Type of support

Rock bolting
- Mechanical Rockbolts
- Grouted Rockbolts
- Combinations

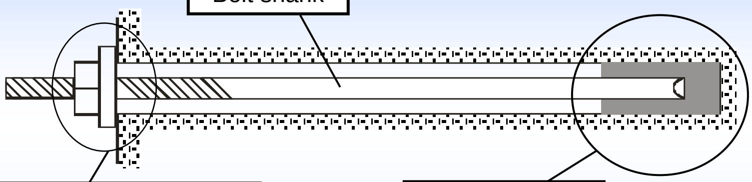
Combination support
- Rockbolts and shotcrete
- Rockbolts and steel
- Rockbolts and timber

Steel, timber and shotcrete support
- Timber
- Steel
- Shotcrete

Type of support

- **Active support**
- **Small material expense**
- **Installation of support can be mechanized**
- **Small amount of manual work ⇒ small risk of accident**
- **Flexibility, adaptable**
- **No space lost because of support**
- **Longwall working: advantages at the longwall entrance**

Advantages of rock bolting



Quelle: Kaufmann, M. , Zur Überwachung von Ankerausbau im Bergbaubetrieb unter Tage

Structure of rockbolts

- ☞ **Hang up and nailing concept**
- ☞ **Beam concept**
- ☞ **Rock arch concept**

Rockbolt theory

Overhead 8.5

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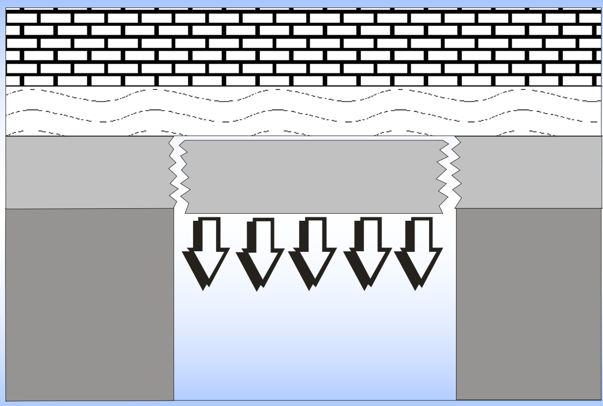

Quelle: Kaufmann, M. , Zur Überwachung von Ankerausbau im Bergbaubetrieb unter Tage

Hang up concept I

Overhead 8.6

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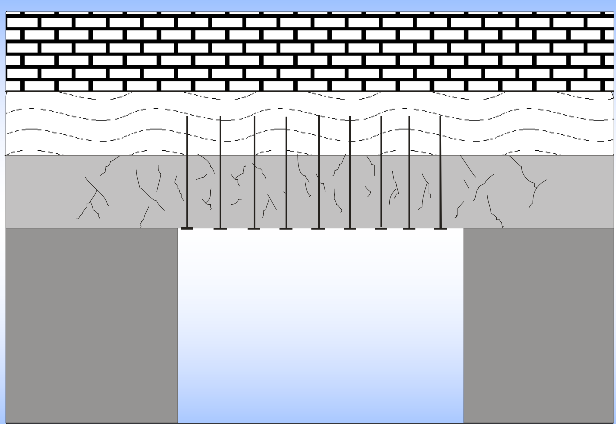
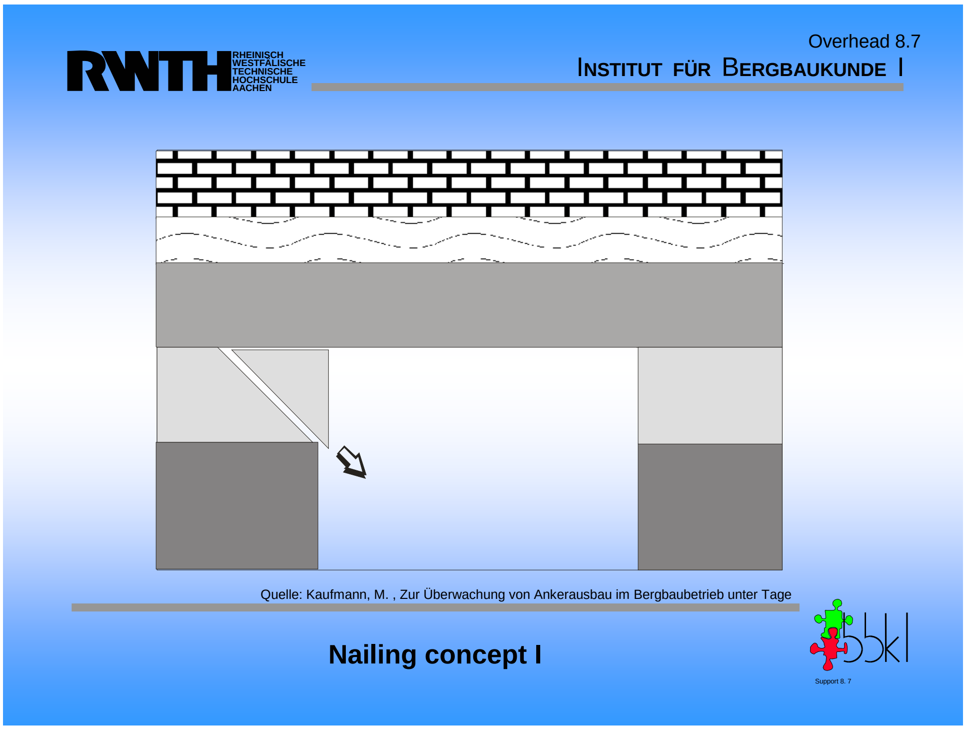
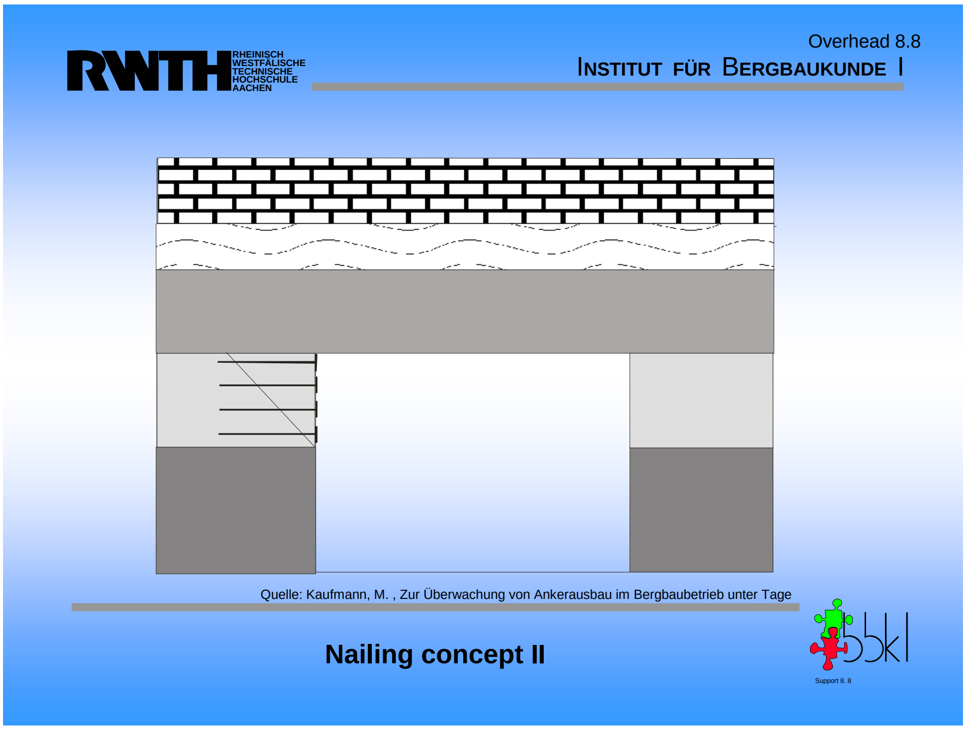
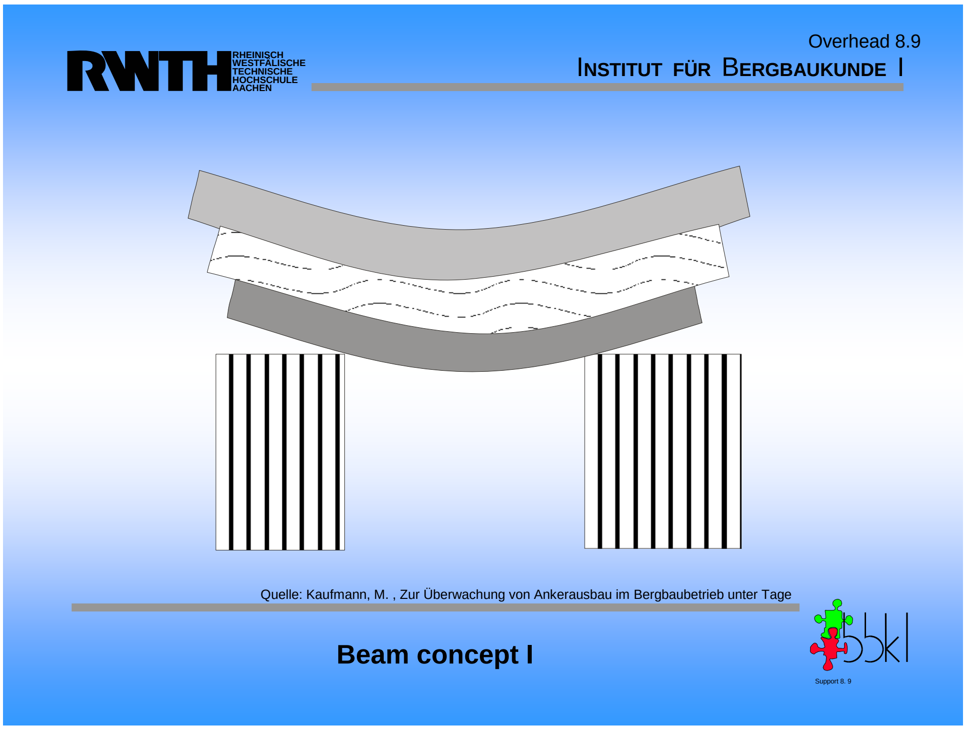


