Performance of Rock Reinforcement Elements subject to Shear Loading

Wouter Hartman

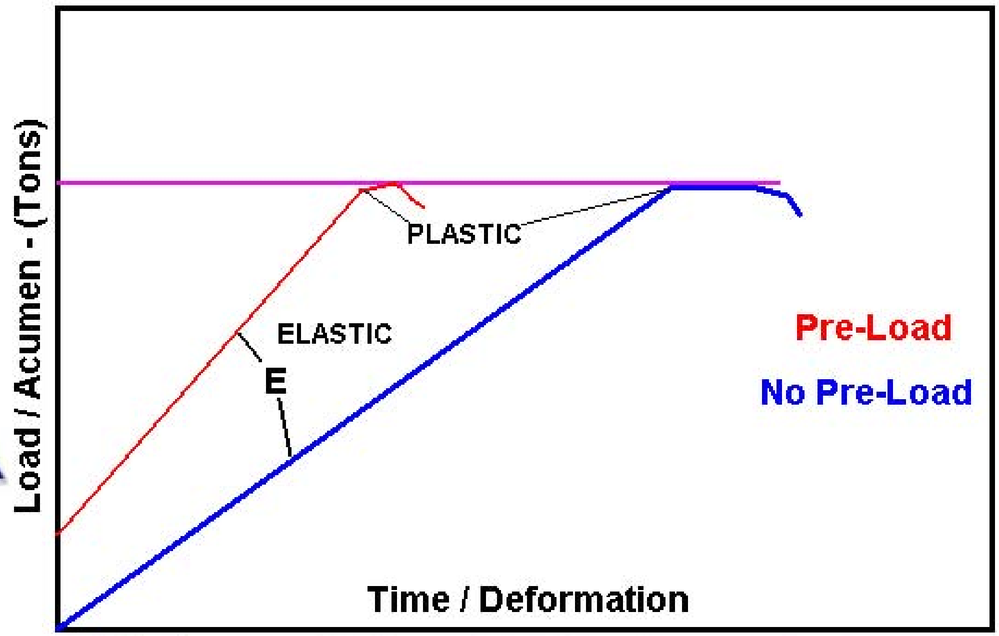
Senior Geotechnical Engineer

WARNING!

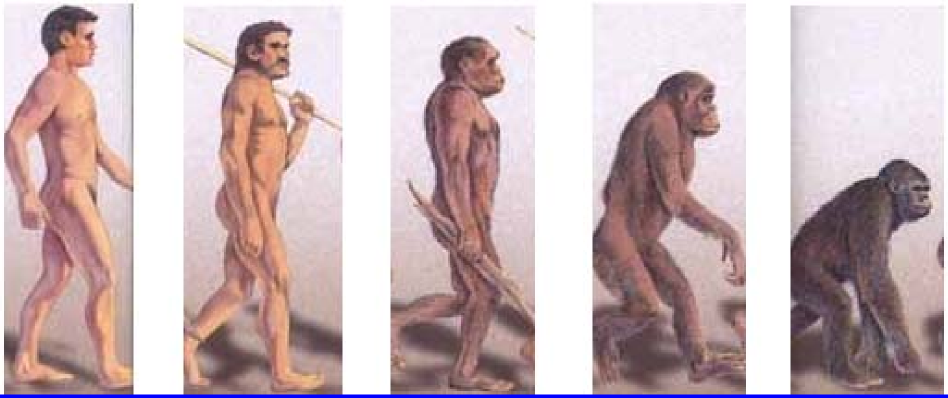
The following presentation may contain:-

- **Scenes of a sensitive nature and may offend some engineers – well it is intended for a more mature audience**
- **Some pictures may display some violence**
- **Language of an explicit scientific or engineering nature may or may not be heard and**
- **It is possible that you might just be subjected to the naked truth**

Rock Reinforcement subject to Shear Loading Research Philosophy



Enthusiam / Gusto



BACKGROUND

Nov '94 – 72 N RAW – Rock slab dislodged resulted in fatality – 75mm shotcrete failed in shear - (Anglo Gold – Vaal Reefs No. 2-Shaft - SA

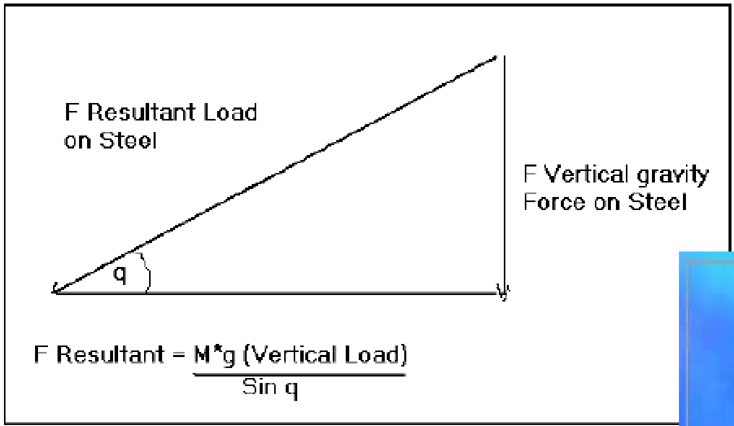
Jan '95 – Underground fatality 53 NE 51 Traveling way - (Anglo Gold – Vaal Reefs No. 2-Shaft - SA) – Rock bolts failed rock dislodged

