Earth Stewardship Science Research Institute

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Geotechnical Properties and Foundation Requirements of the Lunar Laser Ranger at Matjiesfontein Space Geodesy Observatory

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What is a Lunar Laser Ranger (LLR)?

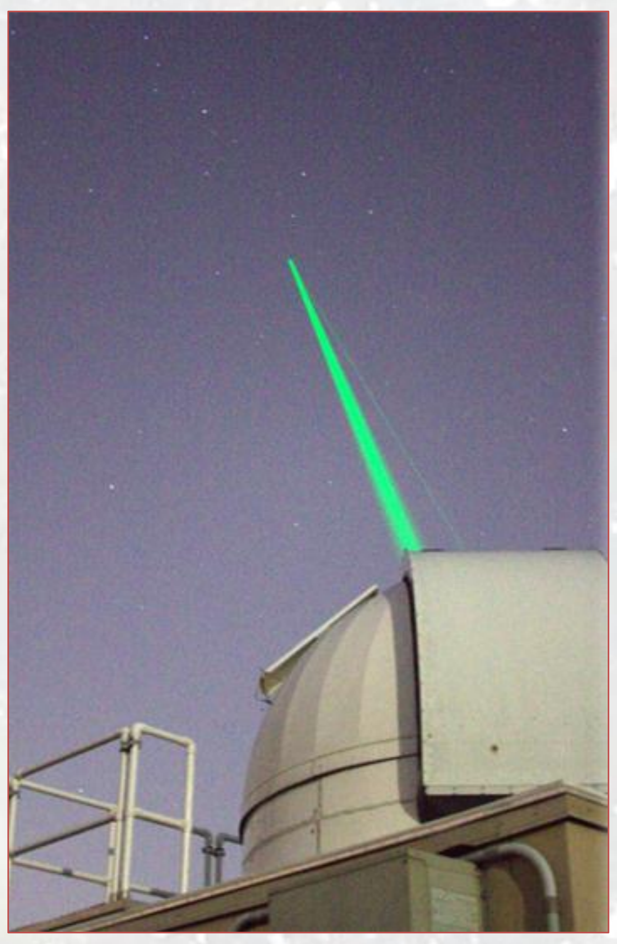
A LLR measures the distance between the Earth and the Moon using a laser. The laser projects to a reflector placed on the moon during the Apollo era. The reflector reflects the light back to the receiver and uses the recorded travel time to calculate the distance.

The LLR needs to be very stable to:

- Point at the exact location on the moon
- Ensure accurate measurements.

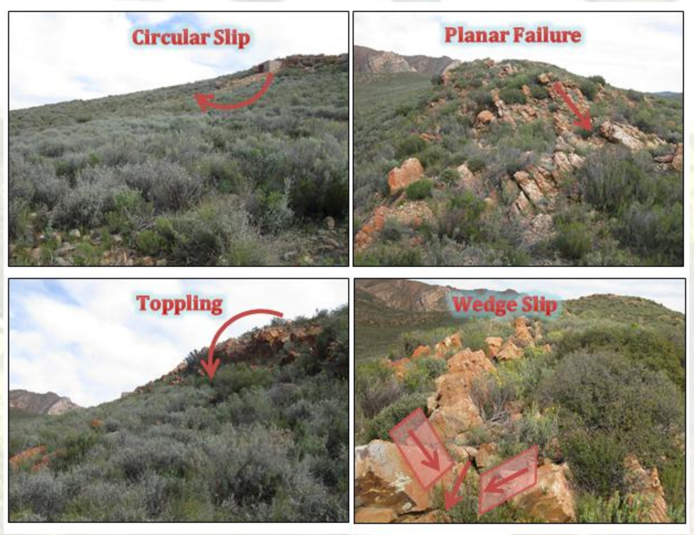
To ensure stability, the following need attention:

- Geotechnical investigations such as slope stability and geology of Matjiesfontein Space Geodesy Observatory (MGO) site,
- Risks during construction



Slope Stability Investigations

To ensure that the ground on which the 7 ton LLR will be built is stable, a complete slope stability analysis needs to be done. The possible failures identified on the site were circular slip, wedge slip, planar failure and toppling. To determine the safety, data were collected in various ways. GPS survey was done to create a 3D model of the site and to analyse circular slip. A joint survey was done in two ways, a Breithaupt compass or an Android application: Rocklogger from RockGecko. This was used to analyse wedge and planar failure.



