CHAMBER OF MINES OF SOUTH AFRICA

SYLLABUS AND REFERENCES FOR THE STRATA CONTROL CERTIFICATE

METALLIFEROUS MINING OPTION
Updated November 1998

1 PART 1 : THEORY

1.1 Basic principles of rock engineering

1.1.1 Terms, definitions and basic quantities:

The following basic terms, definitions and quantities are commonly used in rock engineering. You are required to:

- Define, explain, and where applicable give the units of:
- Mass, gravity, density, force, stress, strain, deformation, displacement, elasticity, uniaxial tension, uniaxial compression, triaxial compression, shear stress, virgin, stress, induced stress, principal stress, k-ratio of stresses, coefficient of friction, friction angle, cohesion, safety factor, rock mass, intact rock, rock quality designation (RQD).
- Calculate areas of the following shapes:
- Square, rectangle, triangle, circle, cylinder..
- Calculate the area mined from mine plans and area supported in tunnels by mesh and lacing.
- Calculate the aerial and volumetric percentage extraction for square or rectangular pillars in a regular bord and pillar layout.
- Calculate the volume and mass (given the density) of prisms with square, rectangular, or circular cross sections.

1.1.2 Intact rock strength

- Explain what is meant by each of the following:
- Rock fracture, peak strength, residual strength, brittle failure, ductile deformation, yield, effective stress, porepressure.
- Describe the following behaviour of rock in principle:
  - The stress-strain behavior of brittle rock in uniaxial compression.
  - The effect of confinement on rock strength
  - The effect of confinement on stress-strain behavior of rock samples – pay particular attention to what happens to rock after it has reached its peak stress.
- Explain the basis of the Coulomb and the Hoek-Brown criteria for intact rock strength
- Explain the significance of each parameter in the Coulomb and Hoek-Brown criteria.
- Calculate the strength of intact rock using the Coulomb and Hoek-Brown criteria

1.1.3 Rock joints and rock mass strength

- Describe the occurrence of rock joints on your mine, number of sets and their orientations
- Explain how the following factors affect the strength of rock joints - infilling type, infilling thickness, roughness, friction angle, water pressure.
- Explain in principle the shear box test for determining joint strength
- Explain the implications of rock joints on rock mass strength
- Explain how joints may affect excavation stability
- Use the equation of Barton and Choubey to calculate the strength of a joint
- Explain the significance of each parameter in the Barton and Choubey equation for joint shear strength
- Apply the Rock Mass Rating (RMR) and the Q-system to classify rock masses.
- Apply the RMR system together with the Hoek-Brown criterion to determine the strength of a rock mass

1.1.4 Suggested references

Brady & Brown. 2nd Ed. Rock mechanics for underground mining. Chapman & Hall, 1993. Chapter 3, 4 and 8.

1.2 Excavation stability

1.2.1 Stresses and rock behavior around stope excavations

- Describe how the stress distribution changes around tabular excavations from shallow to great depth and the implications on stability.
- Describe the interaction of the stresses around a stope with the ground surface at very shallow depths and the implications on stability.
- Describe the distribution and orientation of fractures typically found around stopes at great depth, in plan and in section
- Describe the pattern of fracturing due to the interaction of stopes and gullies at great depth.
- Explain what is meant by elastic and inelastic convergence.
- Describe typical closure and ride directions in stopes.

1.2.2 Stresses and rock behavior around tunnels and service excavations

- Make use of analytical equations to calculate the stresses at a point near a circular opening in rock
- Make use of analytical equations to calculate the stresses on the boundary of a circular opening in rock.
- Describe the stress concentration, directions of principal stresses and potential orientation of fractures around square, rectangular, circular and elliptical openings.
- Describe the effect the k-ratio on stress distributions around the above openings, e.g. do the stresses become greater or do they decrease when the k-ration changes.

- Describe the extent of stress induced fractures and the resulting displacements around tunnels at great depth
- Calculate the rock condition factor (RCF) to predict rock conditions in tunnel is developed in the stope fracture zone at great depth.
- Describe the type of fracturing one can expect around ore-passes in highly stressed ground, the resulting ore-pass shape and potential extent of fracturing.
- Explain how rock joints or bedding planes may result in beam or wedge instability in tunnels or large excavations and how tunnel shapes may be modified to rectify the situation.

1.2.3 Suggested references

Budavari, S. Rock mechanics in mining practice. SAIMM, 1986. Chapter 3 & 5

COMRO. Industry guide to the amelioration of rockbursts and rockfalls. 1988. Appendix E

1.3 Regional and support pillars

1.3.1 Functions of pillars

- Stope pillars for board and pillar mining.
- Yield pillars
- Crush pillars
- Regional stability pillars

1.3.2 Pillar strength and loading

- Describe the effect of width to height ration and rock strength on the strength of a pillar
- Explain the parameters and adjustments used in the method of Ozbay & Ryder to estimate the strength of support pillars.
- Apply the method of Ozbay & Ryder to estimate the strength of support pillars
- Explain the assumptions of the tributary area theory and apply it to determine the stress in a regular system of pillars
- Explain the criteria used to design regional stability pillars at great depth.

