NON–INVASIVE GROUND–PENETRATING RADAR INVESTIGATION OF A FAILING CONCRETE FLOOR SLAB.

Martin L. King, Dany P. Wu and Dr. David C. Nobes

GPR Geophysical Services – New Zealand
PO Box 6056, New Plymouth, New Zealand.
mking@geosurvey.co.nz

Abstract

At a New Zealand wastewater treatment plant there are several large wastewater settlement tanks that are crucial to the operation of the plant. These concrete tanks are 50 metres in diameter and 8 metres deep with the base of each tank approximately seven metres below ground level.

It was discovered that the base of one of these tanks had become distorted resulting in its failure to carry out its function. This presented a major problem for two reasons:

1. The importance of the tank to maintaining sufficient throughput of the overall operation.
2. The danger of contamination of the subsurface water aquifers, which are the main potable water supply for the area, should a tank base failure occur.

Any plans made to repair this problem was faced with a major restriction. Due to the type of construction of these tanks the floor could not be cut into, or disturbed, to any significant extent without risking catastrophic failure.

Ground penetrating radar was used to accurately pinpoint the areas below the base of the tank where voids, which were the root cause of the tank floor distortion, had formed. The information provided using ground penetrating radar enabled grouting repairs, through the floor slab, to be carried out using precisely positioned small diameter holes thus avoiding the risk of catastrophic failure of the tank base.

Introduction

This study concerns a New Zealand wastewater treatment facility which uses large settling tanks, 50 m in diameter, 8 m deep, each holding approximately 14,000 cubic metres of untreated waste liquid. The concrete tank construction consists of a segmented precast concrete wall with a 300 mm thick concrete floor base. The tank floor base consists of an unreinforced 100 mm thick concrete site base slab overlaid by a 200 mm thick, steel reinforced, structural concrete floor slab.

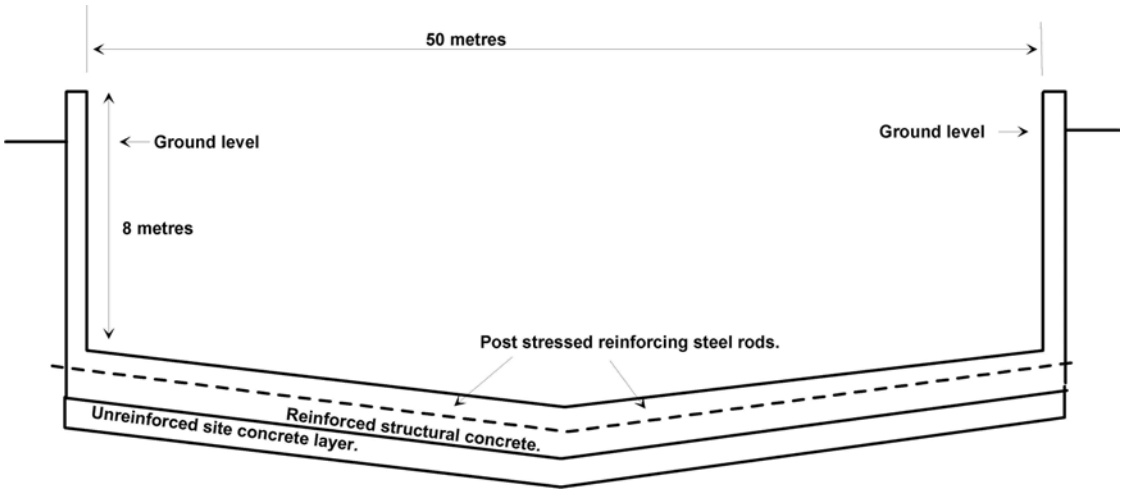

Figure 1 – Wastewater tank cross-section construction detail.

A problem was discovered with one of the tanks when the automatic sweep arm became misaligned, rendering it unoperational. A suspect section of the floor was inspected, revealing a cavity beneath the floor of the tank. The concern was that a significant number of other voids might have formed under the tanks causing the floors to gradually become distorted and leading to eventual rupturing. Any failure of a tank base would create a serious structural and groundwater contamination hazard.

The tank bases slope toward the centre and have a lattice of post-stressed steel rod reinforcing in the structural concrete base. Due to the type of construction it was critical that the concrete floor slab remain substantially intact during investigation and repair operations. Any sizeable disturbance of the floor slab would weaken the concrete and could cause the base to be pulled out of shape by the post stressed steel, resulting in catastrophic tank base failure. The voided areas thus had to be detected, plotted and repaired without significantly disturbing the reinforced floor slab.

