Proceedings of the 11th ANZ Young Geotechnical Professionals Conference – 11YGPC
Queenstown, New Zealand
25 – 28 October 2016

Design and construction of an egress tunnel beneath a working hospital

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ABSTRACT

This paper discusses the construction and underpinning design of a 24 m long egress tunnel as part of the expansion of an existing hospital in western suburbs of Sydney. The first part of the paper presents the site geology, subsurface conditions and the pre-construction condition of the egress tunnel site. The next part of the paper presents the construction methodologies that were considered and explains the basis for selecting a two heading approach. The final part of the paper details the two designs that were adopted for the underpinning works. The paper demonstrates the value of close collaboration between the designers and constructors which enabled the tunnel to be constructed without disruption to the hospital's daily operation.

Keywords: underpinning, tunnel, pedestrian tunnel

1 INTRODUCTION

A recent project was completed to expand an existing hospital in the western suburbs of Sydney to meet the future healthcare needs of the growing community. The project included a new seven storey clinical services building adjoining the current main hospital building with a new comprehensive cancer care centre, a six storey above ground car park, extensive refurbishment to the existing main hospital building, and a new main corridor (egress tunnel) to connect the new and existing main hospital buildings.

The existing main hospital building is located at the northern end of the hospital site. The hospital site slopes gently down towards the north and northwest. As a result of the slope, access to the existing main hospital building at the northern end is from Level 1 and access to the southern end is from Level 3 as presented in Figure 2. The egress tunnel is located beneath the Level 3 slab of the southern end and links Level 1 and Level 2 of the northern end of the existing hospital to the new hospital building. The internal dimension of the egress tunnel is 24 m long, 4 m wide and 8.4 m high. The plan and long section of the egress tunnel is presented in Figure 1 and Figure 2.

This paper discusses the design of the egress tunnel which was required to be both innovative and practical to construct as well as enabling the tunnel to be constructed without disruption to the hospital's daily operation.

2 SITE GEOLOGY

2.1 Site geology

The Penrith 1:100,000 Geological Sheet as per Clark and Jones (1991) indicates that the site is underlain by Bringelly Shale of the Wianamatta Group comprising shale, carbonaceous claystone, claystone, laminate, fine to medium grained lithic sandstone, rare coal and tuff.

2.2 Encountered subsurface condition

The subsurface conditions encountered at the egress tunnel site consist of residual soil overlying Class IV or V Shale, overlying Class III or better Shale as per the Pells et. al.(1998) classification for Sydney Shales. Class III Shale is typically moderately weathered with joints spaced between 3 to 10 m and intact rock strength between 2 and 15 MPa. Class IV and Class V Shale is more weathered and jointed with weaker intact rock strength.

