THE WALL THAT MOVED

Geoff Young

Principal, Douglas Partners Pty Ltd, Sydney Australia

ABSTRACT

A multi-row anchored soldier piled wall was designed to support the sides of a deep basement excavation adjacent to a railway embankment. As part of the approval process, the contractor's consultants had to carry out detailed analyses to demonstrate the suitability of the wall and agreed to a monitoring plan of regular site inspections by a geotechnical engineer including regular surveying of the wall to check on the wall's performance during the construction phase. Construction began, the soldier piles were installed, and excavation and anchoring commenced in stages. Surveying of the wall also started, but the contractor neglected to get the geotechnical inspections required by the monitoring plan. All seems to be going well until unacceptable lateral movements of the retaining wall were detected from the survey. This paper describes the design of the wall, a review of the construction phase information and offers an explanation for the higher than expected wall movements.

1 INTRODUCTION

A proposal retail and residential development with two basement levels was proposed adjacent to a 5 m high railway embankment in suburban Sydney. As part of the approval process, the design had to satisfy approving authorities requirements. The paper discusses the design and construction of the basement shoring wall supporting the railway embankment.

The client for the project was a developer / building contractor who went into liquidation during the project.

2 THE SUBSURFACE PROFILE

Douglas Partners carried out a geotechnical investigation comprising six bores to 10 m depth in 1989 on the site but the development never proceeded. Another geotechnical investigation combined with a contamination assessment was carried out in 2004 and included another nine bores for a different development. The subsurface profile was reasonably uniform across the site and is summarised in Table 1.

Table 1: Summary of Subsurface Profile

Depth	Level	Stratum
0-1 m	RL 22.4 – RL21.4	Loose sandy filling
1.0 m – 2.5 m	RL 21.4 – RL 19.9	Firm Clay
2.5 m – 5.0 m	RL19.9- RL17.4	Stiff and hard clay
5.0 m – 7.0 m	RL17.4 – RL15.4	Class IV-V shale
> 7.0 m	< RL 15.4	Class III Shale

3 THE DESIGN OF THE SHORING WALL

A piling contractor prepared a shoring wall design which was completed in February 2007. The design of the shoring wall to support 6.3 m of excavation and the embankment was for 600 mm diameter long soldier piles at 1.8 m spacings founded below bulk excavation level. Another 600 mm diameter shorter shoring piles were designed between the longer shoring piles thus reducing the soldier pile spacing to 0.9 m. The additional piles were installed to 1 m below the first basement level. The pile spacing remained as 1.8 m below the first basement level.

Two rows of temporary anchors were to be used in each of the long soldier piles and the area between the piles shotcreted. The design was based on basement excavation to RL 16.1 m and the toe of the shoring pile at RL 14.3 m, or 1.8 m socket into medium strength rock. The anchors were to be installed at RL 21.0 and RL18.1 (or 1.4 m and 3.3 m below the top of the wall respectively). The length of the wall along the embankment was approximately 110 m and there were sixty one shoring piles.

The shoring wall was designed to support a profile of 1 m sandy filling, 4 m clay and over 1 m of Class V-IV shale.

In the design, the groundwater level was assumed to be 2 m below ground level, however, it only applied in the permanent case when the basement was tanked because it was assumed that any water would seep out of the excavated face during the temporary case.

4 APPROVAL PROCESS

Part of the approval process involved analysis of the shoring wall supporting the railway embankment. The analysis was carried out by the piling contractor using the computer program WALLAP and parameters obtained from the geotechnical report. The lateral movements were calculated as ranging up to 4 mm near the top of the wall.

A construction monitoring plan which was produced in January 2007 was also required as part of the approval process. The approved monitoring plan involved:

- surveying of the rail track and survey points along the top of the shoring wall at daily intervals;
- inspections by a geotechnical engineer during excavation.

5 THE CONSTRUCTION OF THE SHORING WALL

It is understood that work commenced on site in early 2007. The sixty-one long shoring piles and the intermediate shorter shoring piles were constructed along the railway embankment side of the basement, and excavation commenced. The construction of the shoring wall sequence was given as:

- Install the shoring to the design depth and construct the capping beam;
- Excavate to 1.8 m depth (RL 20.6 m);
- Install the first row of anchors at 1.4 m depth (RL 21.0 m), allow the grout to set and stress the anchors;
- Excavate to 4.8 m depth (RL17.6 m);
- Install the second row of anchors at 4.3 m depth (RL 18.1 m), allow the grout to set and the stress anchors;
- Excavate to 6.1 m depth (RL 16.1 m), the final level.

6 MONITORING OF THE SHORING WALL

Survey monitoring to the railway track and the shoring commenced on 18 April 2007, presumably before any excavation commenced was carried out. Five survey points, named A to E, evenly spaced along the 110 m long capping beam of the shoring wall were used for assessing the lateral movement of the shoring.

