EXAMINATION PAPER

SUBJECT: CERTIFICATE IN STRATA CONTROL – METALLIFEROUS OPTION	**EXAMINER:** G KOTZE
SUBJECT CODE: COMCSC	**MODERATOR:** DA ARNOLD
EXAMINATION DATE: MAY 2011 **TIME:** 3 Hours	**TOTAL MARKS:** [100] **PASS MARK:** 60%

NUMBER OF PAGES: 5

SPECIAL REQUIREMENTS:

1. **Answer all of the Questions 1 to 5**
2. Start each question on a new page.
3. References other than those provided are not permitted.
4. Hand-held electronic calculators may be used. Text (reference notes) may not be programmed in a programmable calculator
5. 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.

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

Question 1 – General (20 marks, 2 marks each)

Answers: A,a,a,a,b,c,c,b,b,c

In each case, write down the correct answer. It is not required to show your calculations

1.1 The peak stress of a cylindrical rock sample, which is subjected to a UCS test is 165 MPa. The strain at this point is 3 x 10^{-3}. The elastic modulus (E) in GPa is:

a) 55 **b)** 5.5 **c)** 550 **d)** 3 **e)** none of these are correct

1.2 The radius of the above sample is 24.1 mm and its height is 0.0974 m. The volume of the specimen in m^3 is:

a) 1.78E-04 **b)** 0.178 **c)** 1.78 **d)** 1.78E-06 **e)** none of these are correct

1.3 The mass of a rock sample is 200 kg. The sample is placed on a flat surface and an object that exerts a force of 10 N is placed on top of the rock. Assume that g=9.81 m.s^{-2}. The normal downward force (in Newtons) experienced by the flat surface is:

a) 1972 **b)** 210 **c)** 2010 **d)** 190 **e)** none of these are correct

1.4 The k-ratio is 0.7. If the horizontal virgin stress is 30 MPa, the vertical virgin stress in MPa is :

a) 42.86 **b)** 21 **c)** 23.33 **d)** 15.00 **e)** none of these are correct

1.5 If the virgin stress in 20 MPa and the induced stress is 10 MPa, the field stress in MPa is:

a) 10 **b)** 30 **c)** 15 **d)** 20 **e)** none of these are correct

1.6 The following lengths of individual pieces of core is recovered out of a total length of drill run of 3m: 0.1 m, 0.3 m, 0.7 m, 0.3m. The RQD is

a) 1.4% **b)** 35% **c)** 47% **d)** 1% **e)** none of these are correct

1.7 A dyke is an example of the following type of rock:

a) Metamorphic **b)** Ultra-paleo **c)** Igneous **d)** Sedimentary **e)** none of these are correct

1.8 The capacity of a support type is 20 units. The demand on the support unit is 15 units. Therefore the factor of safety is:

a) 0.75 **b)** 1.33 **c)** 1.0 **d)** 300 **e)** none of these are correct

1.9 The prevailing stress value in a particular direction is 20 MPa. The effect of pore pressure that was induced can be expressed as 10 MPa. The effective stress (MPa) is:

a) 30 **b)** 10 **c)** 15 **d)** 40 **e)** none of these are correct

1.10 A method for determining the indirect tensile strength of a material is referred to as:

a) Geo-hammer **b)** GPR **c)** Brazillian disk **d)** UCS **e)** none of these are correct

QUESTION 2 – ROCK STRENGTH

2.1. Explain the differences between a strength criterion and a constitutive relation (4 marks)
Constitutive relation: mathematical or numerical relationship which describes the evolution of stress and strains as a material is subjected to loading or changes in loading.
Strength criterion: Predicts the material strength under various permitted stress combinations. It defines the combinations of limiting values of combinations of stress (e.g. sigma1 and 3) for which a material will not fail. When these limiting values are exceeded, the material fails.

2.2. Give examples of two constitutive relations and describe each relation. Include a graph in your descriptions for each (8 marks)
Ryder and Jager pp 147

2.3. Describe the Hoek-Brown criterion (3 marks)
An empirically established criterion for rock and rockmass failure based on tests of intact rock and on rock masses. The peak strength (sigma1) is described in terms of the confining stress (sigma3); m which is laboratory determined constant for the rock mass; s and a which are constants relating to the rock mass characteristics; and lastly, the UCS of intact rock.

2.4. Describe two shortcomings of the Hoek-Brown criterion (4 marks)

It is like the M-C criterion, shear based and therefore if the failure is for example brittle in nature, then the H-B is not appropriate to described failure.

