WALTER BURLEY GRIFFIN INCINERATOR, WILLOUGHBY – CONCRETE REPAIRS

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ABSTRACT
This paper discusses the deterioration of concrete at the Walter Burley Griffin Incinerator, Willoughby and its repair. Investigations into the causes of deterioration to the floors and chimney, the test result findings and repair options considered are discussed. The paper also describes the methods of concrete repair adopted and the further latent conditions that were uncovered during the repairs and how these were managed.

INRODUCTION

The Willoughby Incinerator building was designed by Walter Burley Griffin in association with Eric M Nicholls in 1933-34. It was one of a number of incinerator buildings designed by Griffin and Nicholls that were built between 1930 and 1938 in New South Wales, Victoria, South Australia, Queensland and the Australian Capital Territory. Marion Mahony Griffin also contributed to some of the designs[1].

The Willoughby Incinerator used the Reverberatory Incinerator and Engineering Company's system of the vertical top gravity feed process. The Reverberatory Incinerator was an Australian patented design by Essendon engineer John Boadle[1]. It achieved much higher efficiency than imported counterparts by preheating and partly drying the refuse whilst it moved down a sloping, vibrating grate within the combustion chamber. The combustion chamber was designed to 'reverberate' heat on to the incoming refuse. The vertical top gravity feed process required incinerator buildings to be built on steeply sloping sites or embankments. It is considered that the Willoughby Incinerator was probably Griffin's most successful adaptation of this process to a naturally, steeply sloping landscaped site[2, 3].

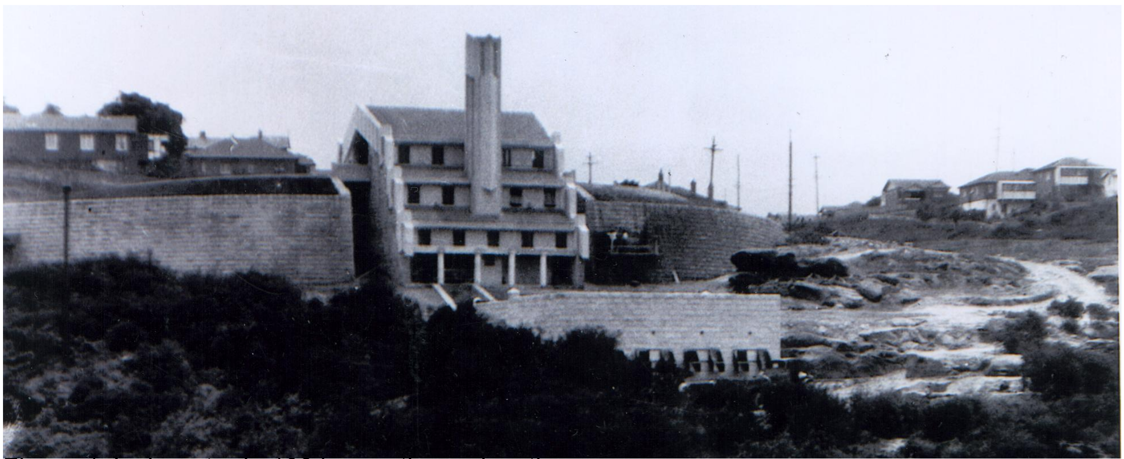

Figure 1: Incinerator in 1934 – southern elevation
Willoughby Council Library photographic collection

The building has 4 levels. The upper floor, at street level, is the delivery floor where refuse and night soil pans were delivered. Below the delivery floor is the trimmer's gallery floor. This floor previously contained a reinforced concrete hopper for the refuse, the trimmer's viewing window to the hopper and the night soil pan cleaning room. Below the trimmer's floor is the furnace floor, which contained the furnace firing and combustion chambers and lockers and shower room on the north side, below the pan cleaning room. Below the furnace floor is the ash floor, where ash was collected in steel skips and transported on rails to the ash bins[1].

