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Composite Slurry Wall and Liner—A Full Scale Test

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ABSTRACT

As part of the plan to increase the capacity of the Port of Brisbane, reclamation of a total area of 235 ha is in progress. The main geotechnical issue at the site is the extremely soft material dredged from the Brisbane River and Moreton Bay shipping channels. Over part of the reclamation area, Menard Bachy was selected by the Port of Brisbane Corporation to carry out deep soft ground consolidation, using the method of Vacuum Consolidation. In 2007, a trial area of 1.5 ha was first implemented. Following successful completion of the trial, a second and larger project was begun in 2009. The new single cell area of 9.3 ha is currently under vacuum depressurization and the soil consolidation is expected to be complete by early 2011.

A significant feature in the vacuum system adopted is the 15m deep soil-bentonite cut-off wall incorporating a high-density polyethylene (HDPE) liner, which is required at the periphery, to isolate the vacuum areas over the depth of the permeable layers in the subsurface profile. To ensure the confinement required for the depressurization, the slurry wall and incorporated liner are joined to a surface cap HDPE liner to complete an air and water tight seal around and over the block of soil.

The initial trial incorporating the deep cut-off wall was a first in Australia and was a success in terms of both outcome and execution with depressurization, under the vacuum membrane, being maintained constantly in the range of -0.80/-0.70 bars over a long period of time of 18 months. Confinement work on the current project, which is taking place over a significantly larger scale and using improved technique, is currently in progress.

The ability of Soil-Bentonite slurry walls incorporating HDPE liners to perform as air-tight and water-tight barriers under high pressure differential (0.8 to 0.7 bars) and subjected to significant deformation has been tested on these large scale projects. The barrier system has proven to be effective for considerable periods of time.

INTRODUCTION

The purpose of the projects in Brisbane, Australia was to improve soft soils for a future expansion of the port facilities (Boyle, De Bok et al., 2007). Mud dredged from the harbor had been previously placed in large spoil areas inside containment dikes and allowed to dewater over time. Clayey deposits were still very soft after a period of several years of draining under their own weight. Moreover, the existing ground under the sea bed consists of soft compressible clay to significant depths (up to 45m). The projects are using a technology called Vacuum Consolidation to pre-consolidate the soils in advance of construction (Masse, Spaulding et al., 2001). Vacuum Consolidation is an evolution of conventional surcharge consolidation and also uses a pattern of vertical drains to accelerate the reduction in water content and thus force accelerated settlement of soft materials. Vacuum Consolidation requires that the block of soil treated be completely confined so that atmospheric pressure can be used to increase stress within the material which in turn will induce its accelerated consolidation.

The seal for the bottom of the Vacuum enclosure is usually, as was the case here, a natural low permeability formation such as a clay layer. An HDPE liner is installed over the treated area to seal the top surface. Finally, the perimeter of the vacuum cell needs to be sealed to prevent transmission of water below the water table and infiltration of air above it. On the Port of Brisbane project, the numerous interbedded layers of sand within the upper clay layer combined with the predicted variation in ground water table level over time due to the settlement induced by the consolidation process dictated the use of a flexible cut off wall (soil bentonite) coupled with an HDPE liner over the upper 8-10 meters. A sketch of the Brisbane vacuum and peripheral wall layout is shown below (Fig. 1).