No inspections by a geotechnical engineer were carried out during the excavation as the contractor had failed to inform the geotechnical engineer that piling and excavation works had commenced.

Although surveying of the railway track and the shoring wall had been continuing since excavation commenced in April 2007, it appeared that nobody was reviewing the surveying results until some lateral movement of the shoring wall of up to 30 mm had occurred in late August 2007. It was at this time that Douglas Partners was asked to assess the situation.

5.1 ANCHOR RECORDS

There were anchors in each of the sixty one long shoring piles constructed adjacent to the embankment. The anchor records were provided and show that the first row of anchors were generally installed and stressed by 4 July 2007. It is assumed that excavation recommenced to 0.5 m below the level of second row of anchors and then the second row of anchors was installed. A summary of the dates for the installation and stressing of the anchors is given in Table 2.

Table 2: Anchor Installation Records

Pile No	Closest Monitoring Point	First Row of Anchors		Second Row of Anchors	
		Drilled & Grouted	Stressed	Drilled & Grouted	Stressed
1 – 12	A	27-29/6/2007	4/7/2007	12-14/7/2007	17/7/2007
13 – 24	B	22-27/6/2007	28/6-4/7/2007	13-14/7/2007	18/7/2007
25 - 35	C	20-22/6/2007	28/6/2007	14-16/7/2007	18-19/7/2007
36 - 45	D	6-7/6/2007	18/6/2007	16-17/7/2007	19-20/7/2007
46 - 61	E	5-15/6/2007	5-15/6/2007	29-30/8/2007	4-18/9/2007

5.1 SURVEY RESULTS

Based on the results of the survey monitoring, the first significant movement of the wall occurred about 12 July 2007 when movements up to approximately 10 mm were recorded. There was another significant movement about 23 August 2007 when movements at about the middle of the wall length increased from about 17 mm to 30 mm. The wall movements on selected days for survey points A, B, C, D and E have been plotted on Figure 1.

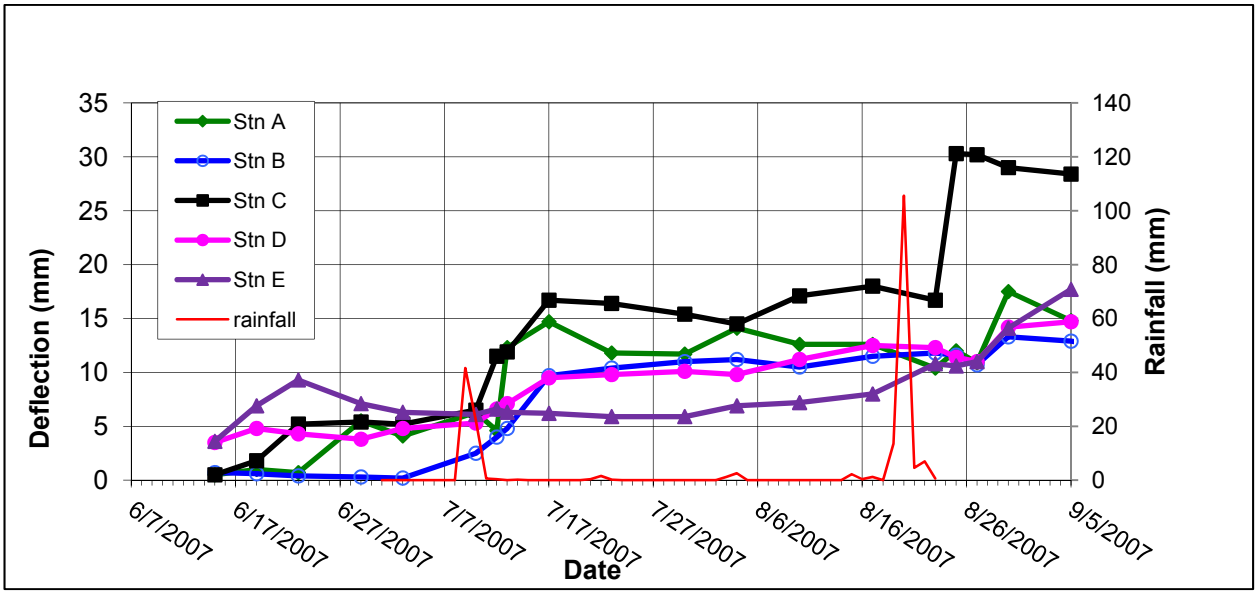

Figure 1: Survey of the Shoring Wall Deflections for the Period June to September 2007

Plotted on the same figure are the daily rainfall measurements for Sydney with most observations recorded from Observatory Hill. As can been seen from the plot, the significant rainfalls occurred on 9-10 July and 20-24 August.

