Geotechnical investigation and design of the Robina to Varsity Lakes rail extension

Patrick Kidd and Mogana Sundaram
Connell Wagner, Brisbane, QLD Australia

Keywords: landfill, tunnel, excavatability, point load index, UCS, investigation

ABSTRACT

The Robina to Varsity Lakes Rail line is a 4.1 km extension to the existing Robina line. The proposed extension will include the construction of a station, two new road bridges, roadworks, a 300m cut and cover tunnel, major sections of cuts up to 14m in depth and significant sections of fill embankments up to 11m in height including the construction of an embankment section into an existing lake. It will also involve construction of track over an existing municipal solid waste landfill, with thicknesses in excess of 29m. A detailed geotechnical investigation of the site was undertaken to quantify the geotechnical challenges within the project area. In consultation with the structural team, the geotechnical engineering team for the project identified and designed solutions to overcome these geotechnical challenges. This paper focuses on the geotechnical issues relating to the proposed tunnel and cut slope excavation of the project.

1 INTRODUCTION

The proposed Robina to Varsity Lakes rail extension will be located immediately to the south of Robina station which is currently the southern most point of South East Queensland's surburban commuter rail network. Figure 1 shows the location of the proposed extension.

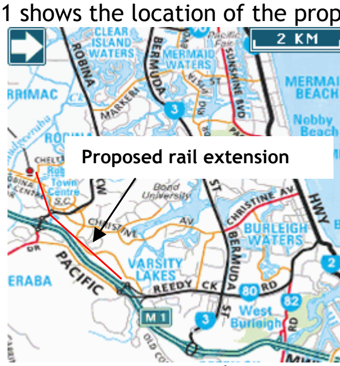


Figure 1 Location Plan

1.1 Background

The proposed rail line project has been under consideration for some time hence a number of geotechnical investigations were undertaken at the site prior to the current investigation. These investigations were reviewed prior to the undertaking of the current investigation to supplement existing information. This was undertaken to ensure that the current investigation satisfactorily categorised the site to allow preliminary and detailed design of the proposed track, roadworks and associated station and structural works.

1.2 Site and project description

The Robina to Varsity Lakes Rail line is a 4.1km extension to the existing Gold Coast Rail Line to the south. The route covers varied terrain including a number of topographic high areas along the northern portion, a number of creeks, and associated low-lying areas in the central and southern portion. In addition, the route traverses significant portions that have been modified from their original landforms by anthropogenic (man-made) impacts. The railway is comprised of a number of small transitional sections of at-grade track between the significant filled and excavated sections and a tunnelled section. Associated with the railway, a number of new road bridges and modifications to the existing road network will also be required.

The proposed route for the rail line is within a restrained corridor that starts from the north at Robina Station and terminates adjacent to Reedy Creek Road at its southerly most point. Initially the route runs south parallel to Laver Drive, passing under Robina Town Centre Drive, Investigator Drive, Easthill Drive and Robina Parkway then across Tarn Lake. From Tarn Lake, the route then runs parallel to the existing Pacific Motorway and continues southward over Coromandel Drive where the proposed station is to be located across a portion of the landfill to the terminus.

2 REGIONAL GEOLOGY

The Geological Survey of Queensland's 1:100000 Murwillumbah Geological sheet indicates that the proposed rail line route is underlain by the Neranleigh Fernvale Beds which comprise phyllite, argillite, metagreywacke, arenite, quartz arenite, quartzite and metabasalt and by Quaternary Alluvium which comprise sand, silt, clay and gravel, along existing and former creeks.

Review of previous investigation reports for the site by Shaw (2005) indicates that the southern portion of the site is underlain by a landfill. Although the landfill is not recognised as a geological unit, it has significant engineering impacts on the rail line, so it has been mentioned for completeness. It is known that the landfill was placed within a void created by quarrying between the mid 1990s and 2002. The depth of the landfill placed ranges from less than 1m to in excess of 29m.

3 MAJOR GEOTECHNICAL ISSUES ON THE PROJECT

Review and analysis of the information collected during the investigations at the site revealed that the two most cost significant geotechnical issues for the project were:-

- Across the proposed cut and cover tunnel site and adjoining cuttings a large amount of very high to extremely high strength rock was identified which would be difficult to excavate.
- A very significant landfill of unknown engineering characteristics was located on the site of the proposed train station which could result in significant problems for proposed foundations and bring about large potential settlement issues.

3.1 Locating a train station over a landfill

Early in the project the locating of the proposed train station over a landfill of significant depth and containing "young rubbish" was identified as a substantial risk to the project. The originally recommended options by the geotechnical team on the project in order of preference were to relocate the station off the landfill site, undertake removal and replacement of the landfill with controlled fill, undertake ground improvement or support the station and track on piles.

