APPLICATION OF GROUND BASED LIDAR FOR MONITORING & STABILITY ANALYIS OF DUMP SLOPE IN OPENCAST COAL MINE: A CASE STUDY

By

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Outline:

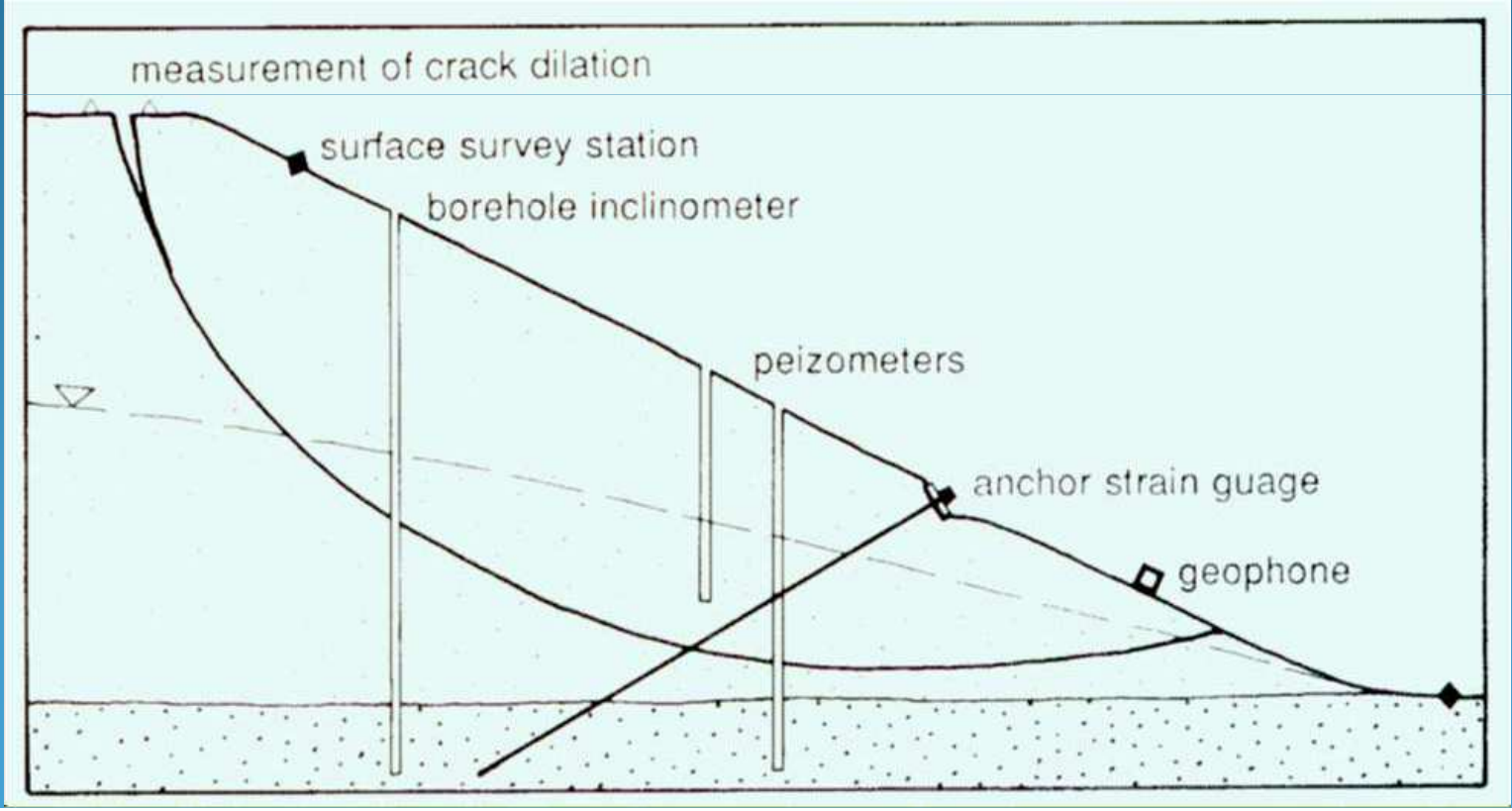
- Introduction
- About study area
- Slope monitoring
- Results & discussions

Introduction

- In surface mining, slope stability and slope monitoring of benches, high wall, spoil heaps are not yet included as integral part of overall pit design. This subject gets importance only when slope failure occurs.
- Slope failure continues to be a source of human & financial loss.
- This study exhibits the geodetic technique of predicting slope deformations on overburden dump at a mechanised open pit (coal).

