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A case study on the investigation and mitigation of dolomite area In Graskop, South Africa

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ABSTRACT: Infrastructure development on dolomitic land continues to be a challenging endeavour in South Africa. This is because the area underlain by dolomite is associated with the formation of sinkholes and subsidences. Currently, about five million South Africans reside or work on dolomitic land. Graskop, a small town in Mpumalanga province, is one of the areas in South Africa which has part of its land underlain by dolomite. In this study, a sinkhole mitigation design for a seven hundred and twenty square meters section of R532 road, between Sabie and Graskop, approximately six kilometres west of the central business district of Graskop is presented. A remedial design that comprised of drilling, blasting, and compacting was recommended based on a detailed geotechnical investigation conducted on-site. The investigation included a desktop study and dolomite stability investigation as per the South African National Standards (SANS) 1936: 2012 parts 1 to 4 Development on Dolomitic Land.

RÉSUMÉ : Le développement des infrastructures sur les terres dolomitiques continue de présenter un défi en Afrique du Sud. En effet, la zone sous-jacente à la dolomite est fortement associée à la formation de gouffres et de subventions. Actuellement, environ cinq millions de Sud-Africains résident ou travaillent sur des terres dolomitiques. Graskop, une petite ville de la province de Mpumalanga, est l'une des régions d'Afrique du Sud où une partie de ses terres repose sur de la dolomite, par conséquent des dolomies. Dans cette étude, une conception d'atténuation de puits pour une section de sept cent vingt mètres carrés de la route R532, entre Sabie et Graskop, à environ six kilomètres à l'ouest du quartier central des affaires de Graskop est présentée. La conception corrective qui comprenait le forage, le dynamitage et le compactage était basée sur une enquête géotechnique détaillée menée sur place. L'enquête comprenait une étude de bureau et une enquête sur la stabilité de la dolomite conformément aux normes nationales sud-africaines (SANS) 1936 : 2012 parties 1 à 4 Développement sur les terres dolomitiques.

KEYWORDS: Dolomite, sinkhole; rehabilitation method.

1 INTRODUCTION

1.1 General

A sinkhole, according to SANS 1936: 2012 parts 1 (South African National Standards (SANS), 2012a), is a feature that occurs suddenly and manifests itself as a hole in the ground. Generally, sinkholes can occur naturally over time but are aggravated in built-up areas. This is often due to leakage and/or ingress of water, stormwater, or wastewater into the subsurface. Also, dewatering of the groundwater table through farming or water pumping can cause the formation of sinkholes. But either naturally or as a result of the development, without a proper risk mitigation measures, sinkhole formation can result in loss of life and damage of infrastructure.

1.2 Study location

The section of road that was investigated is approximately 100 m long and is situated along the R532 (P9/1), which is approximately 23.4 km north of Sabie and 6km west of Graskop within Thaba Chweu local municipality in Mpumalanga Province. The affected road is located within portion 29 of farm Graskop 564 KT at approximate centre coordinates of 24°56'25.97" south and 30°48'45.97" east. The site location is shown in Figure 1.



Figure 1: Site Locality Map (Google Earth, 2020)

2 METHOD OF INVESTIGATION

The dolomite stability investigation was conducted according to the nationally recognized standards for acceptable engineering practice, "SANS 1936: 2012 parts 1 to 4 Development on Dolomitic Land" developed by the South African Bureau of Standards (SABS). Therefore, the investigation comprised of a desktop study, gravity survey, rotary percussion drilling, Electrical resistivity imaging (ERI) survey and rotary core drilling.

2.1 Desktop study

This section involved the review of existing regional, site and surface information. In this investigation, the sources of information consulted included the topographical and geological maps for the area and seismic hazard maps for South Africa.

2.2 Gravity survey

A gravity survey, according to Zonge International, (2021), is a non-destructive in-situ method of measuring the density of subsurface materials. In this study, a total of 64 gravity stations were measured using a single Scintrex CG5 instrument with gravimetric stations set out on a 5m grid. A local gravity base station was established on-site to allow for base station readings to be taken regularly at approximately one-hour interval.

The results obtained from the gravity survey was used to produce a relative Bouguer map, which was used to determine the suitable positions for the boreholes that were to be drilled across the site.