Method

Ground penetrating radar was selected as the best technique to provide the information required in this instance. Ground penetrating radar is a non-invasive electromagnetic geophysical technique for subsurface exploration. Generally resolution increases with increasing frequency whereas depth of penetration increases with decreasing frequency. A balance is therefore necessary to achieve sufficient penetration with suitable resolution.

In this case a GSSI SIR-2 ground penetrating radar system, with a 900 MHz shielded antenna, was used to scan the tank base. Data collection timing was set at 8 nanoseconds giving a penetration of around 350mm assuming an average signal velocity of 0.09m/ns (dielectric co-efficient of 12.) Suitable high and low pass filters were used as well as time varying gain to enhance the data and resultant imaging.

Radar scans were conducted along radial lines commencing at the tank wall and moving towards the tank centre. The resultant radargrams were then analysed and a drawing produced of the suspected subsurface void areas.

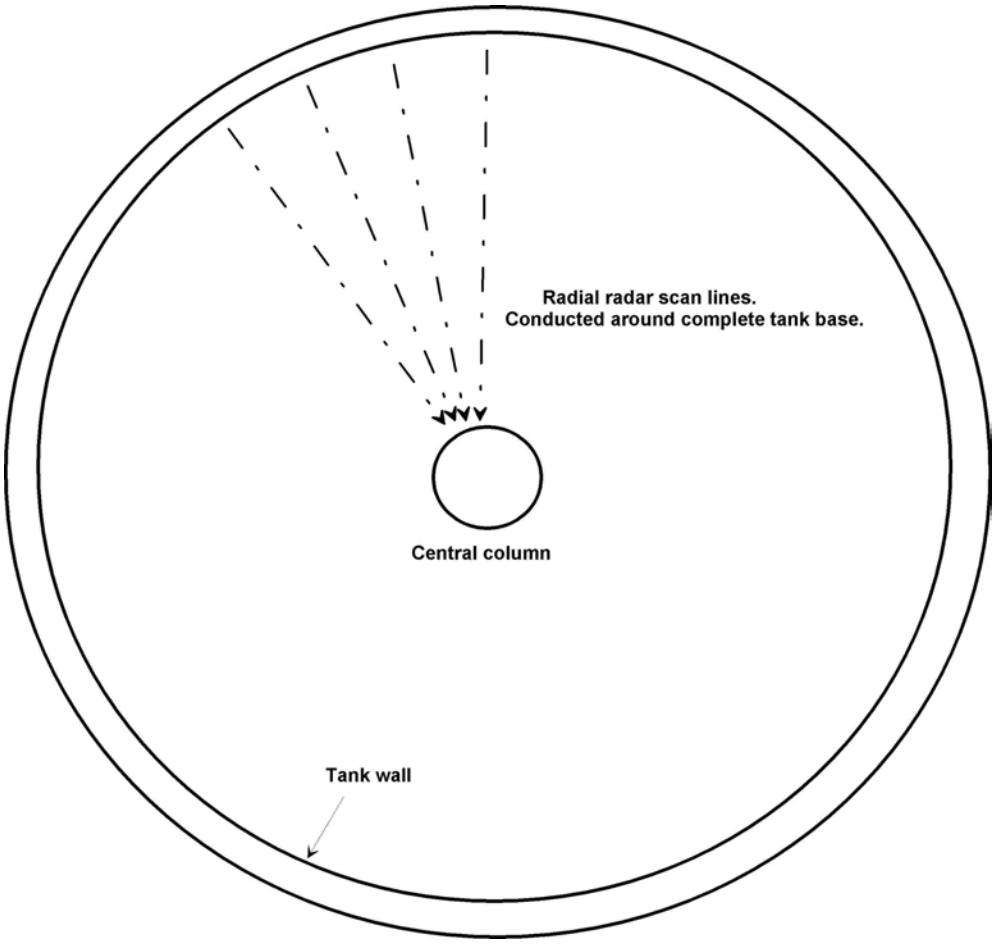

Figure 2 – Plan view of Tank showing radar scan lines.

Results

The resultant data clearly identified areas where voids had formed. It further enabled these demarcated areas to be classified as shallow and/or significant void zones. The site concrete/structural concrete interface could also be seen and areas where the site concrete layer, under the structural layer, had collapsed into the void were obvious.

