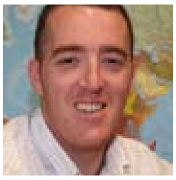
# ZENITH

## Natural Draft Cooling Tower - Mantle Inspection & Repair


**Andrew Kelly ICIOB B.Sc.**

Andrew Kelly has worked in the Industrial Chimney & Construction Industries for 18 years starting as a junior technician, progressing to his current position as Director of Zenith Structural Access Solutions Limited. A graduate of Heriot-Watt University, Edinburgh, Andrew has held various construction positions including Inspection Engineer, Quantity Surveyor, Construction Manager and Commercial Manager.

### Introduction

This paper reviews the background, repair scheme, access and methodology deployed in the repair of a Hyperbolic Cooling Tower at The E.On Ratcliffe-On-soar 2000MW Coal-fired Generating Station in Nottinghamshire, England. See Figure 1

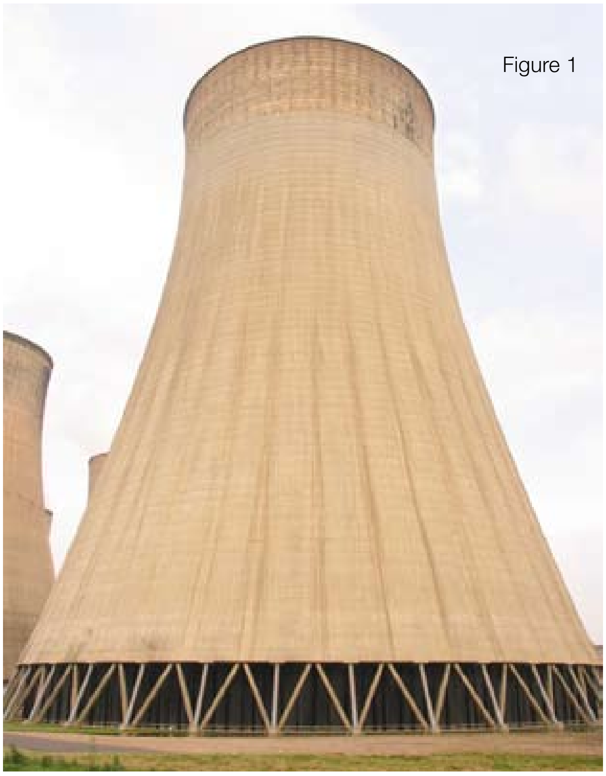


Figure 1

### The paper comprises of the following;

Background & Repair Philosophy
Scope of Works
Pre-Start Considerations
Regulations
Methodology
Technical Problems & Solutions
Review & Conclusions

## Background & Repair Philosophy

### Background

Cooling Towers 1A and 2A are approximately 114 m high with a base diameter of approximately 92 m. The circumference being divided into 40 Meridians. The Towers were constructed with a 7" (175 mm) shell in 1965. The towers were re-strengthened (thickened) with the introduction of an additional 5" (175 mm) thick concrete mantle to approximately two thirds of its height in 1990. During 1998 and 1999 delamination between the mantel and the original tower shell was identified. This defect had occurred to a similar tower at another location. As a result of this, both of the mantels on towers 1A and 2A were inspected in 2001.

This inspection was a visual inspection and supported by impulse radar survey over a limited area on tower 1A, and endorsed with a hole drilling survey at 3m intervals commencing initially from the top of the mantel. Holes were continually drilled down the tower until no further delamination was detected, following which the affected area of the mantel was mapped out.

Full circumferential cracks were identified between the top of the mantel and tower shell on both towers. It was established that the delamination on tower 2A was concentrated in the uppermost 3.00 M of the tower. On tower 1A an area of delamination was detected which extended approximately 22m below the top mantel level. The original scheme predicated a total of approximately 325 bolts and 683 M2 or 3,415 litres of repair zone.

A low modulas flexible seal was applied to the interface of the top of the mantel and the shell.

### Repair Philosophy

The areas of the towers where work was undertaken was identified as the "repair zone". The Client proposed to map the 'repair zone' and use a conventional "stitch and grout" repair method to prevent the delamination from extending. In principal, this comprised of the installation of stainless steel anchors (to tie the inner and outer concrete skins together), followed by the injection of material to fill the void. This would be either cementitious grout or epoxy resin dependant upon the findings of the survey in 2008.

### The repair objective was based on the following philosophy:-

The risk of propagation of the delamination to be prevented.
The long term structural integrity of the concrete shell to be maintained.

## Scope of Works

The Scope of Repair included the following:-

## Definite Works

The supply and maintenance of a site establishment, the management of the Works and the fulfilment of the duties of the Principal Contractor under the CDM Regulations.

The supply and maintenance of safe and appropriate means of access to both the external and internal surfaces of the Cooling Towers over the repair zones.

Trial drilling around the periphery of the delaminations so as to confirm the full extent of the repair zone.

The supply and installation of anchor bolts on a regular grid pattern across the repair zones.

The supply and installation of grout / bleed valves.

The bulk filling of the main void using a cementitious grout to be followed by resin injection at the periphery of the defect, where the crack is too narrow for the cementitious material to penetrate.

