

Solution - Exercise TE-02

Support Design: rock mass classifications based methods

Soutènement : systèmes de classifications

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Ex. TE02.1

- a) Using the data provided it is possible to evaluate the Q-value for the rock mass described, in particular:

En utilisant les données fournies, il est possible d'évaluer la valeur Q pour le massif rocheux décrit, en particulier :

RQD	41%	RQD	41
Joint set number	2 sets plus random	J_n	6
Joint roughness number	Slicken-sided and undulating	J_r	1.5
Joint alteration number	highly weathered filled with 3-5 mm clay	J_a	6
Joint water factor	large inflow with considerable outwash	J_w	0.3
Stress reduction factor	$\sigma_c/\sigma_1 = 65/(220 \times 0.0268) = 11$	SRF	1
Q	(41/6) (1.5/6) (0.33/1)		0.56
Q_{wall}	For $0.1 < Q < 10 \rightarrow Q_{wall} = 2.5 Q$		1.4

Using the table here below it is possible to evaluate the ESR Value for the case described, in particular **ESR = 1.3**

Le tableau ci-dessous permet d'évaluer la valeur ESR pour le cas décrit, soit ESR = 1.3.

Excavation Category		ESR
A	Temporary mine openings.	3 – 5
B	Permanent mine openings, water tunnels for hydro-electric projects, pilot tunnels, drifts and headings for large excavations.	1.6
C	Storage rooms, water treatment plants, minor road and railway tunnels, surge chambers and access tunnels in hydro-electric project.	1.3
D	Underground power station caverns, major road and railway tunnels, civil defence chamber, tunnel portals and intersections.	1.0
E	Underground nuclear power stations, railway stations, sports and public facilities, underground factories.	0.8

This allows evaluating the tunnel span to be used as input parameter for the Q-chart:

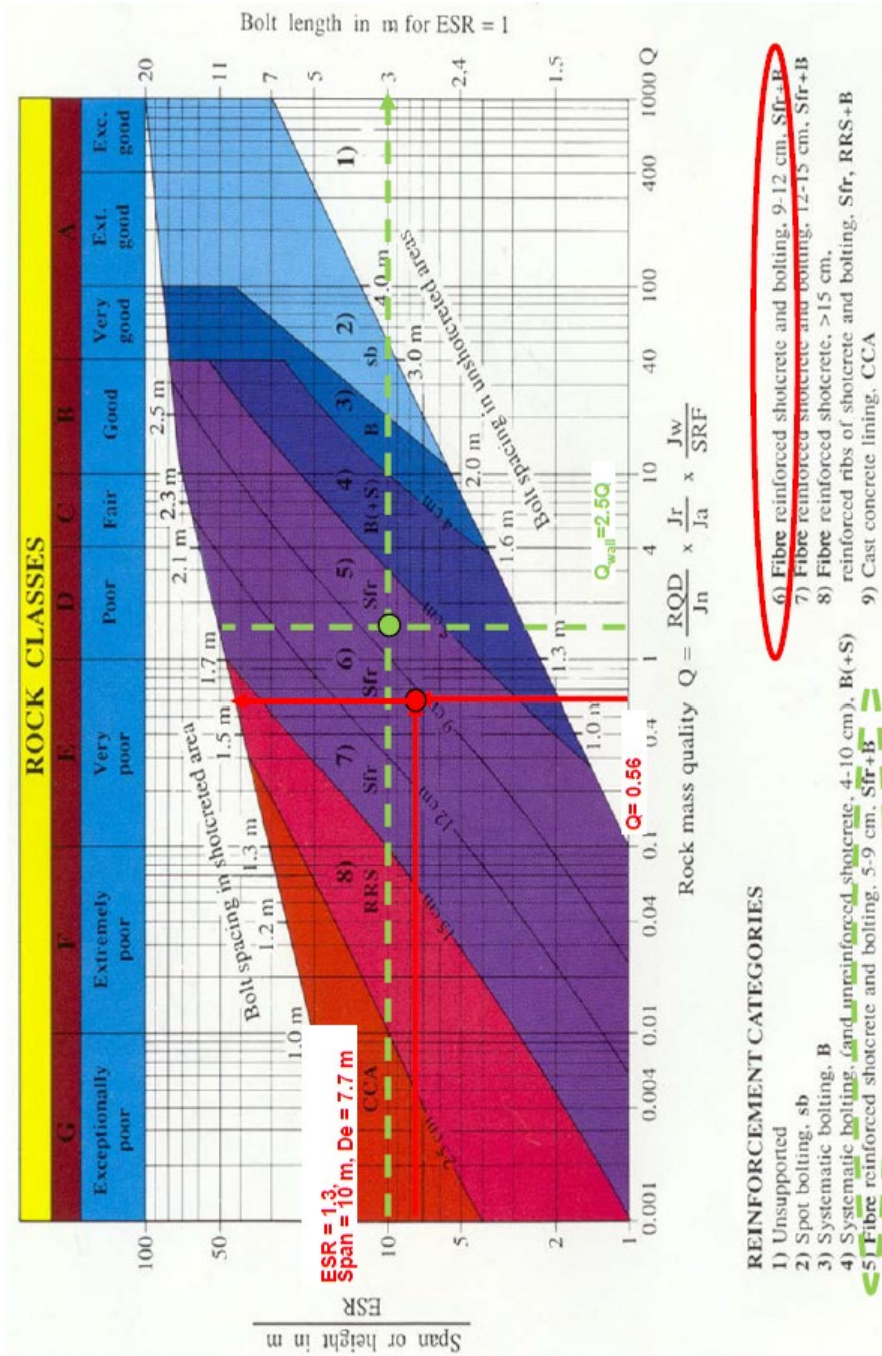
Cela permet d'évaluer la portée du tunnel à utiliser comme input pour le graphique Q :

