SOUTH AFRICAN NATIONAL INSTITUTE OF ROCK MECHANICS

CHAMBER OF MINES OF SOUTH AFRICA
CERTIFICATE IN ROCK MECHANICS

PART 3-3

MASSIVE UNDERGROUND MINING (HARD AND SOFT ROCK)

SYLLABUS

PREAMBLE

TOPICS COVERED

This is a specific mining type paper covering rock mechanics practice applicable in massive mining environments in hard and soft rock at all depths.
The rock engineering knowledge required here is thus of a specific nature, relating to the mining of massive orebodies in hard and soft rock at shallow, moderate and great depth.

CRITICAL OUTCOMES

The examination is aimed at testing the candidate's abilities in the six cognitive levels: knowledge, comprehension, application, analysis, synthesis and evaluation. Thus, when being examined on the topics detailed in this syllabus candidates must demonstrate their capacity for :

- Comprehending and understanding the general rock engineering principles covered in this syllabus and applying these to solve real world mining problems
- Applying fundamental scientific knowledge, comprehension and understanding to predict the behaviour of rock materials in real world mining environments
- Performing creative procedural design and synthesis of mine layouts and support systems to control and influence rock behaviour and rock failure processes
- Using engineering methods and understanding of the uses of computer packages for the computation, modelling, simulation, and evaluation of mining layouts
- Communicating, explaining and discussing the reasoning, methodology, results and ramifications of all the above aspects in a professional manner at all levels.

PRIOR LEARNING

This portion of the syllabus assumes that candidates have prior learning and good understanding of :

- The field of fundamental mechanics appropriate to this part of the syllabus
- The application and manipulation of formulae appropriate to this part of the syllabus as outlined in the relevant sections of this document
- The terms, definitions and conventions appropriate to this part of the syllabus as outlined in the relevant sections of this document.

STUDY MATERIAL

This portion of the syllabus assumes that candidates have studied widely and have good knowledge and understanding of :

- The reference material appropriate to this part of the syllabus as outlined in the relevant sections of this document
- Other texts that are appropriate to this part of the syllabus but that may not be specifically referenced in this document
- Information appropriate to this part of the syllabus published in journals, proceedings and documents of local mining, technical and research organisations.

SYLLABUS

2 GEOTECHNICAL CHARACTERISTICS

2.1 GEOLOGY

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Identify and describe the rock types associated with massive hard rock and soft rock orebodies
- Describe, explain and discuss how the rock types associated with massive orebodies were formed
- Sketch, describe and discuss geological sequences associated with massive orebodies
- Sketch, describe and discuss major geological structures associated with massive orebodies.

2.2 ROCK STRENGTH

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the compressive strengths of rock types associated with massive hard rock and soft rock orebodies
- Describe, explain and discuss the tensile strengths of rock types associated with massive hard rock and soft rock orebodies
- Describe, explain and discuss the relative rockmass strengths of rock types associated with massive hard rock and soft rock orebodies

- Apply the above knowledge to the design of various types of mine workings in massive orebodies.

2.3 ROCKMASS CHARACTERISTICS

2.3.1 GEOTECHNICAL ROCKMASS CLASSIFICATION

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the geotechnical characteristics of rock types associated with massive orebodies
- Describe, explain, discuss and apply standard rockmass classification and assessment systems to predict excavation stability
- Describe, explain, discuss and apply Barton's Q system to classify rockmasses
- Describe, explain, discuss and apply Bieniawski's RMR system to classify rockmasses
- Describe, explain, discuss and apply Laubscher's MRMR system to classify rockmasses
- Apply rockmass classification results to determine the stability of mining excavations
- Apply rockmass classification results to determine the stability of unsupported spans
- Apply rockmass classification results to determine the support requirements of excavations
- Apply rockmass classification results to determine the cavability of mining excavations
- Apply rockmass classification results to determine the fragmentation of caved material
- Describe, discuss and apply rockmass classification techniques for the seclection of massive mining methods
- Determine, discuss and apply rockmass 'm' and 's' parameters for the Hoek and Brown criterion based upon rockmass classification results
- Determine, discuss and apply rockmass deformability from joint stiffness and rockmass classification results
- Describe, discuss and apply the rockwall condition factor (RCF) to predict tunnel stability and support requirements.

3 ROCK AND ROCKMASS BEHAVIOUR

3.1 ROCKMASS BEHAVIOUR AROUND MASSIVE STOPING EXCAVATIONS

3.1.1 GENERAL CONSIDERATIONS

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, discuss and explain the nature of fracturing around massive mining excavations in low, moderate and high stress
- Sketch, describe, discuss and explain how excavation shape and size affects stress distribution and failure of the surrounding rock
- Sketch, describe, discuss and explain how excavation shapes may be optimised to suit the stress environment
- Describe, discuss and explain the factors that affect the stability of blocks of rock that are defined by geological structures
- Describe, discuss and explain the factors that affect the stability of blocks of rock that are defined by joints
- Sketch, describe, discuss and explain how excavation shapes may be optimised to suit the geological environment
- Determine and characterise the stability of massive stoping excavations using the various rockmass classification systems
- Estimate stable spans for excavations by making use of rockmass classification methods
- Estimate excavation support requirements by making use of rockmass classification methods
- Evaluate excavation stability for given mining layouts, geological conditions and stress environments.