1.3.3 Pillar failure

- Describe the stress changes a crush pillar will go through from initial formation at the stope face to ultimate recompaction, using the model developed by Ozbay & Ryder.
- Sketch the complete stress-strain graph for a pillar at width to height ratios of 2,4,6 and 8 and comment on the implications on pillar design.
- Explain the potential failure modes of regional stability pillars at depth and the consequences of such failures
- Explain the meaning of the factor of safety in pillar design and comment on acceptable factors of safety for stable pillar systems.

1.3.4 Pillar layouts

- Make use of the above methods of pillar strength estimation and load calculation to design stable pillar layouts for shallow hard rock mines.

1.3.5 Suggested references

COMRO. Industry guide to the amelioration of rockbursts and rockfalls. 1988. Appendix D
Madden, B J. Squat pillar design in SA collieries. SANGORM Symp. Advances in Rock Mechanics in underground coal mining, Witbank, 1989.
Ryder, J A & Ozbay, M U. 1990. A methodology for designing pillar layouts for shallow mining. Proc. Static and dynamic considerations in rock engineering. Balkema, Rotterdam. Pp. 273 – 286.

1.4 Mining

1.4.1 Mining methods

Explain the layout, mining sequence, equipment and rock mechanics implications of each of the following mining methods:

- Scattered mining
- Longwall mining
- Up-dip mining
- Trackless mining in wide reefs

1.4.2 Rock breaking

- Describe the mechanism of breaking rock by explosives indication the importance of stemming, spacing, burden, hole length and hole diameter.
- Describe the different types of explosives used on your mine and the characteristics which make them suitable for their specific applications.
- Describe drilling rounds used for development ends and stopes
- Describe the method of detonation used in development ends and in stopes.
- Evaluate a given blast design for tunnels or stopes and identify poor design

1.4.3 Mine standards and codes of practice

- Explain in detail the codes of practice and mine standards relating to mine layout
- and strata control on your mine.
- Describe the functions and responsibilities of the rock engineering staff as defined
- in the code of practice of your mine.

1.4.4 Suggested references

Department of Minerals and Energy. 1996 Guidelines for the compilation of a mandatory Code of Practice to combat rock fall and rock burst accidents in metalliferous mines and mines, other than coal mines, 1996.

Hoek, E.* Brown ET. Underground excavations in rock. IMM London. 1980, Chapter 10.

1.5 Geology

1.5.1 Rock types

- Identify the rock types associated with your mine, discuss their relative strengths and explain how they were formed.
- Explain what is meant by the following and classify the rocks on your mine into:
- Sedimentary rocks, metamorphic rocks, igneous rocks.

1.5.2 Rock structures

- Know what the following rock structures are, explain how they affect the stability of
- Excavations and know how they were formed:
- Strata, bedding plane, cross bedding, ripple marks, folding, dykes, sills, normal
- Fault, reverse fault, slickensides, mylonite, gouge, stringers, striations.

1.5.3 Local geology

- Sketch the geological sequence at your local mines and describe the major structures

1.5.4 Suggested references

Lurie, J. South Africa geology, revised edition. 1987 Part A, Chapter 1 to 6

1.6 Support of excavations

1.6.1 Principles of tunnel support

- Explain the objectives of primary and secondary support in tunnels.
- Describe the principles of arch formation, suspension of blocks and beam formation using rockbolts
- Describe the principles for successful support during rockburst
- Explain the relative merits of rock reinforcement methods (e.g. bolts) against rock support methods (e.g. steel arches)

1.6.2 Support units for tunnels

- Describe the support principle of: full column resin bonded & grouted bolts, end anchored bolts, friction bolts (split sets) cone bolts and steel arches
- Explain how you would test the shear strength of resin or grout and determine the critical bond length.

- Describe how grouted and full column resin bolts should be installed.
- Describe how mechanical anchor bolts should be installed.
- Describe the function of wire mesh and lacing.

1.6.3 Tunnel support design

- Calculate support capacity and spacing for a tunnel based on dead weight of rock to be supported.
- Calculate the energy absorption capacity of support units given their load-deformation curves.
- Determine whether a given tunnel support layout is adequate for a given deadweight or dynamic loading condition.
- Design a support layout for tunnels using the principles of deadweight loading and dynamic loading.

