Use of parametric design and BIM to assess rock slope stability and rock support design

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Background

- Started during the conference «Digitalisering i anleggsbransjen» January 8th-9th 2020.
- Supervisors from NGI: Jessica Ka Yi Chui and Tom Frode Hansen.
- Supervisor from NTNU: Charlie Chunlin Li
- Relevant experience: Summer job with contractor installing rock support in rock slopes.

Goal

- Improve engineering geological working methods and workflow in rocks slope engineering
  - Increase benefits from drone scanning.
  - Semi-automatic detection of discontinuities and roughness (PointStudio). Export to Grasshopper.
  - Calculate stability and volumes (Rhino + Grasshopper)
  - Rock support design (Rhino + Grasshopper).
  - 3D-modell with grid (or “pelnr.”) for use to contractors (Open source)
  - Model (FDV) as final documentation (input from contractors).

Motivation

- «Mesta explained this with possible **misunderstandings** between them and the geolog from SVV.»
- «We find the engineering incomplete and that there were **no calculation of stability**.»

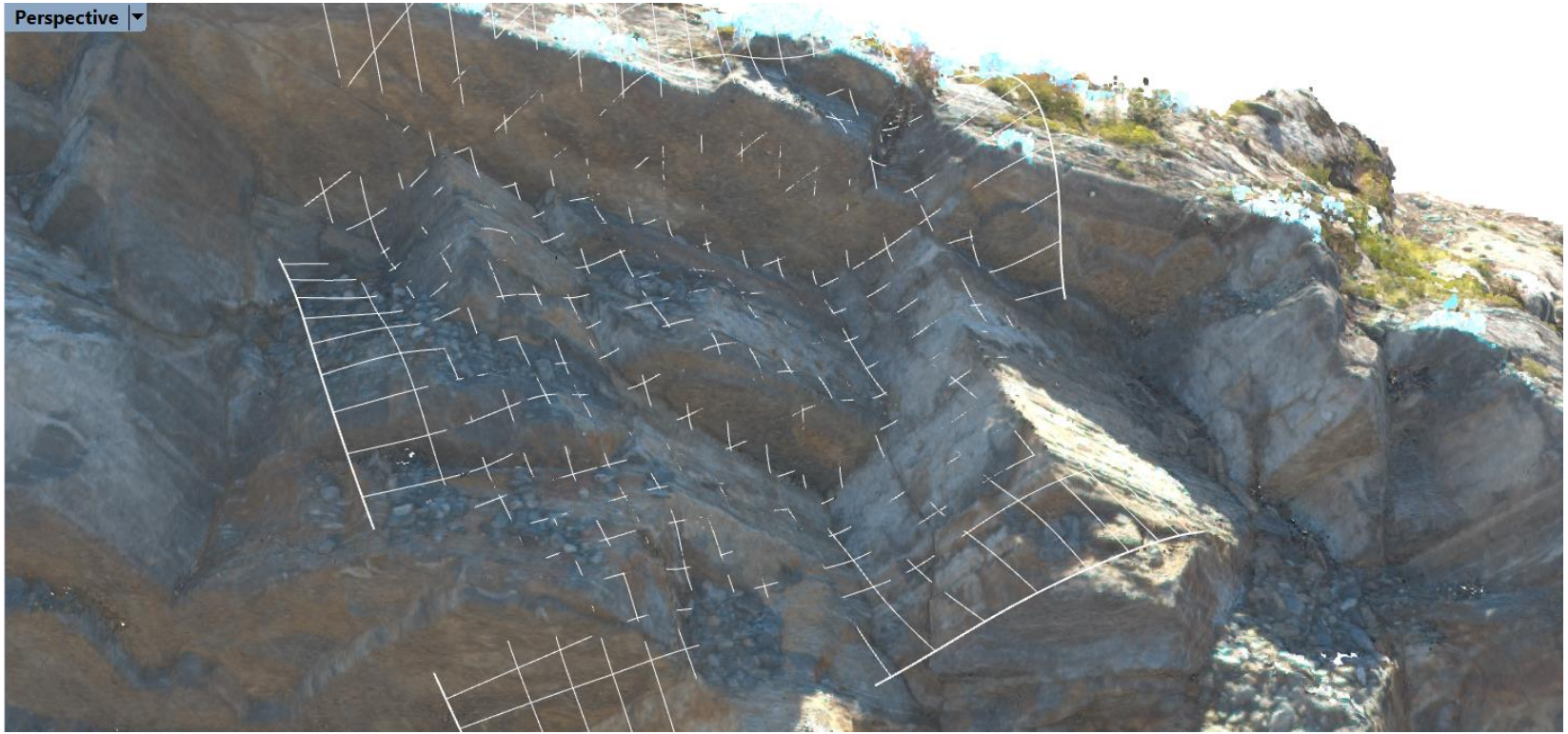
Raset på E18 ved Larvik 13. desember 2019