3.1.2 OPEN STOPING OPERATIONS

3.1.2.1 FRAGMENTATION OF BLASTED ORE

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, discuss, explain and apply standard rockmass classification techniques to determine the fragmentation of blasted ore
- Describe, discuss, explain and determine appropriate blasting practice to achieve suitable fragmentation of blasted ore.

3.1.2.2 FLOW BEHAVIOUR OF BROKEN ORE

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, discuss and explain how broken rock flows in unchoked conditions towards a draw point

- Describe, discuss and explain how broken rock flows in choked conditions towards a draw point
- Describe, discuss and explain the draw of fine and coarse materials in the same column and its effect on dilution
- Describe, discuss and explain the effect of static pillars and temporary hang-ups on the loading of drawpoints
- Evaluate and estimate likely rock flow patterns for given rock property and drawpoint layout conditions
- Evaluate and estimate likely dilution for given rock property and drawpoint layout conditions.

3.1.2.3 ORE DILUTION

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, discuss and explain the geotechnical factors that affect dilution in open stoping operations
- Estimate likely dilution by using rockmass classification methods for given rock property and excavation layout conditions
- Determine remedial measures to limit dilution for given rock property and excavation layout conditions
- Describe, discuss and explain methods of reducing dilution.

3.1.3 CAVING OPERATIONS

3.1.3.1 CAVING AND CAVABILITY

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, discuss and explain the conditions required for successful block caving
- Sketch, describe, discuss and explain the mechanisms associated with the following types of caving :

  Subsidence caving, Stress caving, Chimney caving

- Determine undercut requirements and dimensions by using rockmass classification methods for given block cave situations
- Estimate likely caving behaviour by using rockmass classification methods for given rockmass and undercut conditions.

3.1.3.2 FRAGMENTATION OF BROKEN ORE

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, discuss and explain the factors that affect fragmentation in cave mining operations
- Estimate likely fragmentation by using rockmass classification methods for given rockmass and undercut conditions.

3.1.3.3 FLOW BEHAVIOUR OF BROKEN ORE

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, discuss and explain the factors that affect the flow behaviour of broken ore in cave mining operations
- Sketch, describe, discuss and explain the flow of rock towards drawpoints in sub-level caving layouts
- Sketch, describe, discuss and explain how drawpoint spacing affects dilution and recovery
- Sketch, describe, discuss and explain how the amount of rock blasted affects dilution and recovery
- Sketch, describe, discuss and explain the principles of draw control to limit dilution in block caving operations
- Describe, discuss, explain, compare and contrast the methods of draw control in panel caving and block caving situations
- List, describe and discuss the advantages and disadvantages of each of the above methods.

3.1.3.4 ORE DILUTION

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, discuss and explain the factors that affect dilution in cave mining operations
- Sketch, describe, discuss and explain the remedial measures to limit dilution in cave mining operations
- Describe, discuss and explain the relationship between dilution and recovery for cave mining operations
- Describe, discuss and explain the causes of the above relationship.

3.2 ROCKMASS BEHAVIOUR AROUND SERVICE EXCAVATIONS

3.2.1 ROCKMASS BEHAVIOUR AROUND ACCESS AND SERVICE TUNNELS

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss how rocks and rockmasses may be classified
- Describe, explain and discuss how rockmass classification systems may be used to predict tunnel stability at shallow, intermediate and great depths
- Describe, explain and discuss the nature of fracturing around tunnels at depth
- Describe, explain and discuss the effects and consequences of fracturing on tunnel size
- Describe, explain and discuss the effects and consequences of fracturing on tunnel shape
- Describe, explain and discuss the effects and consequences of fracturing on tunnel stability
- Describe, explain and discuss the phenomenon of time-dependant fracturing and deterioration
- Describe, explain and discuss the effects and consequences of time-dependant fracturing and deterioration on tunnel stability
- Describe, explain and discuss the effects of stress regime and geological structure on rock behaviour and tunnel stability
- Describe, explain and discuss the effect of tunnel size, tunnel shape and tunnel excavation technique on rock behaviour and tunnel stability
- Describe, explain and discuss the optimisation of tunnel size, shape and orientation to suit geological considerations
- Describe, explain and discuss the optimisation of tunnel size, shape and orientation to suit field stress considerations
- Describe, explain and discuss the behaviour of rock surrounding tunnels at depth during seismic events
- Describe, explain and discuss the siting of tunnels with respect to existing, current and future mining operations
- Describe, explain and discuss the siting of tunnels with respect to geological stratigraphy and structures
- Describe how rockwall condition factor (RCF) is determined
- Describe and discuss how the rockwall condition factor may be applied to predict tunnel stability and support requirements
- Apply the rockwall condition factor to predict tunnel stability and support requirements at depth
- Evaluate given rock conditions and field stresses to predict excavation stability
- Evaluate given rock conditions and field stresses to recommend remedial measures to improve excavation stability.

