

HAWERA WATER TOWER RESTORATION

Craig Stevenson ¹ and Hugo Jackson ²

ABSTRACT

The paper discusses the original construction of the Hawera Water Tower built from 1912-1914 and the restoration of the structure carried out in 2004. The restoration included a significant amount of conventional concrete repair, rebuild, strengthening of selected elements, application of migrating corrosion inhibitor, waterproof coatings and the replacement of various window and door elements.

INTRODUCTION

The Hawera Water Tower is a reinforced concrete structure constructed in 1914 to improve mains water pressure for fire fighting purposes. There was a substantial cost associated with building this structure and following the example of other towns, it was decided to incorporate a viewing platform and make the tower an architectural feature of Hawera. The tower is registered with the Historic Places Trust and has a Category I listing.

The reinforced concrete tower is 50m high and constructed as a 7m diameter thin walled cylinder stiffened by 8 external buttresses. In addition, internal stiffening is provided by a large central column, radial beams and 3 levels of internal floors.

The tower contained two separate water tanks in its design. The upper tank held 450,000 litres (100,000 gallons) of water designated solely for fire fighting. Directly underneath was a second tank exactly half the size, to be used for household purposes.

At the time of construction the structure was believed to be the tallest reinforced concrete water tower outside of Great Britain.

While the structure has performed extremely well over it's 90 year life, the concrete had deteriorated and was in need of refurbishment.

It was a requirement that the restoration should repair and protect the structure for a much extended life, with a minimum expectation of 50 years. The final proposal included removal and reinstatement of damaged concrete, strengthening the tower and protecting the remaining steel reinforcing by the application of a migrating corrosion inhibitor followed by application of a cementitious waterproof coating, to all exterior surfaces.



Figure 1: The Hawera Water Tower

HISTORY AND CONSTRUCTION

Destructive fires were a frequent event in early Hawera. Fighting of fires in 1884, 1888 and 1895 relied on wells located at the centre of town. Water was piped to the town in 1901 from the Kapuni stream.

A further fire in 1912 highlighted the lack of water pressure and increased insurance premiums were threatened if Hawera did not improve it's fire fighting capability.

¹ Craig Stevenson, Chief Executive Officer, South Taranaki District Council

² Hugo Jackson, Project Manager, Construction Techniques Ltd



Figure 2: Central Post Office after the 1912 fire

Only four days after the 1912 fire, the Borough Engineer J.C. Cameron had produced a report outlining the options for improving water pressure. These included duplication of the supply pipe, extending the supply pipe and construction of a water tower.

The option of a water tower, being the cheapest was selected and construction was commenced in late 1912.

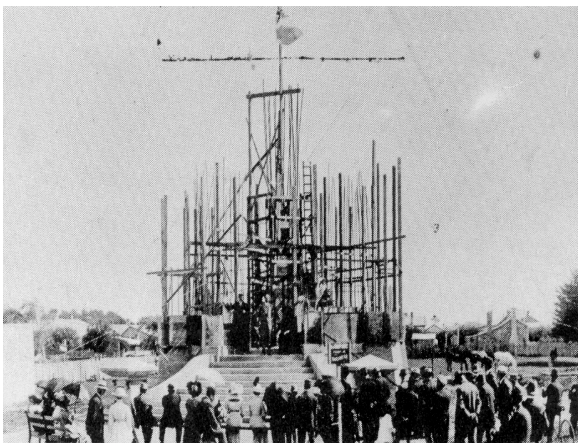


Figure 3: Unveiling of the foundation stone in 1912.

The tower was constructed under the direct supervision of Cameron using day labour. Construction was by cast insitu concrete poured in sequential lifts, between reusable, braced wooden forms. Approx 560 m³ of concrete was mixed and poured by hand. 35 tonnes of square deformed reinforcing bar, imported from Britain was used. Some of the ornamental elements, such as window surrounds and balcony details were precast and then set into the insitu pours.

Over 1,300 tonnes of construction materials were raised manually by a simple gantry rigged at the top of the tower.

In early 1914, shortly before completion of construction, an earthquake was experienced and the tower developed a lean of 760 mm towards the South.

Without informing the Council Cameron set to work to straighten the structure. The low side of the base was fixed, by pouring larger concrete foundations while the high side was undermined by excavation and wetting of the clay substrate. The lower tank was also filled with water to increase loads on the foundation. The tower was brought back to plumb within 7 days and then stabilised by construction of extended foundations.

While the Council congratulated Cameron on the success of the straightening operation he was rebuked for not advising the Council earlier and proceeding without their authority.