Only sigma1 and sigma3 is considered and not the sigma2

It applies only to well jointed rockmasses where joints control the behaviour rather than the rock material or individual planes of weakness. Not applicable to massive rock or discontinuums (large blocks and wedges)

2.5. Name one other strength criterion (1 mark)

Mohr coulomb
Extension strain strength criterion
Griffith's formulation
Peak strength criterion
Residual strength criterion
Barton's joint shear strength
Barton-**Choubey** Shear *strength* Criterion

QUESTION 3 – EXCAVATION STABILITY, PILLAR STRENGHT AND LOADING (20 MARKS)

3.1. The following equation is given:

$$\sigma_{\theta\theta} = \frac{1}{2}q(1+k)\left(1+\frac{R^2}{r^2}\right)+\frac{1}{2}q(1-k)\left(1+\frac{3R^4}{r^4}\right)\cos 2\theta$$

3.1.1 Which quantity is expressed by this equation and for which type of excavation is it valid? (2 marks)
Tangential stress, circular tunnel.

3.1.2. (a) Does the equation provide a solution for a 2D or a 3D state of stress or strain. (1 mark) 2D
(b) Provide the terminology which describes the special state of stress or strain contemplated by the equation? (1 mark) Plane strain

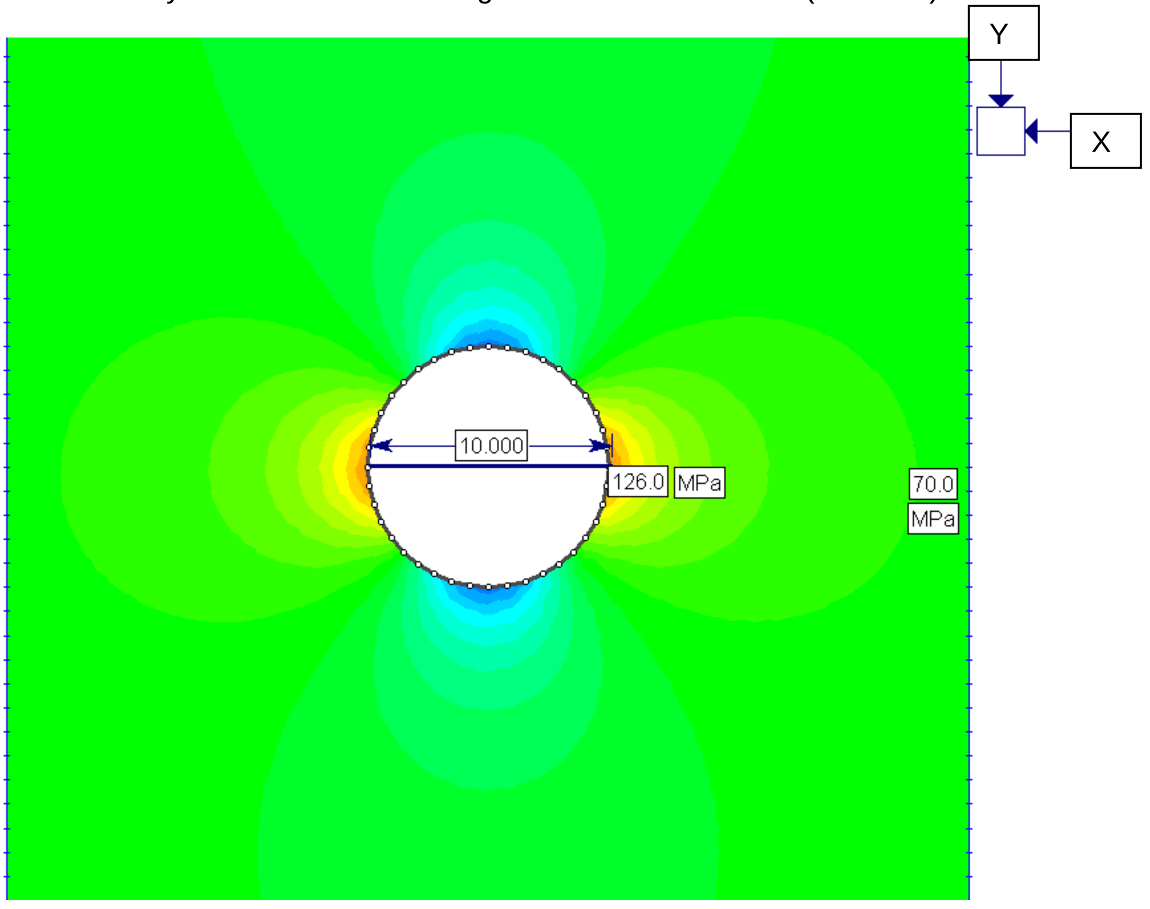
3.1.3. Simplify the equation above for the case when horizontal virgin stress is equal to vertical virgin stress. (3 marks)

