Rehabilitation of Clifton Avenue Reservoir

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Clifton Avenue reservoir in Centurion was recently rehabilitated using innovative techniques to counter persistent leakage due to settlement over 25% of its floor area. Originally built in 1971, the reservoir first showed signs of leakage in May 1997. Rehabilitation of the waterproofing bandages on the reservoir proved unsuccessful and BKS was appointed by the Greater Pretoria Metropolitan Council (GPMC) to resolve the problem.

Background

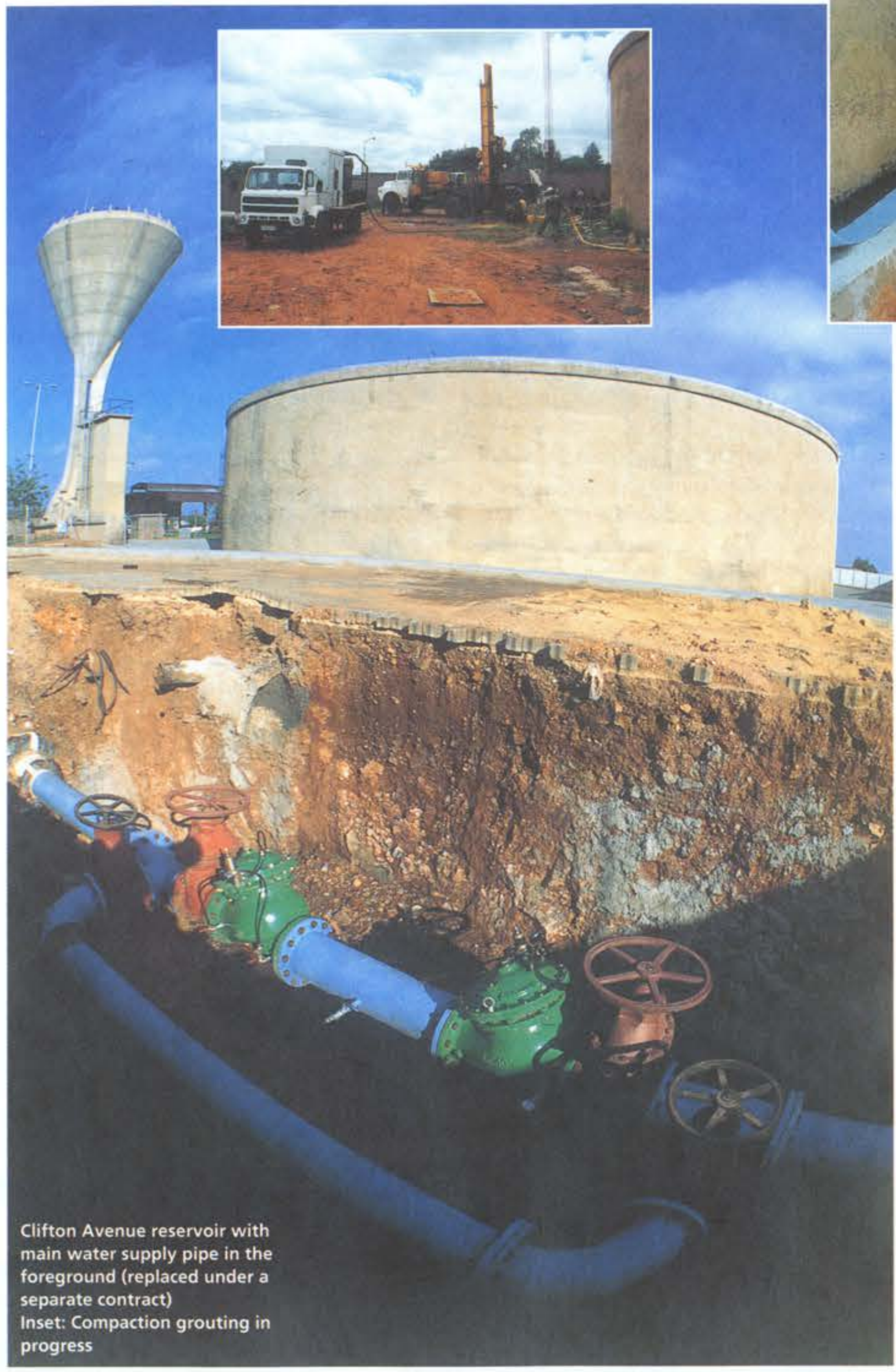
The 14M*l* circular pre-stressed concrete reservoir has a domed roof, an internal diameter of 43,5m and wall height of 9,7m. Its 130mm thick concrete floor increases in thickness to 400mm on the outside to form a wall footing. The free-sliding wall is supported on a continuous rubber bearing and the wall-to-floor joint was sealed with a continuous butyl rubber bandage. The floor is between 1m and 2m below natural ground level. Geologically, the reservoir is underlain by dolomite.

