Complex geology slope stability analysis by shear strength reduction

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Slope stability
Shear strength reduction technique (SSR)

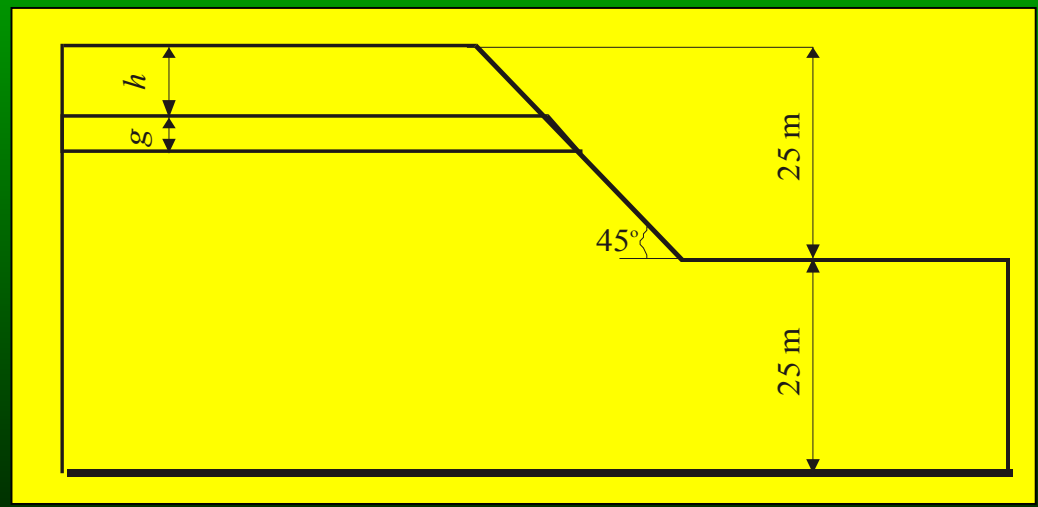
- The stability of slopes may be estimated using 2D limit equilibrium methods (**LEM**) or numerical methods.
- Due to the rapid development of computing efficiency, several numerical methods are gaining increasing popularity in slope stability engineering.
- The factor of safety (**FS**) of a soil slope is defined as the number by which the original shear strength parameters must be divided in order to bring the slope to the point of failure.

$$c_{trial} = \frac{c}{FS_{trial}} \qquad \varphi_{trial} = arctg\left(\frac{tg\varphi}{FS_{trial}}\right)$$

Shear strength reduction technique (SSR)

- It's well known fact that for simple slopes FS obtained from SSR is usually the same as FS obtained from LEM (Griffiths & Lane, 1999; Cala & Flisiak, 2001).
- However, **for complex geology slopes considerable differences between FS values from LEM and SSR may be expected** (Cala & Flisiak, 2001).

Several analyses for the slope with weak stratum were performed to study the differences between LEM and SSR.