The northern, eastern and western walls of the building and driveway retaining walls are faced with rusticated (rock-faced) local sandstone. Internally the building walls are brick masonry. The retaining walls around the building and below the driveways are gravity walls constructed of sandstone. The southern wall of the building, which is stepped with the landscape, previously had metal-bared openings. These were replaced with glazed windows and painted plywood when the building was converted to a restaurant. The internal structure and floors are reinforced concrete. The chimney at the centre of the south elevation is reinforced concrete, with an internal, dry-laid brick flue. The roof of the building has steel trusses and steel and timber tile battens, with green coloured interlocking Marseille tiles. The gable ends have cast in-situ reinforced concrete decorative fascias.

The external concrete faces are sand/cement rendered (areas of original render may have been coloured buff, using mineral pigment[4]). The corners of gables and the southern, stepped wall are terminated with precast concrete octahedral and chevron forms. The chimney concrete has chevron forms to each face, plus precast reconstituted stone 'inverted diamond-point' units set into the eastern and western faces, which change for the top 2.7m of the original design to the northern and southern faces. The reconstituted stone precast units are described in the original specification[4] as 'synthetic stonework of concrete faced with ¼" (6.5mm) selected fine aggregate, structural mortar and pigment'. The original units have a slightly pinkish hue and quartz sparkle, similar to that of pink sandstone.

The Incinerator building and its curtilage, which includes the driveways and land in front of the building to the street and retaining walls and ash pits downhill from the building, are listed on Willoughby City Council's Local Environmental Plan (LEP), the NSW State Heritage Register, by the National Trust of Australia and on the Register of the National Estate. NSW Heritage Council approval is required for proposed remedial works that may alter or remove existing fabric.

BACKGROUND

By the 1960's the incinerator building had fallen into disrepair and the incinerator function was closed in October 1967, although it is understood that the building continued to be used as a sewage pan disposal point until 1974, serving a number of Municipalities[1]. The incinerator was finally saved from demolition in 1976 when plans were put forward to restore and convert the building to restaurant use. The building opened as a restaurant in 1982 and operated for a number of years until 1988. In 1989 the building was converted to office use[3].

In August 1996 fire extensively damaged the upper storey (delivery floor) and roof of the building and caused smoke and water damage to the lower floors. Following repairs the building was reoccupied in September 1997 and continued to be used as offices until at least 2001.

A Conservation Management Plan was prepared for Willoughby City Council in 2001[1].

By 2004 the building was unoccupied. During repainting of external concrete surfaces with anti-carbonation paint the experienced contractor noticed that internal concrete walls to the chimney at furnace floor level had significant structural cracking. Under the guidance of the contractor initial investigations of the chimney concrete were undertaken in April 2004.

Figure 2: Incinerator in July 2004
View from south-east. Delivery floor at the top, trimmer's floor, furnace floor and ash floor below.

Figure 3: Incinerator in July 2004
View on the delivery floor from north-west.

CONCRETE INVESTIGATIONS AND TESTS

The April 2004 concrete investigations and tests were confined to the east and west walls of the chimney at furnace floor level, where significant structural cracking had occurred. These initial tests were confined to testing for depth of carbonation and visual inspection of the concrete and reinforcement. Core samples were taken to inspect reinforcement and to measure the depth of carbonation. Carbonation of the concrete was found to extend far into the 170mm thick chimney wall and past the depth of the reinforcement at the centre of the wall. As feared, the cracks were due to the expansion of corroding reinforcement and the wall concrete had delaminated at the position of the reinforcement. The reinforcement was found to have corroded to such an extent as to have very little or no remaining strength. The compressive strength of the concrete was not tested for, however the concrete showed low strength when cut, either due to poor quality of concrete in the original construction or a subsequent loss of strength due to heat. The inspection report commented that the proportion of sand in the concrete sampled was higher than would be expected of a good quality, modern concrete. It was also observed that the whitish-grey colour of the concrete suggests some damage due to heat, which might have been expected.

