SOUTH AFRICAN NATIONAL INSTITUTE OF ROCK MECHANICS

CHAMBER OF MINES OF SOUTH AFRICA
CERTIFICATE IN ROCK MECHANICS

PART 3-4

SURFACE MINING (HARD AND SOFT ROCK)

SYLLABUS

PREAMBLE

TOPICS COVERED

This is a specific mining type paper covering rock mechanics practice applicable in surface mining operations in hard and soft rock.
The rock engineering knowledge required here is thus of a specific nature, relating to the surface mining of orebodies in hard and soft rock.

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.

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 hard rock and soft rock surface mining operations
- Describe, explain and discuss how the rock types associated with surface mining operations were formed
- Sketch, describe and discuss geological sequences associated with surface mining operations
- Sketch, describe and discuss major geological structures associated with surface mining operations
- Sketch, describe and discuss the influence that major geological structures have on the stability surface mining operations
- Sketch, describe and discuss the effect that major geological structures have on surface mining operations
- Sketch, describe and discuss pervasive geological structures associated with surface mining operations
- Sketch, describe and discuss the influence that pervasive geological structures have on the stability surface mining operations
- Sketch, describe and discuss the effect that pervasive geological structures have on surface mining operations
- Describe, explain, discuss and apply the concept of 'defect analysis' in respect of major and minor geological features.

2.2 ROCKMASS CLASSIFICATION

2.2.1 CLASSIFICATION SYSTEMS

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 hard rock and soft rock surface mining operations orebodies
- Describe, explain, discuss and apply standard rockmass classification and assessment systems to predict excavation stability
- Describe, explain, discuss and apply Terzaghi's descriptive classification to classify rockmasses
- Describe, explain, discuss and apply Lauffer's stand-up time classification to classify rockmasses
- Describe, explain, discuss and apply Deere's rock quality designation index to classify rockmasses
- 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 mining slopes
- Apply rockmass classification results to determine the support requirements of excavations
- Describe and explain how rock quality designation (RQD) may be determined from borehole core
- Describe and explain how rock quality designation (RQD) may be determined from the in-situ rockmass
- Describe and explain the formulation and components of Barton's Q system of rockmass classification
- Describe and explain the formulation and components of Bieniawski's RMR system of rockmass classification
- Describe and explain the formulation and components of Laubscher's MRMR system of rockmass classification
- Compare and contrast these three rockmass classification systems and their respective applications
- Describe and explain what modifications are necessary to apply rockmass classification systems to local conditions.

2.2.2 CLASSIFICATION METHODOLOGY

2.2.2.1 DATA COLLECTION

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

- Describe, explain, discuss and apply core logging techniques to collect rockmass data
- Define and describe the standard terminology for core logging
- Describe, explain, discuss and apply scan line mapping techniques to collect rockmass data
- Describe and explain the implications of the orientation of the scan line on the representivity of recorded data
- Describe, explain, discuss and apply cell mapping techniques to collect rockmass data
- Describe and explain the implications of the orientation of the cell surface on the representivity of recorded data
- Describe, explain, discuss and apply the techniques for capturing rockmass data
- Describe, explain and discuss the characteristics of rockmasses that are measured, mapped and captured to facilitate rockmass classification
- Describe, explain, discuss and evaluate the problems associated with characterising weathered rock.

2.2.2.2 DATA INTERPRETATION

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

- Describe, explain and evaluate the implications and impact of the orientation of survey lines on the interpretation of recorded data
- Describe, explain and discuss the application of stereonets to interpret and analyse rockmass structure data
- Apply stereonet techniques to analyse and interpret given rockmass structure data
- Analyse and interpret rockmass structure data presented in the form of stereonets
- Identify joint trends, failure mechanisms, and other features presented in the form of stereonets.

2.3 ROCK AND ROCKMASS 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 hard rock and soft rock surface mining operations

- Describe, explain and discuss the tensile strengths of rock types associated with massive hard rock and soft rock surface mining operations
- Describe, explain and discuss the relative rockmass strengths of rock types associated with hard rock and soft rock surface mining operations
- Describe, explain and discuss the shear strengths of rockmasses associated with hard rock and soft rock surface mining operations
- Describe, explain and discuss the shear strengths of geological structures associated with hard rock and soft rock surface mining operations
- Apply the above knowledge to the design of workings in surface mining operations.

