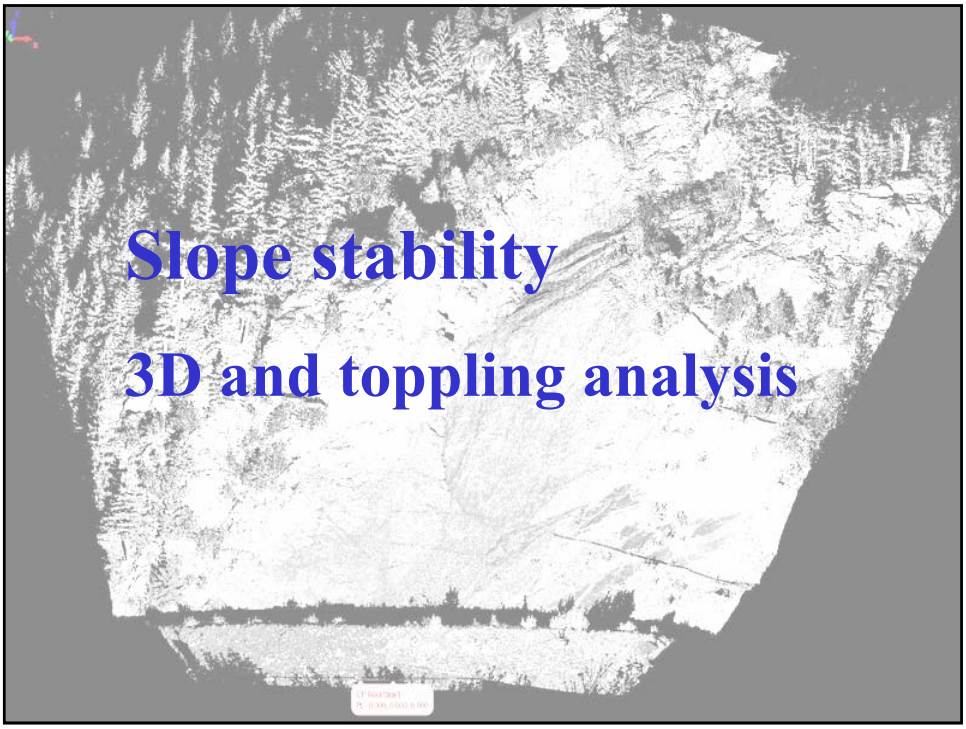
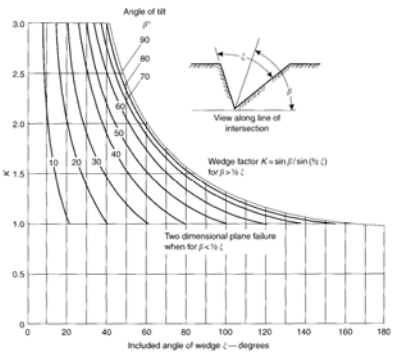
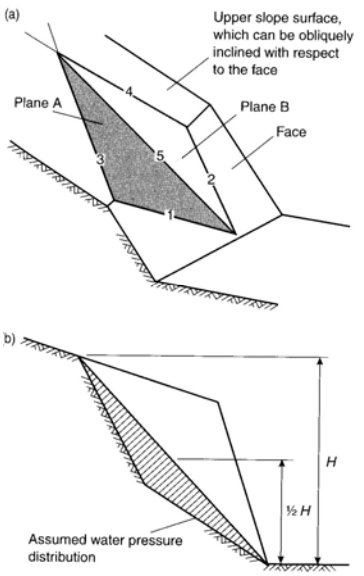

Slope stability
3D and toppling analysis

Classical wedge failure

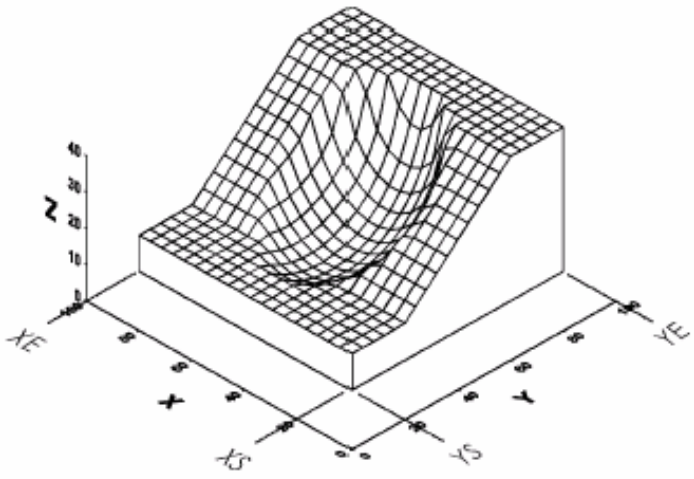
(Hoek and Bray, 1978)