3.2.2 ROCKMASS BEHAVIOUR AROUND SERVICE EXCAVATIONS AND SHAFTS

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss how rocks and rockmasses may be classified
- Describe, explain and discuss how rockmass classification systems may be used to predict service excavation stability at shallow, intermediate and great depths
- Describe, explain and discuss the nature of fracturing around vertical sinking shafts at depth
- Describe, explain and discuss the nature of fracturing around inclined sinking shafts at depth
- Describe, explain and discuss the nature of fracturing around rock passes at depth
- Describe, explain and discuss the effect of stress fracturing and geological structure on the final shape of vertical and inclined shafts
- Describe, explain and discuss the effect of stress fracturing and geological structure on the final shape of rock passes
- Describe, explain and discuss the conditions that may lead to the formation of large unstable rock wedges in vertical shaft sidewalls
- Describe, explain and discuss the conditions that may lead to the formation of instabilities in rock passes
- Describe, explain and discuss the nature of fracturing around service excavations at depth
- Describe, explain and discuss the effects and consequences of fracturing on service excavation size
- Describe, explain and discuss the effects and consequences of fracturing on service excavation shape
- Describe, explain and discuss the effects and consequences of fracturing on service excavation stability
- Describe, explain and discuss the phenomenon of time-dependant fracturing and deterioration
- Describe, explain and discuss the effects and consequences of time-dependant fracturing and deterioration on service excavation stability
- Describe, explain and discuss the effects of stress regime and geological structure on excavation stability
- Describe, explain and discuss the effects of excavation size, shape and orientation on excavation stability
- Describe, explain and discuss the effects of excavation technique on fracturing and the stability of service excavations
- Describe, explain and discuss the effects of excavation sequence on stress fracturing and the stability of service excavations at depth
- Describe, explain and discuss the effects of support sequence on stress fracturing and the stability of service excavations at depth
- Describe, explain and discuss the optimisation of service excavation size, shape and orientation to suit geological considerations
- Describe, explain and discuss the optimisation of service excavation size, shape and orientation to suit field stress considerations

- Describe, explain and discuss the behaviour of rock surrounding service excavations at depth during seismic events
- Describe, explain and discuss the siting of service excavations with respect to existing, current and future mining operations
- Describe, explain and discuss the siting of service excavations with respect to geological stratigraphy and structures
- Describe, discuss and explain how rockmass characterisation may be applied to predict service excavation stability and support requirements
- Describe, discuss and explain how rockmass characterisation may be applied to predict service excavation stability and support requirements
- Apply rockmass characterisation techniques to predict service excavation stability and support requirements
- Evaluate given rock conditions, field stresses, geological conditions, excavation sizes, shapes and orientations to predict excavation stability
- Evaluate given rock conditions, field stresses, geological conditions, excavation sizes, shapes and orientations to recommend remedial measures to improve excavation stability
- Evaluate given rock conditions, field stresses and geological conditions to predict shaft stability
- Evaluate given rock conditions, field stresses and geological conditions to recommend remedial measures to improve stability.

3.3 MINE SEISMOLOGY

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Define, describe and discuss the term seismic event
- List, describe, explain and discuss the factors that determine the nature of seismicity in massive mining
- Describe, explain and discuss the relationship between mine layout and seismicity
- Describe, explain and discuss the relationship between depth and seismicity
- Describe, explain and discuss the relationship between rock types and seismicity
- Describe, explain and discuss the relationship between local geology and seismicity
- Describe, explain and discuss the relationship between regional geology and seismicity
- List, describe, explain and discuss the measures that may be applied to control seismicity
- Describe, explain and discuss measures to reduce the maximum magnitude of seismic events
- Describe, explain and discuss measures to reduce the frequency of seismic events
- Explain the difference between Local magnitude and Richter magnitude

- Describe and explain the following common methods of seismic data analysis :

    Gutenberg-Richter analysis
    Magnitude-Frequency relationship
    Energy-Moment relationship
    Trend analysis

- Describe, explain and discuss the relationships between :

    Event magnitude and Damage caused by seismic events
    Peak particle velocity and Damage caused by seismic events

- Define and discuss the term 'rockburst'
- Describe, explain, discuss and contrast the relationship between :

    Rockburst damage and Seismic source characteristics
    Rockburst damage and Excavation support characteristics

- Describe, explain and discuss the different types of seismic emission sources in massive mining
- Demonstrate familiarity with the guideline for the compilation of a code of practice to combat rock related accidents by being able to :

    Define, describe and explain the term 'seismically active' as defined in the guideline
    Describe and explain the steps necessary to define emission sources in various ground control districts
    Describe and explain the term 'reasonably practicable' in the context of seismic risk management
    Describe and explain the various rockburst damage control measures
    Describe and explain the use of a seismic system to monitor blasting practice, caving activity and slope stability

4 MINING LAYOUT STRATEGIES

4.1 MASSIVE MINING METHODS

4.1.1 CHOICE OF MASSIVE MINING METHOD

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, explain and discuss the fundamental mining and rock engineering principles associated with the following massive mining methods :

    Open stoping methods

Vertical crater retreat
Sub-level caving methods
Block caving methods
Cut and Fill
Drift and fill
Room and Pillar

- Sketch, describe, explain and discuss the layout of the above mining methods
- Sketch, describe, explain and discuss the location and stability of access tunnels and service excavations
- Sketch, describe, explain and discuss how the following orebody geometries and/or combinations of orebody geometries may be mined :

Thick ore horizons, Multiple ore horizons
Steeply dipping ore horizons, Flat dipping ore horizons
Shallow ore horizon, Deep ore horizon
Irregular ore blocks
Scattered ore blocks.