Ekspertutvalgets rapport

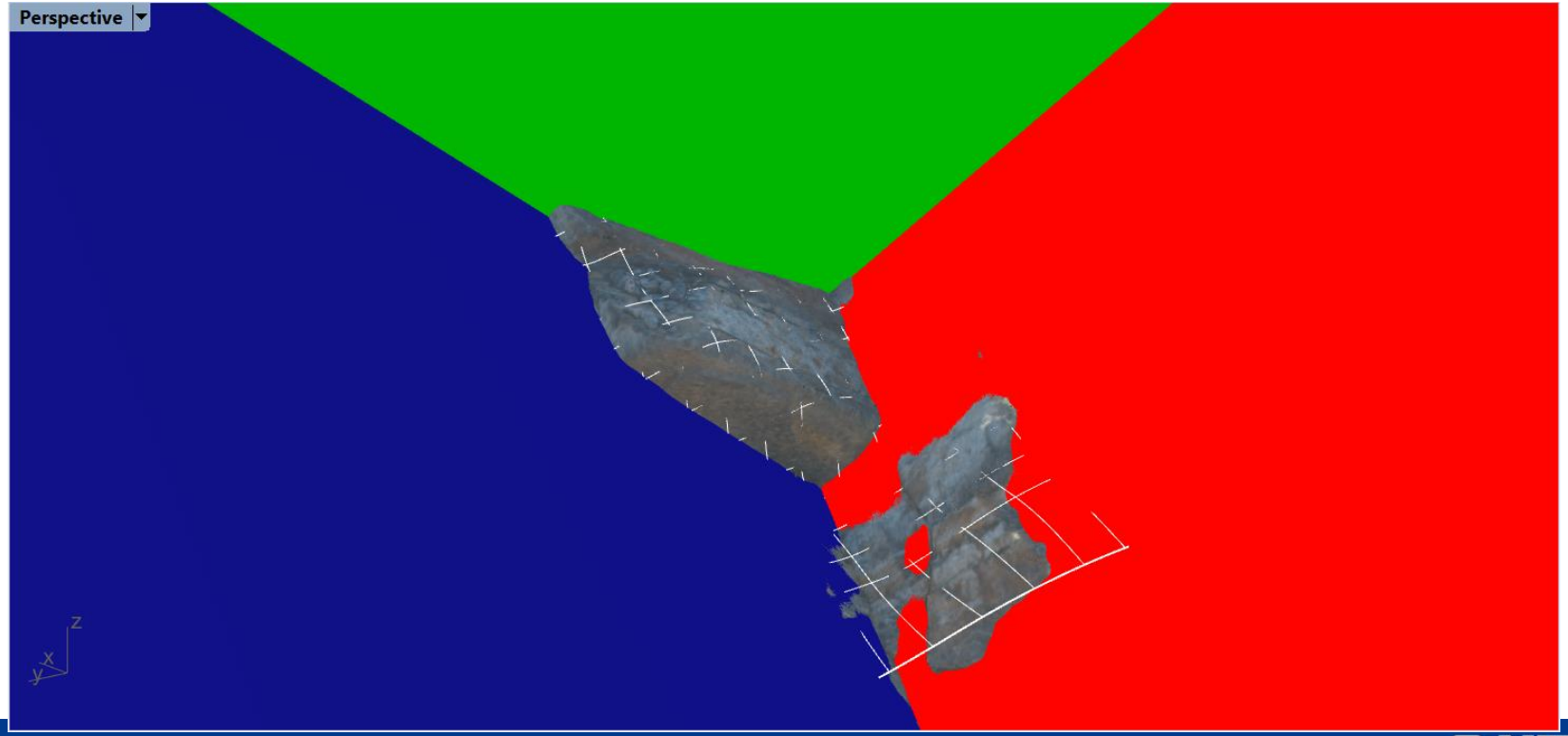
27. februar 2020

Extract volume

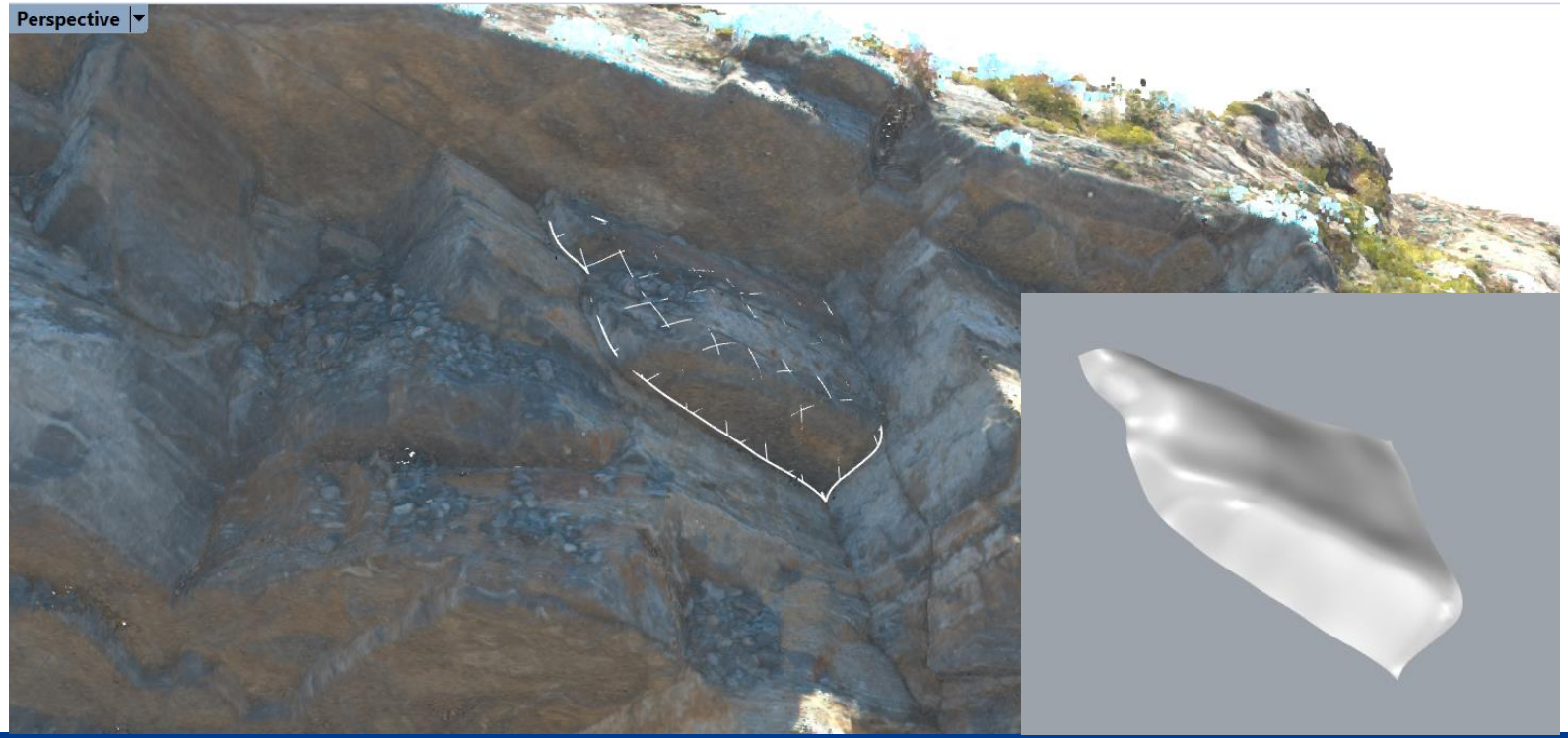
Extract volume: Step 1



Extract volume: Step 2



Extract volume: Step 3

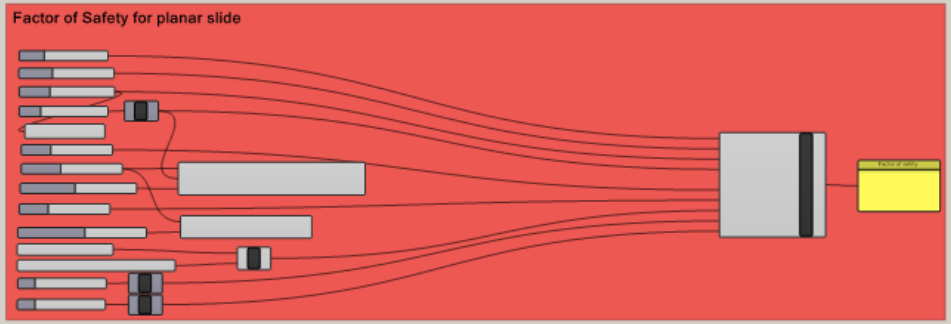


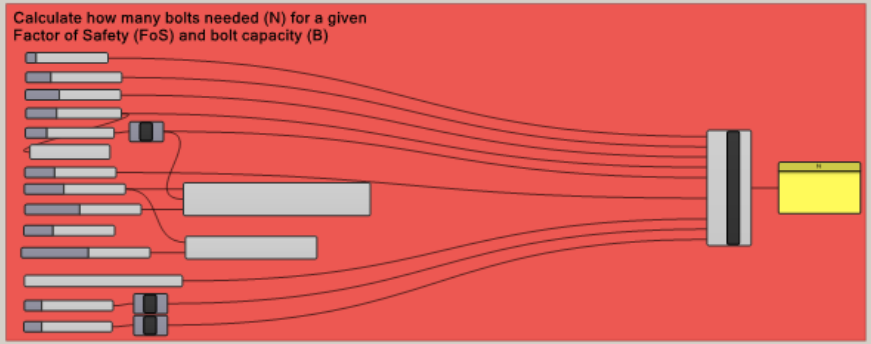