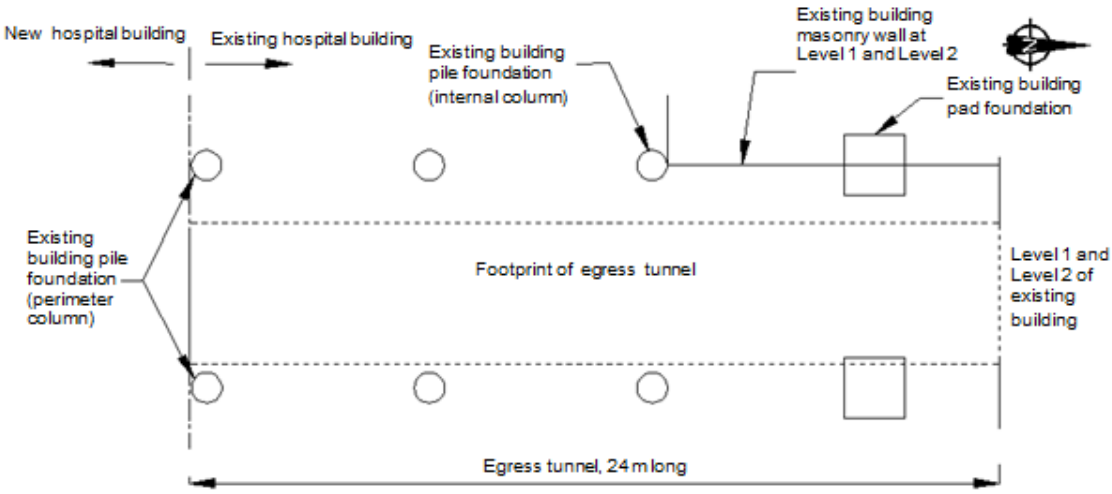

Figure 1. Plan of the egress tunnel site

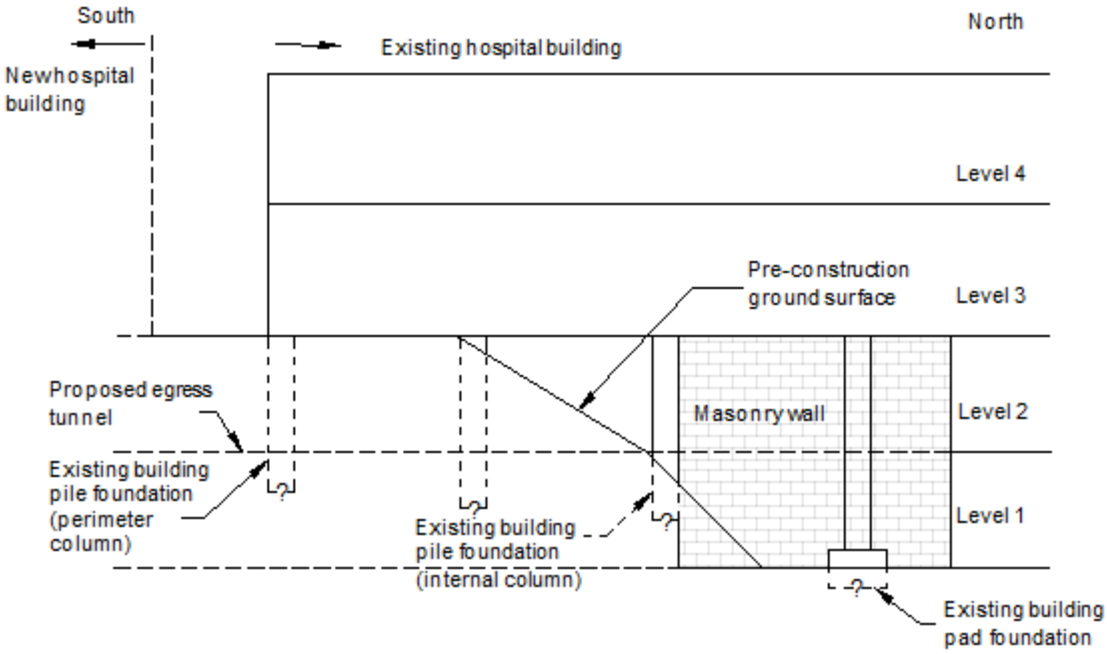

Figure 2. Long section of the egress tunnel prior to excavation and underpinning works

2.3 Existing site condition

A summary of the subsurface and existing site conditions at the egress tunnel site is presented in Figure 3.

Directly beneath the existing hospital Level 3 slab, there are existing live services hung from the slab. These services required to be serviceable during the construction of the egress tunnel to avoid disruption of the hospital daily operations.

There is also an existing masonry wall along the west end of the egress tunnel within the footprint of the egress tunnel. Next to the wall, there was a batter at an angle of approximately 30 degrees above horizontal, sloping upwards away from the wall. The batter was excavated during the construction of the existing hospital to allow for construction of this masonry wall and occupied space on the other side.

There were also existing building foundations immediately adjacent to the footprint of the egress tunnel supporting columns to the floors above. Design drawings of the existing hospital foundations showed that the foundations were unreinforced concrete piles socketed into the ground. The as built founding level of the piles was not provided.

