Timber-piled embankments over soft ground

Remblais de pieux de bois sur sol mou

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ABSTRACT: The City West Link Road Section 3, New South Wales, Australia consists of a 1.7 km length of 4 lane divided dual carriageway. One of the components of the project was to construct the 130 m long Hawthorne Canal Bridge located on soft alluvial soils. Due to land constraints preloading of the bridge approach areas was impossible. Reinforced soil walls were used in those areas to support the sides of the road embankments. To meet the tight settlement criteria as well as to maintain the required pavement transition between the bridge and the road embankments, timber piles were used in the bridge approach areas to fully carry the embankment loads.

RÉSUMÉ: La Section 3 de la route de jonction de l'ouest de la City en Nouvelle Galles du Sud en Australie est composée d'une route à quatre voies de 1,7 kilomètres de longueur. Un des éléments du projet consistait à construire le Pont du Canal Hawthorne, d'une longueur de 130 mètres, se trouvant sur des terres alluviales molles. En raison des contraintes de la terre, le chargement préliminaire des zones d'approche du pont était impossible. Des murs en sol renforcés ont été utilisés dans ces zones pour soutenir les côtés des remblais. Afin de satisfaire aux critères stricts de tassement et de maintenir la transition de chaussée requise entre le pont et les remblais, des pieux en bois ont été utilisés dans les zones d'approche du pont pour porter tout le poids des remblais.

1 INTRODUCTION

The City West Link Road Section 3 in Sydney is part of the Sydney infrastructure upgrade program prepared for the Sydney 2000 Olympics. The project route traverses densely populated residential areas with a total length of 1.7 km. Major components of the project consist of three signalised intersections, a pedestrian overbridge, noise attenuation barriers, an arch structure over an existing rail line, and two bridges across Hawthorne Canal and Iron Cove.

The Hawthorne Canal Bridge (see Figure 1) is located in a soft ground area with alluvial soils up to 15 m thick. The bridge is about 130 m long and is supported on bored piles to depths of 17-18 m. The approach embankments at the two ends of the bridge range between 3-5 m in height. Due to limitation of land, reinforced soil walls have been used to support the sides of the approach embankments. To minimise impacts of ground movement on the bridge abutment piles and the reinforced soil walls, timber piles have been adopted to fully support the embankments.

Stringent settlement criteria have been specified for the bridge approach embankments to ensure that the serviceability requirements of the pavement and the reinforced soil walls are achieved. To enable prediction of ground movements and optimisation of design the finite element method has been used for the analysis of the piled embankments. Field measurements taken during and after the construction of the embankment have been compared with the numerical predictions to confirm the performance of the proposed timber pile system.

2 GEOTECHNICAL MODEL

A total of nine exploratory boreholes were drilled at the bridge abutments, four at Abutment A and five at Abutment B. The borehole information indicates that the site is underlain by a surficial layer of imported fill of 1-1.5 m thick overlying soft to firm clayey alluvial soils extending down to the bedrock level at 12-15 m depth. The interpreted subsurface profile is shown in Figure 2.