Due to external considerations, the first and second options were originally disregarded and a piled solution was sought. After a significant amount of analyses it was determined that a combination of a piled and ground improvement option would be required to allow construction of the station. However, this option proved to be prohibitively expensive. Consequently, the removal and replacement option was further developed to assess it's suitability as a solution. But once again following costing, this option was also considered to be prohibitively expensive. After a very significant amount of work was undertaken to develop these two options, the geotechnical teams preferred solution was implemented to shift the station from the landfill site. The assessment of the various options has not been further described in this paper.

3.2 Excavatability

This section of the paper presents the excavatability assessment that was carried out for the rail extension. Some sections along this route (Chainage 86000 to 86500 and 87040 to 87220) require cuts as deep as 14 m. The excavatability of rock along this route, especially at the proposed cut and cover tunnel section was assessed using site investigation information, laboratory strength data and seismic refraction data that were available from current and previous investigations.

3.2.1 Site Geology (Chainages 86000 to 86500 and 87040 to 87220)

Bedrock along the rail route to the north of Robina Parkway predominantly comprised of arenite (or greywacke). The rock was massive with less than 20 % of the cores (Connell Wagner boreholes) observed to contain moderately developed foliation. This was especially so in the area of the cut &

cover tunnel section (CH 86000-86310). Subordinate horizons of thinly bedded argillite (or siltstone) were observed within the arenite/greywacke.

The dominant geological structure observed in this area was foliation which was poorly to moderately developed. The foliation generally dipped towards south westerly direction. The dip angle ranged between 50^0 – 70^o with an average of about 60^o. Intensely fractured/sheared zones were encountered in a few boreholes and their occurrence was expected to be localised. No other major geological structures were identified in the investigations.

The weathering profile in this area was generally shallow. The depth of residual soil encountered in boreholes was less than 2m. Highly to moderately weathered rock was encountered between 2-6 m which was further underlain by slightly weathered (SW) to fresh (FR) rock.

The bedrock in the Megans Knoll excavation (87040 to 87220) comprised of approximately 50 % argillite and 50% arenite. Deeper weathering (up to 9m of extremely weathered (XW) to distincly weathered (DW) material) was encountered in one of the two boreholes drilled in this cut section.

3.2.2 Geophysical data

A seismic refraction survey was undertaken by GHD (1996) parallel to the rail alignment along the proposed tunnel and adjoining cut. The survey section undertaken indicated a low velocity zone of <500m/s at less than 1.5 m. This was followed by a zone of 1500-2000 m/s. The depth of this zone extended up to about 6m below ground level. This was followed by a zone with a velocity between 2000-3000 m/s with troughs up to 25 m deep. Below this zone a very high velocity zone was interpreted (>3000 m/s) from as shallow as 5m below surface level.

Borehole information available from previous and current investigations (GHD 1996 & Kidd 2007) was plotted on the seismic refraction survey section to compare the velocity interpreted and the rock conditions as encountered. It was found that there was a good agreement between the interpreted seismic velocity and the weathering identified from site investigation boreholes.

The low velocity zone (< 500 m/s) was within the depth identified as residual soil. The intermediate zone 1500-2000 m/s was within the extremely weathered to moderately weathered (MW) zone and >2000 m/s was represented by slightly weathered to fresh rock. The troughs possibly represented deeper weathering that may have developed along geological weak zones (faults and shears). These zones are summarised in Table 1.

Table 1. Seismic Velocity and rock mass weathering from boreholes

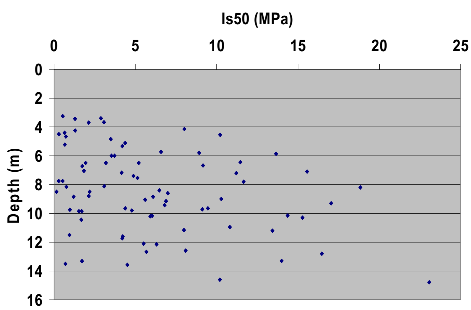
Seismic Velocity (m/s)	Depth (m)	Weathering	Comments
<500	< 1.5	Residual Soil	< 2 m residual soil identified in boreholes
1500-2000	1-6 (troughs up to 8 m interpreted)	XW – MW	6 m maximum depth interpolated from borehole data
2000- 3000	> 6 – 25 m	SW – FR	> 4m from borehole data
>3000	> 5	FR	Fresh & massive rock

3.2.3 Excavatability Assessment based on Seismic Data

The interpreted seismic velocity zones were compared with Caterpillar rippability chart to assess the type of equipment that may be required to excavate the material. As indicated in the rippability chart, rock mass with a seismic velocity up to 3000 m/s was expected to be ripped with dozer D11. Beyond this the rock mass would be marginally rippable to about 3500 m/s. From related literature (Peck and Walker 1976, McGregor 1993) and from our experience, the excavatability chart tends to overestimate the ease of rippability. Therefore, a recommended limit of 2000m/s for a D11 to rip the rock material economically at this site was assumed. It also should be noted that apart from seismic velocity (which is a function of rock strength and defects) the rippability depends on other factors such as equipment type (power, condition), operator's experience, geological structural orientation & ripping direction, and movement restriction of the equipment.

