INNOVATIVE TECHNIQUES IN THE CONSTRUCTION OF EMBANKMENT WIDENING

John Marwick[1]**, Liam Wythes**[2] and **Dane Lidgard**[3]
[1]Senior Associate, [2]Associate, [3]Senior Engineer, Aurecon Sydney

ABSTRACT

Urban constraints to new route acquisition commonly require the widening of railway and motorway formations, and require this to be done with no or minimal land resumption. The sloped sides of cuttings have to become vertical pile walls or sub-vertical nailed slopes, and embankments require retaining walls to support a wider formation. The widening of embankments is typically the more difficult task, and commonly gives rise to significant cost and time to construct issues, particularly where the embankment widening is coupled with construction of a noise wall. The construction of the Southern Sydney Freight Line (SSFL) as an additional track on the existing formation of the Main South Railway has required innovative approaches to this task, using both piled slabs to support the track bed and also retaining walls where the track is supported on an embankment.

1 INTRODUCTION

The construction of retaining walls to widen a formation is typically complicated by the lack of space between the existing embankment slope and the corridor boundary. Two approaches have been developed to this problem on the SSFL. Where wall heights are less than about 3 m, a concrete wall structure has been adopted with a single row of piles and a heel slab to reduce the tilting forces on the wall. With higher walls, a wall structure with a wider footing is required, and this sets up the problem of excavation into the existing embankment slope, which requires an anchored pile retaining wall to temporarily retain the excavated face during construction. Commonly this has been carried out with temporary sheet piling, and the construction problems of this technique next to an electrified railway are discussed.

The innovation with this type of construction is then to replace the temporary sheet piling with a CFA pile wall which can be integrated into the final retaining structure. This allows the wall to be constructed with a reduced width and greater height. This has been carried out for both reinforced soil wall construction and reinforced concrete wall construction.

A concomitant problem arises with the construction of a high noise barrier on the retaining wall, and the paper reviews the techniques that have been used to accommodate the noise barrier posts into reinforced soil wall construction.

The construction of piled slabs is a commonly used arrangement to construct a stable formation without incurring the cost of a bridge, and on one section of the SSFL this construction has been carried out over a metastable slope using temporary minipiles to support the construction plant and bored piles for the final structure, with permanent anchors that then provide stability to the slope.

2 INNOVATIONS WITH RETAINING WALL CONSTRUCTION

2.1 RETAINING WALL OPTIONS

When there is not enough space to accommodate the embankment side slope it is necessary to retain part or all of the height of the widened embankment with a retaining wall. When there is enough room the embankment widening can be constructed using standard techniques, with either a reinforced concrete wall or a reinforced soil wall.

A first level of complication then comes when it is found to be difficult to design for the required factor of safety of the foundation due to the limited strength of the ground. If there is room, a poor subgrade can be more readily built upon with reinforced soil as that form of construction more economically adapts to a wide footing. Where there is not enough space for that approach or where the foundation stability or stiffness is not sufficient it is common to adopt a piled reinforced concrete [RC] wall construction.

Widening of railway formations in an urban location however commonly introduces a further complication with the lack of room not allowing enough space for any of these approaches without a temporary sheet pile or bored pile wall to retain the existing embankment during construction. The retaining walls on the SSFL are typically affected in this way, and the approaches to the resolution of this issue that have been adopted are described.

2.2 INTEGRATION OF THE BACK WALL INTO THE PERMANENT WORKS

The standard reinforced concrete wall on a foundation of two rows of piles has been adopted in several locations on the SSFL project. Where the construction required excavation into the existing embankment these walls are constructed with an anchored pile wall that has coupler bars in its cage to tie it into the pilecap slab, so that it becomes part of the final structure (Figure 1).

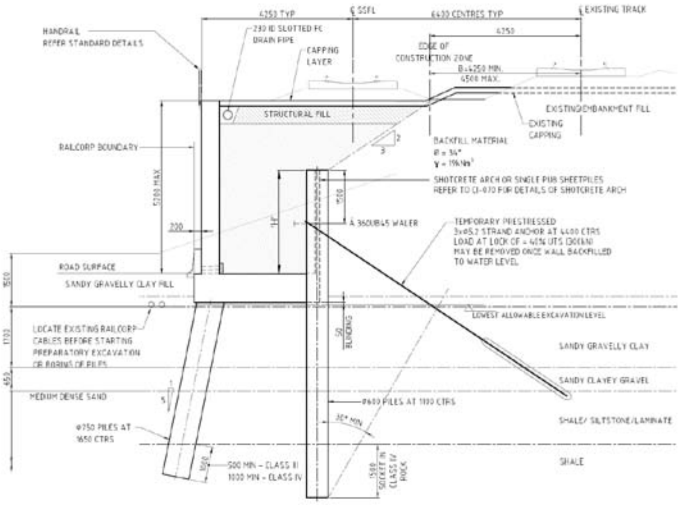

Figure 1: Construction of a two pile row RC piled wall with the back row retaining the embankment during construction

In other locations, where the wall is less than 3m high it is easier to construct with a single row of piles that support a wall with a narrow footing. The pressure on the footing provides an opposing bending force to that arising from the lateral ground pressure on the wall. This form of construction is a composite between a pile wall and a conventional RC retaining wall (Figure 2).