4.1.2 CONDITIONS REQUIRED FOR MINING METHODS

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the conditions required to successfully apply the following mining methods in terms of :

Rockmass characteristics:
Stress regime characteristics:
Open stoping methods
Vertical crater retreat
Sub-level caving methods
Block caving methods
Cut and Fill methods
Drift and fill methods
Bord and Pillar methods.

4.2 REGIONAL STABILITY STRATEGIES

4.2.1 REGIONAL PILLARS

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, explain and discuss the functions of regional stability pillars for the variety of massive mining methods at shallow, intermediate and great depth

- Sketch, describe, explain and discuss the dimensions and layout of regional stability pillars for the variety of massive mining methods at shallow, intermediate and great depth
- Design regional stability pillars for workings at shallow depths
- Design regional stability pillars for workings at intermediate depths
- Design regional stability pillars for workings at great depths.

4.2.2 CROWN PILLARS

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, explain and discuss the functions of crown pillars for the variety of massive mining methods at shallow, intermediate and great depth
- Sketch, describe, explain and discuss the dimensions and layout of crown pillars for the variety of massive mining methods at shallow, intermediate and great depth
- Design crown pillars for massive orebody workings
- Describe, explain and discuss the problems associated with designing adequate crown pillars.

4.2.3 BACKFILL AS REGIONAL SUPPORT

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the functions of backfill as regional support for the variety of massive mining methods at shallow, intermediate and great depth
- Sketch, describe, explain and discuss typical particle size distribution, for :
- Sketch, describe, explain and discuss typical stress-strain curves for :
- Sketch, describe, explain and discuss typical SG s for :
- Sketch, describe, explain and discuss typical drainage characteristics of :
- Sketch, describe, explain and discuss typical pumping characteristics of :

  Classified tailings backfill
  Full plant tailings
  Paste fill
  Rock fill
  Combinations of fill materials

- Sketch, describe, explain and discuss the use and effects of cementitious binders with the above types of fill
- Specify performance criteria, backfill type and placement method to ensure successful backfilling on a mine.

4.2.4 MINE LAYOUT FOR REGIONAL SUPPORT

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, explain and discuss mining layout strategies to ensure regional stability of massive workings at shallow, intermediate and great depth
- Sketch, describe, explain and discuss mining layouts to ensure regional stability of workings at shallow, intermediate and great depth
- Sketch, describe, explain and discuss mining sequences to ensure regional stability of workings at shallow, intermediate and great depth
- Design mining strategies, layouts and sequences to ensure the regional stability of massive workings at shallow, intermediate and great depth.

4.3 LOCAL STABILITY STRATEGIES

4.3.1 MINING LAYOUTS AND SEQUENCES

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, explain and discuss mining strategies, layouts and sequences to ensure local stability of massive workings at shallow, intermediate and great depth
- Sketch, describe, explain and discuss layouts and sequences for the following massive mining methods :

    Open stoping methods
    Vertical crater retreat
    Sub-level caving methods
    Block caving methods
    Cut and Fill methods
    Drift and fill methods
    Bord and Pillar methods

- Evaluate geotechnical data to select appropriate massive mining methods based on stability, dilution and extraction considerations
- Design appropriate massive mining layouts using rockmass classification techniques
- Design the layout of production tunnels, drawpoints and drilling tunnels for open stoping and sub-level caving operations for given geological, geotechnical and stress conditions.
- Design the layout of production tunnels and the undercuts for block caving operations for given geological, geotechnical and stress conditions.
- Design production excavation sequences for the various massive mining methods for given geological, geotechnical and stress conditions.

4.3.2 UNDERCUT LAYOUT AND DESIGN

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Determine and design appropriate massive mining undercut dimensions and layouts using rockmass classification techniques.

4.3.3 SERVICE EXCAVATION LAYOUTS

4.3.3.1 TUNNEL LAYOUTS

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the rock engineering criteria used to determine the optimum size, shape and orientation of service tunnels
- Describe, explain and discuss the rock engineering criteria used to determine the optimum layout, positioning, orientation and spacing of service tunnels relative to :

  Stopes, Pillars
  Geological features
  Other excavations
  Apply these criteria to design service tunnel layouts.

4.3.3.2 DRAWPOINT AND LOADING LAYOUTS

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the rock engineering criteria used to determine the optimum layout, positioning, orientation and spacing of drawpoints and loading bays relative to :

  Stopes, Pillars
  Geological features
  Other excavations

- Apply these criteria to design drawpoint, loading bay and loading tunnel layouts
- Describe, explain and discuss the practical aspects of drawpoint and loading bay layouts and sizes with respect to aspect such as machine size, haul distance, etc.

