UNISA university of south africa

EXAMINATION PAPER

SUBJECT: CERTIFICATE IN ROCK MECHANICS: PAPER 2 **SUBJECT CODE:** COMRME **EXAMINATION DATE:** OCTOBER 2015 **TIME:** 9:00 – 12:00	**EXAMINER:** JJ VAN DER MERWE **MODERATOR:** P GREYLING **TOTAL MARKS:** [100] **PASS MARK:** 60%

NUMBER OF PAGES:

SPECIAL REQUIREMENTS:

1. **Answer all *FIVE* questions.**
2. References other than those provided are not permitted.
3. Only approved hand-held electronic calculators may be used.
4. Write your examination number on the outside cover of each book used and on any graph paper or other loose sheets handed in.

NB: your name must not appear on any answer book or loose sheets.

5. **Write in ink on the RIGHT HAND SIDE of the paper only (only the right hand pages will be marked).**
6. Show all calculations on which your answers are based.
7. Illustrate your answers by sketches of diagrams wherever possible.
8. In answering these questions, full advantage should be taken wherever necessary of your practical experience as well as of the data given.
9. Answers must be given to an accuracy that is typical of practical conditions.

QUESTION 1 Multiple Choice

1) What are the generally accepted units for Seismic Moment under microseismic conditions?

a) mN/m^2 b) Nm/m^3

c) *Nm* d) MJ/m^2

2)What will be the maximum vertical subsidence calculated when using the following formula:

$$\frac{Sm}{0.39\,(h)} = \left[\frac{W}{H}\right]^{0.32}$$

Where the stoping width is 150cm, the depth is 0,08km and the stoping span is 100m?

a) *279mm* b) 158mm

c) 4.06mm d) 931mm

3) The Minerals Act Reg. states that no person is allowed to work in any area where the wet/dry bulb is in excess of _____. Indicate which temperature limits are applicable?

a) 31.5°C/35°C b) 32.5°C/37°C

c) 32°C/36°C d) 29°C/32.5°C

4) What are the generally acceptable units for the Rock Wall Condition factor?

a) KN b) KJ/m^2

c) MPa d) None of the above.

5) Which of the following theories or criterion best describes the propagation of fractures?

a) Griffith Criteria b) Hoek & Brown Empirical criteria

c) Lade Empirical Criteria d) *Tresca's Criterion*

6) On the analysis of seismicity which of the following Es/Ep ratios would suggest a burst type event along a Dyke structure:

a) *0.5* b) 0.8

c) 1.0 d) 1.2

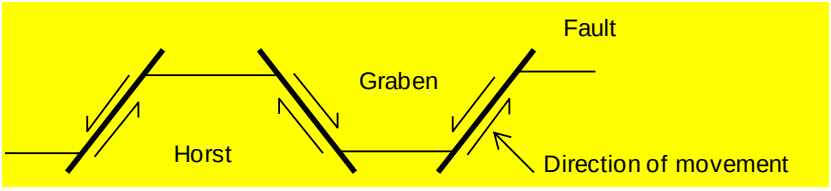
7) When designing shaft pillars and associated excavations, the major principal stress to limit deformation should be reduced to the critical stress which is normally given as:

a) σ_c b) $\frac{\sigma_c}{3}$

c) $\frac{\sigma_c}{4}$ d) $\frac{\sigma_c}{2}$

8) Sketch and annotate a section of a Horst and Graben structure and show relative displacements. (3)

Answer:



9) List the three fundamental rock types, as well as a reef and a mineral being mined from each? (3)

• Igneous Rock -	UG2.	Platinum
• Sedimentary -	Coal/VCR	Coal/Gold.
• Metamorphic -	Basal/VCR	Gold

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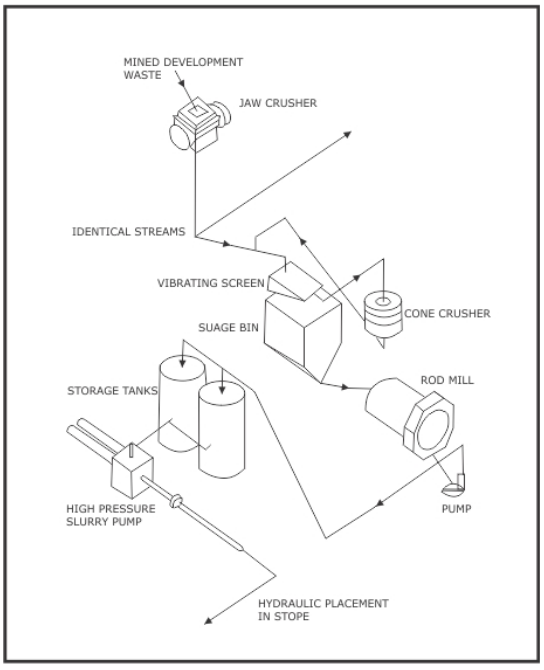
Question 2

2.1 List the factors that need to be considered when comparing laboratory and in-situ results with regards to load/deformation characteristics of a yielding timber prop.

