Minerals Council South Africa

EXAMINATION PAPER

SUBJECT: CHAMBER OF MINES OF SOUTH AFRICA – CERTIFICATE IN STRATA CONTROL – METALLIFEROUS **SUBJECT CODE: COMSCM** **EXAMINATION DATE: 8 OCTOBER 2019** **TIME**: 14:30 – 17:30	**EXAMINER:** JC VAN ZYL **MODERATOR:** J ESTERHUYSE **TOTAL MARKS:** [100] **PASS MARK:** (60%)

NUMBER OF PAGES: 12

THIS IS NOT AN OPENBOOK EXAMINATION – ONLY REFERENCES PROVIDED ARE ALLOWED

SPECIAL REQUIREMENTS:

1. **All candidates** must complete **Questions 1 to 3**. Answer the questions **legibly** in English.
2. **Complete only one of the following questions (4 or 5) in relation to your specific field of study. Question 4: Narrow Tabular Hard Rock and Massive mining; Question 5: Surface mines;**
3. Write your **ID 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.
4. Show all calculations **and check calculations on which the answers are based.**
5. Hand-held electronic calculators may be used for calculations. Reference notes may not be programmed into calculators.
6. Write **legibly** in ink on the **right-hand page** only – **left hand pages will not be marked**.
7. Illustrate your answers by means of sketches or diagrams wherever possible.
8. **Final answers** must be given to an accuracy which is typical of practical conditions. However, be careful not to use too few decimal places (minimum 2) during your calculations, as rounding errors may result in incorrect answers.
   NB: Ensure that the correct unit of measure (SI units) are recorded as marks will be deducted from answers if the incorrect unit is used (even if the calculated value is correct).
9. In answering the questions, full advantage should be taken of your practical experience as well as data given.
10. Please note that you are not allowed to contact your examiner or moderator regarding this examination.
11. Cell phones are **NOT** allowed in the examination room.

1 QUESTION 1 – General

In each case, write down the correct answer. It is not required to show your calculations. Partial marks may be allocated if calculations are shown.

1.1 An elongate (180mm in diameter) yields at 20 tons. If units are installed on a 1.8m x 1.8m skin-to-skin spacing, what is the support resistance offered by the system? To get the correct answer, assume that g =10 m/s^2. (3)

(a) 61.73 kN/m^2; (b) 51.02 kN/m^2; (c) 210 kN/m^2; (d) 73.16 kN/m^2; (e) 61.73 MPa.

1.2 What will the average pillar stress be if the virgin stress is 50 MPa and the extraction ratio is 82%? (3)

(a) 60.98 MPa; (b) 277.78 kN/m^2; (c) 60.98 kJ/m^2; (d) 277.78 MPa; (e) 61.73 MPa.

1.3 Stemming is used in blast holes as a plug to prevent the blowout of explosives and gasses from the blast hole? (2)

(a) True; (b) False; (c) Plug sockets after examination; (d) None of the above

1.4 The k-ratio is 0.7. If the horizontal virgin stress is 30 MPa, the vertical virgin stress in MPa is? (3)

(a) 42.86 MPa; (b) 21 MPa; (c) 23.33 MPa; (d) 15 MPa; (e) None of the above.

1.5 A method for determining the indirect tensile strength of a material is referred to as? (2)

(a) Shear box test; (b) GPR test; (c) UCS test; (d) TCS test; (e) Brazilian disk test

1.6 The capacity of a tendon is 200 MPa. The demand on the tendon is 150 MPa. Therefore the factor of safety is? (3)

(a) 0.75; (b) 13; (c) 1.75; (d) 1.3; (e) 1.6

1.7 A perfectly square shaped haulage (developed on strike) on a mine, is 3.5m wide. The sidewalls are 3.5m high. Calculate the area of wire mesh per meter of tunnel length that is required to support the tunnel if it extends to within 1m of the footwall? (3)

(a) 10 m^2; (b) 8.5 m^2; (c) 9 m^2; (d) 9.5 m^2; (e) 7 m^2.

1.8 An example of a sedimentary rock type is? (2)

(a) Basalt; (b) Quartzite; (c) Sandstone; (d) Gneiss; (e) Andesite

1.9 An example of a metamorphic rock type is? (2)

(a) Basalt; (b) Quartzite; (c) Sandstone; (d) Norite; (e) Andesite

1.10 An example of a igneous rock type is? (2)

(a) Dolomite; (b) Quartzite; (c) Sandstone; (d) Norite; (e) Gneiss

[25]

2 QUESTION 2: Rock Mass Classification and Joints

Following a feasibility study of a newly discovered orebody, it was established that it is economically viable to develop a new mine. A number of exploration boreholes were drilled as part of the geotechnical assessment and orientated core were extracted. The following information from core retrieved at the planned box cut and decline shaft position.