Factor of Safety

Developed by: Olav Roset
Rev: 1.0.1
Rev date: 2020-03-02

Program description

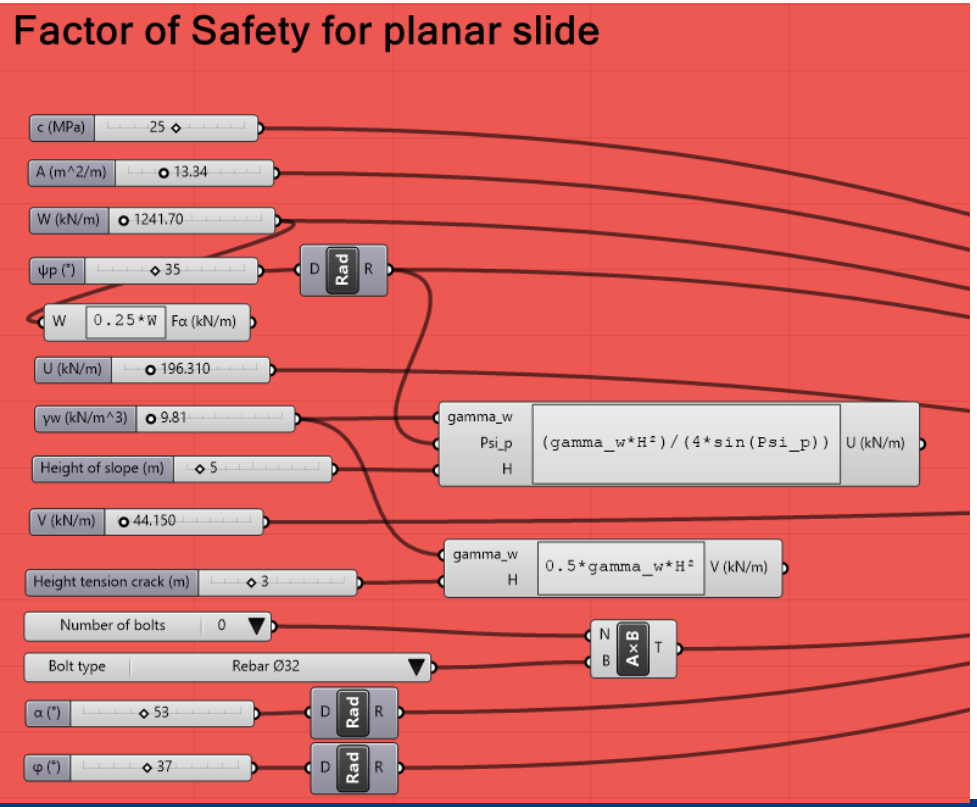
1. Calculates Factor of Safety (FoS) for planar slide.
2. Calculate how many bolts needed (N) for a given FoS and bolt capacity (B).