3.2.4 Laboratory strength test data & discontinuity analysis

The results of point load index (Is50) testing (211 samples) and the unconfined compressive strength (UCS) testing (28 samples) undertaken during this and the previous GHD investigations were examined. The rock sampled in the boreholes for the proposed tunnel and adjoining excavations ranged in strength from 0.2 to 23.1MPa (Is50) and 30.7 to 217.8 MPa (UCS). Rock strengths within the boreholes drilled for the excavation through Megans Knoll (Ch 87090-88090) ranged in strength from 0.7 to 9.0 MPa (Is50) and 29-38 MPa (UCS). Of the samples tested, 50% (81nos.) failed partially or completely along a pre-existing foliation / defects. Figure 2 below demonstrates the relationship between the depth and point load index strength of samples failing through the rock material.



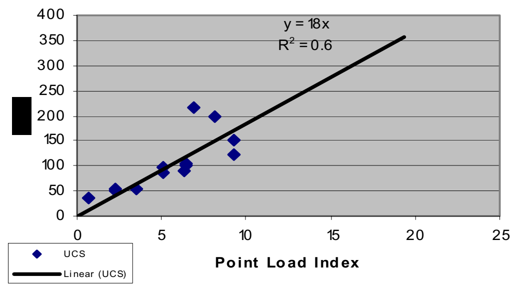
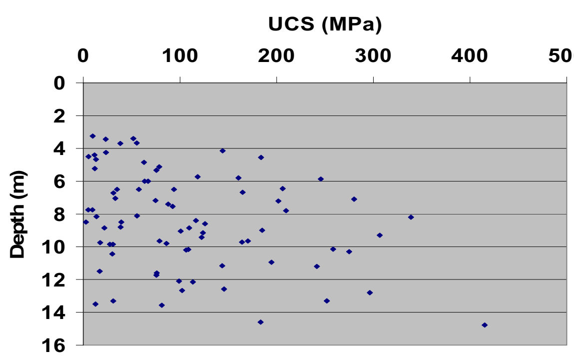


Figure 2 Point Load Index plotted against depth Figure 3 Point Load–UCS Correlation failing through intact rock

An initial correlation between point load index and UCS samples which failed through intact rock from similar depths within the same boreholes was used to determine a multiplication factor for the site. The initial results shown in Figure 3 based on 13 such samples tested produced a multiplication factor of 1:18. Currently further UCS testing is being undertaken to validate the suitability of this ratio. The ratio of Is_{50} to UCS in the Neranleigh Fernvale Beds has been studied by others, including Baczynski (2001) and Look and Griffiths (2001), for the rock types arenite/metagreywacke and argillite/siltstone encountered on this site. They recommend ratios of 1:17 and 1:8 respectively. Baczynski's study specifically referred to samples that failed through intact rock. The results of this study at this early stage are very similar to Baczynski's. The significantly lower ratio found by Look and Griffiths included all failures both through material and along prexisting foliations / defects.

The plotting of point load indices recorded during the investigation which failed through the rock material, multiplied by the 1:18 ratio in Figure 4, gives an appreciation of the likely distribution of rock strength values at this site.



Minimum	5.23
Maximum	415.1
Mean	108.4
Standard Deviation	91.1

Figure 4. UCS distribution with depth along proposed Robina – Varsity Lakes rail line (UCS = 18 X Is_{50})

Based on the extrapolated values shown in Figure 4, review of the data compiled by Baczynski (2001) and Look and Griffiths (2001) together with discussions with local rock testing laboratories and the authors local experience, the arenite encountered on the site is some of the strongest encountered to date within the Neranleigh Fernvale Beds.

An excavatability assessment was also carried out using the method from Pettifer & Fookes (1994). In this method the defect spacing and point load index (Is_{50}) data were used to estimate the excavatability of the rock. A selection of results recorded on samples from varying depth and weathering are plotted on the chart below.