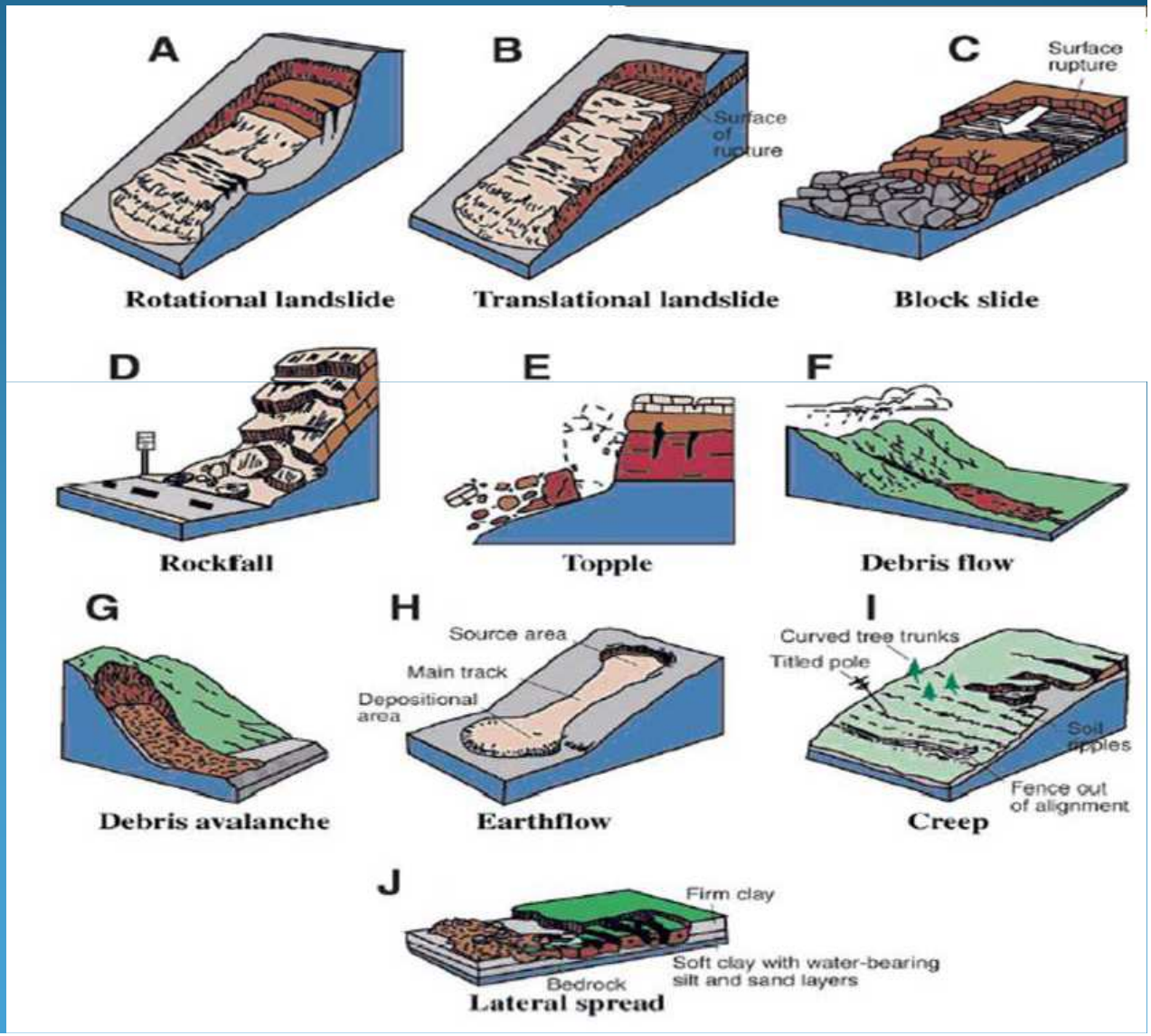
Monitoring of spoil heaps

- Slope monitoring and stability analysis performed at the base and crest portion of the slopes, which exposes the operator to a potential rock fall of blocks above the slopes
- Ground based liDAR, which paves the way for more accurate, rapid and safe rock mass discontinuity measurements



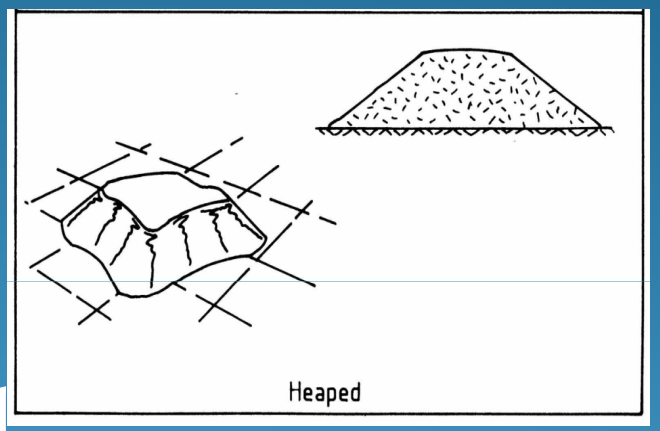
Modes of slope failure

- Failure along pre-determined planes of weakness.
- Failure along lines of maximum stress. i.e. Due to action of frictional and cohesive force in slope, rotational failure occurs & also absence of cohesive force exhibits planar failure.

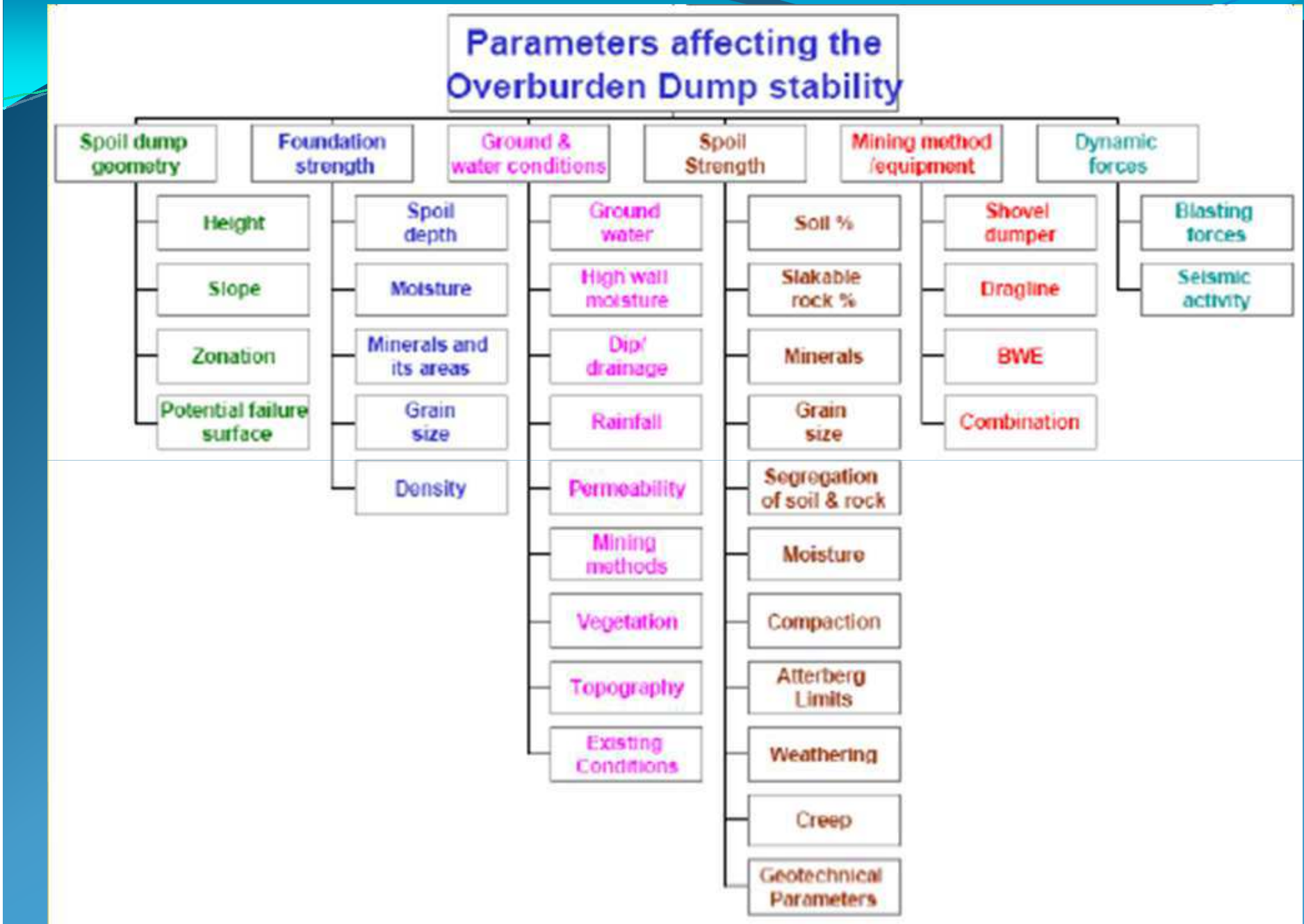


Types of slopes

- Excavated , tipped & natural slopes are the one we generally come across



- Tipped may be of filled spoil heaps/dumps either may be in-pit or out of pit overburden dumps


Parameters affecting the Overburden Dump stability
Spoil dump geometry
Foundation strength
Ground & water conditions
Spoil Strength
Mining method /equipment
Dynamic forces
Height
Slope
Zonation
Potential failure surface
Spoil depth
Moisture
Minerals and its areas
Grain size
Density
Ground water
High wall moisture
Dip/ drainage
Rainfall
Permeability
Mining methods
Vegetation
Topography
Existing Conditions
Soil %
Slakable rock %
Minerals
Grain size
Segregation of soil & rock
Moisture
Compaction
Atterberg Limits
Weathering
Creep
Geotechnical Parameters
Shovel dumper
Dragline
BWE
Combination
Blasting forces
Seismic activity

DGMS Guidelines for Formation of Spoil Banks and Dumps

(1) While removing overburden, the top soil shall be stacked at a separate place, so that, the same is used to cover the reclaimed area.

(2) The slope of a spoil bank shall be determined by the natural angle of repose of the material being deposited, but shall in no case exceed 37.5 degrees from the horizontal. The spoil bank shall not be retained by artificial means at an angle in excess of natural angle of repose or 37.5 degrees whichever is less.