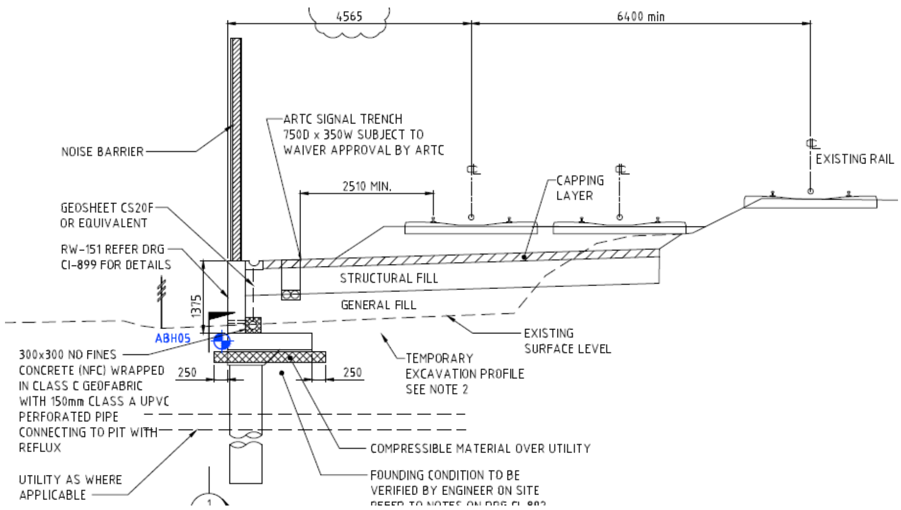

Figure 2: Construction of a single pile row wall to retain a low wall with minimal excavation of the site.

The use of reinforced soil construction also commonly requires the retention of the embankment during construction. This application is illustrated on Figure 3, which shows the commonly adopted sheet pile wall arrangement. At least some of these temporary sheet piles have to be extracted after the wall is completed to remove the risk of them setting up a conduction path for stray currents from the DC power supply.

The commonly found construction issue with this type of structure is the requirement to drive the sheet piling in a power-out of the adjacent passenger tracks to mitigate the risk of a falling sheet pile contacting the overhead power conductor. The other operations of construction, including the construction of the temporary ground anchors, can be carried out next to traffic running on the existing railway.