At first filling of the reservoir after rehabilitation of the bandages during May 1997, leakage was detected on the outside of the reservoir at the wall-to-floor joint, indicating settlement of the floor. A total of 57 monitor points (*Figure 1*) were installed on the wall footing and records kept over 18 months. Gradual settlement of up to 196mm was observed over about 25% of the floor area. Contours were plotted as shown in Figure 1. Cracks also appeared in the ground surface around the reservoir.

Settlement caused the bandage between the wall and the floor to tear, since the wall behaved like a deep beam, spanning the settled footing. A gap of up to 250mm beneath the settled floor contributed towards the reservoir becoming unserviceable.

Geotechnical investigations

Penetrometer tests around the reservoir indicated that no cavities existed in the soil and the area was safe for people and machinery. Dynamic cone penetration tests showed no cavities on the inside of the reservoir. Four vertical and six inclined boreholes were drilled on the outside and 10 boreholes on the inside to evaluate the deep-seated conditions.



Clifton Avenue reservoir with main water supply pipe in the foreground (replaced under a separate contract)
Inset: Compaction grouting in progress

In general, air and sample loss occurred as low density zones were encountered. A video camera survey of the holes confirmed that there were no cavities. Investigations suggested that settlement was caused by saturation of the soil, probably due to poor stormwater drainage and leaking pipes. This resulted in leakage of the reservoir and more water being released into the soil, which exacerbated the problem by causing the collapse of low density material and thus further settlement of the overlying material.

Design considerations

Two solutions to the problem were considered:

- building a new reservoir
- rehabilitating the existing reservoir, including ground improvement, rehabilitating and lining of the structure, and civil work around the reservoir.

Cost-estimates showed rehabilitation to be at least 50% cheaper than building a new reservoir.

Installation of semi-bleeding grout bag

Rehabilitation

Ground improvement was achieved by means of compaction grouting. Cementitious grout was pumped into pre-drilled boreholes under pressure between 1 300kPa at 35 m deep to less than 100kPa at 5m deep. Upstage grouting was done, resulting in compaction of low density material adjacent to the borehole . Primary grouting boreholes were drilled on a 4m grid and secondary boreholes on a 2m grid where required.

Grouting started on the perimeter of the area to be improved. Excessive grout loss necessitated a grout curtain at the perimeter, with boreholes grouted under gravity.

The design parameters for structural rehabilitation were:

- the reservoir had to be watertight
- a 10mm horizontal movement of the reservoir wall and 20mm differential settlement of the reservoir floor had to be accommodated
- penetration of leakage water into the soil had to be precluded.

The best solution to meet these criteria was a primary liner in the reservoir, with a leakage detection and drainage system and a secondary liner beneath that to prevent water leakage from penetrating the soil. For the primary liner, 2mm thick ethyl vinyl acetate (EVA) Hyperliner was chosen because of its ability to accommodate anticipated movement. Un-reinforced flexible polypropylene (FPP) — 1mm thick Aqualastic — was used over the first metre width on the inside of the reservoir wall, and 0,9mm scrim reinforced flexible polypropylene as secondary liner underneath the leakage detection system over the remainder. All membranes were supplied and installed by Aquatan.