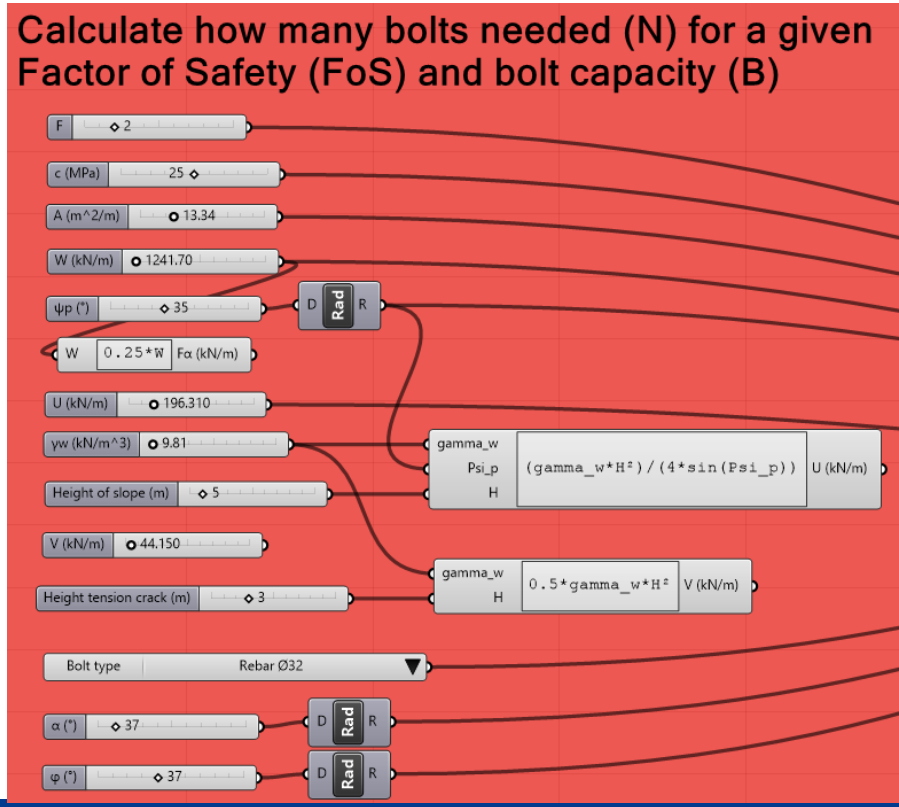




Input Factor of Safety (FoS)

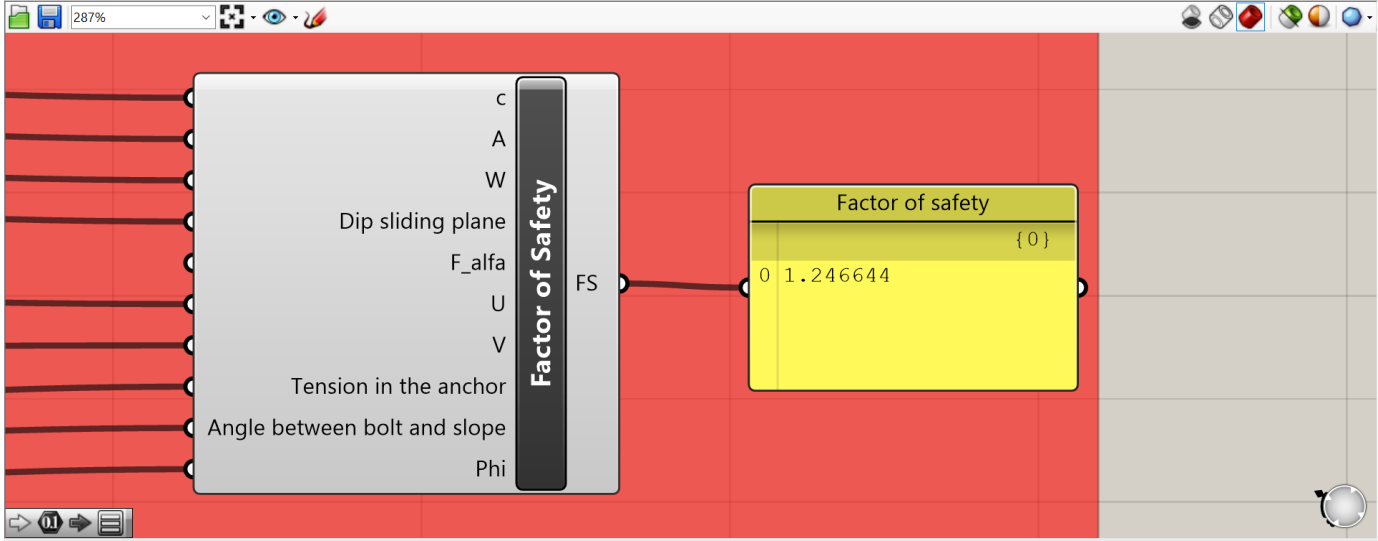
Input number of bolts (N)



