Numerical Modelling of Earthquake Triggered Landslide in Jointed Rock Slope

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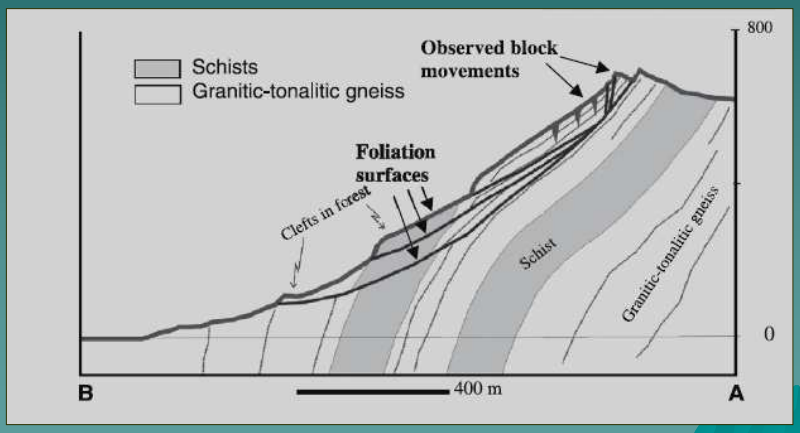
Case Study

- 700-m high rock slope in Western Norway
- The objective is to assess the static and seismic slope stability using UDEC

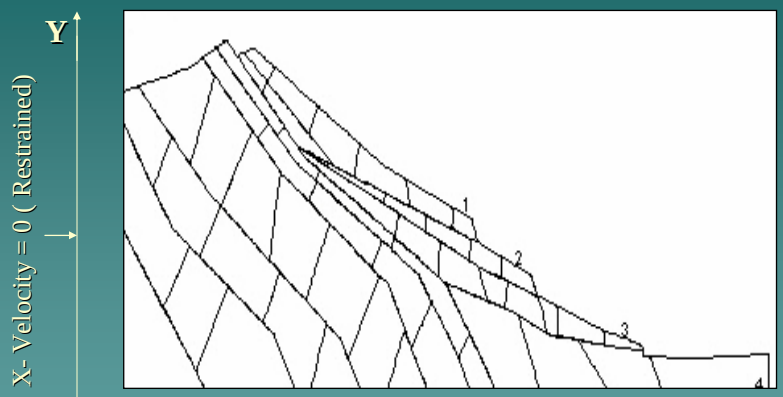
Geological Description of the Area

- Slope area ------ Granitoid gneiss with zones of schist (Robinson *et al.*1997)
- Average slope angle ~ 36º
- Cross-joints striking NW- SE
- Discontinuities are rough and undulating
- Joint walls altered with surface strains, others tightly healed

Cross-section of the slope showing the foliation planes and observed block movements (Bhasin *et al*. 2004)



UDEC Modelling



Geometrical Properties of Model
Barton *et al.* 1977, Lama *et al.* 1991

Blocks		Discontinuities	
Density	2680 kg/m3	Joint Normal Stiffness	1.615 e11 Pa
Elastic Modulus	40 e9 Pa	Joint Shear Stiffness	1.615 e11 Pa
Poisson's Ratio	0.25	Cohesion	0
		Tensile Strength	0
		Friction Angle	42^{o}

Static Stability Analysis

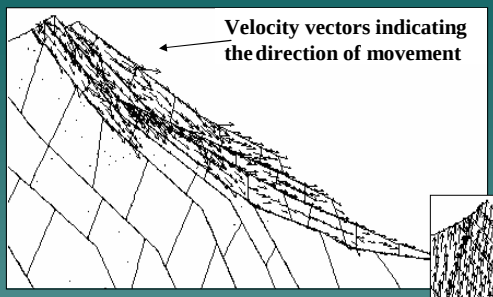
- Simulate the actual conditions
- Insitu stresses i.e. the ratio of the horizontal stress to vertical stress in the rock mass is taken unity (K_o=1)
- Analyzing under static conditions (i.e. gravity load analysis) until the equilibrium

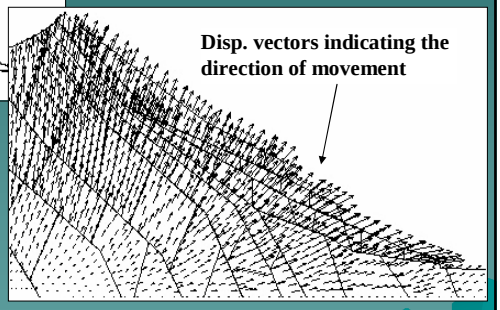
Effect of Reduced Joint Properties

- With time, there is a possibility of reduction in joint properties (Coulson 1972, Barton and Choubey, 1977 Bhasin *et al.*, 2004)
- Five Cases

Case A	$F_r = 42^o$
Case B	$F_r = 30^o$
Case C	$F_r = 25^o$
Case D	$F_r = 20^o$
Case E	$F_r = 15^o$

Effect of Reduced Joint Properties





Case	Friction angle	Static X-Displ. (cm)
A	42°	2.852
B	30°	2.330
C	25°	2.191
D	20°	3.067
E	15°	6.088