A more comprehensive scope of concrete tests was undertaken in February 2005. These tests examined more thoroughly the causes of concrete deterioration in order that the most appropriate methods for conserving the structure could be determined. Tests were undertaken to other levels of the chimney and to areas of original floor. The objective was to gain a broader understanding of the extent to which the concrete structure had deteriorated, the causes of deterioration and to prepare a scope of works for repair. For practical and cost reasons concrete sampling and tests to the chimney were limited to areas accessible from internal floors. The upper, external portion of the chimney was not tested at this time.

Initially it had been intended that tests to the floor slabs should act as 'control samples' against which the chimney concrete quality could be measured. However, it was found that the floor slab reinforcement had also corroded.

In total, fifteen concrete core samples were taken from ten locations. Seven core samples were taken from the chimney concrete, to give data at each floor level and to all aspects of the chimney accessible from inside the building. Eight core samples were taken from areas of floor slab that are original to the c.1934 construction, four at the delivery room floor and four at the trimmer's room floor. Each core sample was visually inspected and the depth and condition of reinforcement recorded. The depth of concrete carbonation was also tested for. In addition to visual inspection a covermeter survey was undertaken to determine typical depths of concrete cover to reinforcement. Ten core samples that had sufficient section were then removed to a testing laboratory and compressive strength tested. Of these ten samples, four samples from the chimney were sent for petrographic testing to determine the cement and aggregate content and to inspect for any deleterious content.

The concrete was found to be both heavily carbonated and chloride contaminated. Severe corrosion of reinforcement steel to the incinerator chimney and less severe corrosion of the floor slab reinforcement was found.

The majority of the concrete sampled from the chimney was extremely friable. There were voids within the concrete, resulting from poor compaction practices when built, and cracks around the reinforcement due to the corrosion and expansion of the reinforcing steel. Low compressive strength results confirmed site observations of poorly compacted and friable concrete. Prolonged exposure of the chimney concrete to intense heat from the furnace may also have affected the strength of the concrete. This theory was further supported by the comparatively good condition and strength of the chimney concrete sampled at ash floor level, below the former furnace level, where the heat from the furnace would probably have been less intense.

Concrete sampled from the floor slabs did not exhibit poor, friable concrete as widespread or severe as in the chimney. The concrete was nonetheless slightly friable at many of the test locations. As with the chimney cores there was evidence of voids within the concrete. There were also bony (large aggregate with lack of fine aggregate) sections of concrete towards the bottom of several of the core samples removed, indicating that the concrete had been poorly compacted.

Chloride ion content tests of the chimney concrete at delivery and trimmer's floor level (sampled at reinforcement depth) gave results below the threshold level at which corrosion is likely to commence. However, the chloride ion content of the chimney concrete at furnace and ash floors was extremely high and many times greater than the threshold content at which chloride-induced corrosion is likely to commence. The nature of reinforcement corrosion observed at other levels suggested that chloride-induced corrosion may have been taking place at all levels of the chimney. By testing samples at incremental depths into the concrete it was found that chloride ion levels increased with depth. This indicated that it was very likely that calcium chloride was added to the concrete mix as an accelerator or surface hardener[5] when the structure was built.

Subsequent to the 2005 investigations a copy of the original specification for the building was found[4]. The concrete mix specification confirmed the test findings that calcium chloride was added to the original concrete mix. The specified dosage was 3lbs of calcium chloride per bag of cement. In the 1930's a bag of cement weighed 125lb[6]. Therefore the design dosage of calcium chloride by weight of cement was approximately 2.4% (a further clause of the specification refers to 3% calcium chloride admixture by weight of cement). At the time the maximum recommended quantity of calcium chloride admixture to accelerate the concrete set or act as a surface hardener was 3% by weight of cement, 'since larger proportions often reduced the strength of the cement'[5].

From modern research the threshold for the likely onset of chloride-induced corrosion is nowadays generally considered to be 0.4% weight of chloride to weight of cement. This value can be influenced by the environment, concrete quality and cement type but is the value considered to represent a finite but low risk of chloride induced corrosion[7]. The design chloride content of the incinerator concrete is therefore approximately six times that which is likely to bring about reinforcement corrosion.