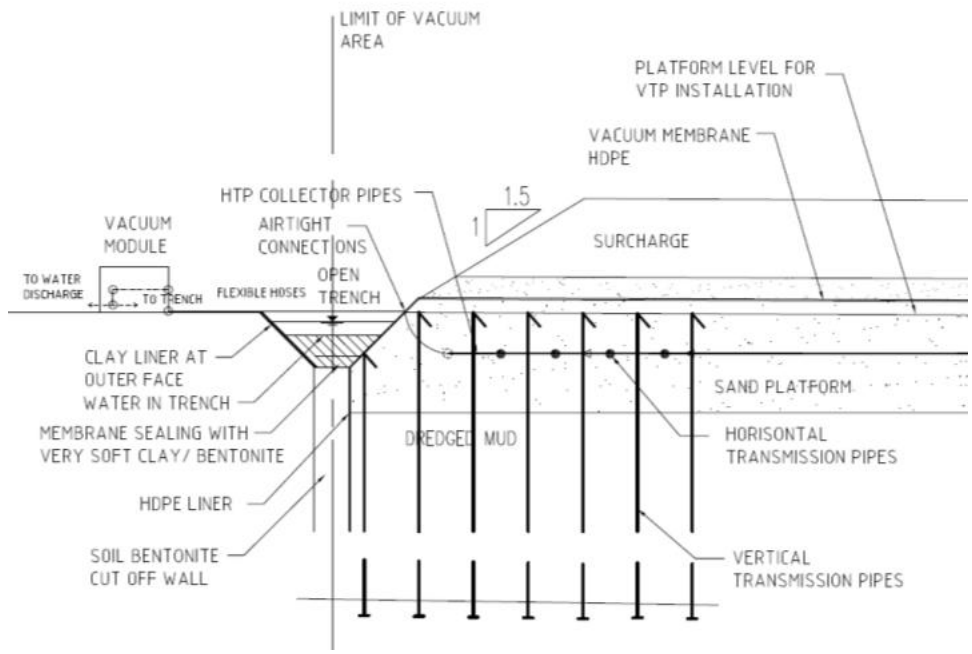

Figure 1. Simplified cross section of Vacuum layout

Once the areas were capped and the vertical barrier liners material were joined to the horizontal capping liners, the entire area was subjected to a vacuum of 0.8 bars, where quality monitoring was provided by instrumentation designed to detect and locate defects in the system.

There were two areas treated by Vacuum Consolidation, one trial in 2007 of 1.5Ha involving the use of a 750m long cut off wall over an approximate area of 7,000m^2. In 2009, a full scale production project of 9.3Ha was performed requiring the installation of a 1,250m long cut off wall enclosing an approximate area of 19,000m^2 (Berthier, Ameratunga et al., 2009). The trial is the L-shaped area shown on the left picture below (Fig. 2); the second (production) area is shown on the picture on the right below.

Figure 2. Aerial views of the Brisbane site, trial (left), production area (right)

An interesting aspect of these vacuum projects was that they afforded the opportunity to test the behavior of the barrier systems over a considerable area and throughout an extended pumping duration. Further, different methods of placing and jointing of the HDPE liner were used in the two projects, providing additional opportunity to evaluate the relative effectiveness of both systems.

Importantly, the data presented herein provide confidence in the lapped jointing of the liner material in the slurry wall backfill under considerable stress and strains, whilst affording considerable savings over other systems.

COMPOSITE SLURRY WALLS

Most slurry walls are backfilled with a homogeneous blend of soil-bentonite (SB) or soil-cement-bentonite (SCB) or cement-bentonite (CB) mixtures. These mixtures are designed to stop the lateral movement of groundwater. Occasionally, due to site conditions which might include possible gas permeation, desiccation or severe chemical contamination, any of which might cause concern as to the effectiveness of the conventional backfill blends, there might be a need for further protection. In a small number of cases, an additional barrier may be inserted into the wall for extra safety. Materials used for the secondary barrier have included plastic and steel sheet piles but most commonly, high density polyethylene (HDPE) liner material is used. Examples of projects where composite slurry walls have been used include:

- Methane containments at landfills

- Desert conditions where flash floods might apply water quickly to a desiccated wall.
- Highly contaminated groundwater containments where conventional blends might fail.

Different methods have been used to establish continuity between the plastic sheets and these methods can have a significant impact on the cost of the project. One method uses an interlocking joint similar to a sheet pile. For the interlocking system, the sheets are slid into position vertically, usually using a temporary steel frame. (Fig. 3)

Figure 3. Installation of liner in slurry wall using temporary steel frame

A second method is to overlap the panels with no physical connection. With this method, the pressure of the backfill provides the seal between the two sheets (Fig. 4).

Figure 4. Liner being placed with overlapped joints

CONSTRUCTION METHODS USED AT THE PORT OF BRISBANE

The trench for the cut-off was excavated to a depth of approximately 15 meters with an extended-stick 80 ton excavator. Bentonite slurry was used to support the excavation through the extremely weak clays and saturated sands as shown below (Fig. 5).

Figure 5. Excavating the trench supported by bentonite slurry

During the trial project in 2007, the liner was placed using adjacent vertical sheets 10 meters wide. The base of the liner was weighted and each panel was lowered into the slurry with an approximate 2.0 meters overlap over the previous panel. Panels were 8 meters deep, which was sufficient to extend below the sea level. Once the panels were placed, the trench was backfilled with soil-bentonite mixed material. Panels being placed during the trial are shown below (Fig. 6).

Figure 6. Placing HDPE panels vertically with overlap

For the larger second project, a horizontal roller was developed which allowed for an increase in placement productivity and reduced the number of overlap joints required (Fig. 7). The depth of the HDPE liner was 7 meters and only one overlap was required every 200 meters of wall.