August '95 – Underground fatality 56 N Haulage - rock bolt failure and tunnel sidewall failure – (Anglo Gold – Vaal Reefs No. 2-Shaft - SA)

March '97 – Underground mesh & lace crew 10 S 15 - fatality – Cable bolt failure on brow angle installation – (Impala Platinum – SA)

April '99 – Multiple fatality – Rock bolts bend and failed - over large intersection – direct shear tests (Guillotine) confirmed bolt shear strength = tensile strength – (Impala Platinum – No. 11- Shaft – SA)

BACKGROUND
– (From 2000 : Bushveld Conference – SA – Lessons learned in decline support design)



Angle of installation	Loading formulae for bolts	% Load reduction on steel	Additional calculation factor
90°	F_R=m*g	0	1
60°	F_R=1,15*m*g	13,4	1,15
45°	F_R=1,414*m*g	29,3	1,42
30°	F_R=2*m*g	50	2

BACKGROUND

May '2000 – UG2 Stopes throw blasting project - No. 1 Shaft – In-stope bolting at 60 degree angle bolts failed at almost two thirds of its tensile strength – no fatality - near miss – Impala Platinum

February '03 – Jandam Decline – Pajingo Goldmine – Nth Queensland – Large fall of ground - Near miss drill rig operator – Fault / dyke intersection, split set installation – Bolts on the drill rig boom failed in shear

March '03 – Stope footwall failure – Pajingo Goldmine – Cable bolt failure installed on the angle across fault – Near Miss shift boss

BACKGROUND

ACARP – AUSTRALIAN COAL ASSOCIATION RESEARCH PROGRAM

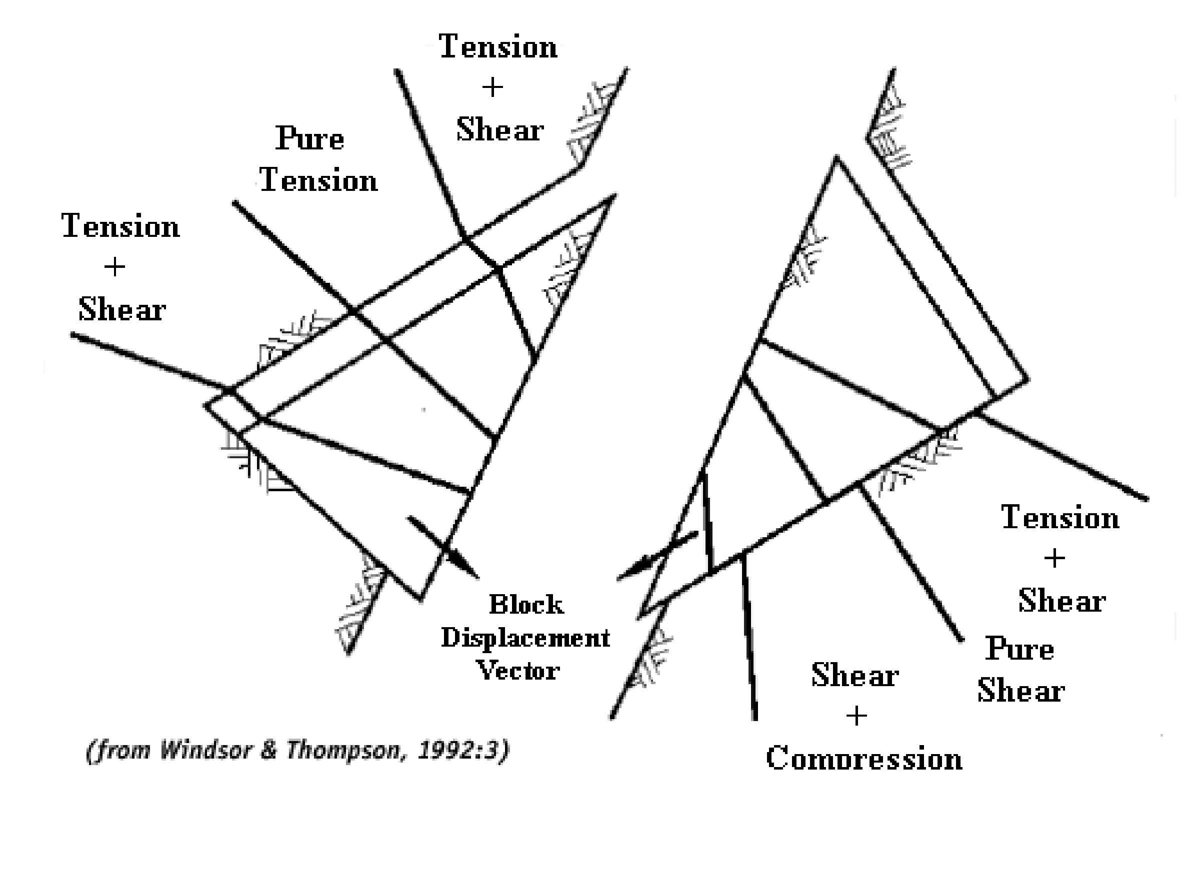
Provided funding for a project – Nov '02