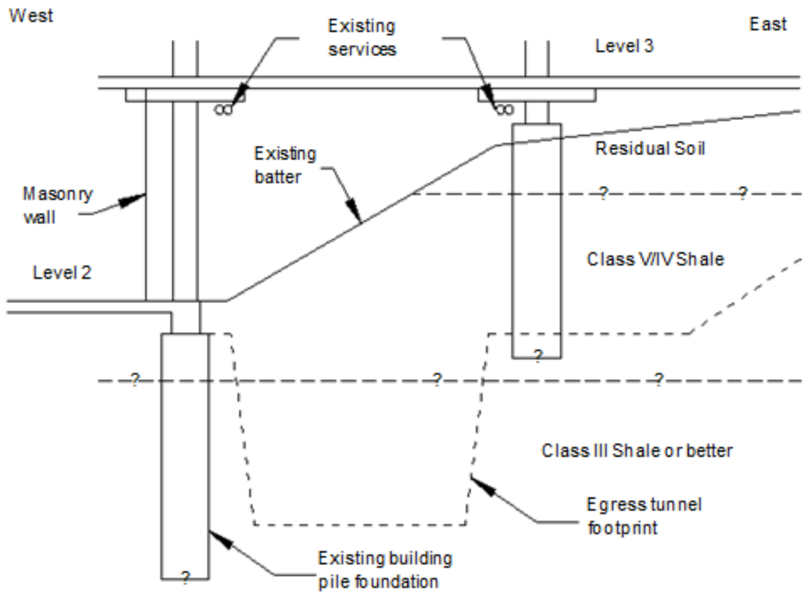

Figure 3. Cross section showing summary of encountered subsurface and existing conditions

3 CONSIDERED CONSTRUCTION AND UNDERPINNING METHODOLOGIES

3.1 Constraints

The design drawings of the existing hospital showed the existing building foundations along east side of the egress tunnel did not extend below the invert of the egress tunnel. The egress tunnel had to be constructed without affecting the columns supported by these. This may have required the columns to be underpinned to below the egress tunnel invert because:

- Rock was not strong enough to support the loads from the columns on a ledge.
- Unknown existing pile depth.
- Existing foundations are unreinforced and therefore could not handle the stress caused by the excavation of the egress tunnel.

Three different construction and underpinning methodologies were considered for the construction of the egress tunnel and are described briefly in the following section.

3.2 Temporary shoring option

The temporary shoring method involved transferring load from the existing column using a horizontal steel beam and vertical props. It was proposed that a steel beam would be placed below the drop-down of the column at the bottom of the Level 3 slab, extending from one column's drop-down to the next column's drop-down across the width of the egress tunnel. The shoring props would be located at each end of the beam as support to keep the beam in place. The construction of the underpinning would commence once the temporary shoring was in place. The temporary shoring would be removed after completion of the permanent underpinning works involving extension of the columns.

This option was eliminated due to the spatial constraints of the site. Approximately 6 m long beams would have been required to extend from one column to the other. The builder considered it would be a challenging task to place the beam at the intended locations due to the tight site access. This method was also excluded due to the availability of suitable shoring props in the market that were at least 4 m long and can withstand the high existing column loads.

3.3 Top down excavation option

The top down excavation method involved excavation of the egress tunnel without any underpinning works. The construction would have involved a 1.5 m deep and 2.2 m wide vertical excavation stage to allow for installation of the support which included anchors, strip drains and shotcrete prior to installation of the egress tunnel wall in front of the vertical face. The 1.5 m x 2.2 m excavation was proposed due to uncertainty of the existing pile depth which might be affected due to the excavation of the egress tunnel and rock defects that might be encountered on the vertical face. Excavation for the next stage could only have proceeded once support installation for each stage was completed.

Whilst this method did not require underpinning as the existing piles would not have been exposed, it was deemed not to be feasible due to constructability of the excavation support. It would have required a repetitive process of excavation and installation of excavation support, increasing the construction time of the egress tunnel beyond that which was permitted in the tight programme.

3.4 Two heading excavation option

The two heading excavation approach involves excavation in two headings, a top heading and a lower heading. The top heading was excavated to the top of the Level 2 slab and the lower heading was excavated to the invert of the egress tunnel. The excavation of a top heading provided adequate access for underpinning works of the two internal columns and demolition of the two perimeter columns prior to excavation of the lower heading. At the same time the pile toes are kept below the base of the top heading. The lower heading excavation proceeded following the completion of the underpinning works.

This method was selected as it provides the best access beneath the existing hospital building and an efficient and practical design for the underpinning works. More importantly, the construction could be undertaken without compromising the integrity of the existing hospital building foundations and eliminated the potential risks caused by the site constraints.

4 TWO HEADING EXCAVATION METHOD

4.1 Construction sequence details

The construction sequence was carefully defined as it formed a critical part of the design. The egress tunnel was excavated from the southern end of existing hospital towards the Level 1 and Level 2 wall at the northern end. This sequence tied in well with the construction program which had allowed for excavation at the south of the existing hospital building for the new hospital building prior to excavation of the egress tunnel.