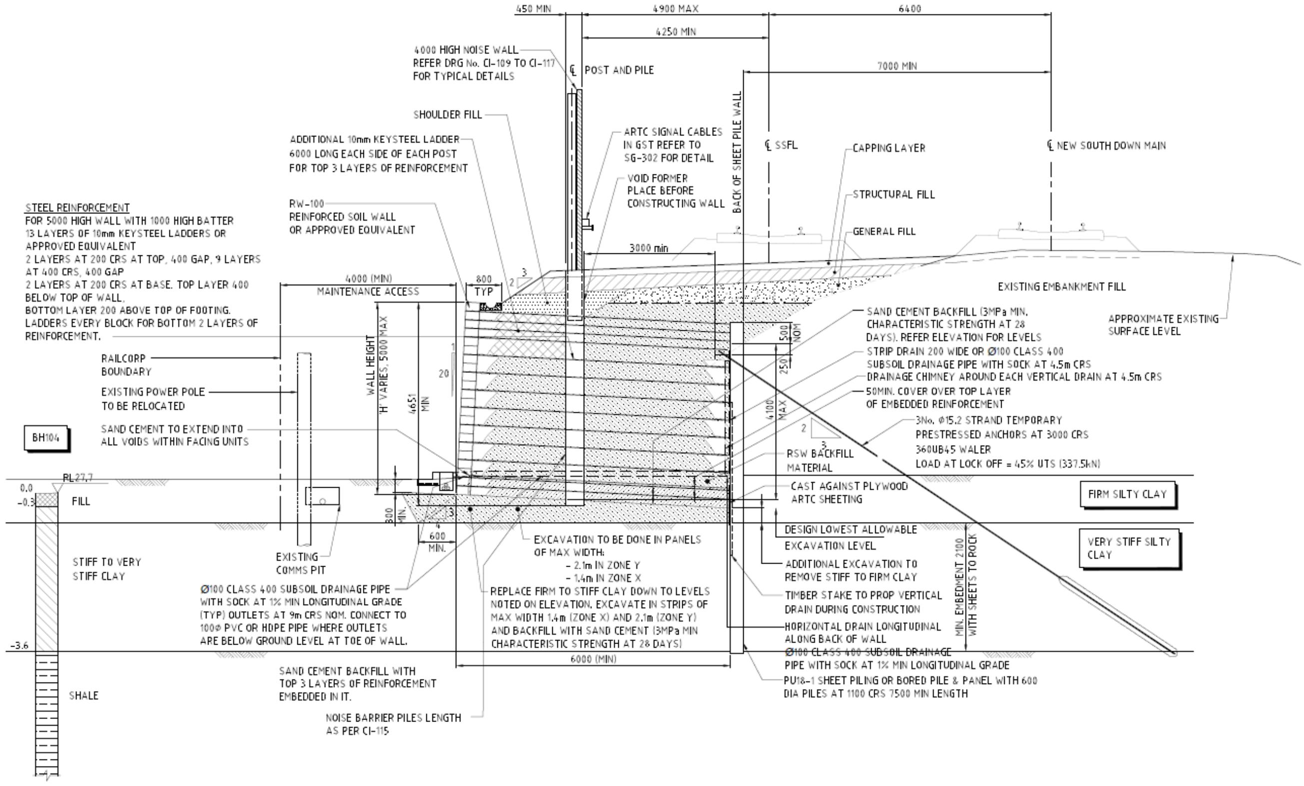

Figure 3: Reinforced soil wall with an anchored sheet pile wall to retain the embankment during construction.

The alternative to the use of temporary sheet piles is to retain the embankment with a wall of bored piles, using a segmental cage that is inserted one segment at a time to avoid the need for a power–out during construction, as shown on Figure 4.

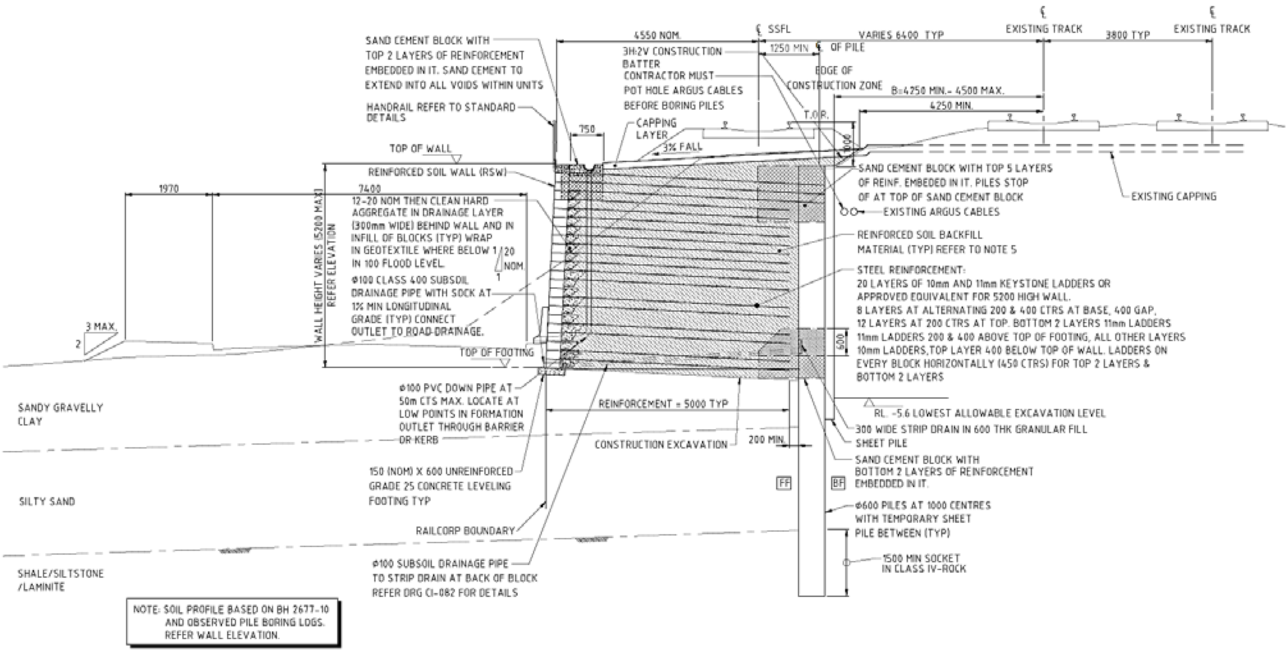

Figure 4: Reinforced Soil Wall with the Existing Embankment Retained On a Bored Pile Wall That Is Integrated Into the Final Wall Structure.

This wall is constructed on an alluvium that required the incorporation of the bored piles into the final structure to provide some of the anchorage against sliding of the composite wall. To achieve this, the bottom rows of soil reinforcement are anchored into the pile wall with a sand cement or concrete block (Figure 5). A sand cement block is also detailed at the top of the reinforced soil block, but in that case the purpose is to achieve full anchorage at the end of the reinforcement to prevent pull out type failures.

The reinforced soil fill used is a crushed sandstone, which once compacted becomes a stiff block of fill. The design method followed is the RTA design specification R57.

