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Stone Restoration at the Houses of Parliament in London
Rénovation de la maçonnerie en pierre du Parlement de Londres
Steinrestaurierung am House of Parliament in London

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SUMMARY

This paper describes the deterioration which occurred in the masonry of the Houses of Parliament in London as a result of air pollution, and the restoration program which has been carried out over twelve years. The policy governing the conservation work is set out and details are given of stone cleaning and repair techniques. The temporary works adopted for the restoration of the Victoria Tower are described, with an outline of the cast iron roof repairs and regilding. Dynamic methods are described for testing the structural integrity of slender pinnacles.

RÉSUMÉ

Cette communication traite de la dégradation qu'a subi la maçonnerie du Parlement à Londres par suite des effets de la pollution de l'air. Elle présente le programme de rénovation de ces douze dernières années. Elle montre la stratégie adoptée pour les travaux de protection ainsi que divers détails sur les techniques de nettoyage et de réparation de la maçonnerie en pierre. Elle décrit également les mesures de construction auxiliaires prévues pour la Tour Victoria, en fournissant des informations succintes sur les travaux de réparation et d'enjolivure de la toiture. Enfin, elle fournit des indications sur les méthodes d'essais dynamiques utilisées pour évaluer l'intégrité des flèches de tour très élancées.

ZUSAMMENFASSUNG

Der Beitrag beschreibt den Verfall des Mauerwerks am Londoner House of Parliament infolge Luftverschmutzung und das Restaurierungsprogramm der zurückliegenden zwölf Jahre. Es werden die Strategie der Konservierungsarbeiten und Details der Steinreinigung und -reparatur vorgestellt. Die Baumassnahmen für die Reparatur des Victoria Tower werden beschrieben, mit kurzen Ausführungen zur Reparatur des gusseisernen Daches und der Verschönerungsarbeiten. Ferner werden dynamische Testmethoden zur Beurteilung der Integrität der schlanken Turmspitzen beschrieben.

1. INTRODUCTION

1.1 The Houses of Parliament, properly known as the Palace of Westminster, stand on the historic site of the medieval royal palace where Parliament originated. The previous palace was almost completely destroyed by fire in 1834 except for Westminster Hall with its magnificent hammer beam roof dating from 1394. The present Houses of Parliament were built between 1840 and 1865 by the architect Charles Barry, assisted by the gothic designer Augustus Welby Pugin.

1.2 The building is founded in the Thames gravels on a mass concrete raft up to 3m thick. The structure is of loadbearing masonry supplemented by cast iron beams and columns, with brick jack arches to support internal floors. The roofs are trusses of cast and wrought iron covered by 1000 x 750mm cast iron tiles. The area of the site is about 30,000m^2 and there are 13 internal courtyards. The clock tower, Big Ben, is 93m high and the 119m Victoria Tower was the tallest building in the world when it was completed in 1860.

2. CONSERVATION, RESTORATION AND REPAIR

2.1 Stone Deterioration

Although Charles Barry was aware that the polluted air from coal burning in Victorian London had a severe effect on stone buildings, the stone he chose was a magnesian limestone from Anston in Yorkshire. It carved well and could be supplied in blocks up to 1300mm thick, but stone decay was apparent even before the building was completed. The surface of the stone was eroded over the decades and by 1926 some 200T of loose fragments had been handpicked, denuding much of the rich decorative carving. Because the stone was not marked at the quarry so that it could be laid in its natural bedding plane exfoliation occurred where stones were laid with the bed parallel to the surface of the masonry. A programme to restore some of the most noticeable defects was begun in the 1930s but it was interrupted by the second world war. Clean air legislation of the 1950s eliminated the smoke, smogs and airborne acidity caused by coal burning, so the rate of decay reduced and buildings which had been cleaned then remained clean.

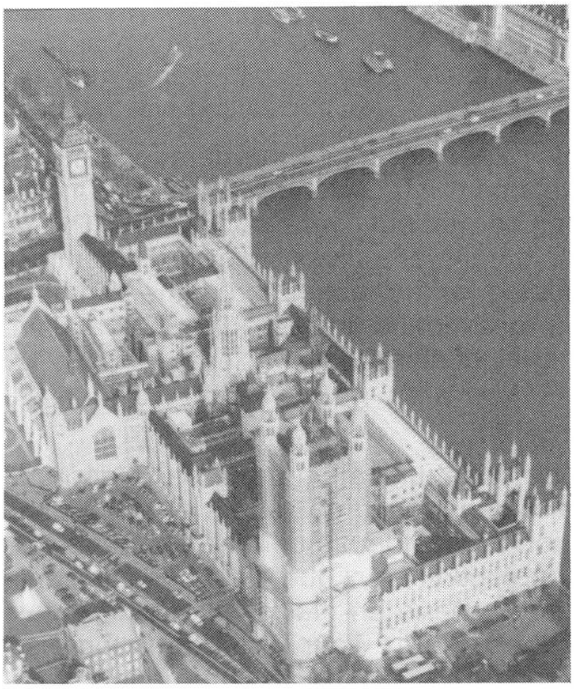

Fig. 1 The Houses of Parliament

2.2 The Repair Programme

2.2.1 The work required was in three categories: conservation, restoration and repair, and a programme covering all the external facades has been carried out as follows:

Phase 1	New Palace Yard	1981 - 1982
Phase 2	West Front	1982 - 1984
Phase 3	North Elevation	1982 - 1984
Phase 4	The Clock Tower - Big Ben	1982 - 1984
Phase 5	River Front	1985 - 1986
Phase 6	The Central Tower	1986 - 1989

Phase 7	South Elevation	1990 - 1991
Phase 8	The Victoria Tower	1990 - 1994

2.2.2 The original Anston quarry was worked out many years ago and the repairs were made using an oolitic limestone from Clipsham in the county of Rutland which is a good colour match and somewhat harder than Anston. It was carefully marked at the quarry to ensure correct bedding in the building.

3. CONSERVATION POLICY

3.1 From the outset a conservation policy was established with the following principles:

- Retain and conserve as much of the original fabric and decorative detail as possible.
- Research the history of the original work before specifying any repairs.
- Make careful records before, during and after repairs and prepare an archive document detailing all restoration.
- Where possible, use the traditional techniques of the original builders.
- Where possible, use non-destructive testing to avoid loss of original fabric.
- Avoid irreversible processes.
- Aim for a 40 year maintenance cycle.

3.2 It was decided to allow weathered stone to remain provided that it was sound with no water traps and when cleaning stone, to accept a "grubby clean" sufficient for repairs to be carried out, rather than risk unnecessary damage to the surface in trying to achieve a pristine finish. Although stone cleaning has aesthetic benefits, it can cause further damage and its main purpose in conservation terms is to reveal the full extent of the repairs which are needed. When limestone fresh from the quarry is first laid, moisture dries out and carries salts to the surface of the masonry forming a protective crust. If cleaning removes this crust the durability of the stone is reduced.

4. STONE CLEANING TECHNIQUES

4.1 Water Washing

4.4.1 Trials conducted with the assistance of the Building Research Establishment concluded firmly in favour of water washing. However, it is always important to avoid saturating the stone and to avoid water penetrating into the building. Just sufficient water was applied by very fine nebulae sprays to soften the dirt so that it could be gently and carefully brushed off. Close supervision of the contractor was invariably necessary to avoid excessive watering. To prevent water penetration through mortar joints repointing was necessary before water washing and all mortar joints were cleaned with a pencil blast gun before repointing. Despite trying many methods, no entirely satisfactory way was found to prevent water getting in at windows so someone was always present on the scaffolding whenever water was being sprayed and a second person with a radio was stationed inside to report any ingress of water.

4.1.2 Attempts to measure dampness at various depths in the stone did not yield reliable results, but it was clear that the masonry becomes saturated very quickly indeed and is extremely slow to dry out. To prevent water running down the face of the building and saturating lower parts, plywood slurry gutters were erected with pipes taking the water to settling tanks.

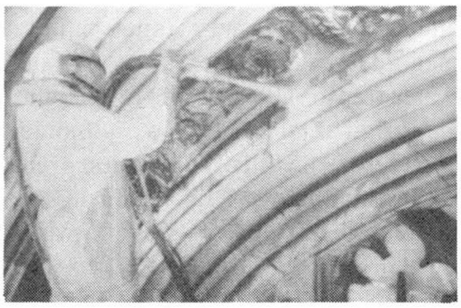

Fig.2 Blast Cleaning

4.1.3 In some situations where stone was sound and smooth, relatively light soiling was removed simply by wet sponging.

4.2 Blast Cleaning

4.2.1 For some parts of the building such as the libraries, oak panelled fine rooms and air conditioned archives of irreplaceable historic documents, the risk of water penetration could not be accepted and semi-dry blast cleaning was adopted using silica grit graded from 0.5mm down. The grit was selected after trials of various gradings and of other abrasives such as aluminium oxide and crushed nut shells.

4.2.2 A disadvantage of blast cleaning is that the natural crust on the stone is damaged. Other disadvantages are the noise and dust, and a mottled shading which is sometimes caused by the way the gun nozzle is manipulated or by markings beneath the original surface of the stone. Advantages are that work can continue through the winter and the rate of progress is more predictable than for water washing.

