WORKSHOP 5: STUDENT SHEET 1

Investigating the Engineering Geology of Ecton

Behaviour of rock masses

The following system was devised by Bieniawski for the South African Council for Scientific and Industrial Research (CSIR).

Introduction

When failure of a rock mass occurs, it usually takes place along one or more planes in the rock, e.g. bedding planes, faults or joints. Failure is usually speeded up by the presence of water in the rock mass. The design of a tunnel needs to take into account:

- The **"strength"** of the rock in an intact rock mass (expressed as the uniaxial compressive strength, i.e. how resistant it is to a force acting in one direction). This is measured by a Schmidt hammer
- **Drill core quality** i.e. the percentage of lengths of core which are over 10 cm long per metre of core.
- Spacing of joints and bedding planes
- Roughness of joints and bedding planes
- Wetness of joints and bedding planes
- Orientation of tunnel compared to strike of bedding
- Span (width) of tunnel

NB. The Tables refer to "fractures" but this mean any discontinuity in the rock, including bedding planes, joints and fault planes.

Investigation

Work through the measurements shown in each Table, and allocate a "rating" to each one. The rating shows how good or bad the rock mass will be if a tunnel is driven into it.

First, measure the strike of bedding planes (take 6 measurements and average them)

1	2	3	4	5	6	Total	Average ° Mag.

What would be the direction of a "new tunnel", if it was dug at right angles to the road? ________° Magnetic.

Is this parallel to the strike or the dip of the beds? ______________

Table 1 CSIR Geomechanics classification of fractured rock masses

FACTORS WHICH AFFECT ROCK STRENGTH AND THEIR RATINGS

a) Uniaxial compressive strength. Use the Schmidt Hammer and enter the results on Figure 5.3. Use the graph, Figure 5.4, to find out the uniaxial compressive strength from each reading. Average your values and then RING the appropriate rating below.

Factor	Ranges of values (1 Mega Pascal, MPa = 1 MN/m^2)				
Uniaxial comp strength of intact rock	> 200 MPa	100-200 MPa	50-100 MPa	25-50 MPa	1-25 MPa
Rating	15	12	7	4	0 - 2

b) Drill core quality, RQD. Imagine that you have drilled through the rock. Estimate the percentage of your core that is in fragments of over 10 cm length. Do this by measuring 5 metres on the rock surface and then estimating as above.

Then RING the appropriate rating in the table below:

RQD	90-100%	75-90%	50-75%	25-50%	< 25%
Rating	20	17	13	8	3

c) Spacing of fractures (bedding planes, faults or joints). Measure the average spacing and then RING the appropriate rating below

Spacing	> 3 m	1-3 m	0.3-1m	50-300 mm	< 50 mm
Rating	30	25	20	10	5

d) Condition of fractures (bedding planes, faults or joints). RING the rating.

Condition of fractures	Very rough surfaces. Tight	Slightly rough surfaces. Separation <1 mm	Weathered. Separation >1 mm	Slickensided surfaces or gouge <5 mm thick	Soft gouge >5 mm thick, or fractures open >5 mm
Rating	25	20	12	6	0

e) Groundwater state RING the rating below:

Wetness along fractures	Dry	Damp	Wet	Dripping	Flowing
Rating	15	10	7	4	0

f) Rock Mass Rating, i.e. total ratings for the 5 categories above =___

g) Rating adjustment for fracture orientation in driving a tunnel (Note negative values) – See Table 2 for method

Fracture orientation relative to tunnel heading	Very favourable	Favourable	Fair	Unfavourable	Very unfavourable
Rating	0	-2	-5	-10	-12

Table 2. The effects of the orientation of the strike and dip of fractures in tunnelling

Strike perpendicular to tunnel axis				Strike parallel to tunnel axis		Dip 0^o to 20^o irrespective of strike
Drive with dip		Drive against dip				
Dip 45^o - 90^o	Dip 20^o - 45^o	Dip 45^o - 90^o	Dip 20^o - 45^o	Dip 45^o - 90^o	Dip 20^o - 45^o	
Very favourable	Favourable	Fair	Unfavourable	Very unfavourable	Fair	Unfavourable

h) Total Rock Mass Rating (value from f above, allowing for the value from g) = __

i) Rock Mass Classes determined from Total Rock Mass rating (h)

Rating	100-81	80-61	60-41	40-21	<20
Class number	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

Finally use your results from i to find out the "stand up" time for a tunnel of 2m span from Figure 5.5 below.

