ZENITH

Re-strengthening of reinforced concrete chimney

Introduction

This paper reviews the background, philosophy, repair scheme, scope and methodology used in the inspection and re-strengthening of a reinforced concrete chimney.

Figure 1

Background

The climate in the region is continental. In the summer the temperatures can reach more than 53 Degrees Celsius and in winter the temperature can sink as low as minus 58 Degrees Celsius. The structures are exposed to some of the most extreme weather conditions this continent can experience.

This particular structure was constructed and commissioned in 1984 and has suffered from the absence of a proactive inspection and maintenance plan. (Figure1).

In recent years the asset management and the local authorities have actively pursued a shift in attitude from reactive to proactive maintenance. Zenith was engaged to provide an inspection criteria to determine a 'benchmark' condition in order to engage future inspection and maintenance.

Inspection Philosophy

The inspection criteria produced by Zenith was taken from the CICIND publication 'Manual for Inspection and Maintenance of Concrete and Brickwork Chimneys' and some additional information taken from various past experiences.

The inspection philosophy was to engage a partially destructive inspection of critical and less critical items including concrete windshield performance, capping detail, flue duct inlets and supports, lining performance, gas seals, expansion joints and surface coatings.

The detailed inspection impacted on the off-stream timeline. The asset management considered the off-stream duration and pursued a second option. The second option was based on a non-destructive visual examination of all accessible components. The reduced scope limited the conclusions that could be drawn from the inspection but suitable to allow a basic 'benchmark' result to be formulated.

The final scope required a visual examination only of the critical and less critical components.

Inspection Findings

The uppermost section of the concrete windshield was found to be in a very poor condition. The reinforced concrete was found to be porous with large sections of spalling and decaying concrete noted throughout. Cavities through the windshield were found in three different elevations (Figure 2). Reinforcement steel was found in a serviceable condition but the concrete was now in a state of disrepair (Figure 3). The capping detail was found to be serviceable.

Figure 2

Figure 3

The chimney lining comprised of a brickwork construction with refractory screed finish. The lining was found to be performing well with no significant defects. The refractory screed was missing from the uppermost barrel of brickwork. However, the underlying brickwork and the remaining lining performance were deemed to be satisfactory in the absence of any intrusive or laboratory testing, given the service life of the chimney.

Repair Scheme

The strength and durability of the top of the chimney windshield was deemed to have weakened significantly and required re-strengthening. A number of options were available.

However, in this environment and taking into account the resources available the preferred option was to re-strengthen the top of the chimney with a 'sheath' or cladding of steel and cementitious concrete grout. This technique has been used in a number of similar projects where there has been general degradation over the full circumference for a relatively short distance from the top. The steel sheath compensates for the loss of steel reinforcement and all that is required of the existing concrete is a very limited compression capacity. At the top of the chimney, the main loading is in the circumferential direction and for this reason, the plates are butt welded on the vertical joints. A fillet weld suffices for the connecting the plates on the horizontal joints as there is little loading in the vertical direction in this region.

This sheath was designed with a 50 mm nominal cavity between the new steel sheath and the original concrete substrate. The cavity was filled with a non-shrink cementitious grout.

The additional weight of this scheme is estimated to be less than 1.5% of the overall weight and therefore deemed to be within construction tolerances and not requiring structural design calculations. There is also a marginal increase in the diameter of the structure, 100 mm over a limited height, and therefore not being affected by additional wind loading.

Governing Factors

Environment

The repair scheme proposed was to limit any off-stream time to a minimum. This repair scheme could be completed on-stream to a safe distance from the top of the chimney (3.00 meters). The final 3.00 meters was completed during day shift with the chimney re-commissioned during the night shift, having a minimal impact.

Resources

The design of the scheme remains fairly flexible as regards final material selection. The steel sheath was designed around readily available materials and sized to reduce wastage.

A number of cementitious grouts were reviewed. The preferred option was a pourable non-shrink grout and the final design proved to be cost effective and readily available.

Execution of the Works

On completion of the final design scheme being approved by the asset manager and the local integrity authorities the fabrication works could be undertaken (Figure 4). Plate steel was cut and rolled to suit the diameter of the structure. A number of final design modifications were completed including the inclusion of 'stand off' rods at the top of each plate and the omission of potential grouting bleed valves.

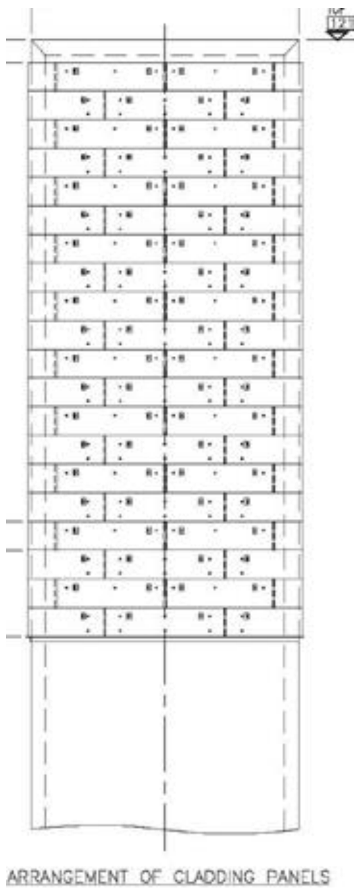

Figure 4

The initial step is to establish a definitive level for the repair scheme. In this scenario +111.00 meters from grade was the position of the support ring (Figure 5). The support ring is an angled ring beam bolted to the existing windshield. Following completion of the ring beam the steel 'sheath' construction can begin. The first course of steelwork is offered into position and tack welded into position. This is repeated until a full circumferential 'course' of steelwork is complete. Once the first course is complete the ring becomes self supportive. The final welding can then commence. Once completion of the first course of steelwork is complete the installation of the cementitious grout can commence. Simultaneous operations can then be considered with plate course construction and grouting being completed in parallel to reduce construction time (Figure 6). In practice the coursed steel construction continued to no more than one course prior to grouting. This allowed us to maximize repetitive working techniques without compromising on the quality control of the cementitious grouting.

The repair work continued to within 300 mm from the top of the chimney where a final interface with existing capping detail was established (Figure 7).

The sheath was then coated with a final protective paint system, which performed as an environmental resistant paint system and aircraft obstruction warning coating.

The repair scheme was competed in approximately 40 shifts with off-stream time reduced to 3 day shifts.

Considerations

A conflict between the final specification and the local code of practice for this type of repair surfaced following completion of the repair. The local codes called for the inclusion of steel reinforcing with the cavity. However, support from the design team and the engineering council negated the requirement of the local code and final sanction of the repair.

Future Maintenance

The future inspection criteria have been developed to include inspection of the modified region of the chimney and develop of a proactive maintenance scheme to ensure the longevity and performance of the structure.

Acknowledgements

Scott Smith – Construction Supervisor and the Zenith Field Team.


Figure 5


Figure 6


Figure 7