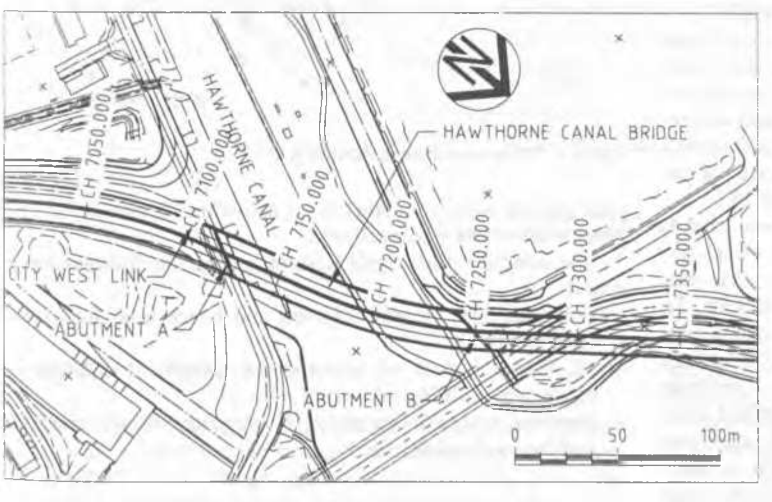

Figure 1. Site plan

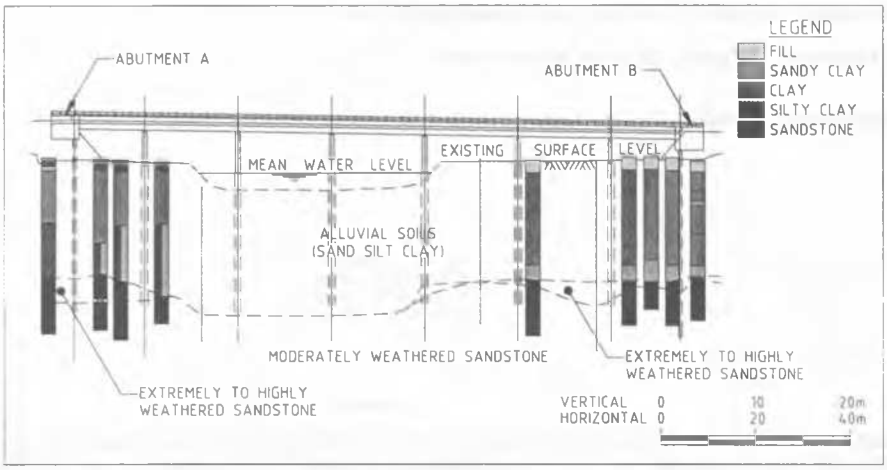

Figure 2. Subsurface profile

Table 1. Geotechnical parameters

Layer	Depth (m)	γ_t (t/m^3)	E' (MPa)	v'	c' (kPa)	ϕ' (deg)
Fill	0-1.5	1.9	5	0.3	2	30
Clay	1.5-7	1.7	3.5	0.4	2	28
Sandy/silty clay	7-13.5	1.8	6	0.3	5	30
EW/HW sandstone	13.5-15.5	1.9	20	0.3	50	30
MW sandstone	>15.5	2.2	200	0.3	100	30

The geotechnical parameters adopted in the design and analysis are summarised in Table 1.

3 DESIGN CONSIDERATIONS

A preload embankment with 2 m high surcharge above the finished road level was constructed earlier starting 6 m east of Abutment A and extending further to the east. The settlement measurements of the preload embankment indicated that at the time of the construction of the bridge approach embankment (within 6 m of the abutment) the primary consolidation settlement below the preload embankment had been fully completed. On the Abutment B side, away from the bridge approach area, the proposed City West Link Road intersected the existing road (as shown in Figure 1) where the ground had been preloaded for years under the existing road embankment. Because of the above situations both of the bridge approach embankments were not subjected to embankment settlement in the adjacent areas.

The bridge approach areas at Abutments A and B could not be preloaded because of site constraints. Reinforced soil walls were adopted to support the sides of the embankments in order to reduce land take. These walls were finished with sandstone facing for aesthetic reasons and they were sensitive to differential ground settlement. The maximum differential settlement of the foundation soils was specified to be limited to within 0.5%.

An array of timber piles (300 mm toe diameter) was considered for installation below the embankments in the bridge approach areas. The piles were designed to fully carry the embankment loads, thereby minimising foundation settlements. To effectively transfer the embankment loads onto the piles, a concrete pile cap in the size of 1 m by 1 m (square) and 0.4 m deep was cast over each timber pile at the ground surface. A bridging layer consisting of two layers of geotextile embedded in three layers of compacted granular fill (250 mm thick each layer) was constructed over the pile caps. The required strength for each geotextile layer was 75 kN/m (at 3% strain) for Abutment A and 35 kN/m (at 3% strain) for Abutment B. The layout of the timber

