

Soil Bentonite Cut-off Walls for Confinement of Existing Landfills: Tempe Tip - A Case Study

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Abstract: The construction of a soil-bentonite (SB) barrier wall in 2004 to confine a landfill at Tempe Tip adjacent to Sydney Airport was the first of its kind in Australia. This paper reviews briefly the circumstances under which the remediation strategy for the site was implemented and how it was decided to use the SB method for the hydraulic barrier wall. The SB methodology is then described with an emphasis on key aspects of the Tempe case study. Finally, the results of piezometers monitoring before and after construction are reviewed to assess the wall performance.

1 INTRODUCTION

1.1 Contaminated lands management strategies

The impact of contaminated lands submitted to groundwater influence is particularly felt in populated areas and the selection of an adapted remediation strategy in the presence of such sites is a necessary step to enable a harmonious urban growth.

Out of the three main strategies for dealing with contaminants, the most expensive is to treat the soil, whether *in-situ* or *ex-situ*. In addition to posing health issues during the excavation phase of the contaminants, these methods have also the disadvantage of releasing substantial amounts of CO₂ during the combustion of fossil fuels used to operate the treatment plants.

The second “pump and treat” method consists in the installation of series of well points connected to pumps with the objective of permanently controlling the groundwater flow in a contaminated environment. This system requires the construction or the availability of a treatment plant to cater for the discharged contaminants. Long term monitoring is also essential given possible fluctuations in the ground water levels as well as local variations in subsoil hydraulic conductivity.

The last “confinement” method requires in most cases the installation of a vertical hydraulic barrier associated with a capping of the site with the objective of permanently isolating a contaminated area. Groundwater barriers can be closed or opened, associated or not associated with a groundwater collection system.

Confinement strategy is generally considered as the most cost-effective and reliable method to mitigate the impact of contaminated sites on the environment in the long term.

1.2 Groundwater barriers

Groundwater barriers are used to maintain a separation between contaminated and non-contaminated groundwater regimes. Vertical barriers are constructed underground to stop, collect and/or treat the flow of contaminated groundwater. They entail a wide range of technologies such as slurry cut-off walls, grouting (jet grouting, vibrating beam), bio-polymer trenches, permeable reactive barriers (PRB), and soil mixing, with different objectives depending on the site conditions and requirements.

Slurry cut-off walls are in essence very low permeability vertical barriers (10^{-9} m/s or less) using deep open trench excavation methods.

2 SOIL BENTONITE WALLS

2.1 History

Slurry cut-off walls using soil-bentonite (SB) methodology originated in the 1940s and have been particularly popular in the US since the 1970s when new legislations shifted the responsibility of management of contaminated sites onto the private sector.

2.2 A simple, well proven method

In essence, the soil-bentonite technique is a continuous trench that is dug under a bentonite slurry that maintains the stability of the trench walls, even below the water table. Once the trench is dug to full depth where it is usually keyed into a low permeability layer, it is backfilled with a blend of excavated soils, bentonite and bentonite slurry. The blended mixture is placed using either a tremie or by sliding it down the slope to form a continuous low-permeability barrier to the lateral flow of ground water.

2.3 Main characteristics

SB walls are typically 600 to 1000 mm thick with virtually no limitation in depth. In 2006, a SB wall was constructed in Mayfield, Australia, to a maximum depth of close to 50m.

The hydraulic conductivity of SB samples are typically of 10^{-9} m/s (comparable to a low permeability clay) making these barriers virtually impermeable in effect. The backfill “mix” design which is different for every site, relies on incorporating the right amount of highly active clay (bentonite), whether under dry or hydrated form, in the excavated soils, as well as maintaining a sufficient proportion of fines (minimum of 15%). Fig. 1 summarizes the relationship between permeability (in cm/sec) and bentonite fraction (in dry weight) for different types of soils.

SB is also sufficiently stable under elevated gradients as demonstrated by the SB samples permeability tests carried out in permeameters cells (such as under ASTM D-5084) often under gradients of 50 or above.

Water content of SB during and after placement is generally in the range of 25 to 35% which corresponds to backfill slumps in the 100 to 150mm desirable range for placement in the trench.