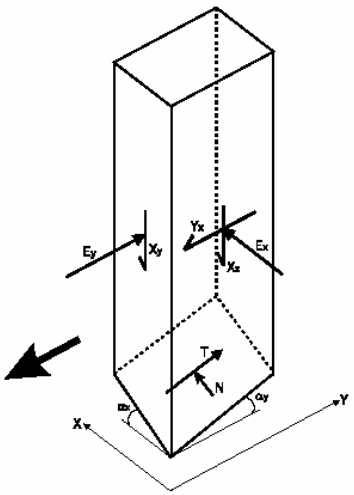




Bishop's Simplified Method of Columns

(Hungr, Geotechnique, 1987, Hungr et al., CGJ, 1989)



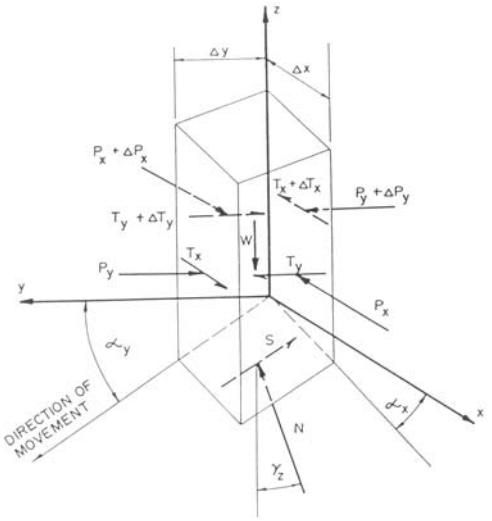


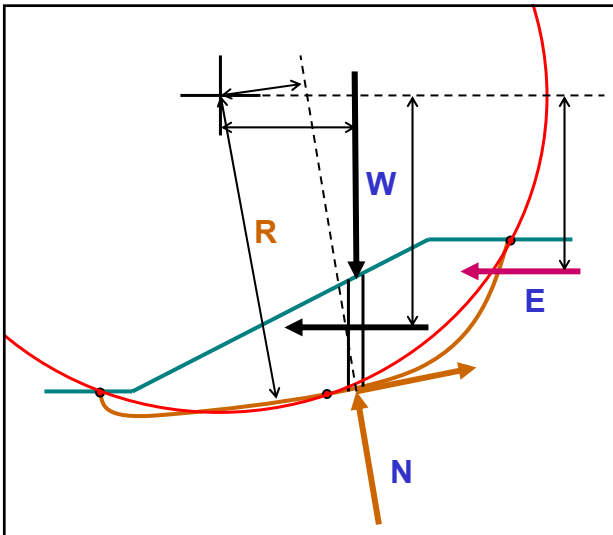
1st Bishop's Assumption: X=0 (no internal shear)

$$m_\alpha = \cos\gamma_z\left(1+\frac{\sin\alpha_y \tan\phi}{F\cos\gamma_z}\right)$$

γ_z=dip angle

$$N = \frac{W - cA\sin\alpha_y / F + uA\tan\phi\sin\alpha_y / F}{m_\alpha}$$

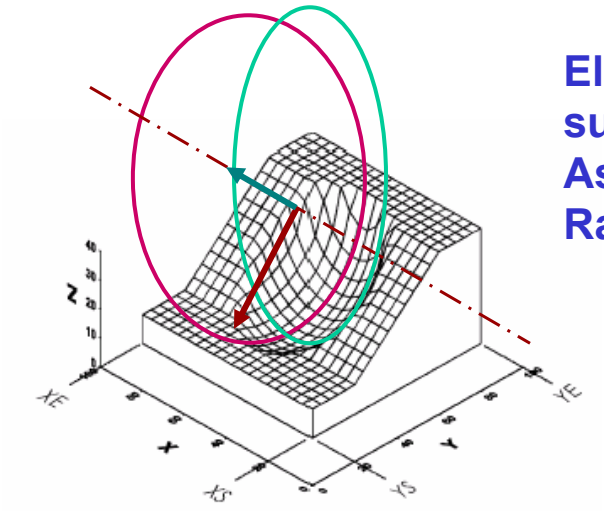




2nd Bishop's Assumption: Moment equilibrium

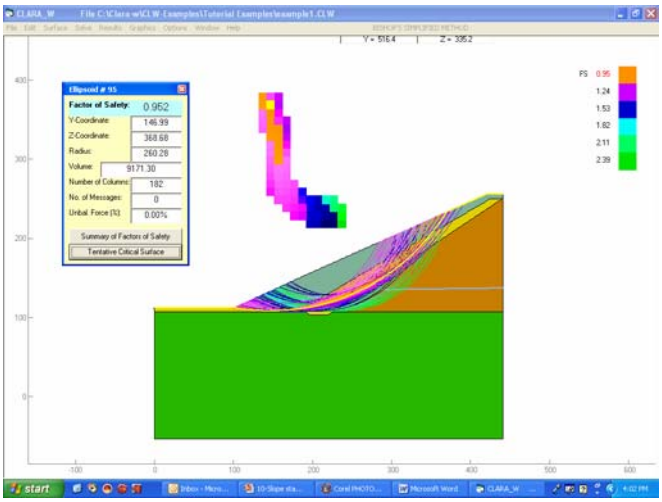
Fredlund-Krahn modification (1977)

$$F = \frac{\sum [cAR + (N - uA)/R \tan\phi]}{\sum Wx - \sum Nf \cos\gamma_z / \cos\alpha_y + \sum kWe + \sum Ed}$$