(3) Loose overburden and other such material from opencast workings or other rejects from washeries or from other source shall be dumped in such a manner that there is no possibility of dumped material sliding.

(4) Any spoil bank exceeding 30m in height shall be benched so that no bench exceeds 30m in height and the overall slope shall not exceed 1 vertical to 1.5 horizontal.

(5) The toe of a spoil-bank shall not be extended to any point within 45m of a mine opening, railway or other public works, public road or building or other permanent structure not belonging to the owner.

About study area:

- Study is carried out at OCP-2 mine of SCCl, RG-III area, Ramagundam, Andhra Pradesh.
- Lease area is of 387 hectares. Mine is located between N18° 37' 02" to 18° 40' 42" & E79° 33' 13" to 79° 36' 43", falls in SOI topo sheet no.65N/10.
- Dump design & geometry of Adriyala external overburden truck dump:

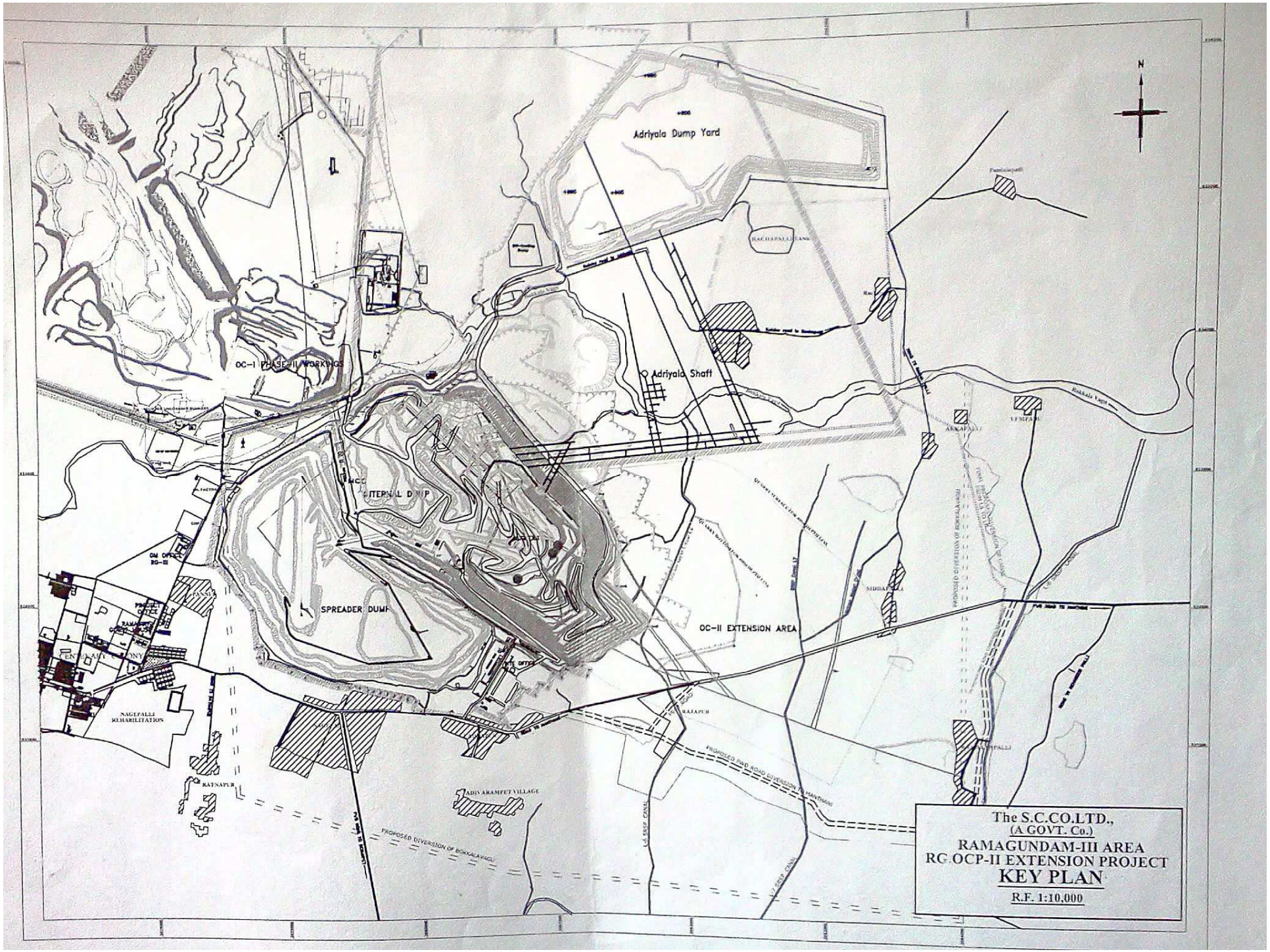
Overall dump height=45m

Maximum low dump height=30m

Maximum high dump height=22.5m

Angle of repose for one lift of 30m height=37°

Adriyala external overburden truck dump area is around 213.53Hectares with approximate volume of 800.74 lakhs bank Cu.m at present.


N
Adriyala Dump Yard
OC-I PHASE-II WORKINGS
Adriyala Shaft
SPREADER DUMP
OC-II EXTENSION AREA
NAGEPALLI REHABILITATION
RATNAPUR
ADIVARAMPET VILLAGE
PROPOSED DIVERSION OF BONKALAYAGU
PROPOSED PWD ROAD DIVERSION ALIGNMENT
The S.C.CO.LTD.,
(A GOVT. Co.)
RAMAGUNDAM-III AREA
RG OCP-II EXTENSION PROJECT
KEY PLAN
R.F. 1:10,000

Slope Monitoring

- Slope monitoring is carried out by terrestrial laser scanner of RIEGL make-Austria, model LMS-Z420i, consists of high performance long range 3-Dimensional scanner, associated operating and processing software RiSCAN PRO, which is calibrated and oriented with a high resolution digital camera.
- **Specifications:**

Range up to 1000m.

Measurement accuracy up to 5mm.

Measurement rate up to 12000 points per second.

Field of view up to 80˚X360˚.

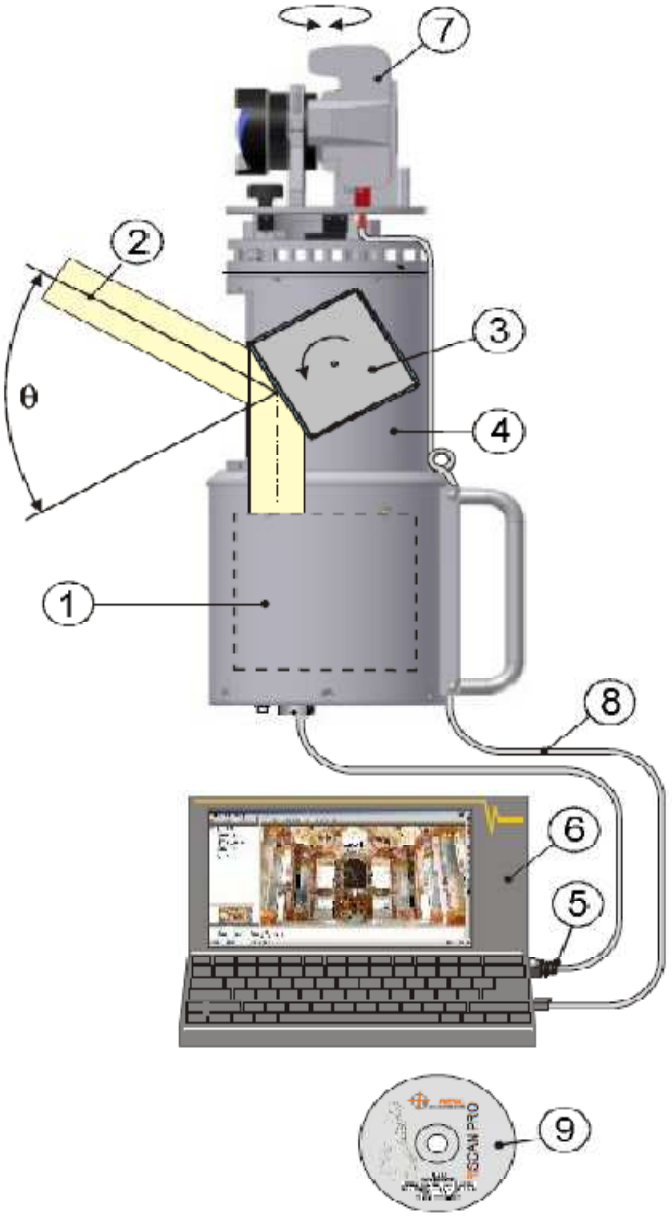
TCP/IP data interface, easily allowing wireless data transmission.