Consolidation and compressibility: even though laboratory testing has shown that compressibility of SB material is generally high (Baxter 2005), this is compensated by the fact that the long term effective stresses remain low and almost independent of depth (Filz 1996). In addition, based on the trench thickness, 90% consolidation is reached in 2 to 8 weeks. Personal previous site observations indicated no noticeable residual long term settlements above or adjacent to constructed SB walls.

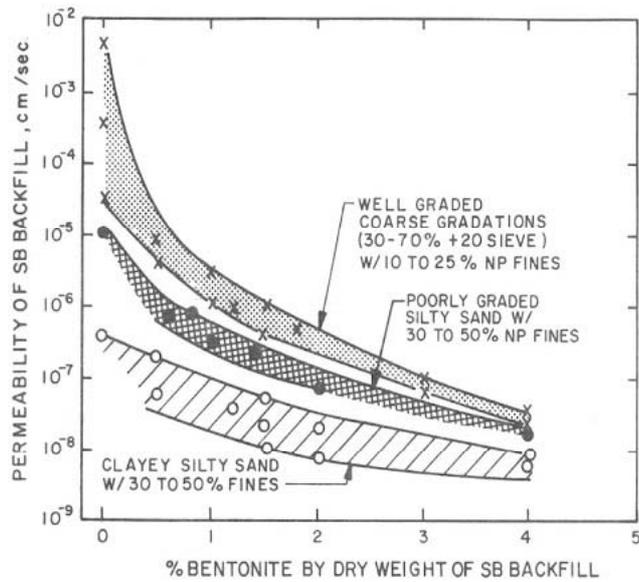


Fig. 1. Permeability vs. bentonite fraction in various soils

2.4 Benefits

According to a US EPA study in 1998, there are various reasons why soil-bentonite (SB) walls have been the most common form of groundwater barriers used on contaminated sites. Some of these reasons are:

- continuous trenches (i.e. no joint or seal)
- (systematic) key inspection possible
- long term effective life (at least 30 years)
- generally no offsite disposal of soil required (as per cement bentonite or plastic concrete walls) since the excavated material is re-used
- flexibility with batching and placement.

3 CASE HISTORY OF TEMPE TIP

3.1 The site

The site is located in the Sydney suburb of Marickville, NSW and is situated alongside the Alexandra Canal which communicates with the Cooks River close to Botany Bay.

A former 40 ha old landfill consisting of sanitary and industrial waste was backfilled over a 90 years period to reach a maximum depth of 17m. Further to the presence of high concentrations of ammonia and heavy metals, the NSW EPA declared that the site was presenting “a significant risk of harm” to the environment. Subsequently the Marickville Council entered into a

Voluntary Remediation Agreement (VRA) to prevent the ongoing migration of leachate (Mitchell 2006).

3.2 Remediation strategy

A cut-off wall keyed in the aquitard was assessed to be the most suitable approach based on established and ongoing monitoring and in terms of cost-effectiveness and provision of a greater level of certainty of success compared to a pump and treat system.

The SB was assessed to be the most suitable method based on cost and degree of certainty compared to a grouting method (jet). Finally, the SB was built in conjunction with capping of entire site to minimize infiltration.

3.3 Cut-off wall specifications

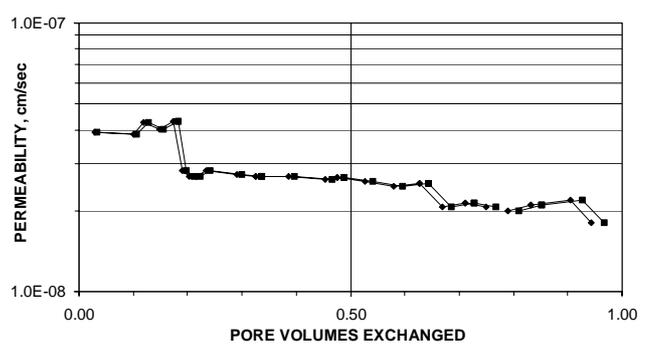
The design called for a U-shaped downgradient barrier anchored one meter into the aquitard (residual clays and extremely weathered sandstone), with a minimum thickness of 0.6m for a wall permeability of 10^{-9} m / s. A collection system running parallel to the wall was designed to collect leachate and maintain hydraulic head within landfill below 1mAHD in order to manage seepage through the wall at acceptable levels. The collected leachate transferred through six pumping stations to a leachate treatment plant on site.