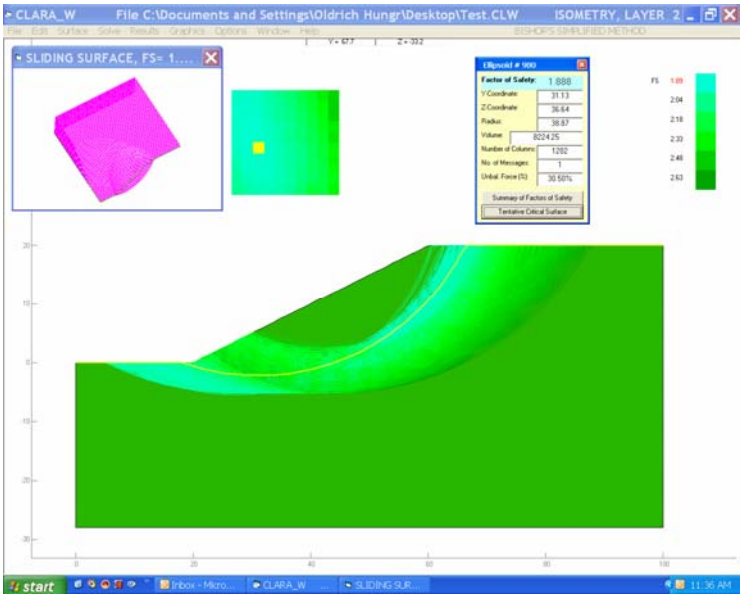


Ellipsoidal surfaces: Aspect Ratio=D/R

"Automatic search"

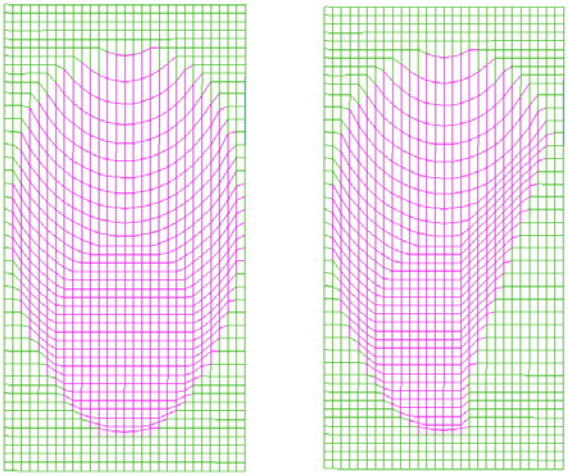


Grid search



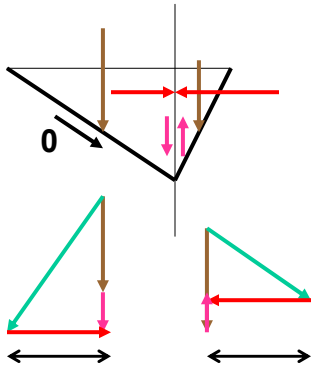
Lateral force equilibrium in 3D

Implicitly satisfied in symmetrical problems,
but NOT IN ASYMMETRICAL PROBLEMS



Lateral force balancing procedure

(Hungr, 1997)