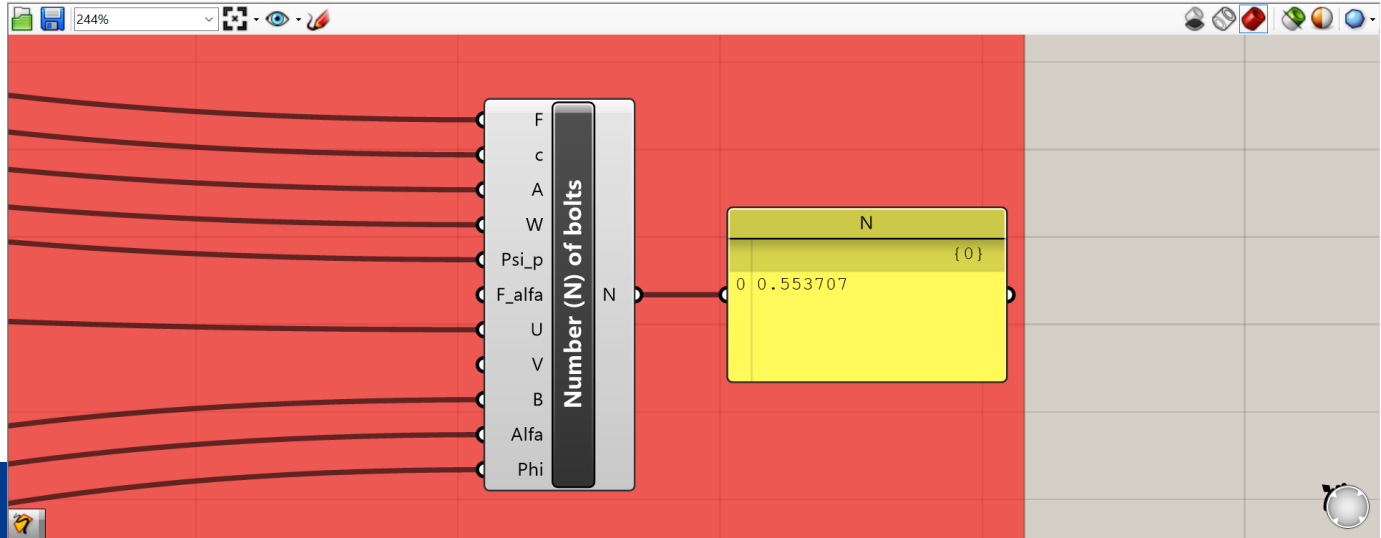


NTNU

Output Factor of Safety (FoS)



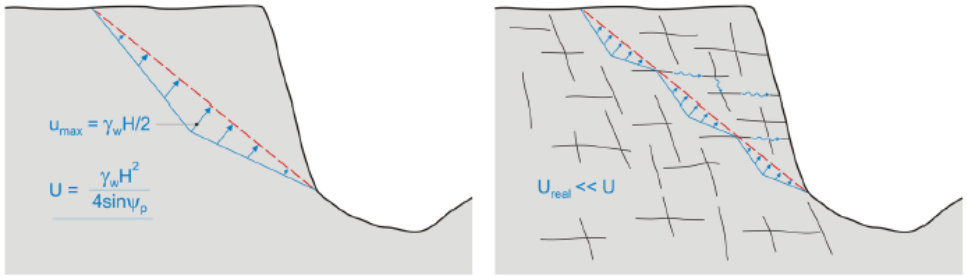
Output number of bolts (N)



To be discussed

Basert på Nilsen og Palmstrøm (2000) og Nilsen (2016) antas at trekantfordelt vanntrykk som beskrevet ovenfor representerer "worst case". Videre legges til