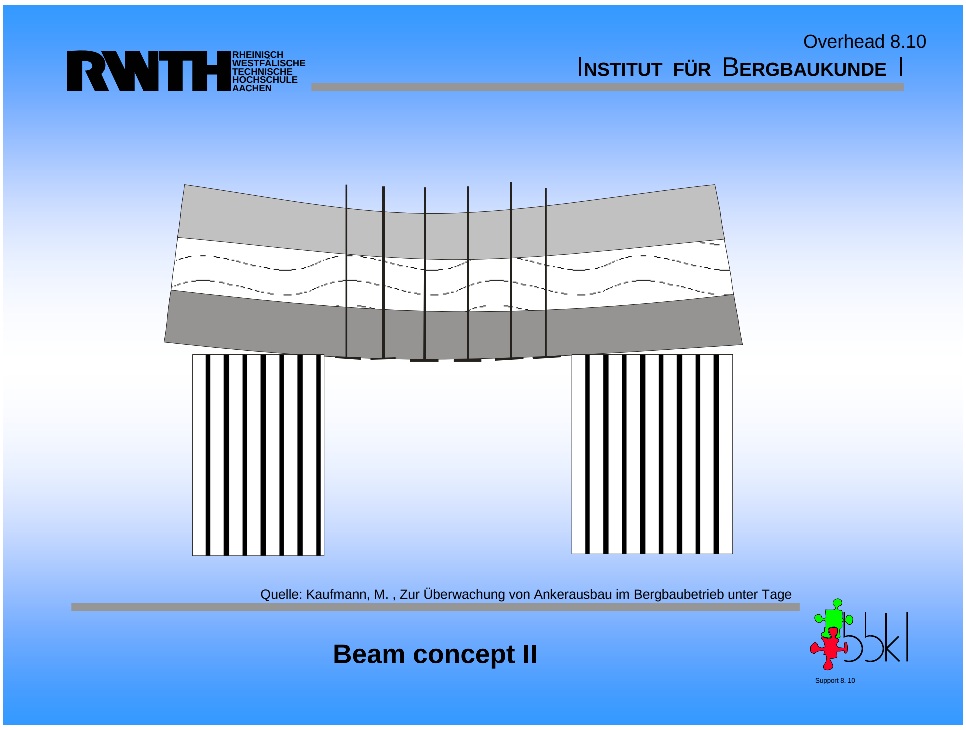
Quelle: Kaufmann, M. , Zur Überwachung von Ankerausbau im Bergbaubetrieb unter Tage

Hang up concept II


Overhead 8.7
Institut für Bergbaukunde I
Quelle: Kaufmann, M. , Zur Überwachung von Ankerausbau im Bergbaubetrieb unter Tage
Nailing concept I
Support 8. 7