$$\text{Span / Portée} = 10 \text{ m} \rightarrow D_e = \text{Span} / \text{ESR} = 7.7 \text{ m}$$

$$\text{Wall height / Hauteur des parois} = 10 \text{ m}$$

Using the Q-Chart it is possible to obtain the support system both for the crown (roof support) and the side-walls:

En utilisant le Q-Chart, il est possible d'obtenir le système de support à la fois pour la voûte et pour les piédroits :



Roof support / Soutènement de la voûte:

Bolt spacing at ~1.6 m / Boulons avec espacement d'environ 1.6 m

Bolt length of 3 m / Boulons de longueur de 3 m

SFR shotcrete of ~9 cm / Béton projeté avec fibres d'environ 9 cm d'épaisseur

Side wall support / Soutènement des piédroits:

Bolting at 1.8 m spacing / Boulons avec espacement d'environ 1.8 m

Bolt length of 3 m / Boulons de longueur de 3 m

SFR shotcrete of 7 cm / Béton projeté avec fibres d'environ 7 cm d'épaisseur

- b) Using the rock mass description provided it is possible to use the method proposed by Bieniawski to estimate the RMR-value, in particular:

En utilisant la description du massif fournie, il est possible d'utiliser la méthode proposée par Bieniawski pour estimer la valeur RMR, en particulier :

Rock material strength	65 MPa	Rating	7
RQD (%)	41%	Rating	8
Joint spacing (m)	0.05 m	Rating	5
Condition of joints	continuous, slicken-sided, separation 1-5mm	Rating	10
Groundwater	inflow = 50 l/min	Rating	4
		RMR	34

This value is the same for both crown and side-walls. / Cette valeur est la même pen voûte et piédroits.

Using the information given about the joint orientation is it possible to evaluate the correction of the RMR-value. According to the description two corrections are possible: fair and very unfavourable. The Adjusted RMR will consider the worst case, thus:

Les informations fournies sur l'orientation des joints permettent d'évaluer la correction de la valeur RMR. D'après la description, deux corrections sont possibles : moyenne et très défavorable. Le RMR ajusté prend en compte le cas le plus défavorable :

Adjustment = -12

Adjusted RMR = 22

The value obtained (i.e. Adjusted RMR) is the input values for the table of the RMR-System:

La valeur obtenue (soit le RMR ajusté) constitue l'input du tableau du système RMR :