4.3.3.3 LARGE CHAMBER LAYOUTS

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the rock engineering criteria used to determine the optimum size, shape and orientation of large service chambers
- Describe, explain and discuss the rock engineering criteria used to determine the optimum excavation methodology and sequence for large service chambers
- Describe, explain and discuss the rock engineering criteria used to determine the optimum support methodology and sequence for large service chambers
- Describe, explain and discuss the rock engineering criteria used to determine the optimum layout, positioning, orientation and spacing of large service chambers relative to :

    Stopes, Pillars
    Geological features
    Other excavations

- Apply these criteria to design large service chambers layouts.

4.3.3.4 ROCKPASS LAYOUTS

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the causes of instability in rockpasses
- Describe, explain and discuss the effects of instability in rockpasses
- Describe, explain and discuss the options available for stabilising rockpasses
- Describe, explain and discuss the options available for supporting rockpasses
- Determine appropriate rockpass layout, orientation and support measures using rockmass and stress characterisation techniques
- Assess the suitability of rockpass layout, orientation and support measures for given sets of rockmass and stress conditions
- Describe, explain and discuss the rock engineering criteria used to determine the optimum size, shape and orientation of rockpasses
- Describe, explain and discuss the rock engineering criteria used to determine the optimum layout, positioning and spacing of rockpasses relative to :

    Stopes, Pillars
    Geological features
    Each other

- Apply these criteria to design rockpasses
- Describe, explain and discuss the rock engineering criteria used to rehabilitate damaged rockpasses.

4.3.4 SHAFT LAYOUTS

4.3.4.1 SHAFT PROTECTION PILLARS

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, explain and discuss the rock engineering criteria used to design incline shaft protection pillars at shallow, intermediate and great depth
- Sketch, describe, explain and discuss the rock engineering criteria used to design vertical shaft protection pillars at shallow, intermediate and great depth
- Calculate stress, strain and tilt in vertical shafts using equations for circular shaft pillars in an elastic medium
- Apply the results from the above calculations to design appropriate shaft pillar dimensions
- Design shaft layouts for given depth, geology and rockmass conditions
- Explain the limitations that concrete linings and steelwork place on allowable movements in shafts.

4.4 LAYOUT DESIGN CRITERIA

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the derivation and application of layout and support design criteria for massive mining operations at shallow, intermediate and great depth
- Describe, explain, discuss and apply layout design criteria applicable to all of the massive mining situations set out above.

5 MINING SUPPORT STRATEGIES

5.1 STOPE SUPPORT STRATEGIES

5.1.1 ROCKWALL REINFORCEMENT

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the variation in the behaviour of rock surrounding stoping excavations at shallow, intermediate and great depth
- Describe, explain and discuss how this affects the support requirements at shallow, intermediate and great depth

- Evaluate and determine appropriate support requirements in given circumstances in terms of the following factors :

  Rock conditions, Field stresses, Geological features

- Describe, explain and discuss appropriate support strategies to control stope hangingwall under static conditions at shallow, intermediate and great depth
- Determine the required support reaction for static conditions given typical fall of ground dimensions and loading conditions
- Describe, explain and discuss appropriate support strategies to control stope hangingwall under dynamic conditions at shallow, intermediate and great depth
- Determine the required support reaction for dynamic (rockburst) conditions given typical fall of ground dimensions and loading conditions
- Sketch describe, explain and discuss the function, use and installation of cable bolting to stabilise open stopes
- Sketch, describe, explain and discuss the function, use and installation of cable bolting to stabilise cut and fill stopes
- Sketch, describe, explain and discuss the function, use and installation of cable bolting to stabilise pillars
- Sketch, describe, explain and discuss methods of installation of cable bolts in the above situations
- Determine and design cable bolt layouts, strengths and performance characteristics for a given open stoping situations
- Determine and design cable bolt layouts, strengths and performance characteristics for a given cut and fill stoping situations
- Determine and design cable bolt layouts, strengths and performance characteristics for a given pillar extraction situations
- Evaluate rock conditions, field stresses and mining layout circumstances to determine bolting requirements for the above stoping situations
- Describe, explain and discuss the special problems of supporting wide orebodies at shallow, intermediate and great depths
- Describe, explain and discuss appropriate strategies to ensure stability under the above conditions
- Describe, explain and discuss the special problems of supporting multiple, closely spaced orebodies at shallow, intermediate and great depths
- Describe, explain and discuss appropriate strategies to ensure stability under the above conditions.

5.1.2 PILLARS AS STOPE SUPPORT

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the behavioural characteristics and applications of the following types of pillar :