$k=1 \Rightarrow$

$$\sigma_{\theta\theta} = \frac{1}{2}q(1+1)\left(1+\frac{R^2}{r^2}\right)$$

$$= q\left(1+\frac{R^2}{r^2}\right)$$

3.1.4. The plot below was obtained from a 2D boundary element numerical modelling program. The quantity that is contoured is the vertical stress around the tunnel (section view) at a depth of 2400m below surface. The value of the vertical stress in the skin of the excavation is indicated. The diameter is also given in meters. Compare the value of stress in the skin as indicated by the modelling with a calculation that you must perform using the simplified equation in 3.1.3. Assume that g = 9.81 m/s^2, the density of the rock = 2700 kg/m3 and E = 70 GPa. (5 marks)



q= 2700 x 9.81 x 24 00
= 63.57 MPa (1 mark)

Kirsch at skin => r=R=5

$$\sigma_{\theta\theta} = q\left(1+\frac{R^2}{r^2}\right)$$

Thus $= 63.57x(1+1)$ *(2 marks)*

$= 127.14MPa$

The analytical solution (Kirsch) is higher than the modelled solution and the former is exact and thus more accurate than the model. (2 marks)

3.2. What is meant by the term tributary area theory? (3 marks)
Each pillar in a large mined area carries an equal share of the overload. Spans must be large and pillars must be placed on a regular grid for the theory to be valid. The size of the area that is supported by each pillar is equal to the C^2, the centres spacing squared (for square pillars, regular board widths). The explanation pertaining to support units were also accepted.

3.3. A hard rock, tabular orebody is mined using a regular board and pillar layout. The mine plan indicates an area at a certain depth below datum where an APS of 10 MPa was calculated. The collar elevation of the shaft is 20m below datum. The boards are 10 m wide and the square pillars are 15 m wide, respectively. Assume that the density of the rock is 3000 kg.m^{-3}. Assume g = 10 m.s^{-2}.

3.3.1 Calculate the depth of the orebody below surface. (3 marks)

$\sigma_p = \frac{q}{1-e}$, *q=σ_p* (1-e)*

$e = 1 - \frac{w_1 w_2}{C_1 C_2}$, *but w1 = w2 and C1=C2=w+b for square pillars and regular boards. Thus e= 1 – $w^2/(w+b)^2$=1-$(15^2/(15+10)^2)$= 0.64*

q= (10e6) * (1-0.64)=3.6 MPa

h=q/(ρ*g)= 3.6e6 /(3000*10) = **120 m below surface**

3.3.2 If the pillar strength is 15 MPa, calculate the factor of safety. (2 marks).
FOS=capacity/demand = 15/10=1.5

Question 4 – TESTING AND MONITORING METHODS (20 MARKS)

4.1 Describe the geophysical technique of Ground Penetrating Radar, and name a typical application. (3 marks)
Electromagnetic pulses are transmitted into rock or other medium and reflected back to the receiver upon encountering an interface characterising two mediums with different dielectric constants. The transmitted frequency of the pulse determines the resolution whilst factors such as the electric properties of the medium and power of transmitter determines the depth of penetration. Applications includes: finding blind boreholes, detecting bedding plane separation, triplets, domes and calcite filled veins, faults and dykes, depth of fracturing as wells IRUPS.

4.2 State the six parameters that uniquely characterise a seismic event. (6 marks)
X Y Z time energy moment

4.3 State whether the following statements are <u>true</u> or <u>false</u>. If false, indicate a reason to motivate your answer:

4.3.1 When determining the orientation of a feature through a borehole camera inspection, strike and dip uniquely describe the orientation of such a geological feature. (2 marks)

False. Dip and dip direction uniquely describes orientation. When specifying dip and strike, you also need to specify rake.

4.3.2 Normal faulting results in a loss of ground due to the displacement of the reef. (2 marks) True

4.3.3 Geophones measure ground acceleration. False. Ground velocity (m/s).(2 marks)

4.3.4 Geological discontinuities such as joints and faults increase rock mass strength (2 marks) False. Decreases rock mass strength.