3.4 Mix design

The objective of the mix design is twofold:

- obtain lower and upper limits of fines content and fraction of dry bentonite necessary to achieve the maximum permeability with in situ soil samples, and
- carry out long term permeability testing on in-situ samples using the leachate as a permeant with the objective of assessing any potential detrimental effect of contaminants on wall hydraulic performance (test example in Fig. 2).

The tests indicated that a 2% addition in dry bentonite to the



excavated blended materials was sufficient to consistently achieve less than 10^{-9} m / s permeability.

Fig. 2. Example of long term permeability test using contaminants as permeant showing both cell inflow and outflow (test 069P8) – resulting permeability = 2.3×10^{-10} m / s

3.5 Wall construction

The wall, 1430 m long, was constructed using a specially design long reach 80 tons excavator to a maximum depth of 20m and a minimum width (bucket size of the excavator) of 800mm. The limited space allowable on site between the toe of the landfill and

the edge of the canal imposed the transport of the excavated material to a designated mixing area for blending and mixing purposes. A 10m wide working platform was established to allow excavation of the trench as well as truck traffic for transportation of the backfill material out and back in the trench as shown in Fig. 3.

The Eastern wall alignment falling within the landing Sydney airport North-South runway OLS approach and take-off surfaces, which imposes maximum height restrictions, required the execution of the works during night curfews on 40% of the wall.



Fig. 3. Excavation along Western end during day shift.

3.5 Quality control

The quality control program carried out throughout the works is an essential feature of SB walls since it is important to ensure that the mix design criteria are met even in presence of heterogeneous subsoil conditions.

The tests performed on the bentonite slurry, whether during hydration in the slurry pond or in the trench, such as Marsh viscosity, density and filter press are not specific to SB and will not be discussed here. Note that slurry densities in the trench are typically in the range of 1.3 to 1.6 g / cm³.

The objective of testing the backfill material is to ensure that both fines content (usually passing the #200 sieve or 75 µm) and material properties, such as in place density and slump, fall within the criteria objectives.

Permeability tests performed on samples taken from the platform before backfilling or sometimes inside the trench after placement, are essential to compare actual field values with specifications. Measured hydraulic conductivities are often an order or two of magnitude below the target, e.g. values as low as 3×10^{-11} m / s have been found in Tempe.

3.6 In-situ testing and monitoring

The high level of publicity during the contract for the first application of a groundwater barrier wall on a contaminated area in Australia, generally translated into a sustained level of control during every phases of the design and construction of the wall.

The wall in-situ monitoring program included the installation of external and internal piezometers (31 nos. in total) to monitor the groundwater response during and after the works and in particular measure the impact on the tidal amplitude (under the influence of the Alexandra canal) and check the ability of the sys-

tem to maintain a maximum level for the contaminated groundwater level behind the wall.

An immediate rise of groundwater level by 1 – 2 m upstream of the wall during construction gave a good indication that the wall was globally impermeable.

The piezometric response, measured as the ratio of tidal amplitudes before and after the wall, resulted in ratios generally between 10 and 35%.

The contaminated groundwater head behind the wall stabilised at EL + 1.6m or 600mm above the target, with water collection volumes of 60 m³ / day.

4 CONCLUSION

Confinement of old contaminated sites is a relatively new concept in Australia. The installation of a SB barrier at Tempe has been monitored. Its success in its past and current performance is due to the fact that:

- the wall demonstrated to be providing an impermeable barrier (immediate rise around 1m to 2m near canal after construction),
- sampling and analysis confirms water level monitoring data and indicates a significant improvement in groundwater quality outside the wall (as expected),
- pumping from collection system recorded around 60kL/d (or 0.6L/s), when system was fully operational,
- based on current information, water level will be able to be maintained <1mAHD at which level seepage rates through the wall would be 0.0095L/s or 0.5% of the estimated flow rate of leachate into the Canal prior to wall construction.

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