CP 302 CAPSTONE PROJECT

DEGRADATION OF ROCK JOINT ROUGHNESS AND ITS QUANTIFICATION

UNDER THE SUPERVISION OF :
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1.INTRODUCTION

This report outlines a study on the degradation and quantification of rock joint roughness, focusing on the application of photogrammetry to real rock samples. Understanding joint roughness is critical for geotechnical engineering and rock mechanics.

The Significance of Rock Joint Roughness

Rock joint roughness is a fundamental parameter influencing the mechanical behavior of rock masses, including shear strength, deformability, and hydraulic conductivity. Its degradation due to weathering, seismic activity, or mechanical loading can significantly impact the stability of rock slopes, tunnels, and foundations. Traditional methods for roughness quantification often involve subjective visual assessment or destructive physical measurements. This study explores advanced, non-contact techniques to provide more accurate and objective assessments.
With progressive shearing, the asperities on joint surfaces degrade, leading to a reduction in joint roughness and consequently affecting shear strength and stiffness.

Quantifying this degradation is crucial for understanding long-term stability and for developing predictive models in rock mechanics. This project focuses on evaluating joint roughness of real rock sample and joint roughness of pop sample that includes before and after shearing, using a combination of photogrammetry techniques, direct shear testing and CAD-assisted sample preparation. The integration of piezoelectric strain sensors enables precise measurement of small strain responses, thereby facilitating accurate estimation of shear stiffness.

2.OBJECTIVES

1. To estimate the joint roughness coefficient on real rock sample by using **photogrammetry technique.**

2. To prepare Plaster of Paris (POP) joint samples that replicate natural rock joint roughness.

3. To allow POP samples to attain constant weight before testing, ensuring stability in mechanical properties.

4. To design roughness profiles using CAD software and imprint them on POP samples for controlled studies.

5. To conduct direct shear tests on the prepared samples and measure the shear stress–displacement response and use piezoelectric strain sensors for detecting micro-strains prior to macroscopic shearing, thereby calculating shear stiffness.

6. To quantify changes in joint roughness before and after direct shear testing.

7. To evaluate the relationship between roughness degradation and shear behavior.

3.METHODOLOGY

1. **Literature review** for understanding and applying photogrammetry technique on real rock sample.
2. **Sample Preparation:**
   - Rock samples (available in the laboratory) are used to characterize natural roughness.
   - POP samples are prepared to replicate joint surfaces and are left to dry until they attained constant weight.
   - CAD software was used to design specific roughness patterns (controlled asperities, sinusoidal/triangular profiles), which are imprinted on POP samples to create artificial roughness.
3. **Roughness Measurement (Pre-shearing):**
   - Photogrammetry technique is employed to capture surface topography.
   - Surface roughness indices are computed from the 3D surface model.

4. Direct Shear Testing:

- Direct shear tests were conducted on POP samples after they attain constant weight.
- Shear stress vs. displacement curves are obtained.

5. Roughness Measurement (Post-shearing):

- Photogrammetry is repeated to capture post-shearing surface degradation.
- The reduction in roughness parameters is quantified.

6. **Data Analysis:**

- Comparison of pre- and post-shear roughness.
- Correlation of roughness degradation with shear stiffness and shear strength reduction.

4.WORK PROGRESS SO FAR

- **Reviewed literature** on joint roughness characterization, photogrammetry techniques, and shear testing.
- Conducted initial trials of **photogrammetry** on available rock samples to become familiar with the method.
- **Developed CAD-based roughness profiles** for artificially imprinted roughness for controlled experiments.