Rock mass class	Excavation	Rock bolts (20 mm diameter, fully grouted)	Shotcrete	Steel sets
I - Very good rock RMR: 81-100	Full face, 3 m advance.	Generally no support required except spot bolting.		
II - Good rock RMR: 61-80	Full face, 1-1.5 m advance. Complete support 20 m from face.	Locally, bolts in crown 3 m long, spaced 2.5 m with occasional wire mesh.	50 mm in crown where required.	None.
III - Fair rock RMR: 41-60	Top heading and bench 1.5-3 m advance in top heading. Commence support after each blast. Complete support 10 m from face.	Systematic bolts 4 m long, spaced 1.5 - 2 m in crown and walls with wire mesh in crown.	50-100 mm in crown and 30 mm in sides.	None.
IV - Poor rock RMR: 21-40	Top heading and bench 1.0-1.5 m advance in top heading. Install support concurrently with excavation, 10 m from face.	Systematic bolts 4-5 m long, spaced 1-1.5 m in crown and walls with wire mesh.	100-150 mm in crown and 100 mm in sides.	Light to medium ribs spaced 1.5 m where required.
V - Very poor rock RMR: < 20	Multiple drifts 0.5-1.5 m advance in top heading. Install support concurrently with excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1.5 m in crown and walls with wire mesh. Bolt invert.	150-200 mm in crown, 150 mm in sides, and 50 mm on face.	Medium to heavy ribs spaced 0.75 m with steel lagging and forepoling if required. Close invert.

The required support is:

Systematic bolts 4-5 m long, spaced 1-1.5m, wire-mesh, and shotcrete 100-150 mm thick. Steel ribs might be required. Moreover, it is suggested to advance with top-heading and bench.

Le soutènement requis est le suivant :

Boulonnage systématique. Boulons de 4 à 5 m de long, espacés de 1 à 1.5 m, treillis métallique et béton projeté de 100 à 150 mm d'épaisseur. Des cintres en acier peuvent être nécessaires. En outre, il est suggéré d'avancer en section partielle.

Ex. TE02.2

- a) Using the data provided it is possible to evaluate the Q-value for the rock mass described, in particular:

En utilisant les données fournies, il est possible d'évaluer la valeur Q pour le massif rocheux décrit, en particulier :

RQD	70%	RQD	70.0
Joint set number	2 sets plus random	J_n	6.0
Joint roughness number	slightly rough ($\Rightarrow$ rough planar)	J_r	1.5
Joint alteration number	highly weathered only stain, (altered non-softening mineral coating)	J_a	2.0
Joint water factor	70 m water head = 7 kg/cm ² = 7 bars	J_w	0.5
Stress reduction factor	$\sigma_c/\sigma_1 = 85/(80 \times 0.027) = 39.3$	SRF	1.0
Q	(70/6) (1.5/2) (0.5/1)		4.4
Qwall	For $0.1 < Q < 10 \rightarrow Q_{wall} = 2.5 Q$		11

Using the table here below it is possible to evaluate the ESR Value for the case described, in particular **ESR = 1.0**

Le tableau ci-dessous permet d'évaluer la valeur ESR pour le cas décrit, soit ESR = 1.0.

Excavation Category		ESR
A	Temporary mine openings.	3 – 5
B	Permanent mine openings, water tunnels for hydro-electric projects, pilot tunnels, drifts and headings for large excavations.	1.6
C	Storage rooms, water treatment plants, minor road and railway tunnels, surge chambers and access tunnels in hydro-electric project.	1.3
D	Underground power station caverns, major road and railway tunnels, civil defence chamber, tunnel portals and intersections.	1.0
E	Underground nuclear power stations, railway stations, sports and public facilities, underground factories.	0.8

This allows evaluating the tunnel span to be used as input parameter for the Q-chart:

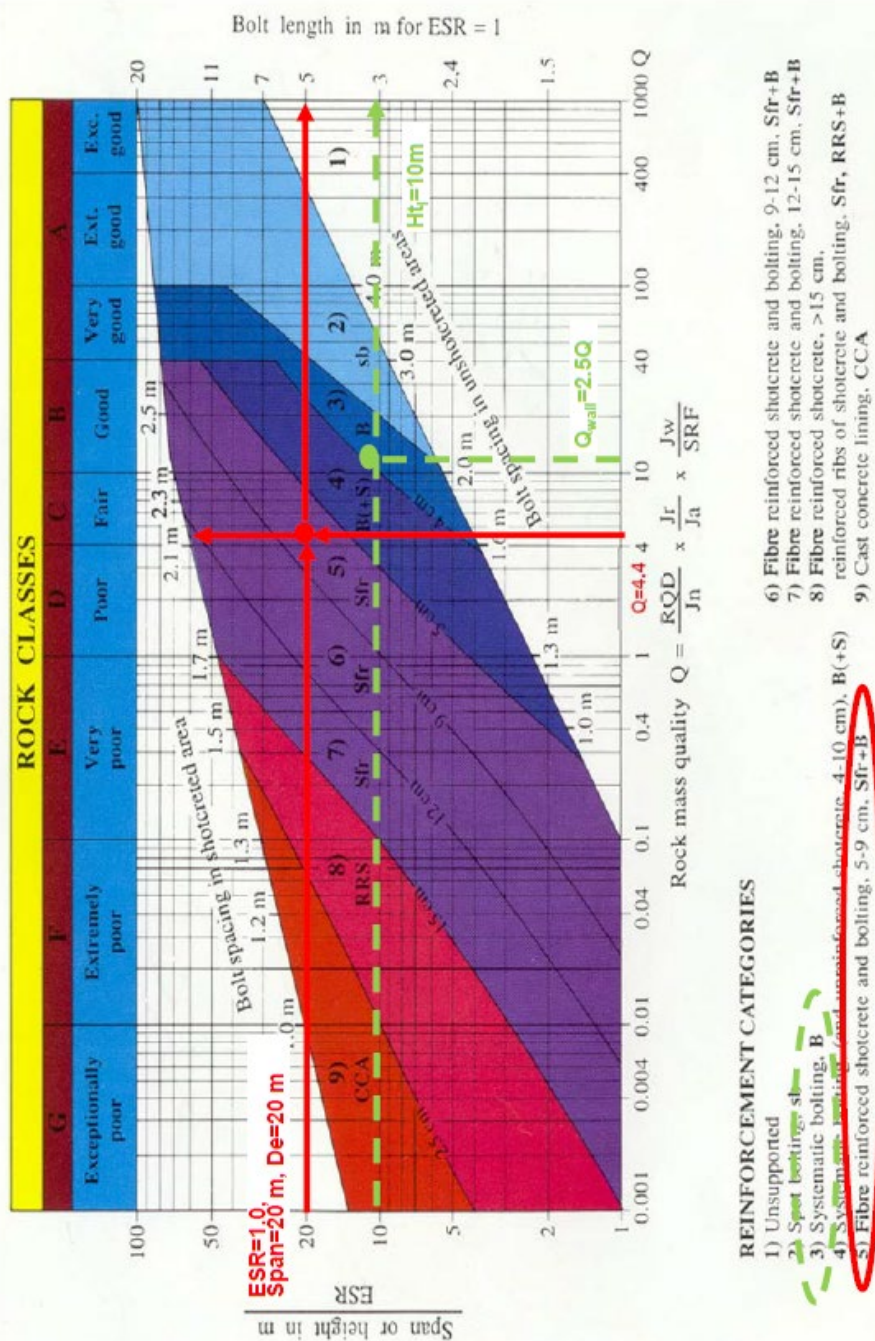
Cela permet d'évaluer la portée du tunnel à utiliser comme input pour le graphique Q :

$$\text{Span / Portée} = 20 \text{ m} \rightarrow De = \text{Span} / \text{ESR} = 20 \text{ m}$$

$$\text{Wall height / Hauteur des parois} = 10 \text{ m}$$

Using the Q-Chart it is possible to obtain the support system both for the crown (roof support) and the side-walls:

En utilisant le Q-Chart, il est possible d'obtenir le système de support à la fois pour la voûte et pour les piédroits :



Roof support / Soutènement de la voûte:

Bolt spacing at ~2.1 m / Boulons avec espacement d'environ 2.1 m

Bolt length of 5 m / Boulons de longueur de 5 m

SFR shotcrete of ~7 cm / Béton projeté avec fibres d'environ 7 cm d'épaisseur

Side wall support / Soutènement des piédroits:

Bolting at ~2.3 m spacing / Boulons avec espacement d'environ 2.3 m

Bolt length of 3 m / Boulons de longueur de 3 m

Thin shotcrete to cover or no shotcrete / couche fine de béton projeté ou pas de béton projeté

