A study of the stability mechanism within shallow mining operations that will impact on the sustainability of Platinum Mines

The CSIR Research and Innovation Conference
Natural Resources and Environment
Mr Bryan Watson
Senior researcher
27 February 2006
Agenda

• Introduction
  What is rock engineering and the goals behind the programme?

• Significance
  What are the potential benefits of this research?

• Site description
  Stoping conditions under which the research was conducted.

• Observations & instrumentation
  Data collection for numerical models and development of behavioural theory.

• Elastic modelling
  Results of a numerical model compared to observations and instrumentation.

• Solutions
  Analytical and inelastic numerical modelling.

• Implications
  How the findings can be used.

• Conclusions
  Impact on short term profitability and efficiency and contribution to long term sustainability.
Introduction

• What is rock engineering?

Study of rock behaviour and support requirements around man-made excavations.

Wooden poles (elongate support)

30 m

Pillar

Haulage tunnel
Problem statement

- Support in shallow platinum mining operations is typically provided by in-stope pillars - a significant percentage of ore reserves are locked up in these pillars, which reduces the life of mine.

- If all pillars created in a single year across the Platinum industry were reduced in size by 1.0 m, approximately R1,0 billion profit could be realised annually.

- There is potential for increasing life-of-mine and thus a positive contribution towards sustainability.
Plan of instrumentation site
Strike slip fault to north of site
FOG adjacent to stability pillar
Support in the evaluated stope
Geotechnical and instrumentation results

Geological log

- Bastard Reef
- Mottled anorthosite (Middling 3)
- Spotted anorthosite (Middling 2)
- Anorthositic norite (Middling 1)
- Pyroxenite

Geotechnical log

- UCS Strength (MPa)
- Joints/m > 45°
- Joints/m < 45°
- Stress measurements

Stress (MPa) vs. Depth (m)

© CSIR 2006
www.csir.co.za
Virgin stress condition
Elastic convergence

Stress measurements

30 mm

31 mm
Elastic stress results

K-ratio = 1.2

K-ratio = 0.5

Horizontal stress (MPa)

Height above stope (m)

Depth (m)

Stress (MPa)

Depth (m)

Height above stope (m)
Strike section showing possible plate formation
Open vertical joint
Standard beam solutions

- **Built-in ends:**
  \[
  \sigma_{\text{max}} = \frac{\rho g L^2}{4t} + \sigma_h
  \]
  \[
  \delta_{\text{max}} = \frac{\rho g L^4}{32 Et^2}
  \]

- **Freely-supported:**
  \[
  \sigma_{\text{max}} = \frac{3\rho g L^2}{4t} + \sigma_h
  \]
  \[
  \delta_{\text{max}} = \frac{5\rho g L^4}{32 Et^2}
  \]
Freely supported beam

![Graph showing stress vs. intact beam thickness with deflection and stress values.](image)

- **Stress (MPa)**
  - 0
  - 50
  - 100
  - 150
  - 200
  - 250

- **Deflection (mm)**
  - 0
  - 50
  - 100
  - 150
  - 200
  - 250

- **Intact beam thickness (m)**
  - 0
  - 2
  - 4
  - 6
  - 8
  - 10
  - 12
  - 14

- **Estimated beam thickness from underground observations and geotechnical logging**
  - 7 m - 8.75 m

- **Base of beam**
- **Top of beam**
- **Measured**
- **Estimated**
- **Deflection**
Modified beam analysis (analytical solution)

- Built-in ends:
  \[ \sigma_{\text{max}} = \frac{k\rho g L^2}{4t} + \sigma_h \]
  \[ \delta_{\text{max}} = \frac{k\rho g L^4}{32Et^2} \]

- Freely-supported:
  \[ \sigma_{\text{max}} = \frac{3k\rho g L^2}{4t} + \sigma_h \]
  \[ \delta_{\text{max}} = \frac{5k\rho g L^4}{32Et^2} \]
Freely supported beam using modification

Estimated plate thickness from underground observations and geotechnical logging 7 m - 8.75 m

Min stress
Max stress
Measured
Measured
Deflection

Stress (MPa)
Deflection (mm)
Intact plate thickness (m)
Comparison between two freely supported beam methods

- Estimated beam thickness from underground observations and geotechnical logging: 7 m - 8.75 m

- Estimated plate thickness from underground observations and geotechnical logging: 7 m - 8.75 m
Shear plane
Inelastic modeling showing compression and tensile stress zones
Inelastic stress distribution above the centre of the panel

- Applied $K = 0$
- Applied $K = 0.5$
- Applied $K = 0.75$
- Applied $K = 1$

- Zone of vertical joints
- Underground measurements

$K$-ratio = 1.2
Implications of the findings
Significance of findings

Pillar
Conclusions

• The numerical and analytical analyses show that a complex beam or plate structure developed over the stope.
• The hangingwall behaviour is best described by a modified version of the freely supported beam theory.
• Stable stope spans may be determined by comparing the stress developed at the centre and edges of the beam to the rock strength.
• In-panel pillars left in old workings could possibly be partially or completely mined out on retreat at relative low cost.
• Extraction ratios of current workings can be improved slightly using the same procedure as for old workings.
Contributing authors:

- DP Roberts
- S Coetzer
- N Singh
- F Flanagan

Are acknowledged for their contribution