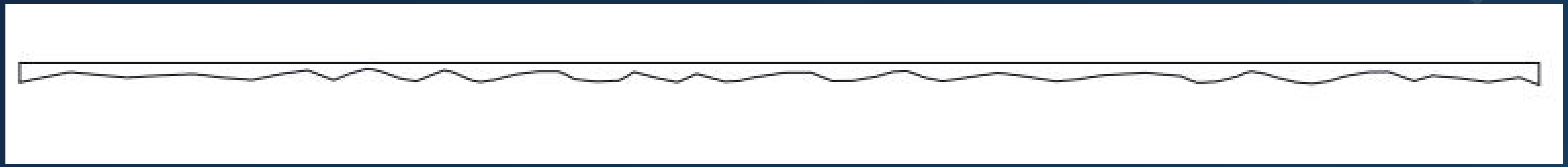
5.FINDINGS/RESULTS

- CAD-designed roughness patterns (controlled asperities, sinusoidal/triangular profiles) are successfully fabricated and will imprint on POP samples to create artificial roughness.

- Here are the two cad-designed roughness profiles for 3d printing.

DOWNWARD ROUGHNESS PROFILE

UPWARD ROUGHNESS PROFILE



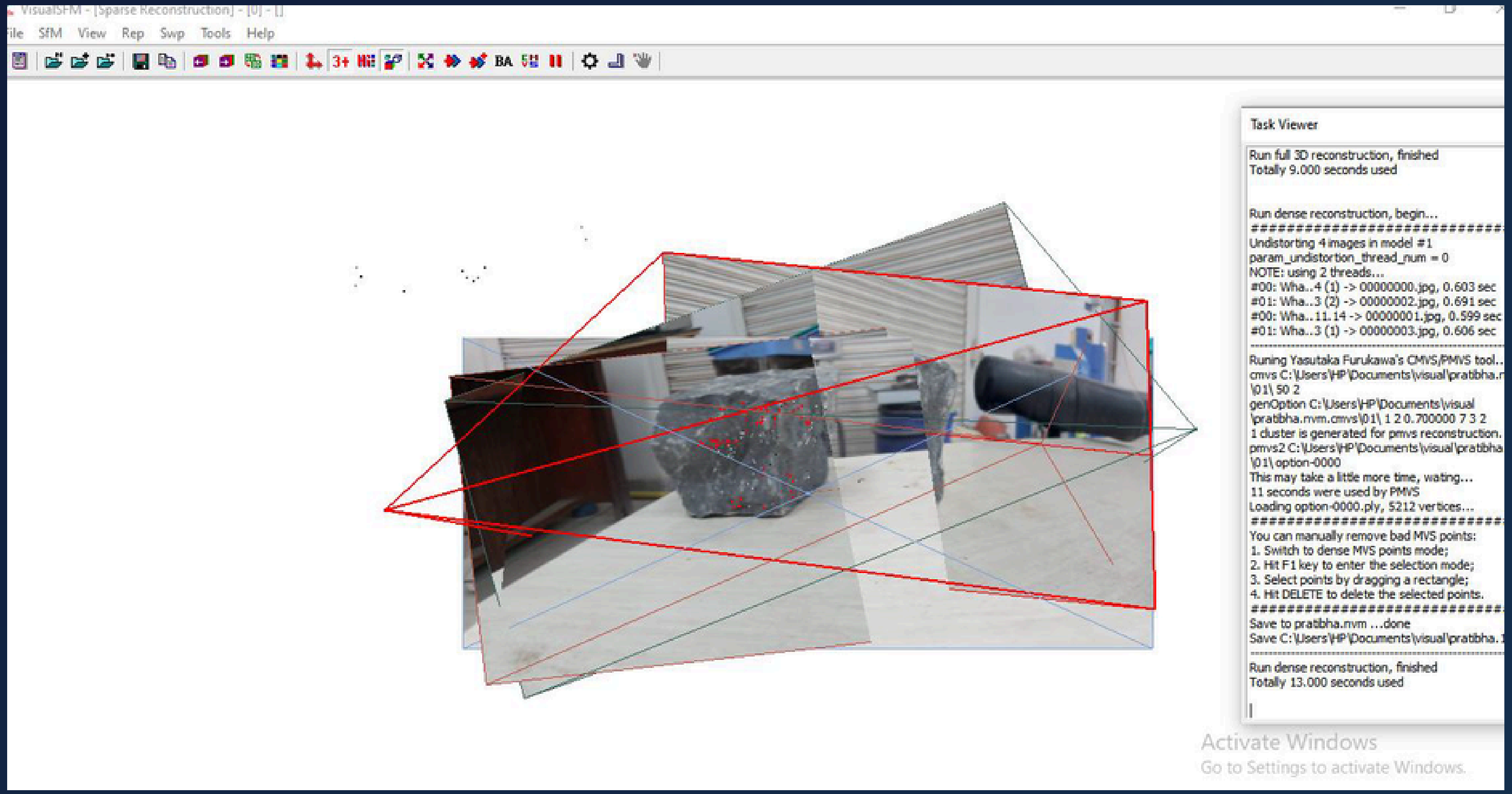
- Develop and apply a robust methodology for precisely quantifying rock joint roughness on rock sample by using photogrammetry.