Figure 7. Placing the HDPE liner with a horizontal roller.

PROJECT DATA

The interesting aspect of these two projects is that they represented a very unusual test of a slurry wall system constructed under full scale conditions and operating over long periods of time. The cells were subjected to vacuum pressure for periods exceeding 18 months (Trial) and 10 months (currently still under way for the Main area) and extensive data were collected from the instrumentation internal to the blocks at various points around the site. Vacuum depression was measured beneath the overlying HDPE membrane and at various depths within the Vertical Transmission Pipes to ensure the depression was applied throughout the entire soil profile and the results are shown in (Fig. 8).

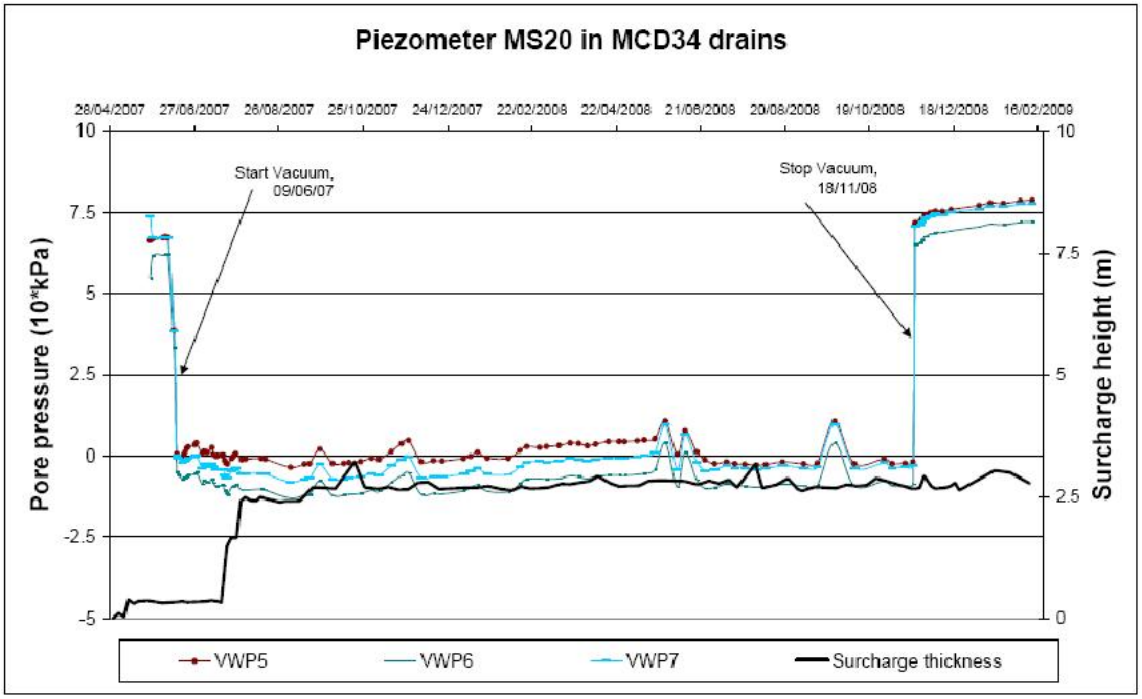

Figure 8. Vacuum pressures at various elevations vs. time on production project

The above plot for the trial section shows that the pressures were lowered to approximately negative 0.7 to 0.8 atmospheres and maintained over 18 months. Interestingly, when some vacuum pumps breakdowns occurred, there was an immediate reaction which translated in the loss of depression but vacuum was restored quickly after pump repair was completed.

As a result of the pressure application to the cells, they demonstrated significant vertical and lateral deformations along their boundaries. Vertical settlements due to consolidation exceeded 2.5 meters and in the vicinity of the composite slurry wall there were several inclinometers which measured horizontal wall deformations up to 200mm. Typical inclinometer data are shown on the following plot (Fig. 9).