- b) Using the rock mass description provided it is possible to use the method proposed by Bieniawsky to estimate the RMR-value, in particular:

En utilisant la description du massif fournie, il est possible d'utiliser la méthode proposée par Bieniawski pour estimer la valeur RMR, en particulier :

Rock material strength	85 MPa	Rating	7
RQD (%)	70%	Rating	13
Joint spacing (m)	0.11 m	Rating	8
Condition of joints	slightly rough, highly weathered, separation < 1mm	Rating	20
Groundwater	water pressure/stress = 0.32	Rating	4
		RMR	52

This value is the same for both crown and side-walls. / Cette valeur est la même pen voûte et piédroits.

Using the information given about the joint orientation is it possible to evaluate the correction of the RMR-value. According to the description two corrections are possible: fair, fair to very favourable. The Adjusted RMR will consider the worst case, thus:

Les informations fournies sur l'orientation des joints permettent d'évaluer la correction de la valeur RMR. D'après la description, deux corrections sont possibles : moyenne et moyenne à très favorable. Le RMR ajusté prend en compte le cas le plus défavorable :

Adjustment = -5

Adjusted RMR = 47

The value obtained (i.e. Adjusted RMR) is the input values for the table of the RMR-System:

La valeur obtenue (soit le RMR ajusté) constitue l'input du tableau du système RMR :

Rock mass class	Excavation	Rock bolts (20 mm diameter, fully grouted)	Shotcrete	Steel sets
I - Very good rock RMR: 81-100	Full face, 3 m advance.	Generally no support required except spot bolting.		
II - Good rock RMR: 61-80	Full face, 1-1.5 m advance. Complete support 20 m from face.	Locally, bolts in crown 3 m long, spaced 2.5 m with occasional wire mesh.	50 mm in crown where required.	None.
III - Fair rock RMR: 41-60	Top heading and bench 1.5-3 m advance in top heading. Commence support after each blast. Complete support 10 m from face.	Systematic bolts 4 m long, spaced 1.5 - 2 m in crown and walls with wire mesh in crown.	50-100 mm in crown and 30 mm in sides.	None.
IV - Poor rock RMR: 21-40	Top heading and bench 1.0-1.5 m advance in top heading. Install support concurrently with excavation, 10 m from face.	Systematic bolts 4-5 m long, spaced 1-1.5 m in crown and walls with wire mesh.	100-150 mm in crown and 100 mm in sides.	Light to medium ribs spaced 1.5 m where required.
V - Very poor rock RMR: < 20	Multiple drifts 0.5-1.5 m advance in top heading. Install support concurrently with excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1.5 m in crown and walls with wire mesh. Bolt invert.	150-200 mm in crown, 150 mm in sides, and 50 mm on face.	Medium to heavy ribs spaced 0.75 m with steel lagging and forepoling if required. Close invert.

The required support is:

Systematic bolts 4 m long, spaced 1.5-2 m, wire-mesh, and shotcrete 50-100 mm thick. Moreover, advance with top-heading and bench could be required.

Le soutènement requis est le suivant :

Boulonnage systématique. Boulons de 4 m de long, espacés de 1.5 à 2 m, treillis métallique et béton projeté de 50 à 100 mm d'épaisseur. En outre, un avancement en section partielle pourrait être nécessaire.

Ex. TE02.3

- a) Using the data provided it is possible to evaluate the Q-value for the rock mass described, in particular:

En utilisant les données fournies, il est possible d'évaluer la valeur Q pour le massif rocheux décrit, en particulier :

RQD	80%	RQD	80.0
Joint set number	3 joint sets	J_n	9.0
Joint roughness number	Stepped and rough	J_r	3.0
Joint alteration number	Tightly closed, unweathered joints	J_a	1.0
Joint water factor	Wet but not dripping (minor flow)	J_w	0.7
Stress reduction factor	$\sigma_c/\sigma_1 = 160/(800 \times 0.0275) = 7.3$	SRF	1.5
Q	(80/9) (3/1) (1/1.5)		11.7
Qwall	For Q > 10 → Qwall = 5 Q		58.7

Using the table here below it is possible to evaluate the ESR Value for the case described, in particular **ESR = 1.6**

Le tableau ci-dessous permet d'évaluer la valeur ESR pour le cas décrit, soit ESR = 1.6.