2.3 Rotary percussion drilling

Rotary percussion drilling is a non-coring drilling method used to drill through soft to hard rocks such as limestone, chalk, or mudstone (Kumar and Kumar, 2016). In this drilling system, the rock chips are lifted to the surface during drilling permitting their examination (Kumar and Kumar, 2016). During the investigation, six percussion boreholes were advanced from ground level using a Thor percussion drilling rig with a 165 mm

diameter down the hole hammer operated with a 19 bar, 27.6 m³/min compressor. The boreholes were terminated upon proving six meters depth of competent rock or based on the driller's discretion (SANS 1936: 2012, part 2).

2.4 Rotary core drilling

Rotary core drilling was carried out to ensure a detailed understanding of the subsurface conditions. The rotary core is a drilling method used for obtaining representative core samples of subsurface material.

A YWE D90 drill rig was used to drill two rotary cored boreholes on-site using a NWD4 double tube core barrel with an inner split tube for recovery of 52 mm diameter soil and rock samples. During the drilling, Standard Penetration Test (SPT) tests were carried out to determine the consistency of the subsurface material. Additionally, laboratory testing was conducted on representative core material recovered from the drilling.

2.5 Electrical resistivity imaging survey

Electrical Resistivity Imaging (ERI) is a non-destructive in-situ method for subsurface investigations. A 64-channel electrical resistivity meter capable of 250-Watt power at a variable peak voltage of 600 volts and 2.5 was utilized in this investigation. A total of three (No. 3) traverses were completed with positioning of the traverses limited to the edge and a single lane of the R532.

This survey was carried out to establish the contact between dolomite and other materials beneath the site after drilling and the gravity survey showed high variability in the quality of subsurface material.

3 RESULTS OF THE INVESTIGATION

3.1 Desktop study

A review of the 1:250 000 geological series map, 2430 PILGRAM'S REST, shown in Figure 2 as well as observations made during the site investigation, it is evident that the site is underlain by Malmani. Most of the economic gold mineralisation of the Sabie-Pilgrim's Rest goldfields is hosted within the dolomite and dolomitic residuum of the Malaman Subgroup (Vmd) belonging to Chuniespoort group within the Transvaal Supergroup. This blue/grey, hard rock dolomite generally contains zones or lenses of very hard, grey chert.

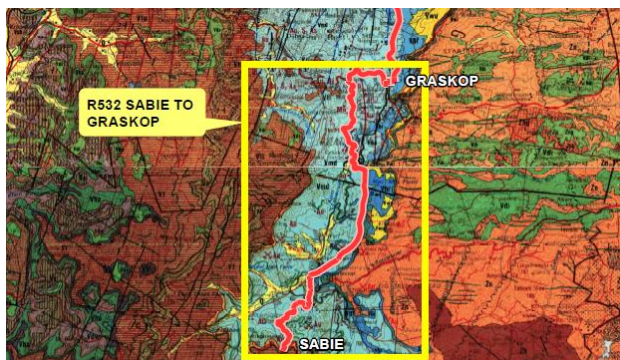


Figure 2: An extraction of a 1:250 000 geological series map, 2430 PILGRAM'S REST (Council For Geoscience in Pretoria, 2019)

3.2 Gravity survey

In Figure 3, the gravity survey results are shown. The results revealed that the site is characterized by a gravity high along the north and south-eastern portions of the site, indicating shallow bedrock. Conversely, the central and the southwestern portions

of the site are characterized by a gravity low to gravity gradient, and this may suggest zones of possible deep bedrock.

