GEOTECHNICAL INVESTIGATION OF DECLINE SHAFT PORTALS

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The location of a decline shaft portal can have far reaching implications if the geotechnical conditions are not suited for safe and cost effective excavation. Ideally the portal should be positioned in an area where the excavation requires minimal support and the portal can be formed in reasonably competent rock. In many cases, however, the shaft is linked to an underground mining plan and the shaft may have to pass through poor ground conditions. Determining the optimal position at which tunnelling can commence i.e. the portal, is critical and requires a thorough geotechnical investigation.

Methods used to acquire information for the assessment of the ground conditions are discussed in this paper. Selection of the appropriate methods is dependent on the anticipated ground conditions, the phase of investigation and restrictions due to site access and budget. Non-invasive techniques are often used during preliminary phases and invasive techniques for the detailed investigation. The methods used during each phase of investigation are discussed.

Two case studies are then presented to provide examples of the investigative methods used in two different environments. The first being a flat featureless site with thick soils and deeply weathered bedrock, while the second is a mountainous site with differentially weathered rocky outcrops. Based on these cases, it is clear that an understanding of the geology and geomorphology of the site is vital to the final geotechnical assessment.

Key words: Decline shaft, boxcut, geology, geomorphology, geotechnical, portal.

1.0 INTRODUCTION

In many cases, rather than selecting a position which is best suited to start tunnelling, the location of a shaft is dependant on an underground mining plan. When projected back to surface, the ground conditions may not be ideal for tunnelling. Excavation of a boxcut through the upper soils and weathered bedrock provides access to a point or portal, where tunnelling may commence safely. Determining the correct portal position is important for project costing purposes and requires thorough geotechnical investigation. A typical geotechnical investigation would be carried out in two phases, namely a preliminary and detailed investigation.
2.0 OBJECTIVES

The objective of a geotechnical investigation is to provide an indication of the ground conditions prior to design and construction. The preliminary investigation aims to provide an overview of the subsurface conditions across a large area at a relatively low cost and short period of time. An estimation of depth to bedrock, extent of weathering and basic soil characteristics is obtained during this phase of investigation. If any parameters are found to be unsuitable for the construction of the shaft i.e. extremely thick soils, or bedrock with very poor rock mass quality, then an alternative area can be investigated in a relatively short space of time and at a relatively low cost.

Once a suitable area has been located, or if the shaft position is locked to an underground position and cannot be moved, a detailed investigation is required to provide additional parameters regarding soil properties, rock mass quality and the structural, or geological regime of the site. These parameters are used for final design of the shaft, including determination of the portal position, boxcut depth, sidewall angles and shaft support requirements.

3.0 METHODS

A number of investigative methods are available, the selection of which may depend on a number of factors. These include the budget, geological and geomorphological setting, accessibility on site and the phase of investigation.

3.1 Preliminary Investigation

The methods used in a preliminary investigation generally include a desk study, site inspection, non-invasive techniques and at times, invasive techniques. A desk study provides an initial overview of the site in terms of the geological and geomorphological setting. Data may be obtained from sources either published (e.g. literature and maps) or unpublished (e.g. old exploration borehole logs and previous geotechnical reports). As part of the desk study, Google Earth provides a preliminary overview in terms of topographical and structural geological setting (Figure 1).

![Figure 1](image_url)

Figure 1. An overview of the site topography and structural geological setting of a site using Google Earth.
An inspection of the site helps to confirm interpretations made during the desk study. Observations of the site topography and accessibility will be useful when planning the next phase of investigation. Mapping of outcrops confirms the geology and together with topographical information, an indication of expected weathering depths may be obtained. Measurement of joint orientations (from outcrops, or from within excising excavations) will provide further indication of the structural regime of the area. For all mining projects, exploration borehole cores should be available. These provide additional information regarding geological and geotechnical setting of the site.

Following on from the site inspection and desk study, further information may be required via either invasive, or non-invasive techniques. Invasive techniques include testpitting, large diameter hole augering and borehole drilling by either percussion or rotary core (Figure 2). These methods provide an indication of soil profile, depth to bedrock, depth of weathering, rock quality and water table depth. Access and space for testing equipment may be limited when the site is built up, or if it is in an ecologically, or archaeologically sensitive area. Invasive techniques are also generally costly and time consuming.

**Figure 2.** Investigative methods: a) testpitting, b) large diameter auger hole drilling, c) inclined rotary core borehole drilling, d) DPSH penetrometer testing.
Non-invasive techniques may be better suited for a preliminary investigation. These generally require less operating space and are relatively quick and cost effective. This is advantageous when the site may be moved and the investigation re-done. Non-invasive techniques include geophysical testing (e.g. seismic, gravity, resistivity, or magnetic) or DPSH testing (dynamic penetration super heavy) (Figure 2). Although invasive by way of physical penetration of the probe into the soil, DPSH testing does not require much surface space to conduct the test and is relatively quick and cost effective. These non-invasive techniques, however, have their limitations. They only provide a general indication of depth to bedrock and structural setting. Select invasive methods may have to be used to assist in acquiring the basic information required to conclude the preliminary phase of investigation.

3.2 Detailed Investigation

In order to obtain as much information as possible regarding the soil and rock properties for final design of the shaft portal and boxcut, invasive field testing techniques are required. For soil, a profile of the near surface soils are best obtained via profiling of testpits or auger holes. Laboratory testing of soil samples obtained during this process provides an indication of soil characteristics for design of the boxcut side walls. An indication of whether the excavated material can be re-used in roads or terraces, is also obtained.