The leakage detection system (*Figure 2*) comprised:

- a 15MPa/15mm concrete screed laid to falls and dividing the reservoir into four quadrants, each draining into a newly installed 100mm stainless steel drainage pipe
- a secondary liner, protected by geotextile
- a reinforced concrete ring beam on the inside of the reservoir wall to attach the primary liner
- no-fines concrete over the secondary liner
- sand-cement plaster on top of the no-fines to create a smooth surface for the primary liner.

The wall-to-floor joint was critical to the design. A special angle iron was fixed to the wall to prevent the primary liner from being pushed into the gap created by the reservoir wall moving outwards during water loading. The floor level of the reservoir was raised by about 300mm due to the leakage detection system, requiring modification of all pipes protruding through the floor (*Figure 3*).

The settled wall footing was raised by casting new concrete, bonded to the existing concrete with dowel bars (*Figure 4*). A new continuous rubber bearing was glued to the underside of the wall. The new bearing had to be installed to the same stress as the bearing over the rest of the wall to ensure constant wall restraint over the whole circumference. Thus, a semi-bleeding grout bag was used, into which non-shrink Pyrogrout with a 10% expansion was pumped to a pressure of 1 350kPa.

Concentration of stormwater in dolomitic areas had to be avoided to prevent settlement and sinkholes. Stormwater drainage at the reservoir was poor. During rehabilitation, the area surrounding the reservoir was paved and an open stormwater channel built around the reservoir to drain stormwater from the paving and roof of the reservoir. Stormwater and leakage water is drained into the municipal stormwater system.