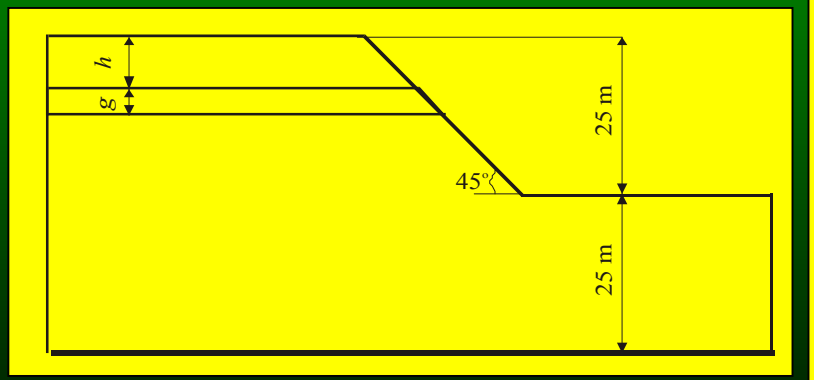


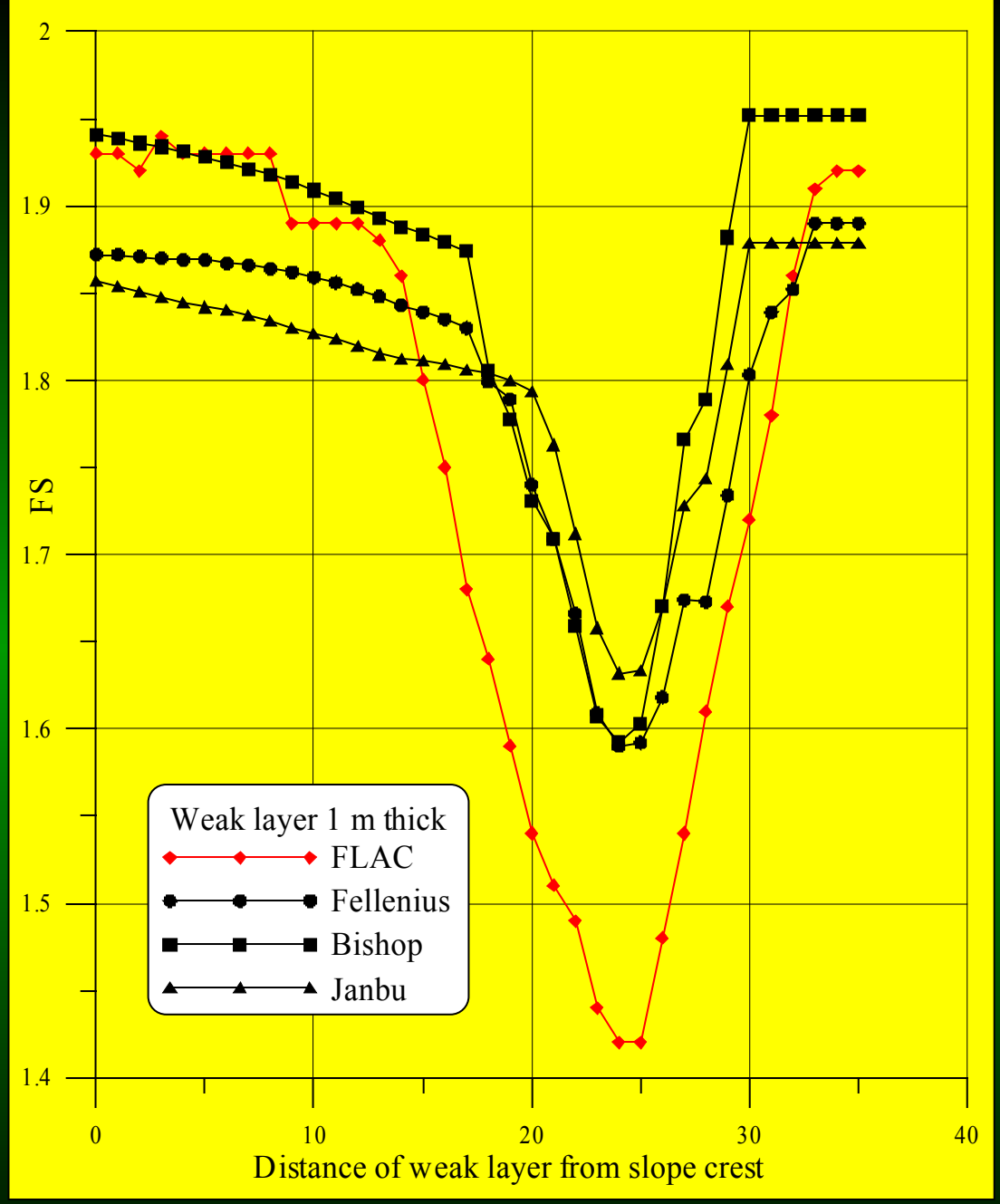
SSR versus LEM

Weak layer 1m thick

Hard soil c=75 kPa, ϕ=30°

Soft soil c=25 kPa, ϕ=10°



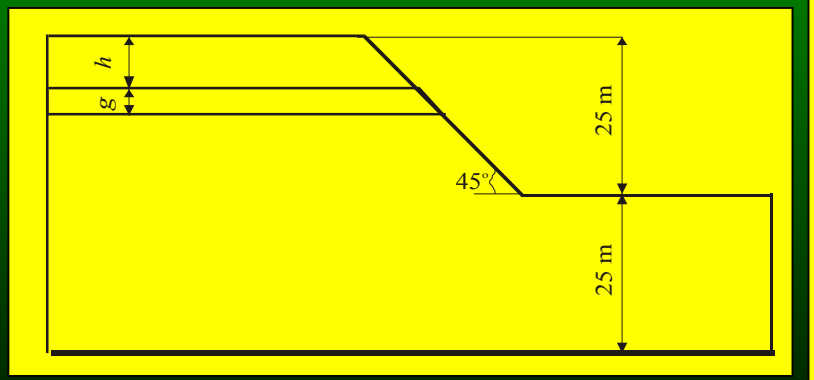


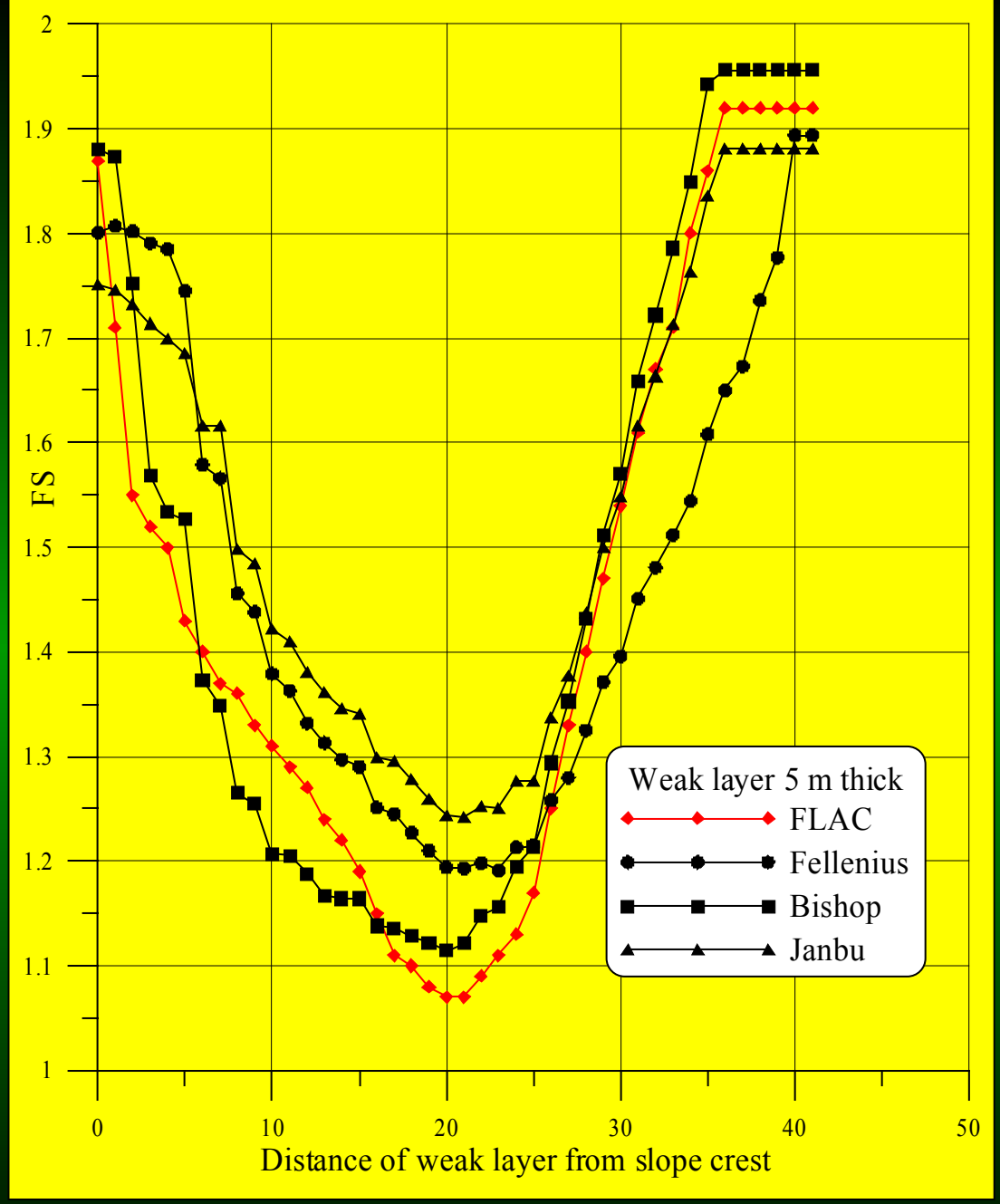
SSR versus LEM

Weak layer 5m thick

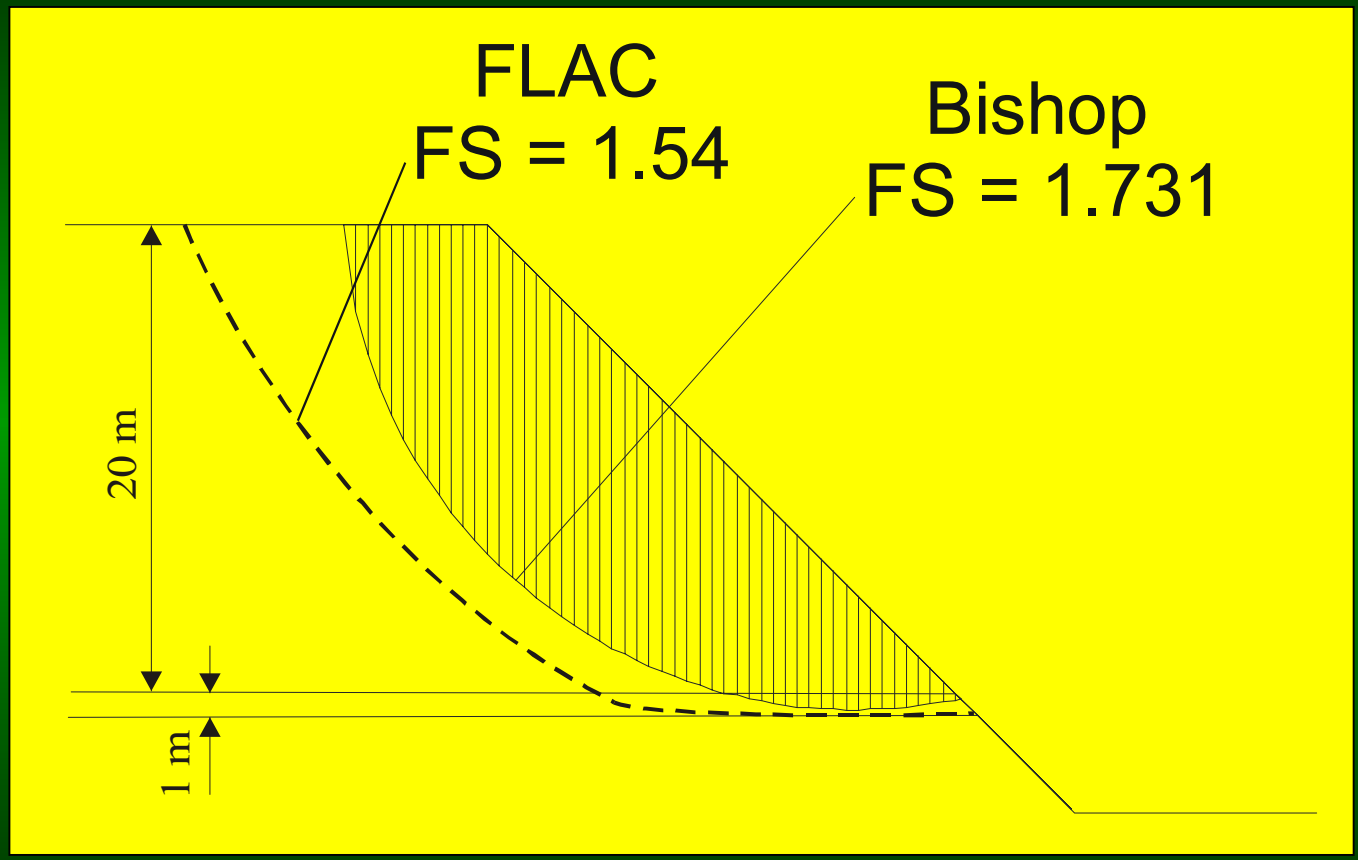
Hard soil c=75 kPa, ϕ=30°

Soft soil c=25 kPa, ϕ=10°

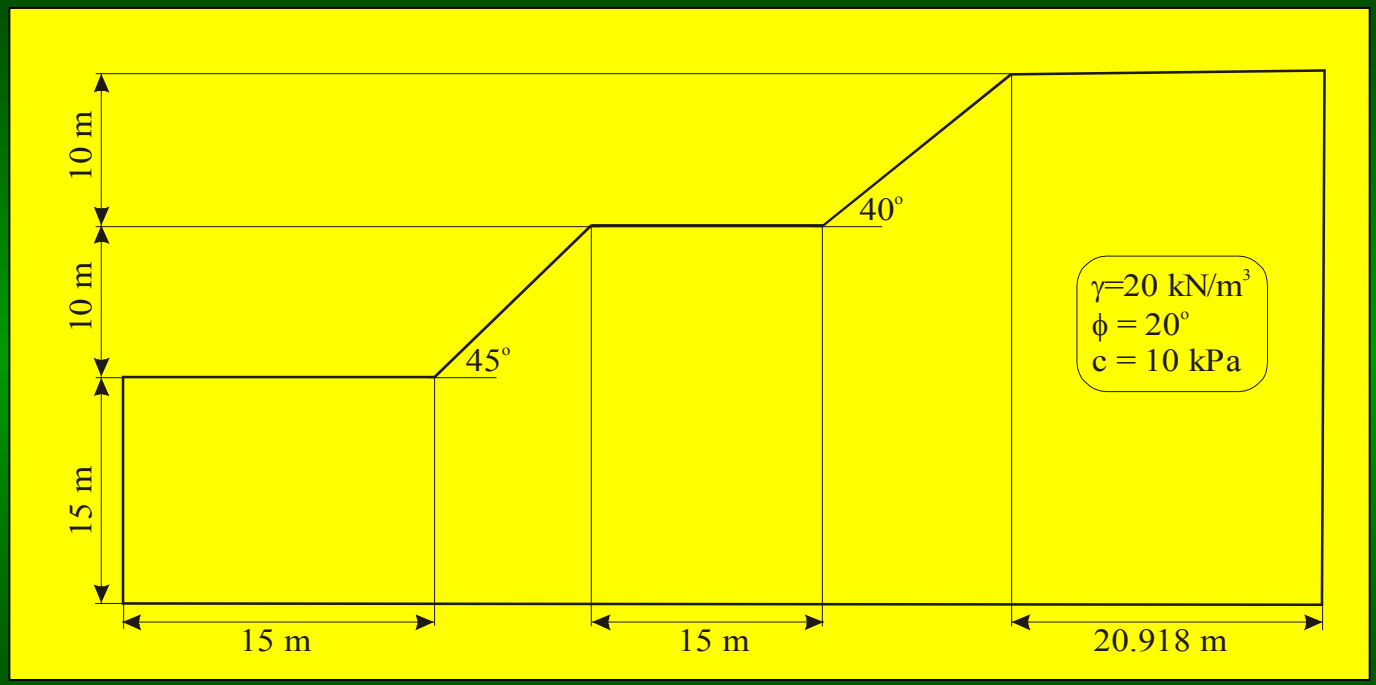