To complete the concrete investigations, in November 2007 tests were undertaken to the areas of the trimmer's and delivery floor slabs not previously investigated and to the upper reaches of the chimney, accessible only from a cherry picker. Tests were also made to the roof gable end concrete, not previously tested. To mitigate the number of core samples required initial testing was by half-cell potential mapping, to assess the extent of reinforcement corrosion beneath the concrete surface. Limited small core samples were then taken to the depth of the reinforcement to verify the half-cell potential results by visual inspection of the reinforcement and to test for concrete carbonation and chloride content.

CONCRETE TEST FINDINGS

It was found that chloride-induced reinforcement corrosion was taking place in the cast in-situ concrete elements of the building as a result of calcium chloride added to the concrete at the time of construction. In addition, the carbonation front had penetrated the concrete past the depth of the reinforcement, resulting in the breakdown of the bonded chloride, which releases chlorides ahead of the carbonation front. In many elements the full depth of the concrete was carbonated. The presence of both chlorides and carbonation makes the reinforced elements more susceptible to corrosion than when there is only one source of attack present. Corrosion of reinforcement bars ranged from light surface corrosion scale to heavy corrosion scale. In areas of heavy corrosion the expansion of the reinforcement steel had caused the concrete to crack and spall.

The half-cell potential results for the chimney were more than -300 mV in all areas tested. In addition, visual examination of the reinforcement showed active corrosion on the surface of the reinforcement. While the chloride content tests above the trimmer's floor gave low results, below the trimmer's floor the chloride content of the chimney concrete was at least three times the threshold level likely to induce corrosion.

The extent of reinforcement corrosion and concrete deterioration had affected the whole of the chimney structure. However, it did appear that the extent of reinforcement section loss was greatest below trimmer's floor level, where the chloride content of the concrete tested as greatest. The reinforcement section loss to the east and west walls of the chimney at furnace level exceeded 50%, which had resulted in severe cracks to the concrete.

Above trimmer's floor level, where the chloride content of the concrete tested as lower, the reinforcement section loss appeared generally less severe, but with some isolated patches of higher corrosion. Where tested the section loss to reinforcement bars above trimmer's floor level was found to be in the order of 15-20%, with approximately 80-85% of the reinforcement section remaining. Concrete cracking due to reinforcement corrosion was present to the full height of the chimney but was less severe above trimmer's floor level than at the lower, furnace floor level.

Variable chloride levels were recorded in the delivery floor and trimmer's floor slabs. Whilst most floor areas tested had chloride levels below the threshold level, on the eastern section of the delivery floor slab six times the threshold level was recorded. This did not agree with the half-cell potential readings. Recent screeding of the surface of the floor slab and low moisture content may have moved the half-cell potential readings towards more positive values (less likelihood of reinforcement corrosion); however, these more favourable readings may not necessarily have been indicative of the severity of the steel corrosion. Visual inspection showed active reinforcement corrosion taking place and the extent was general. By visual inspection it was estimated that the section loss to floor slab reinforcement was between 5% and 20%. In many areas the soffit of the concrete had spalled as a result. Also, it is possible that heat from the 1996 building fire may have weakened the concrete matrix to the underside of these floors.

Active reinforcement corrosion was observed to both gable ends. However, the eastern gable end exhibited a higher degree of corrosion. The condition of the reinforcement was similar to that of the floor slabs. At both gable ends the chloride content exceeded the threshold level for chloride-induced corrosion. The compressive strength of the gable end concrete tested was between 12 and 14.5Mpa, which is relatively weak.

CONSIDERATION OF CONCRETE REPAIR OPTIONS

The repair methods to conserve the concrete structure were to follow the principles of the Burra Charter[8], which are to do as much as is necessary but as little as possible. The repair methods were also to be formulated in conjunction with all structural engineering requirements for the safe execution of the works and stability of the building. The conservation management plan[1] was also to be followed.

The concrete investigations found that both chloride-induced and carbonation-induced corrosion of reinforcement steel was active within all elements of the c.1934 concrete structure. To not repair the concrete was not an option as these combined mechanisms for corrosion would continue to be active whatever environment the concrete is in. For example, in internal areas, when the building is reoccupied, the ability of calcium chloride to absorb water vapour from the atmosphere may accelerate the corrosion of reinforcement.