Key Project objectives:-

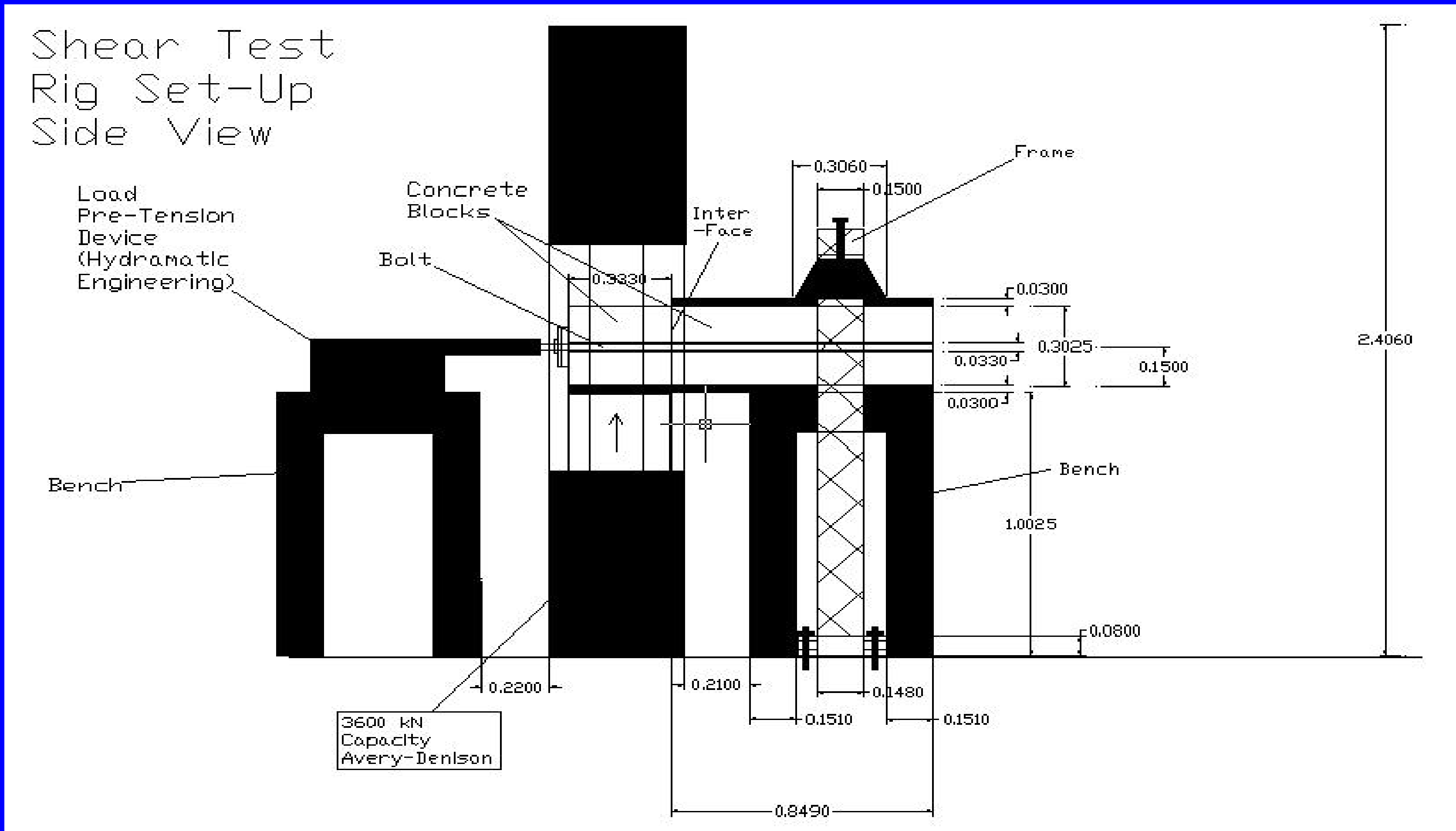
- **To study the effect of the variables on the performance of reinforcement elements subjected to shear loading conditions with a special emphasis on pre-loading (i.e. torque).**
- **A significant improvement in the level of understanding the performance of reinforcement elements under shear loads — a role that is fundamental to good roof control in Australian coal mines, open stopes, open-cut ramps, wall stability and underground tunnels.**