SSR versus LEM



SSR versus LEM
benched slope case



SSR versus LEM
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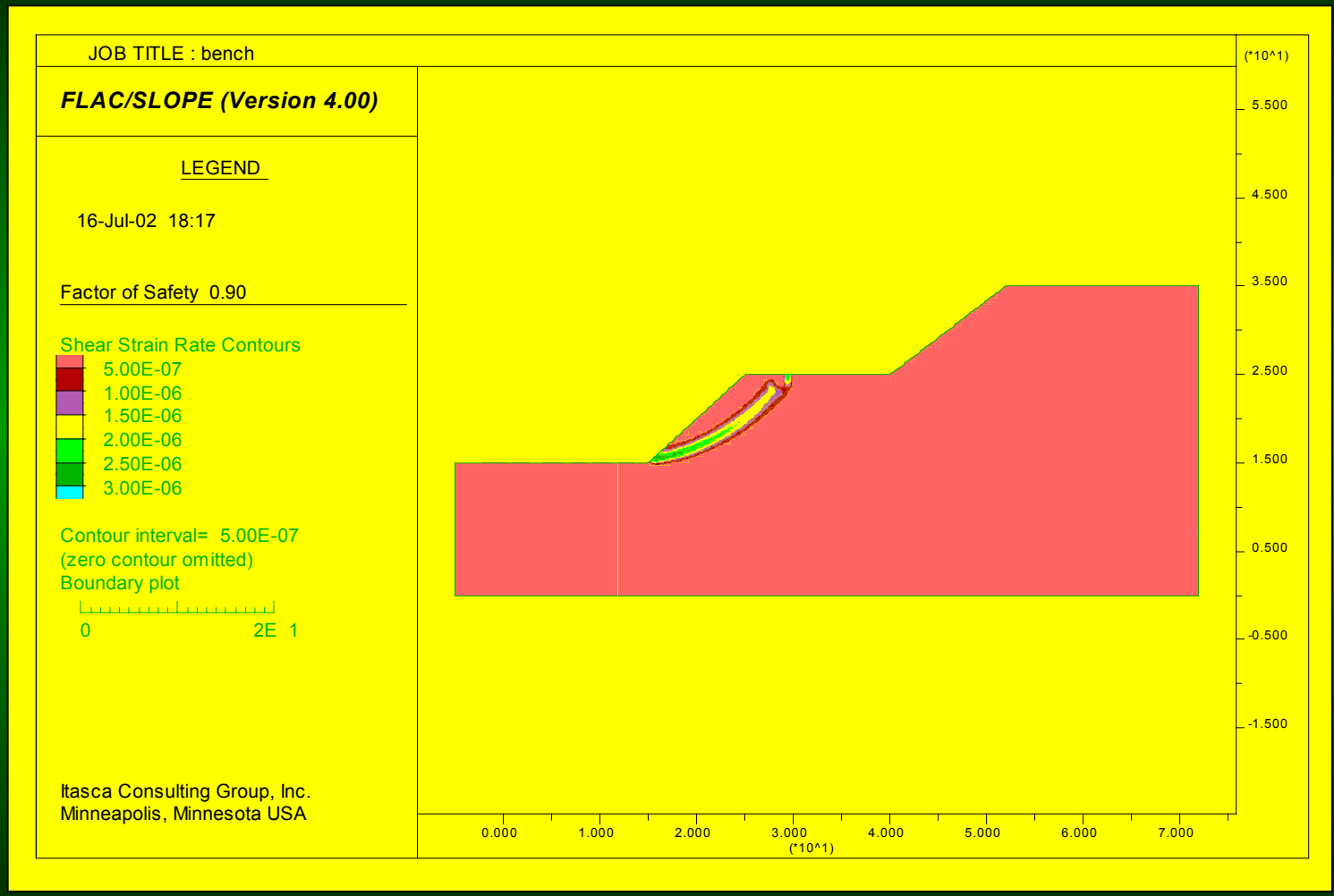
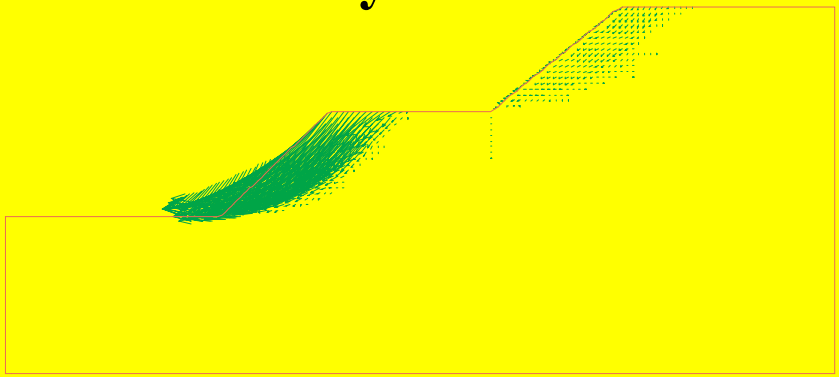


Modified shear strength reduction technique

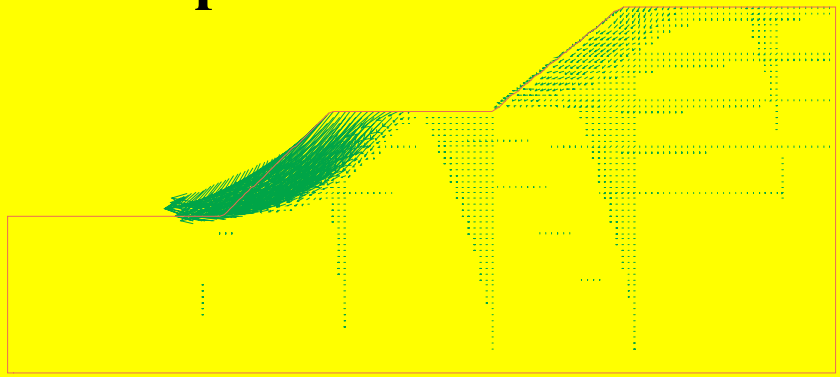
1. Apply classic SSR technique to calculate FS_1 (FLAC/Slope).
2. Export *.dat file to FLAC. Calculate the initial, stable situation by increasing c and ϕ.
3. Find the representative number of steps (N_r) which characterises the response time of the system. Use $1.1N_r$ for further calculations.
4. Calculate situation for FS_1(check out for communication between FLAC and FLAC/Slope and elimination of any mistakes).
5. Reduce c and ϕ to find further FS_i (prepare *.dat file manually or using Excel; each time start from the initial, stable *.sav file).