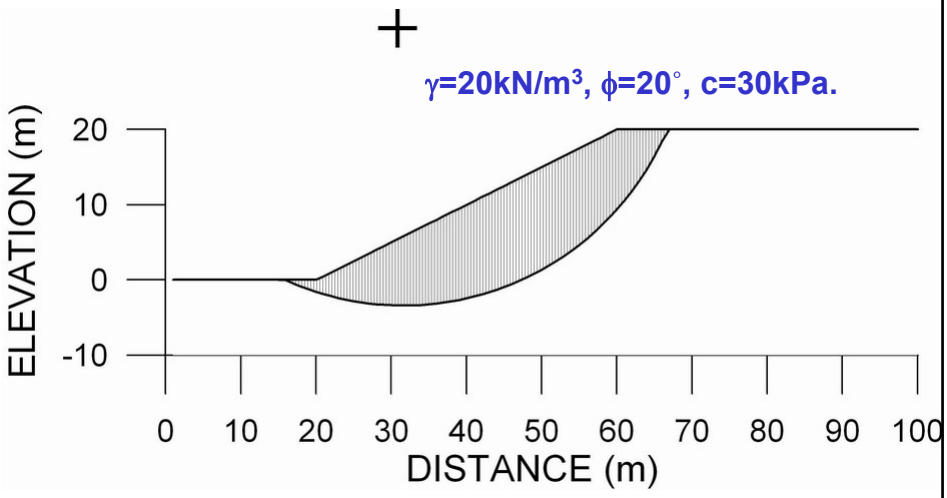


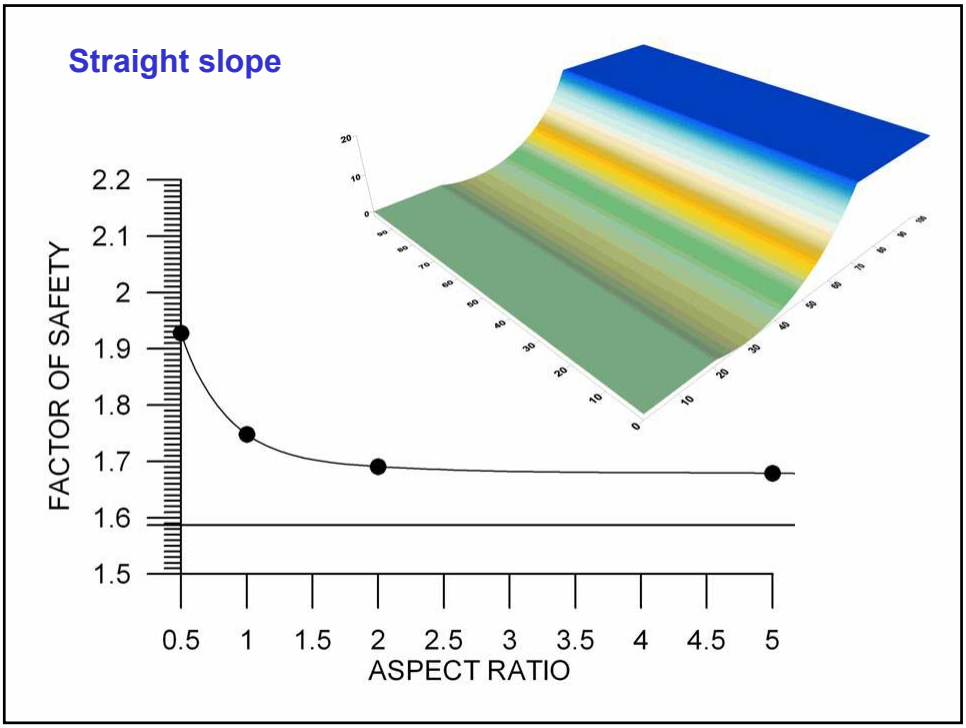
Forces equal

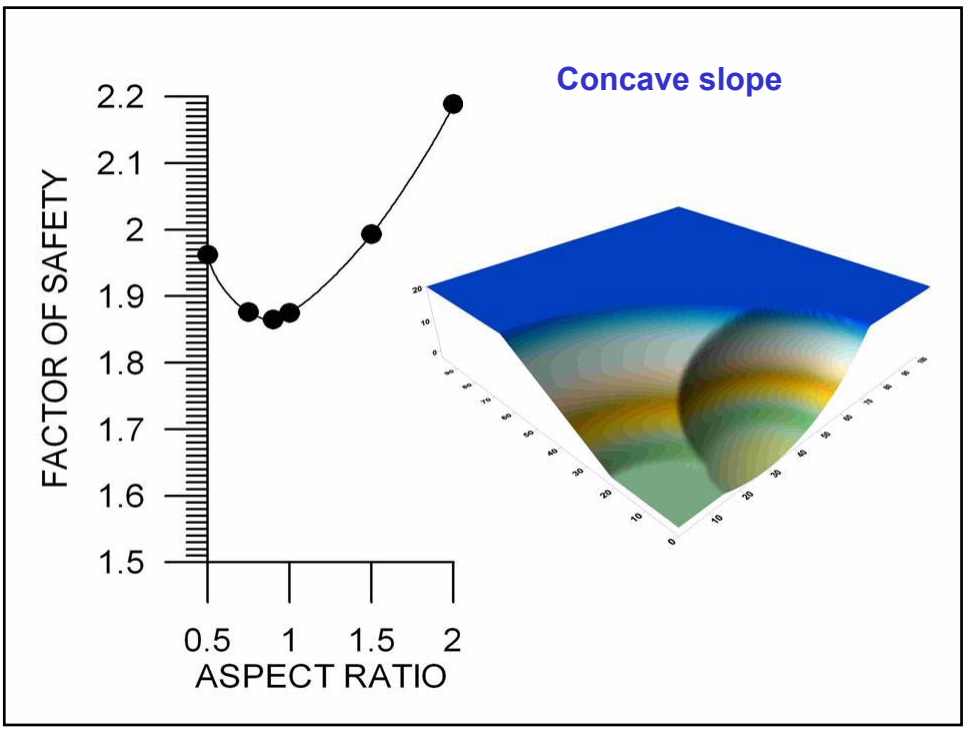
Internal shear couple:

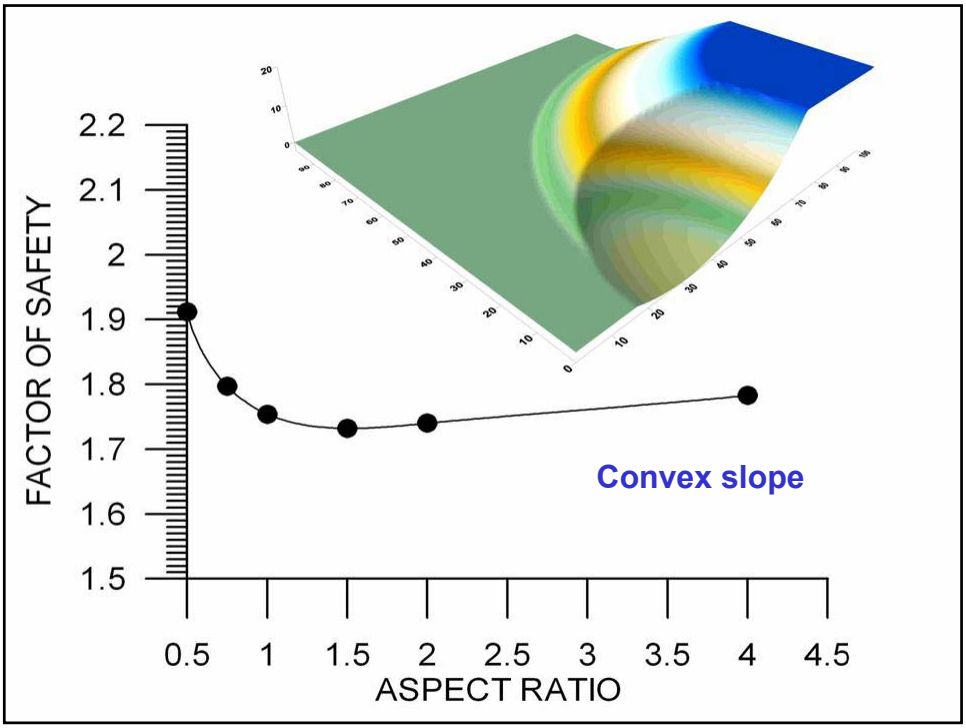
Add vertical interslice shear forces, proportional to the column weight. Iterate until equilibrium established.

Parametric study, Case 1



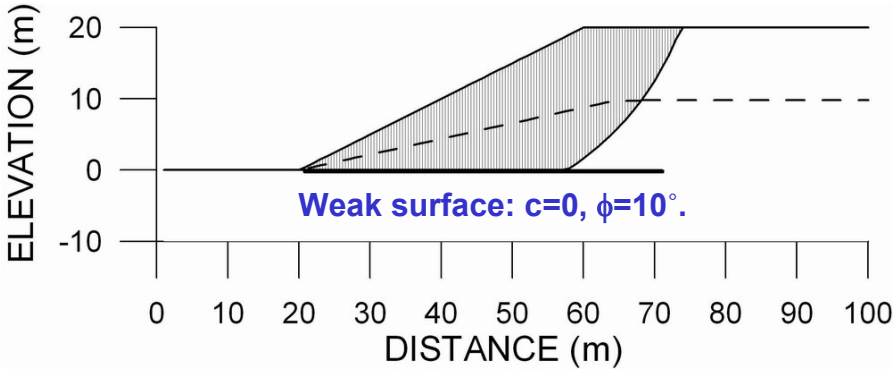

Straight slope
FACTOR OF SAFETY
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
ASPECT RATIO


Concave slope
FACTOR OF SAFETY
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
0.5
1
1.5
2
ASPECT RATIO