A ROCK SAMPLE

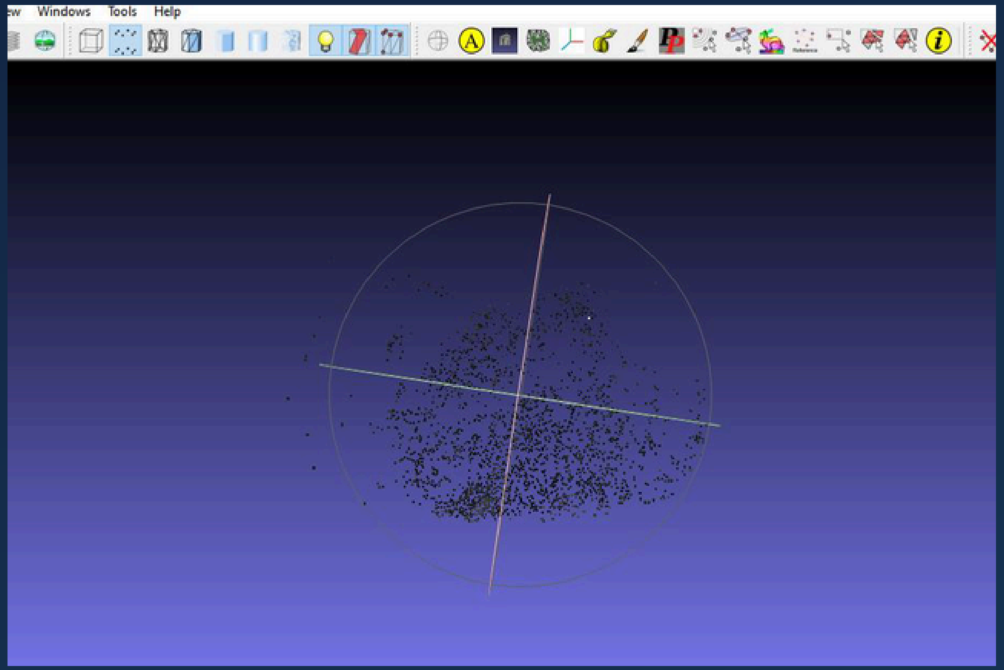
- **CONDUCT PHOTOGRAPHY:** TAKE MULTIPLE OVERLAPPING PHOTOGRAPHS (60-80% OVERLAP BETWEEN CONSECUTIVE PHOTOS) AND ALSO TAKE AT DIFFERENT ANGLES SO THAT IT COVERS TOP AND SIDES.

Taken photograph at different sides and angles

IMPORTING PHOTOS INTO PHOTOGRAMMETRY SOFTWARE (VisualSFM)