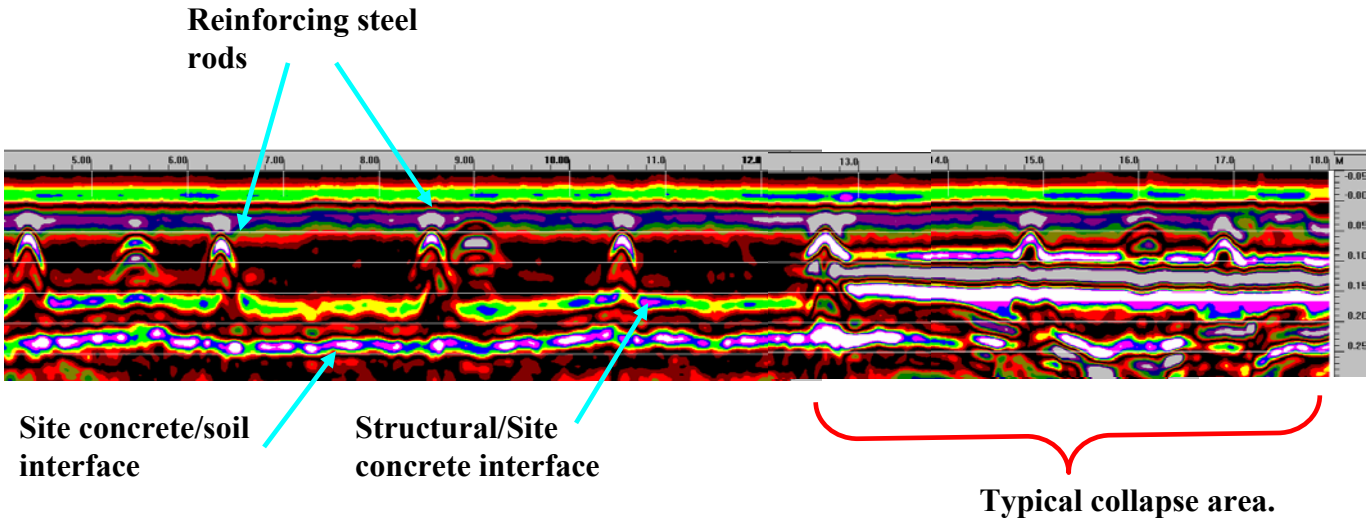

Figure 3 – Radargram showing cross-section through tank concrete base. Scan taken prior to repair.

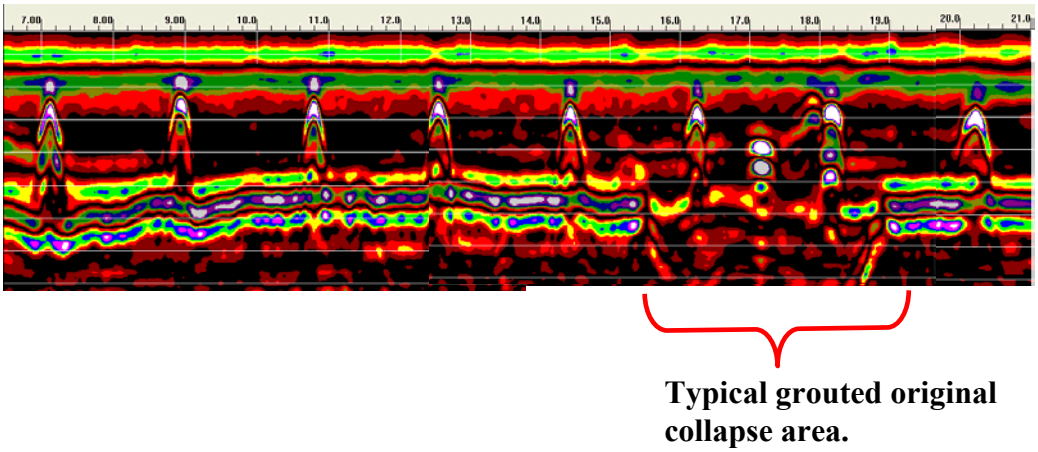

Figure 4 - Radargram showing cross-section through tank concrete base. Scan taken after repair.

A scaled AutoCad drawing was used to delineate the detected voids, large and small, enabling accurate targeting of sub-base voids for repairs without risk of serious damage to the tank floor. Precisely positioned 50 mm diameter holes were drilled through the base and specially prepared grout was used to fill the voids. The extent to which each grouting operation was successful could also be monitored. A final radar survey was used to confirm successful elimination of the cavities.

