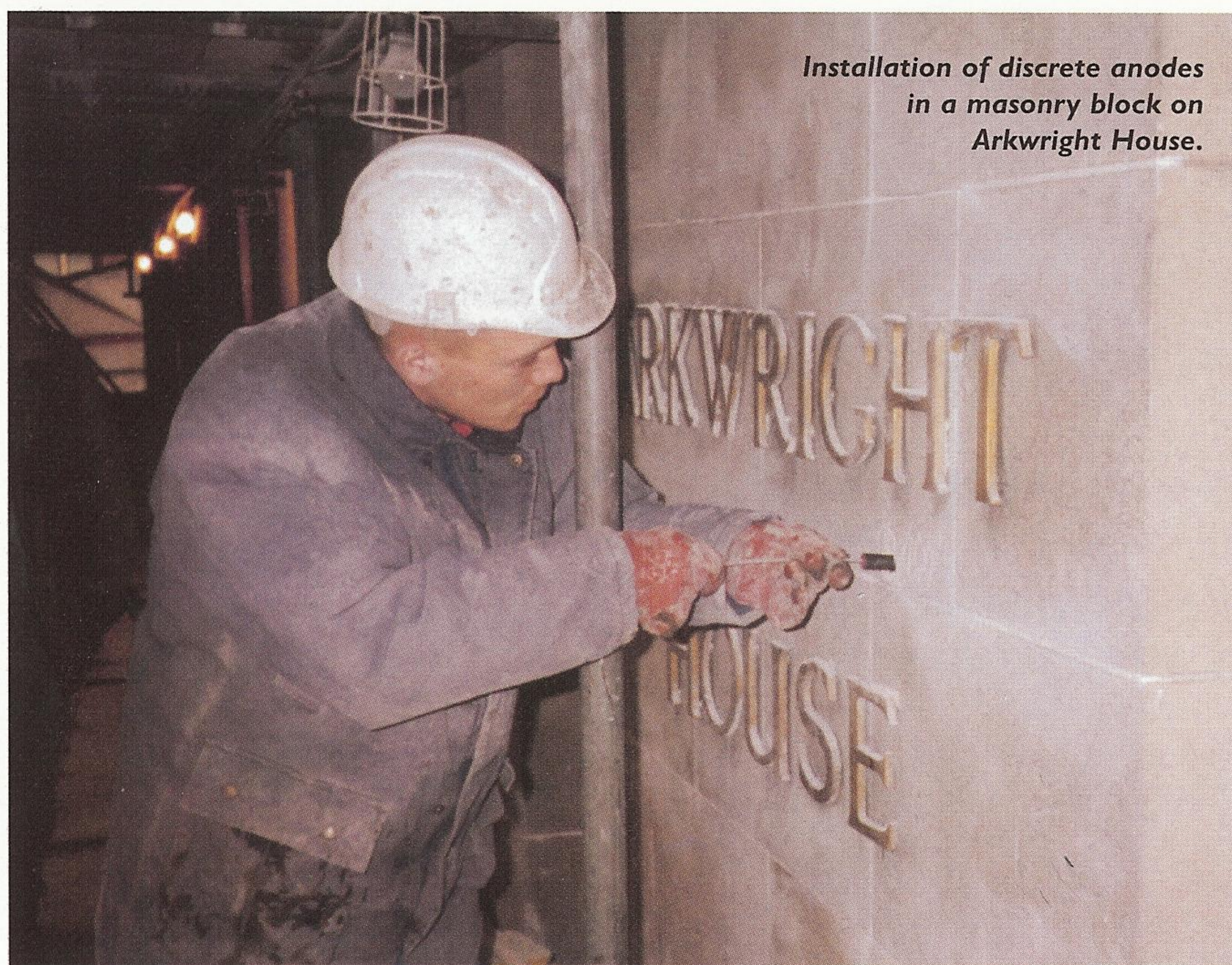
Arkwright House is an important part of Manchester's heritage. It was designed in a neo-classical style by local architect Harry S. Fairhurst (1868/9 – 1945). Named after the eighteenth century Lancashire cotton magnate, Richard Arkwright, the building was constructed in 1927 as the headquarters of the English Sewing Cotton Company.

During the Second World War, the building was used as the North West Command Post of Government with an office and sleeping quarters dedicated for Winston Churchill's use during his strategic visits to the North West. After the war, Arkwright House was used as the offices of the Department of Transport. Today, the 80 000 ft² building is owned by Phillips and Drew Fund Management Ltd and used as prestigious city centre office space.