Figure 5.3. Recording sheet for Schmidt Hammer tests

Location		Date:		Lithology:	
Blow no:	Hammer reading	Strength from Fig. 5.4 (MPa)	Blow no:	Hammer reading	Strength from Fig. 5.4 (MPa)
1			11		
2			12		
3			13		
4			14		
5			15		
6			16		
7			17		
8			18		
9			19		
10			20		

Notes:

- Calculate the strength after each blow, using Figure 5.4, and remembering to allow for hammer orientation.
- When you have got all your readings, discard the lowest 50% of strength values.
- Use the remaining 50% of values to calculate the average strength.
- Average strength = ________ MPa.
- This is the uniaxial compressive strength. Use it to ring the appropriate rating in Table 1a.

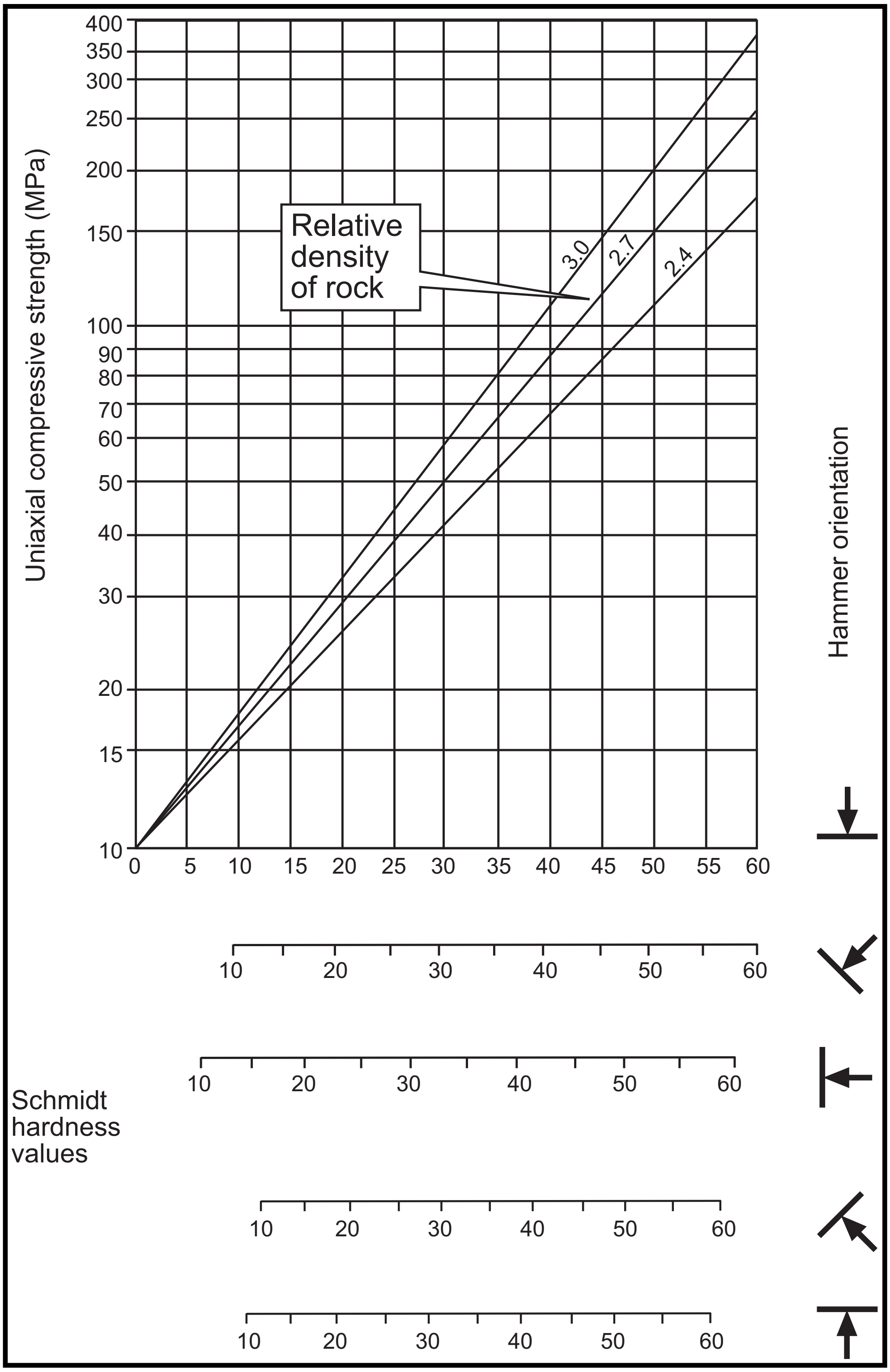

Fig 5.4. Relationship between Schmidt hardness and the uniaxial compressive strength of a rock. Assume a density of 2.7 for limestone. Allow for hammer orientation as shown.

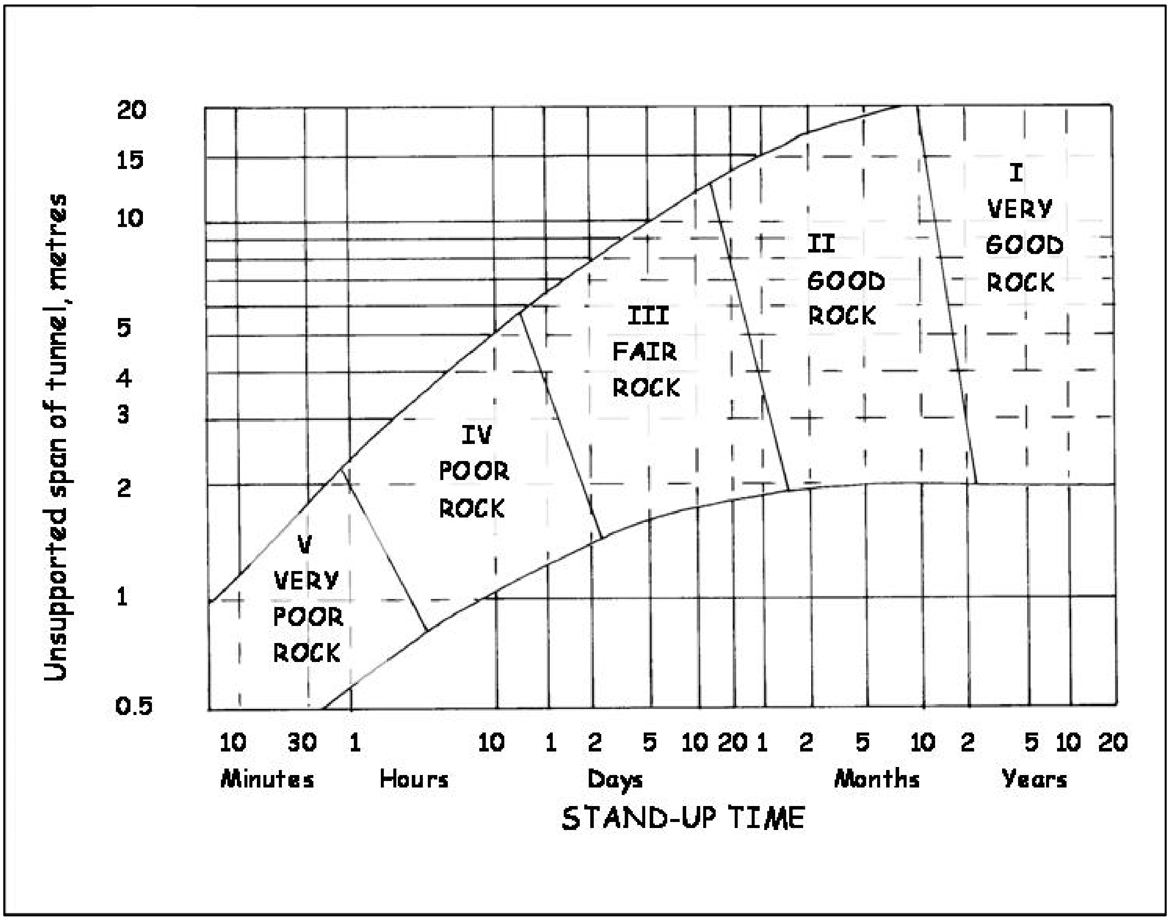

Fig 5.5 The relationship between the stand-up time of an unsupported tunnel and the Rock Mass Class from Table i, above.