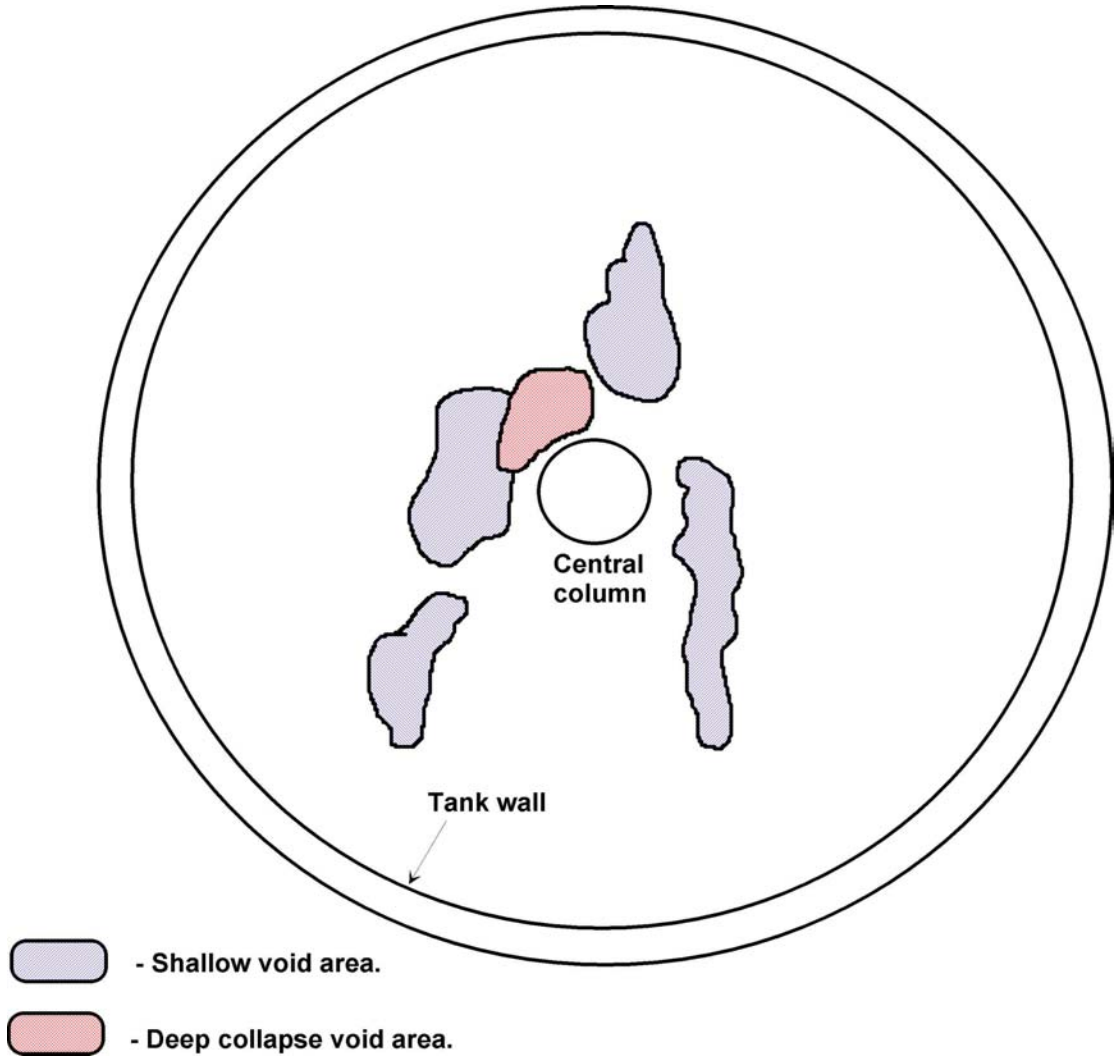

Figure 5 – Plan view of typical void location plotted to scale using radargram results.

Summary

A ground penetrating radar was successfully utilised as part of the repair procedure on failing concrete floor slabs. The cause of the distortion in the concrete floor slabs was discovered to be voids formed beneath the layers of concrete.

The non-invasive and non-destructive nature of a ground penetrating radar survey fulfilled the requirement for the method needed to delineate the areas where voids have formed. The requirement was put in place due to the way the floor slabs were constructed.

Data produced by the initial surveys were used to pinpoint areas to be repaired. The repair procedure was conducted successfully and this was later confirmed by a further ground penetrating radar survey. The tanks are now fully operational as parts of the wastewater treatment plant.