Many buildings across Europe and the USA were constructed in a similar fashion to Arkwright House in the period of 1900 to 1940 and as such many of these, although lasting for

Table 2. Optional strategies for providing durability		
Remediation option	Description	Considerations
Do nothing/monitor	Carry out minimum repairs and monitor the continuing degradation until further action is required	Such an approach is appropriate for those areas that have the potential for corrosion but are presently not actively corroding. Further repairs likely within 10 to 15 years.
Conventional repair	Repair areas where steelwork has suffered significant loss of section and areas where expansive corrosion has resulted in significant disruption to the adjacent building fabric. (i.e. structural adequacy has been compromised).	Reconstruction is the most effective long term solution but is disruptive and expensive and hence should be restricted to areas that are considered essential.
Corrosion inhibitor	Inhibitors can be applied to exposed surfaces, injected, buried as emitters or fogged into voids to control corrosion of the steelwork.	Corrosion rate monitoring is recommended to ascertain effectiveness of the inhibitor and reapplication may be anticipated at 5 to 10 year intervals.
Cathodic protection	Steelwork is protected from corrosion by the application of a small current at low voltage. Discrete anodes may be inserted into the mortar infill between the cladding and the steel frame.	Ongoing monitoring and adjustment is required. Time to first maintenance is determined by the life of the anodes which should provide at least 25 years service.

*At the time of the project both Peter Bolton and Michael Robinson were employed by Chesterton PLC before joining Richard Ellis St. Quintin recently.



“...the damage pattern reported for Arkwright House is consistent with those being widely observed for steel-framed buildings of the same era.”

many decades, are now showing signs of problems due to the effects of corrosion of the steel frame.

In the UK, the problem has been colloquially referred to as ‘Regent Street Disease’ (akin to ‘concrete cancer’ for reinforced concrete structures). The use of such emotive terms indicates the concern that is generated by these problems. As with true medical conditions, the sooner the symptoms are correctly recognised, the faster and more effectively an appropriate treatment can be initiated.

Identifying the problem

The embedded steel frame is clad in outer skins of masonry and, sometimes, inner skins of brickwork. At the time of construction, it was common practice to fill the resultant voids with ‘mason’s mortar’.

Unfortunately, the mortar can act as a direct path for moisture penetrating the structure and causing corrosion of the stanchions behind the cladding.

The build up of exfoliated rust layers, sometimes expanding as much as 10 – 20 mm for only 2 or 3 mm of base steel, has caused tensile forces to build up behind the masonry resulting in cracking and movement of the block and brickwork. This physical effect in turn exacerbates the problem by acting as a path for fur-

ther moisture ingress and an acceleration of corrosion.

Detailed surveys conducted by the Roderick O’Connor Partnership (RoCp) with involvement by Mott MacDonald were able to identify the nature and extent of the problems and allow the development of appropriate repair and protection strategies.

It is important to note that the damage pattern reported for Arkwright House is consistent with those being widely observed for steel-framed buildings of the same era.

Tables 1 and 2 summarise both the extent of the problem around the building and the decision making principles applied.

The worst problems seemed to be focused on the top three (of seven) floors making traditional repair unavoidable. This was achieved by removing the external cladding, removing the corrosion products by the needle-gun method and treating the steelwork with a formulated coating finish for future protection prior to re-establishing the façade.

This work is disruptive by nature and expensive due to its labour intensity. Since, as ever, economics are paramount and, although corrosion was less evident in other areas, the risk of future disruption could not be tolerated. As such, a global view of protection to the entire structure was required.

Following extensive investigation

of alternative methods of repair to stop the unacceptable progress of corrosion, the design team opted to compare two short-listed corrosion protection methods: impressed current cathodic protection (ICCP) and surface-applied corrosion inhibitors (S-ACI) in the form of a pilot prior to commencement of the full works.

The main contractor (John Mowlem & Company PLC) commissioned a specialist North West-based company, C-Probe Technologies Limited (with installation sub-contractor, Llewellyn Stonecare Limited) to design both pilot systems with future system expansion in mind.

Pilot scheme

The choice of protection system for the entire structure was not only based on the technical outcome of the pilot schemes, but also the ease of expansion as well as the level of future maintenance required to ensure long term corrosion protection.