Modified shear strength reduction technique

Velocity vectors

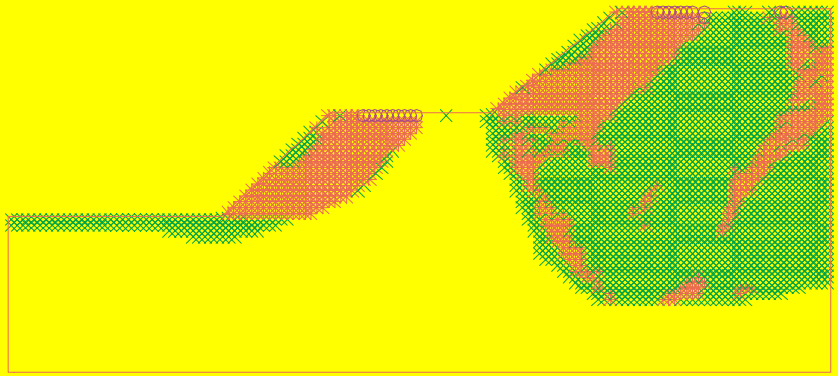


Displacement vectors

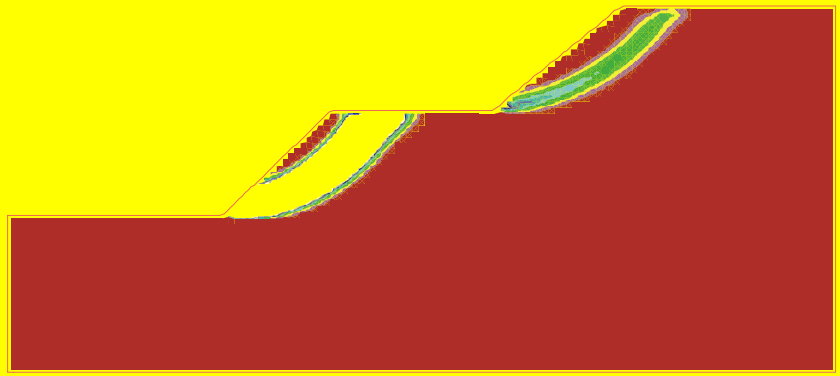


$FS_2 = 1.00$

Plasticity indicators

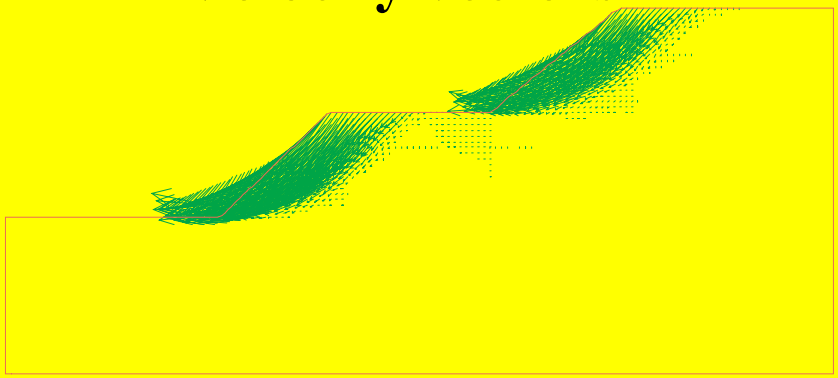


Shear strain rate

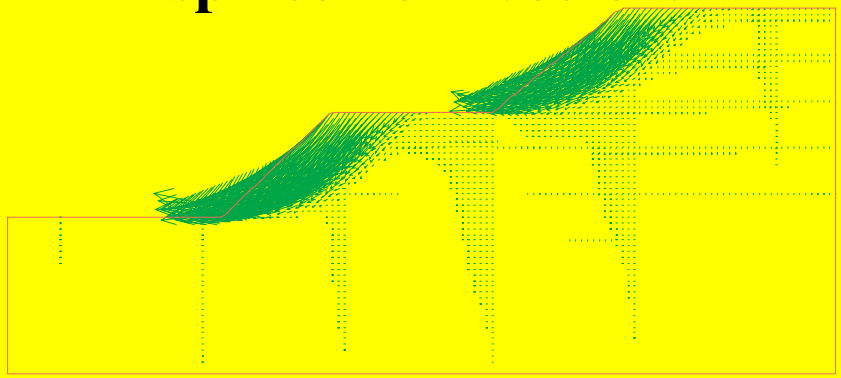


Modified shear strength reduction technique

Velocity vectors

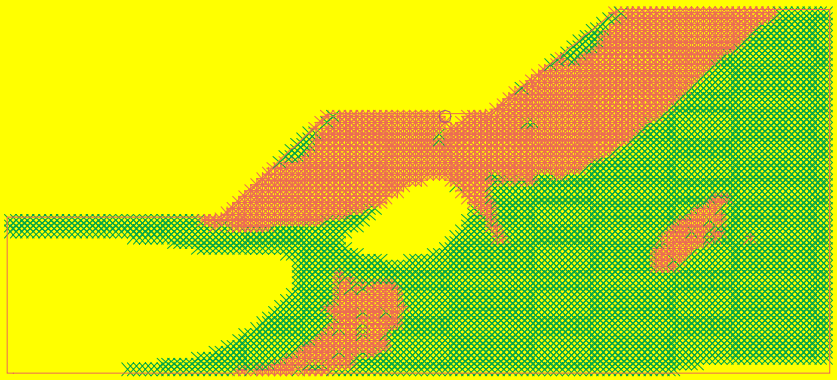