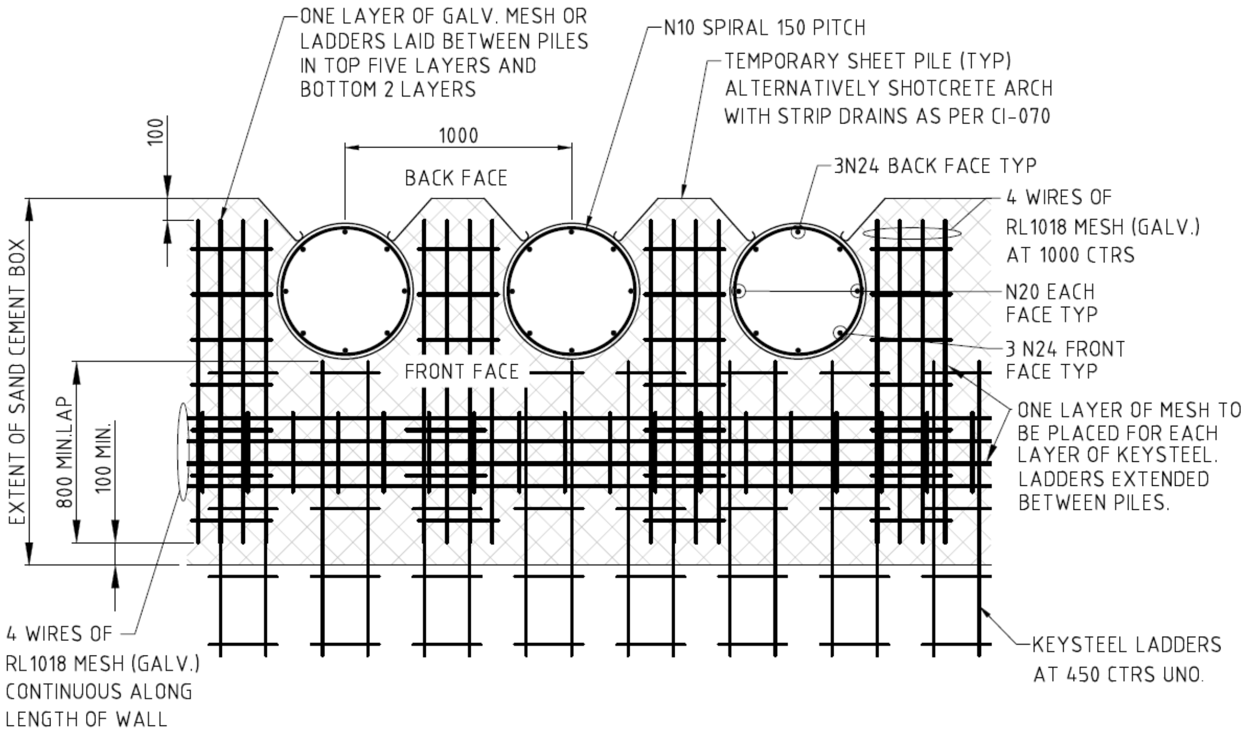

Figure 5: Detail of anchorage of reinforced soil reinforcement into a pile wall.

2.3 ACCOMMODATION OF NOISE WALL BARRIER POSTS IN A REINFORCED SOIL WALL

Another common feature of retaining walls for widening a railway formation in an urban location is the need for noise barriers. The typical noise barrier on the SSFL is constructed with Hebel panels that are either 3 m or 4.5 m long, supported on galvanised steel posts. These noise barrier posts are commonly fixed to concrete retaining walls with a base plate and holding down bolts, though that method requires accurate setting out and also requires fabrication of the posts with a thick base plate.

With a reinforced soil wall the posts cannot be readily bolted to the top of the wall, and so are constructed as embedded items in the height of the wall. However, with a noise barrier that is constructed at grade a commonly used and economical method of construction is to found the barrier posts on piles (not footings) and set these steel posts into a socket that is cast into the pilecap. This allows the posts to be supplied with minimal or no additional fabrication beyond cutting to length and punching holes for attachment angles to fix the barrier panels in place.

With a low height retaining wall the posts are more readily just founded on a pile using the standard detail for at grade construction. The height of the wall is then effectively just an increase in the structural height of the barrier. However, once the retaining wall height exceeds about 1.2m to 1.5 m it becomes more effective to fix the barrier posts at the top of the retaining wall as well as at the base of the post. The fixing at the base is achieved with the weight of the wall on the pilecap, or for a high wall, with a simple pad footing. With the details used on the SSFL the fixing at the top of the wall has to adapt to the distance of the barrier post behind the back of the wall facing units.

With a retaining wall that does not extend to the full height of the embankment (Figure3) the noise barrier piles are typically restrained on the wall facing side with a beam of sand cement. In contrast to that, a post that is on a full embankment height wall has to be at the face of the wall to provide the required clearances to the adjacent rail traffic. On the SSFL the detail for that has the post set in an alcove that is developed in the face of the wall by the laying of the wall facing blocks. The fixing to the posts at the top of the retaining wall is made with a bracket that is bolted to the noise barrier post and cast into a concrete beam that runs down the length of the wall and is also cast around the reinforced soil straps or wires in the top 600-1200 of the reinforced soil block (Figure 7).

The alcove in which the post is erected is filled with high slump concrete.