A 60 m long exploration diamond drill hole, with orientated drill core, has been drilled to gather information on expected ground conditions. You must analyze the orientated core recovered from the hole. You record a total of 450 joints in the core. There appears to be two distinct joint sets, dipping at roughly 60 and 80 degrees respectively including some random joints. While the one set is rough and undulating, the other is smooth and planar. Traces of micaceous filling, varying in thickness from 0 – 3 mm, are visible in the joint planes. No water seems to be present. There also appears to be a 3.0-metre thick weathered dyke running through the middle of this zone, at an angle of 45 degrees.

2.1 Calculate the rock mass quality based on the Q-system, using the tables provided in Appendix 1. State your reason for each value chosen for use in the rock mass rating. (8)

2.2 State the relationship between RMR and Q as proposed by Bieniawski, 1989 and then convert your Q rating calculated in Question 2.1? (3)

2.3 Laubscher suggested changes to the Bieniawski Rock Mass Rating system. This system takes the basic RMR value, as defined by Bieniawski, and adjusts it. How did he adjust the rating system? (4)

2.4 Barton and Choubey developed the following equation:

$\tau = \sigma_n \cdot \tan(\Phi_b + JRC \cdot \log_{10}(JCS / \sigma_n))$. What is determined by this equation? (1)

2.5 What is the significance of each parameter of the Barton and Choubey equation i.e. what does each parameter in the equation mean? (4)

2.6 Given the following: $\Phi_b = 28°$, JRC = 17 and JCS = 110 MPa, calculate τ when σ_n = 1.0 MPa and σ_n = 3.0 MPa. (6)

2.7 What is the effect of increasing σn? (2)

2.8 What tool or instrument can be used to determine JCS? (2)

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3 QUESTION 3: Monitoring and Instrumentation

There are usually a number of instrumentation options for each rock engineering parameter to be monitored. The table below lists the parameters to be monitored and the recommended instruments. You are required to complete the table. Make sure to clearly label your answers.

Q	Parameter to be monitored	Recommended Instrument	Marks
3.1		Four peg closure ride station	1
3.2	Stope closure (24 hr or remote readings)		2
3.3		Backfill closure meter	1
3.4	Opening / closing up of discontinuities		2
3.5	Load in Elongate support		1
3.6		Pack load cell	1
3.7	Load in Backfill		1
3.8		Roofbolt load cell	1
3.9	Fracturing in rock close to an excavation <10m and <50m		2
3.10	Fracturing around an excavation		2
3.11		Various geophisical including radio and seismic tomography	2
3.12		CSIR doorstopper strain cell in one hole	1
3.13	Stress field (3D)		2
3.14	Ground Motion		2
3.15	Slope Displacement		4

[25]

Note: Candidates to select only one of the following option questions

4 QUESTION 4: Support (Underground Candidates tabular and massive mining)

4.1 Name the two general design rules for tendon support frequently used within the mining industry for the length and spacing of tendons in tunnels? (2)

4.2 What do you understand by the term critical bond length? (2)

4.3 List five points to take into consideration when designing access tunnels in medium to deep stress conditions? (5)

4.4 Use the empirical design charts supplied (Annexure 2) to assist you in answering the questions below. Write down your examination number in the space provided and submit it with your answer book.

A new twin decline shaft system will be developed to access the orebody discussed in Question 2, the dimensions of the excavations will be 6.0m wide x 6.0m high to accommodate the required infrastructure and trackless mobile machinery used at the site.

4.4.1 You are tasked to recommend the initial primary tendon support requirements by applying the general design rules for tendon support in terms of.

(a) Tendon length and (1)

(b) Tendon spacing. (1)

(c) Use your Q rating calculated in question 2.1 and the empirical chart to determine the maximum unsupported span for a factor of safety of 1. (3)

4.4.2 The project team will consist of a limited number of multiskilled personnel, who will be responsible to install all the required infrastructure and services during initial development. You are therefore required to further recommend the maximum time period the excavations can remain unsupported making use of your RMR value calculated in question 2.2. Use the empirical chart to motivate your answer. (3)

4.4.3 The numerical value of the index Q varies on a logarithmic scale from 0.001 to a maximum of 1,000 to classify the Rockmass. In a table, describe the classification values from exceptionally poor to extremely good (3)

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5 QUESTION 5: Slope stability (Surface mine candidates)

5.1 List /describe three categories of stability evaluations, which follow directly from rock mass characterization approaches. (6)

5.2 Use the empirical design chart and information supplied (Annexure 3) to assist you in answering the questions below. Write down your examination number in the space provided and submit it with your answer book.