The construction sequence for the upper and lower headings is presented as a series of cross sections in Figure 4. The upper heading was excavated in 2.2 m advances to the Level 2 slab level. The 2.2 m advances allowed for careful excavation around the existing perimeter columns in order to inspect the location of the pile toes and allowed for an alternative design should the subsurface conditions differ and internal pile toe depths be higher than expected. The perimeter column pile toes were exposed within the upper heading excavation. The perimeter column loads were transferred temporarily to the adjacent shoring wall piles which were constructed for the new hospital building prior to further excavation of the upper heading. The load transfer was designed by the project's structural consultants. After the load transfer for each perimeter column was completed, the excavation progressed to complete the first 2.2 m advance. The east and west faces were excavated at 1.5H:1V batters. The underpinning works for the internal columns were then undertaken before commencement of the lower heading.

The lower heading was excavated to the invert of the egress tunnel. The excavation was undertaken in 6 m advances to allow for installation of face support prior to further excavation. The east and west faces of the excavation were excavated at 0.5H:1V batter permanently supported by anchors, strip drains, mesh and shotcrete prior to excavation of the next advance. The new perimeter columns were then constructed to complete the underpinning works. The loads which were temporarily transferred to the shoring wall piles were transferred into the new columns.

4.2 Underpinning design

4.2.1 Internal column underpinning

The construction sequence of the internal column underpinning is presented in Figure 4. The underpinning of each internal column involved construction of four new piles, two blade walls and a rigid headstock. At each internal column, four new piles, two at each side of the column were drilled and poured from the completed upper heading excavation level to 0.5 m below the tunnel invert using a low head height piling rig. The piles were 0.5 m in diameter and 4.2 m long. Similar to the perimeter column design, the internal column piles were designed in accordance with AS3600. The two blade walls, one at each side of the column were constructed to the bottom of the headstock. The blade walls were 0.5 m long, 1.8 m wide and 3.2 m high. The headstock (2.9 m long x 1.8 m wide x 1.3m high) was then constructed to the existing column drop-down. Non-shrink grout was applied between the headstock and drop-down to provide uniform contact for load distribution from the column above to the headstock. The existing services within the headstock were protected with 50 mm compressible lagging. The exposed existing column face within the headstock was scabbled to ensure good surface contact between the existing concrete and new concrete.