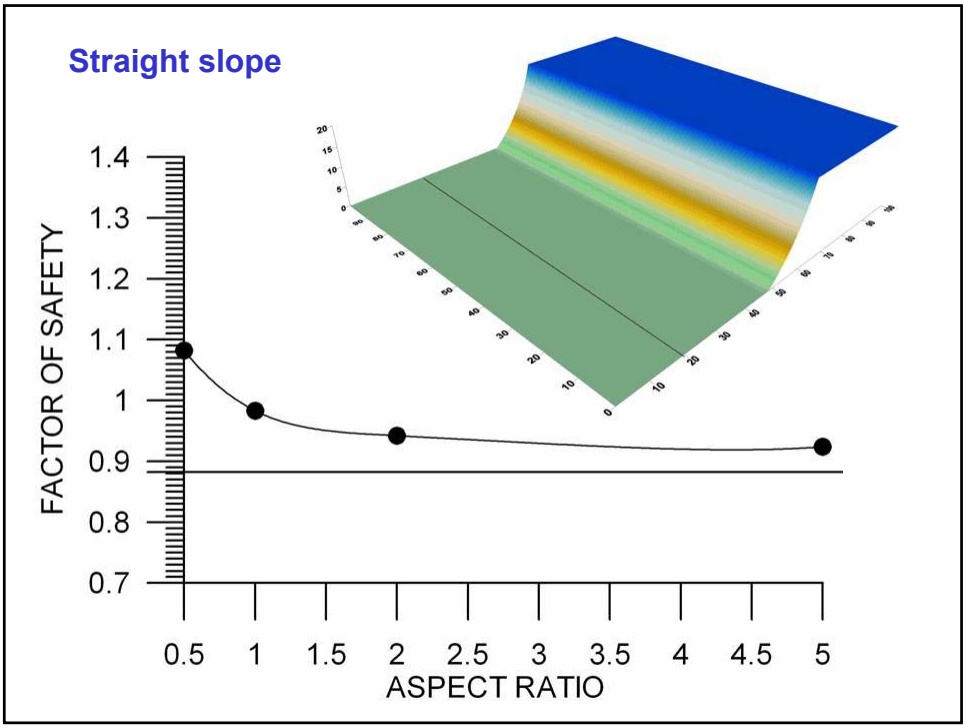


Parametric study, Case 2

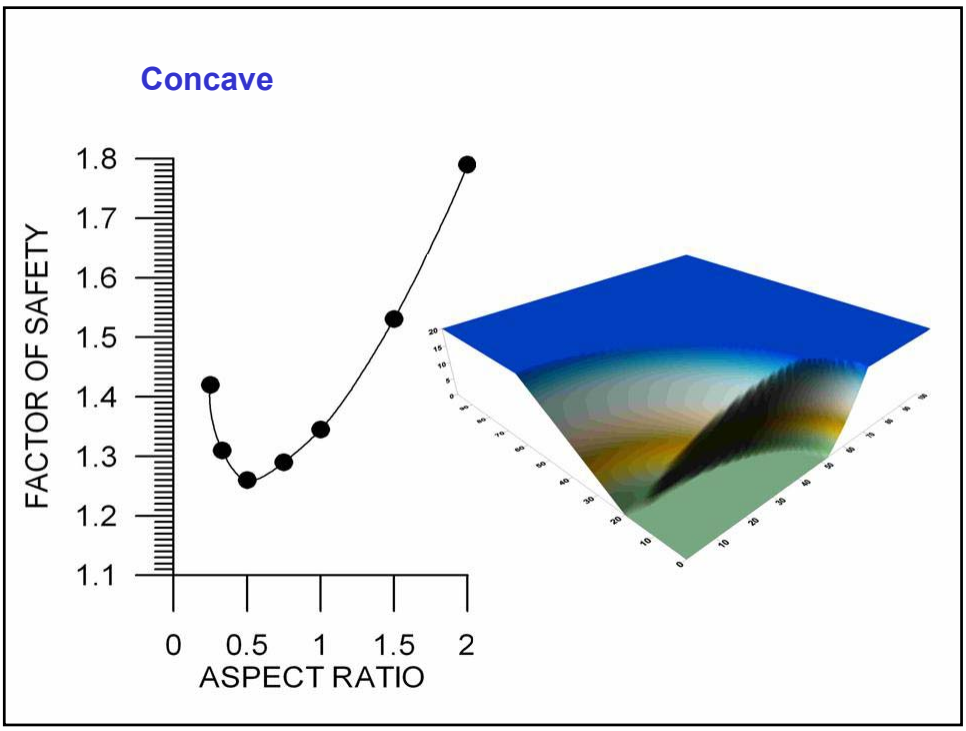
γ=20kN/m^3, ϕ=20°, c=30kPa.



