

**ANNEX
TUNNELLING CLASSES
EXAMPLE**

Tunnel "Example"

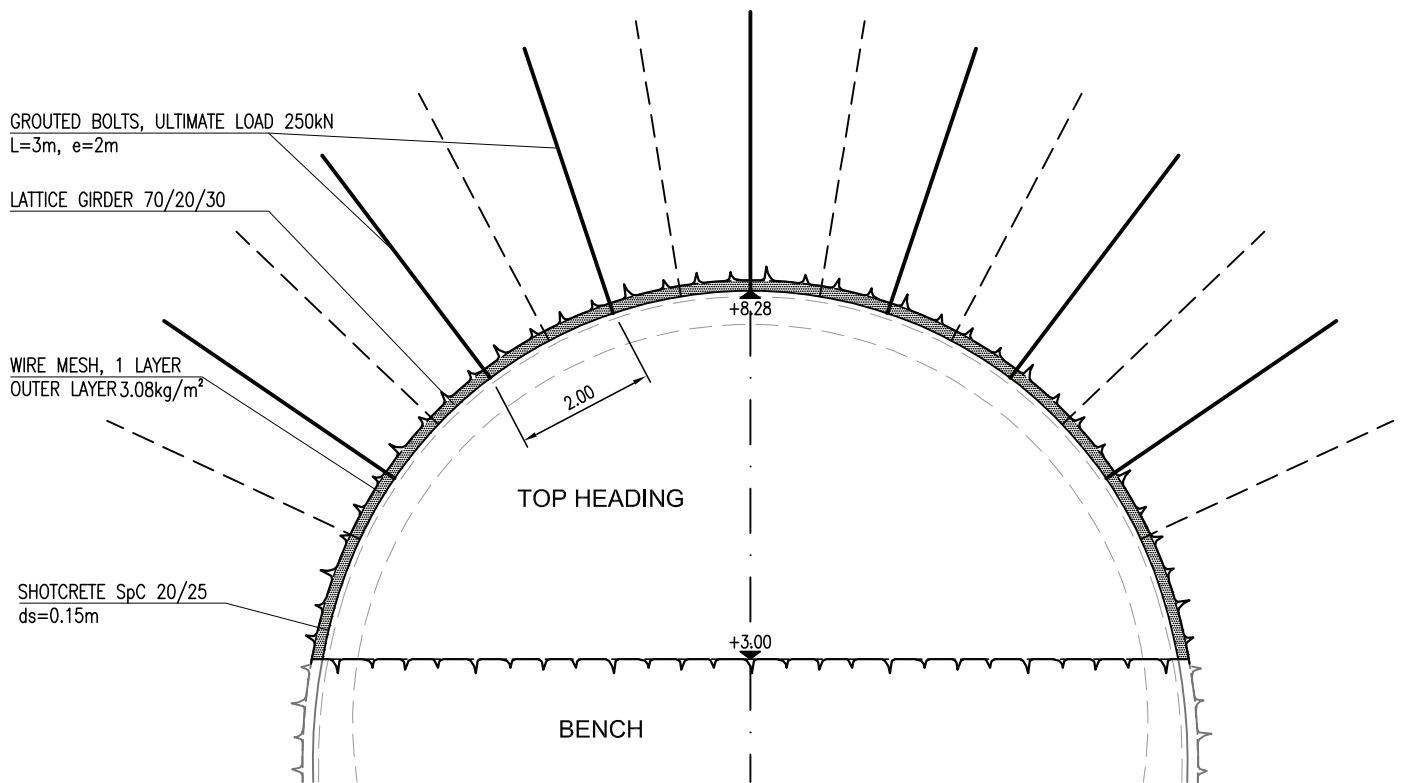
Standard support type: 5/1 (top heading)