Excavation Category		ESR
A	Temporary mine openings.	3 – 5
B	Permanent mine openings, water tunnels for hydro-electric projects, pilot tunnels, drifts and headings for large excavations.	1.6
C	Storage rooms, water treatment plants, minor road and railway tunnels, surge chambers and access tunnels in hydro-electric project.	1.3
D	Underground power station caverns, major road and railway tunnels, civil defence chamber, tunnel portals and intersections.	1.0
E	Underground nuclear power stations, railway stations, sports and public facilities, underground factories.	0.8

This allows evaluating the tunnel span to be used as input parameter for the Q-chart:

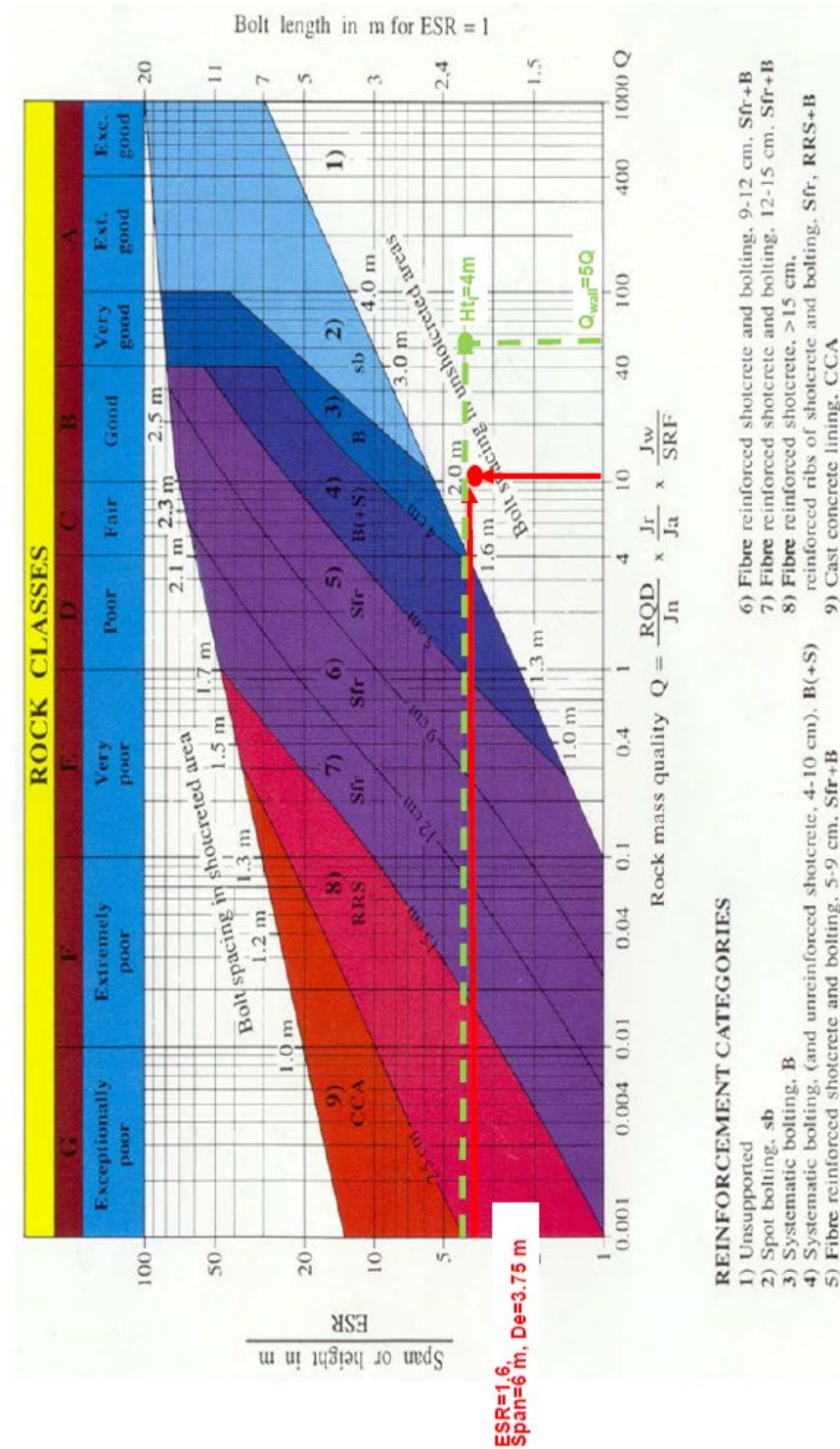
Cela permet d'évaluer la portée du tunnel à utiliser comme input pour le graphique Q :