The ICCP system was based on discrete anodes manufactured from Ebonex[®] conductive ceramic. This material allows a degree of versatility in the choice of dimensions and is essentially inert so that no future degradation problems of the anode material are anticipated following installation. Discrete anodes have the added advantage of being buried within the structure and therefore sheltered from damage and hidden from view.

In addition to the question of whether the ICCP system would provide current through voided areas, the anode spacing was also a matter for conjecture and most readily resolved through the use of a pilot study.

The corrosion inhibitor system selected was based on emitter technology. A capsule contains the inhibitor (usually an amino-alcohol organic type) which provides extended protection by releasing small concentrations of vapour, sufficient to form a protective film over the steel surface.

Both systems are inserted into drilled holes and made good, with appropriate care, from the external façade.

The ICCP system operates by passing a protection current from the drilled-in anodes (+ve) to the steel frame (-ve) in an electrical circuit. Since no cathodic protection system

will pass current through dry air; it therefore needs a medium through which to complete the circuit (the electrolyte), in this case, conveniently, the very 'mason's mortar' which acted as the instigator of the problem. Data was taken for both pilot systems.

In the case of the ICCP, this was achieved using the C-Probe CPI0P embeddable reference electrode by measuring the steel potential before and after energisation of the system and applying EC Standard performance criteria.

For the S-ACI, the monitoring system comprised the C-Probe CPI0I embeddable corrosion rate probe¹. This method directly measures the rate at which corrosion is progressing and as such the rate at which it is diminished through use of the inhibitor.

Both pilot studies were successful in that they met the expectations of tackling the corrosion processes.

The design team in consultation with Mott MacDonald and the system designer (C-Probe) chose to progress with the ICCP system for extrapolation of protection to the rest of the building.

The primary reasons were:

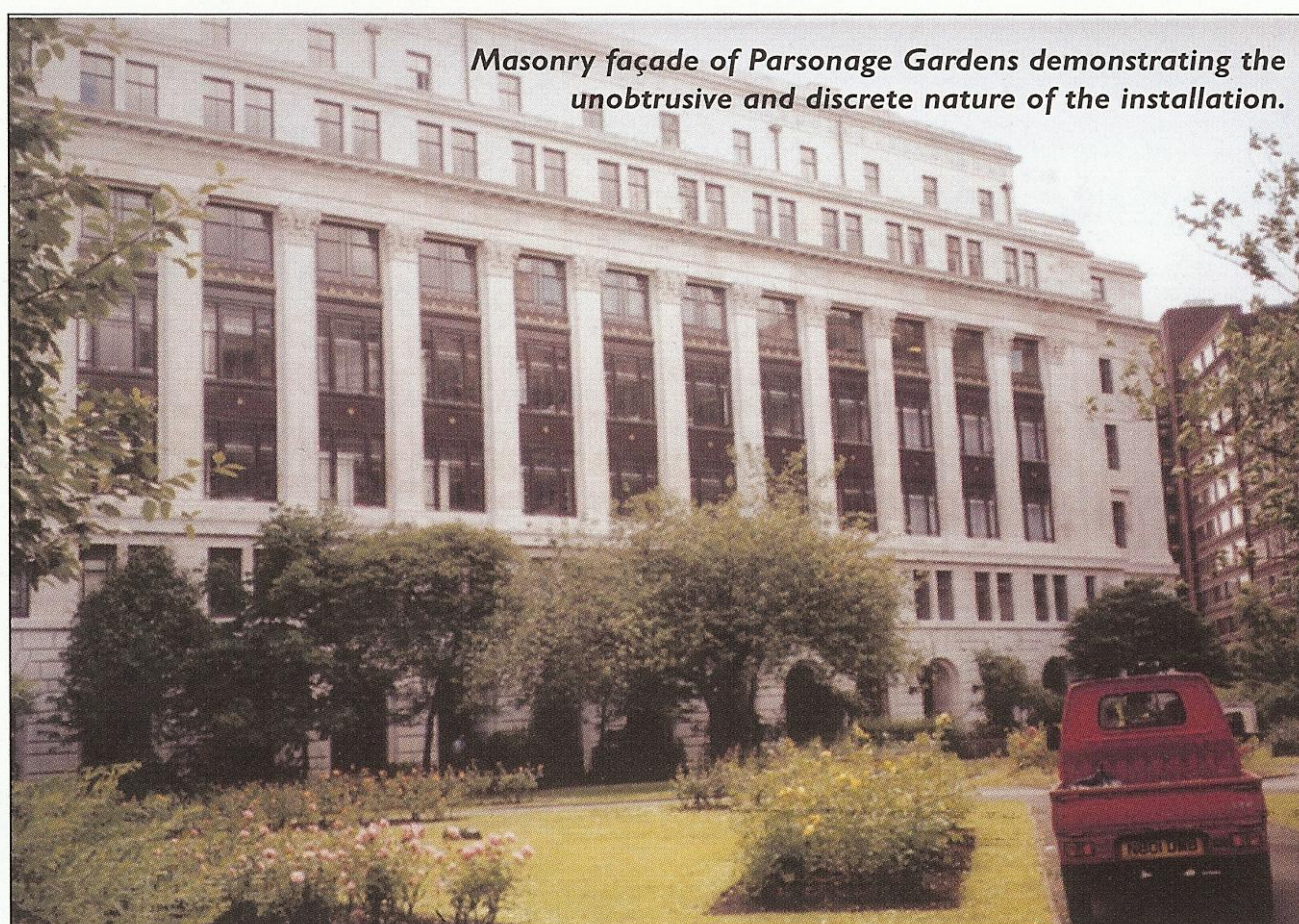
- Final installation visual aesthetics.
- Control of protection.
- Longevity of the installation.
- Ease of availability.