5.2.1 A new pit will be excavated to extract the orebody discussed in Question 2, the final depth of the pit will be 60m and the life of mine is expected to be approximately 5 years. (a) Comment on a suitable factor of safety for the slope and (b) recommend the slope angle assuming the MRMR value is equal to your calculated RMR value from question 2.2 (6)

5.2.2 If you were to design the slope for a box cut from where a decline shaft system will be developed, what factor of safety will you use for the slope and motivate your answer. (5)

5.2.3 The numerical value of the index Q varies on a logarithmic scale from 0.001 to a maximum of 1,000 to classify the Rockmass. In a table, describe the classification values from exceptionally poor to extremely good (3)

Total marks: 100

Annexure 1

	STRESS REDUCTION FACTOR	
A	No shear, faults, dyke or weakness zone	1
B	One shear, fault, dyke or weakness zone	2.5
C	One shear, fault, dyke or weakness zone with blocky ground conditions	4
D	Curved joints or dome structure approaching a pothole, reef roll or OPL's	7.5
E	Curved joints or dome structure approaching a pothole, reef roll, OPL's with blocky ground conditions	8
F	Many faults, dyke and weakness zones.	9
G	Wide shear zone	10

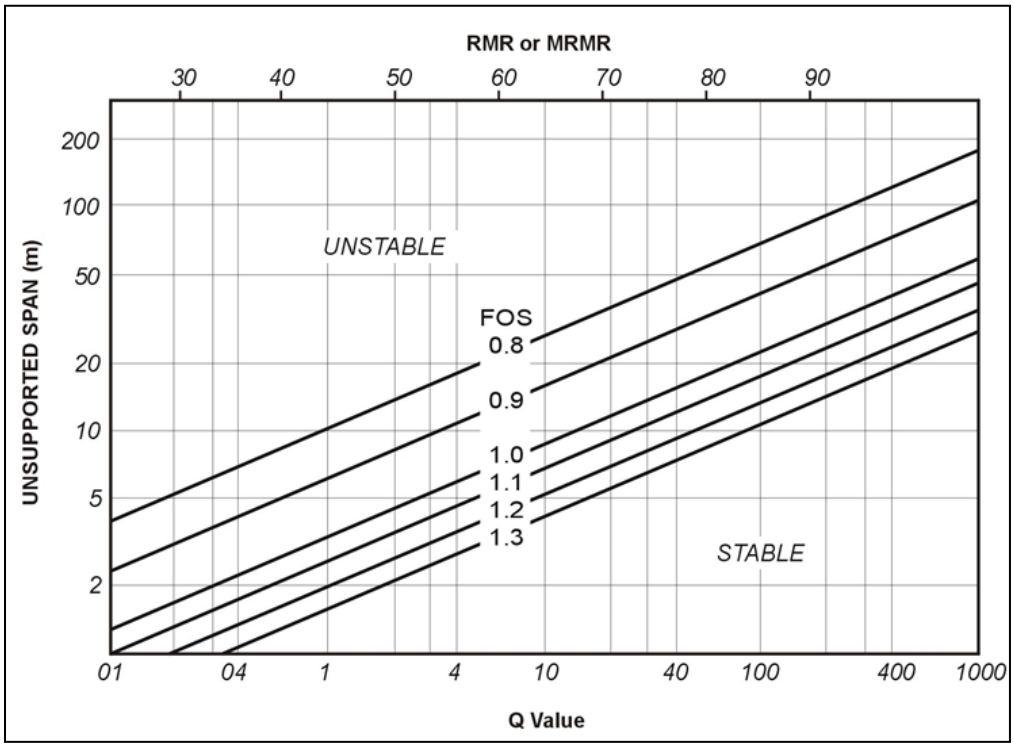
	JOINT ALTERATION NUMBER	
A	Tightly healed, hard rockwall joints, no filling	0.5
B	Slight infill, coating < 1mm	1
C	Joint filling > 1 mm	2
D	Joint filling > 3 mm	4
E	Zones or bands of disintegrated or crushed filling, open joints.	8