For the period 7-17 July 2007 and in the area of piles 1 to 45, it would be reasonable to assume that the basement excavation was within 1 m of the final design level and was in rock before 9 July 2007 in order to construct the second row of anchors which are recorded as being grouted, but not stressed, between 12 and 17 July 2007. As noted above, a substantial period of rainfall was recorded on 9 – 10 July 2007. The anchors were not stressed until after 17 July 2007 by which time the movement had occurred.

A more substantial rainfall event occurred around the time of 18-25 August 2007. The second row of anchors for piles 46 to 61 were drilled and grouted by 30 August 2007. Based on the substantial amount of rain recorded during the week of 20 to 27 August 2007, it is likely that no major excavation work would have been carried during that week and the records show that the second row of anchors in piles 46 to 61 were installed during the following week. Therefore, excavation of the basement along this section of the wall (Station E) would probably have been nearly completed by 20 August 2007 which is before the heavy rain and before the second row of anchors were installed and stressed.

Survey monitoring continued after the shoring wall movement of August 2007 but there was no significant movement recorded after August 2007 even after some substantial rain events as is shown in Figure 2.

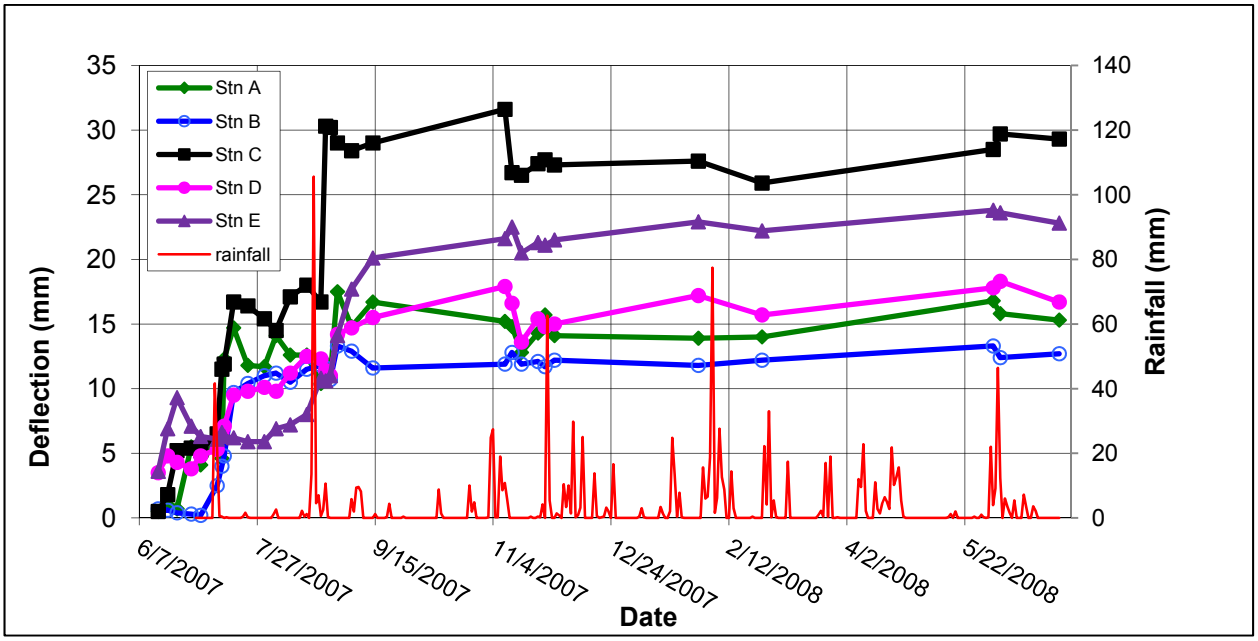

Figure 2: Survey of the Shoring Wall Deflections for the Period June 2007 to July 2008

7 CONCLUSIONS AND COMMENTS

Based on the surveying results, it appears that the significant lateral movements occurred in the shoring wall during the period between the basement excavation having been nearly completed and before all the anchors were stressed. It was also during that period that there were some substantial rain events.

It is considered that the lateral movement of the shoring is due to water pressure acting on the shoring. The first significant movement occurred after a substantial rain event and before the second row of anchors had been completely stressed. The second significant movement occurred after a more substantial rain event before the stressing of second row of anchors had been completed. This suggests that the assumption that there would be no water pressure behind the wall during the temporary case may not have been sufficiently conservative, particularly in the short term case where only the top row of anchors was acting to restrain the excavation/shoring height before the complete second row of anchors were stressed. 7 conclusions

The Contractor was a bit unlucky in that the rain events occurred at critical times in the construction. The lateral movements would have been less if the second row of anchors had been stressed at the time of the rain events.

It is noted that following the initial movement and stressing of the anchors, there was no significant movement until the second major episode of rain. After the second rain period and stressing of the anchors, there has been no significant increase in the rate of wall movement recorded, even after some substantial rain events in late 2007 and early 2008.