Round length: $>1.30\text{m}$ & $\leq 1.70\text{m}$

Multiple-drift tunnelling: Top Heading / Bench / Invert

Ring closure distance $< 120\text{m}$ behind face of top heading excavation

⇒ Tunnelling Class 5/2.1



Tunneling Class Top Heading		Round Length up to / ùm				
TC 5/2.21		Top Heading	1.7m / 0.03 m			
Installation site	installation time	Support elements (for 1 m of Tunnel)		Volume/ round	Volume/ m of tunnel	
Top heading						
T	Immediately after excavation round	Shotcrete SpC 20/25	ds= 0.15m	4.49 m³	2.64 m³	
T	Immediately after excavation round	Wire mesh 1.96cm²/3.08kg/m²	1 outer Layer	29.95 m²	17.62 m³	
T	Immediately after excavation round	Lattice girder	YES	17.62 m	10.36 m	
T	max. 2 excavation rounds behind top-heading face	Grouted bolts	Ultimate Load 250 kN, 0 m	21.00 m	12.35 m	
				Excavation volume	87.72 m³	51.60 m³

Tunnel "Example"
calculating Tunnelling Class 5/2.21
Top heading

Top heading		ü _m =0.03 m	5/2.21		
Excavation profile	51.60 m ²	Round length	up to 1.7 m		
Support elements (for 1 m of Tunnel)		Unit	quantity	Rating factor per unit of quantity	Ratio
Bolts	Friction bolts (Swellax or equivalent)	m		0.8	
	Grouted bolts	m	12.35	1.1	13.59
	Self- drilling bolts	m		1.7	
	Tube bolts	m		2.0	
	Prestressed grouted bolts	m		2.5	
Face Bolts	Number of bolts in the face	ST		8.0	
	Installation of face plates	ST		1.7	
	Installation of face plates plus prestressing	ST		5.0	
Spiles	Driven spiles	m		0.5	
	Non-grouted spiles	m		0.6	
	Friction spiles	m		0.8	
	Grouted spiles	m		0.9	
	Self drilling spiles	m		1.3	
	Grouted hollow bar spiles	m		1.6	
Grouting in excess of 10kg per m of bolt, spile, footing micropile		kg		0.1	
Wire mesh	Outside with steel arch	m ²	17.62	1.0	17.62
	inside with steel arch	m ²		1.5	
	Outside without steel arch	m ²		2.0	
	Top heading invert	m ²		0.8	
	Additional reinforcement, face wire mesh	m ²		2.0	
Arches and wall beams		m	10.36	2.0	20.73
Shotcrete	Top heading and bench headings	m ³	2.64	20.0	52.86
	Top heading invert, top heading footing (elephant footing)	m ³		12.0	
	Face	m ³		14.0	
	Filling spandrels and over excavation	m ³		14.0	
Deformation gaps	without ductile elements	m		3.5	
	with ductile elements	m		5.0	
Steel-Sheet forepoling		m ²		5.5	
Footing micro piles	micropiles dia. ≤ 38mm	m		4.5	
	micropiles dia. > 38mm	m		5.0	
Partial face excavation		ST		22.0	
Top heading footing (elephant's foot)		m		50.0	
Demolition of top-heading invert arch during bench excavation		m		50.0	
Summation					104.80
Rating area					47.52 m²
Support number					2.21

Tunnel "Example"