  Crush pillars, Yield pillars, Rigid pillars

Crown pillars, Rib pillars

- Estimate the strength of hard rock pillars by using rock classification techniques and pillar strength equations
- Apply Ryder and Ozbay's procedure to derive the strength of hard rock pillars
- Describe, explain and discuss the stress-strain behaviour of square pillars at various width to height ratios
- Describe, explain and discuss the post peak behaviour in the above situations
- Describe, explain and discuss tributary area theory in respect of pillar design
- Describe, explain and discuss the limitations of tributary area theory in respect of pillar design
- Estimate pillar stresses using tributary theory
- Describe, explain and discuss the effect of joints and other weaknesses on pillar strength
- Describe, explain and discuss the role of loading system stiffness in the stability of pillar systems once pillars have exceeded their peak strength
- Describe, explain and discuss the effect of loading system stiffness on the mode of failure of pillars
- Describe, explain and discuss the mechanism of foundation failure of pillars
- Describe, explain and discuss the factors that affect foundation failure of pillars
- Describe, explain and discuss the factors that are taken into consideration when designing pillar support systems
- Design in-stope pillar support layouts for the variety of massive mining methods
- Describe, explain and discuss the functions and use of pillars as a means of ground control in steeply-dipping massive open stope
- Describe, explain and discuss the functions and use of pillars as a means of ground control in shallow-dipping massive orebodies
- Describe, explain and discuss the functions and use of post pillars as a means of ground control in cut and fill operations
- Describe, explain and discuss how the stability of sill or rib pillars may be assessed
- Design appropriate pillar systems for given rockmass characteristics, stress environments and mining situations.

5.1.3 BACKFILL AS STOPE SUPPORT

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the backfill characteristics and types of backfill required for filling in the following mining situations :

  Cut and Fill operations
  Drift and Fill operations
  Vertical Crater Retreat operations

Shallow Wide-reef operations

- Describe, explain and discuss how backfill fits into the mining cycle in the above situations
- Describe, explain and discuss how backfill assists in improving the stability of rock masses
- Determine the support resistance offered by backfill given the backfill performance characteristics
- Evaluate given rockmass and mining situations and note the potential benefits of backfilling in these situations
- Evaluate given rockmass and mining situations and recommend appropriate backfill type and placement procedures

5.2 SERVICE EXCAVATION SUPPORT STRATEGIES

5.2.1 TUNNEL SUPPORT STRATEGIES

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, explain and discuss the various behaviour of rock around excavations at shallow, intermediate and great depth
- Describe, explain and discuss how this affects tunnel support requirements at shallow, intermediate and great depth
- Describe, explain and discuss the objectives primary support in tunnels
- Describe, explain and discuss the objectives secondary support in tunnels
- Describe, explain and discuss the concept of integrated support in tunnels
- Describe, explain and discuss various support strategies for :

  Return Airways
  Roadways, Haulages, Crosscuts
  Travellingways
  Winzes, Raises
  Tunnel intersections
  Tunnels traversing faults, Tunnels traversing dykes
  Undercuts, Drawpoints
  Gathering drives, Drilling drives

- Describe, explain and discuss the strategies to support tunnels under the following conditions :

  Low stress with joint controlled behaviour
  High stress where stress fractures dominate stability
  Seismic and rockburst conditions

- Determine appropriate support strategies for tunnels for given layouts, rockmass conditions, stress regimes and geological circumstances.

5.2.2 SUPPORT OF DRAWPOINTS

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, explain and discuss support measures for drawpoints, loading bays and similar excavations at shallow, intermediate and great depth
- Sketch, describe, explain and discuss support measures for drawpoints, loading bays and similar excavations where the stress to strength ration of the rockmass approximates unity
- Sketch, describe, explain and discuss special support measures for high wear areas of drawpoints, loading bays and similar excavations.

5.2.3 SUPPORT OF ROCKPASSES

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, explain and discuss support measures for rockpasses and similar excavations at shallow, intermediate and great depth.

5.2.4 SUPPORT OF LARGE CHAMBERS

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, explain and discuss the various behaviour of rock around large excavations at shallow, intermediate and great depth
- Describe, explain and discuss how this affects large excavation support requirements at shallow, intermediate and great depth
- Describe, explain and discuss rockmass classification schemes for the determination of support strategies for large chambers
- Describe, explain and discuss the application of the rockwall condition factor methodology to design support for large excavations at depth
- Apply the rockwall condition factor (RCF) methodology to design support for large excavations at depth
- Describe, explain and discuss the effects of excavation sequence on support installation
- Determine appropriate excavation sequences to facilitate support installation
- Describe, explain and discuss the effects of excavation sequence on support effectiveness
- Determine appropriate excavation sequences to facilitate support effectiveness
- Describe, explain and discuss the rules of thumb for determining the length and spacing of tendons in large excavations
- Apply these rules of thumb to the design of support in large excavations

- Describe, explain and discuss the effects of overstoping and understoping on the stability and support requirements of off-reef excavations
- Determine appropriate support strategies for large chambers for given mining and shaft layouts, rockmass conditions, stress regimes and geological circumstances.

5.2.5 SUPPORT OF SHAFTS

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss rockmass classification schemes for the determination of support strategies for shafts
- Determine appropriate support strategies for vertical shafts for given mining and shaft layouts, rockmass conditions, stress regimes and geological circumstances
- Determine appropriate support strategies for inclined shafts for given mining and shaft layouts, rockmass conditions, stress regimes and geological circumstances
- Determine appropriate support strategies for roadways for given mining and shaft layouts, rockmass conditions, stress regimes and geological circumstances.

5.3 SUPPORT DESIGN CRITERIA

5.3.1 STOPE SUPPORT DESIGN CRITERIA

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss stope support requirements in terms of :

  Initial stiffness, Yieldability
  Areal coverage
  Support resistance, Energy absorbtion

- Describe, explain and discuss how support resistance varies for static and dynamic conditions.