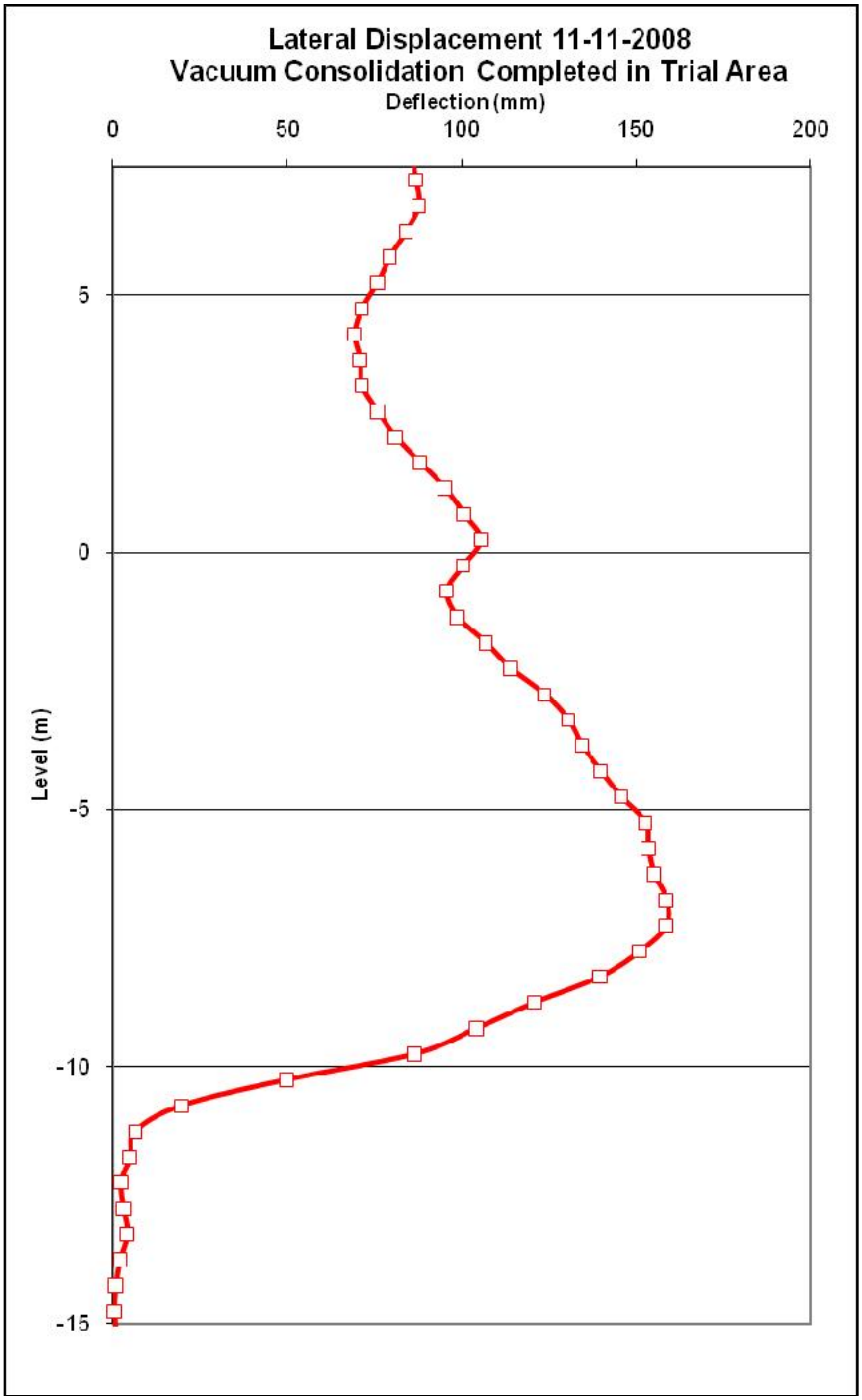

Figure 9. Typical Inclinometer Readings

Despite the severe total and differential deformations applied on the slurry wall no loss of efficiency of the confinement was recorded during the consolidation process confirming the ability of the composite Soil Bentonite/HDPE wall to sustain such displacements whilst maintaining extremely low permeability (between 10^{-8}m/s and 10^{-9}m/s).

CONCLUSIONS

The implementation of vacuum consolidation incorporating a 15m deep soil bentonite cut-off wall, a first in Australia, has proved to be very successful. De-pressurization under the vacuum membrane was constantly retained, in the range of -0.80/-0.70 bars (atmospheres) throughout the extended vacuum pumping phase.

The Port of Brisbane Vacuum Consolidation projects represented an unusual opportunity to evaluate a full-scale test of a pressurized slurry wall system. Two methods of installing the liner material were used and evaluated.

Conclusions from this project are as follows:

- The slurry wall system was an effective way of providing lateral air-tight and water-tight containments, both above and below the water table.
- The overlapping method of creating the joints formed an effective seal, even under conditions of extreme stress and deformation.
- Both the vertical and horizontal roller methods of HDPE sheet installation resulted in air-tight installations.

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