Operated by any standard PC or notebook.

Fully portable, rugged & robust.

10.2 mega pixel, 20mm focal length external mounted camera.

Principle of Scanner Operation



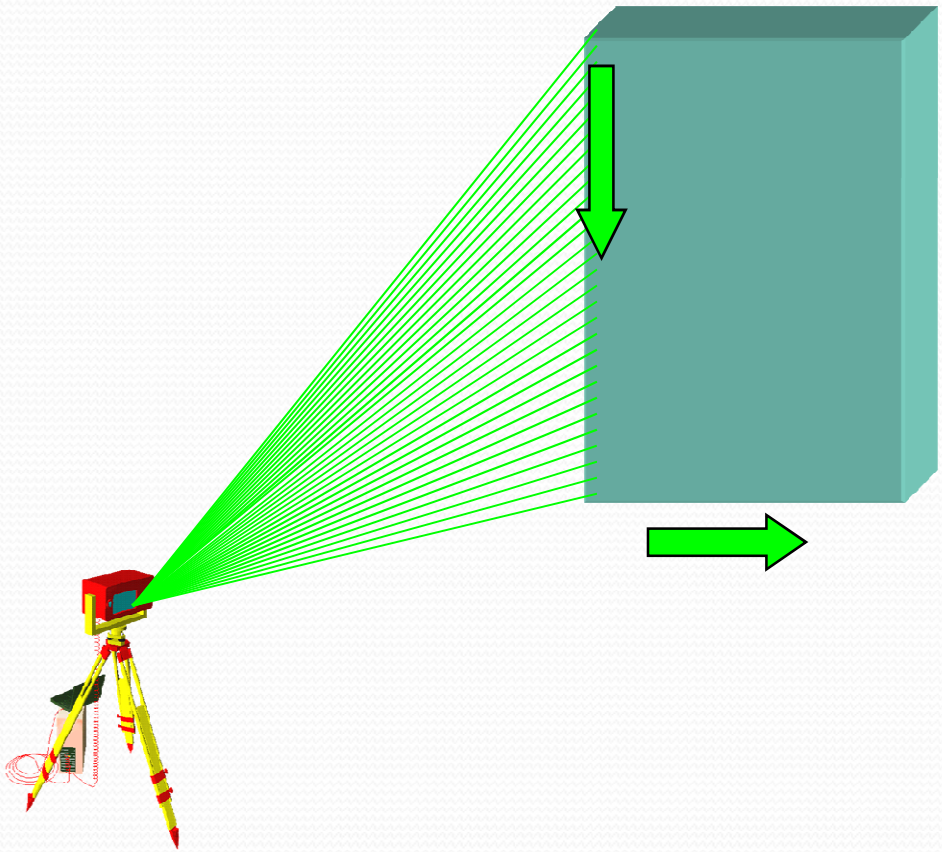
The **range finder electronics (1)** of the 3D scanner *RIEGL* LMS-Z420i is optimized in order to meet the requirements of high speed scanning (fast laser repetition rate, fast signal processing, and high speed data interface).

The *vertical deflection* ("line scan") of the **laser beam (2)** is realized by a **polygon (3)** with a number of reflective surfaces. For high scanning rates and/or a vertical scan angle θ up to 80°, the polygonal mirror rotates continuously at adjustable speed. For slow scanning rates and/or small scanning angles, it is oscillating linearly up and down. The *horizontal scan* ("frame scan") is provided by rotating the complete **optical head (4)** up to 360°.

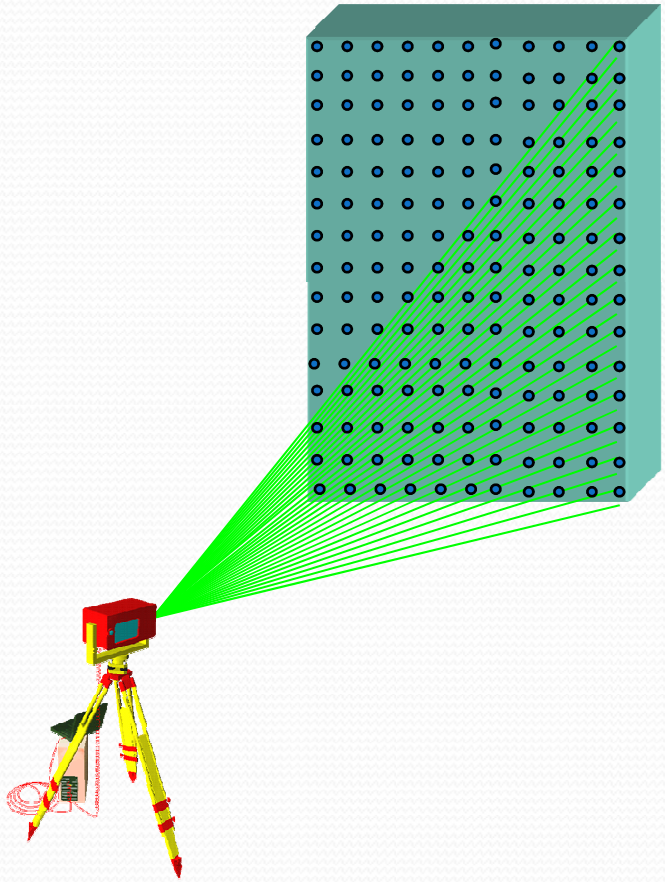
Scandata: RANGE, ANGLE, and SIGNAL AMPLITUDE are transmitted to a **laptop (6)** via **TCP/IP Ethernet Interface (5)**. **Camera (7)** data are fed into the same laptop via **USB/firewire interface (8).**

The RiSCAN PRO software (9) allows the operator to perform a large number of tasks including sensor configuration, data acquisition, data visualization, data manipulation, and data archiving. RiSCAN PRO runs on platforms WINDOWS XP, 2000 SP2, or NT SP4.

Laser sweeps over surface



…..and then for the full surface



Merits:

- It doesn't require the use of prism as commonly used in survey
- Thousand of points are monitored rapidly rather than single prism location
- No need for fixed installation
- The system can be moved into areas of limited access because of its portability
- TLS can be able to access over steeply dipping slopes, critical zones prone to hazards like rock fall, cantilever, sliding slope etc. Areas which are not accessible can be approached by laser scanner such as high wall in benches
- Profile's accuracy is much better in LIDAR than any other instrument. Also TLS will be able to plot the true geometry of the slope.