Construction was finished in 1914 at a cost of £4,500.

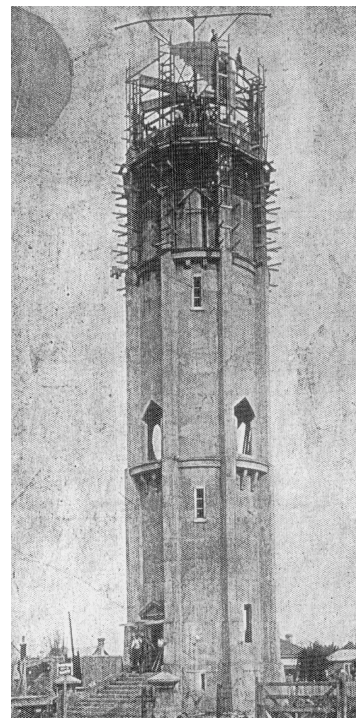


Figure 4: The tower during construction 1913

DETERMINATION OF DETERIORATION

In 1958 the tower was used for the last time for fire fighting and in 1964 the tower was drained to improve the seismic response.

Falling spalled concrete became a hazard and the tower was closed to visitors in 1988.

A condition assessment report performed by Cowie Rockell and Chong in 1989 identified that chloride concentrations and carbonation levels were high enough to predict that corrosion of the steel reinforcing would be occurring over the whole structure. It was evident that repairs would be necessary.

Opus International Consultants produced a further report in 2000, which indicated that chloride and carbonation levels had further increased. This report also detailed extensive spalling of concrete, examined possible repair options, calculated repair quantities and estimated the cost of the restoration options.

The tower's owners, South Taranaki District Council, adopted a Management Plan for the tower in 2001 which resolved to repair and maintain the tower to a safe state with the intention that the tower be reopened to the public. The Council's main objective was to obtain the maximum increased life for the tower within the cost constraints. To best achieve this, a wide range of restoration options were considered.

Cathodic protection of the structure was considered, but testing indicated that there was poor electrical continuity of the steel reinforcing and the cost of establishing connections between the individual steel bars would make this option prohibitively expensive.

Desalination of the concrete was also examined but quickly discarded on the basis of cost.

RESTORATION

Tender documents were prepared which detailed requirements for a repair and protection system that would give the maximum increased life, which, when taken together with a maintenance plan to be developed in conjunction with the successful tenderer would give the tower a much extended life.

The tender documents contained a specification which was largely performance based indicating the desired outcomes rather than a prescriptive specification. The specification recognised that the corrosion of reinforcement was a major cause of the deterioration and that it would not be practical to completely stop this corrosion. A large emphasis was placed on selecting a repair and protection system which would best remove the deteriorated material and provide a mechanism for arresting future deterioration. In February 2004, a contract was let for restoration of the tower.

The contract scope included:

- Removal of degraded concrete and reinstatement using specialist mortars.
- Application of FRP strengthening
- Application of migrating corrosion inhibitor
- Application of cementitious waterproofing coating
- Replacement of various windows and doors.

Access

The scope of the work was such that full interior and exterior scaffolding of the tower was required. This was complicated by the tower's circular cross section, the stairs at the base and the profile of the tower which bells at the top. Component systems did not have the required flexibility and a tube and clip system was erected. This was then covered with a double layer of scrim screening to provide some protection from the weather and to contain any construction debris. The 40m height meant that a specific design by Registered Engineer was required.



Figure 5: Scaffold erection

Hydro demolition

Deteriorated concrete was removed by hydro demolition. With this process extremely high pressure water jetting erodes the concrete.

Operating pressures are 6 to 7 times higher than conventional water blasters. This process is less likely to further propagate cracking than conventional jack hammering and has the added advantage of producing an excellent profile to key reinstatement concrete.

The extremely high pressures generated pose potential dangers to the operators and a long lance reduces the possibility of directing the jet at the operator. This necessitates a wide scaffold.



Figure 6: Hydro demolition of degraded concrete

The contract was let on the basis of an estimated volume of concrete to be removed and reinstated. However, during the hydro-demolition process it was found that the volume of degraded concrete requiring removal was twice the original estimated volume.



Figure 7: Facade panels after hydro demolition

Cleaning and priming of reinforcing

Hydro demolition is effective in removing rust scale from the surface of the exposed steel reinforcing.

Reinforcing bars found to have a significant loss in cross sectional area were either cut out and replaced or supplemented by lapping in an equivalent sized bar alongside. Where lap distances were insufficient, single sided fillet welds were used to achieve continuity of strength.