grunn at håndbøkene 274 og V224 foreslår sikkerhetsfaktor 1,5-2 ved "worst case" vanntrykk.

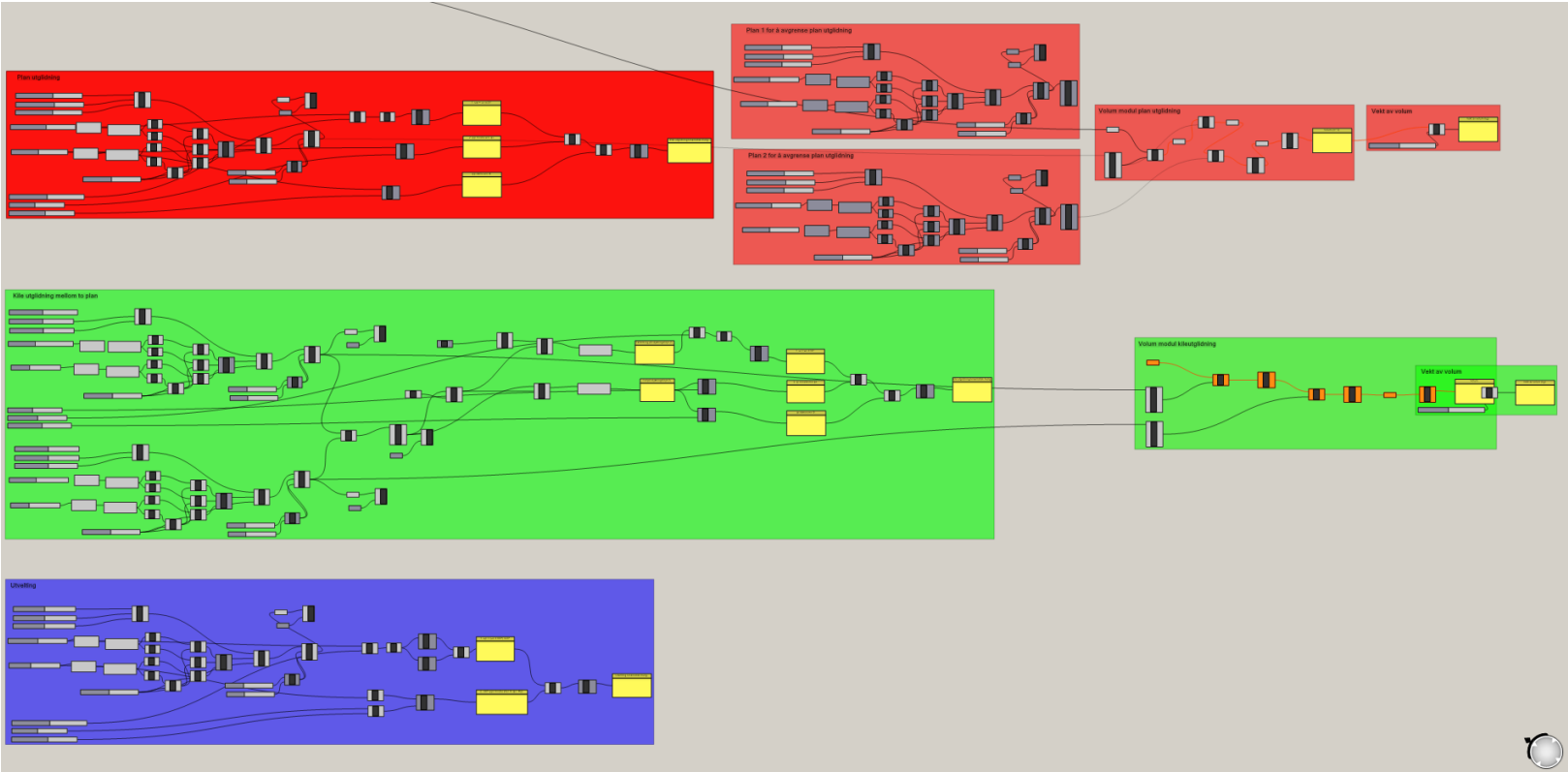
Fig. 4 Commonly used "worst case" water pressure configuration (*left*) compared with the more likely worst case scenario with resultant "real" water pressure" $U_{real} \ll U$ (*right*)



