CAMPUS MLC GLAZED TERRACOTTA FACADE: 'ENGINEERING' CONSERVATION

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ABSTRACT

Conservation works to the glazed terracotta clad facades of the Campus MLC Building located in North Sydney were completed in 2006.

This paper describes the problems that had developed in the terracotta facades and the process of developing a conservation approach, including diagnosis of the deterioration mechanisms and development of an engineered solution. The paper also describes the innovative approaches adopted in delivering the conservation works, including the form of contract design and procurement of replacement terracotta units, and detailing of their installation.

The experiences from this project illustrate the challenges of preserving unloved, yet significant, building facades using similar building materials and systems so as to maintain the significance and authenticity of the facade.

INTRODUCTION

Conservation works were undertaken on the glazed terracotta façades of the Campus MLC Building, 105 Miller Street, North Sydney, during 2005 following a series of investigations dating back to the 1980s.

The building is H-shaped in plan with the main wing fronting Miller Street, a smaller wing fronting Denison Street and a taller central lift core connecting the two buildings. The lift core and end walls of the office buildings are reinforced concrete structural shear walls and are clad in glazed terracotta units.

The design of the MLC Building, North Sydney, by Bates, Smart & McCutcheon, was based on SOM's Lever House in New York. Bates, Smart & McCutcheon designed buildings in Adelaide, Perth, Brisbane, Hobart and North Sydney for MLC between 1955 and 1958 and introduced major features such as curtain walls and articulated cores. The building was Australia's largest office building on completion in 1957 with over 42,000sqm of office space.

The building is listed on the:

- North Sydney Local Environmental Plan
- RAIA NSW Chapter – Register of 20th Century Buildings of Significance
- National Trust of Australia (NSW) - Register

The statement of significance on the NSW State Heritage Inventory includes the following:

"*The first high rise office block in North Sydney and the largest for a number of years after its construction. Seminal building on subsequent high-rise design in Sydney and utilised construction and structural techniques not previously used in Australia. First use of curtain wall design; first use of modular units in Australia. Major landmark in North Sydney.*"

A HISTORY OF PROBLEMS

Like most buildings, the problems developed over time. In the 1980s, concerns were raised over issues with the terracotta clad walls (amongst other items). Various incidents occurred, leading to further investigations through to 1997, when façade repair works were finally undertaken. These works included extensive conservation work to the aluminium and glass curtain wall, a major interior refurbishment, but only limited repairs to the terracotta facades.

Uncertainty over the safety of the glazed terracotta clad portions of the façade continued. Further investigations led to engineering advice that these facades needed to be either overclad, or demolished and reconstructed, at a high financial cost and with substantial impact on the heritage significance of the building.

A HISTORY OF INVESTIGATIONS

The following investigation reports had been prepared up until 2003:

- Thermographic surveys carried out in 1983.
- Report on External Facades Including Terra-cotta Tiling and Glazed Curtain Wall. Report for MLC Head Office, February 1987.
- Updated Report On External Facades Including Terra-Cotta Tiling And Glazed Curtain Wall, December 1990.
- MLC Building North Sydney – Façade Repair Maintenance Manual, March 1997.
- 105 Miller Street, North Sydney – Terracotta Tiled Façade Investigation, September 2002.
- 105 Miller Street, North Sydney – Tiled Façade Survey – July 2003.

The report in 1987 concluded that considerable physical deterioration had taken place, and that it could be expected to accelerate. The lack of expansion joints in the terracotta system did not release the combination of stresses resulting from the expansion of the terracotta units due to moisture absorption, diurnal changes in temperature, shrinkage and creep of the concrete wall.

Though widespread drumminess was reported in all previous reports, the 1987 report suggested that delamination of blocks and mortar assisted by expansion in reinforcement due to rust could cause face of blocks to move outwards. Unfortunately, this theory was not further tested on the areas surveyed by thermography.

The 1997 repair works involved installing restraint ties to the terracotta facades on a 1.2m grid. These limited remedial works increased the factor of safety against a sudden large-scale failure.

In early 2000, there was a change of building owner with the subsequent loss of many previous records. This of course, makes things difficult. Retention of building information saves time, money and allows consultants to review previous recommendations prior to embarking on their own investigations.

Subsequent reports in 2002 and 2003 appear to have been prepared without access to the prior work They identified extensive drumminess of the terracotta façade and raised serious concerns over its structural stability. The resultant recommendations were to overclad the terracotta facades with an aluminium composite cladding or to demolish and reconstruct the terracotta walls.