4.3.5 A joint plane which is exactly orientated in the plane of the major and the minor principle stress is contributing towards stability of the ground conditions. False. Sigma1 would contribute to destabilise the feature and drive instability (2 marks)

4.4 Give one example of an instrument that can be used to monitor in-situ load deformation characteristics of an elongate support unit (1 mark). Load cell

QUESTION 5 – MINING (ROCK BREAKING) AND STOPE SUPPORT DESIGN (20 MARKS)

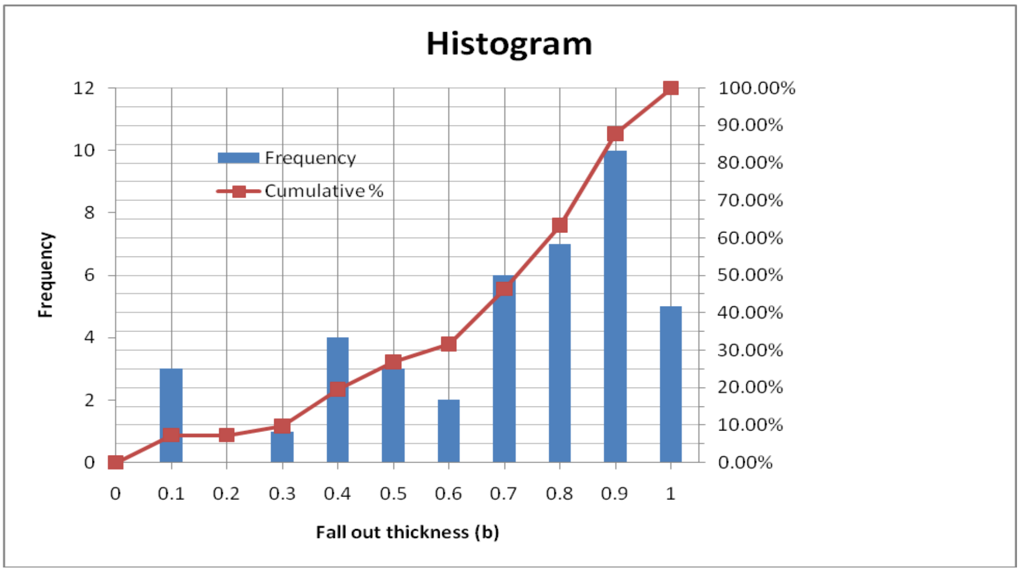
5.1. When breaking rock by means of explosives, some factors need to be considered in the design of the blast. Explain each of the following terms and indicate their role: stemming; burden; hole diameter. (6 marks)

Spacing (Burden): Burden is the distance between top holes measured along the face, and also the vertical distance between top and bottom holes. The correct burden will ensure proper breaking of the rock, along the entire length of the panel, making it easier to clean and support the panel and contributing to non-adverse ground conditions..

STEMMING (TAMPING): Stemming is used in a blast hole as a plug to prevent the blowout of a blasthole. It is often a clayish material with enough strength to confine the explosives in the hole and to allow the explosive energy to be transferred into rock mass, thus into breaking the rock.

Hole diameters: The closer the hole diameter is to the explosive diameter, the more effective is the transfer of blast energy from the explosive to the surrounding rock. The effectiveness of rock breaking is improved. On the contrary, de-coupling can be used as a technique to control blast damage to the sidewalls of an excavation.

5.2. (a) You are provided with the composite graph below which represents a Histogram of fall out thickness in metres (for rock falls and rock bursts) and a line graph of cumulative fallout thickness (for rock falls and rock bursts). Determine the 95% cumulative fallout height under both rockfall and rockburst conditions from the graph below. (1 mark)



Answers between 0.9 m and 1.0 m (inclusive) were accepted.

(b) You are also given the following additional information:

- Rock density = 2 650kg/m^3;
- The hangingwall must be brought to rest within 0.2m of downward movement;
- The ejection velocity is 3m/s;

Determine rockfall support resistance and rockburst energy absorption criteria. (4 marks)

Assumption: the support units are spaced 1m on strike x dip

i) The rockburst support design criterion.

$E = \frac{1}{2}mv^2 + mgh$

$= 0.5 \times (1.0 \times 1.0 \times 0.95) \times 2\,650\ kg/m^3 \times (3\ m/s)^2 + (1.0 \times 1.0 \times 0.95) \times 2650\ kg/m^3 \times 9.81\ m/s^2 \times 0.2\ m$