BACKGROUND – (From 2003 Sydney Presentation)

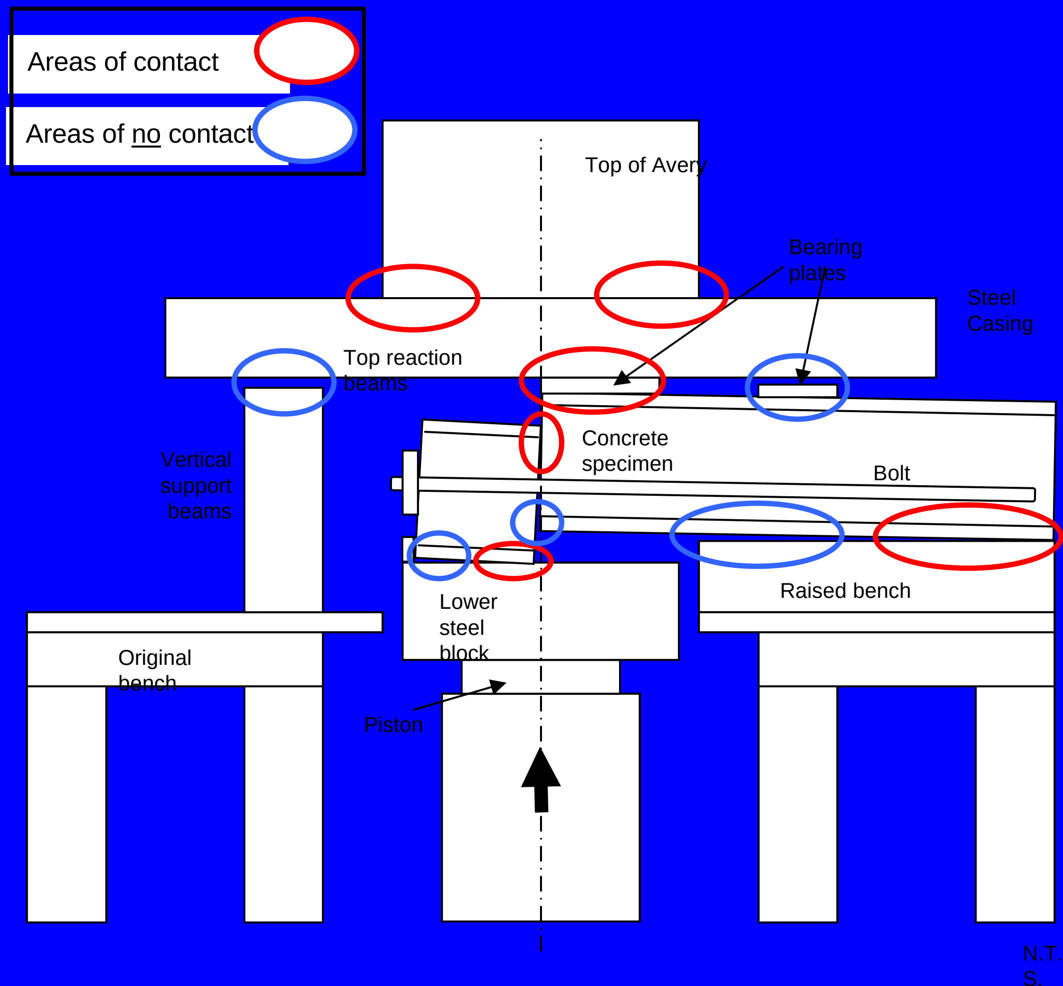
- Different mechanical behaviour depends on the reinforcement intersecting a discontinuity which opens or one which remains closed during block displacement



BACKGROUND
– (From 2003 Sydney Presentation)



BACKGROUND
Modifications to testing setup - 2004



Influencing Parameters:

i - The Rock Mass

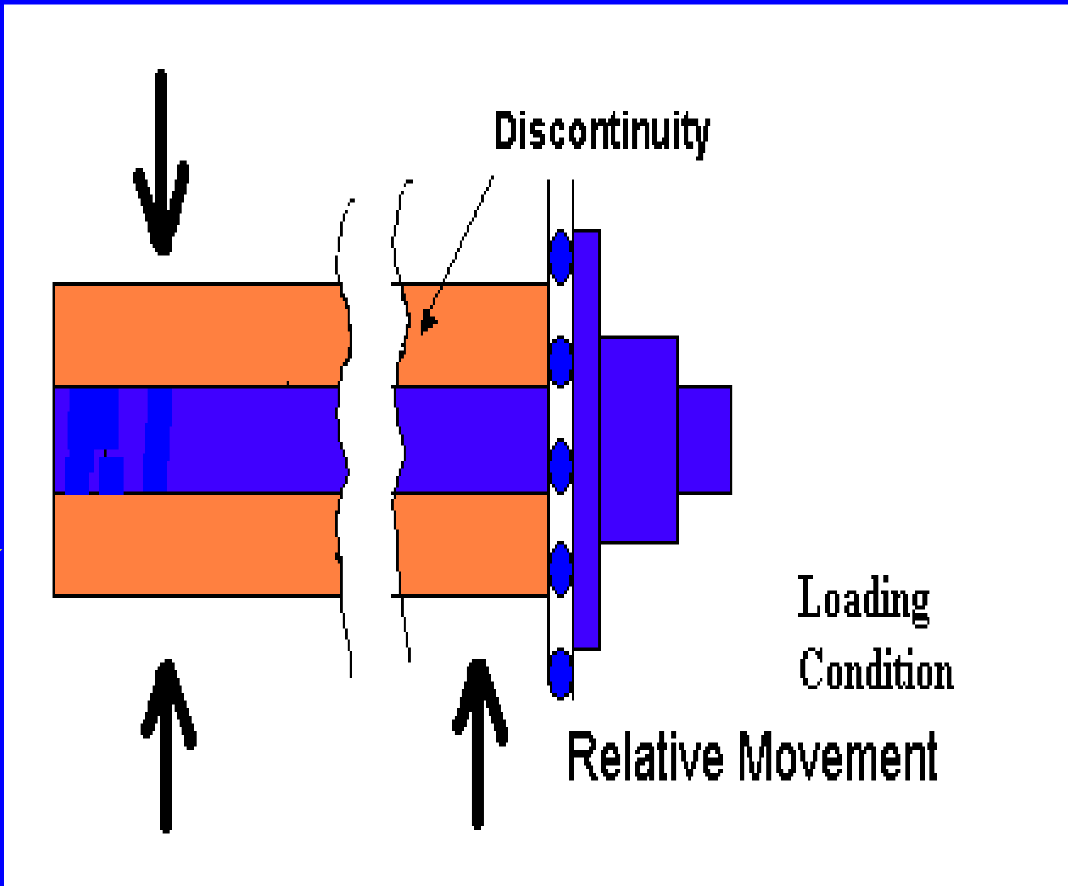
ii - The reinforcement element system

iii - Loading Conditions

Influencing Parameters:

i - The Rock Mass

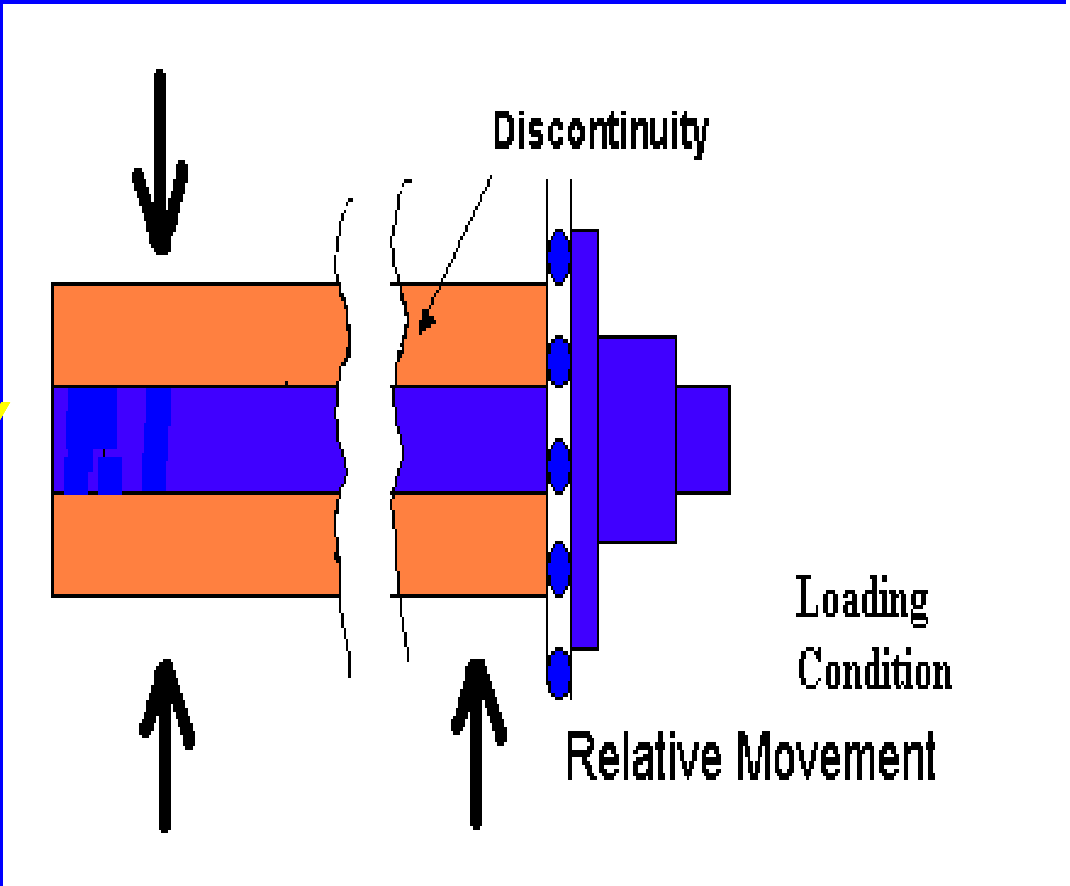
- ***Joint opening / aperture***
- ***Joint surface roughness***
- ***Joint strength***
- ***Dilatancy during shearing***
- ***Deformability of host rock***
- ***Rock deformability vs bolt deformability***