These recommendations were likely made primarily with public safety in mind. There is a childcare facility, outdoor seating, sidewalks and parking surrounding the building. Whilst the recommendations were not invalid, the owners were interested in exploring other possibilities.

A NEW DIRECTION

The owners subsequently brought together a multi-disciplinary team to investigate the options available to them, including Jackson Teece Chesterman Willis (JTCW) as Heritage Architect, International Conservation Services (ICS) as Architectural Conservator and Hyder Consulting (Hyder) as Façade Engineer. That said, the most important member in the team was probably the owner.

The owner's brief was that the works should mitigate their risk and be relatively cost-neutral when compared to other options, as well as address the heritage significance of the building. With this brief in mind, the project team was determined to retain the existing glazed terracotta fabric unless it was proven impossible or not cost effective to do so.

Consequence of Failure and Remedial Options

The 2003 report stated that the terracotta facades required over-cladding or re-cladding in the near future, and that these were the only two options that could offer certainty of the structural performance of the façade. Further knowledge might have given increased reassurance as to the stability of the facades, however, the report stated there was no way to check the physical condition of every element of the façade, and a risk of failure therefore still existed.

But was this the issue? Did we need to check every element of the façade or could we make certain assumptions and achieve the owners brief?

DIAGNOSING THE PROBLEMS

Further investigation by Hyder and ICS was aimed at determining the nature of deterioration, construction details and likely cause of the problems, as well as developing further options for conservation and/or repair.

Determining Construction Details

Hyder/ICS undertook a rope access inspection of representative drops of the façade in order to understand the problems. Whilst this had been done before by others, it was important that the appropriate engineering team was deployed to understand the façade construction and its problems. Generally, remedial solutions can only be appropriately specified after understanding the construction of a building/structure and determining the nature of deterioration.

These inspections and subsequent investigations revealed that the concrete walls were clad to full height with terracotta units and were constructed in the following manner:

- Galvanised steel shelf angles installed approximately every second floor.
- Mild steel mesh fixed against the shear walls using steel 'tag' brackets attached with shot-fired nails and only having a supplementary lateral restraint action.
- Units placed vertically with brass clips interlocking into the dovetail recesses, and held to the reinforcing mesh with copper tie wire.
- 'Spacers' placed in the horizontal joints only.
- Terracotta joints pointed using sand cement mortar.
- Flowable mortar poured in behind the units (approximate mortar thickness 25mm).
- The terracotta units had a near-white ceramic body and glazed blue faience surface with two distinct types of glaze, Type A – dark blue mottled glazed finish and Type B – light blue glazed finish.
- The units were 14" (350mm) x 5 1/8"(130mm) and had a series of dovetails to interlock with the mortar. Units were 25mm thick, with a further 25mm for the dovetails The mortar bed of units was interlocked with the reinforced concrete wall behind by 25mm wide by 50mm deep horizontal rebates. Rebates were at 2' (600mm) centres, vertically.

The in-fill mortar between the terracotta and the reinforced concrete walls was reinforced by the mesh which is tied back to the reinforced concrete wall. It was hypothesised that the terracotta tiling system might be acting as a membrane and that despite extensive, detachment between the mortar and concrete wall, this might prevent the façade from excessive bowing outwards. If so, the integrity of the mortar and mesh system might give increased reassurance as to the current stability of the facades, provided corrosion of the reinforcement mesh was arrested.

Deterioration Mechanisms

A number of deterioration mechanisms were identified during the course of the investigations.

Terracotta spalling at shelf angles - chipping and spalling of the terracotta body at shelf angle locations due to corrosion of the shelf angle. The corrosion was generally located along the front edge of the angle section and this had caused a number of units to debond. The expansive corrosion product had caused some units to rotate, inducing forces into the adjacent units, resulting in chipping and spalling at the edge of the units immediately above and below. In some locations, the corroding shelf angles had also resulted in the face of the units breaking off at the dovetails due to expansive pressures of the corrosion product.

Corrosion of the mesh, fixings and shelf angles - caused by water penetration combined with a relatively porous backing mortar and localised cracks and voids. The level of corrosion was generally minor, except at voids. Therefore, it was not considered that corrosion was the primary cause of debonding of the mortar. Testing of the mortar for carbonation and chloride content determined that both these mechanisms were not directly responsible for the corrosion. Chloride content was measured by weight of concrete, and although the results were slightly elevated, mortar has a higher cement content than standard concrete and thus the measured values were not considered to be above the threshold concentration required for the initiation of corrosion. Carbonation had generally not occurred in the mortar with the exception of localised carbonation at cracks and exposed surfaces. This localised carbonation would allow the reinforcing mesh in these locations to corrode but not result in expansive forces that could lead to delamination.