Rocklogger Application

Breithaupt compass

Various stability analyses have been done at the MGO. It is important to consider all the studies and their results before an investigation at the 'proposed site 2 for LLR' can commence.

Slope stability analyses have been done at the following locations:

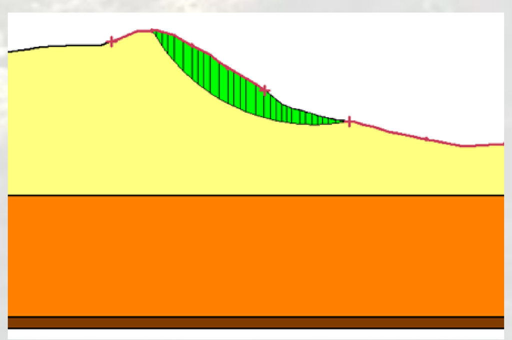
- Gravimeter Vault site,
- Proposed site 1 for LLR,
- Administrative buildings.

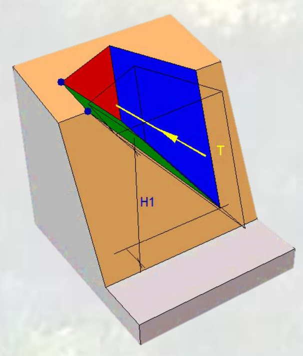
All of these studies have determined that these areas are safe against circular slip, toppling and wedge failure. The only instability that may occur on the site is possible planar failure if an access road with a cut of 2m is to be made on the northern side of the site. The cut will expose the toe of the inclined quartzitic sandstone, which may lead to a failure. As stabilizing this slope would be expensive, together with environmental reasons, it was decided to move the access road to the southern side of the hill.

Critical Factor of Safety (FOS)

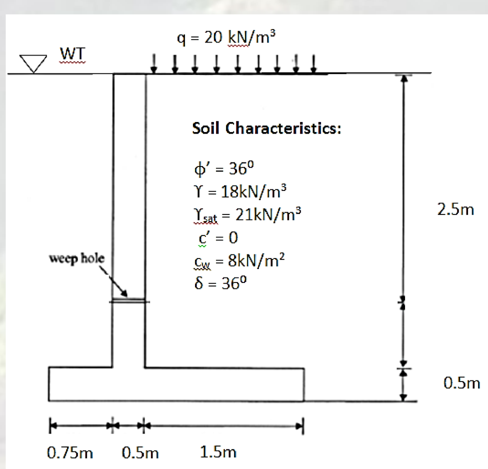
Analysis location	Circular Slip	Safe?	Wedge Slip	Safe?
Gravimeter Vault	1.9	✓	No wedge to form	
Proposed site 1 for LLR	1.3	✓	2.34	✓
Administrative buildings	3.1	✓	N.A.	

Typical analysis of Circular- and Wedge-Failure





A retaining wall was designed for the site where the administrative buildings will be placed to ensure the safety of the building as a cut will be made into the toe of the slope. It was decided that a cantilever retaining wall will be the best solution. After a conservative design approach it was calculated that the FOS against overturning is 2.2 and the FOS against sliding is 1.2. Steel reinforcement for the concrete retaining wall with sufficient anchorage was designed.



Geological Properties

The topography of this site is generally flat, with small hills distributed throughout. Following a geotechnical investigation, the general regolith profile of this area could be described as:

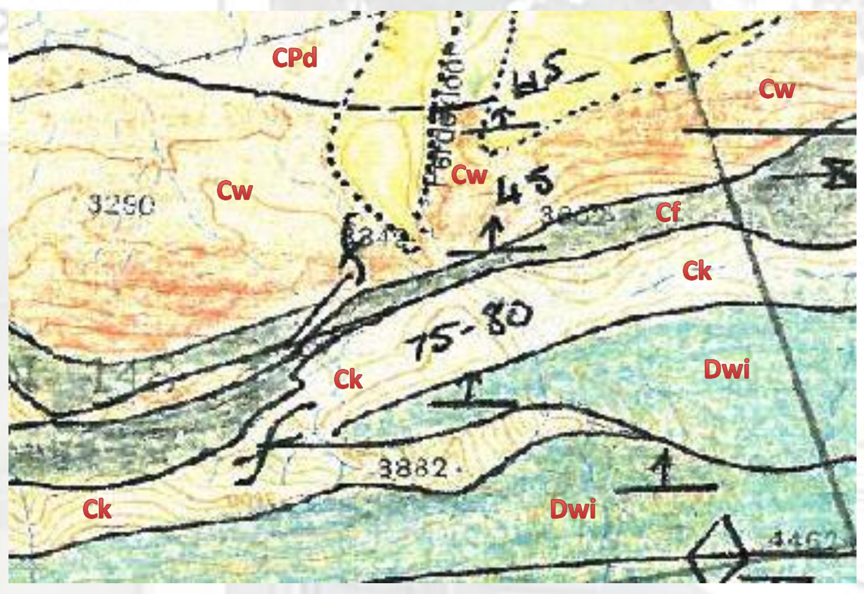
0.2m	Dry, light brown, loose, intact, boulders and gravel in a sandy matrix. Hill wash.
0.5m	Slightly moist, dark reddish-orange, dense, intact, boulders and gravel with limited sandy matrix. Hill wash.
0.6 - 1m	Refusal on highly to moderate weathered thinly bedded shale or mudstone. Bedding planes sub-vertical