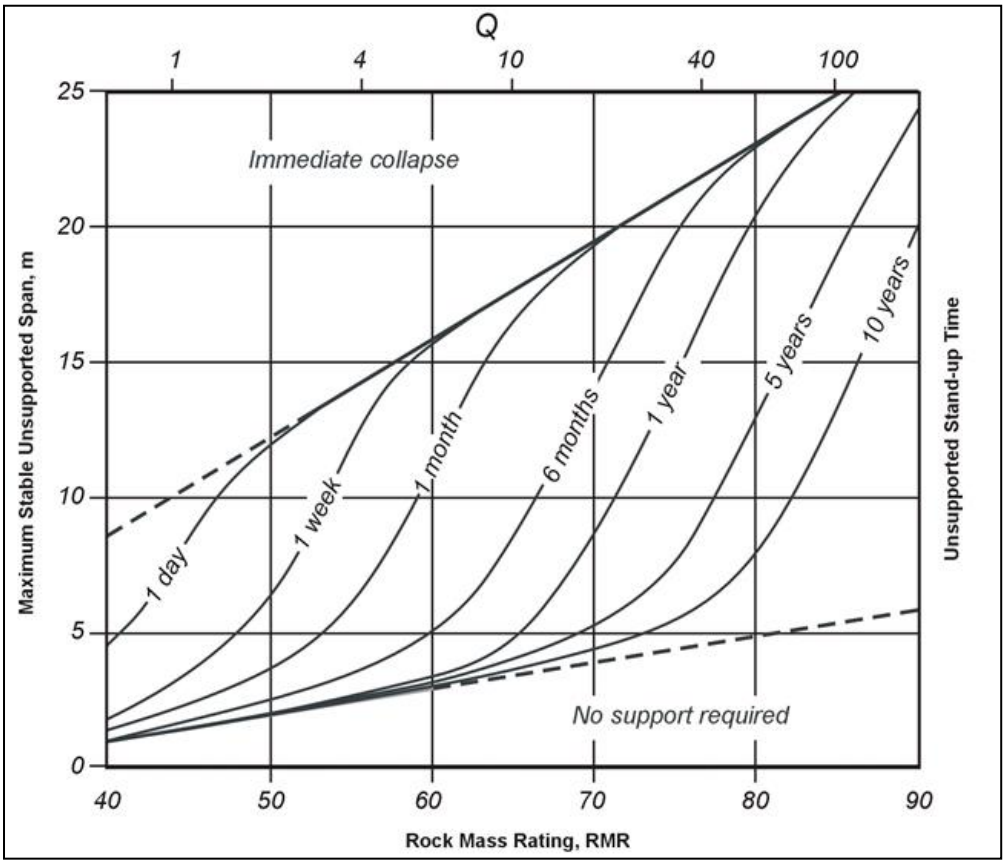
	JOINT SET NUMBER	
A	Massive, no to few joints	1
B	One joint set	2
C	One joint set plus random joints	3
D	Two joint sets	4
E	Two joint sets plus random joints	6
F	Three joint sets	9
G	Three joint sets plus random joints.	12
H	Four or more joint sets, random, heavily jointed.	15
I	Crushed rock	20