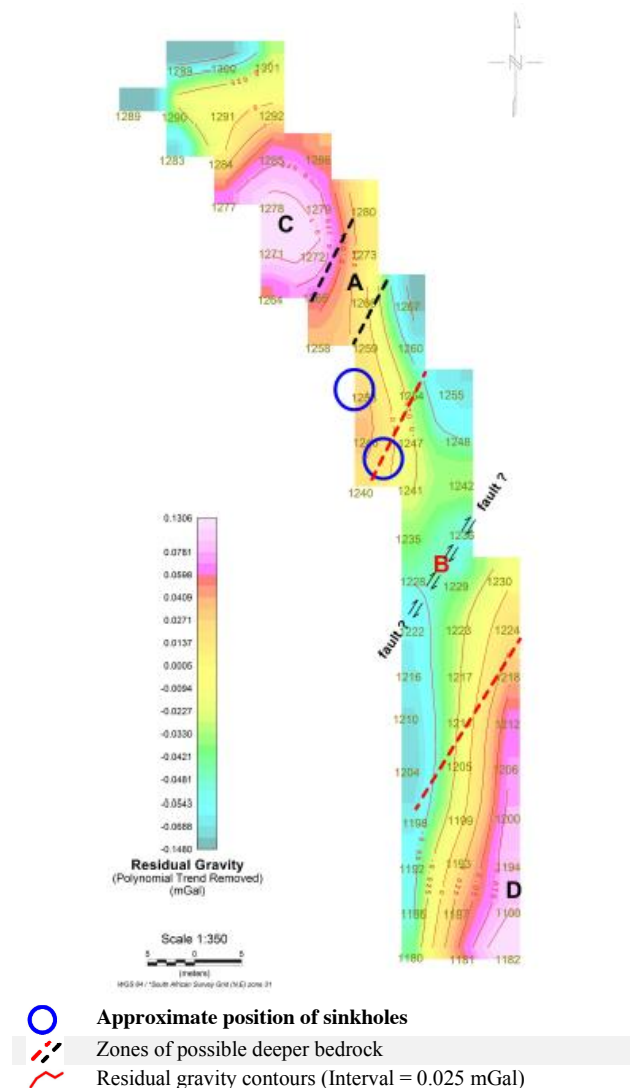


Figure 3: Gravity Survey Results

3.3 Rotary Percussion and Core Drilling

The drilling confirmed that the site is underlain by dolomite and dolomitic residuum of the Malaman Subgroup (Vmd) belonging to Chuniespoort group within the Transvaal Supergroup. Furthermore, the borehole drilling revealed that the site is underlain by cavities between the depth of 1m and 27m below the ground level. The presence of cavities was indicated by zero penetration rate, total air, and sample loss during drilling.

3.4 Electrical resistivity imaging survey

Figure 4 presents a 3D view of the ERI results incorporated with the gravity and borehole surface layers. The ERI results shows a good correlation with the interpretation completed for the gravity data.

The resistivity profile between GBH02 and GBH04 shows a decrease in resistivity well below the resistivity values measured for interpreted basement (dolomite) material. This indicates that this region forms part of a possible fault zone.

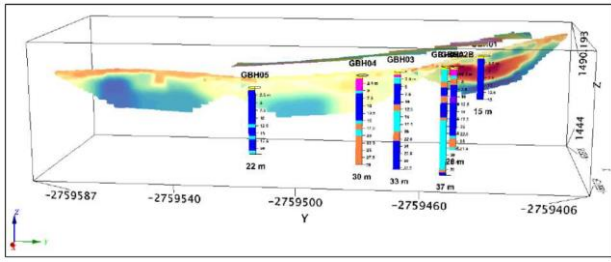


Figure 4: ERI results incorporated with gravity and borehole surface layers.

3.5 Groundwater

Groundwater strikes were not observed in any of the boreholes drilled on-site; therefore, it was assumed that groundwater would be located within the dolomite bedrock at depths greater than those investigated.

4 LAND USAGE AND HAZARD CLASSIFICATION

Based on the results of the investigation, the land usage for the site was classified as IN1 and the area falls under D4 (additional site-specific precautionary measures are required) in terms of dolomite area designations as per SANS 1936: 2012 part 2 (South African National Standards (SANS), 2012a). Furthermore, the site was allocated two (2) Dolomite Stability Zones:

- **Zone A:** IHC5//1 which is classified as reflecting a high inherent susceptibility for the formation of small size sinkholes and subsidence with respect to ingress of water and a low susceptibility for the formation of all size sinkholes and subsidence with respect to water level drawdown.
- **Zone B:** IHC 7/8//1 which is classified as reflecting a high inherent susceptibility for the formation of large to very large sinkholes and subsidence with respect to ingress of water and a low susceptibility for the formation of all size sinkholes and subsidence with respect to water level drawdown.

5 MITIGATION DESIGN

5.1 General

It was recommended that the section of the investigated road be closed as the precautionary measures for IHC 7/8//1 cannot normally achieve a tolerable hazard rating and are considered as uneconomical or impractical.