Straight slope



Concave



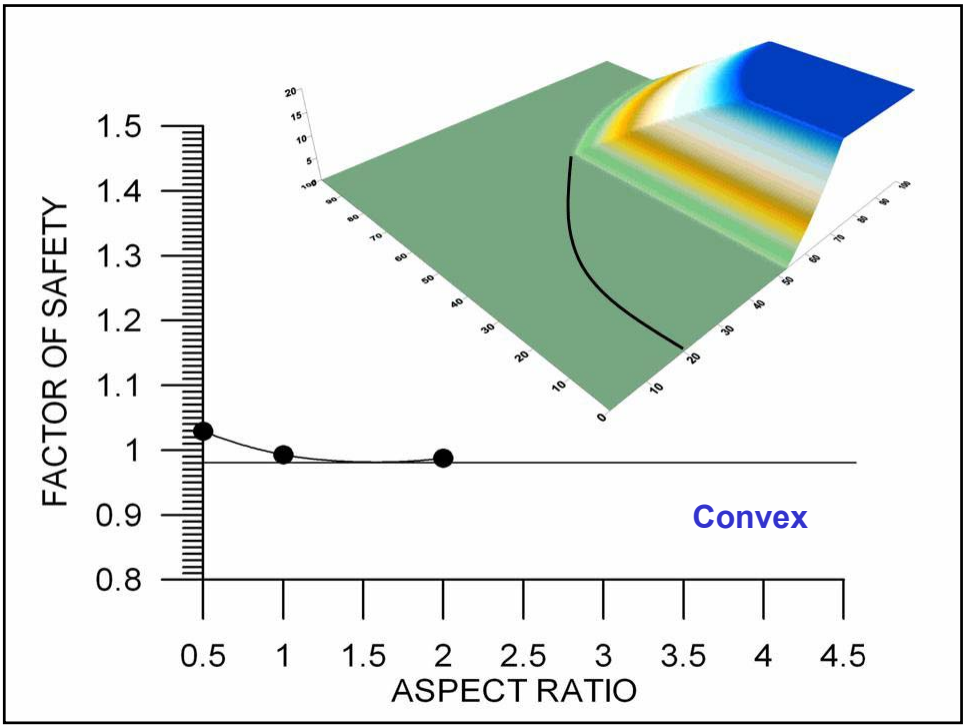
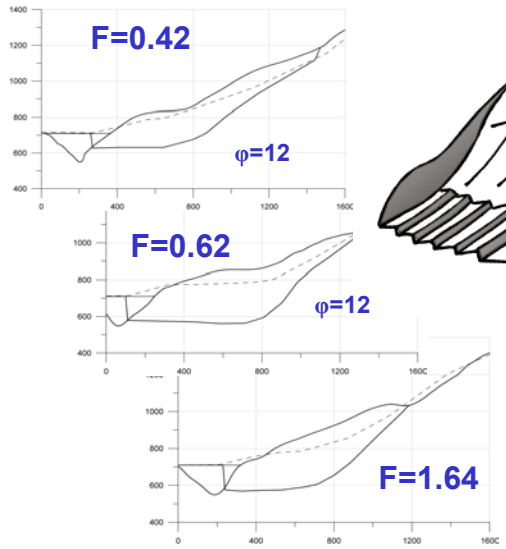


Table 1, Summary, Ellipsoidal Surfaces

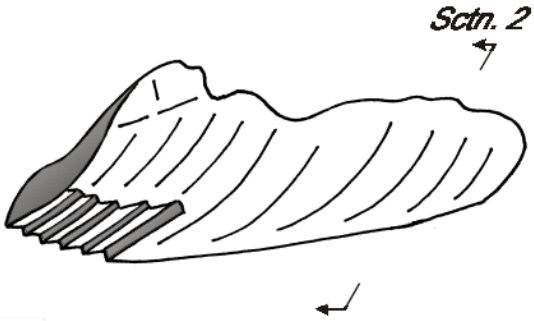
Slope	AR	Volume	F	%
Straight	∞	-	1.587	100
Concave	0.9	7560	1.865	117
Convex	1.5	10 100	1.732	109

Table 2, Summary, Compound Surfaces

Slope	AR	Volume	F	%
Straight	∞	-	0.885	100
Concave	0.5	6970	1.260	142
Convex	∞	17300	0.986	104



φ=36°, c=330 kPa

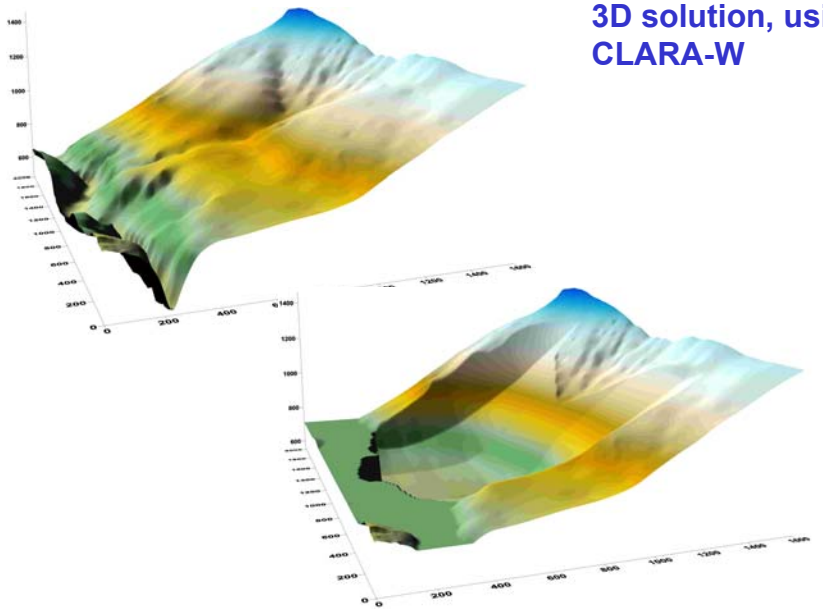


Future?