3 ROCK AND ROCKMASS BEHAVIOUR

3.1 SLOPE STABILITY AND SLOPE FAILURE

BASIC MECHANICS OF SLOPE FAILURE

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 continuum mechanics as applied to slope stability
- Describe, explain and discuss the concept of rockmass failure as applied to slope stability
- Describe, explain and discuss the role of discontinuities in slope stability and slope failure
- Describe, explain and discuss the role of step path failure in slope stability and slope failure
- Describe, explain and discuss the role of shear strength in slope stability and slope failure
- Describe, explain and discuss the role of friction, cohesion and unit weight in slope stability and slope failure
- Describe, explain and discuss the role of sliding due to gravitational loading in slope stability and slope failure
- Describe, explain and discuss the influence of water and water pressure in slope stability and slope failure
- Describe, explain and discuss the influence of water pressure on shear strength
- Describe, explain and discuss the influence of water pressure in discontinuities
- Describe, explain and discuss the concept of effective stress.

3.1.2 SLOPE FAILURE MECHANISMS

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 phenomenon of plane failure
- Sketch, describe, explain and discuss the phenomenon of wedge failure
- Sketch, describe, explain and discuss the phenomenon of circular slip failure
- Sketch, describe, explain and discuss the phenomenon of toppling failure
- Sketch, describe, explain and discuss the phenomenon of tensile failure.

3.1.3 GROUNDWATER EFFECTS

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 phenomenon of groundwater in terms of the following aspects :

  Rockmass permeability, Groundwater flow, Groundwater pressure

- Sketch, describe, explain and discuss the effects of groundwater on the stability of surface mining operations
- Describe, explain and discuss the measures that can be taken to reduce the effects of groundwater on mining operations.

3.1.4 HARD ROCK SLOPE STABILITY

3.1.4.1 HOMOGENEOUS ROCKMASS SLOPES

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

- Sketch, describe, explain, discuss and apply empirical rockmass classification techniques to evaluate slope stability
- Describe, explain, discuss and apply the MRMR classification system to evaluate slope stability
- Describe, explain, discuss and apply the RMRB classification system to evaluate slope stability
- Describe, explain, discuss and apply the Haines and Terbrugge approach to evaluate slope stability

- Evaluate slopes using the above techniques.

3.1.4.2 STRUCTURALLY CONTROLLED SLOPES

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

- Sketch, describe, explain, discuss and apply analytical techniques to evaluate slope stability
- Evaluate slopes exposed to planar failure
- Evaluate slopes exposed to wedge failure
- Evaluate slopes exposed to toppling failure
- Evaluate slopes exposed to step path failure.

3.1.5 SOIL AND LOOSE ROCK SLOPE STABILITY

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

- Describe, explain and discuss the investigation, analysis and evaluation of slopes comprising the following types of materials :

  Soil and overburden
  Deeply weathered rock
  Spoil piles.

3.1.6 ADVANCED EVALUATION TECHNIQUES

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

- Describe, explain, discuss and apply the following advanced techniques to evaluate the stability of slopes :

  Limit Equilibrium Analyses
  Factor of Safety, Probability of Failure
  Numerical Analyses
  Flac, Udec

- Describe, explain and discuss the circumstances in which application of the above techniques is warranted.

3.1.7 EARTHQUAKE LOADING

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

- Describe, explain and discuss the effects of earthquake loading on surface mining operations
- Describe, explain and discuss measures to minimise the effects of earthquake loading on surface mining operations
- Describe, explain and discuss the phenomenon of localised seismicity and its effects on surface mining operations
- Describe, explain and discuss measures to minimise the effects of localised seismicity on surface mining operations.

4 MINING LAYOUT STRATEGIES

4.1 SURFACE MINING METHODS

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 surface mining methods :

  Quarrying
  Open Pit mining
  Strip mining.

4.2 SLOPE DESIGN PRINCIPLES

4.2.1 SLOPE STABILITY

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 principles associated with the concept of the factor of safety of a slope
- Describe, explain and discuss the stability and failure of slopes for which factors of safety can be calculated
- Describe, explain and discuss the stability and failure of slopes for which factors of safety cannot be calculated

- Sketch, describe, explain and discuss the relationship between critical slope height and critical slope angle
- Sketch, describe, explain, discuss and apply the probabilistic approach to slope design.