A. Dense 3 d reconstruction of 2 d images obtained from visualSFM



B. Point cloud of the 3 d surface obtained from cloudcompare

The software detects common points in different photos

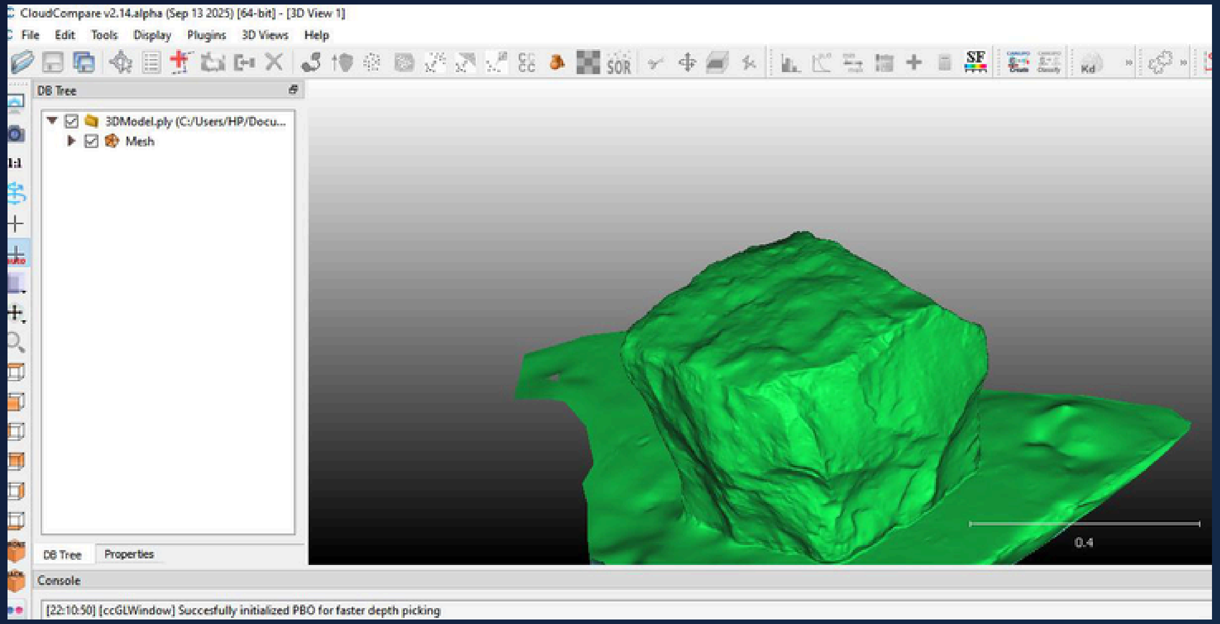
It creates a sparse point cloud(rough structure of rock)

Then it builds a dense point cloud

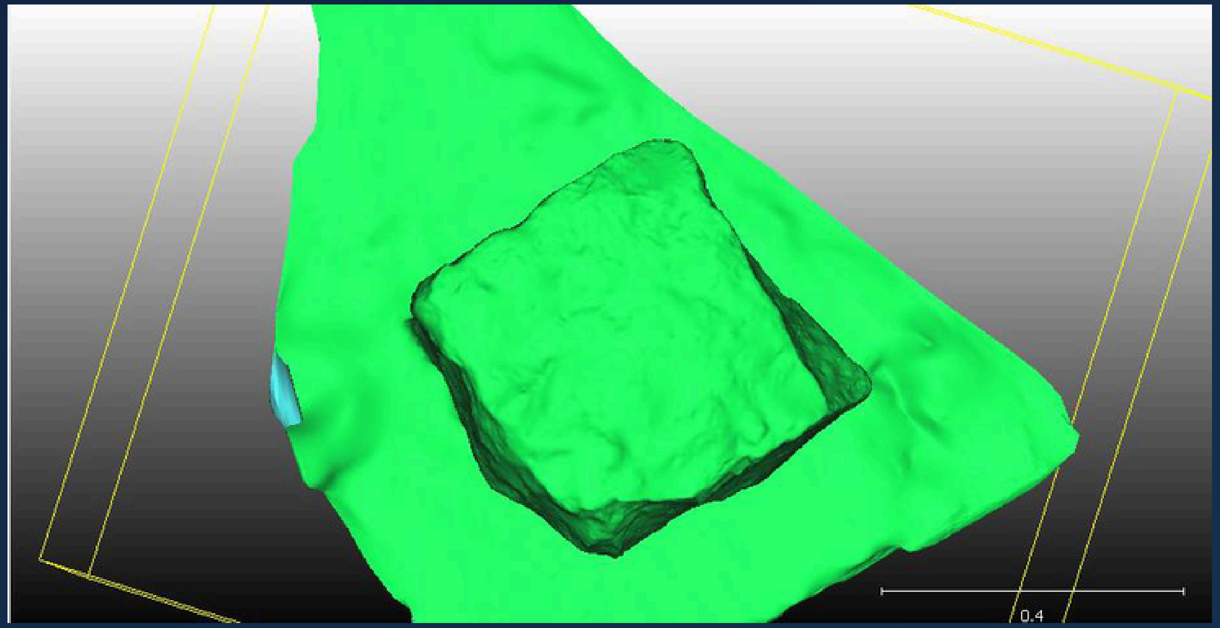
This gives a very detailed 3D representation of the rock surface