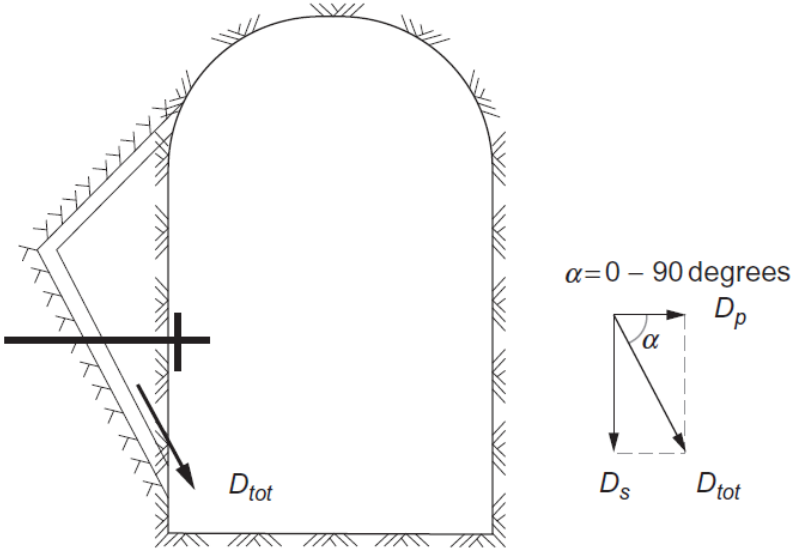
From report «*Raset på E18 ved Larvik 13. desember 2019*».

- Conservative standard?
- Should we use more time on deciding were the water is flowing and realistic «worst case»?
- How to deal with swelling clay and time dependant weakening i FoS?

Kinematic analysis



Optimum bolt angle



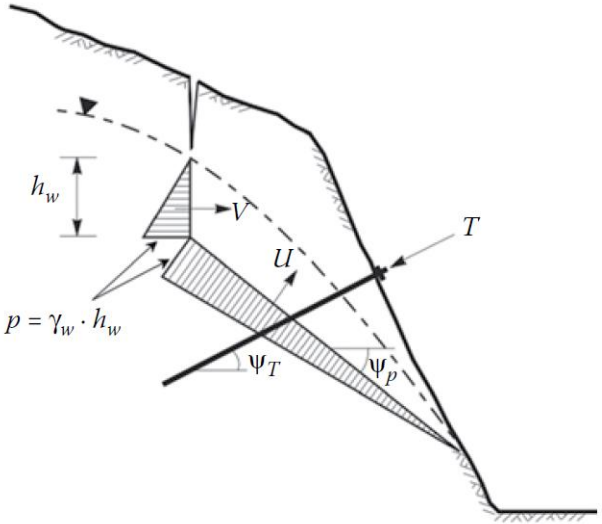
$$T = Wg\frac{\sin\psi - \cos\psi\tan\phi}{\cos\alpha + \sin\alpha\tan\phi}$$