4.2.2 The technique entails a variety of nozzle sizes and careful control of the pressure and water content depending on the stone characteristics and whether the surface is ashlar or fine carving. The pressures used were of the order of 1.5 bar with water at the rate of 1 litre/minute. Staff responsible for specifying and supervising the work were given practical experience off-site before the contract began so that they could appreciate the difficulties of working in heavy protective clothing with air fed helmets in a confined space, dust and noise. This experience led to a decision to use pressure gauges on hypodermic needles to insert into the air lines for independent pressure checks.

4.3 Chemical Poultices

Alkaline clay poultices were used to a limited extent, particularly to remove the staining from anti-pigeon gel and for the very delicate medieval carvings on Westminster Hall.

4.4 Other Stone Cleaning Methods

4.4.1 Acid cleaning methods were not appropriate to this carbonaceous stone, although on granite and brick buildings 5% hydrofluoric acid solution has been used with success. Very high pressure water jets were also inappropriate with such a relatively soft stone.

4.4.2 Small scale laser cleaning trials were conducted and showed promise. The laser readily removes sooty deposits and sulphate encrustations leaving the surface of the stone undisturbed. Lasers present their own safety hazards and considerable development work will be needed to scale up the system for areas of ashlar, but the method has proved very satisfactory for cleaning fine carvings and was used to remove Victorian limewash from medieval limestone statues in Westminster Hall.

5. STONE REPAIR AND REPLACEMENT

5.1 After cleaning, each area was reinspected and a detailed schedule of repairs was prepared. Defects included sulphate attack, stone spalling. clay beds and faults within the stone, missing pieces and water traps. The aim was to retain as much of the original stonework as possible, accepting weathered profiles. Repairs were undertaken where failure was likely during the 40 year maintenance cycle, to prevent water traps, to reduce the rate of decay and to reinstate important architectural details.

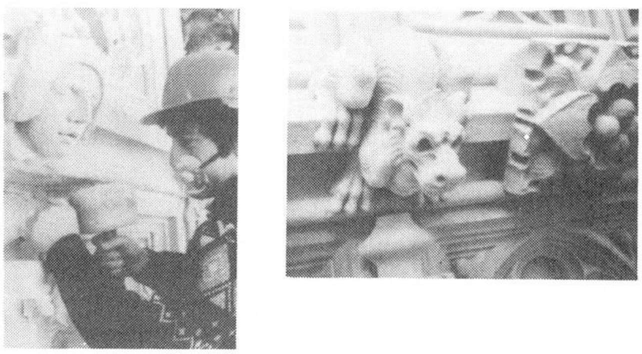

Fig.3 New Carvings

5.2 The stone repairs ranged from repointing, to dressing out water traps, repairing with stone dust mortar, piecing in small areas, the renewal of ashlar blocks and the replacement of elaborate carvings. For the Victoria Tower, which was by far the largest phase and included particularly rich ornamentation, a stone carving workshop was established on site staffed by masons and stone carvers who were able to recreate accurately the decayed decorative carvings, heraldic devices, statues and building details which it was necessary to cut out and replace.

5.3 Individual replacement ashlar blocks were fixed with four stainless steel dowels: one in each face. While the stones were being placed the vertical dowels were held up with thin blades and then dropped into place under gravity. The horizontal dowels were pulled into place by a technique known as "mousing". This entails overdrilling the hole and inserting the dowel full depth with a thin string wound spirally around it. When the stone is in place the string is pulled, drawing the dowel into its working position. When some original stones were cut out it could be seen that the Victorian masons had used exactly the same method.

5.4 Pinnacle Stability Testing

The inadequate structural stability of several very slender pinnacles was a matter of concern. Load tests and dynamic resonance tests were carried out from which it was possible to identify failed bedding joints and pinnacles which should be rebuilt. With careful dismantling the majority of original stones were able to be reused, but with stainless steel dowel bars inserted. Having established the value of measuring the natural vibration frequency of the stone pinnacles to indicate failed bed joints and pinnacles which might eventually topple in extreme winds, a sophisticated laser monitoring technique was developed. Vortex shedding from even a light wind vibrates a pinnacle sufficiently for the natural frequency to be measured with a laser mounted on a remote rooftop. By traversing the spot of laser light down the pinnacle from top to base, fault planes are indicated by discontinuities in the vibration frequency of the pinnacle. In this was all the pinnacles on the Palace can be checked in two days and the technique is now used for planned maintenance inspection at 4 year intervals.

6. THE VICTORIA TOWER

6.1 Temporary Works

6.1.1 The access scaffolding for the 119m high Victoria Tower, which weighed 1000T and used 110km of scaffold tube, was founded on bored piles and supported over the adjacent roofs of the Palace on Bailey bridge towers and trusses. In view of the prominence and importance of the site, it was designed to the wind loading and other standards of a permanent structure. At upper levels the scaffold was tied back into the masonry using stainless steel drill anchors which were later made good with stone plugs and the positions were recorded for future use.