Available remedial treatments for chloride-induced corrosion are; patch repair, migrating surface applied corrosion inhibitors, chloride extraction, cathodic protection or demolition and reconstruction.

1. Patch repair, the most commonly used method for concrete repair, is only effective if all contaminated concrete is removed and corroded reinforcement cleaned and treated. If this is not done corrosion around a patch can accelerate due to ‘incipient anode effect’. In regards to the incinerator structure patch repair alone was unviable as removal of chloride contaminated concrete would require the removal of all original concrete. Patch repair has been used, however, were concrete had failed locally and needed to be replaced.

2. Migrating surface applied corrosion inhibitors (SACI) rely on the inhibitor penetrating into the concrete to the depth of the reinforcement and forming a protective layer on the steel surface. However, the effectiveness and rate of penetration to the steel has not been fully established in the field. Recent studies on a new generation amino alcohol based SACI found that it was effective in slowing the rate of reinforcement corrosion when compared to control samples not treated and that it was effective in inhibiting corrosion in the presence of chlorides. However, it was found not to be effective when applied after the initial onset of corrosion[9]. Also, typical penetration rates are in the order of up to 75mm in 28 days. Therefore, in the case of the incinerator structure, where cover to reinforcement exceeds 75mm and active corrosion is taking place, surface applied corrosion inhibitors would not be effective in slowing the rate of corrosion and prolonging the life of the building.

3. Electrochemical chloride extraction (desalination) is an electrochemical technique similar in procedure to realkalisation. A DC current is passed between the steel reinforcement and a temporary surface anode to remove chloride ions from the concrete. Negatively charged chloride ions are repelled from the negatively charged steel and are forced outwards towards the temporary anode where, over a period of six to eight weeks, they are collected in the electrolyte and removed along with the temporary anode[10]. The electrochemical process requires the reinforcement to be sufficiently continuous to act as the cathode and for the concrete matrix and surface to be sufficiently intact to conduct the current to the temporary anode. In the case of the incinerator chimney neither of these conditions existed.

   Electrochemical chloride extraction alone would not have been effective in treating the incinerator concrete as it would not have solved the problem of carbonation-induced corrosion of reinforcement steel. The chimney reinforcement was severely corroded and for reasons of strength (and continuity to enable an electrochemical process to work) areas of reinforcement would require replacing or supplementing. A surface applied, non-invasive system was therefore inappropriate for all the repairs necessary and a solution more disruptive to the surface of the concrete would be necessary. Also, it is a relatively recent technique with very little field data available. As with realkalisation, there is some concern over the long-term performance of this treatment and potential side effects to the concrete. It is therefore felt that the choice of desalination for heritage buildings should be considered cautiously[10].

4. The most effective long term method for treating both chloride-induced and carbonation-induced corrosion of reinforcement steel is impressed current cathodic protection (ICCP). ICCP is an electrochemical repair technique that halts corrosion of the reinforcement steel. It is a well understood and proven repair technique. ICCP works by passing continuous electrical current between the reinforcement steel (cathode) and a permanent anode of sufficient strength to stop the anodic reaction. Corrosion cannot occur unless the anodic and cathodic reactions both operate and corrosion is therefore suppressed[10]. The permanent anode, in the form of mesh or wires, is fixed into the surface of the concrete and the surface concrete reinstated.

   For impressed current to pass between the reinforcement cathode and the introduced anode all reinforcement needs to be connected and the concrete needs to be monolithic. If not all steel and concrete are in contact then the reinforcement that is not connected will corrode at an accelerated rate. In the case of the incinerator building it would be necessary to connect all reinforcement by welding in connecting reinforcement.

   In addition to being a proven technique, ICCP is relatively cost effective, quick to install and does not require repeat applications, as might other remedial treatments. For these reasons it was considered to be the most viable and economic solution for maintaining and protecting the incinerator concrete in the long-term.