	JOINT WATER	
A	Dry	1
B	Dripping water	0.5

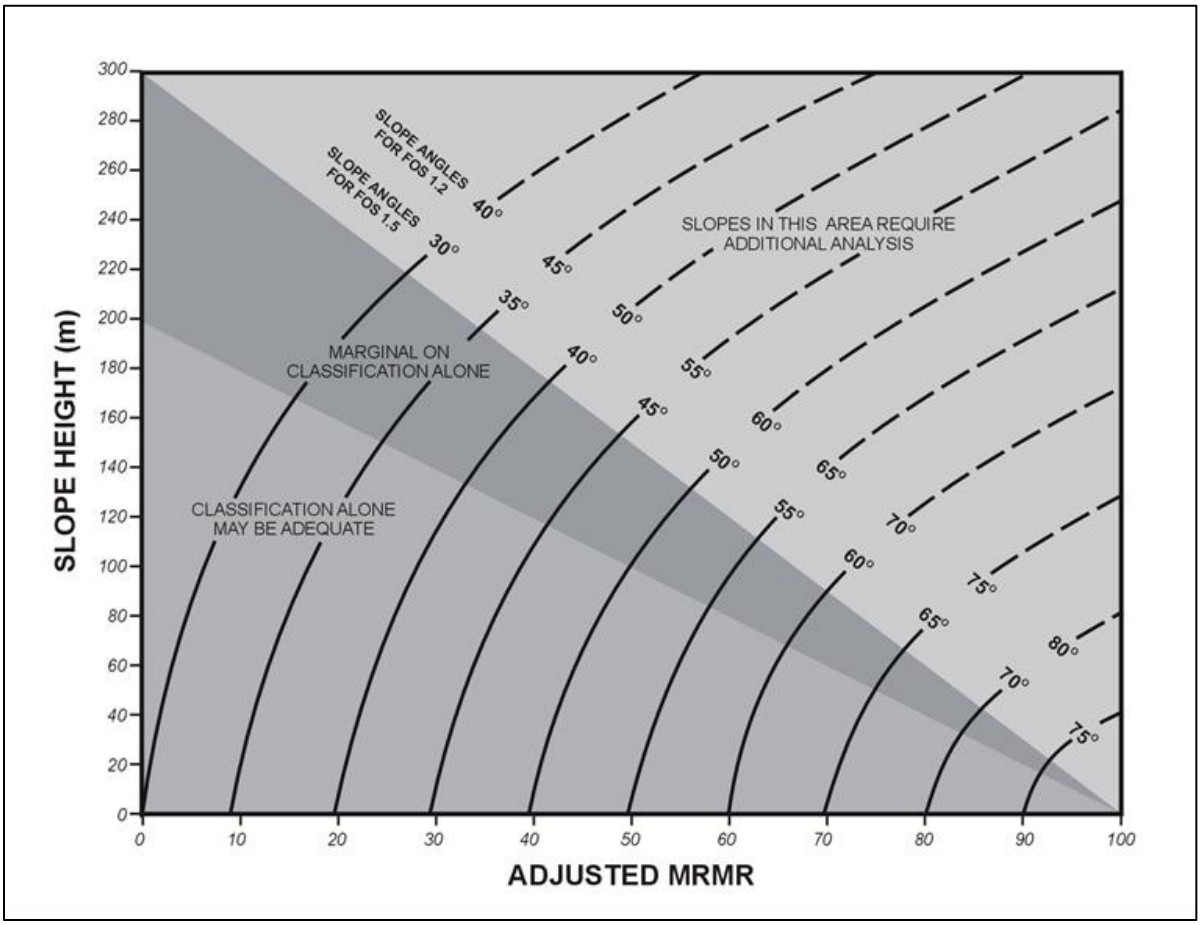
	JOINT ROUGHNESS NUMBER		
A	Discontinuous joints		4
B	Rough or irregular	undulating	3
C	Smooth	undulating	2
D	Slickensided,	undulating	1.5
E	Rough or irregular	planar	1.5
F	Smooth	planar	1
G	Slickensided	planar	0.5

Student Number_____ **Annexure 2**





Student Number_____ **Annexure 3**



Consequences of failure	Examples	Minimum FOS
Not serious	No person-entry	1.2
	Individual benches and small temporary slopes	1.3
Moderately serious	Any slope of a permanent or semi-permanent nature.	1.5
Very serious	Medium sized and high slopes carrying major haulage roads or underlying permanent mine installations	2.0

Formulas:

$$Q = \frac{RQD}{J_n}\frac{J_r}{J_a}\frac{J_w}{SRF} \qquad RMR = 9\log_e Q + 44$$

$$\sigma_1 = \sigma_3 + \sigma_{ci}\left(m_b\frac{\sigma_3}{\sigma_{ci}} + s\right)^a \qquad \sigma_1 = \sigma_3 + \sigma_{ci}\sqrt{m_i\frac{\sigma_3}{\sigma_{ci}} + 1}$$

$$GSI > 25 \qquad GSI = RMR_{76} \qquad GSI = RMR_{89} - 5$$

$$GSI < 25 \qquad Q' = \frac{\mathrm{RQD}}{\mathrm{J_n}}\frac{J_r}{J_a} \qquad GSI = 9\log_e Q' + 44$$

$$m_b = m_i \exp\left(\frac{GSI - 100}{28}\right) \qquad RQD = 115 - 3.3\,x\,Jv$$

$$GSI > 25 \qquad s = \exp\left(\frac{GSI - 100}{9}\right) \qquad a = \frac{1}{2} \qquad \sigma_1 = \sigma_3 + \sigma_{ci}\sqrt{m_b\frac{\sigma_3}{\sigma_{ci}} + s}$$

$$\sigma_{tm} = \frac{\sigma_{ci}}{2}\left(m_b - \sqrt{m_b^2 + 4s}\right) \qquad \sigma_{cm} = \sigma_{ci}\sqrt{s}$$