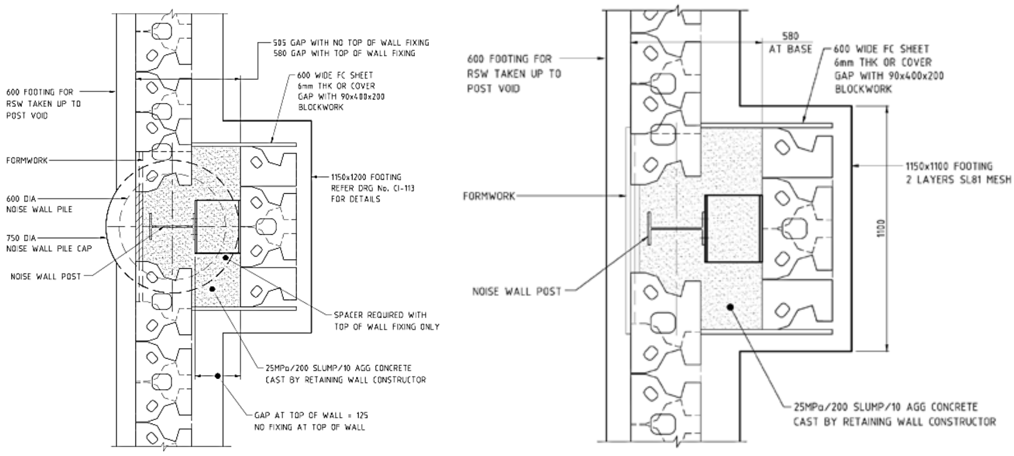

Figure 6: Accommodation of Noise Barrier Posts in Masonry Faced Reinforced Soil Wall

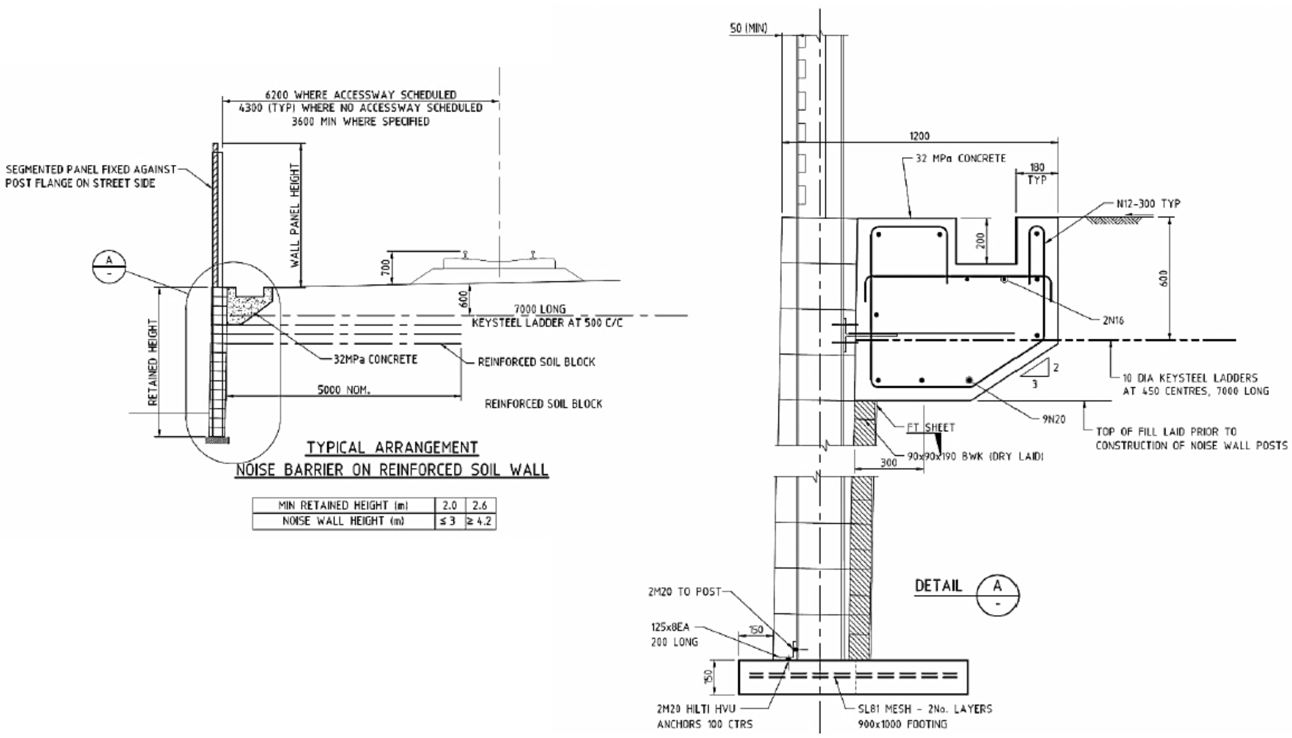

Figure 7: Accommodation of Noise Barrier Posts in a high reinforced Soil wall with Restraint from a Top Fixing

3 CONSTRUCTION OPTIONS FOR A PILED SLAB

3.1 SCOPE OF CONSTRUCTION OPPORTUNITY

When widening an embankment with the aid of a retaining wall is not practical, it is common practice to then proceed with the construction on a viaduct. This typically involves an additional order of cost. Piled slab construction is an alternative that is more economical than construction of a bridge deck. It is basically the construction of a cast in place short span bridge deck with the embankment fill used for false work, and with all the piles extending up to the deck instead of being limited to the support of a pier substructure.