(5)

- Loading rate in lab versus underground loading rates
- Condition of timber (dry/cracked/Moisture content)Humidity
- Angle of installation
- Buckling effect (length/diameter)
- Dynamic closure rates
- Quarzi static closure
- Mining Cycle
- Blast damage

2.2 Sketch and describe a typical waste fill back fill system from receiving the waste to placement. (7)

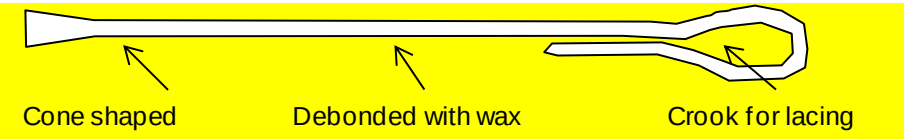


2.3) List, sketch and describe two yielding type grouted tendons generally used in footwall excavations in seismically active areas. Show a typical load displacement graph for each unit.

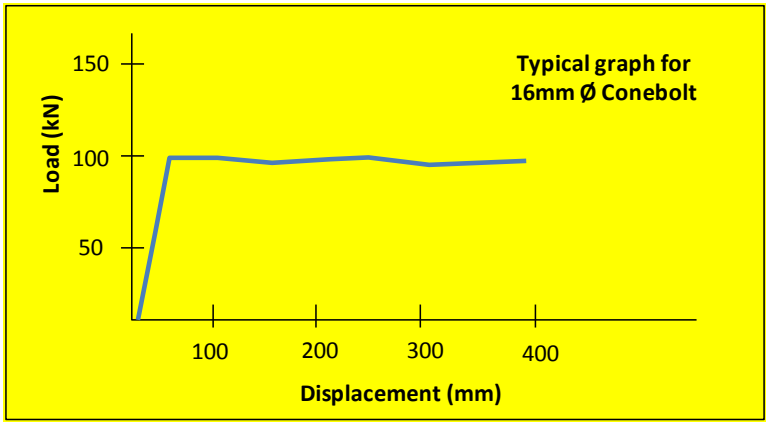
(8)

Answer:

Cone bolt

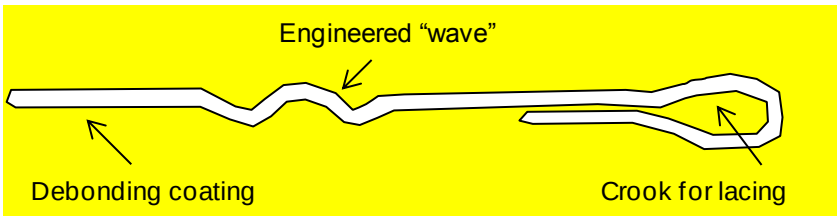


- *The cone shape tendon is grouted into a hole.*
- *The steel rod is coated with a special debonding agent.*
- *Mode of yield, the debonded tendon pulls through the grout maintaining a support resistance / load while yielding.*

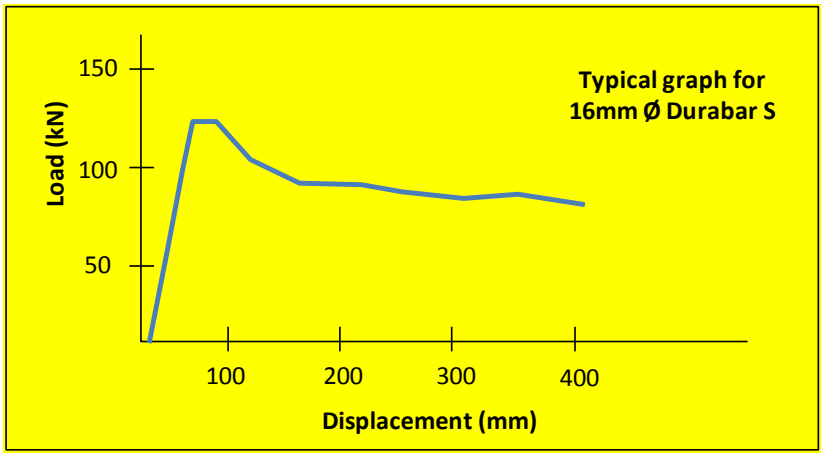


(4)

Durabar



- *Tendon grouted into hole.*
- *Rod coated with debonding agent.*
- *Mode of yield. Slips through grout with smooth load / deformation characteristics through the wave path created in the grout by the shape "wave" of the bar.*



(4)

Shepherd's Crook (smoothbar)

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Question 3

Describe and explain how the following variables would influence the indicated strength of rock samples tested in tri-axial compression.