$$\text{Span / Portée} = 6 \text{ m} \rightarrow D_e = \text{Span} / \text{ESR} = 3.75 \text{ m}$$

$$\text{Wall height / Hauteur des parois} = 4 \text{ m}$$

Using the Q-Chart it is possible to obtain the support system both for the crown (roof support) and the side-walls:

En utilisant le Q-Chart, il est possible d'obtenir le système de support à la fois pour la voûte et pour les pénédroits :



Roof support / Soutènement de la voûte :

Unsupported / pas de soutènement nécessaire

Side wall support / Soutènement des piédroits :

Unsupported / pas de soutènement nécessaire

- b) Using the rock mass description provided it is possible to use the method proposed by Bieniawsky to estimate the RMR-value, in particular:

En utilisant les données fournies, il est possible d'évaluer la valeur Q pour le massif rocheux décrit, en particulier :

Rock material strength	160 MPa	Rating	12
RQD (%)	80%	Rating	17
Joint spacing (m)	0.4 m	Rating	10
Condition of joints	Stepped and rough, tightly closed, unweathered	Rating	30
Groundwater	Wet but not dripping	Rating	7
		RMR	76

This value is the same for both crown and side-walls. / Cette valeur est la même pen voûte et piédroits.

Using the information given about the joint orientation is it possible to evaluate the correction of the RMR-value. According to the description two corrections are possible: very unfavourable. The Adjusted RMR is:

Les informations fournies sur l'orientation des joints permettent d'évaluer la correction de la valeur RMR. Selon la description, les deux corrections sont identiques : très défavorable. Le RMR ajusté est :

Adjustment = -12

Adjusted RMR = 64

The value obtained (i.e. Adjusted RMR) is the input values for the table of the RMR-System:

La valeur obtenue (soit le RMR ajusté) constitue l'input du tableau du système RMR :

Rock mass class	Excavation	Rock bolts (20 mm diameter, fully grouted)	Shotcrete	Steel sets
I - Very good rock RMR: 81-100	Full face, 3 m advance.	Generally no support required except spot bolting.		
II - Good rock RMR: 61-80	Full face, 1-1.5 m advance. Complete support 20 m from face.	Locally, bolts in crown 3 m long, spaced 2.5 m with occasional wire mesh.	50 mm in crown where required.	None.
III - Fair rock RMR: 41-60	Top heading and bench 1.5-3 m advance in top heading. Commence support after each blast. Complete support 10 m from face.	Systematic bolts 4 m long, spaced 1.5 - 2 m in crown and walls with wire mesh in crown.	50-100 mm in crown and 30 mm in sides.	None.
IV - Poor rock RMR: 21-40	Top heading and bench 1.0-1.5 m advance in top heading. Install support concurrently with excavation, 10 m from face.	Systematic bolts 4-5 m long, spaced 1-1.5 m in crown and walls with wire mesh.	100-150 mm in crown and 100 mm in sides.	Light to medium ribs spaced 1.5 m where required.
V - Very poor rock RMR: < 20	Multiple drifts 0.5-1.5 m advance in top heading. Install support concurrently with excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1.5 m in crown and walls with wire mesh. Bolt invert.	150-200 mm in crown, 150 mm in sides, and 50 mm on face.	Medium to heavy ribs spaced 0.75 m with steel lagging and forepoling if required. Close invert.

The required support is:

Full face advancement. Local bolting in crown 3m long, spacing 2.5m. Shotcrete 50mm where required.

Le soutènement requis est :

Avancement en pleine section. Boulonnage local en voûte. Boulons de 3 m de long, avec un espacement de 2.5 m. Béton projeté de 50 mm là où c'est nécessaire.