Displacement vectors

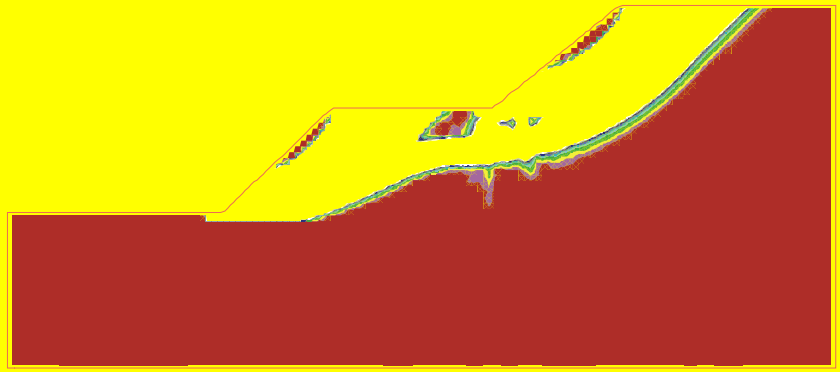


$FS_2 = 1.24$

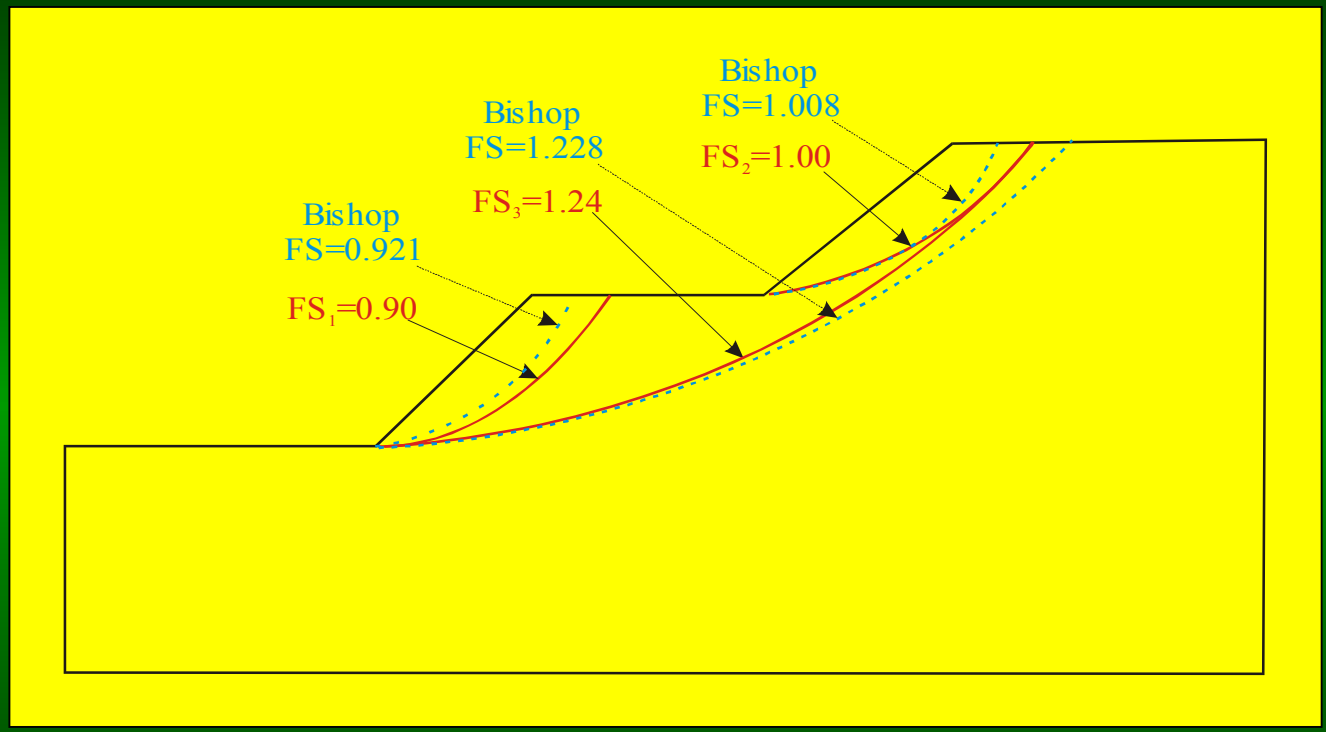
Plasticity indicators



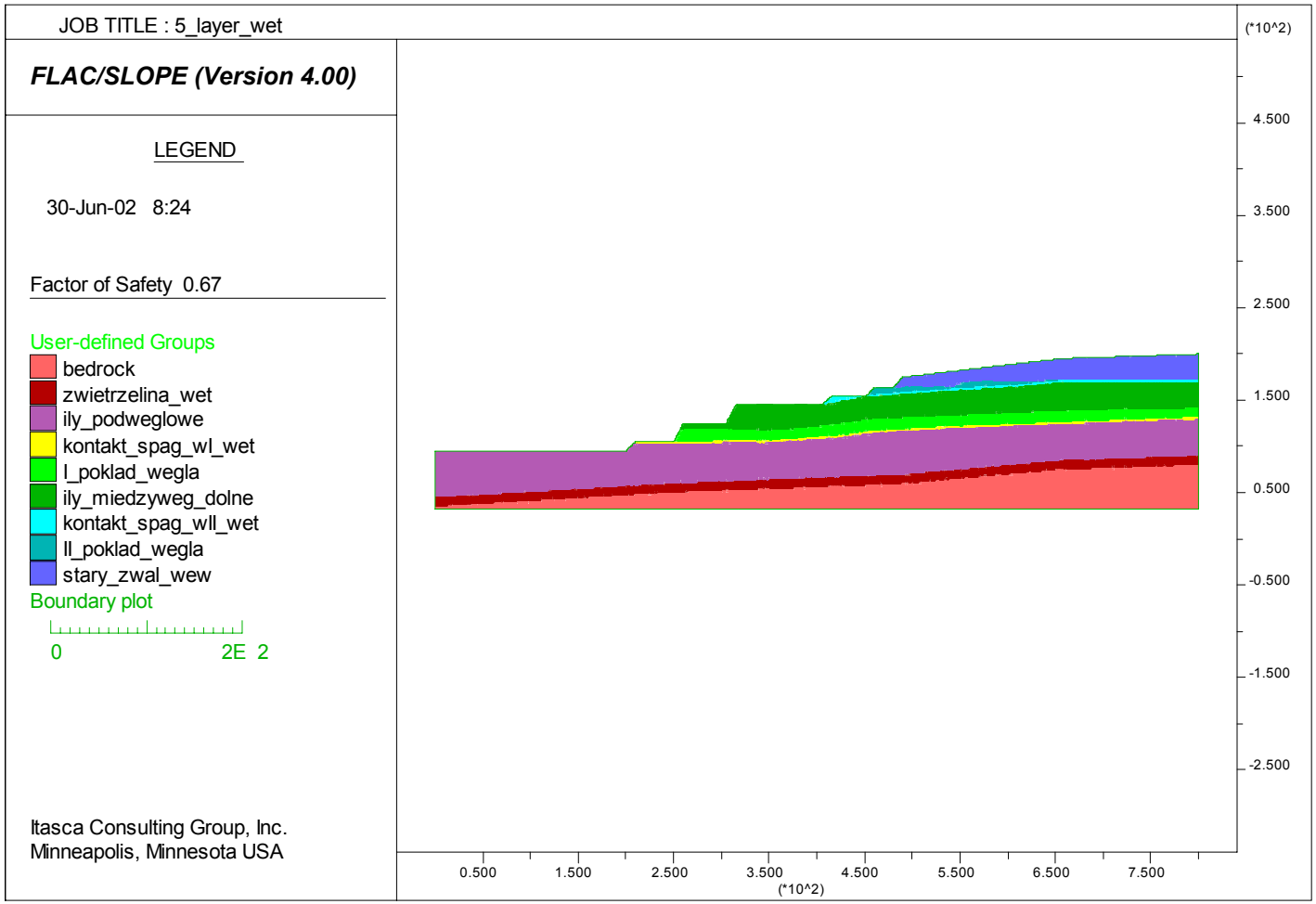
Shear strain rate



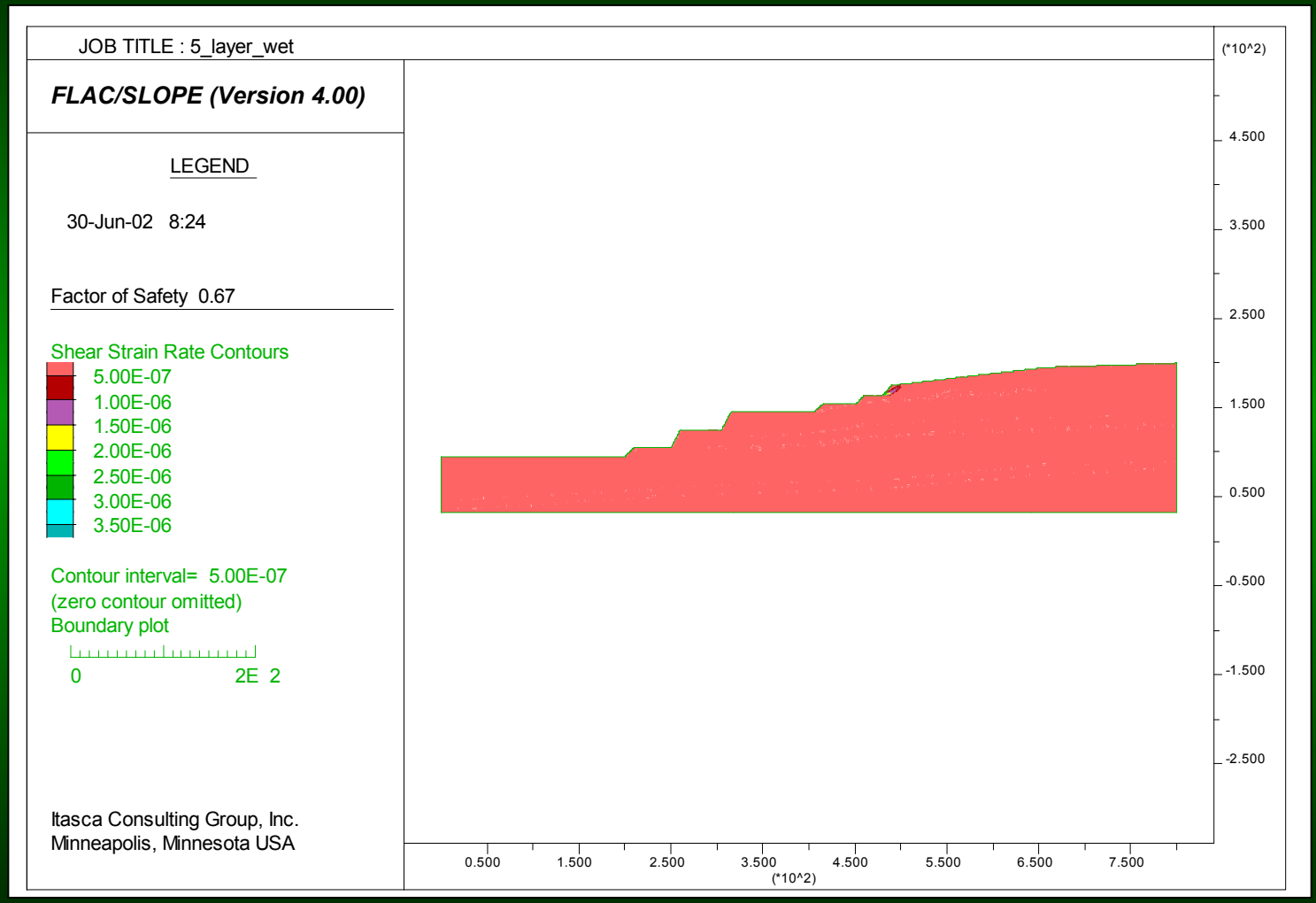
MSSR versus LEM
benched slope case



Shear strength reduction technique
Large, complex geology slope case



Shear strength reduction technique
Large, complex geology slope case