All exposed reinforcing was coated with a cement based passivating compound prior to concrete reinstatement.

Concrete reinstatement

A number of processes were used to reinstate the removed concrete. The versatility and track record of a complete repair and protection system was very important. A variety of repair materials and techniques were proposed at the time of tender to cater for repairs of different sizes, orientation and form. The dry sprayed gunite process was used extensively and approximately 70% of the repair volume was reinstated using this method. It was possible to load the dry spray machine at ground level and convey the gunite to the top of the tower, for application. This removed the need to winch equipment and materials to the top of the tower for application by other processes.

The 40–45m vertical lift was however close to the maximum possible with this system and a pair of large compressors was required. Rebound losses were high and a booster pump was also required to increase water pressure for injection water at the gunite nozzle.

Where the extent of repair to be reinstated neither extended to the full depth nor to the edge of a concrete member, gunite was sprayed directly into the void. Where the repairs extended through or to the edge of a member, gunite was sprayed against plywood back or side forms.

It was found that the best match to the weathered texture of the existing concrete could be achieved by scraping the fresh gunite with a steel float held perpendicular to the concrete surface.



Figure 8: Guniting reinstatement of concrete

Extreme deterioration had occurred on 2 of the 8 facade panels surrounding the lower water tank and early on in the contract a decision was made to remove these 2 panels entirely and re-pour them between forms, using techniques very similar to the original construction. A flowable, small aggregate, self compacting concrete was specifically formulated for this purpose. This was winched to the top of the tower in bags and mixed at this location.

Cementitious hand patch mortars were used for very small repairs.

Migrating corrosion inhibitor

The contract called for the application of a migrating corrosion inhibitor to all exterior surfaces and the interior floors and beams. A corrosion inhibitor is a substance which, when applied onto the concrete as an impregnation, leads to a delayed start of corrosion and/or a reduction of the rate of corrosion. The inhibitor selected for this project, migrates through the concrete and forms a protective layer around the reinforcement, reducing the access of oxygen to the steel surface. The specific parameters of the concrete and environment do impact on the degree of performance of any corrosion inhibitor.

As part of a robust repair and protection system, the corrosion inhibitor can provide a significant additional barrier to the continuation of reinforcement corrosion. To maintain consistency in the repair products and ensure compatibility, Sika Ferroguard 903 was selected.

This was applied by low pressure back pack spray in a three coat application process.

Migration to the steel was predicted to occur at a rate of between 3-20 mm per day and should have reached the steel within 2 to 3 weeks of application. Confirmation of penetration was confirmed from cores cut to steel depth at completion of the contract. A programme of testing was proposed to check the ongoing presence of the inhibitor at the location of the reinforcing steel.

FRP application

Carbon fibre strengthening was specified to supplement the strength of various structural elements where corrosion of reinforcing steel had reduced steel areas and reduced original flexural capacity.

However, the greatly increased volume of concrete repair meant that FRP application was deleted from the contract to remain within the project budget. The elements requiring strengthening were re-engineered and additional structural steel supports were installed as an alternative. With this approach it was conceded that the member would have reduced capacity but structure loads could effectively be redistributed to adjacent members, which were less compromised.

Cementitious coating

The application of a cementitious coating to all exterior surfaces followed the application of the migrating corrosion inhibitor.

This coating has a dual function of providing a water resistant barrier to further reduce the permeability of the concrete and also to give the tower a more uniform appearance to mask the contrast between the areas repaired and the extremely weathered existing concrete.

It was acknowledged that all cementitious coatings have a tendency to bloom slightly under certain environmental conditions and this could not be avoided. All due care was taken to apply the coating under favourable conditions but it was accepted that some variations in appearance might exist.

Application was by brush at the request of heritage Architects to ensure the texture of the underlying concrete and the cold joints from the original construction were not obscured.



Figure 9: Application trial for cementitious coating

LONG TERM PERFORMANCE REQUIREMENTS

Monitoring of the repair system will be undertaken by the contractor for fifteen years. This will involve visual inspections at five yearly intervals. Detailed as-built drawings were prepared during the restoration work to accurately map the location of repairs undertaken.

During future inspections, any deterioration observed can be compared to the as-built drawings to define the likely cause and extent. In addition, sampling will be carried out at representative locations to determine the continued presence of the migrating corrosion inhibitor

While the contractor has undertaken responsibility to repair future deterioration in reinstated areas it is conceded corrosion will not be totally eliminated by the current restoration works and further repair of any future deterioration may be required.

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