Limitations

- A 3D laser scanner can't access any sort of vegetative slopes either dead or alive as well as in terrains.
- 3D laser scanner shall not be able to work on high absorption surface such as coal, due to less or zero reflectivity.
- The disadvantages of laser scanning is difficulty in automatic extraction of edges, joints or uneven surfaces and a difficulty in dealing with immeasurable part.
- TLS does have limits like field of view, range etc.

Main functions in LIDAR monitoring

- Data Acquisition
- Data Processing
- Data Analysis

Data acquisition

- The whole field work is carried out by 2 sets of measurements in a length of time span over a slope face. Scan positions may be same or different for each set
- Registration of scanned data and thus image data in a local coordinate system is based on fine scanning of retro-reflectors
- Data acquisition is done by following steps:
  - Reconnaissance Survey.
  - Scanner setup & Tie point's fixation.
  - Project creation in a file and acquisition of scanned data.
  - Selection of Point density.
  - Image acquisition.
  - Coloring of Scans.
  - Fine Scanning of tie points.
  - Fine Scanning of selected area.

Reconnaissance Survey:

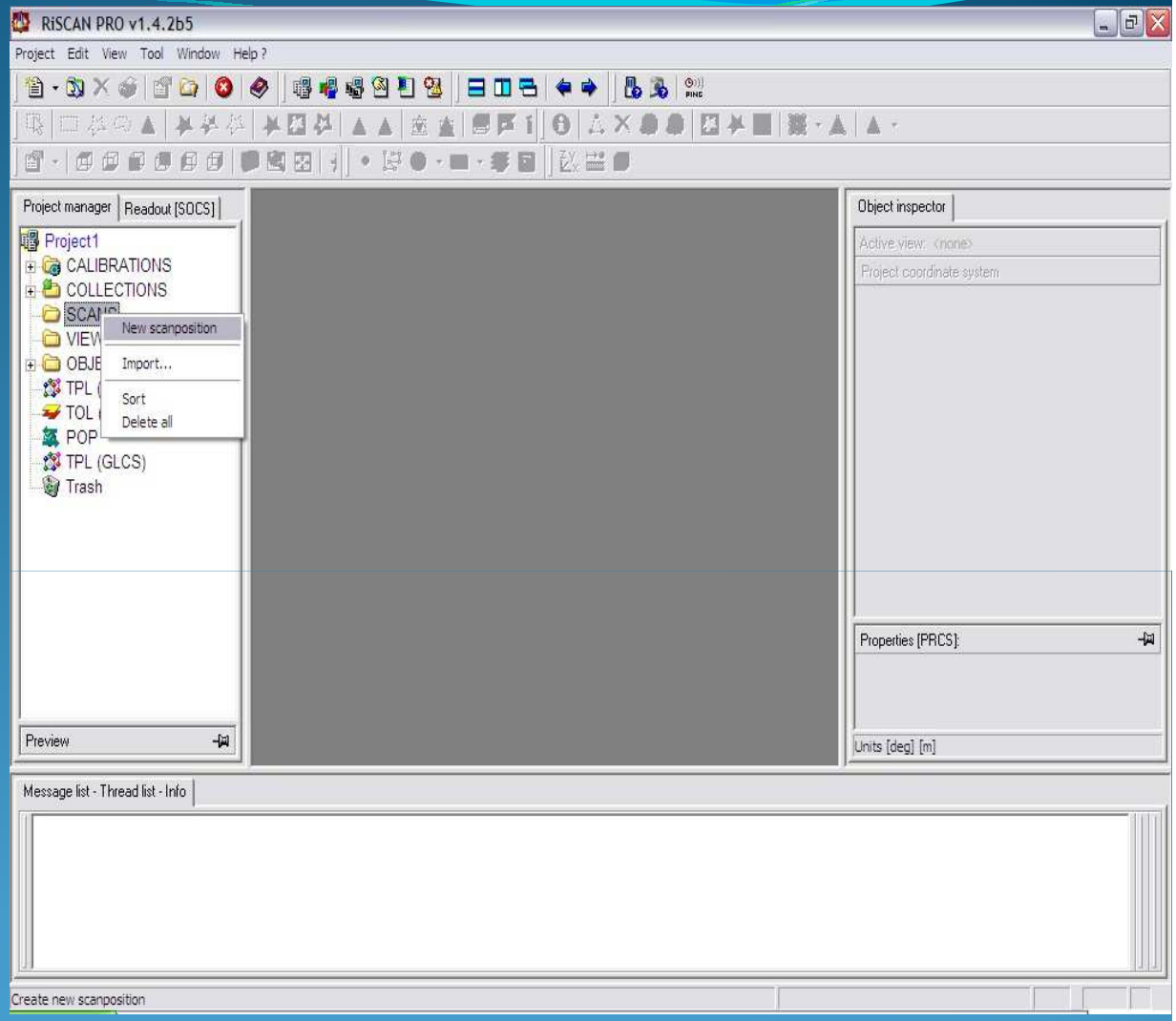
To position the scanner at suitable location, there is a need of area reconnaissance

Scanner setup & Tie point's fixation:

1. Scanner is set on tripod, camera is to be mounted on scanner and connected to the Laptop and external battery.
2. With RiSCAN PRO software, field data would be collected and processed.
3. To orient scanned profile of the dump to desired grid system, tie points are to be fixed with retro-reflectors near and within 50m radius to the scanner, whose coordinates are to be fed in to the process. These tie points are surveyed by total station conducting a precise traverse.
4. Tie points are collected for each scan position/set. These points are then imported and read after fine scan of tie points.

Project creation and acquisition of scanned data:

In RiSCAN PRO software, project created with specific name. Set attributes to the project i.e. I.P addresses of the instrument and camera model's calibration.



Selection of Point density:

Point density can be set varying from 1mm to 5cm. In this case study, point density has been limited to 1cm for a range of 100m from the scanner. For moderate accuracy “Overview Scan with a point density of 3.5cm”. High accuracy “Panorama Scan with a point density of 2.1cm”