Modified shear strength reduction technique

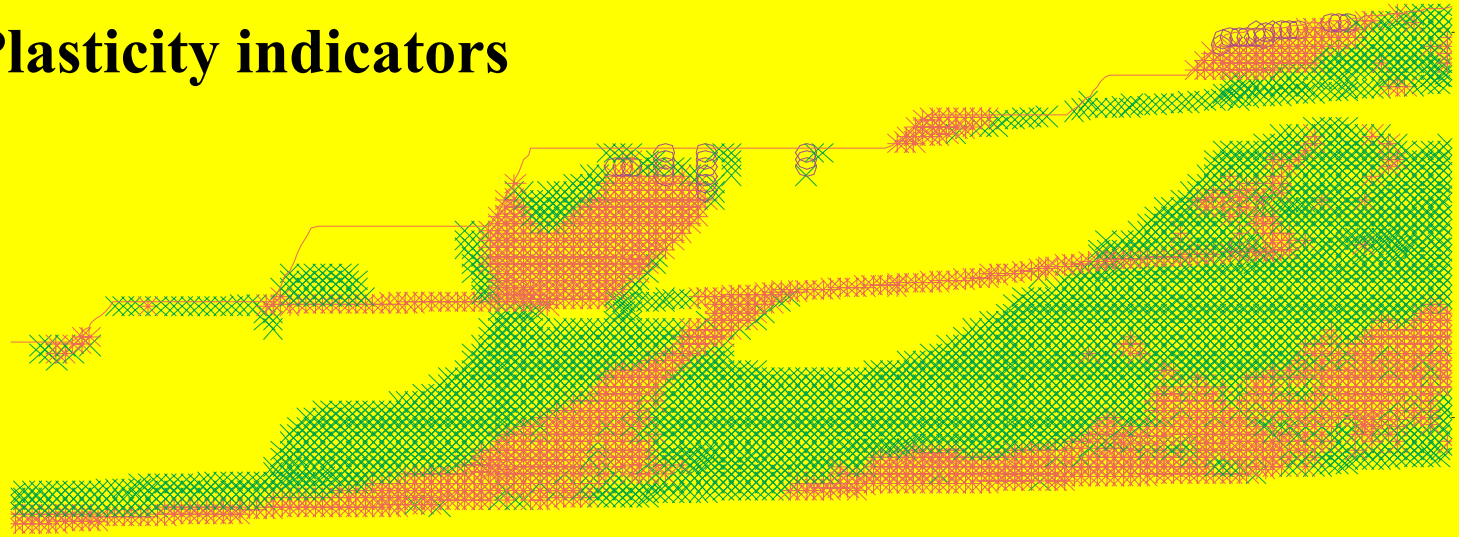
Displacement vectors

Shear strain rate

$FS_2 = 0.87$

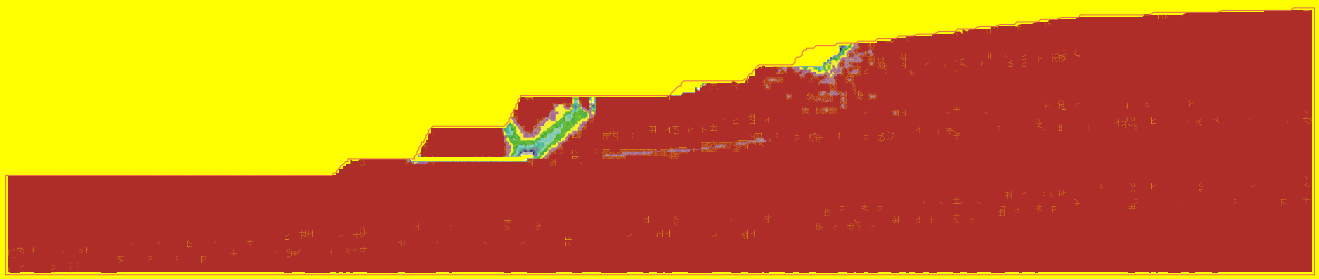
Modified shear strength reduction technique

Plasticity indicators



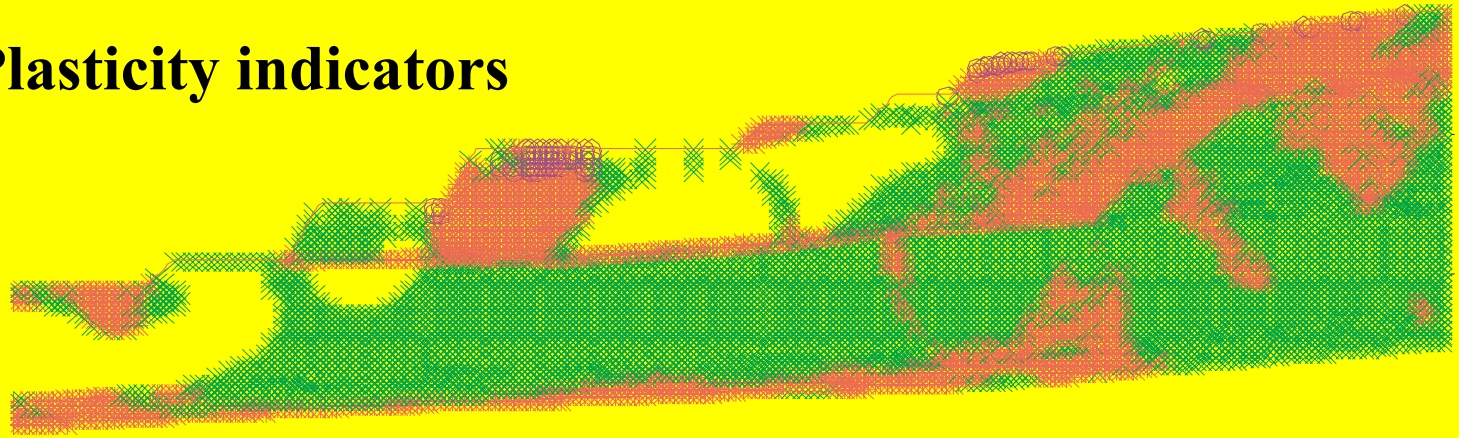
$FS_3 = 1.02$

Shear strain rate



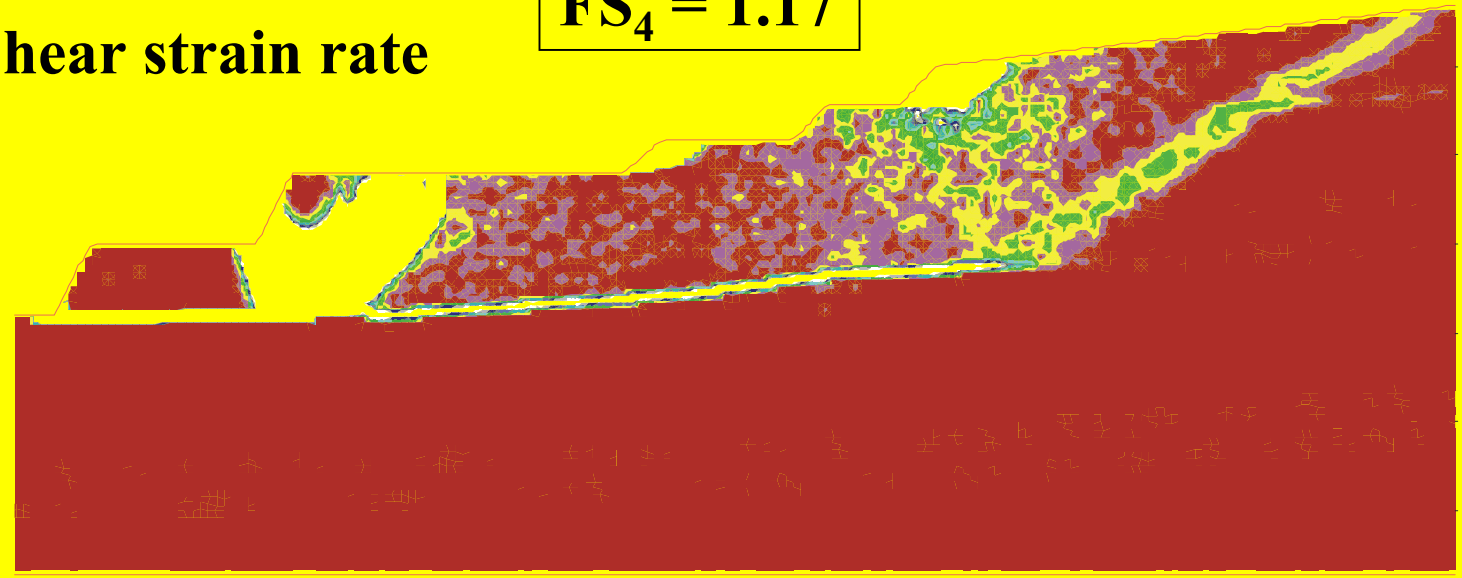
Modified shear strength reduction technique