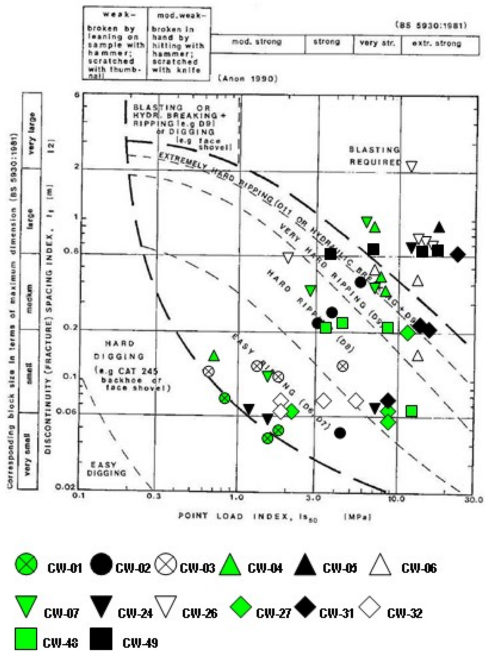


Figure 5 Excavatability assessment using point load index (Is_{50}) and defect spacing from borehole data

Figure 5 indicates data from various boreholes plot in the region of "rippable" to "blasting required". Review of the sample descriptions indicated that the points in the "rippable" field are mostly from XW to HW zones and MW materials mostly plot in the "hard" to "very hard" ripping fields (using D8 and D9 dozers). Some MW and most of the SW-FR data plot in the "extremely hard ripping" and "blasting required" regions. Based on this methodology it was apparent that combinations of ripping equipment and blasting will be required to excavate the material economically.

3.2.5 Excavatability Recommendations

Based on seismic refraction survey data and strength-defect spacing relationship, the following guidelines were provided to the contractor's estimators to outline what was expected to be required to excavate the rock material economically along the proposed tunnel and the cuttings adjacent to the north and south of tunnel

- 1-3 m with D8 dozers
- 3-5 m with D11 dozers (hydraulic hammers and or blasting may be required within this zone)
- > 5 m blasting

The proposed cutting to the south of Tarn Lake through Megans Knoll (CH 87040-87220) was expected to have similar rock conditions. Therefore, it was recommended that up to approximately 50% of the rock that was to be removed from this area should also be considered to be marginally rippable to unrippable (i.e. 50% with D8 & D11 and 50% require blasting). Excavation between (CH 87090-88090) most likely could be carried out using D8 & D11 with some small sections requiring hydraulic hammers.

Due to uneven weathering profile that may have developed, there would be isolated sections shallower than 5 m which might require hydraulic hammers and or blasting to excavate in major sections.

3.2.6 Design Changes

Based on the information provided on excavatability on the site, the alignment of the deep excavations was amended as much as possible to provide maximum clearance from noise and vibration sensitive structures. By maximising standoff distances, the maximum possible charge size can to be used, whilst remaining inside the noise and vibration standards to facilitate the rock excavation as economically as possible. The investigations undertaken also enabled the specification of two differing cut angles within the proposed permanent excavations. To minimise the proposed support requirements the proposed excavation angles were set at 60^0 for the east face and 75^0 for the west face, due to the impact of the foliations dip into the excavation from the eastern cuts.

4 CONCLUSIONS

All available geotechnical information for a project must be reviewed to provide the most comprehensive geotechnical picture of the site and to provide best value for money by targeting follow up investigations to maximise the gathering of additional information.

The use of geological mapping data is very important in allowing optimisation of cut batter design angles, which can reduce significantly the requirement for ground support.

Subject to further testing a UCS to $Is_{(50)}$ strength ratio for samples failing through intact rock of between 1:17 and 1:18 for the Arenite/Metagreywacke and Argillite within the Neranleigh Fernvale Beds seemed to be a reasonable assumption.

5 REFERENCES

Kidd, P.R. (2007). *Geotechnical Investigation Report, Robina to Varsity Lakes Rail Line*. Trackstar Alliance, Brisbane

Shaw, P. (2006). *Geotechnical Aspects of Subsurface Investigations at the Proposed Reedy Creek Railway Station Site*. Shaw:Urquhart, Brisbane

Baczynski, R. P. (2001). *Intact Rock Strength of Neranleigh Fernvale Strata*. Australian Geomechanics September

Look, B. G. and Griffiths, S. G. (2001). *An Engineering Assessment of the Strength and Deformation Properties of Brisbane Rocks*. Australian Geomechanics September

GHD. (1996). *Examination of Proposed Railway Works at Robina*. GHD, Brisbane

Pettifer, G. S. and Fookes, P. G. (1994) *A revision of the graphical method for assessing the excavatability of rock*. Quarterly Journal of Engineering Geology. 27, 145-164

Macgregor, F. (1993). *Rippability of Rock*. Phd thesis. University of New South Wales, Sydney.

Peck, W. A. and Walker, L. K. (1975). *Application of Seismic Measurements to Engineering Design, Insitu Testing For Design Parameters*, The Institution of Engineers, Australia