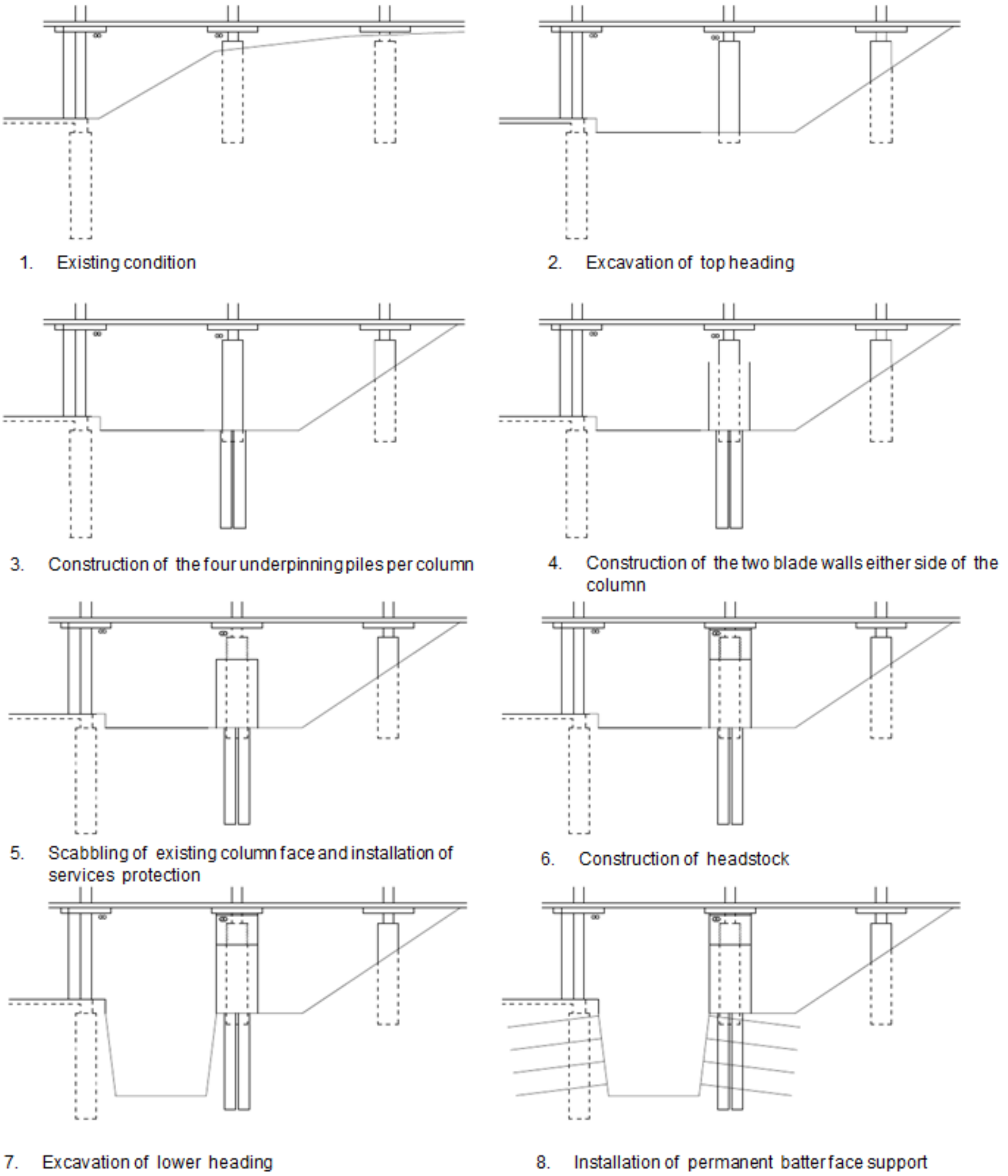

Figure 4. Lower heading, upper heading and internal columns construction sequence

4.2.2 Perimeter column underpinning

Figure 5 presents the construction sequence of the perimeter column underpinning. The perimeter column underpinning design involved demolition of existing columns and construction of new longer columns. The underpinning design adopted for the internal columns (as described in Section 4.2.2) could not be utilised for the perimeter columns due to its location which would have resulted in the underpinning columns being within the tunnel envelope. Therefore, demolition and reconstruction of the existing perimeter columns was the approach adopted.

Each new perimeter column was constructed from base of the Level 3 existing edge beam to the invert of the egress tunnel. The columns were 0.75 m in diameter and 8.2 m long, socketed 0.5 m below the tunnel invert level. The columns were designed in accordance with Section 10 – Design of Columns for Strength and Serviceability of the AS3600-2009 Concrete Structures standard. Chemical anchors and non-shrink grout were used at the contact between the existing edge beam and the newly constructed column to provide a durable connection between the two structural elements. Once the new perimeter concrete gained adequate strength, the loads were removed from the shoring wall piles and introduced to the new columns.

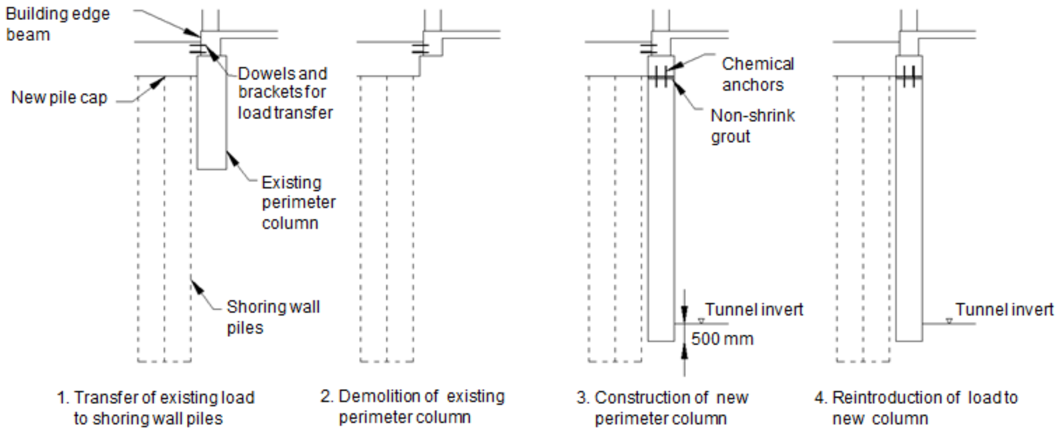

Figure 5. Northsouth cross section of perimeter columns construction sequence

5 CONCLUSION

The construction and underpinning design adopted for the egress tunnel demonstrate an innovative, practical and effective solution for a spatial constraint site. The construction of the egress tunnel was completed successfully without any impacts or disruption to the ongoing operation of the existing hospital.

(a) *(b)*

Figure 6. (a) The excavated egress tunnel looking north; and (b) a completed headstock and pair blade walls

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