Influencing Parameters:

ii - The reinforcement element system

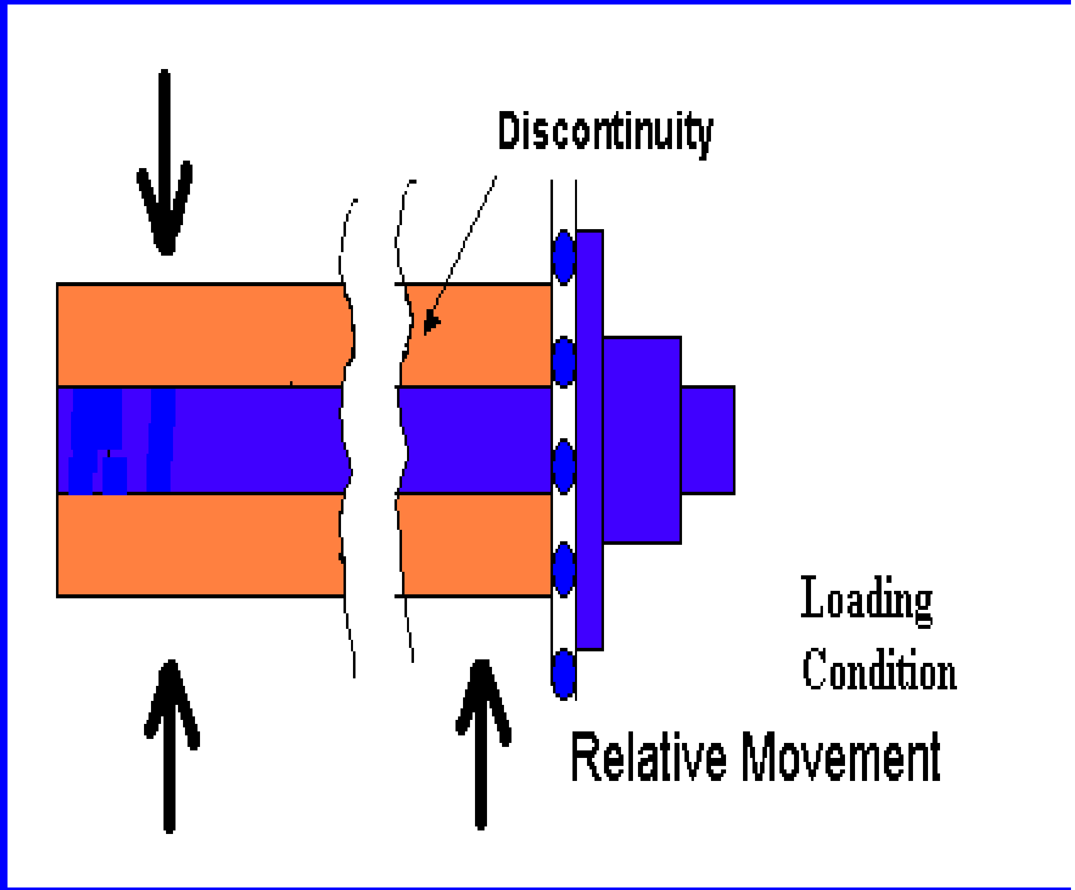
- ***Bolt material and its strength and deformability***
- ***Bolt deformability vs rock and encapsulation deformability***



Influencing Parameters:

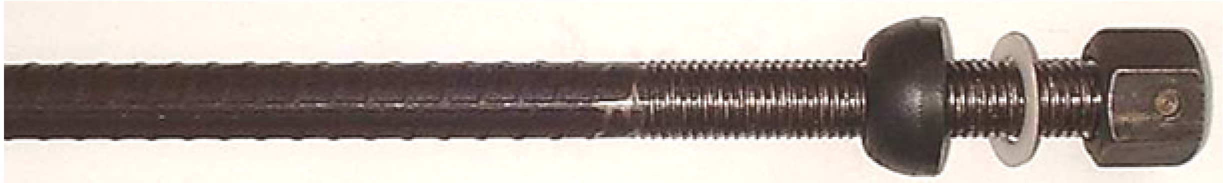
iii - Loading Conditions

- ***Pre-loading of bolts (tensioning & torque)***
- ***Normal stress on the shear surface***
- ***Shear displacement-induced tension & compression***



Reinforcement Element

Jennmar JBX High Tensile Roofbolt (Jennmar, 2004)



Summary of mechanical and physical properties for Jennmar JBX Roofbolt

Typical Yield Strength	240kN **~655 MPa**
Typical Ultimate Tensile Strength	335kN **~914 MPa**
Typical Elongation to Fracture	19-20%
Thread	24mm cold rolled, 150mm length I.S.O. M24, 3 Pitch
Nut	Hot Forged
Bolt length	**1.2m**
Bolt Diameter	**21.6mm**

Reinforcement Element Encapsulation

Summary of mechanical and physical properties for Minova Lokset Resin at an age of 24 hours (Minova, 2004):

Uniaxial compressive strength	> 60 MPa
Youngs modulus	> 6.5 GPa
Push out force[1]	> 72 kN

[1] Measured on a 22mm bolt, 50mm encapsulation in 28mm hole, with slow set resin