Debonding between backing mortar and concrete - with the exception of shelf angle locations, it appeared that the nature of the bond between the unit and the backing mortar was generally secure across the facades. However, concerns about the bond between the mortar backfill and the structural concrete arose from the large areas of drumminess recorded on the façade. The debonding of the mortar at this interface was confirmed as the primary cause of the drumminess.

Lack of stress relief - Another mechanism causing units to crack and debond was the inability of the current system to accommodate the vertical forces in the system caused by shrinkand creep of the sub-structure, thermal expansion, and a number of short-term effects following construction.

Spalling of the terracotta glaze - It appeared that the façade system had allowed water ingress through mortar joints, cracks and spalls in the terracotta glaze, along with roof cappings, windows and other non-watertight locations. The glaze was relatively impermeable to water vapour and the resultant evaporation of water from behind, and through, the units had resulted in the crystallisation of soluble salts and expansive forces just behind the glaze, causing it to spall.

DEVELOPING SOLUTIONS

Corrosion of Mesh and Mesh Fixing Brackets

Corrosion of the backing mesh, nails and clips was reported in 2002 as being a threat to their ability to provide the necessary lateral restraint to prevent the units from pulling away from the substrate. In those areas which were opened in 2002, it appeared that the protective environment to the reinforcement had been lost due to carbonation of the mortar and the ingress of moisture. The mesh however, did not generally show severe corrosion. Furthermore, in areas where corrosion of the mesh had occurred, there was no evidence of cracking or spalling of the mortar or terracotta units.

Therefore, considering the age of the building, the rate of corrosion of the mesh reinforcement may indicate that the initiation period might have just passed, and so if it takes 45 years to reach the current state, could a reversal process (i.e. electrochemical repair such as cathodic protection) be considered to arrest further corrosion?

Cathodic protection (CP) - was therefore considered as a repair and protection method. CP would reduce or eliminate corrosion of the mesh. This would be achieved by making the mesh a cathode via an impressed direct current (DC) or by the use of sacrificial anodes.

Impressed current cathodic protection systems utilise an inert anode material, such as catalysed titanium, which is forced to slowly corrode in favour of the mesh.

Sacrificial or galvanic CP is based on the principle of dissimilar metal corrosion and the relative position of the specific metals in the galvanic series.

However, based on Hyder's experience of CP systems in reinforced concrete structures, it was determined that an impressed current system would not be practical in this application.

An impressed current CP system relies on the electrical continuity of the steel it is designed to protect, but also on the full embedment of that steel in an electrolyte – which transports the current. This could not be assured behind the terracotta units without extensive opening up of the heritage fabric and this was the main problem with the practicality of this solution. The decision was therefore made not to pursue this repair and protection method further.

Terracotta Spalling and Corrosion at Shelf Angles

It was clear that the galvanised shelf angles were undergoing corrosion and causing expansive forces in the horizontal bed joints and subsequent spalling of units. The works undertaken in 1997 did not adequately address this issue and corrosion continued to occur.

Cathodic protection (CP) was again considered to prevent further corrosion of these angles, and hence reduce the undesirable expansive forces in the horizontal bed joints. Again, in light of the practicality and cost of this type of system, CP was not regarded as the optimum solution as the mesh behind the units would also have to be part of the system.

Therefore, with CP considered as impractical, rectification of the shelf angles would require either full exposure, cleaning and protection of the existing shelf angles with appropriate coatings, or replacement of the original shelf angles with new stainless steel angles, which would not be susceptible to corrosion.

A decision was made to replace all the shelf angles with new stainless steel angles. This involved pinning rows of units above and below the shelf angles to take the dead load whilst installing the new angle one row above the original shelf existing angle.

Lateral Restraint

The extensive drumminess of the tiling system across the façade required the installation of additional lateral restraint and movement joints to accommodate differential expansion/ contraction of the sub-structure and terracotta tiling system.

Hyder determined that the units were not in risk of pulling away from the mortar as they were mechanically interlocked with the mortar by the dovetails of the units. Also, the fact that the mortar and mesh reinforcing would act as a membrane meant that its flexural strength should not be totally disregarded. As such, a well designed pinning system could enhance the restraint of this membrane back to the substrate with only minor damage to heritage fabric.