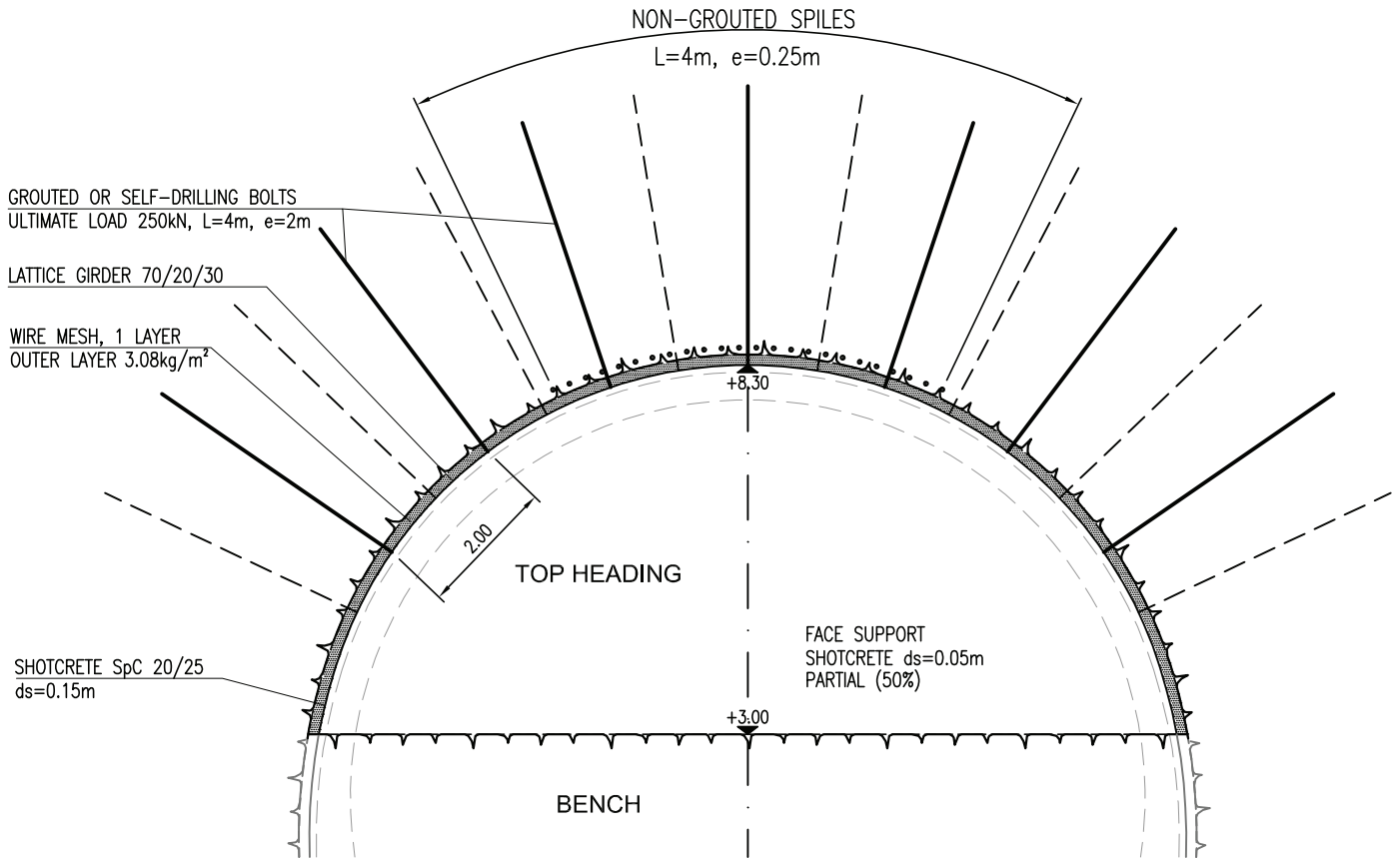
Standard support type: 5/2 (top heading)

Round length: $>1.30\text{m}$ & $\leq 1.70\text{m}$

Multiple-drift tunnelling: Top Heading / Bench / Invert

Ring closure distance $< 120\text{m}$ behind face of top heading excavation

⇒ Tunnelling Class 5/3.53



Tunneling Class Top Heading		Round Length up to / ùm		Volume/ round	Volume/ m of tunnel
TC 5/3.53		Top Heading 1.7m / 0.05 m			
Installation site	installation time	Support elements (for 1 m of Tunnel)		Volume/ round	Volume/ m of tunnel
Top heading					
T	before excavation round	Non-grouted spiles	L= 4 m	100.00 m	58.82 m
T	Immediately after excavation round	Filling spandrels		0.70 m ³	0.41 m ³
F	Immediately after excavation round	Shotcrete SpC 20/25	ds= 0.05m (50%)	0.01 m ³	0.01 m ³
T	Immediately after excavation round	Shotcrete SpC 20/25	ds= 0.15m	4.51 m ³	2.65 m ³
T	Immediately after excavation round	Wire mesh 1.96cm ² /3.08kg/m ²	1 outer Layer	30.06 m ²	17.68 m ²
T	Immediately after excavation round	Lattice girder	YES	17.68 m	10.40 m
T	max. 2 excavation rounds behind top-heading face	Self-drilling bolts	Ultimate Load 250 kN, 0 m	15.00 m	8.82 m
T	max. 2 excavation rounds behind top-heading face	Grouted bolts	Ultimate Load 250 kN, 0 m	15.00 m	8.82 m
			Excavation volume	88.33 m³	51.96 m³