This step converts points into a solid surface model of the rock

Export this 3D model into CloudCompare for surface analysis



A typical representation of an image obtained from 3d scanning.



For Roughness Analysis:

In CloudCompare

Use profile/scan lines across the rock surface

Extract height variations or calculate Joint Roughness Coefficient(JRC)

Here are the scanline data (12 diameters)

(crest and trough are vertical coordinates in mm; asperity = crest − trough)

Scanline	Crest (mm)	Trough (mm)	Asperity (mm)
1	2.8	1.5	1.3
2	3.1	1.6	1.5
3	3.4	1.9	1.5
4	3	1.4	1.6
5	2.9	1.3	1.6
6	3.6	2.05	1.55
7	3.2	1.6	1.6
8	3.5	1.8	1.7
9	3.7	2.15	1.55
10	3	1.5	1.5
11	2.7	1	1.7
12	3.45	1.9	1.55

Maximum asperity (taken for JRC calculation) = 1.70 mm (from scanlines 8 & 11).

A maximum asperity of 1.70 mm indicates a significant vertical irregularity on the rock joint surface. This value is a direct measure of the peak-to-trough height of the largest roughness feature found along the scanline.

(Root Mean Square) Z2 = 1.70/6.20 = 0.3

Here are the Review of literature of empirical equations to determine JRC using Z2 at a sampling interval of 6.20 mm.

Model used	Fitting relation	jrc
JRC = a + b ⋆ (Z2)	JRC = −4.51 + 60.32 ⋆ (Z2)	12.02
JRC = a + b ⋆ log(Z2)	JRC = 28.43 + 28.1 ⋆ log(Z2	12.63
JRC = a + b ⋆ √Z2	JRC = −16.99 + 56.15 ⋆ √Z2	12.4
JRC = a + b ⋆ tanZ2	JRC = −5.05 + 64.28 ⋆ tan(Z2)	13.02
JRC = a + b ⋆ tan-1(Z2)	JRC = −5.05 + 64.28 ⋆ tan(Z2)	13

By these theoretical calculations we got JRC value range from 12-13

6.FUTURE WORK PROPOSED

- Conduct direct shear tests on POP samples after attaining constant weight.
- Record stress–displacement behavior along with micro-strain data from piezoelectric sensors.
- Perform pre and post-shearing photogrammetry to capture surface degradation.
- Quantify the reduction in roughness indices and relate them to shear stiffness and strength reduction.
- Compile results into a comprehensive study on roughness degradation and its mechanical implications.

7.CONCLUSION

This study establishes a clear digital workflow to quantify rock-joint roughness using photogrammetry and surface profiling. High-overlap photographs produced accurate 3D reconstructions from which linear profiles were extracted and slope-based metrics (Z2) calculated and converted to JRC estimates. The method yields objective, repeatable pre-test measurements and overcomes much of the subjectivity in visual JRC assessment. Although laboratory shear tests and post-shear rescanning remain planned, the current work validates the imaging and processing pipeline and defines a reliable protocol for data capture. Next steps—direct shear testing, micro-strain monitoring, and validation with contact profilometry—will allow us to relate measured asperity loss to reductions in initial stiffness and peak shear strength. Ultimately, integrating photogrammetric roughness data with mechanical tests will produce empirically calibrated relations useful for tunnel, slope, and foundation design.

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THANK YOU