3.1.1 Specimen end effects (2)

The specimen should be flat to 0.02mm and shall not depart from perpendicularity to the axis of the specimen by more than 0.001 radian (about 3.5mm) or 0.05mm in 50mm.

3.1.2 Sample grain size (2)

The grain size must be 10:1 diameter to the largest grain size in the rock material.

3.1.3 Loading rate (2)

Load on the specimen shall be applied continuously at a constant stress rate such that failure occurs within 5-10min of loading, alternatively the stress rate shall be within the limits of 0.5-1.0 MPa/s

3.1.4 Orientation of bedding within the sample (2)

Samples must be drilled perpendicular to the direction of the bedding planes and not parallel as this may report weaker rock strengths.

3.1.5 Sample width: height ratio (2)

Width to height ratio must be 0.5 or 0.33.

3.2.1 Describe and explain how samples may be collected for shear strength determination? (2)

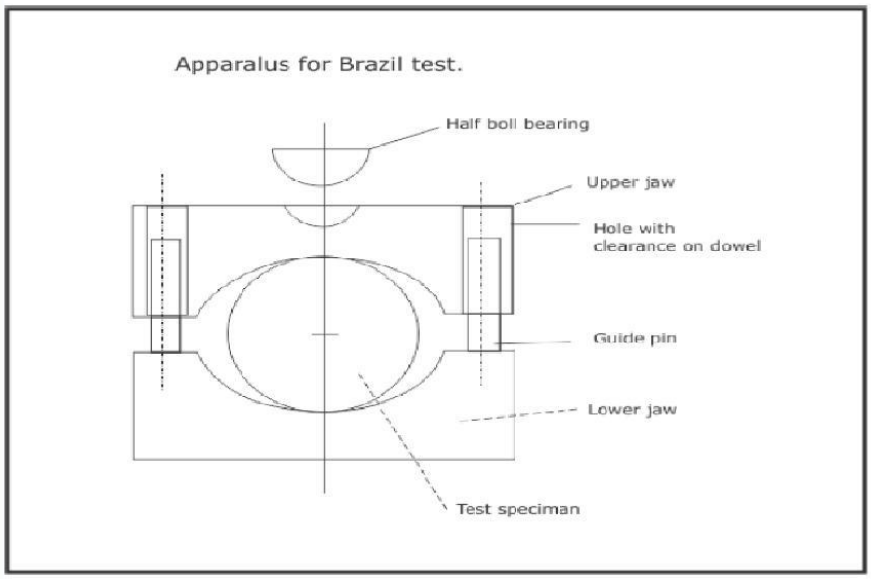
For shear strength tests, blocks or core samples can be selected, as long as the target discontinuity is present in the sample and the test plane must preferably have a minimum area of 2500m² or this minimum area of 2500mm²equate to a sample dimension of:

- Circular: 28mm radius and 56mm diameter;
- Square: 50mm.

3.2.2 Describe and explain how samples are prepared for shear strength determination? (2)

Test specimens are generally prepared by sawing rock cores into 7.5 to 10cm lengths or by sawing square rock samples to fit into two shear boxes. The shear surface must be aligned to fall between the two shear boxes in order to determine the shear strength of the discontinuity surface. Cate is to be taken not to damage the discontinuity surface during transportation and preparation.

3.2.3) Sketch and discuss how Brazilian indirect tensile strength tests are carried out?(6)



This test is intended to measure the uni-axial tensile strength of prepared rock specimens indirectly by the Brazil test. The justification for the test is based on the experimental fact that most rocks in biaxial stress fields fail in tension at their uni-axial tensile strength when one principal stress is tensile and the other finite principal stress is compressive with a magnitude not exceeding three times that of the tensile principal stress.

Figure above shows the setup for the Brazilian disk test used to determine the tensile strength of the specimen in an indirect test, where compressive stresses are used to induce tensile failure of the sample. The thin disc is placed in a test machine, which applies a load (Figure 13) in a single direction allowing sample expansion in the other direction and therefore tensile failure. Figure 13 also shows the existence of the induced tensile stress in the sample when subjected to this test, as estimated with numerical models.

Various samples are prepared to have a representative result and tested after being installed in the test machine by applying a load using a pressure pump. The load indicator (gauge) will show an increase in load up to the point where the test specimen fails, after which the load will drop.