It was considered that if alternative means of fixing the terracotta back to the concrete wall was able to be engineered, then the drumminess was not of concern. Further, the corrosion of the mesh would not be of concern either, as the ties would provide the lateral restraint back to the concrete wall.

Therefore, a decision was made to install additional ties to supplement those already installed in 1997. Ties were to be placed on a grid pattern through the glazed units, backing mortar and into structural concrete.

Movement joints were to be installed beneath the replacement shelf angle to accommodate vertical forces and spaced vertically in new sections of tiling to accommodate horizontal forces.

Engineering Calculations

Engineering calculations were undertaken to ensure these proposed solutions could resist likely wind and seismic loadings, thermal movements and the dead load on shelf angles. These calculations determined that lateral restraint ties would be required at approximately 500mm centres.

Replacement Terracotta Units

Following trials on site, it was identified that removal of the existing units without damage would not be practical and that many units would be destroyed during the process. This was due to the units being relatively brittle and the fact that they were interlocked with the mortar and the mesh.

It was therefore proposed that new matching units would need to be manufactured with white body and glaze to match existing to replace damaged or broken units.

Spalling of Terracotta Glaze

The relative impermeability of the glaze to water vapour led to a build up of moisture behind the glaze and a background level of salts behind the glaze. These salts could not be removed without removing the glaze. As such, it was likely that spalling of the glaze would continue unless the following was achieved:

- Moisture ingress was halted at all entry points.
- Current moisture in the system was removed.
- Salts were removed from behind the glaze.

Application of a desalination poultice was trialled, but had only limited effectiveness, even when the glaze was removed. Replacement of spalled glaze with a fired glaze was also not possible; the only option was patching and painting with a suitable coating. In order to maximise long-term performance of this system, a decision was made to remove the glaze and deteriorated surface of the unit body back to sound substrate prior to patching and painting. This had the advantage of also removing significant amounts of silt build-up beneath the glaze. The system used to patch and paint the terracotta units was an Edison Coatings product supplied out of the United States where repairs to glazed terracotta buildings are more prevalent.

We also investigated the possibility of applying a waterproofing product such as silane to the mortar joints. However, application of such a waterproofing product raised concerns regarding the breath-ability of the joint mortar following treatment. If the breathability was reduced, then this may actually increase the rate of spalling in the future as it may have impeded the evaporation of moisture through the mortar joint, thereby increasing the amount of moisture that escapes through the unit.

It was therefore decided not to apply any waterproofing products at this time, but to concentrate on reducing the amount of water entering the system – a solution that met with the Burra Charter's proviso of doing "as much as necessary but as little as possible".

Feasibility and Trials Study

Whilst the above remedies were grounded in diagnostic, structural, materials and remedial engineering logic along with conservation philosophy, the practicality of the remedies needed to be tested in order to reduce the likelihood of cost increases due to latent conditions during the construction phase.

A trial stage on the easily accessible area of the terracotta façade was supervised by Hyder to allow a more thorough understanding of the practicality of the strategy to be developed and to allow a contractor to trial work methods before negotiating a contract, in line with the owner's preferred procurement strategy.

The broad aim of the feasibility and trials study was to:

- Confirm and further understand the deterioration mechanisms.
- Confirm the building construction.
- Assess the feasibility of the proposed remedial strategy.
- Undertake further testing to confirm deterioration mechanisms.
- Undertake testing of selected materials.
- Develop an appreciation of the issues relating to carrying out the proposed works.
- Undertake prototype trials of the methods proposed and assess their practicality and affect on building tenants.

The results of the trials generally confirmed that the proposed remedial solutions were appropriate, and also allowed further refinement of the details to be undertaken.

FINAL SCOPE OF WORK

Following the successful completion of the trials, the scope of works was finalised

- Install ties to rows of existing units above and below shelf angle locations.
- Removal of one row of existing units at shelf angle.
- Removal of existing shelf angle.
- Installation of new stainless steel shelf angles.
- Re-installation of existing or installation of new units.
- Incorporate movement joints beneath the replacement shelf angle and vertically in new sections of tiling.
- Manufacture of new/replacement units, including investigating and taking samples of the existing units, developing a specification for replacement units and prototypes of units.
- Procurement of new units from an international manufacturer.
- Delivery of new units to site
- Seal around windows and penetrations through façade.

PROJECT DELIVERY MODEL

Various procurement options were available to the owners. These included traditional tendering (lump sum or schedule of rates), however, considering the unique nature of the works (in that something like this hadn't really be done before), it was proposed that the owner's brief could best be achieved by undertaking the project using a negotiated contract arrangement with a guaranteed maximum price (GMP).