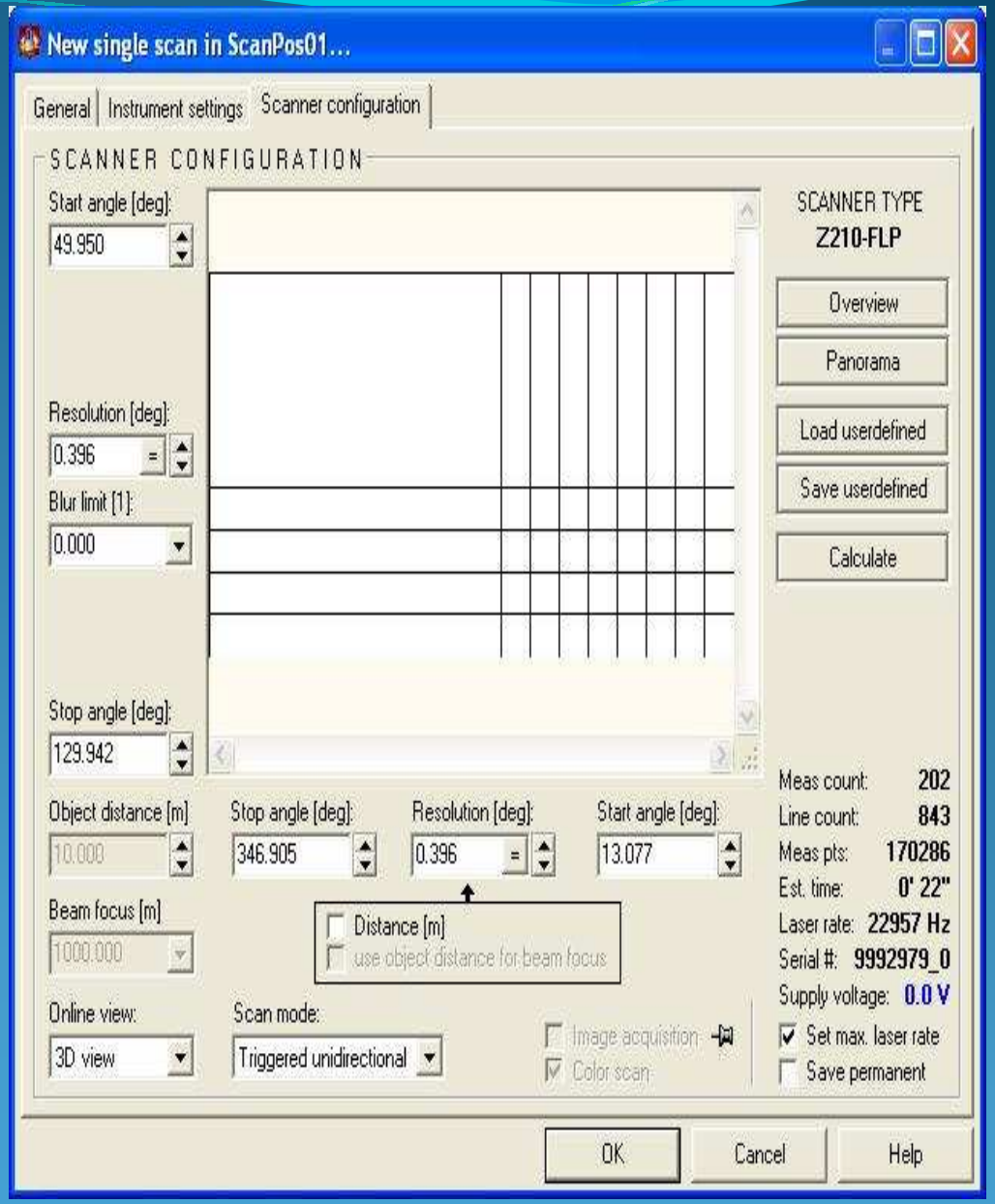
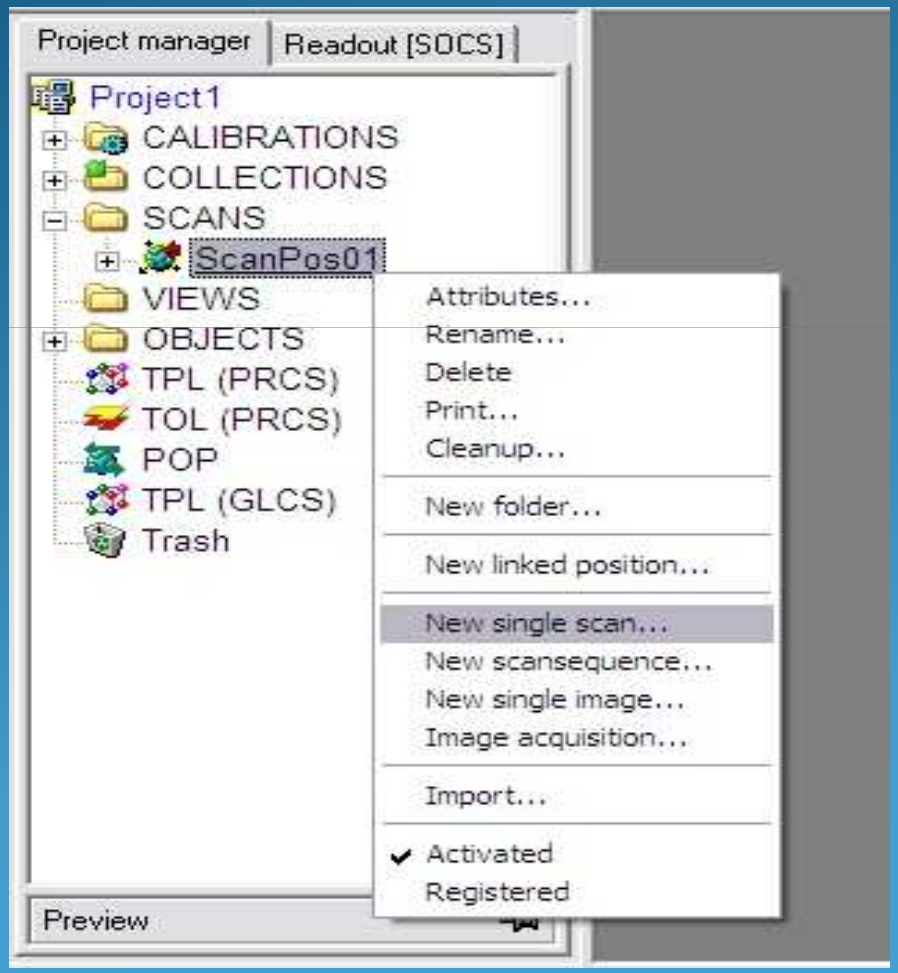
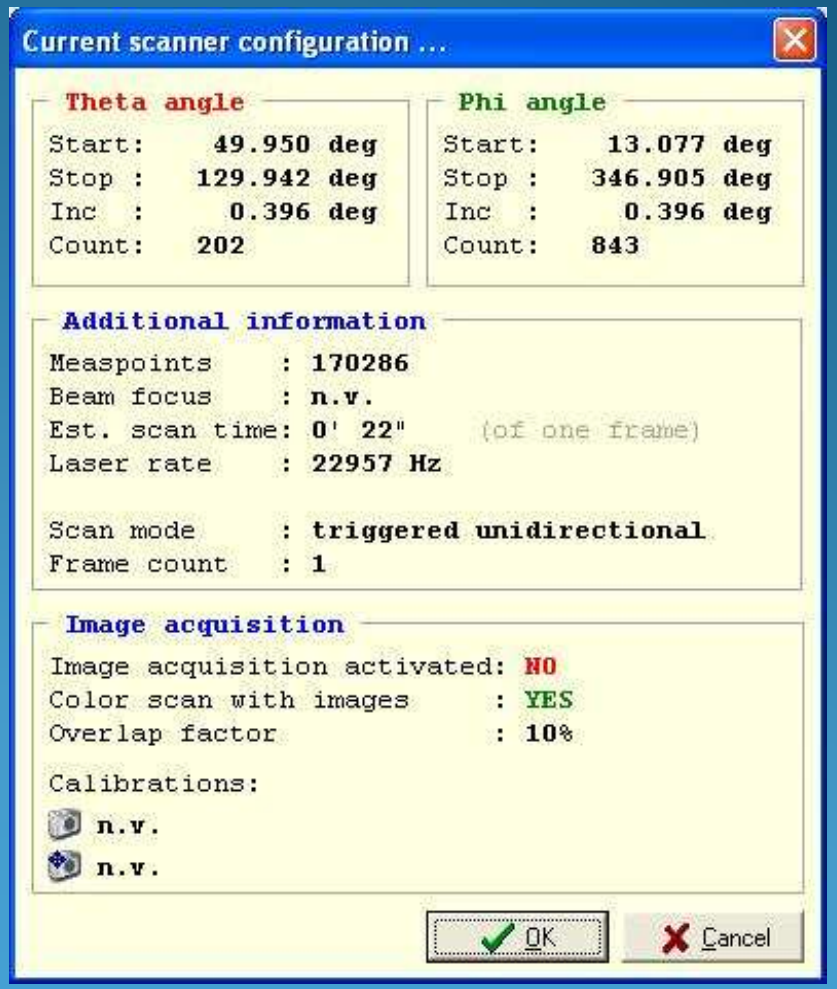