In the event that the road is to be re-opened, the following SANS 1936-1 site-specific measures shall be implemented on land designated as D4:

- Site characterization, analysis and design, specification of precautionary measures, supervision of implementation and formulation of a dolomite risk management plan shall be undertaken by a Competence Level 4 geo-professional.
- The foundation design, design of the culverts, precautionary measures and dolomite risk management plan shall specifically address and effectively mitigate the dolomite risk present on the site.
- All aspects of the development proposal shall be reviewed and approved by the local authority, who may request a further review by an authority-designated Competence Level 4 peer, if required.

Sinkhole rehabilitation works, should be conducted in accordance with the requirements of South African National

Standards (SANS), (2012), and the measures shall apply both to the road and to the surrounding areas. Upon completion of the rehabilitation works, the site should be landscaped to facilitate proper drainage and to avoid the ponding of surface water along the road section. The upgrade of the stormwater drainage and monitoring along the road should also be conducted.

5.2 Rehabilitation

The accepted practice requires sinkholes to be rehabilitated according to the inverted filter method using dynamic compaction (DC). The inverted filter method is designed to prevent future mobilisation of the backfilled material. The use of DC backfilling ensures that people are not exposed to further collapse of the sinkhole during backfilling and compaction. This method does not require persons to enter the hole. Figure 5 illustrates the rehabilitation recommended

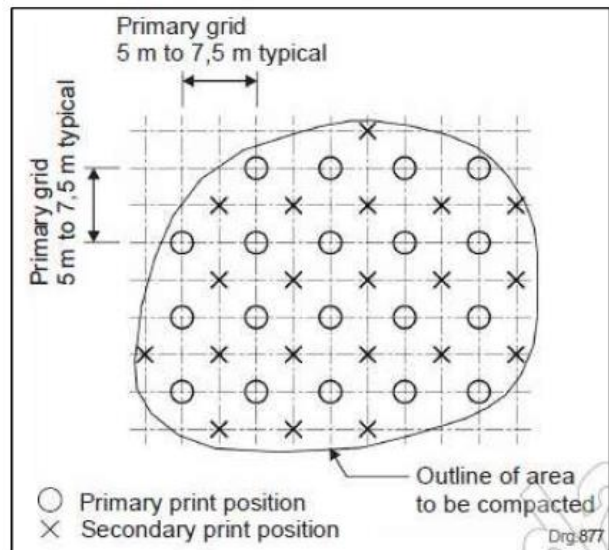


Figure 5: Typical layout of a dynamic compaction grid.

Prior to the dynamic compaction, 15 m holes will be drilled on site to pre-collapse the overburden material using confined blasting. Furthermore, the embankment to the South West of the site shall be cut to an angle of 60 degrees to further stabilise it. The material recovered from the blast and the cut shall be used to backfill the site.

Dynamic compaction will be undertaken using a mobile crane fitted with a free-fall winch and braking system and with a single line pull adequate to handle the specified pounders. The crane shall remain stable when the pounder is accidentally dropped into a cavity.

Compaction shall be undertaken by repeatedly dropping a flat-bottomed or ball-type pounder (tamper) on an area. Assuming that a 14-tonne pounder will be dropped through a height of approximately 20 m on a 7x7 m grid for primary compaction, and a 7x7 m grid shifted 2.5 m diagonally, for secondary compaction, followed by ironing blows.

The depth of penetration using dynamic compaction can be predicted using the equation proposed by Ménard and Broise, (1975):

$$y = 0.5\sqrt{wH} \quad (1)$$

With a pounder weight of 14 tonnes, and a 20 m drop height, the equation predicts penetration to 8.4 m. The crater formed during compaction at each print position shall be backfilled with G8 or better material in accordance with TRH14 as compaction progresses.

5.3 Additional investigation

An Environmental Impact Assessment is recommended prior to any construction. The geohydrological study should address the general groundwater conditions.

5.4 Risk management plan

Surface drainage on site occurs towards the south west and west. It is important to avoid concentrated water ingress into the ground at all times, during and after the rehabilitation. All the stormwater trenching be treated as indicated SANS 1936: 2012.

A detailed site-specific Dolomite Risk Management Strategy (DRMS) should be developed by the professional team according to SANS 1936-4: 2012, to mitigate the hazard associated with the developments on such land. Ground water monitoring should form an essential part of this DRMS, and dewatering should be prohibited in this area.

6 GENERAL

All the boreholes were backfilled in accordance with the SANS1936 - 2 to prevent the hole acting as a preferential flow path through which water might enter the profile either from the surface or from perched groundwater.

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