$$\partial T/\partial\alpha = 0$$

$$\alpha = \phi$$

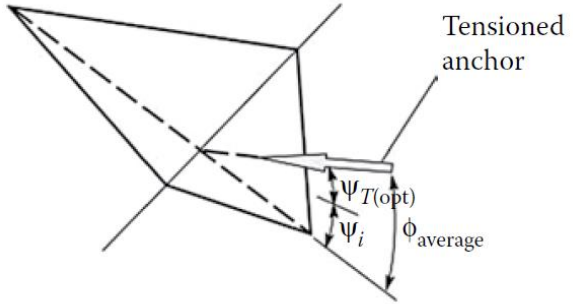
From «Rockbolting», Charlie Chunlin Li, 2018.

Planar slide



$$\phi = (\psi_p + \psi_{T(opt)})$$

Wedge



$$\psi_{T(\text{opt})} = (\phi_{\text{average}} - \psi_i)$$

$$\alpha_{T(\text{opt})} = (180 + \alpha_i)$$

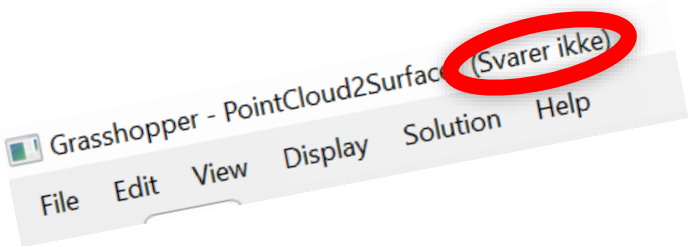
From «Rock Slope Engineering»,
Duncan C. Wyllie, 2017.

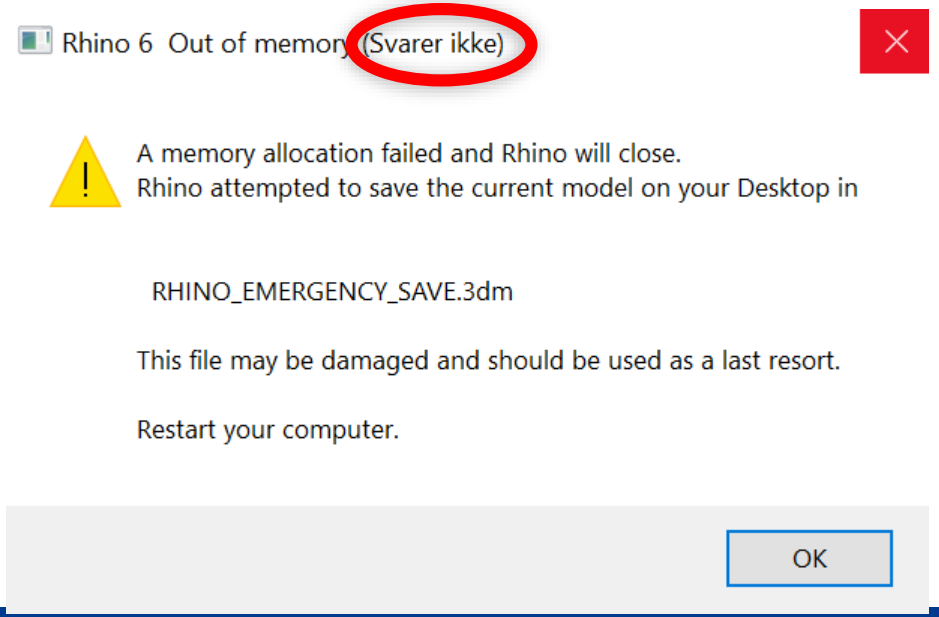
Benefits

+ Greater drone scan benefits.
+ Ability to enter discontinuities both from field mapping and semi-automatic crack detection in Pointstudio → can be used directly to extract volume.
+ Volume can be used directly in stability calculations. No need to go via Swegde etc.
+ Possibility of optimizing the number of bolts and positions.
+ Intuitive model to use for contractor. Can avoid misunderstandings.
+ Model to communicate around during execution.
+ Dynamic model. Easily change parameters to test sensitivity of different parameters and enter new data.
+ Easier for inspector (“tredjeparts kontrollør”) to get involved in the project.
+ Possibility of entering finished rock support in model for final documentation (FDV-model).

Challenges (so fare)

- Big files
- Hard for student-pc.





Further work

- Join Sweco’s inspection of rock slopes (Vestfold).
- Semi-automatic detection of discontinuities and roughness. Export planes and roughness from PointStudio to Grasshopper.
- Factor of Safety for wedge and toppling.
- Create workflow to make BIM-model for contractor and as final documentation.
- How to register dip and plunge for installed bolts in field (gyro + RTK?).
- How to include MWD-data in rock slope engineering.

- Feel free to give me input ☺