Tunnel "Example"
calculating Tunnelling Class 5/3.53
Top heading

Top heading		üm=0.05 m	5/3.53		
Excavation profile	51.96 m ²	Round length	up to 1.7 m		
Support elements (for 1 m of Tunnel)		Unit	quantity	Rating factor per unit of quantity	Ratio
Bolts	Friction bolts (Swellex or equivalent)	m		0.8	
	Grouted bolts	m	8.82	1.1	9.71
	Self-drilling bolts	m	8.82	1.7	15.00
	Tube bolts	m		2.0	
	Prestressed grouted bolts	m		2.5	
Face Bolts	Number of bolts in the face	ST		8.0	
	Installation of face plates	ST		1.7	
	Installation of face plates plus prestressing	ST		5.0	
Spiles	Driven spiles	m		0.5	
	Non-grouted spiles	m	58.82	0.6	35.29
	Friction spiles	m		0.8	
	Grouted spiles	m		0.9	
	Self drilling spiles	m		1.3	
	Grouted hollow bar spiles	m		1.6	
Grouting in excess of 10kg per m of bolt, spile, footing micropile		kg		0.1	
Wire mesh	Outside with steel arch	m ²	17.68	1.0	17.68
	inside with steel arch	m ²		1.5	
	Outside without steel arch	m ²		2.0	
	Top heading invert	m ²		0.8	
	Additional reinforcement, face wire mesh	m ²		2.0	
Arches and wall beams		m	10.40	2.0	20.80
Shotcrete	Top heading and bench headings	m ³	2.65	20.0	53.04
	Top heading invert, top heading footing (elephant footing)	m ³		12.0	
	Face	m ³	0.76	14.0	10.70
	Filling spandrels and over excavation	m ³	0.41	14.0	5.76
Deformation gaps	without ductile elements	m		3.5	
	with ductile elements	m		5.0	
Steel-Sheet forepoling		m ²		5.5	
Footing micro piles	micropiles dia. ≤ 38mm	m		4.5	
	micropiles dia. > 38mm	m		5.0	
Partial face excavation		ST		22.0	
Top heading footing (elephant's foot)		m		50.0	
Demolition of top-heading invert arch during bench excavation		m		50.0	
Summation					167.98
Rating area					47.52 m²
Support number					3.53

Tunnel "Example"