The site is on the boundary between the Cape and Karoo Supergroups. Rocks typically found here are:

- Quartzite (Table Mountain Group),
- Sandstone (Table Mountain Group),
- Tillite (Dwyka Formation),
- Shale (Karoo Supergroup).

The geological map shows the formations with:

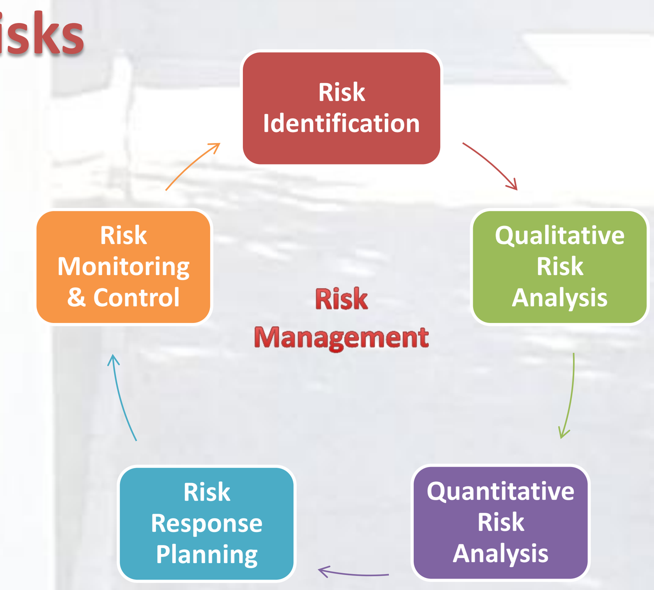
- CPd – Dwyka formation
- Cw – Waaipoort formation
- Cf – Floriskraal formation
- Ck – Kweekvlei formation
- Dwi – Witpoort formation



Construction Risks

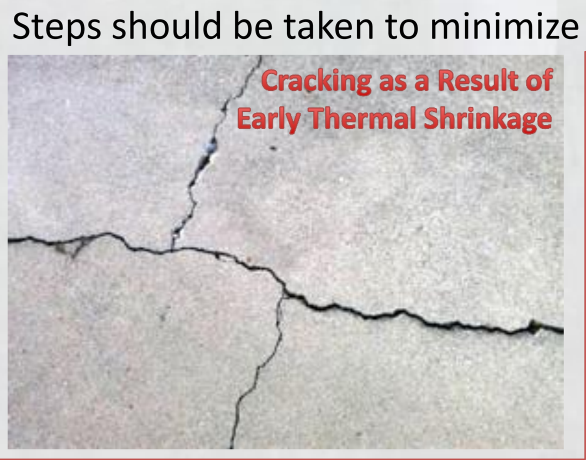
Close attention should be paid to possible risks that may occur during the construction period and they should be managed appropriately. Risks such as:

- Early thermal shrinkage,
- Construction quality,
- Subsurface geological and geotechnical conditions,
- Site access,
- Availability of resources,
- Productivity of labour, labour disputes or strikes,
- Damage to persons or property,
- Security of site.



There are many more risks that may occur, thus a complete risk register should be developed prior to the start of construction operations to ensure smooth operations.

The main concern during construction is early thermal shrinkage. Early thermal shrinkage is an exothermal reaction due to the hydrations of cement. This causes variations of temperature within the concrete, which then leads to cracking. This can influence the geometry and dimensions of the structure and can cause displacement of the LLR, which lowers the accuracy of the measurements. Steps should be taken to minimize the effects of early thermal shrinkage.



Cracking as a Result of Early Thermal Shrinkage

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