   Expert advice is required to design, install and monitor a cathodic protection system. Because there are different levels of chloride-induced and carbonation-induced corrosion activity in different parts of the structure ICCP requires regular monitoring and adjustment to ensure that comprehensive protection is achieved. The choice of Contractor for the incinerator repairs was based on the Contractor's technical expertise in impressed current cathodic protection.

5. Demolition and reconstruction was considered the least preferred option for any element of the incinerator building as it would result in the total loss of historic building fabric. It was only to be considered when all other conservation methods had been investigated and assessed.

   In the course of repairs, once the 1980's chimney cap had been removed, the internal faces of chimney concrete were found to be in far worse condition than previous tests to the exterior of the chimney had predicted. The deterioration of reinforcement and damage to concrete was such that there was no option other than to demolish and reconstruct the top five metres of the chimney.

   Rather prophetically we wrote in April 2005, 'If demolition and reconstruction of the chimney structure is found to be necessary, for reasons of public safely for example, the existing precast concrete elements and fire bricks should be conserved for incorporation into the rebuilt chimney. Design of the rebuilt chimney should incorporate the original upper section of the chimney, as discussed in the conservation management plan'. The conservation management plan advises that, 'The reinstatement of the top of the flue, which is an obligation of the lessee under the lease, should be regarded as a high priority'.

   The original top 2.7m of chimney had been removed in 1954 and replaced with plain rendered brickwork This brickwork height was removed when the building was converted to restaurant use because it was considered unsafe[1]. It was a condition of the lease that the top portion of the chimney be reinstated to Walter Burley Griffin's original concrete design, with chevron and inverted diamond-point details, but this had never been done. The current remediation works were to make provision for this, either as part of the current works or in the future, depending on available funds.

CONCRETE REPAIRS TO FLOORS, BEAMS AND GABLES

When the incinerator was adapted to restaurant use in the 1980's the floors were changed and added to. Only the northern portions of the floors date from 1934. ICCP has been installed to these areas of floor. The floor soffits were scabbled to remove cracked and spalled concrete and to give a key for the repairs. The reinforcement was checked for electrical continuity and structural section and the floors verified for the intended future use. It was found that no augmentation of reinforcement for the purposes of strength was required. The ICCP anodes were fixed into the underside slabs and the concrete soffits reinstated with sprayed concrete (shotcrete). Old patch repairs made to beam soffits in the 1980's where removed and remade. For ICCP to be effective the previous repair reinforcement paint and epoxy mortar, which would have impeded current flow, needed to be removed.

The roof gable ends are in-situ concrete, approximately 150mm thick, rendered externally with precast concrete octahedral and chevron forms at each corner. The ICCP anodes were installed from the inside face so as not to alter the external appearance. The inside face was then reinstated with sprayed concrete to the original stepped profile.

CONCRETE REPAIRS TO THE CHIMNEY

Concrete repairs to the incinerator chimney have proven the most problematic to achieve. Initial investigations to the chimney at furnace level had determined that the thinner, 170mm thick, east and west walls were beyond repair and needed to be broken out, the reinforcement replaced and the concrete recast. The thicker north and south walls, which are 300mm thick, appeared to be in better condition, with less evidence of reinforcement corrosion and cracked concrete. It was believed that ICCP would be feasible to both of these walls. Subsequently it was found during the works that that the south wall concrete had cracked and delaminated where reinforcement had corroded to the inside face. The flue brick lining prevented access to the internal face of this wall to reinstate concrete, ensure the electrical continuity of reinforcement and to install ICCP anodes. The decision was therefore taken to remove and recast this section of south wall. Consequently at furnace floor level only the flue bricks (dating from 1954) and the north wall of the chimney remain original.

A full access scaffold was erected and the 1980's chimney cap removed, allowing the internal faces of concrete between the brick flue and outer concrete to be viewed. The internal face of concrete for at least 3.3m below the top was very friable with negligible strength and large areas of delamination. The condition was much worse than previous core sample test reports had predicted. In addition, there were numerous rogue steel bars projecting into the internal chimney space from the concrete (possibly original shutter ties). The interior of the chimney was lined with flue bricks, with a small space between the flue bricks and the outer concrete chimney. In discussion with the contractor it was agreed that installation of ICCP to the upper portion of the chimney as existing was not practicable given the severe extent of deterioration of reinforcement and concrete and restricted access between the flue lining and concrete. Had the flue bricks alone been removed patch repair would have been extremely uneconomic, whilst maintaining the structural integrity of the chimney, because of the extent of concrete and reinforcement replacement required.