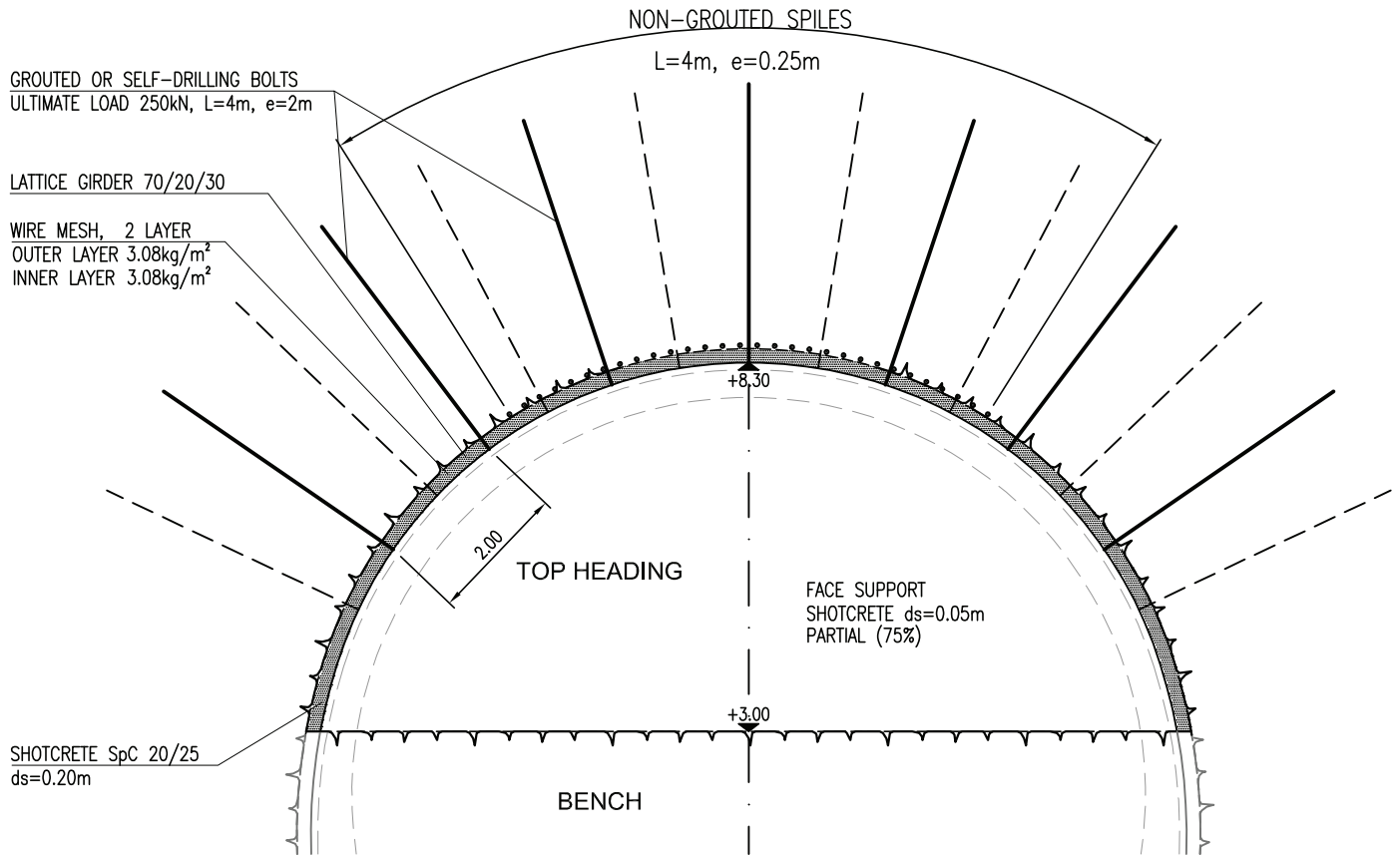
Standard support type: 5/3 (top heading)