If the soils are deeper than the reach limit of an excavator or auger rig, assessment of these soils may be done by rotary core drilling. Although recovery of soils is difficult, relatively undisturbed Shelby samples of soil may be obtained and SPT (standard penetration testing) carried out to provide an indication of soil consistency. Once through the soils, rotary core drilling provides a relatively accurate depth of the soil-bedrock contact, the depth of weathering within the bedrock and rock mass quality. Rock strength can be determined by testing of core samples by either PLI (point load index) or UCS (unconfined compressive strength) testing. Logging of the core provides a detailed description of the rock, its weathering and joint conditions. It also includes measurement of core recovery and RQD (rock quality designation). These are all used to calculate the rock mass quality. Two commonly used methods are Barton’s Q (Barton et al 1974), or Bieniawski’s RMR, or rock mass rating (Bieniawski 1989). The calculated values provide a rating of the rock mass quality for tunnelling and enable the selection of support required in the boxcut sidewalls, portal brow, or tunnel hangingwall.

Inclined rotary core drilling may be required when it is suspected that vertical joints have a large bearing on the over all stability of the decline shaft or boxcut excavation. Orientation of the core allows for measurement of joint orientations, which when plotted on to a stereonet (Figure 3) provides an indication of the predominant joint sets. From this, potential sidewall and hanging wall failures can be identified and the boxcut design modified to allow for safer sidewall angles and, or sufficient support.

If ground water is suspected to be present, piezometers should be installed into the boreholes. This will confirm the presence of a ground water table and whether it will have an affect on stability. Lugeon (or packer) testing at regular depth intervals during core drilling will assist in determining the degree of rock fracturing and openness of joints. If an aquifer is suspected to be present, pump-out testing of a larger diameter
percussion borehole will help in estimating the anticipated volume of water which may enter the shaft during construction.

![Figure 3. A stereonet plot of the joint orientations and main joint sets.](image)

### 4.0 CAST STUDIES

#### 4.1 Nchwaning Manganese Mine

Situated north of Kuruman in the Northern Cape Province, Nchwaning Mine lies well within the semi arid Kalahari. The ore body is approximately 500m below surface and requires shaft access. A decline shaft was constructed to provide vehicular access and conveying of ore to surface. The shaft went through a number of problematic horizons, including 20m of collapsible aeolian sands, 30m of variably calcretised sands and gravels and 30m of highly expansive clay. This was then followed by up to 80m of weathered shale. All together over 800m of challenging ground conditions were encountered along the shaft.

Since the area is covered the Kalahari sands, the landscape is flat and featureless with no outcrops to map. Preliminary investigation included review of old exploration borehole logs and creation of a geological section (Figure 4). With this interpretation of the subsurface horizons, percussion boreholes were drilled and DPSH tests carried out in the proposed boxcut area. This provided an indication of the sand consistency and confirmed the depth at which calcretization was competent enough for tunnelling to start.
Figure 4. A geological long section of the Nchwaning decline shaft.
Detailed investigation included the drilling of rotary core boreholes through the upper sediments into the weathered shales. Analysis of the core samples allowed for the determination of the rock mass quality. Pump out testing of the aquifer above the clay unit provided an indication of the amount of water to be encountered during tunnelling. Monitoring of the piezometers installed within the boreholes showed that the local water table had been drawn down while the tunnel passed though and that there were no immediate concerns regarding further water ingress.

4.2 Der Brochen Platinum Project

Unlike the topography of the Kalahari, Der Brochen Project is located in a mountainous area south of Steelpoort in Mpumalanga (Figure 5). The project area hosts two main platinum bearing reefs, the Merensky and UG2 reefs. Both span 25km on strike and 8km on dip. Underground access would be from either sides of a mountainous ridge. Three adits and a gathering haulage were required to provide horizontal access to an underground network from the one side of the ridge (Figure 5) and two decline shafts from the other side.

![Figure 5](image)

Figure 5. The mountainous terrain of the Der Brochen Project near Steelpoort

Since the positions of the adits and shafts were fixed to an underground plan and were required to enter on reef, the aim of the investigation was to determine portal positions where tunnelling could commence safely and where the boxcut size was minimal. Preliminary investigations included the study of published literature and geological maps. Review of exploration boreholes, detailed geological, structural and topographical maps provided an initial indication of the expected ground conditions. Geological and joint mapping provided a preliminary indication of portal positions.

Drilling of vertical rotary core boreholes was required within the preliminary phase to confirm the depths of weathering and the likely portal position. It was found that the pyroxenitic Merensky reef, which lies within more competent anorthositic and noritic
units, is preferentially weathered. Where the mountain slope is less steep, weathering was found to be more pervasive. Based on these findings, some of the adits were moved to reduce the size of the boxcut. The detailed investigation included inclined and orientated core drilling to further define the rock mass quality for boxcut side slope design and initial tunnelling support requirements.

5.0 CONCLUSION

A number of methods are available for the investigation of decline shaft portals. Although using of all of them would provide an impressive assessment of the ground conditions, a number of aspects restrict their use. These include budget, surface and sub-surface conditions and restrictions. A typical geotechnical investigation for a decline shaft would be carried out in two phases. A preliminary investigation would determine the ideal location of the shaft, while the detailed investigation would provide information required for final design and construction. Although the above case studies provide examples of sites which are in different environments, the ground conditions at one site cannot be assumed to be similar even though the shafts might be a few metres apart on the same reef outcrop. In addition to the need for a comprehensive geotechnical investigation for each shaft location, an understanding of the geology and geomorphology of the site is vital to the final geotechnical assessment.

References