4.2.2 SLOPE GEOMETRY

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 role and importance of the following slope geometry constituents:
  Bench, Bench stack, Spill berm, Ramp berm, Overall slope
- Determine optimum slopes for given rockmass and mine layout circumstances.

4.2.3 GEOTECHNICAL SECTORS

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

- Describe, explain and discuss the principles associated with determining geotechnical sectors in surface mining operations
- Determine geotechnical sectors for given rockmass and mine layout circumstances.

4.2.4 MINING LAYOUTS

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 role and importance of the following surface mining layout aspects:
  Geology, Structure, Geotechnical sectors
  Slope geometry, Wall curvature
  Service life, Temporary walls, Active walls, Final walls
  Mining sequences, Push backs.

4.2.5 SERVICE LAYOUTS

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 role and importance of access roadways in surface mining layouts.

4.3 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 apply appropriate criteria to design of surface mining layouts.

5 MINING SUPPORT STRATEGIES

5.1 SLOPE 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 fundamental rock engineering principles associated with supporting rock slopes.

5.2 SERVICE 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 fundamental rock engineering principles associated with supporting roadways.

5.3 SUPPORT DESIGN CRITERIA

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 principles of reinforcement to prevent sliding
- Describe, explain and discuss slope support requirements in terms of :

  Initial stiffness, Yieldability
  Areal coverage, Containment.

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 design and select appropriate support for slopes
- Describe and discuss the following rockwall support types and their application :

  Mechanically anchored bolts, Cable bolts, Friction bolts
  Cement grouted bolts, Resin bonded bolts
  Full-column grouted/bonded bolts
  Prestressed tendons
  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
- Describe and discuss the following rockfall protection measures and their application and designn:
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  Catch fences, Catch walls, Berm widths
  Thin sprayed linings

6 INVESTIGATION TECHNIQUES

6.1 SITE INVESTIGATION

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

- Describe, explain, discuss and apply site investigation techniques, procedures and assessments covering the following aspects :

  Drilling, Logging, Mapping, Sampling, Measuring, Testing

- Describe, explain and discuss the application of such site investigation techniques and procedures to the characterisation and assessment of the following aspects :

  Geology, Rockmass, Groundwater, Slope stability

- Describe, explain, discuss and apply the following site investigation techniques and procedures to classify, characterise and assess rockmass conditions :

  Scanline mapping, Cell mapping, Window mapping, Photogrametric mapping, Stereographic projection.

6.2 SLOPE STABILITY ANALYSIS

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

- Describe, explain, discuss and apply the following slope stability evaluation techniques and procedures :

  Empirical analyses
  Kinematic analyses
  Limit equilibrium analyses
  Numerical analyses
  Finite element analyses, Finite difference analyses

- Describe, explain, discuss and apply the stereographic projection techniques to analyse and evaluate slope stability
- Describe, explain, discuss and apply techniques and procedures for dealing with isolated rockfalls.

6.3 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.

6.4 MONITORING

6.4.1 ROCK SLOPE MONITORING

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

- Describe, explain and discuss the reasons for monitoring rockmass movement and slope stability in surface mining operations
- Sketch, describe, explain and discuss the techniques used to measure deformations in surface mining excavations
- Describe, explain and discuss the equipment used to measure deformations in surface mining excavations
- Describe, explain and discuss how displacements in the rockmass are determined
- Describe, explain and discuss how the components of ground movement may be derived from these determinations
- Calculate components of ground movement from given sets of monitoring data
- Interpret given ground movement data and determine the effect on slope stability
- Describe, explain and discuss the use of piezometers to measure and monitor groundwater levels and porewater pressures in surface mining excavations
- Interpret given groundwater data and determine the effect on slope stability
- For given sets of surface 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
  Interpret practical monitoring data and determine slope failure modes and the behaviour of slopes with time.

6.5 MODELLING

6.5.1 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 application of the following codes to tackle various problems :
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  Flac, Udec, Dips

- 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.