Overhead 8.8
Institut für Bergbaukunde I
Quelle: Kaufmann, M. , Zur Überwachung von Ankerausbau im Bergbaubetrieb unter Tage
Nailing concept II
Support 8. 8


Overhead 8.9
INSTITUT FÜR BERGBAUKUNDE I
Quelle: Kaufmann, M. , Zur Überwachung von Ankerausbau im Bergbaubetrieb unter Tage
Beam concept I


Overhead 8.10
INSTITUT FÜR BERGBAUKUNDE I
Quelle: Kaufmann, M. , Zur Überwachung von Ankerausbau im Bergbaubetrieb unter Tage
Beam concept II

Overhead 8.11

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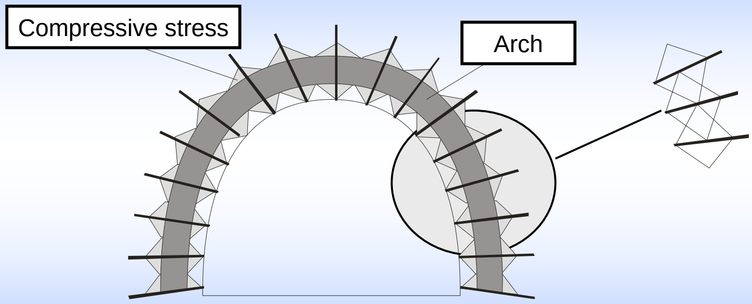

Quelle: Kaufmann, M. , Zur Überwachung von Ankerausbau im Bergbaubetrieb unter Tage

Rock arch concept

Support 8. 11

Overhead 8.12

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- **Tensioning** (pretensioning, not pretensioned)
- **Length** (Long bolt, short bolt)
- **Anchormechanism** (mech. anchor, resin anchor)
- **Length of anchor** (in the whole borehole, in the end of the borehole)
- **Bolt material** (steel bolt, plastic bolt)

Quelle: Kaufmann, M. , Zur Überwachung von Ankerausbau im Bergbaubetrieb unter Tage

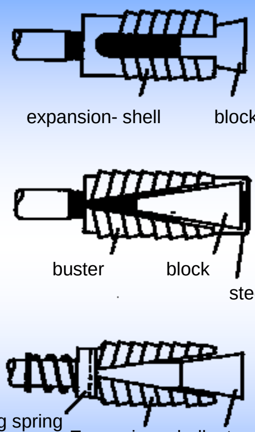
Classification of Rockbolts

Support 8. 12

Overhead 8.13

RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

INSTITUT FÜR BERGBAUKUNDE I



Quelle: Kaufmann, M. , Zur Überwachung von Ankerausbau im Bergbaubetrieb unter Tage

Expansion shell bolts

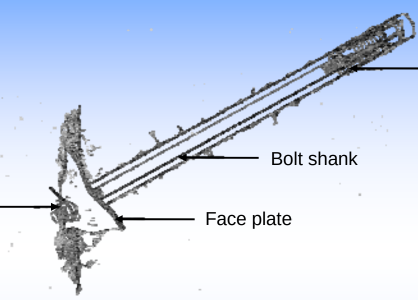
bbk I

Support 8. 13

Overhead 8.14

RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

INSTITUT FÜR BERGBAUKUNDE I



advantages :

- relatively inexpensive
- immediate support action after installation
- by rotating the bolt, a torque is applied to the bolt head and tension accumulates in the bolt
- high bolt loads can be achieved

disadvantages :

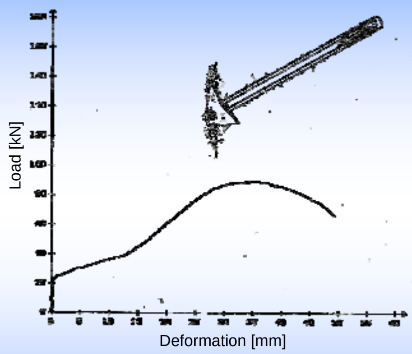
- limited to use in moderately hard to hard rock
- looses ist reinforcement capacity as a result of blasting
- can only be used for temporary reinforcement unless corosion protected and post-grouted

Quelle: B.Stillborg, Professional Users Handbook for Rock Bolting, Schweden 1994

Expansion bolts

bbk I

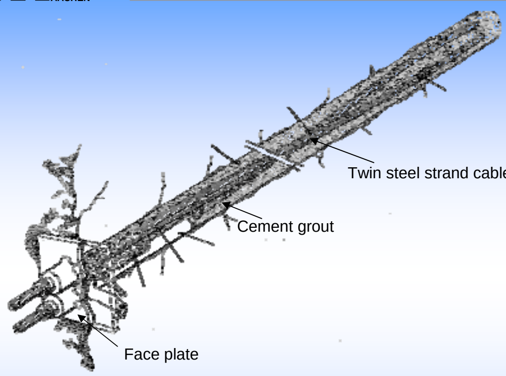
Support 8. 14



Steel quality designation:	700 N/mm²
Steel diameter:	16 mm
Yield load, steel:	140 kN
Ultimate load, steel:	180 kN
Ultimate axial strain, steel:	14 %
weight of bolt without face plate and nut:	2 kg/m
Recommended borehole diameter:	35-38 mm

Quelle: B.Stillborg, Professional Users Handbook for Rock Bolting, Schweden 1994

Expansion bolt: technical data

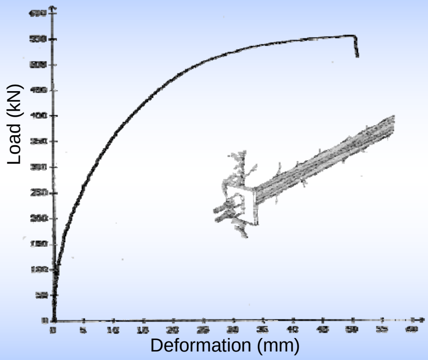


advanttages :
- inexpensive
- competent and durable reinforcement system
- can be installed to any lengthin narrow areas

disadvantages :
- using standard cement requires several days curing before the cable can take full load
- quality of grouting is difficult to check
- can not be used in water carrying boreholes