Image acquisition:

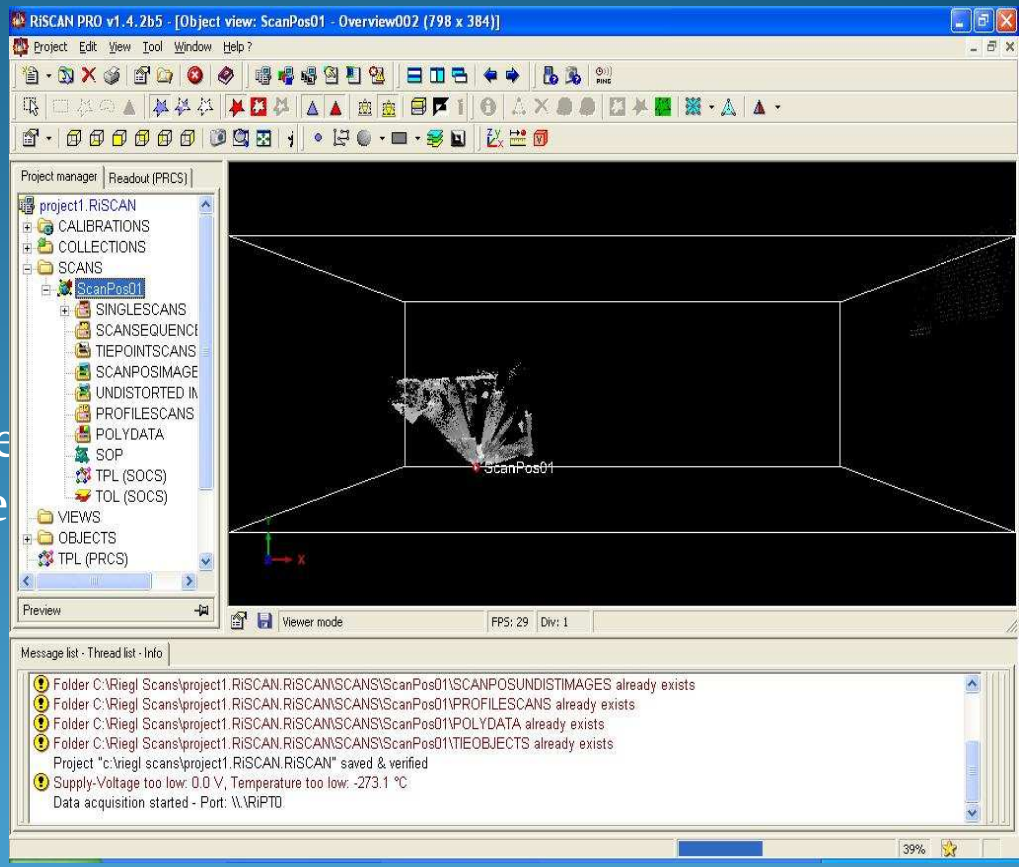
Image acquisition is through Digital Camera, which takes photographs at 360° all around the Scanner





Coloring of Scans:

For better visualization of scanned image, it is required to go for coloring of scanned images by overlapping it with digital image. The colored image would facilitate to locate the tie points and to delete un-wanted objects



Fine Scanning of tie points:

After giving fresh numbering to retro-reflectors/tie points, the same would be fine scanned automatically through the feature available in the software. This would facilitate proper orientation of scanned data to the concerned local coordinate system in further data processing.

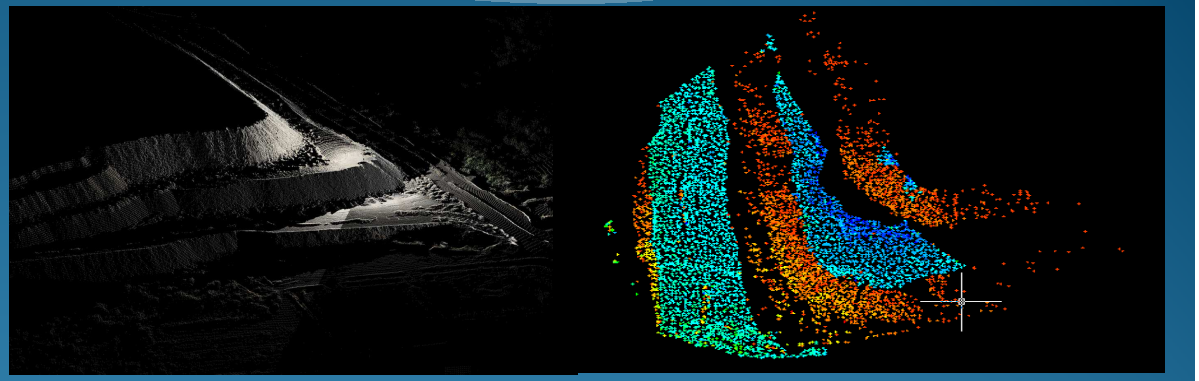
Fine Scanning of selected area:

Specific area of interest would be fine scanned with high point density

Data processing

- **Data registration:**

Different scans will be oriented to the grid system by registering tie points in RiSCAN PRO software. With this all scans will be co-related to user defined coordinate system.



- **Exporting Data:**

To facilitate better processing of data for quantity evaluation in Projects, data will be exported into Cyclone software in ***.3dd** format.

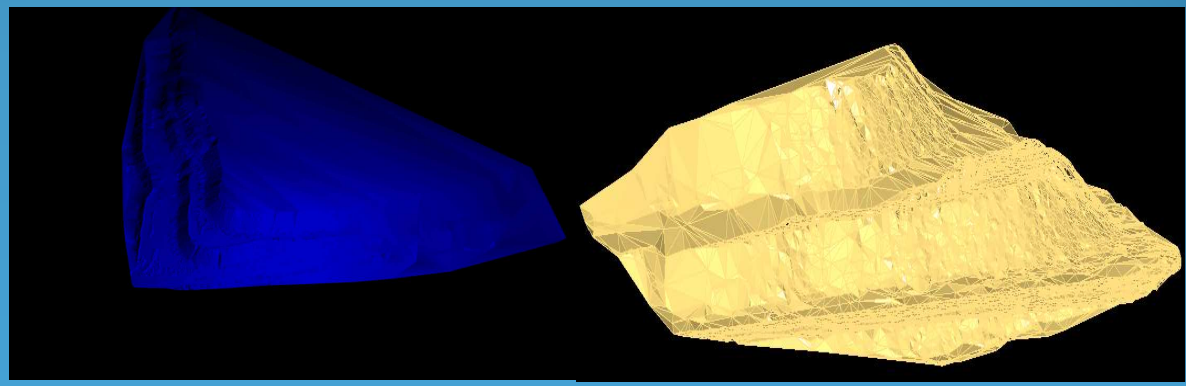
- **Project creation and importing data in "Cyclone":**

A project will be created in cyclone software with specific name and the *.3dd file will be imported in to it.