- Specimen NX 54mm core diameter.
- Thickness is = radius of specimen (27mm)
- Loading rate 200N/s or (15-20sec)

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Question 4

4.1) You are appointed as Rock Engineer at the North-West shaft where the shaft sinking is still in progress. The design is to pre-extract the inner shaft pillar from an adjacent shaft after which the shaft will be sunk through the mined out area. Reef intersection is at 2500m below surface.

4.1.1 What would your support recommendation be for the inner shaft pillar and the outer shaft pillar, also substantiate your choice of support? (4)

Inner pillar - Cement packs should be used such as the Grinaker cement packs as they do not rot as in the case of timber and they eliminate the chances of fire in the main air intake of the mine. The load /deformation graph is predictable as the packs can be designed to have the required load.

You do not want to make us of a stiff support system such as back fill in the inner pillar as there is a possibility that excessive loads may be generated within the backfill which may lead to a number of potential problems such as wedge failure in the shaft at the reef intersection, failure along the shaft lining.

Outer pillar - Back fill and timber packs/ Elongates should be considered in the outer shaft pillar. The use of well-designed stabilizing pillar will assist to limit the amount of closure, ride and tilt within the shaft

The correct design of the stabilizing pillars within the shaft pillar is curtail as point loading may be generated along the shaft, above and below the reef intersection. This may result in shaft failure.

4.2 You are asked to assist the shaft engineer with the design of a floating steel section.

4.2.1 List what relevant information must be supplied to the engineer to enable him to do the design? (3)

- Closure and ride at the reef intersection (expansion guides)
- Tilt along the shaft
- Seismicity
- Distance along the shaft above and below the reef intersection where bed separation can be expected. (length of the floating steel work)

4.2.2 How would you go about obtaining the relevant information? (2)

The best method to obtain the information required is by making use of an Elastic, Boundary Element program such as Minsim, Map3d,Minsim, besol/ms, MINAP which can calculate the induced strain and stress along the shaft, Convergence along the reef intersection and tilt. You can also determine the size and position of the stabilizing pillars within the shaft pillar.
Underground observations in the pre-extracted shaft pillar panels.

4.2.3 Shortly list the rock properties that you will require? (3)

You will require the following information that can be obtained from laboratory rock sample tests.

- UCS strengths of the rock
- Young's modules
- Module of Rigidity
- Poisons ratio.
- Homogeneity of rock mass
- Isotopic properties.

4.3 You are required to monitor the stability within the shaft after the sinking phase has been completed. Shortly discuss how you would go about to achieve the following?

4.1.2.1(4.3.1)Monitoring program (3)

You will require monitoring for the following issues

- Closure at the reef intersection
- Strain gauges on the streel work
- Ride/displacement along the shaft
- Seismicity within the shaft pillar.
- Shaft examination to measure the movement within the floating section so as to allow for adjustment to be made.

4.3.2.2(4.3.2)Instrumentation required and where they must be installed (3)

All instruments should be electronically connected as access to the reef intersection subsequent to a shaft pillar extraction is limited and it can be monitored on a daily basis with predetermined limits that can be connected to an alarm system that will warn the control room operator of any movement that may restrict the movement of the shaft convayens.

Instruments required.

- Closure meters in the reef intersection
- Strain/ load gauges on the steel work
- Lasers to detect movement along the shaft steel work.
- Lasers to detect ride within the shaft.

4.4 Shortly discuss what the advantage of doing an early shaft pillar extraction?(2)

Advantage

- Leaving a shaft pillar at 2500m below surface will require an excessively large pillar which will result in the lockup of ore reserves.
- The shaft can start generating revenue at an early stage of the shafts live.
- Expensive and extensive footwall development will be limited as on reef mining can start once the inner shaft pillar has been completed. The alternative is to first develop to the boundaries of the shaft pillar, where after on reef raise development must be completed before mining can commence.
- Any movement along the shaft barrel can be addressed at an early stage of the shaft life.

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Question 5

5.1 Name the two blasting methods for smooth wall blasting of an underground tunnel at a depth of 3000m and briefly describe how it is done. (5)

(5)1. Smooth wall Blasting

- Space perimeter holes at 300mm
- Ensure that the holes are parallel to one another and the direction is correct
- Calculate the decoupling to approximately 60-80% (depending on the explosives used) and the rock type that needs to be excavated
- With the use of plastic tubing space the explosive charge to decouple them and minimise the effect of the gas energy
- The round is timed that the cut, then the-inner- then the lifters and lastly the perimeter holes are blasted

5.2. Skinning or trimming

- Space perimeter holes at 300mm
- Ensure that the holes are parallel to one another and the direction is correct.
- With the use of low density explosives designed for the rock type the be excavated (Trimex) fill 2/3 of the hole and ensure that the hole is tamped correctly
- The round is timed that the cut, then the-inner- then the lifters and lastly the perimeter holes are blasted

5.2. You are appointed as the Rock engineer on ABC mine and you have a twin decline system that was developed 30m apart. You are required to monitor for ground movement along the excavations.