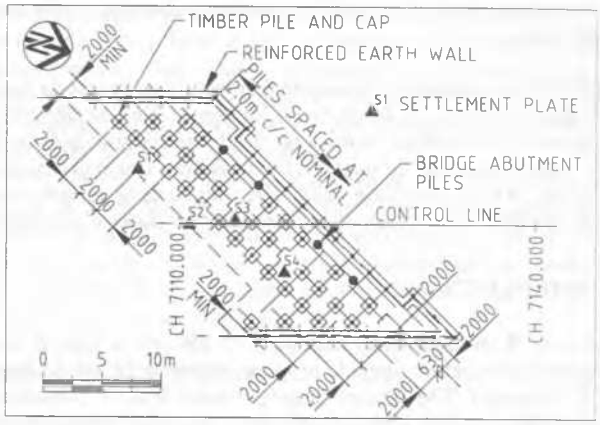

Figure 3. Pile arrangement at Abutment A

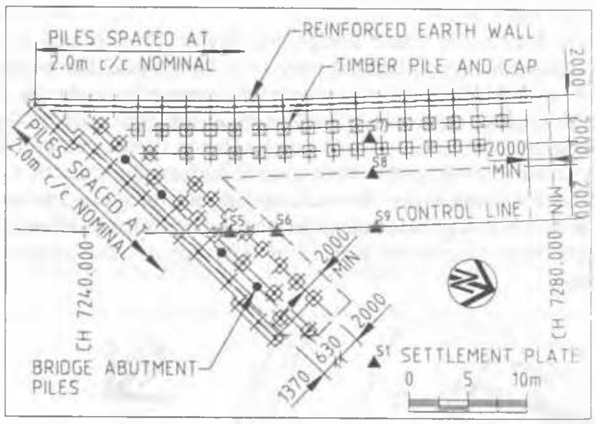

Figure 4. Pile arrangement at Abutment B

piles and the associated pile caps is shown in Figures 3 and 4 for Abutments A and B respectively.

The adopted timber pile system serves the following purposes:

- Fully supports the embankment and hence limit foundation settlement.
- Minimises impact of embankment settlement and ground movement on bridge abutment piles.
- Provides a smooth transition between the bridge abutment and the road embankment.