Quelle: B.Stillborg, Professional Users Handbook for Rock Bolting, Schweden 1994

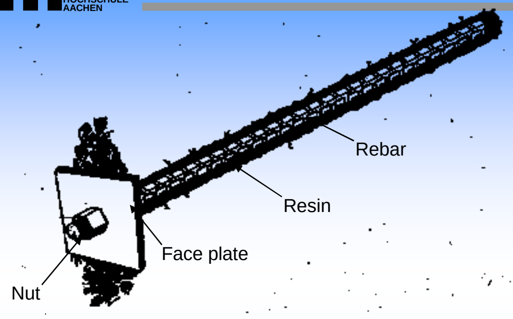
Cement grouted cablebolt- Twin steel strand



Steel quality designation:	1950 N/mm²
Cable diameter:	2 x15,2 mm
Yield load, cable:	500 kN
Ultimate load, cable:	500 kN
Ultimate axial strain, cable	4,8
%Wweight of cable	2,1 kg/m
Recommended borehole diameter:	48-64 mm

Quelle: B.Stillborg, Professional Users Handbook for Rock Bolting, Schweden 1994

Cable bolt: technical data



advantages :

- properly installed, it is a durable reinforcement system
- provides high load bearing capacity in hard rock conditiones
- gives rapid support action after installation

disadvantages :

- borehole diameter is crucial to the proper mixing and setting of the resin
- difficults with resin cartridges in underground enviroment
- resin ncan be messy and hazardous to handle
- resin has a limited shelf life

Quelle: B.Stillborg, Professional Users Handbook for Rock Bolting, Schweden 1994

Resin grouted rockbolt - Rebar

RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

Overhead 8.19

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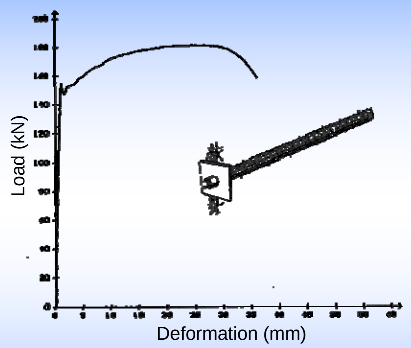


Steel quality designation:	570 N/mm²
Steel diameter:	20 mm
Yield load, steel:	120 kN
Ultimate load, steel:	180 kN
Ultimate axial strain, steel:	15 %
Weight of bolt without faceplate and nut: 2,6 kg/m	
Recomended borehole diameter:	35± 5 mm

Quelle: B.Stillborg, Professional Users Handbook for Rock Bolting, Schweden 1994

Cement grouted rockbolt: technical data

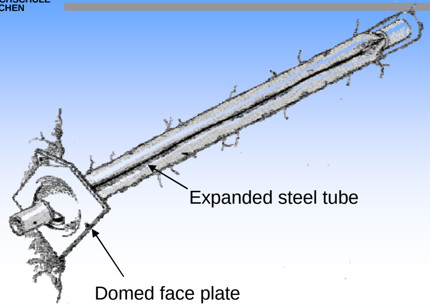
bbk I

Support 8. 19

RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

Overhead 8.20

INSTITUT FÜR BERGBAUKUNDE I



advantages :
- rapid and simple installation
- gives immediate support action after installation
- can be used in a variety of ground conditiones

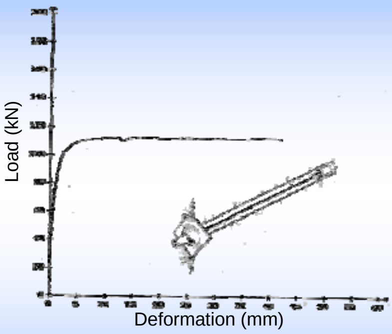
disadvantages :
- relatively expensive
- long term installation requier coated Swellex
- requiers a pump for installation

Quelle: B.Stillborg, Professional Users Handbook for Rock Bolting, Schweden 1994

Friction anchored rockbolts - (Swellex)

bbk I

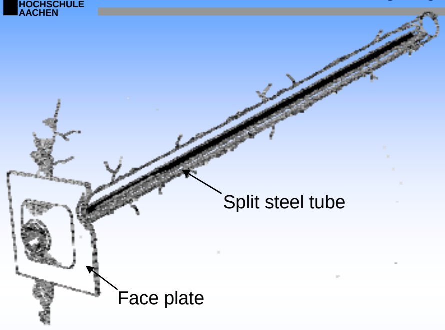
Support 8. 20



Tube diameter:	26/ 36 mm
Ultimate load, expandedsteel tube:	215 kN
Ultimate axial strain, steel:	15 %
Weight of bolt without face plate:	2- 4 kg/m
Recommended borehole diameter:	31-52 mm

Quelle: B.Stillborg, Professional Users Handbook for Rock Bolting, Schweden 1994

Swellex, typ EXL: technical data



advantages :
- simple installation
- gives immediate support action after installation
- no hardware other than jackleg or jumbo boom for installation
- easy application of wire mesh

disadvantages :
- relatively expensive
- borehole diameter is crucial in the prevention of failure during installation
- successful installation of longer bolts can be difficult
- cannot be used in long term installationes unless protected against corrosion (the steel is sensitive to corrosion both at ist inside and outside surface)

Quelle: B.Stillborg, Professional Users Handbook for Rock Bolting, Schweden 1994

Friction anchored rockbolts- Split Set

Overhead 8.23

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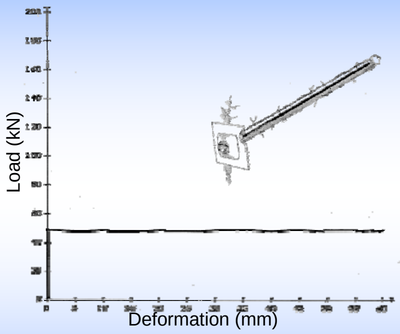

Tube diameter:	39/ 46 mm
Yiels loa, steel tube:	136 kN
Ultimate axial strain, steel tube:	16 %
Weight of bolt without face plate:	1,8- 2,8 kg/m
Recommended borehole diameter:	35-45 mm

Quelle: B.Stillborg, Professional Users Handbook for Rock Bolting, Schweden 1994

Friction anchored rockbolts: technical data

Support 8. 23

Overhead 8.24

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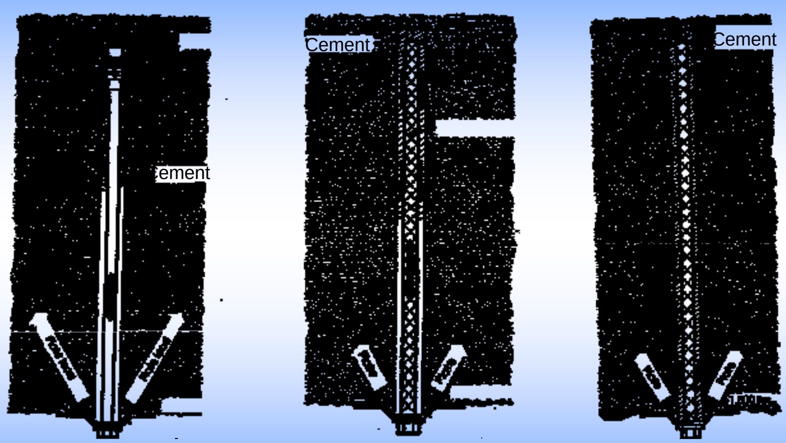