The SSFL Project has two piled slab structures – both at Liverpool. They present the two situations that occur with a piled slab:

- The piled slab over a buried rubbish dump just south of Liverpool Station. This presents the situation of an embankment that can support all construction access and provides support for the casting of the full width of the slab.

- The piled slab next to the steep high bank of the Georges River, which is typical of sites where there is no safe access for the pile construction equipment and incomplete support for casting of the deck slab.

3.2 PILED SLAB CONSTRUCTION WITH SUPPORT FROM THE EMBANKMENT FOR CONSTRUCTION

Construction of a piled slab with embankment support over its full width presents no special challenge. The piled slab structure has the same formation as a bridge, with ballast kerbs set at the clearance that is allowed for ballast cleaning as is adopted on a bridge superstructure, and a cantilevered steel walkway structure which supports the cable troughs that are commonly required.

The piles are driven in a retreating operation along the formation, final trim earthworks done and a blinding layer cast with a polythene sheet over it to allow the embankment fill to drop away if the embankment is prone to settlement.

This type of structure is used at Liverpool to enable construction over a buried rubbish deposit, with high strength geogrid being used for an embankment basal layer to provide stability and control over differential settlement (Figures 8 and 9). Driven square RC piles are used to avoid issues with rubbish extraction and with the methane that is in this deposit.

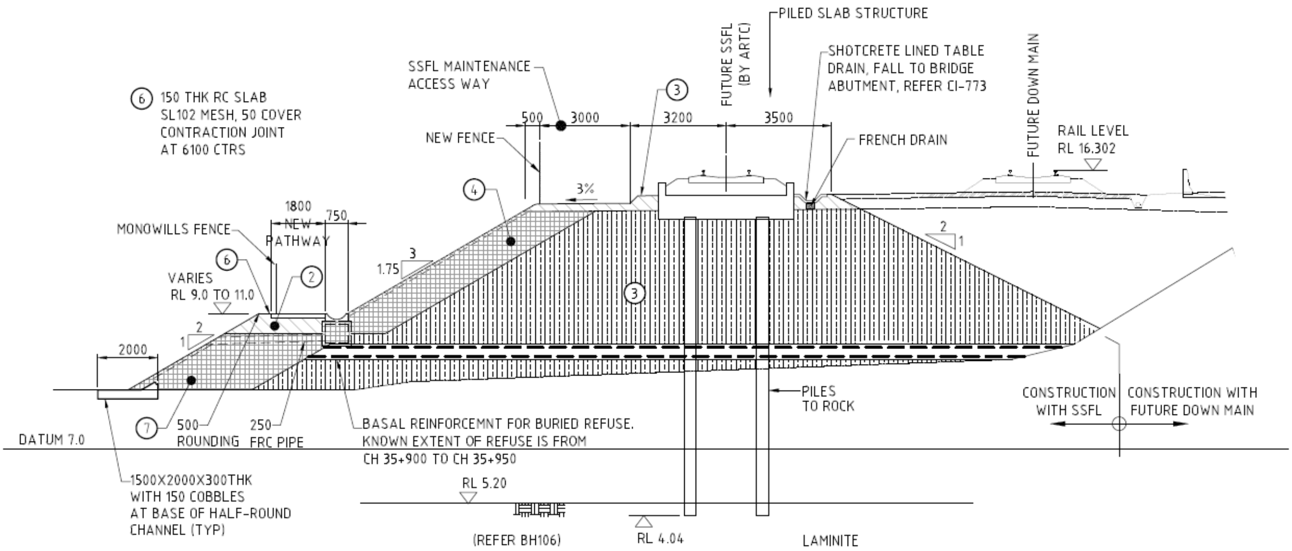

Figure 8: Typical Cross Section through Piled Slab with Embankment Support.