5.3.2 TUNNEL, CHAMBER AND SHAFT SUPPORT DESIGN CRITERIA

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss excavation support and rockwall reinforcement requirements in terms of :

  Initial stiffness, Yieldability
  Unit length, Areal coverage
  Support resistance, Energy absorbtion

- Describe, explain and discuss how support resistance varies for static and dynamic conditions
- Calculate required support resistances for static conditions
- Calculate required support resistances for dynamic (rockburst) conditions
- Calculate support loads for support systems made up of various units
- Calculate energy absorption for support systems made up of various units
- Describe, explain and discuss support requirements for time-dependent (creep) conditions.

5.4 SUPPORT AND SUPPORT SYSTEM TYPES AND CHARACTERISTICS

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Apply rockmass classification systems to select appropriate support for stopes, tunnels and chambers in massive mines
- Apply the rock condition factor (RCF) to select appropriate support for tunnels in high stresses
- Describe and discuss the following rockwall support types :

  Mechanically anchored bolts, Cable bolts, Friction bolts (split sets,
  Cement grouted bolts, Resin bonded bolts
  Full-column grouted/bonded bolts
  Yielding bolts (cone bolts)
  Multiple rod bolts, Multiple strand cable anchors
  Prestressed tendons
  Steel arches, Massive concrete linings
  Shotcrete, Gunite, Thin sprayed linings
  Wire mesh, Rope lacing, Tendon straps

- Characterise the following aspects of the above units :

  Their principles of operation
  Their technical specifications
  Their load-deformation characteristics
  The methods of ensuring support unit quality
  Their installation/application procedures
  The methods of ensuring their installed quality

- Design and evaluate the use of appropriate support units, support systems, support patterns and installation procedures for given rockmass conditions, stress regimes and mining layouts.

6 INVESTIGATION TECHNIQUES

6.1 ROCK TESTING

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss various rock testing procedures
- Interpret and incorporate test results in analysis and design.

6.2 MONITORING

6.2.1 SUBSIDENCE MONITORING

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, explain and discuss the techniques used to measure surface subsidence
- Describe, explain and discuss the equipment used to measure surface subsidence
- Describe, explain and discuss how vertical and horizontal displacements are determined
- Describe, explain and discuss how strains and tilts may be derived from these determinations
- Calculate strain and tilt from given sets of measurements
- For given sets of underground mining and surface infrastructure conditions :

  State, describe, explain and discuss what types of measurements need to be made and monitored
  Describe, explain and discuss required monitoring station layouts
  Describe, explain and discuss appropriate monitoring programs
  Describe, explain and discuss the frequency of measurements
  Interpret, explain and discuss given subsidence data in terms of likely surface behaviour.

6.2.2 EXCAVATION DEFORMATION MONITORING

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, explain and discuss the techniques used to measure deformations in underground excavations
- Describe, explain and discuss the equipment used to measure deformations in underground excavations
- Describe, explain and discuss how displacements in the rockmass are determined
- Describe, explain and discuss how strains and tilts may be derived from these determinations
- Calculate strain and tilt from given sets of measurements
- For given sets of underground mining conditions :

    State, describe, explain and discuss what types of measurements need to be made and monitored
    Describe, explain and discuss required monitoring station layouts
    Describe, explain and discuss appropriate monitoring programs
    Describe, explain and discuss the frequency of measurements
    Interpret, explain and discuss given monitoring data in terms of likely excavation behaviour.

6.2.3 IN-SITU STRESS MEASUREMENT AND MONITORING

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, explain and discuss the techniques used to measure in-situ stress in the underground rockmass
- Describe, explain and discuss the equipment used to measure in-situ stress in the rockmass
- Interpret, explain and discuss given stress measurement data in terms of likely rockmass, pillar or excavation behaviour.

6.2.4 SEISMIC MONITORING SYSTEMS

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, discuss and explain how to determine objectives for a seismic monitoring system in massive mining operations
- Explain and discuss key performance criteria for seismic networks
- Explain and discuss the evaluation of historic seismicity for network design
- Explain and discuss the requirements of spatial coverage
- Explain and discuss the needs of various stakeholders for seismic information with respect to monitoring objectives
- Describe, discuss and explain how to derive a compromise between ideal network layout and the following constraints :

Accessibility constraints
Budgetary constraints

- Describe, discuss and explain the factors that need to be considered in placing seismometers
- Explain and discuss how seismometer placement could affect the event location accuracy of a seismic system
- Explain and discuss how seismometer placement could affect the sensitivity of a seismic system
- Describe, discuss and explain relevant procedures to ensure that seismic monitoring information is distributed effectively to stakeholders
- Describe, discuss and explain methods of quality assurance in seismic system management
- Describe and discuss relevant aspects of seismic system audits
- Describe and discuss methods to assess stakeholder needs
- Describe and discuss methods to identify possible shortfalls between seismic monitoring objectives and seismic system performance.

6.3 MODELLING

6.3.1 NUMERICAL MODELLING

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the selection of appropriate codes to tackle various problems
- Describe, explain and discuss the input of appropriate parameters to investigate various problems
- Describe, explain and discuss the interpretation of output in the investigation of various problems.