Plasticity indicators



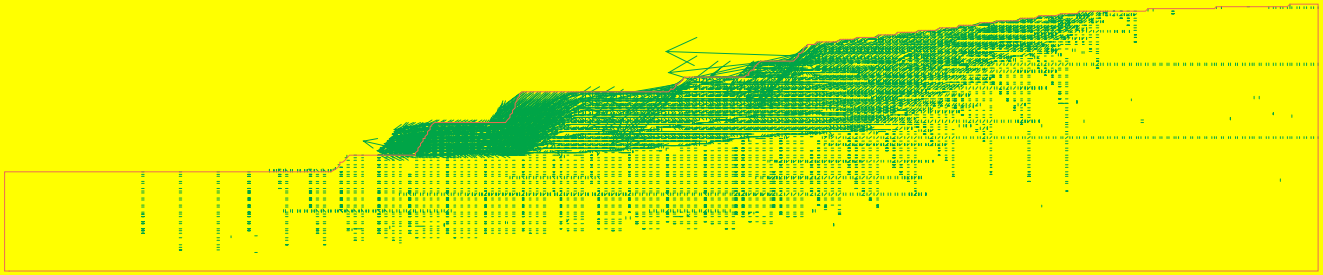
Shear strain rate

$FS_4 = 1.17$



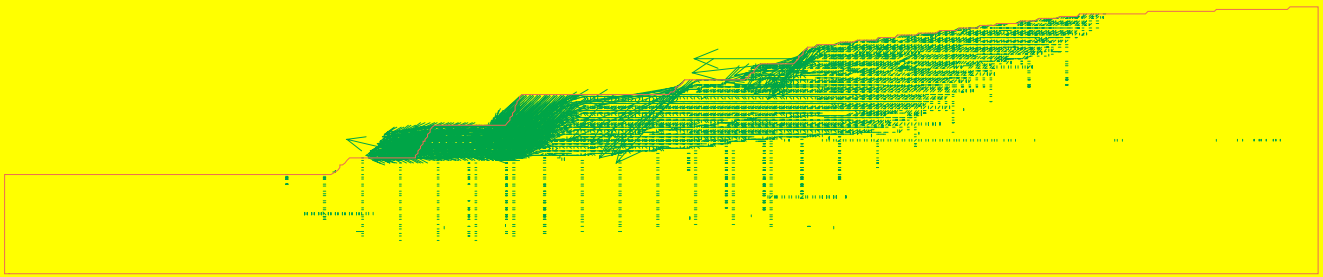
Modified shear strength reduction technique

Displacement vectors



Velocity vectors

$FS_5 = 1.29$

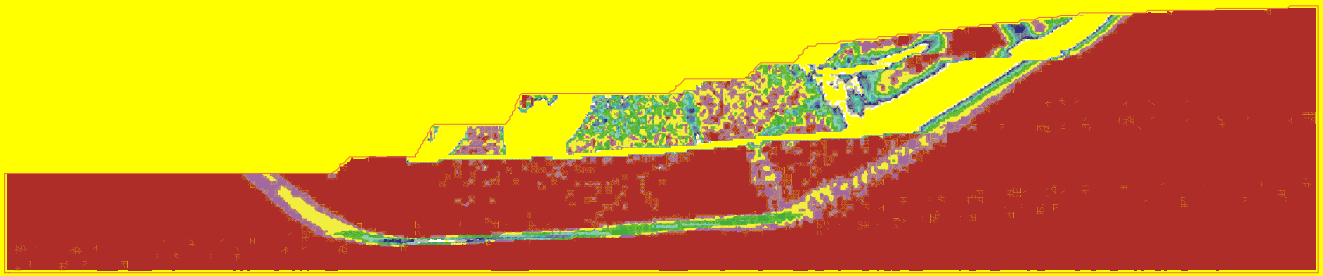


Modified shear strength reduction technique

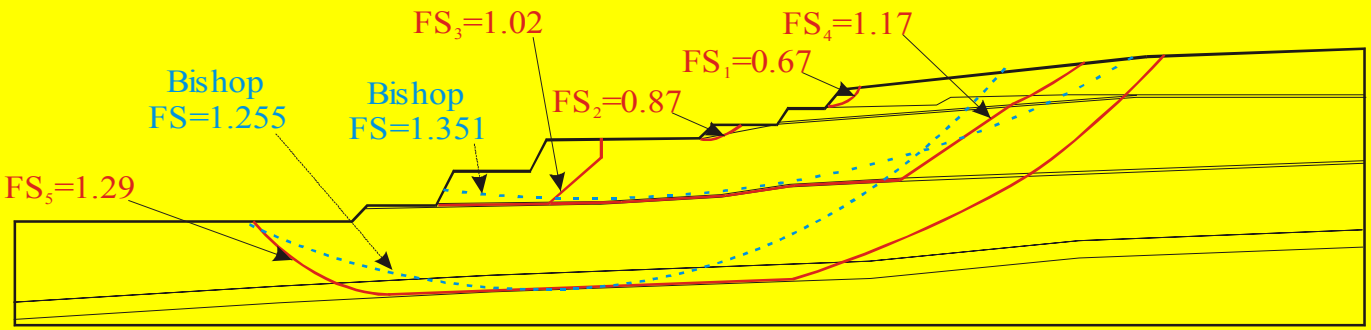
Plasticity indicators

Shear strain rate

$FS_5 = 1.29$



MSSR versus LEM
large, complex geology slope case



Conclusions

- For a **simple, homogeneous slope**, FS calculated with SSR are usually the same as FS obtained from LEM.
- In the case of **a simple geometry slope consisting of two geological units**, FS calculated with SSR may be considerably different than FS from LEM.
- In the case of complex geometry and geology slopes SSR technique is much more "sensitive" than LEM.
- Another step forward is the modified shear strength reduction technique – MSSR.
- Application of SSR/MSSR with FLAC may be recommended for the large-scale slopes of complex geometry.
- Such a powerful tool as MSSR with FLAC gives the opportunity for the **complete stability analysis for any slope.**
- Limitations: visibility, interpretation.
- **Verification !!!**