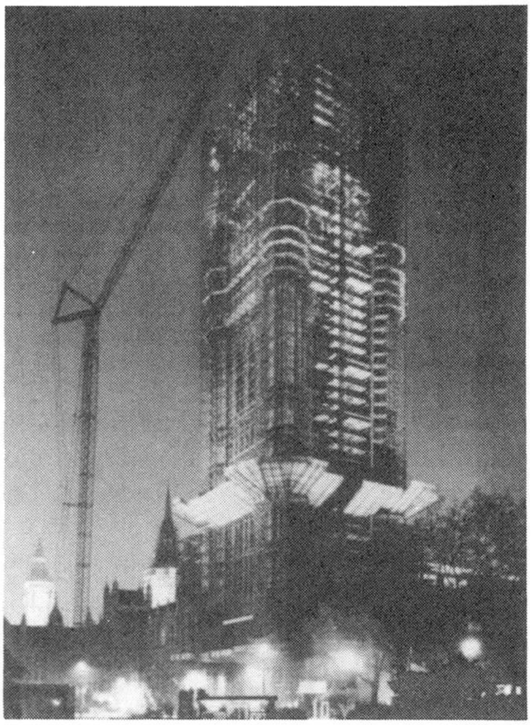

Fig.4 Victoria Tower Scaffold

6.1.2 A safety fan projected from the scaffold just above Palace roof level. Slurry gutters were installed below alternative working platforms, with gullies and downpipes leading to settling tanks at ground level. The working areas of the scaffold were totally enclosed with fire resistant translucent sheeting and the leaded windows were protected with plywood cut to the gothic profiles. To ensure that stable environmental conditions were maintained for the archive rooms within the tower, a mechanical ventilation and filtration system was provided to feed air through the working area to the existing air conditioning plants.

6.1.3 The tower floodlighting remained in operation during the works and there was favourable press comment on the scaffold as a work of art in itself.

6.2 Victoria Tower Roof

6.2.1 The Victoria Tower is roofed with large cast iron tiles on a trussed framework of cast and wrought iron. This is surmounted by a 28m high flag mast supported by ornate ironwork. Originally the tiles had a zinc anti-corrosion treatment which had failed very quickly in the acid Victorian city air and had been overcoated with a patent treatment. Research showed that many layers of lead based paint had also been applied over the years.

6.2.2 The aim was to put the roof in repair and provide a protective treatment which would last some 40 years. The accumulated layers of dirt and paint were removed back to bare metal by air abrasive blasting. Lead precautions included a full working enclosure, protective suits with air supply, air sampling outside the enclosure, disposal of the spent grit and dirt under controlled conditions and a decontamination unit for workmen. Broken cast iron tiles and jointing rolls were repaired by stitching, cold cast welding and off-site welding in an oven with controlled heating and cooling. Some new iron tiles, rolls and missing decorative features were cast, and after reassembly the roof surface was shot blasted and hot zinc sprayed. Pitting in the metal surface was stopped with an epoxy filler, followed by a sealing coat and finally a colour finish of vinyl co-polymer paint.

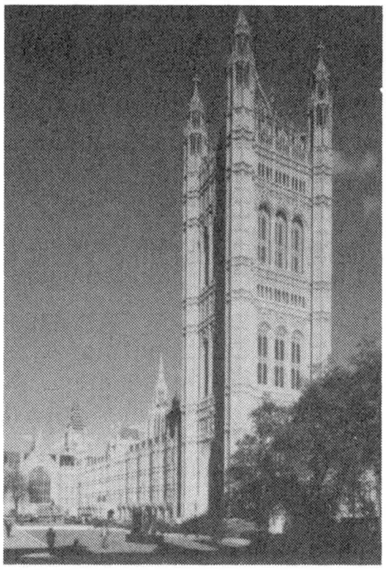

Fig.5 Restoration Complete

6.3 Gilding

From analysis of paint scrapings, research in the Public Record Office, old photographs and contemporary descriptions it became clear that the gilding had originally been much more extensive and it was decided to restore the original decorative scheme. The gilding design was faithfully restored using 4,000 sheets of gold leaf and the completed scheme achieves a balance with the restored clock tower at the opposite end of the building, as Barry and Pugin originally intended.

7. BIRD PROTECTION

Birds, particularly pigeons, roosting on buildings are a problem throughout London. Stone coloured nets and sprung stainless steel wires were therefore fixed over balconies, around statues and across other perching areas. These measures are not generally visible from ground level.