$$GSI < 25 \qquad s = 0 \qquad a = 0.65 - \frac{GSI}{200} \qquad \sigma_1 = \sigma_3 + \sigma_{ci}\left(m_b\frac{\sigma_3}{\sigma_{ci}}\right)^{0,65-\frac{GSI}{200}}$$

$$\sigma_{tm} = 0 \qquad \sigma_{cm} = 0$$

$$\sigma_{ci} > 100\ \text{MPa} \qquad \mathrm{E_m\,(GPa)} = 10^{\left(\frac{\text{GSI-10}}{40}\right)}$$

$$\sigma_{ci} < 100\ \text{MPa} \qquad \mathrm{E_m\,(GPa)} = \sqrt{\frac{\sigma_{ci}\,(MPa)}{100(MPa)}}\,10^{\left(\frac{\text{GSI-10}}{40}\right)}$$

$$\tau = \sigma_n \tan\left[\phi_a + JRC\log_{10}\left(\frac{JCS}{\sigma_n}\right)\right] \qquad A = \frac{\pi D^2}{4}$$

$$\varepsilon_{xx}=\frac{1}{E}\{\sigma_{xx}-\nu(\sigma_{yy}+\sigma_{zz})\}\quad \gamma_{xy}=\frac{1}{G}\tau_{xy}\quad \varepsilon_{xy}=\frac{1}{2G}\tau_{xy}\quad G=\frac{E}{2(1+\nu)}$$

$$\varepsilon_{yy}=\frac{1}{E}\{\sigma_{yy}-\nu(\sigma_{xx}+\sigma_{zz})\}\quad \gamma_{yz}=\frac{1}{G}\tau_{yz}\quad \varepsilon_{yz}=\frac{1}{2G}\tau_{yz}\quad K=\frac{E}{3(1-2\nu)}$$

$$\varepsilon_{zz}=\frac{1}{E}\{\sigma_{zz}-\nu(\sigma_{xx}+\sigma_{yy})\}\quad \gamma_{zx}=\frac{1}{G}\tau_{zx}\quad \varepsilon_{zx}=\frac{1}{2G}\tau_{zx}$$

$$\sigma_{xx}=\lambda\Delta+2G\varepsilon_{xx}\quad \tau_{xy}=G\gamma_{xy}\quad \tau_{xy}=2G\varepsilon_{xy}\quad \Delta=\varepsilon_{xx}+\varepsilon_{yy}+\varepsilon_{zz}$$

$$\sigma_{yy}=\lambda\Delta+2G\varepsilon_{yy}\quad \tau_{yz}=G\gamma_{yz}\quad \tau_{yz}=2G\varepsilon_{yz}\quad \lambda=\frac{E\nu}{(1+\nu)(1-2\nu)}$$

$$\sigma_{zz}=\lambda\Delta+2G\varepsilon_{zz}\quad \tau_{zx}=G\gamma_{zx}\quad \tau_{zx}=2G\varepsilon_{zx}$$

$$E=\sigma/\varepsilon$$

$$\sigma_{zz}=0\quad \varepsilon_{zz}=-\frac{\nu}{E}(\sigma_{xx}+\sigma_{yy})$$

$$\upsilon=\varepsilon_r/\varepsilon_a$$

$$\varepsilon_{xx}=\frac{1}{E}(\sigma_{xx}-\nu\sigma_{yy})\quad \gamma_{xy}=\frac{1}{G}\tau_{xy}\quad \sigma_{xx}=\frac{E}{1-\nu^2}(\varepsilon_{xx}+\nu\varepsilon_{yy})\quad \tau_{xy}=G\gamma_{xy}$$

$$\varepsilon_{yy}=\frac{1}{E}(\sigma_{yy}-\nu\sigma_{xx})\quad \sigma_{yy}=\frac{E}{1-\nu^2}(\varepsilon_{yy}+\nu\varepsilon_{xx})$$

$$\varepsilon_{zz}=0\quad \sigma_{zz}=\nu(\sigma_{xx}+\sigma_{yy})$$

$$\varepsilon_{xx}=\frac{1}{E}\{(1-\nu^2)\sigma_{xx}-\nu(1+\nu)\sigma_{yy}\}$$

$$\varepsilon_{yy}=\frac{1}{E}\{(1-\nu^2)\sigma_{yy}-\nu(1+\nu)\sigma_{xx}\}$$

$$q=\rho gH\quad \sigma_v=q\quad \sigma_h=kq$$