Cement grouted rockbolt (complete and borholeend)

Support 8. 24

Overhead 8.25

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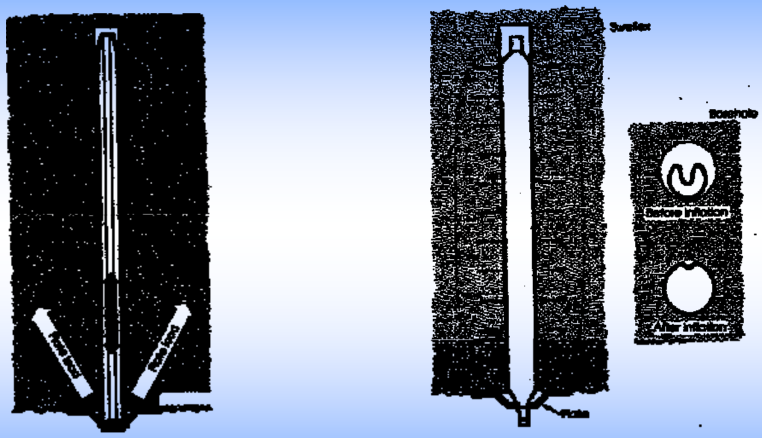
RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN



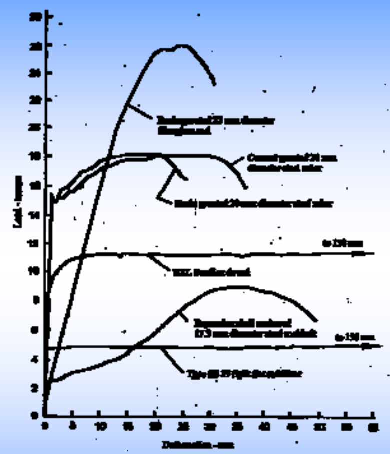
Friction anchored rockbolt- Swellex

Support 8. 25

Overhead 8.26

INSTITUT FÜR BERGBAUKUNDE I

RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN



Quelle: Hoek, Support of Underground Excavation in Hard Rock, Rotterdam 1997

Datas of different anchor systems

Support 8. 26

Herstellerinformation:AtlasCopco

Manuel rock drill at work

Quelle: Deilmann Haniel

Anchor setting boom

Overhead 8.29

RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

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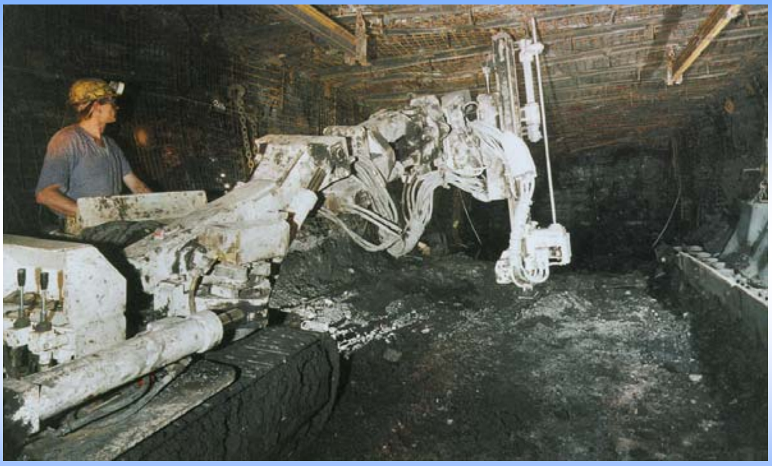


Quelle: Deilmann Haniel

Rock bolter at work

Support 8. 29

Overhead 8.30

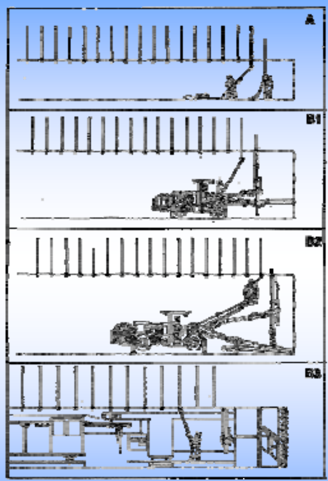
RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

INSTITUT FÜR BERGBAUKUNDE I

Quelle:Deilmann Haniel

Rock bolter - Tamrock

Support 8. 30



A: manuel drilling and setting of anchors

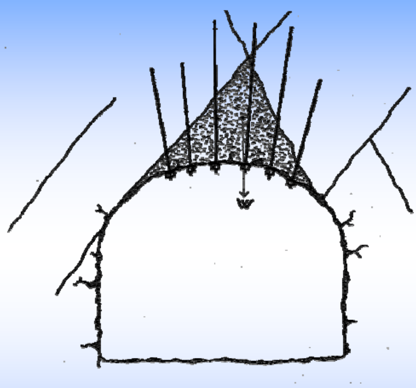
B1: semimechanised process, drilling with boomer, setting manuel

B2: semimechanised process, drilling with boomer, setting manuel from the lifting platform

B1: semimechanised process, drilling with boomer, setting manuel

Quelle: B.Stillborg, Professional Users Handbook for Rock Bolting, Schweden 1994

Process steps



Stabilising of an vertical wedge

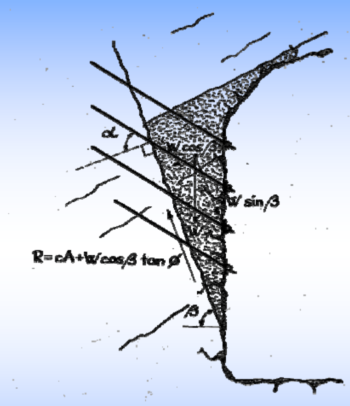
Dimensioning:

- n number o rockbolts
- W weight of wedge
- γ safety factor $2 < \gamma < 5$
- F load bearing cacacity

$$n = \frac{\gamma * W}{F}$$

Quelle: B.Stilborg; Rock Bolting, Trans Tech Publications, 1994

Support design: wedge free to fall



Stabilisation of a horizontal wedge

Dimensioning:

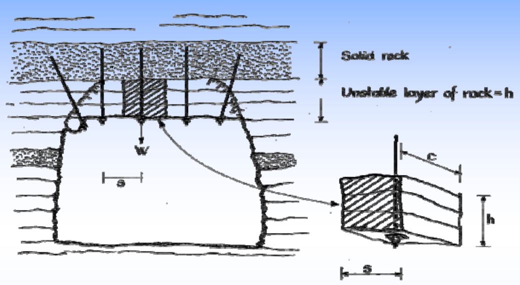
- n number of rockbolts
- W weight of the wedge
- γ safety factor 2< γ <5
- F yield load of anchor
- ϕ angle of friction of the sliding surface
- β dip of the sliding surface
- α angle between the plunge of the bolt and the normal of the sliding surface
- c cohesive strength
- A base area

$$n = \frac{W*(\gamma*\sin\beta - \cos\beta*\tan\beta) - c*A}{B*(\cos\alpha*\tan\phi + f*\sin\alpha)}$$

Quelle: B.Stilborg; Rock Bolting, Trans Tech Publications, 1994

Support design: wedge free to slide

Support 8. 33



Stabilisation of an unstable layer of horizontal bedding plans overlayed by solid rock

Dimensioning:

- W weight of rock
- γ safety factor 1,5< γ <3
- F yield load of the anchor
- c,h bolt spacing
- c bolt spacing
- A wedgesite
- ρ rock density
- g acceleration due to gravity

$$W = s*c*h*\rho*g$$

$$n = \frac{\gamma*W}{F}$$

Quelle: B.Stilborg; Rock Bolting, Trans Tech Publications, 1994

Support design: unstable layer

Support 8. 34

Overhead 8.35

RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

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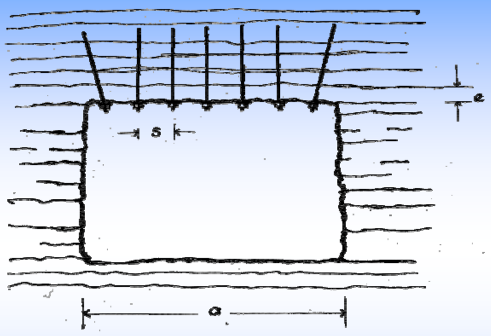

Reinforcement of a horizontally- bedded roof in weak rock to form a beam or slab

dimensioning:

- s anchor distance in cross- direction s<3*e
- c anchor distance in longitudinal- direction
- e thickness of the stratum
- a width of the roadway
- F yield load of the anchor
- l length of the anchor
- n number of anchors each row
- k reinforcement factor k>2

Quelle: B.Stilborg; Rock Bolting, Trans Tech Publications, 1994

Support design: beambuilding

Support 8. 35

Overhead 8.36

RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

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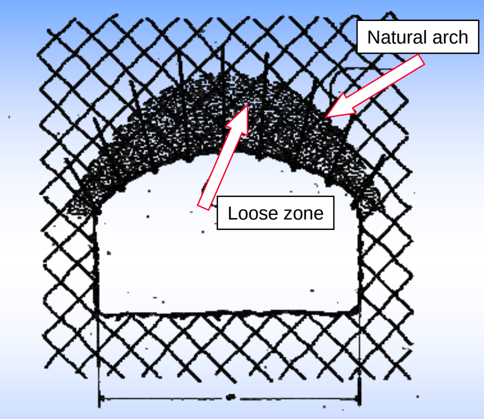

dimensioning:

anchoring the loose zone in the natural

curb ring of the arch

L= 1,40 + 0,184*a

- a width of the roadway
- L length of the anchor

Quelle: B.Stilborg; Rock Bolting, Trans Tech Publications, 1994

Support design: arch concept

Support 8. 36

Overhead 8.37

RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

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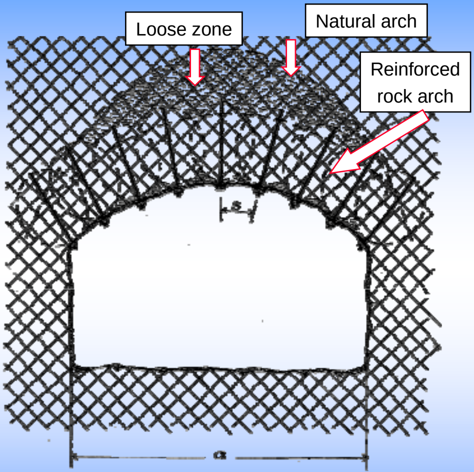

dimensioning:

Building a new curb ring. By the load-bearing capacity of the anchor the rock is compressed and is able to hold himself and the loose zone above

L/s > 2

s < 3*e

s bolt spacing

L length of the anchor

e thickness of the stratum

Quelle: B.Stilborg; Rock Bolting, Trans Tech Publications, 1994

Support design: arch concept

Support 8. 37

Overhead 8.38

RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

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Timber support

- polygon support
- one leg
- frame timbering

Steel support

- steel roadway arch
- ring support
- polygon support

Concrete support

- gunned concrete support
- concrete block support
- concrete paneel support

Different support systems for roadways

Support 8. 38

Overhead 8.39

RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

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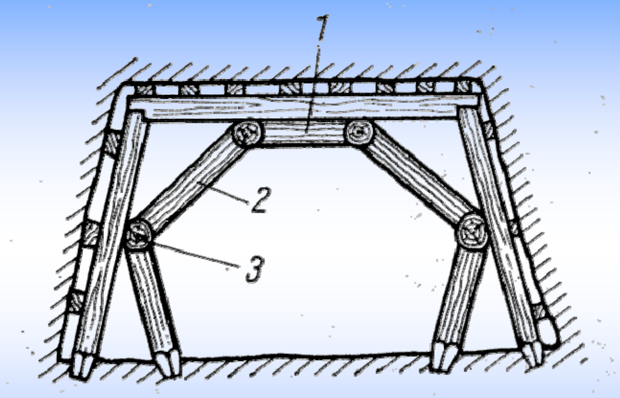

1 bar

2 cross- bar

3 cap

Deutscher Verlag für GrundstoffindustrieRoschlau/ Heintze, Wissensspeicher Bergbau

