SOUTH AFRICAN NATIONAL INSTITUTE OF ROCK MECHANICS

CHAMBER OF MINES OF SOUTH AFRICA
CERTIFICATE IN ROCK MECHANICS

PART 1

ROCK MECHANICS THEORY

SYLLABUS

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PREAMBLE

TOPICS COVERED

This is a general paper covering basic rock mechanics theory applicable in all types of mining environment.
The theoretical rock mechanics knowledge required here is thus of a fundamental nature, and is not specific to any particular type of mining.

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 STRESS AND STRAIN

2.1 STRESS AND STRAIN COMPONENTS

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

- Describe, explain and illustrate the complete state of stress at a point
- Indicate the positive sense of normal and shear stresses
- Calculate the principal stresses from shear components in two dimensions
- Calculate the normal and shear components of stress on a plane at any orientation in a two-dimensional stress field given either the principal stresses or the stress components in the x-y directions
- Calculate the principal stresses from shear components in three dimensions
- Calculate the normal and shear components of stress on a plane at any orientation in a three-dimensional stress field given either the principal stresses or the stress components in the x-y and z directions
- Calculate the principal strains from strain components in two dimensions
- Calculate strain components in any orientation given either the principal strains or strain components in the x-y directions
- Determine the principal stresses making use of the Mohr-circle representation of stresses in two dimensions given the stress components on a plane
- Determine the stress components on a plane making use of the Mohr-circle representation of stresses in two dimensions given the principal stresses
- Describe, explain and illustrate the normal and shear stresses induced in the following members under their own weight :

A simply supported beam
A cantilever beam
A built-in beam

- Note the positions of maximum tension, maximum compression and maximum shear in each case.

3 CONSTITUTIVE BEHAVIOUR

3.1 CONSTITUTIVE RELATIONSHIPS

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

- Identify, describe and explain the following constitutive relationships:

  Elastic
  Plastic
  Elasto-plastic
  Strain softening
  Strain hardening

- Interpret these relationships citing material examples
- Calculate strain components from stress components for elastic materials in two dimensions using Hooke's law
- Calculate stress components from strain components for elastic materials in two dimensions using Hooke's law
- Calculate strain components from stress components for elastic materials in three dimensions using Hooke's law
- Calculate stress components from strain components for elastic materials in three dimensions using Hooke's law
- Describe and explain the concept of plane strain
- Calculate the elastic strain energy density in elastic materials
- Describe, explain and define the following terms:

  Dilation Angle
  Associated Flow
  Non-associated Flow

- Describe, explain and indicate on a stress-strain graph for rock material the onset of inelastic behaviour, dilation and strain softening
- Identify, describe and explain time-dependent behaviour
- Interpret this behaviour citing material examples.

4 ROCK PROPERTIES

4.1 ROCK STRENGTH

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

- Identify, describe and explain the possible modes of failure of rock in uniaxial compression
- Describe and explain the effect of orientation on strength results for anisotrophic rocks such as shales
- Sketch, describe and explain the complete axial stress-strain graph for rock in uniaxial compression
- Sketch, describe and explain the complete axial stress-strain graph for rock in triaxial compression
- Indicate the following for the above two cases :

    the associated radial strain
    the associated volumetric strain
    the associated brittle-ductile transition
    the associated residual strength
    Hysteresis in the post peak portion of the curve

- Describe and explain brittle behaviour of rocks based upon Griffith's theory
- Explain the basis for the Griffith criterion
- Explain the basis for the Coulomb criterion
- Identify, describe and explain the assumptions of the Coulomb criterion
- Describe and explain the orientation of the failure surface predicted by the Coulomb criterion
- Describe and explain how the cohesion and friction angle required by the Coulomb criterion may be determined from rock tests
- Explain the basis for the Hoek and Brown criterion
- Describe and explain how to apply the Hoek and Brown criterion to predict rock failure
- Describe and explain how the 'm'-parameter for intact rock required for the Hoek and Brown criterion may be obtained
- Sketch, describe and explain :

    The stress-strain behaviour of brittle rock in uniaxial compression
    The effect of confinement on rock strength
    The effect of confinement on the stress-strain behaviour of rock samples
    What happens to rock after it has reached its peak strength

- Sketch, describe and explain :

    Rock fracture, Brittle failure

Ductile deformation, Yield
Peak strength, Residual strength
Effective stress, Pore pressure
The volume effect on the strength of intact rock.