Case E

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As the friction angle reduces, shear displacement increases thereby indicating the unstability of the blocks

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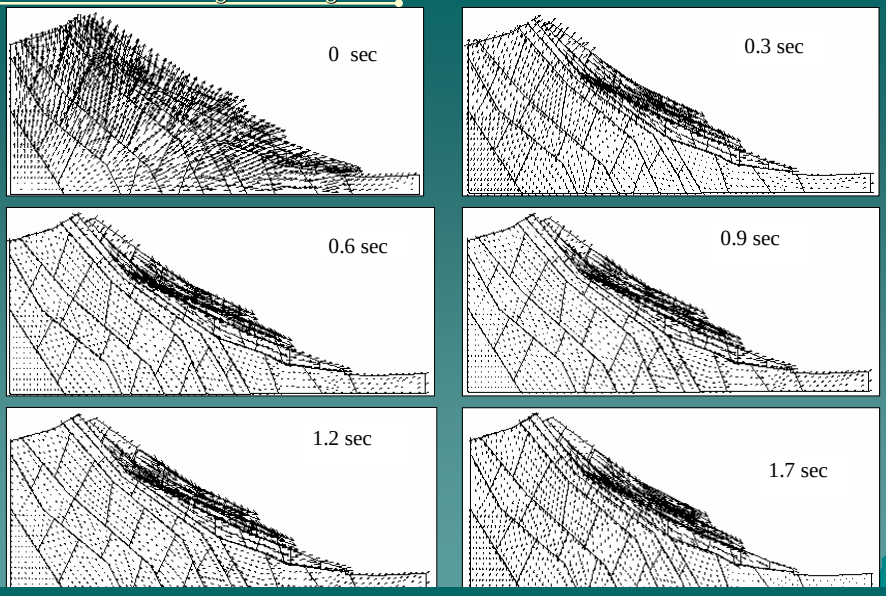
Seismic Input Motion

- After simulating the insitu and gravity load conditions, seismic input is applied
- A 3-Hz sinusoidal shear wave was applied at the base
- The stress wave corresponding to maximum velocity of 0.053 m/s is applied

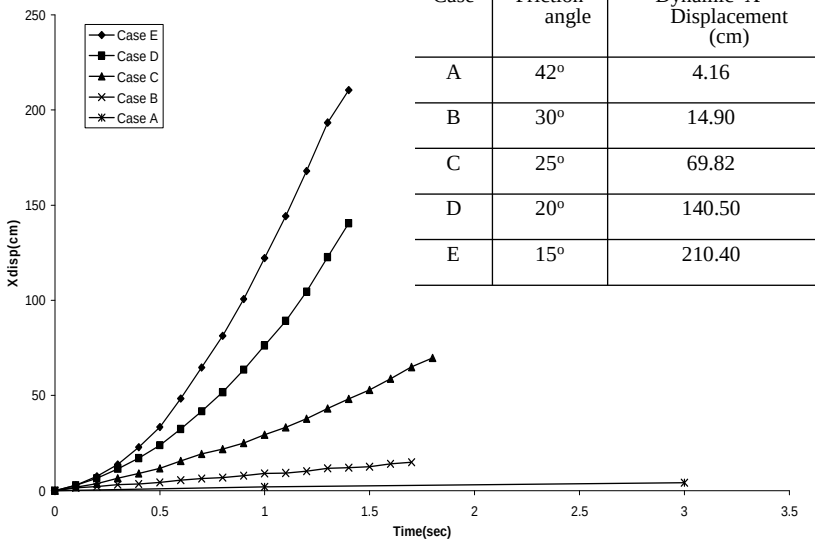


Failure Process of the slope in Case B, friction = 30^{o}

Time taken for each seismic analysis run = 72 Hrs (3 Days)

FAILURE OF SLOPE WITH FRICTION ANGLE 25º

Seismic Displacement



Case	Friction angle	Dynamic X-Displacement (cm)
A	42º	4.16
B	30º	14.90
C	25º	69.82
D	20º	140.50
E	15º	210.40

Conclusions

- This reduction in the shear strength at the joint interfaces leads to the instability of the slope resulting in sliding, rolling and rotation of rock mass down the slope
- Thus, careful estimation of interface properties is very essential to estimate the stability of the slopes

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THANK YOU

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In the early days, slope failure was always written off as an act of god

But today, attorneys can always find someone to blame and someone to pay for the damage – especially when the damage involves loss of life and property

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Varunavat Landslide Photos

Conclusions-2

- Case study of the slope consisting of jointed rock in western Norway has helped in gaining an insight into the failure mechanism of slope
- Reduction in interface properties is due to weathering action, ingress of pore water due to rain and gouge material
- Thus, careful estimation of interface properties is very essential to estimate the stability of the slopes
- Software's like UDEC or other distinct element codes which allows translational and rotational movement and therefore suitable for such problems
- Moreover seeing the unstability in the slope, measures like shotcreting and cable bolting should be carried out for the stability of such slope problem

- The dominant frequency at the rock site is in the range of 3-10 Hz
- Sinusoidal earthquake input applied at the base of the slope