This still required the remedial solutions to be properly specified. The consultant team's brief was for a technical overview of the works, following preparation of a technical specification combining prescriptive and performance based requirements.

R M Watson, the Contractor that undertook the trials, was selected based on successful completion of the trial works and previous favourable experience. The contract was negotiated based on lump sum and schedule of rates items. Rates were obtained for labour, materials, types of work and access. The results from the trials were used by R M Watson to allow some pricing certainty to be obtained.

The GMP was based on a schedule of rates and was administered using a cost-plus contract available from the RAIA. There also was an incentive scheme based on a share of any savings. A major driver for this approach was to do the works at times to minimise tenant disruption. In practice, this required cooperative problem-solving and flexibility throughout the project.

REPLACEMENT TERRACOTTA UNITS

A specialist manufacturer was located to produce matching replacement units. Two types of units had to be replicated; both were 350 x 130 mm x 25mm thick, however one was blue/grey pulsachrome glazed terracotta units and the others were blue/grey plain glazed terracotta units.

Local manufacture was not possible as the terracotta manufacturing plants had long since closed. It was also not deemed worthwhile to investigate using smaller artisan pottery works as the scale of manufacture required adequate quality assurance and manufacturing capacity. Manufacturers were located in the United Kingdom and the United States. Eventually Boston Valley Terracotta (BVTC) from upstate New York was selected as the suppliers.

As the units were to be manufactured in the United States, quantities had to be determined and samples of the glaze finish had to be sent so that an adequate match to the glaze could be developed by the suppliers.

Procurement of units therefore had long lead time (12-18 months) and this meant a delayed start to the project. The glaze matching process required samples to be sent to BVTC and replica samples to be sent back and compared on site.

Colour matching was very difficult and to our surprise matching the plain units was the hardest. Not only did the colour have to be matched, but also the 'sheen', reflectance and texture. The original units showed great variation in the composition of their colours, something that had become a natural part of the look of the building, but that would prove to be difficult to reproduce. It appeared that rather than being an intentional colour variation, the original glaze preparation and firing methods used to manufacture the units resulted in this variation. In this instance, the existence of a computerised manufacturing system and quality assurance proved to be a hindrance!

The way the project team decided to introduce variation into the colours of the glaze was to select a small number of set glaze colours and manufacture a certain quantity of each, then distribute these across the facades in order to try and obtain a 'natural' variation. This worked effectively for the pulsachrome glaze, but less well with the plain colour glaze.

WORK IN PROGRESS

Once the glaze colours were finalised, the site was established using swinging stage access over protective hoardings where required. The fact that noisy works during business hours may lead to the tenants claiming rent abatement for whole building meant that noisy works could not be undertaken between 8am and 5pm, and night works were not permitted by Council.

This led to a development application having to be obtained to undertake noisy works from 6-9pm at night. Justifying this DA required acoustic monitoring of the ambient background noise and analysis of the noise emissions from similar sites being worked on by R M Watson at the time. The acoustic analysis was undertaken by Hyder and presented to North Sydney Council as part of the development application which was eventually approved.

The works were staged around the building. Noisy works such as drilling in the pins were all undertaken between 6 and 9pm, as were the demolition works to the terracotta units. Unit setting and glaze repairs were undertaken during normal working hours.

The works were regularly inspected by Hyder and ICS, with advice provided on specific problems as they arose. Some of these issues discovered during the construction phase required additional repair works not originally anticipated, including more extensive deconstruction and re-cladding at corner areas.

CONCLUSION

The end result of the project was very favourable. The original terracotta cladding was retained. The cost was approximately $2.5 Million, about 5% over the GMP and within the owner's contingency. The tenants were very happy as were the owners, who have resolved the public safety issues without affecting the heritage significance of the building.

The main shortcoming of the works was that the colour matching of the units in some areas of the façade was not as good as we had hoped. If the difficulties of getting an adequate colour match could have been foreseen more clearly and advance colour matching work undertaken, perhaps the match would have been better.

Also, in the future, spalling of the glaze is likely to recur, although the extent remains to be seen. Regardless, the methods and materials are now available to achieve a satisfactory repair of these areas without extensive intrusion.

Overall however, the project stands as an example of how a cooperative approach between owners, tenants, contractors and consultant teams involved on heritage projects can successfully 'engineer' the conservation of the fabric of our modern heritage.