Laboratory Rock Mass (concrete) Steel Contained

Concrete Properties

E = 32.4 GPa

Joint Geometry : Smooth - Constant

The Testing Facility

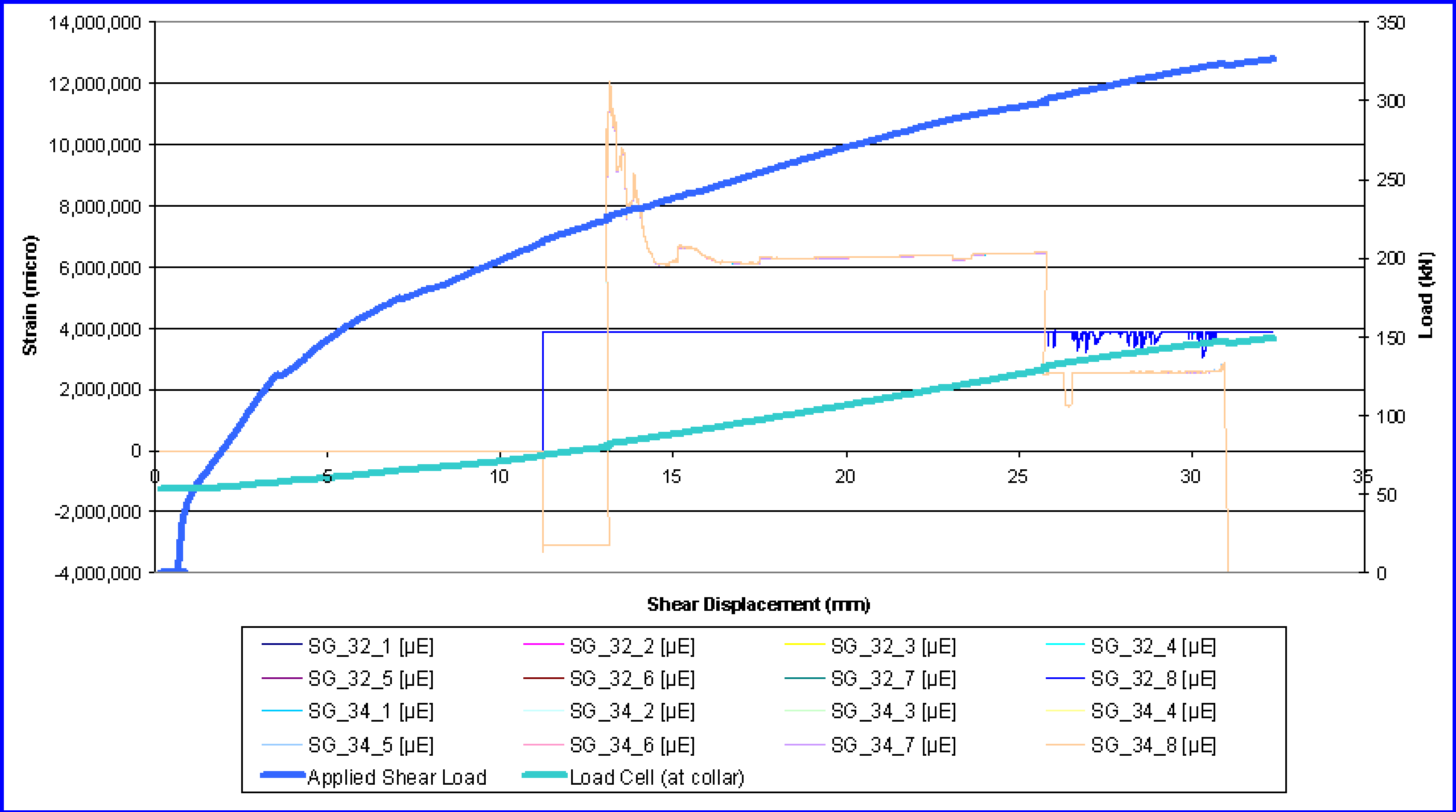
The Test and Resulting Gap

The Result

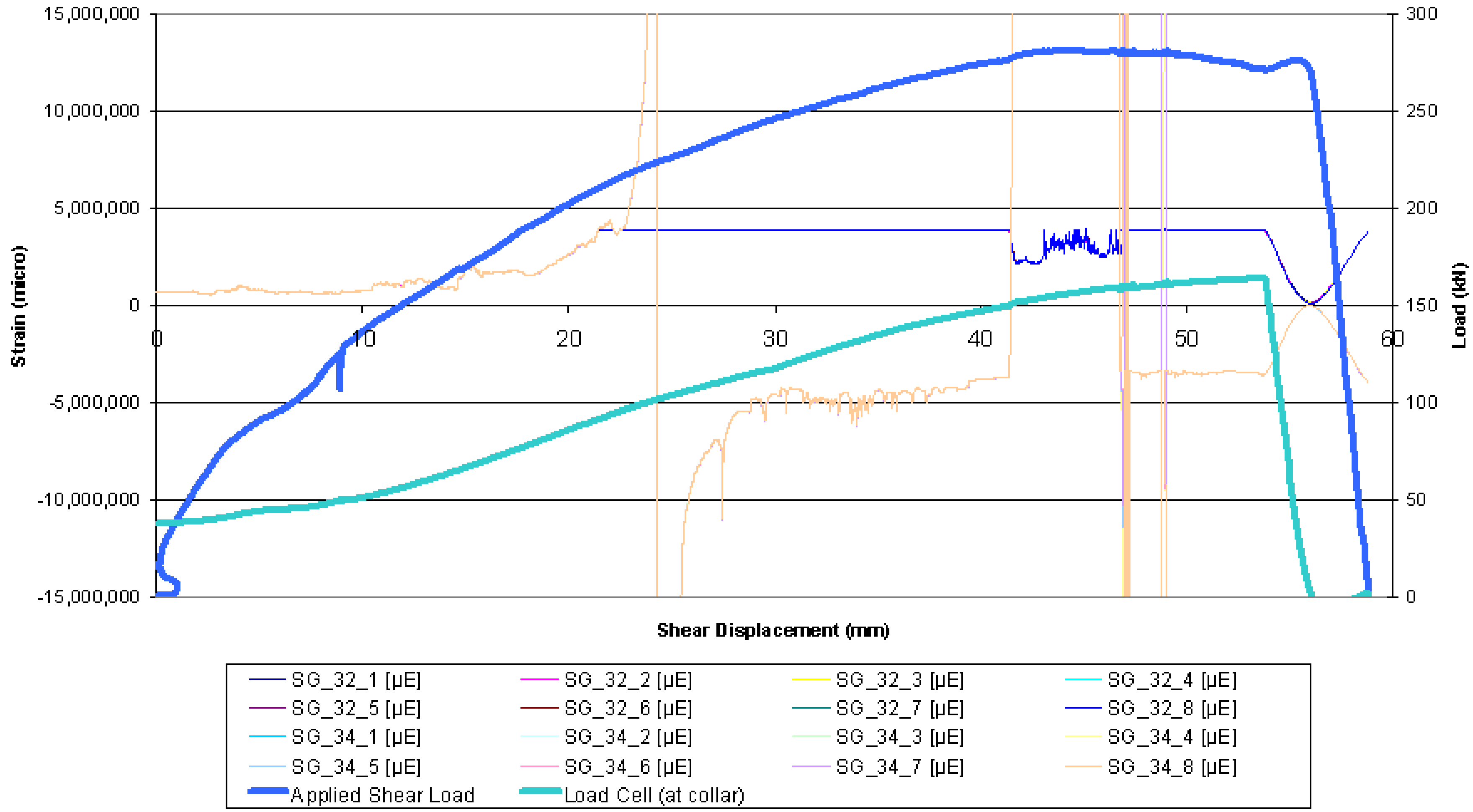
MANAGEMENT
ENGINEERING
ENVIRONMENT

The Result

The Result – 55kN pre-load



The Result – 38kN pre-load



Acknowledgements

MANAGEMENT
ENGINEERING
ENVIRONMENT

Somewhere across the Tasman – South Island
"Luck has nothing to do with it says the brave engineer….."