- **Editing/ Cleaning unwanted objects**
- **Unifying the point cloud:**

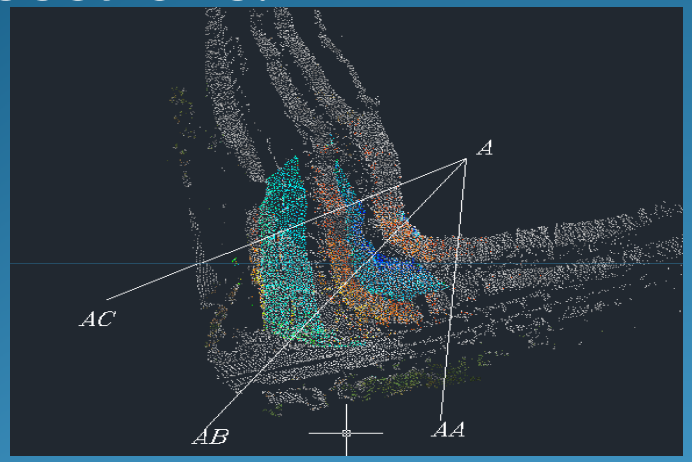
To make individual point cloud as single point cloud, unification will be done. Point density may be reduced, as per the need.

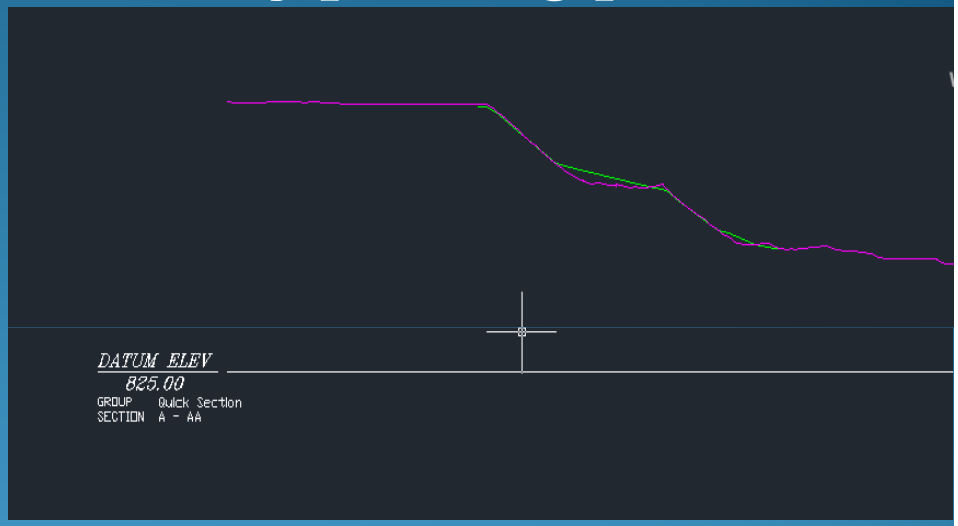
- **TIN (Triangular Irregular Network) Surface creation**

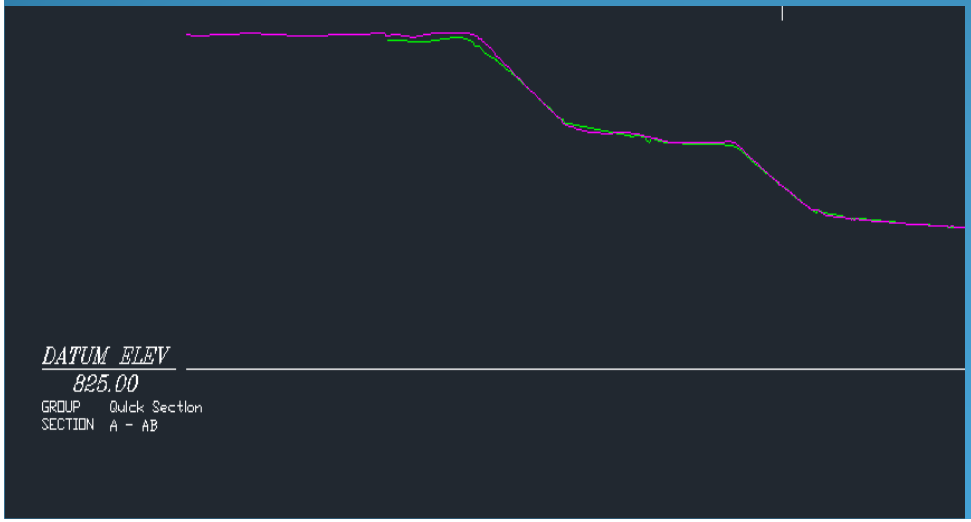


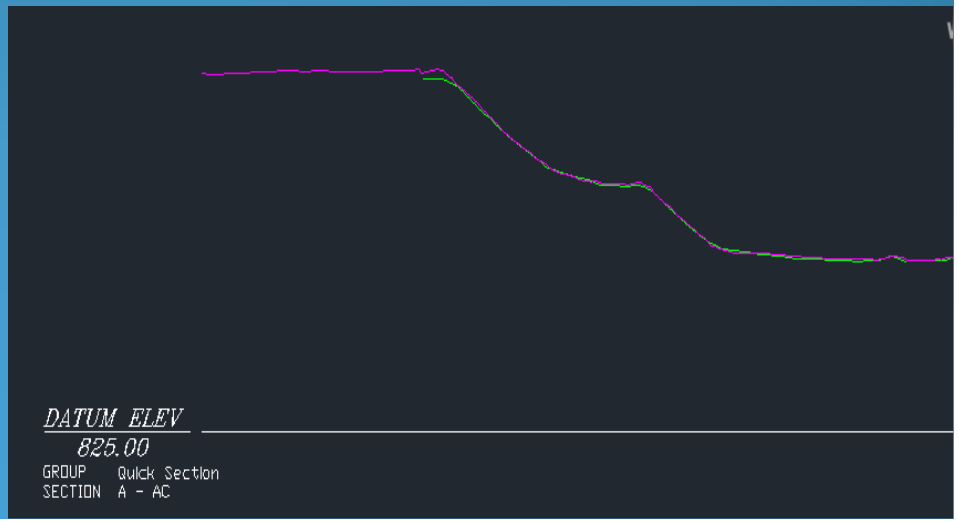
Data Analysis

Using a CAD software, importing the two TIN surface models to a same coordinate system, then analysing the vertical difference between the two by plotting profile & sections.









RESULTS & DISCUSSIONS

- ✓Dump slope is predicted to be stable throughout my study excluding some other factors like erosion, formation of ridges along slopes etc.
- ✓This currently reduces the dump strength by removal of top soil on dump and causes in resulting of tension cracks, which could affect the factor of safety and other parameters in dump slope.
- ✓While scanning, some surfaces may be blocked due to terrain, obstacles and scanning angle. Therefore, no data can be obtained for those. This area has been assumed by interpolation.
- ✓No data areas are also attained due to the selection of two scanning stations which were not set at same location. Therefore, I suggest installation of a fixed base-plate for scanning station
- ✓Drains need to provide at suitable places for better drainage
- ✓Dump floor need to be levelled in regular

Discussions:

- ✓We can also assign LIDAR with a automated scanning principle for data acquisition, analysis and prediction of slope stability, their by improving approach.
- ✓Also conducting trials on excavated slopes would be essential for better prospect.

THANK YOU