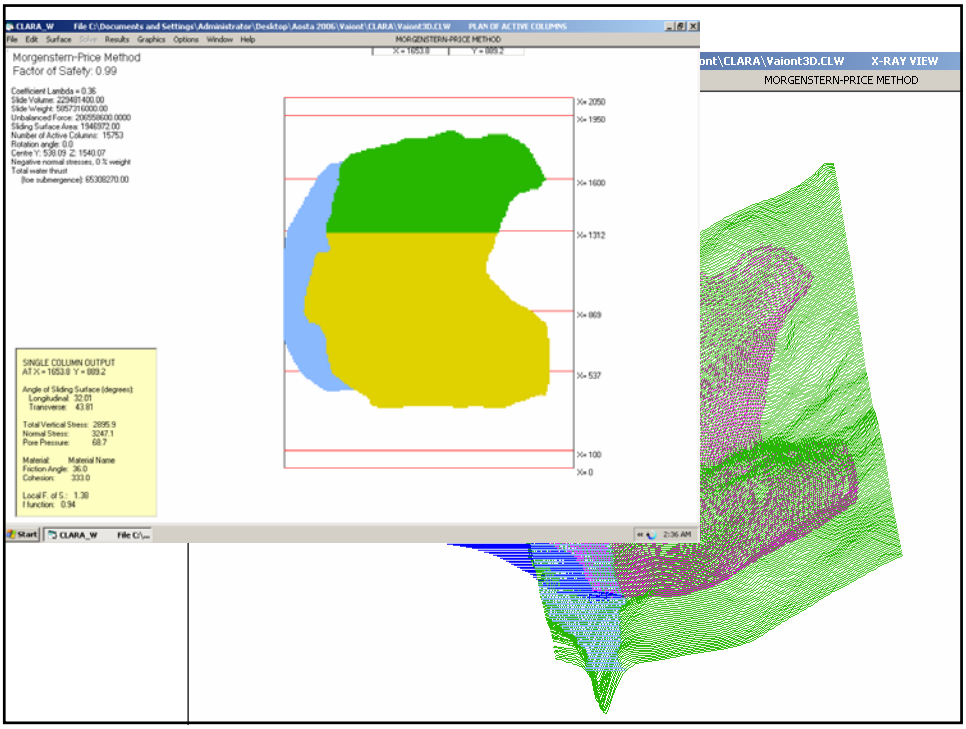
Vaiont:

A laterally-constrained slide

(Hendron and Patton, 1985)



3D solution, using CLARA-W



Conclusions:

1) The effects of plan curvature are not always easy to estimate

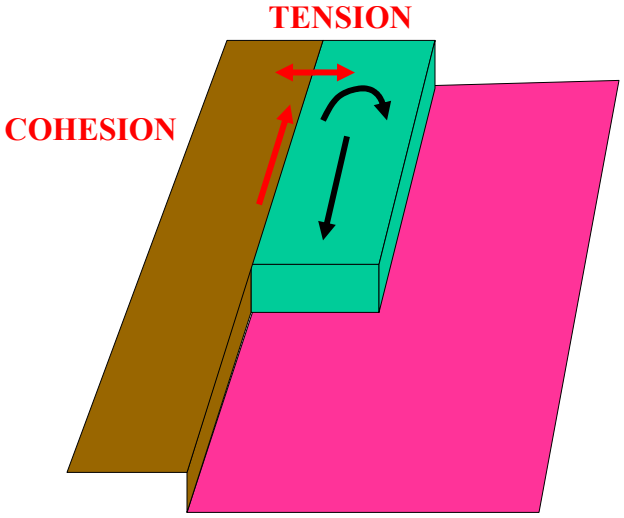
2) 3D analysis is not difficult, why rely on "rules of thumb"

3) Research needed to analyse asymmetric surfaces

Acknowledgment:

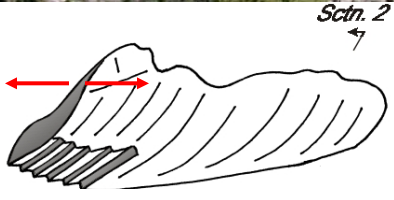
Spring, 2001 graduate class of EOSC 529, "Advanced Geotechnique", in the Geological Engineering Program at UBC

Strongly asymmetric slide



Strongly asymmetric slide

Cheakamus Canyon, 1996



Isometry of rupture surface (after Hendron and Patton, 1985)

Vaiont (1963)