1.6.4 Principles of stope support

- Explain how the rock to be supported in tabular stopes changes with increasing depth.
- Describe the types of support which would be adequate at different depths: shallow, intermediate and great depth.
- Explain the effect of seismicity on rock behavior and what type of support is required to control rock during a seismic event.
- Explain the functions of face support, internal support and regional support in tabular stopes.

1.6.5 Stope support elements

- Describe the construction method, load-deformation characteristics and areas of application of the different types of stope support used on your mine.
- Explain the effect of loading rate on timber
- Explain how backfill may be used to provide local and regional support.
- Explain how mine tailings backfill is recovered, distributed to the underground workings and placed in a stope.
- Calculate the support resistance and energy absorption capacity of support elements in a support layout.

1.6.6 Stope support design

- Apply the support design methodology in the guidelines for preparing a code
- of practice to design support for a given set of rock conditions and given support
- types under static and dynamic loading.
- Evaluate a given support system in terms of the methodology presented in the
- guidelines for preparing a code of practice for rock falls and rock bursts.

1.6.7 Suggested references

COMRO. Industry guide to the amelioration of rockbursts and rockfalls. 1988, Chapter 3, Appendix E, F.
Department of Minerals and Energy. Guidelines for the preparation of a mandatory code of Practice.

1.7 Testing and monitoring methods

1.7.1 Rock strength tests

Describe, in principle, the testing equipment, method of sample preparation and testing Procedure for:

- Uniaxial compression tests on rock samples
- Point load testing
- Brazilian indirect tensile strength
- Triaxial compressive strength tests

1.7.2 Monitoring

- Describe the objectives of monitoring
- Describe in principle how you would monitor stope closure, tunnel sidewall dilation, depth of fracturing in sidewalls, bedding separation in the hanging wall of a stope.
- Describe each of the following instruments, explain what they measure and how it is measured:
  tape, rod and wire extensometers, doorstopper and triaxial stress cells, closure meter, borehole-scope
- Know how to install and take readings of monitoring equipment used on your mine.
- Interpret data obtained from the above monitoring equipment to identify impending instability, rock failure, opening of fractures in rock, loosening of rock.

1.7.3 Suggested references

Brandy & Brown. 2nd Ed. Rock mechanics for underground mining. Chapman & Hall, 1993. Chapter 4 & 18

2. PART 2 : PRACTICAL

2.1 Mine plans

2.1.1 Plan interpretation

- Identify the plan symbols which are used on your mine.
- Explain the co-ordinate system used on your mine
- Plot offset measurements on mine plans
- Draw sections through mine plans to show changes in elevation of seams and effects of geological structures such as faults of dykes.
- Transfer information between plans of different scales.
- Determine the mean dip and strike of a seam using peg elevations on mine plans.
- Locate yourself and determine orientations in underground workings using mine plans.
- Examine stope plans and identify deviations from prescribed shapes.
- Examine stope plans and identify potential rock related problems due to face shapes or geological structures.

2.2 Stope stability

2.2.1 Underground inspection of stope excavations

- Note the position of boxholes, gullies, travelling ways and crosscut intersections in stopes.
- Identify dangerous roof conditions, brows, slips and faults and indicate what support is required according to the mine codes of practice.
- Identify rolls, faults, dykes and folds and transfer this information to mine plans.
- Make use of stope plans to check whether pillars and face shapes are correct.
- Identify stope fracturing and major joint sets.
- Identify the causes of falls of ground.
- Sketch and describe falls of ground in stopes.

2.2.2 Practical support installation in stopes

- Demonstrate how stope support types used on your mine should be installed.
- Demonstrate how temporary supports should be safely removed.
- Assess installed stope and gully support and recommend remedial measures if inadequate.
- Assess the performance of pillars in stopes.
- Recommend additional support in poor or dangerous ground conditions where mine standards are inadequate.

2.3 Tunnel stability

2.3.1 Inspection of tunnel excavations

- Identify stress fracture patterns and major joint sets in tunnels.
- Identify faults and dykes and transfer this information to mine plans.
- Identify dangerous brows or friable, blocky ground that requires additional support.
- Identify blast fractures and barrels of blast holes.
- Sketch and describe falls of ground in tunnels.

2.3.2 Practical installation of tunnel support

- Indicate the correct location and orientation of support for tunnels and for breakaways.
- Identify departures from recommended support.
- Identify difficulties which may have necessitate departures from recommended support.
- Demonstrate the correct installation procedure of support types used in your mine.
- Identify poor installation of support and recommend remedial measures.
- Recommend additional support in situations where mine standards are inadequate.
- Identify failed support and the mode of failure.

2.4 Practical geology

- Identify samples of the main rock types found on your mine and classify them as
- sedimentary, igneous or metamorphic.
- Identify the main rock types in underground workings
- Point out weak layers or other important horizons in underground workings.

2.5 Monitoring

- Install monitoring equipment used on your mine
- Take measurements on monitoring equipment used on your mine