$= 11328.75\ J/m^2 + 4939.34\ J/m^2$

$= 16268.09\ J/m^2$

$= 16.3\ kJ/m^2$ *(2 marks)*

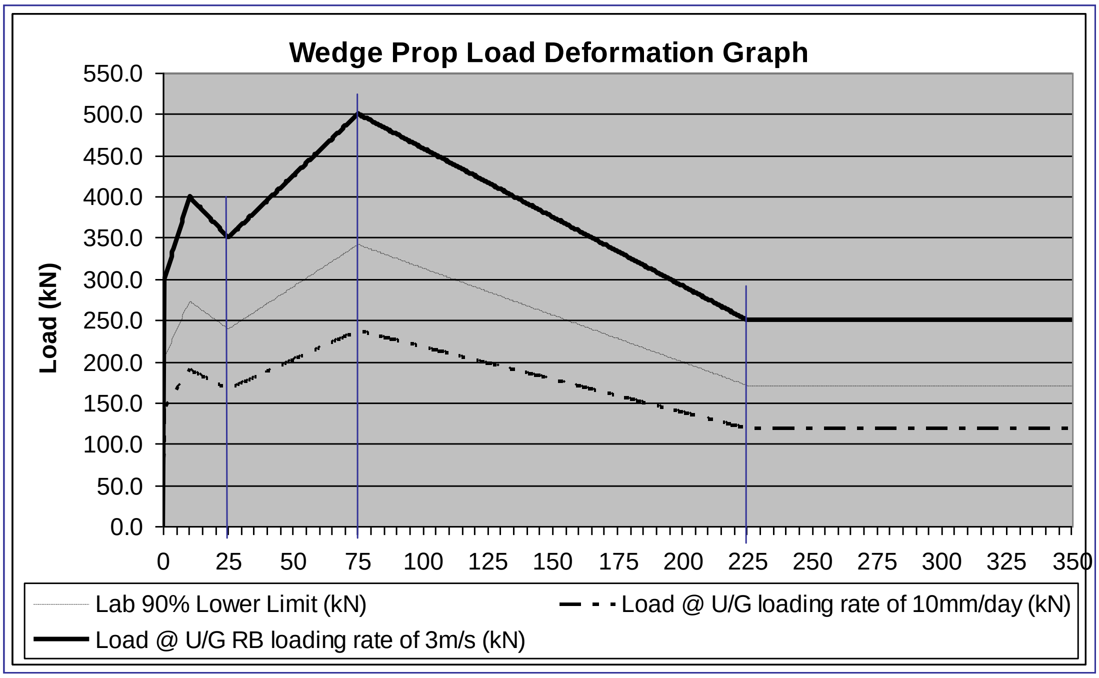
ii) S.R. = Load per unit / Area per unit

$= (1 \times 1 \times 0.95 \times 2650 \times 9.81)\ N / 1\ m^2$

$= 24.70\ kN/m^2$

5.3 Describe the term ‘bedding in’ in timber based support units. (2 marks) The compaction of timber fibres in a unit. When experiencing load the timber unit initially sheds load as a result of bedding-in of the fibres and thereafter provides load as per design.

5.4 Describe the effect of loading rate on the performance of timber support units when comparing the load / deformation characteristic determined in laboratory tests to the performance under i) quasi-static (rockfall) and ii) dynamic (rockburst) conditions. You must include a graph as an aid to your description. (5 marks)
The higher the loading rate, the larger the load response for the same amount of deformation. Thus under dynamic conditions the load response will be higher than for lab conditions. Under lab conditions the load response will be higher than under quasi-static conditions underground.



5.5 Laboratory press test results yield the following information about a prototype elongate support unit:

Force (kN)	Deformation (mm)
500	38
1 000	54
1 500	70
2 000	100
2 500	168
3 000	240

The rock engineer has designed an elongate support layout such that each of these prototype elongates will support 5 m^2. With the aid of the laboratory test data, determine how much deformation would be measured on the elongate if the dead weight created by a 5m thick hangingwall beam is to be supported? The density of the hangingwall rock is 2700 kg/m^3 and you can assume that g = 9.81m/s. (2 marks)

5m^2 x 5 m = 25m^3 volume to be supported.

Mass = density x volume

Mass= 25 x 2700 = 67500 kg

Weight = 9.81 x 67500 = 662 175 N= 662.18 kN

Without a graph (seeing that this question is only worth 2 marks): Assuming piece-wise linear load-deformation response between consecutive data points, one can argue that 662kN lies between 1/5 and 2/5 of a 500 kN increment above 500 kN.

There is 54 mm – 38 mm = 16mm deformation for the range 500 to 1000 kN.

1/5 of 16mm = 3.2 mm. 38mm + 3 mm = 41 mm
2/5 of 16mm = 6.4mm. 38 mm + 6 mm = 44 mm.

Thus between 41 mm and 44 mm of deformation will be caused by a deadweight of 662 kN. (this is the range of answers accepted).