Frame timbering with polygon support

Support 8. 39

Overhead 8.40

RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

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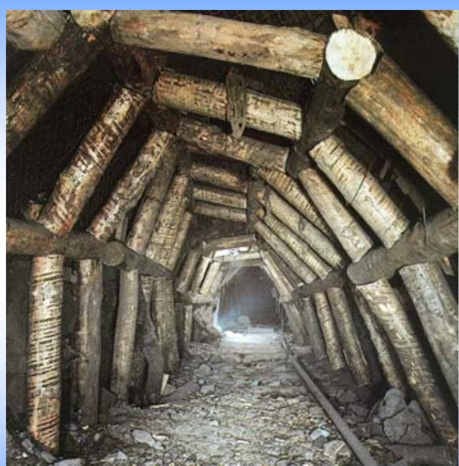

Timber polygon support

Support 8. 40

Overhead 8.41

RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

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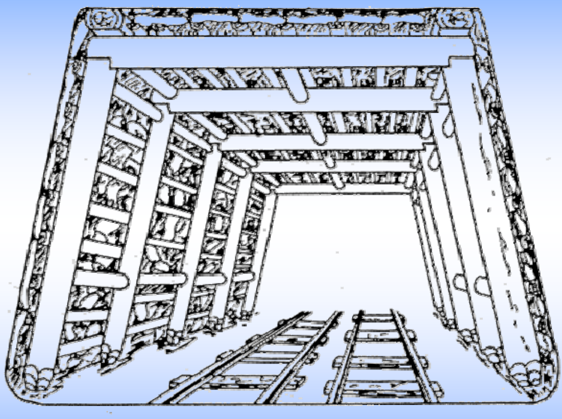

VGE, Reuther, E.-U., Lehrbuch der Berggbaukunde

German frame timberring support

Support 8. 41

Overhead 8.42

RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

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Frame support with wood and steel

Support 8. 42

Overhead 8.43

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RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

Frame support with steel

Support 8. 43

Overhead 8.44

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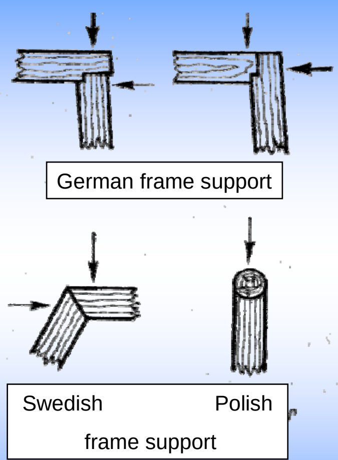
RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN



<u>German, Swedish frame support:</u>

- load- bearing capacity in horizontal direction is possible

<u>Polish frame support:</u>

- load- bearing capacity only in vertical direction

Deutscher Verlag für GrundstoffindustrieRoschlau/ Heintze, Wissensspeicher Bergbau

Different types of frame support

Support 8. 44

Overhead 8.45

RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

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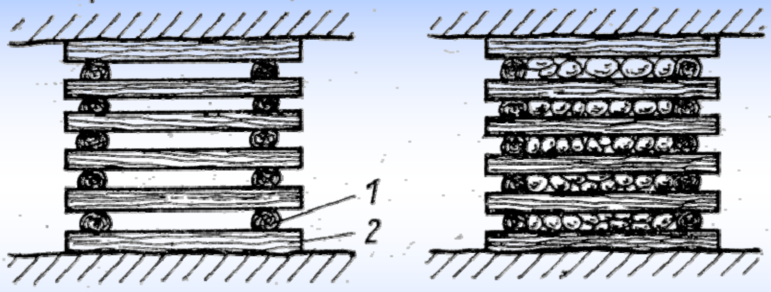
Timber chock | Timber crib



cross timber | longitudinal timber

Deutscher Verlag für GrundstoffindustrieRoschlau/ Heintze, Wissensspeicher Bergbau

chock - timber crib

Support 8. 45

Overhead 8.46

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- oldest support used in the mining branch
- can only be used by low rock ressure and availabillity of wood
- can only be used for temporary reinforcement

Present applications:

RSA goldmining, longwall face, mining parallel heading

USA hightech longwall face, against front abutment pressure

Timber support - application

Support 8. 46

\+ low wight, easy transportation
unproblematic handling
indicating overload by cracking noise

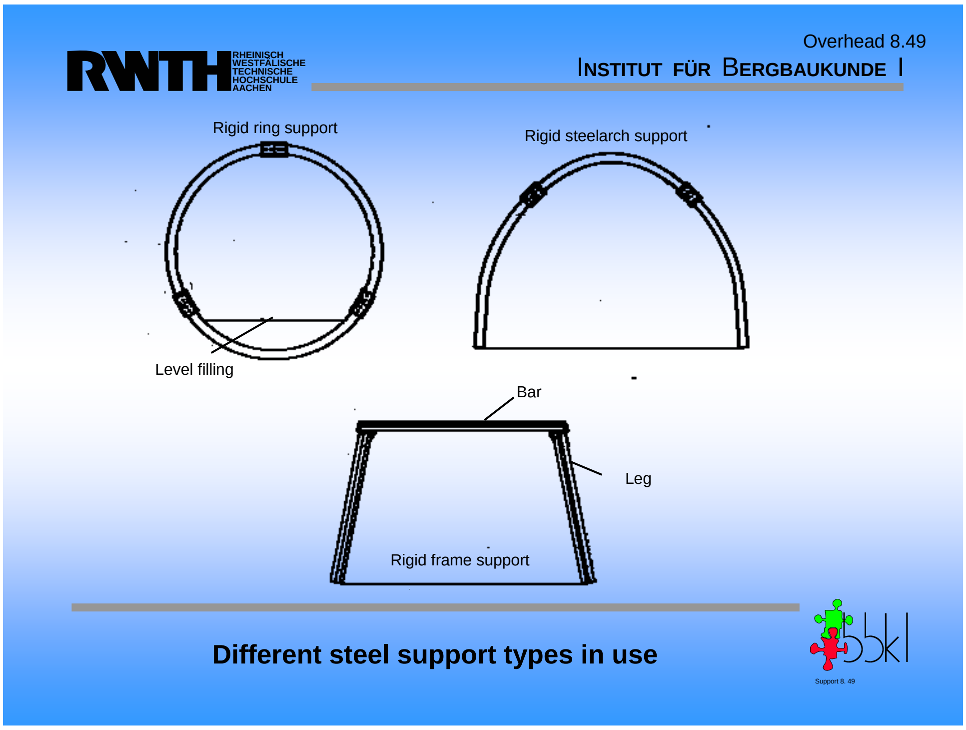
\- Short lifetime under wet conditions
can not be used after salvage
flammable
skilled workforce