Although the capital cost of components is higher for an ICCP system than for the inhibitors, it is significantly less expensive than the anticipated costs associated with long term maintenance and protection by traditional means.

The protection system

The impressed current cathodic protection (ICCP) system is designed to protect the front faces of the steel-frame stanchions located behind the masonry and brickwork façades to avoid future build up of corrosion products causing disruption to the building.

These types of systems apply a permanent protection current to change the condition of the steel electrochemically from a state of corrosion to a state of protection (passivity). Provided the system is managed and the current remains switched on, the structure will be protected for its lifetime.



Masonry façade of Parsonage Gardens demonstrating the unobtrusive and discrete nature of the installation.



Brickwork and masonry façades on St Mary's Parsonage and Back South Parade following installation.

Table 3. Example system performance						
LEVEL 4	Zone 14			Zone 15		
	Potential (mV)					
Base	-243	-247	-213	-198	-226	-237
ON	-514	-964	-917	-929	-1065	-978
Instant OFF	-387	-616	-507	-589	-829	-617
4 hr OFF	-192	-210	-168	-190	-437	-207
4 hr decay	195	406	339	339	392	410

In the case of Arkwright House, additional early detection sensors have been installed to the ground level prior to deciding any future protection strategy in these lower risk areas.

The ICCP system consists primarily of four main components: anode, cathode, power system and monitoring instrumentation.

The anode is an inert conductive ceramic material with a long life and requires zero maintenance once installed. The cathode is simply steel connections shot-fired to the stanchion. The power system is an electronic unit capable of providing output of 24V at 3A DC. The monitoring instrumentation consists of embedded silver/silver chloride/potassium chloride reference electrode, which are durable and again requires no maintenance once installed. These specialist parts are cabled together and tested under strict QA procedures prior to energisation.

The installed ICCP system is managed using C-Probe's AchillesCP; a state-of-the-art network management software system which can be inter-

rogated on-site using a portable laptop computer or off-site using a telephone modem link.

System performance

The performance criteria applied are those covered under the European standard for management of cathodic protection systems as well as those applied by the interpretative skills of trained corrosion engineers.

Table 3 outlines sample data comparing initial condition with three month ICCP performance from zones 14 and 15 on level 4 of the building clearly demonstrating satisfactory performance.

In all, there are 24 controllable zones protecting levels 1 to 7. It is important to note that the ICCP system in totality is operating constantly at a power consumption of a few watts, such is the efficiency of the design.

Additional monitoring has also been installed for the ground floor level comprising corrosion potential sensors. These will be used to trend the ongoing corrosion condition of the steel frame without disruption of

the external fabric. The owner has adopted a neural-network system, which has the capacity to 'learn for itself' over the forthcoming months and years. This will allow very sophisticated alarming to be developed with self-regulation a real target in the future, thereby further reducing the maintenance costs of operating the system.

The neural network is also capable of expansion to other building control facilities, such as electronic carpark space control, air conditioning, air quality, security and lighting controls.

In this way, it is possible to increase the functionality of the building to cover many aspects of healthy working as well as a few intrinsic luxuries if so desired.

This is only possible due to the open network capabilities of the management system.

Acknowledgements

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