6.6 RISK MANAGEMENT

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

- Describe, explain and discuss the various elements of a comprehensive risk management strategy for an open pit mine.
- Describe, explain, discuss and generate information for the following elements of a risk assessment and hazard control program:
- Hazard maps, Ground control management plans, Evacuation procedures, Engineering interventions
- Describe, explain, discuss and generate information on acceptable limits on surface mine slope design.

6.7 AUDITING FOR BEST PRACTICE

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 SURFACE MINING

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 used in surface mining operations
- Describe, explain and discuss the methodologies and applications 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 blast hole layouts used in surface mining operations

- Describe, explain and discuss the spacing of blast holes in surface mining operations
- Describe, explain and discuss the direction of drilling of blast holes in surface mining operations
- Describe, explain and discuss the drilling of long holes in surface mining operations
- Describe, explain and discuss the types of initiation used in the above layouts
- Describe, explain and discuss the sequence of initiation of blast holes in surface mining operations
- Describe, explain and discuss the importance of blast-hole drilling accuracy in the following applications :

  Temporary walls, Moving walls, Final walls
  Back damage
  Trim blasting, Buffer blasting
  Cushion blasting, Smooth blasting, Pre-split blasting
  Longhole drilling.

7.3 BLASTING PRACTICES

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

- 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, Angled pre-splitting
  Concurrent smooth blasting
  Post-splitting

- Describe, explain and discuss the methodologies and typical applications of each technique
- List and discuss the advantages and disadvantages of these techniques
- Evaluate and determine blasting requirements for the variety of surface mining applications making use of knowledge of explosives
- Evaluate and determine appropriate blasting rounds to suit given conditions in surface mining operations

- Evaluate and determine appropriate explosive types to suit given conditions in surface mining operations
- Evaluate and determine appropriate initiation techniques to suit given conditions in surface mining operations
- Evaluate and determine appropriate detonating techniques to suit given conditions in surface mining operations
- Evaluate and determine appropriate blasting techniques to suit given conditions in surface mining operations
- Evaluate and determine appropriate slope geometries and dimensions to achieve optimum blasting efficiencies.

8 ENVIRONMENTAL EFFECTS

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 surface mining methods on the following issues :

  Blast vibration damage to buildings and structures

- Describe, explain and discuss techniques and design tools to limit potential blast vibration damage
- Describe, explain and discuss the concept of peak particle velocity in this regard
- Describe, explain and discuss techniques and design tools to limit the effects of air blasts
- Describe, explain and discuss techniques and design tools to limit the effects of mining on groundwater
- Describe, explain and discuss techniques and design tools for :

  Spoil heaps
  Tailings dumps
  Long-term rehabilitation of the ground surface
  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 in major geological structures or disturbances
  Mining in localised disturbed, weak or poor ground conditions

Mining in highly weathered conditions
Mining in localised high or anomalous stress situations
Dealing with excessive overbreak situations
Dealing with excessive back damage situations.

10 REFERENCES

PREAMBLE

1 GEOTECHNICAL CHARACTERISTICS

10.2 GEOLOGY

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10.3.1 CLASSIFICATION SYSTEMS

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10.3.2 CLASSIFICATION METHODOLOGY

10.3.2.1 DATA COLLECTION

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10.3.2.2 DATA INTERPRETATION

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10.4 ROCK AND ROCKMASS STRENGTH

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11.1.1 BASIC MECHANICS OF SLOPE FAILURE

11.1.2 SLOPE FAILURE MECHANISMS

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11.1.3 GROUNDWATER EFFECTS

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11.1.4 HARD ROCK SLOPE STABILITY

11.1.4.1 HOMOGENEOUS ROCKMASS SLOPES

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11.1.5 SOIL AND LOOSE ROCK SLOPE STABILITY

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11.1.6 ADVANCED EVALUATION TECHNIQUES

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11.2 EARTHQUAKE LOADING

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12.3 MINING LAYOUTS

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14.4 MONITORING

14.4.1 ROCK SLOPE MONITORING

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14.5 MODELLING

14.5.1 NUMERICAL MODELLING

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14.6 RISK MANAGEMENT

14.7 AUDITING FOR BEST PRACTICE

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15 ROCKBREAKING IN SURFACE MINING

15.1 CUTTING TECHNIQUES

15.2 DRILLING TECHNIQUES

15.3 BLASTING PRACTICES

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