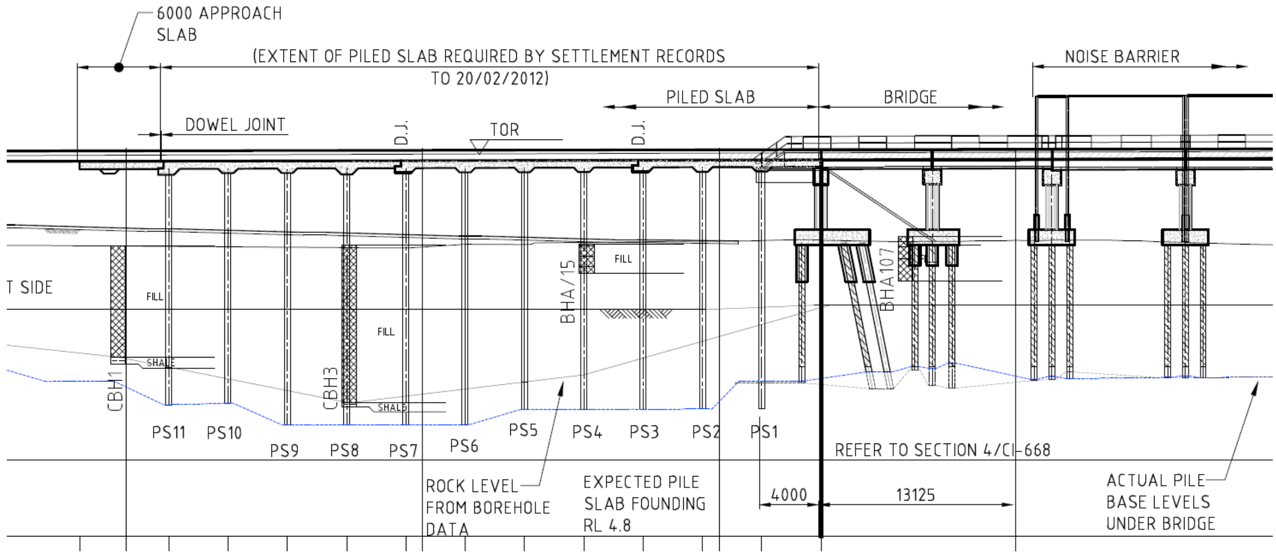

Figure 9: Long Section through Piled Slab with Embankment Support.

The adjacent railway track, which is for the RailCorp system, is presently under construction, also on a piled slab. In that case however, the thickness and nature of the rubbish have been considered to be suited to bored rather than driven pile construction.

Other applications of this type of construction were considered for locations where there was insufficient space for a formation directly on an embankment with its standard width shoulders.

3.3 PILED SLAB CONSTRUCTION WITH INCOMPLETE SUPPORT FROM THE EMBANKMENT

Construction of a piled slab with incomplete support for the access of piling equipment and support for construction of the deck slab represents an additional challenge, as a deck has to be provided to do this.

The embankment next to the Georges River at the north end of Liverpool Station is steep, with an angle of up to 45 degrees. It is typically comprised of cohesive alluvium and as is commonly found with river banks, it derives part of its stability from the roots of its dense cover of trees and lower storey vegetation. Not only is widening the formation with a simple embankment not possible here, but the existing track that is next to the top of the bank has a stability that has only been accepted for use as a freight siding.

The arrangement that is adopted in this case is to construct a temporary supporting deck formed with timber planks spanning transversely on a grillage of H section steelwork founded on driven piles of 100 SHS section. The piles are driven to develop the required load capacity and extend to a deep layer of stiff alluvium. They are comprised of segments with spigot and socket joints and are driven progressively one trestle ahead of deck erection using a small tracked excavator (Figure 10).

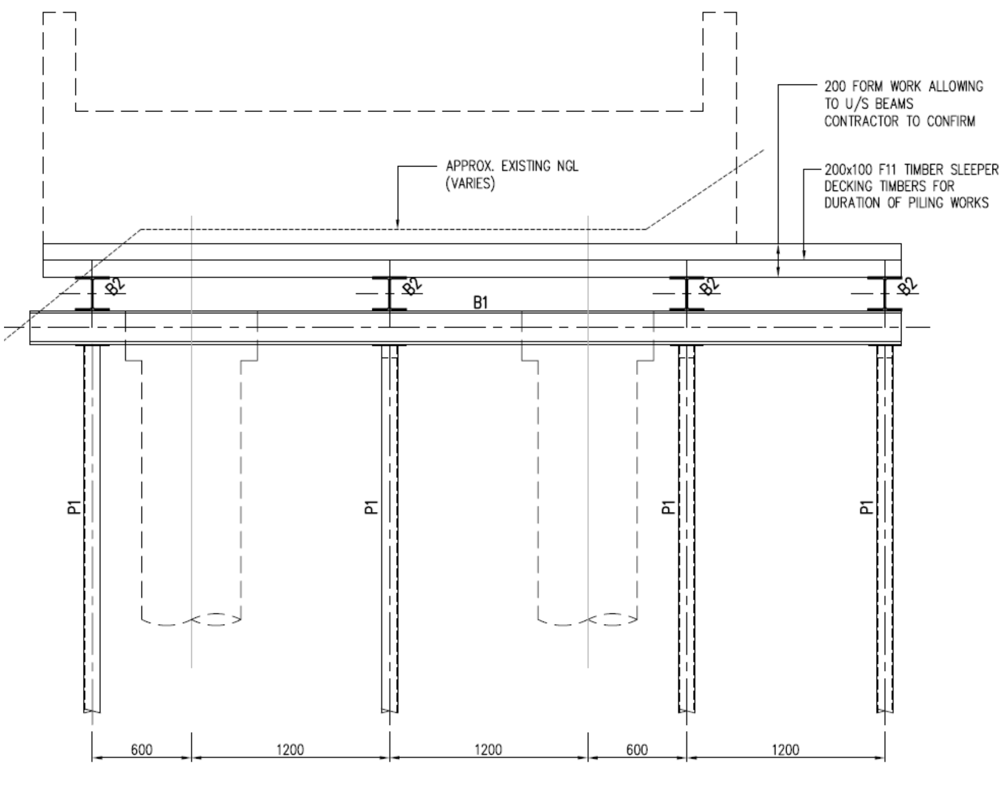

Figure 10: Temporary Support Deck for Installation of Permanent Piled Slab.