List 3 types of borehole extensometers and briefly describe the difference. (4)

Wire extensometer

Simple wire extensometer, which consists of a steel clip used to anchor the extensometer into a hole drilled for monitoring purposes. The steel cable is attached to the anchor and a short piece of tape is inserted into the hole up to a point where just the tape is sticking out of the hole.

Multi point extensometer

The simplest and cheapest of the borehole extensometers, this device consists of small spring anchors that, with a suitable length of wire trace attached, are pushed into a borehole to predetermined depths. The spring anchors have expanded diameters that are greater than the diameter of the borehole and in this way can be jammed in the borehole, thereby anchoring the attached trace wire at the desired position. Each wire trace is cut to a length such that a short (e.g. 300 mm) length of measuring tape attached to the free end will just protrude from the collar of the borehole.

Rod extensometer (tell tails)

A rod extensometer is a system of grouted reference points in a borehole that are connected to a measuring head at the collar of the borehole by means of rods encased in PVC tubes. A dial gauge or an electronic movement detector detects movement of the rods at the borehole collar.

Sonic probe extensometer

Sonic probe extensometers are another variation on the concept of measuring points positioned at predetermined depths along a borehole. In this case, the spring clip anchored reference points contain magnets that 'reflect' ultrasonic pulses back down a flexible magneto-strictive probe to a portable readout unit. The distances between reference points are determined by measuring the relative differences in arrival times of the reflected pulses.

5.3 As a rock engineer, why would you install a borehole extensometer instead of simple measuring pegs around an excavation? (3)

Installing pegs on the sidewalls will only give you an indication as to the total rock movement into the exaction from both side walls or hang and footwall whereas the extensometer can give you the following information:

- Depth of failure/movement into specific side or hanging wall.
- Effectiveness of grouted support units(failure extended past the support)
- Beam failure in shallow stopes.
- Height if instability in beam failure

5.4 List the different numerical modelling techniques and Codes that applies the techniques? (4)

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MODELLING TECHNIQUE	CODE
BOUNDARY ELEMENT TECHNIQUES	MAP3D,MINSIM, BESOL/MS, MINAP, DIGS
FINITE ELEMENT TECHNIQUES	PHASE 2
FINITE DIFFERENCE TECHNIQUES	FLAC, FLAC 3D
DISTINCT ELEMENT	UDEC, 3 DEC
KEYBLOCK METHODS	BLOCKEVAL SOFTWARE, JBLOC

5.5 The following numerical modelling approaches are available. Shortly discuss each approach, showing your understanding of each approach? (4)

- Elastic vs nonlinear

An elastic model will often allow you to determine the boundaries within which the real results lie, before inelastic analysis is attempted. Since non-linear models are often difficult to calibrate and interpret, it is important to question the model accuracy, its ability to reproduce known outcomes and its deformation pattern stability at various grid sizes before applying the model in the analysis. Depending on the 'problem' to be analysed and the outcome expected, a decision on the appropriate approach is made. If a comparison of the depth of fracturing into the pillar walls caused by different mining layouts is required, an elastic model could be appropriate and the results could be analysed to indicate the probability of fracturing, the extent of stress increase, and even the application of potential for failure using the Hoek-Brown failure criterion. However, if an accurate estimation of the depth of fracturing into the pillar walls is required, the use of a non-linear or inelastic model is required.

- Two dimensions vs three dimensions:

The underground environment is a three-dimensional environment. In some cases, a two-dimensional analysis is physically incorrect (wave propagation), but may still be useful. Three-dimensional analyses may never just be discarded in favour of less time-consuming and easier two-dimensional analyses and when a two-dimensional programme is to be used, it must be justified. In many cases, the application of plane-strain and plane-stress concepts can be used to justify the use of two-dimensional models.

- Static vs Dynamic:

  Most commonly used codes are static in that they allow stress changes and the determination of equilibrium in steps. Executing dynamic analyses, the effects of damping and wave dispersion must be evaluated while grid sizes must allow the suitable presentation of waveforms.

- Deterministic vs Probabilistic:

  Since most models are based on deterministic mechanics (where results will be unique), it is important to test models for sensitivity to input parameters or to present results in a probabilistic form.