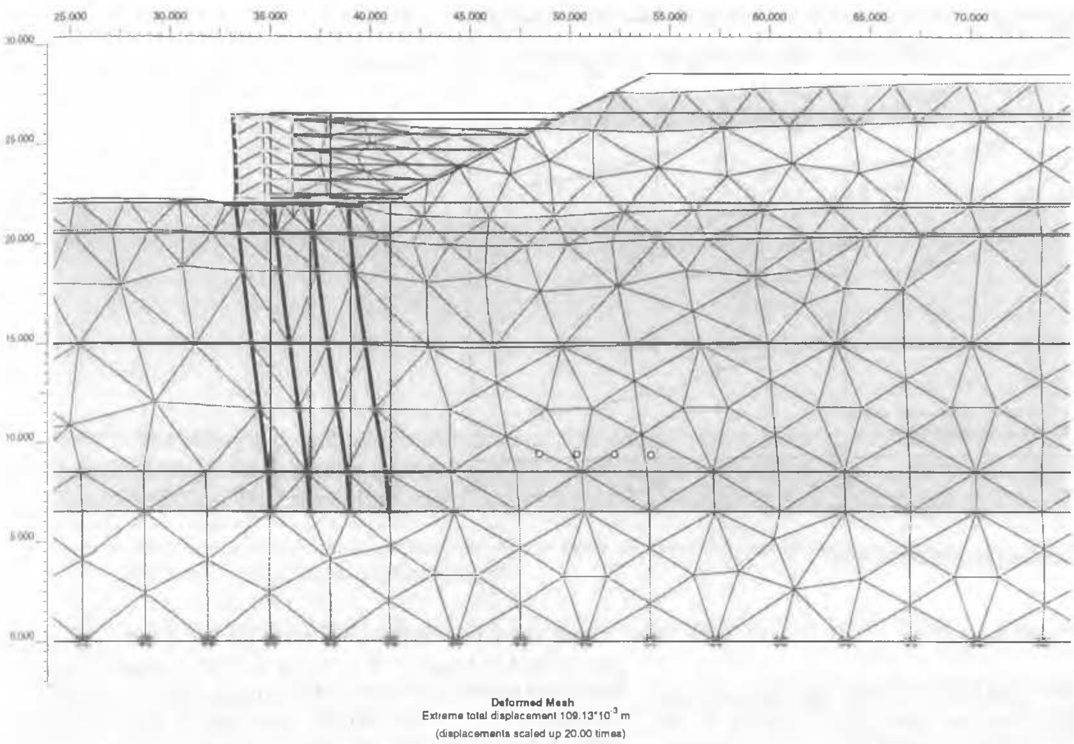

Figure 5. Deformed finite element mesh

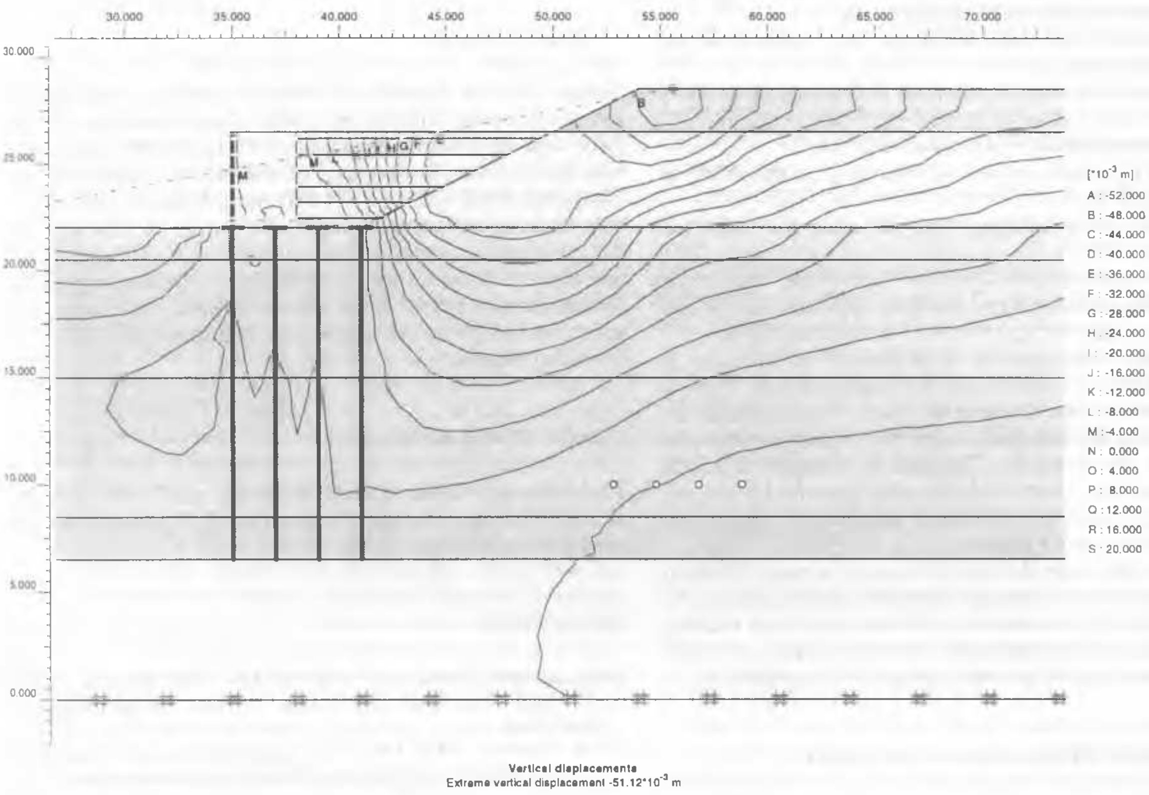

Figure 6. Contours of vertical displacements

4 DESIGN METHODOLOGY

The finite element program PLAXIS (Brinkgreve and Vermeer 1998) was adopted for the analysis and design of the timber-piled embankments. The program was used to fully model the construction sequence as well as the soil-structure interaction. Various arrangements of the foundation treatments were investigated by numerical modelling in order to develop the most cost-effective solution.

British Standard 8006 (1995) has also been adopted to confirm the design of the bridging layer over the timber piles. This includes checking of the timber pile spacing, the pile cap size and the strength of the geotextile embedded in the bridging layer.