The drilling of a series of 75mm diameter cores across the repaired zone to demonstrate the effectiveness of the repair works to be supplemented by borescope examination of the holes.

The making good of all new and existing core and drill holes across the repair zone with polymer modified cementitious mortar.

Repairs to the crack between the mantle and the original shell at the +99.50m AOD level.

## Optional Works

The application of appropriate face seals to any internal or external surface cracks where water leakage from the void had been identified or was suspected.

## Pre-Start Considerations

Safe Methodology / Rescue Procedure.
Flexible / Practical Methodology.
Grouting of 'Repair Zone'.

Zenith favoured their cathead / cradle arrangement typically deployed on similar and dissimilar projects. The system principally requires the tower to be off-load during initial installation but can be adapted to complete work on load based on the clients requirements and satisfaction of stringent Health & Safety requirements as required on this project.

The cathead system is piecemeal constructed at the top of the tower. The manageable components are hoisted into position via a traditional winch system and lifting davit. The cathead system is assembled in sections to form one continuous unit. The system is counter balanced with an internally located weight or anchorage.

On completion of assembly and installation the system is tested a pre-determined safe working load, normally 375 Kg but it can be engineered to a capacity of 800 Kg S.W.L.

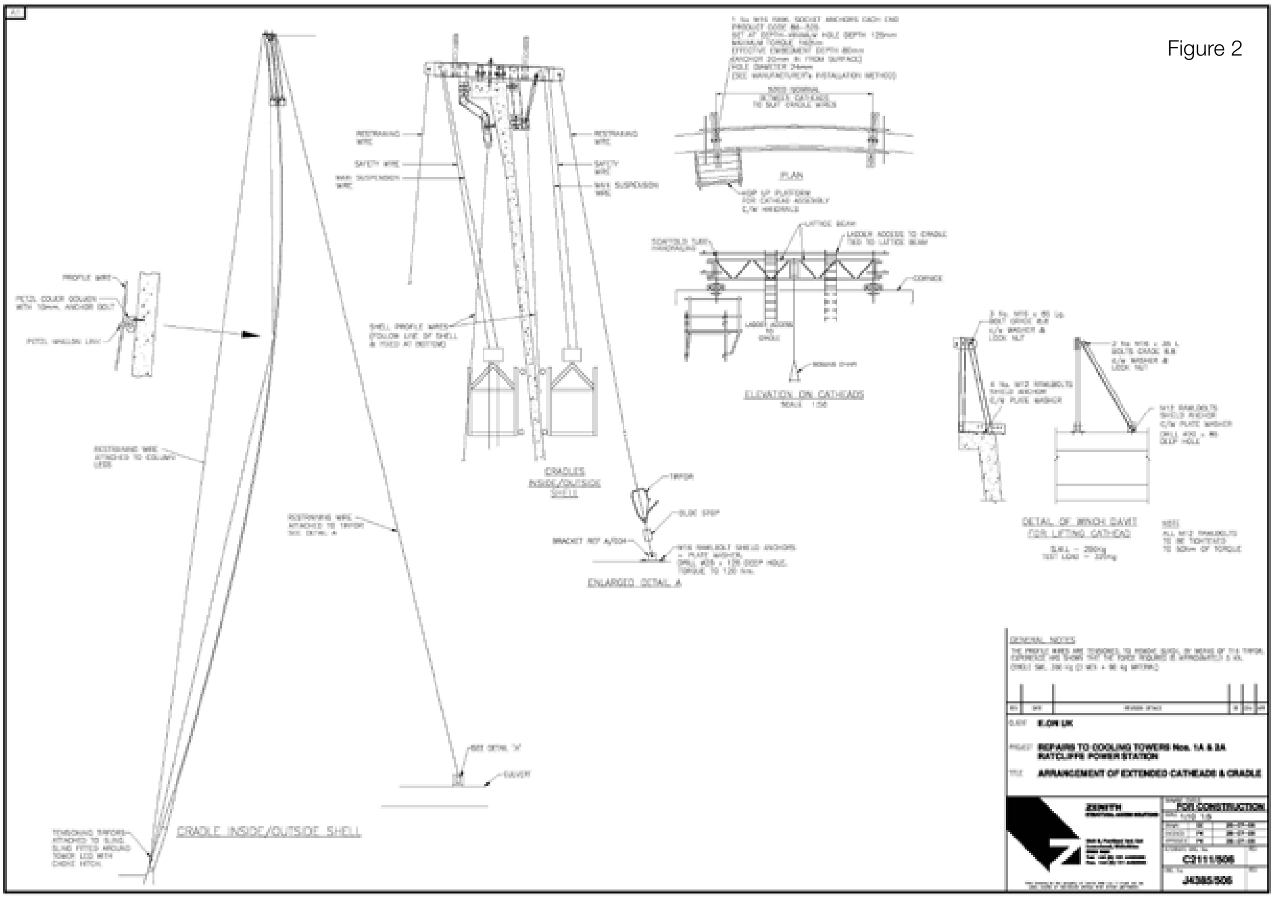



Figure 2

The cradle platform follows the tower profile by the use of temporary wires fixed into the shell and tensioned at ground level. When moving the system circumferentially around tower the tension of the counter weight anchorage is marginally released. The system can then be re-positioned to the next vertical working position.