This deck is then used to support the piling machine to bore the 600 diameter permanent piles, after which the slab is cast on the deck. Some of the 600 diameter piles then protrude a short distance above the surface of the sloping river bank, and for these the casting of the pile column requires a short length of duct formwork. The 600 diameter permanent piles extend to rock, which is close to but above the level of the river bed. The temporary deck structure is sacrificial. Its design was developed by the piling Contractor, Wagstaff Piling from an earlier design provided by Aurecon and suites the weight of the piling machinery used (Figure 10).

Part of the length of the deck has partial support of its width on the existing ground and in that section the permanent piles are more widely spaced on the row furthest from the river.

The final construction includes permanent anchors to retain the piled slab against the existing slope, with the gap between the side of the piled slab and the embankment being filled with sand cement to allow for the support from the ground to the piled slab structure. The level of prestress is chosen to achieve stability for the piled slab and concomitantly to support to the top of the embankment. In this way, during construction the river bank supports the piles, and after construction is complete the piled frame provides additional support to the embankment (Figure 11).

Track drainage is cast into the sand cement to release lateral drainage water from the existing rail formation to the area under the deck. The river bank down slope of the piled slab continues to rely upon the vegetation and its roots for its surface stability, just as it did before construction.

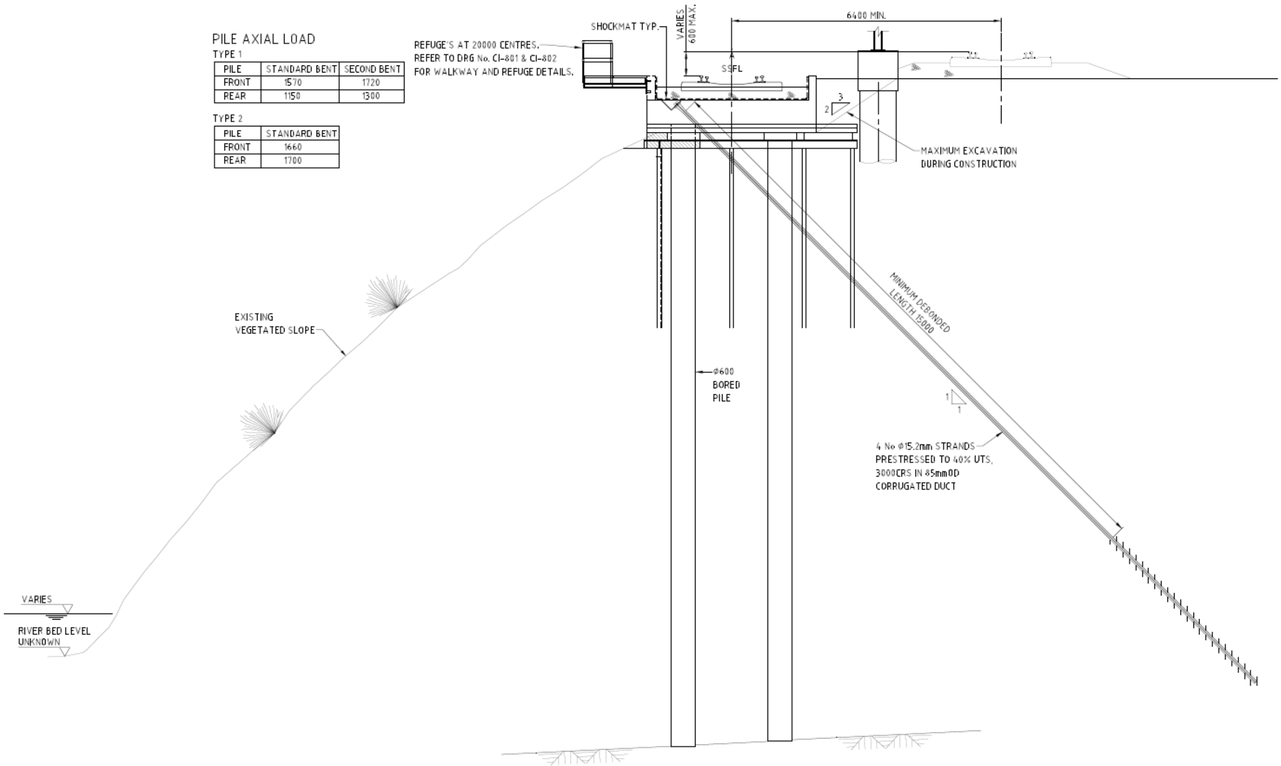

Figure 11: Typical Cross Section through Piled Slab with Incomplete Embankment Support.

4 REFERENCES

ARTC/Connell Wagner Pty Ltd. *Geotechnical Factual Report, Southern Sydney Freight Line, Australian Rail Transport Corporation*. 2007.

Roads and Traffic Authority NSW. *QA Specification R57, Design of Reinforced Soil Walls*. 2002.

Australian Standard. *AS5100, Bridge Design*. 2004.