Advantages and disadvantages of timber support

<u>riggid support</u>
• load- bearing capacity

<u>yielding support</u>
• load- bearing capacity
• movement capacity

Steel support: riggid and yielding support


Overhead 8.49
RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN
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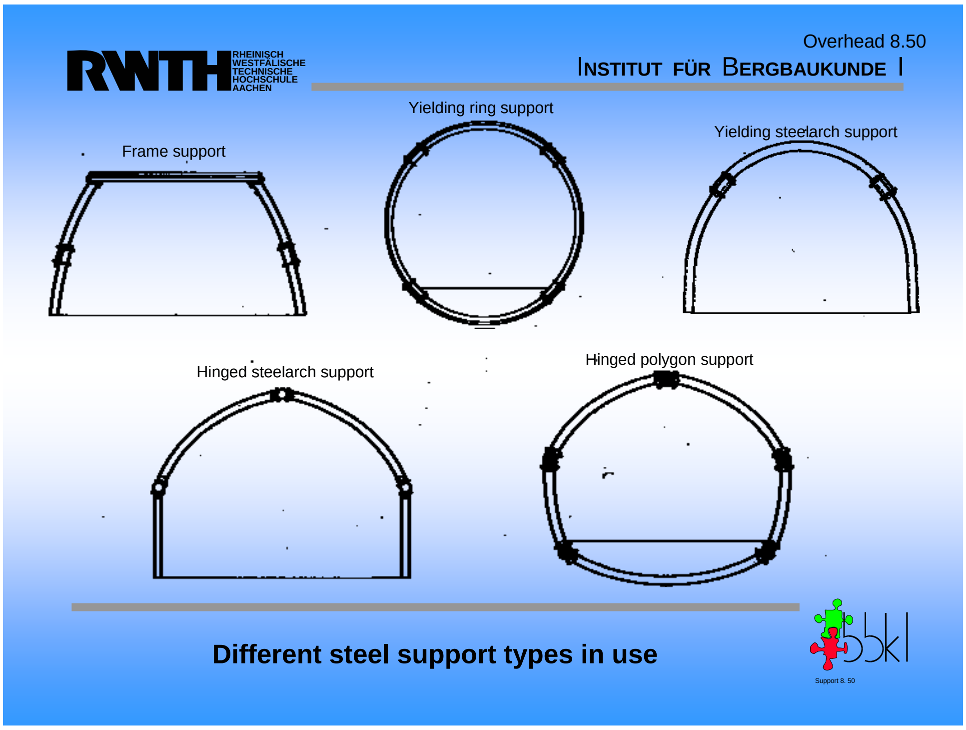
Rigid ring support
Level filling
Rigid steelarch support
Bar
Leg
Rigid frame support
Different steel support types in use
Support 8. 49


Overhead 8.50
RWTH RHEINISCH WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN
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Frame support
Yielding ring support
Yielding steelarch support
Hinged steelarch support
Hinged polygon support
Different steel support types in use
Support 8. 50

Overhead 8.51

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Bochumer Eisenhütte Heintzmann GmbH & Co.KG

Roadway in ring profile

Support 8. 51

Overhead 8.52

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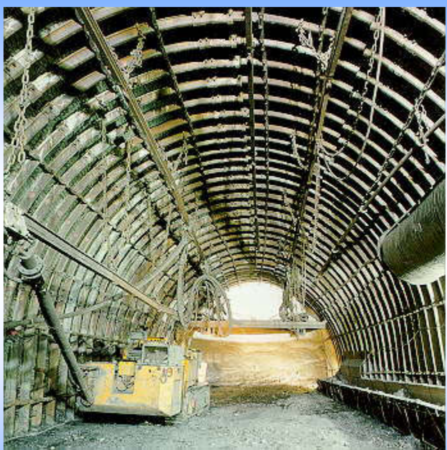

Deilmann - Haniel

Steel support with boarding

Support 8. 52

Overhead 8.53

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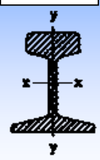
Rail profil



Rail profile

$W_X = 5*W_Y$

I- profil

Pit steel profile - I - profile or GI - rpofile

$W_X = 4*W_Y$

Steel profiles I

Support 8. 53

Overhead 8.54

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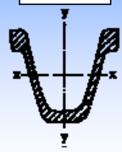
TH profil



TH - profile or u- channel section

TH = Toussaint and Heintzmann (1932)

$W_X = W_Y$

buckle- proof, yielding

Bell profil

Bell profile

Steel profiles II

Support 8. 54

Overhead 8.55

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Deilmann - Haniel

Steel support with boarding

bbk I

Support 8. 55

Overhead 8.56

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Shotcrete- layer

bbk I

Support 8. 56

Overhead 8.57

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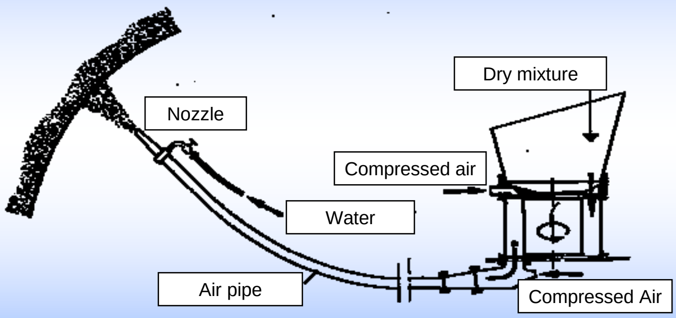
Dry shotcrete

used by importance of immediate support action



Dry shotcrete

Support 8. 57

Overhead 8.58

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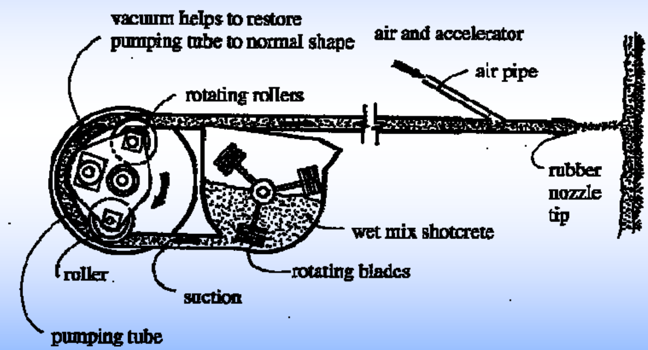
Wet shotcrete

no immediate support, as a result of the building material characteristics



Wet shotcrete

Support 8. 58