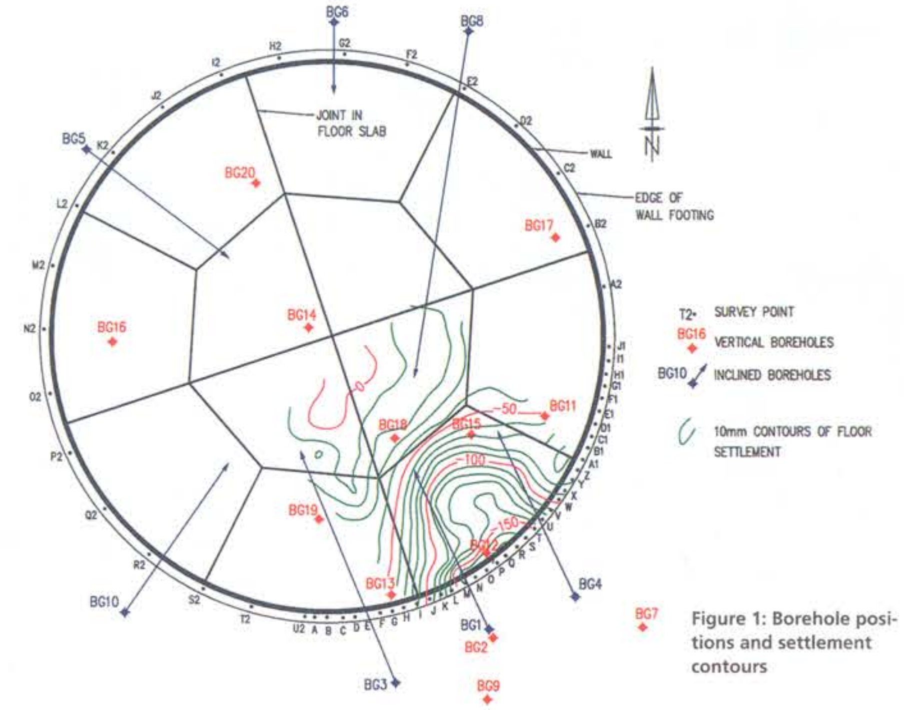


Figure 1: Borehole positions and settlement contours

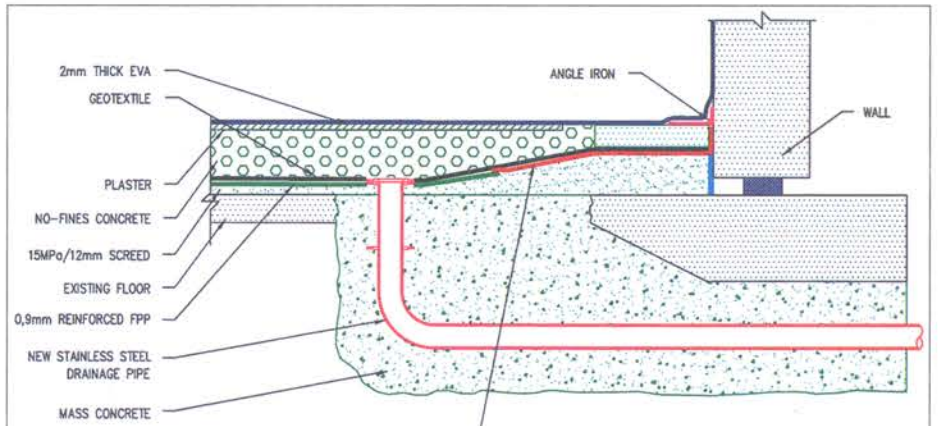


Figure 2: Detail of leak detection system

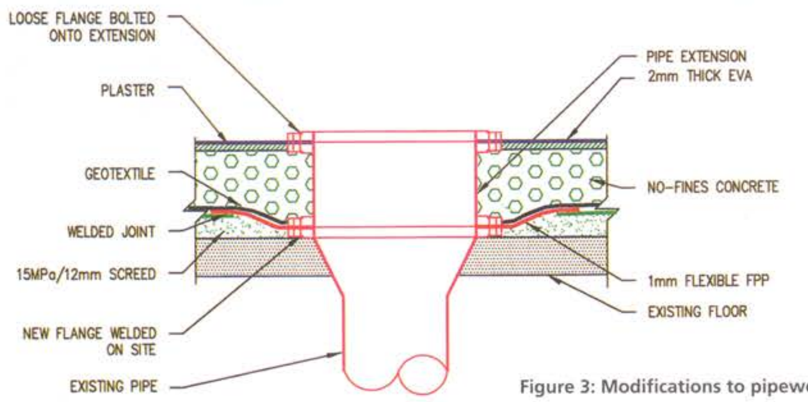


Figure 3: Modifications to pipework

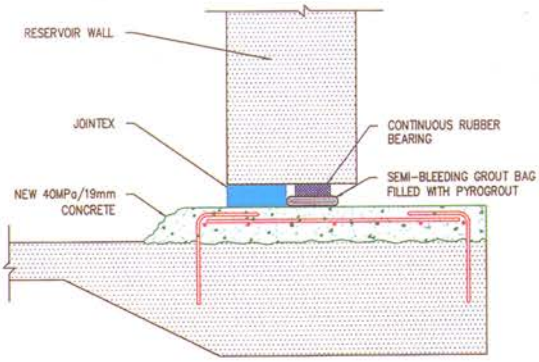


Figure 4: Rehabilitation of wall footing

Rehabilitation success

Fixed monitoring points were installed on the wall and wall footing. Differential movement between the footing and wall will be measured monthly until August 2000. After three months, the maximum differential settlement between the wall and the footing was only 1,5mm — well within the 20mm design value. The leakage rate of the reservoir is currently about 300m*l*/minute — also within the design value. At the current selling price of water of R2,90/k*l*, the loss per year is about R300.

The R3,1-million cost of rehabilitation, less than half the cost of a new reservoir, which would also have required ground improvement, comprised:

- ground improvement : R1 597 000
- primary and secondary liners : R465 000
- improvement of drainage : R371 000
- structural rehabilitation : R604 000
- pipework : R140 000.

Conclusion

Successful rehabilitation of the Clifton Avenue reservoir under difficult conditions has proved that rehabilitation can be an economically viable alternative to the replacement of problem reservoirs.

Project statistics

Area of primary liner: 2 755m^2
Area of secondary liner: 1 500m^2
Volume of no-fines concrete: 210m^3
Volume of grout: 1 450m^3
Length of drilling for grouting: 4 600m

Project team

Client: Greater Pretoria Metropolitan Council
Consulting Engineer: BKS (Pty) Ltd, Pretoria
Contractor for ground improvement: Esor (Pty) Ltd
Sub-contractor for linings: Aquatan (Pty) Ltd