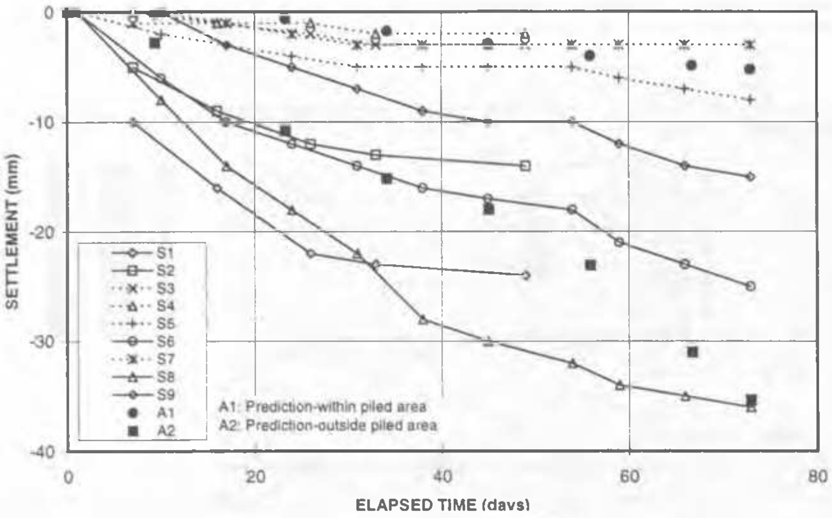

Figure 7. Measured and predicted ground settlements

5 FINITE ELEMENT ANALYSIS

The construction sequence and the interaction between soils and various structural components have been fully modelled in the PLAXIS analysis. The numerical modelling process includes (for Abutment A):

- Construction of the preload embankment with 2 m high surcharge adjacent to the bridge approach area.
- Allowance for full primary settlement of the soil below the preload embankment.
- Installation of four rows timber piles at 2 m spacing and to a depth of 15.5 m.
- Construction of pile caps (pin-joined with piles).
- Erection of the reinforced soil wall panels (155 mm thick) to a height of 4.5 m.
- Construction of the bridging layer including the geotextile over the pile caps.
- Progressive placement of layers of fill and the reinforcing strips (50 mm wide by 4 mm thick by 3000 mm long at 750 mm horizontal and vertical intervals) to the final road level.

The deformed finite element mesh (scaled up 20 times) is given in Figure 5. It is shown that the reinforced soil block is pushed outward by the fill behind the block. The calculated lateral deflections of the wall panels vary from 95 mm at the top of the wall to 85 mm at the toe. The ground settlement was predicted to be less than 5 mm within the piled area and 35 mm outside of the piled area. The calculated contours of vertical displacements are shown in Figure 6.

The timber piles have also bent forward as a result of lateral ground movement. The predicted maximum lateral deflection of the timber piles is in the order of 110 mm, maximum bending moment is 50 kN-m and maximum axial force in the pile is 650 kN. These forces are all within the capacity of the timber piles.

6 INSTRUMENTATION AND MONITORING

Nine settlement plates have been installed at the base of the embankment between the pile caps and outside of the piled areas to monitor the performance of the timber-piled embankments. Four settlement plates S1-S4 were installed at Abutment A (see Figure 3) and five settlement plates S5-S9 at Abutment B (see Figure 4). The measured settlements are plotted as shown in Figure 7. It is noted that for both abutments the measured settlements within the piled areas (S3, S4, S5 and S7) are in the range of 2-8 mm and settlements outside the piled areas (S1, S2, S6, S8 and S9) are 14-36 mm. Significant reduction in settlement is evident in the areas where the timber piles are installed.

The calculated settlements from the PLAXIS analyses are also plotted in Figure 7. It is noted that fully drained conditions have been assumed in the PLAXIS analysis and so the calculated settlements are the final primary settlement at each construction stage. Good agreement has been achieved between the field measurements and the numerical predictions.

7 CONCLUSIONS

Timber piles in conjunction with concrete pile caps and the overlying geotextile reinforced bridging layer have been successfully used to support the approach embankments adjacent to Hawthorne Canal Bridge, part of the recently completed City West Link Road Section 3. The timber pile system was able to control the embankment settlement to within 10 mm and meet the specified maximum differential settlement of 0.5%. The finite element method used for the design of the timber-piled embankments was proved to be effective where the forces in the structures and the deformation of the foundation soils were satisfactorily predicted.

8 ACKNOWELEDGEMENT

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