6.4 AUDITING

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the concept of monitoring for understanding, prediction and design.

7 ROCKBREAKING IN MASSIVE MINES

7.1 CUTTING TECHNIQUES

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss geotechnical aspects associated with various non-explosive rock breaking procedures that include :

  Tunnel boring, Raise boring

- Describe, explain and discuss the methodologies and applications of these techniques
- List and discuss the advantages and disadvantages of these techniques.

7.2 DRILLING TECHNIQUES

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Sketch, describe, explain and discuss the different rounds used in shaft sinking
- Describe, explain and discuss the different cuts used in shaft sinking
- Describe, explain and discuss the types of initiation used in the above rounds
- Describe, explain and discuss the sequence of initiation of blast holes used in the above rounds
- Sketch, describe, explain and discuss the different rounds used in tunnel development
- Describe, explain and discuss the different cuts used in tunnel development
- Describe, explain and discuss the types of initiation used in the above rounds
- Describe, explain and discuss the sequence of initiation of blast holes used in the above rounds
- Sketch, describe, explain and discuss blast hole layouts in massive stopes
- Describe, explain and discuss the drilling of blast holes in from drilling drives in massive sub-level open stopes
- Describe, explain and discuss the drilling of blast holes in from drilling drives in massive vertical crater retreat stopes
- Describe, explain and discuss the direction of drilling of blast holes in massive stopes
- Describe, explain and discuss the sequence of initiation of blast holes in massive stopes
- Describe, explain and discuss the importance of blast-hole drilling accuracy in the following applications :

  Shaft sinking, Chamber excavation, Tunnel development
  Massive stoping operations
  Cushion blasting, Smooth blasting.

7.3 BLASTING PRACTICES

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- List and discuss the advantages and disadvantages of these techniques
- Evaluate and determine blasting requirements for tunnels making
- Describe, explain and discuss the effect of the following parameters on blast damage :

  Explosive type, Initiation method,
  Initiation sequence, Hole orientation

- Describe, explain and discuss the objectives and effects of de-coupling explosives
- Describe, explain and discuss the methods by which de-coupling of explosives is achieved
- Describe, explain and discuss the following excavation cushion blasting and smooth blasting techniques :

  Pre-splitting
  Concurrent smooth blasting
  Post-splitting

- Describe, explain and discuss the methodologies and typical applications of each technique
- Evaluate and determine appropriate blasting rounds to suit given conditions in tunnels
- Evaluate and determine appropriate explosive types to suit given conditions in tunnels
- Evaluate and determine blasting requirements for stopes making use of knowledge of explosives
- Evaluate and determine appropriate blasting rounds to suit given conditions in stopes
- Evaluate and determine appropriate explosive types to suit given conditions in stopes.

8 SURFACE AND ENVIRONMENTAL EFFECTS

8.1 SURFACE EFFECTS

8.1.1 SUBSIDENCE ENGINEERING

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the following terms in the context of surface subsidence :

Angle of draw, Curvature, Tilt, Critical span
Horizontal strain, Vertical subsidence, Differential subsidence

- Describe, explain and discuss the following surface expressions of subsidence:
- Tension cracks, Compression humps, Ridges, Thrusts
- Describe, explain and discuss how mining height to depth ratio affects the type and severity of surface subsidence
- Describe, explain and discuss the effects of geological structures on surface subsidence.

8.1.2 SURFACE PROTECTION

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss how the following surface features are affected by subsidence :

  Roads, Buildings, Pylons, Lands, Streams, Pans

- Describe, explain and discuss possible remedial measures that may be applied to surface structures to limit subsidence damage
- Describe, explain and discuss possible changes that may be made to underground mining layouts to reduce subsidence damage
- Determine potential subsidence damage to the following types of structure for given mining depths and mining heights using published damage tables :

  Roads, Buildings, Pylons

8.2 ENVIRONMENTAL EFFECTS

8.2.1 LONG-TERM STABILITY AND THE ENVIRONMENT

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the possible effects and consequences of given mining methods on the following issues :

  Long-term stability of the ground surface
  Groundwater
  Ultimate closure of the mine

- Describe, explain and discuss the possible effects and consequences of given factors of safety on the following issues :

Long-term stability of the ground surface
Groundwater
Ultimate closure of the mine.

9 MINING STRATEGIES IN DIFFICULT CIRCUMSTANCES

The candidate must be able to demonstrate knowledge and understanding of the above subject area by being able to :

- Describe, explain and discuss the geotechnical aspects of dealing with the following difficult circumstances :

  Mining through geological structures or disturbances
  Mining in localised disturbed, weak or poor ground conditions
  Mining in localised high or anomalous stress situations
  Mining in areas of high water pressures and/or large water inflows
  Remnant mining
  Pillar mining
  Rehabilitation of previously mined areas.
  Dealing with excessive overbreak situations
  Dealing with runaway caving situations

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14.2 DRILLING TECHNIQUES

14.3 BLASTING PRACTICES

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15.2.1 LONG-TERM STABILITY AND THE ENVIRONMENT

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