Figure 4: View down the chimney from the top with c.1980's cap removed showing the general extent of delaminated, friable concrete.

Figure 5: View inside chimney with flue bricks removed, showing typical extent of reinforcement corrosion.

Application was made to the NSW Heritage Council for the top 3.6m of the chimney to be carefully taken down and reconstructed, with provision to takedown and rebuild a further 1.8m, or so, should this be found to be necessary. It was considered most important not to demolish to below where the chimney exits the building and to retain the bottom height of chevron and inverted diamond-point detail, to allow the chimney to be reconstructed to its previous form from an existing base.

Prior to any taking down, site measurements of the chimney concrete and diamond-point details were taken. Concrete profile dimensions were also interpreted from c.1934 photographs, by counting diamond-points and measuring chevron angles from elevations for example, and from original drawings reproduced in the conservation management plan. In interpreting these sources slightly more weight was given to site measurements and photographs rather than the drawings, as the drawings are not necessarily 'as built'. That said the drawn dimensions appeared close to the site measurements and to the dimensions and angles interpreted from photographs.

As a third and final check it was recommended that the Walter Burley Griffin Society be asked to review the interpretation of dimensions against other available evidence. The chimney chevrons appear to use 45° angles in elevation, which flatten to approximately 32° in profile. This may have been a geometric device that Griffin used on other buildings.

In total approximately 5m height of chimney was carefully taken down, together with the brick flue lining. Deterioration of concrete and reinforcement was found to continue below this level, to as far as the trimmer's floor. Because we did not want to lose the form of the chimney above the roof a structural scheme has been devised to carefully remove corroded reinforcement and friable concrete from the inside of the chimney whilst stabilising the external veneer of sound concrete using a reinforcement armature and sprayed or rendered concrete backing. A concrete, vertical transfer structure will then be constructed inside the chimney to permanently retain the external concrete veneer and provide a structurally sound base from which to reconstruct the chimney in concrete to Griffin's original design and height.

The inverted diamond-point details to the exterior of the chimney are precast concrete units with reconstituted stone facing, which are stack bonded within vertical rebates cast into the chimney concrete. Each unit was marked with a removable marker and its position recorded before removal. Each precast unit has steel reinforcement that in many cases has corroded and caused cracking. Where possible the units are to be repaired and reused. Where necessary replacement units are to be manufactured, working from Griffin's original specification[4], to replace those units that cannot be repaired. It is proposed that the reinstated precast concrete units shall be isolated from the chimney concrete so that the unit reinforcement does not need to be connected to the ICCP system.

At the time of writing this paper the chimney walls to the delivery floor are being recast in-situ and the upper walls are being prepared for stabilisation prior to the installation of the vertical transfer structure.

CONCLUSIONS

For concrete repair projects such as the Willoughby Incinerator it is important to first obtain a thorough understanding of the modes of deterioration, by both visual inspection and up-to-date testing methods. Research to obtain copies of original specifications and drawings may help enormously and provide vital information. An understanding of the available methods of repair, their viability and how they may each act to protect or be detrimental to the structure are also prerequisites to repair. In addition to manufacturer's advice, thorough research is required to understand the possible limitations or ineffectiveness of some repair systems proposed.

It is advisable to engage a contractor who has expertise in all methods of repair. This will allow flexibility on site to cope with latent conditions, whilst taking into account budget and time constraints. However much prior investigation and tests are undertaken, if not all faces of the concrete can be viewed it is likely that unexpected conditions may be found.

The willingness of the client and project team to consider all aspects of conservation, whilst understanding the limitations, and not just what might seem expedient structurally at the time is also vitally important. In the case of the Incinerator building through thorough research, analysis and perseverance a conservation method has been found and implemented.

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