4.2 JOINT STRENGTH

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

- Represent and describe the occurrence of rock jointing, the number of joint sets and their orientations
- Describe and explain the effect of friction angle on joint strength
- Describe and explain the effect of infilling on joint strength
- Describe and explain the effect of water on joint strength
- Sketch, describe and explain the typical shear resistance-displacement behaviour of smooth joints
- Sketch, describe and explain the typical shear resistance-displacement behaviour of rough joints
- Sketch, describe and explain the effect of surface roughness on joint shear strength
- Compare and contrast typical shear resistance versus shear displacement behaviour of smooth and rough joints
- Describe and explain the effect of increasing the normal stress on the behaviour of joints under shear loading
- Describe and explain the effect of surface roughness on joint shear strength
- Describe and explain the concept of roughness angle and its effect on initial shear resistance according to Patton's theory
- Describe and explain the effect of surface roughness on dilation during shear on a joint
- Describe and explain the effect of the above on rock stability in unconfined situations
- Describe and explain the effect of the above on rock stability in confined situations
- Apply Barton's equation to estimate the peak strength of joints
- Describe and explain the difference between joints, fractures and cracks.

5 STRESS IN ROCK AND ROCKMASSES

5.1 STRESS ESTIMATION

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

- Explain Heim's Law
- Calculate the expected stress regime in rock based upon gravity and the Poisson effect only
- Explain and comment upon the reasons why stresses may vary from those calculated above
- Describe and explain virgin stresses encountered in the different mining areas of South Africa
- Describe and explain the principles of stress measurement using strain cells
- Explain and comment upon the reasons for the large variations in the results of the above stress measurements
- Describe and explain the principles of stress measurement based upon AE principles
- Explain and discuss the use of Kirsch equations in respect of stress determinations.

6 ROCKMASS PROPERTIES

6.1 ROCKMASS PROPERTIES

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

- Describe, explain and illustrate the volume effect on the strength of intact rock
- Describe, explain and illustrate the role of joint strength on the strength of a rockmass
- Describe, explain and illustrate, the role of joint frequency on the strength of a rockmass
- Describe, explain and illustrate the role of joint length on the strength of a rockmass
- Describe, explain and illustrate the role of intact rock strength on the strength of a rockmass
- Describe, explain and illustrate the role of groundwater on the strength of a rockmass
- Describe and explain the general relationship between strength and seismic wave velocity in a rockmass.

6.2 ROCKMASS CLASSIFICATION

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

- Apply Barton's, Bieniawski's and Loubscher's geomechanics classification systems to classify rockmasses

- Determine rockmass 'm' and 's' parameters for the Hoek and Brown criterion, based upon rock classification
- Apply the Hoek and Brown criterion to estimate the strength of a rockmass
- Identify, describe and explain the limitations of the Hoek and Brown criterion
- Estimate rockmass deformability from joint stiffness and rockmass classification results.

REFERENCES

1 STRESS AND STRAIN

6.3 STRESS AND STRAIN COMPONENTS

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Brady BHG & Brown ET 1993 Rock Mechanics for Underground Mining Chapman & Hall New York Chapter 2

Obert L & Duvall WI 1967 Rock Mechanics and the Design of Structures in Rock John Wiley & Sons New York Chapters 1, 2

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Budavari S (ed) 1986 Rock Mechanics in Mining Practice SAIMM Jhb Chapter 1, 3, 5

7 CONSTITUTIVE BEHAVIOUR

7.1 CONSTITUTIVE RELATIONSHIPS

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Obert L & Duvall WI 1967 Rock Mechanics and the Design of Structures in Rock John Wiley & Sons New York Chapters 3, 6, 10

Jaeger JC & Cook NGW 1969 Fundamentals of Rock Mechanics Chapman & Hall London Chapters 4, 5, 6, 7, 9, 10, 11, 12

Budavari S (ed) 1986 Rock Mechanics in Mining Practice SAIMM Jhb Chapter 1

8 ROCK PROPERTIES

8.1 ROCK STRENGTH

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8.2 JOINT STRENGTH

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9 STRESS IN ROCK AND ROCKMASSES

9.1 STRESS ESTIMATION

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10 ROCKMASS PROPERTIES

10.1 ROCKMASS PROPERTIES

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10.2 ROCKMASS CLASSIFICATION

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Stacey TR 2001 Best Practice Rock Engineering Handbook for 'Other' Mines
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