The system deployed ensures that all surfaces of the tower can be accessed externally and internally with only marginal effort.

See Figure 2 on previous page

## Rescue System

An enormous emphasis was placed upon the importance of developing a safe system of work and in particular a functional and practical safety procedure for the rescue of a stricken operative and reducing the risk of exposure of others.

In conjunction with the client's safety team, Zenith developed a safe system for rescue including every potential scenario. A mock demonstration was completed at site with all parties to the contract satisfied. On completion of the mock demonstration, the work could then proceed.

See Figure 3

Figure 3

## Grouting

The grouting of the 'repair zone' required careful consideration. The parameters of the grouting specification were limited to the following:-

a) The interface bond strength shall be not less than 1 N/mm² at 7 days.

b) The compressive strength at 28 days shall be not less than 40 N/mm².

c) The maximum positive grouting pressure at the point of injection to the void shall not exceed 0.5 bar (0.05 N/mm²).

d) The viscosity of cementitious grouting materials shall be such as to enable the complete filling of cracks and voids down to a width of 3mm.

Zenith completed a number of trails with varying success rates. On completion of a successful trial a low viscosity grout typically used in pre & post tensioning cable construction was adopted.

## Regulations

Regulations - UK Legislation
The cathead system to satisfy the following legislation / regulations and Accepted Codes of Practice and Standards.

Factories Act – Various Revisions
Health & Safety at Work Act 1974
Regulations / Accepted Codes of Practice (ACOP'S)

Management of Health & Safety at Work Regulations
Provision and Use of Work Equipment Regulations
Construction (Design and Management) Regulations
Construction (Health, Safety & Welfare) Regulations
Lifting Operations and Lifting Equipment Regulations
Work at Height Regulations

British Standards, European Norms and More:

| | |
|---|---|
| **BS 5974** | Temporarily installed suspended scaffolds & access equipment. |
| **BS EN 12811-1:2003** | Temporary works equipment. Scaffolds. Performance requirements and general design |
| **BS EN 12811-2:2004** | Temporary works equipment. Information on materials |
| **BS ISO 4308-1:2003** | Cranes and lifting appliances. Selection of wire ropes. |

## Methodology

Following installation of the access equipment the first step was to identify the 'repair zone'. This was achieved by hammer testing and drilling at pre-determined locations in vertical strips. A borescope was utilized to inspect any void and assist with measuring the width of any delamination. The results showed that the delaminated 'repair zone' had extended from the top of the tower to within 10.00 M of the lower ring beam in a number of locations.

The size of the repair zone impacted on the extent of work to be completed. In order to stitch the 'repair zone' approximately 2000 holes were cored through both layers of the shell. Stainless steel bolt assemblies were inserted at 1.45 M grid centres throughout, 'stiching' each concrete layer together. Variations in wall and delaimantion thickness required careful consideration to avoid excess waste of a valuable commodity.

On completion of the stitch procedure Zenith then tackled the task of grouting the repair zone, which had now extended to approximately 4,200 M2 (or 14,000 Litres).

A further site grouting trial was completed in a 10 M x 10 M area to ensure the success of the method / material selection.

The procedure adopted required the drilling of holes to the depth of the delamination at pre-determined locations throughout the repair zone. The grout was batched at ground level and pumped to the workface using a grouting machine and pump. Careful monitoring of delivery pressure was completed to ensure the parameters of the specification were not exceeded. Grout was delivered to the lowest position of the repair zone until the grout had filled to that position. Once the void had been filled the process was repeated progressively up the tower moving in vertical and horizontal planes depending upon the now established repair zone. The procedure continued until the repair zone was grouted in full.

See Figure 4

Figure 4

## Technical Problems & Solutions

Potential loss of grout material could have been a considerable problem. The low viscosity material had proved to flow into small openings less than 3mm wide. Although this proved advantageous in delivering the grout into the bulk of the repair zone, a potential concern arose in that the grout would flow into the smallest of openings.

The original scheme called for the installation of a caulk to seal the bolt/plate interface. In practice the uneven concrete surface between the shutters proved too difficult to install a flat plate flush with the internal shell without a gap thereby allowing the grout to freely flow outwards.

In order to ensure the integrity of the seal between the steel plate and the internal surface of the shell the interface was packed with a suitable material both levelling the internal surface to accommodate the plate and sealing any opening around the perimeter of the bolt.

## Review & Conclusions

The approach and planning to this scheme ensured that the client's requirements were met in full without significant impact on the day to day operation of the station.

The extent of repair scheme at Ratcliffe, which had not been predicted, presented a typical access problem for Zenith. The flexibility of the Cathead System allowed the work scope to expand without impacting on the methodology adopted.

The stitching procedure was completed in a methodical and efficient manner ensuring that the specification was adhered too and that the integrity sought was achieved.

The grouting technique adopted proved to be a practical solution to a major repair scheme.

See Figure 5

Figure 5


## Acknowledgements

Mr Bob Knight – E.On Engineering

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