Round length: $>1.30\text{m}$ & $\leq 1.70\text{m}$

Multiple-drift tunnelling: Top Heading / Bench / Invert

Ring closure distance $< 120\text{m}$ behind face of top heading excavation

⇒ Tunnelling Class 5/4.93



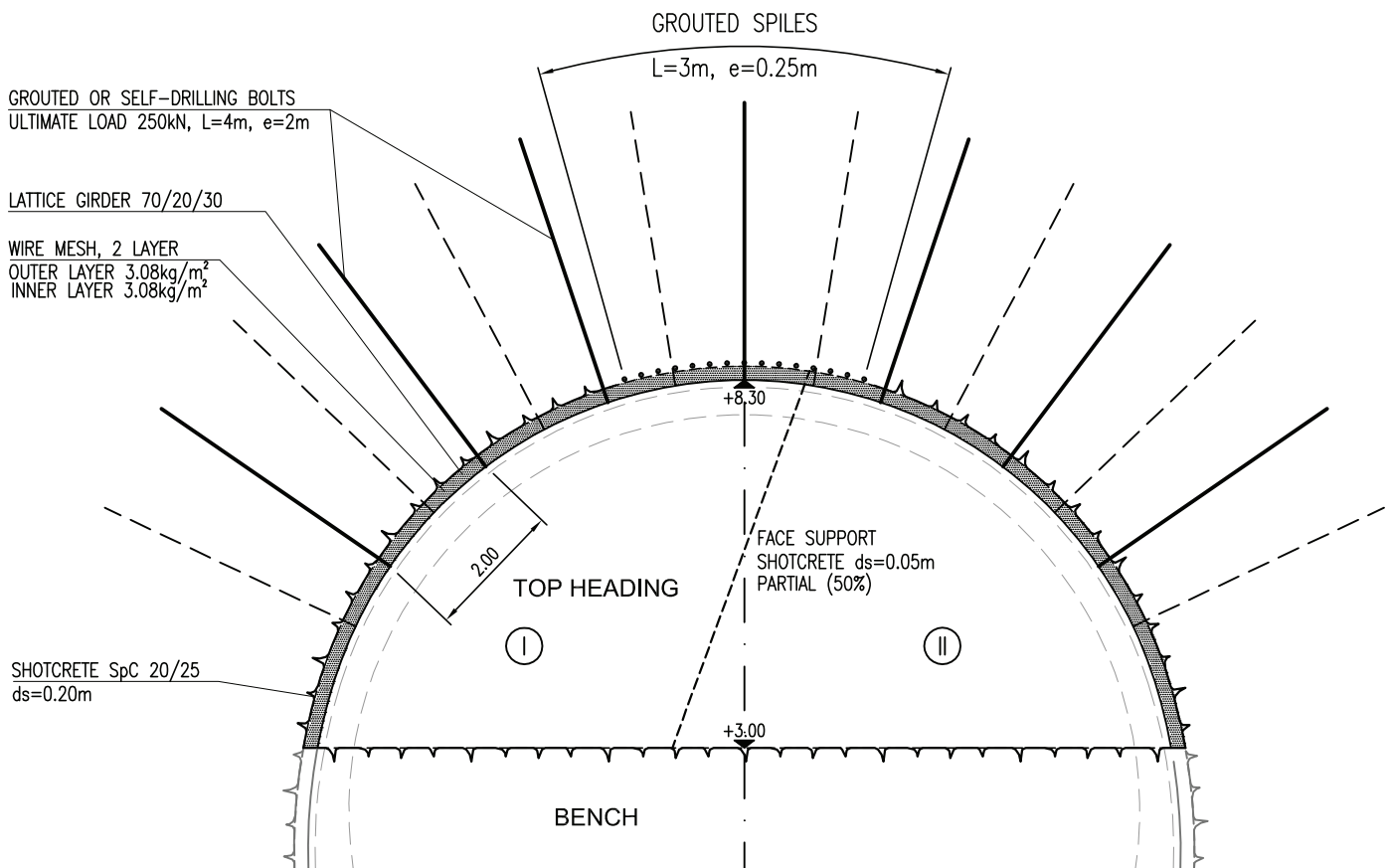
Tunneling Class Top Heading		Round Length up to / \ddot{u} m		Volume/ round	Volume/ m of tunnel
TC 5/4.93		Top Heading	1.7m / 0.05 m		
Installation site	installation time	Support elements (for 1 m of Tunnel)		Volume/ round	Volume/ m of tunnel
Top heading					
T	before excavation round	Non-grouted spiles	L= 4 m	128.00 m	75.29 m
T	immediately excavation round	Filling spandrels		0.85 m ³	0.50 m ³
F	immediately after excavation round	Shotcrete SpC 20/25	ds= 0.05m (100%)	0.03 m ³	0.02 m ³
T	immediately after excavation round	Shotcrete SpC 20/25	ds= 0.2m	6.01 m ³	3.54 m ³
T	immediately after excavation round	Wire mesh 1.96cm ² /3.08kg/m ²	1 outer Layer	30.06 m ²	17.68 m ²
T	immediately after excavation round	Wire mesh 1.96cm ² /3.08kg/m ²	1 inner Layer	30.06 m ²	17.68 m ²
T	immediately after excavation round	Lattice girder	YES	17.68 m	10.40 m
T	max. 2 excavation rounds behind top-heading face	Self-drilling bolts	Ultimate Load 250 kN, 0 m	15.00 m	8.82 m
T	max. 2 excavation rounds behind top-heading face	Grouted bolts	Ultimate Load 250 kN, 0 m	15.00 m	8.82 m
Excavation volume				89.88 m³	52.87 m³

Tunnel "Example"
calculating Tunnelling Class 5/4.93
Top heading

Top heading		ǖm=0.05 m	5/4.93		
Excavation profile	52.87 m ²	Round length	up to 1.7 m		
Support elements (for 1 m of Tunnel)		Unit	quantity	Rating factor per unit of quantity	Ratio
Bolts	Friction bolts (Swellex or equivalent)	m		0.8	
	Grouted bolts	m	8.82	1.1	9.71
	Self-drilling bolts	m	8.82	1.7	15.00
	Tube bolts	m		2.0	
	Prestressed grouted bolts	m		2.5	
Face Bolts	Number of bolts in the face	ST		8.0	
	Installation of face plates	ST		1.7	
	Installation of face plates plus prestressing	ST		5.0	
Spiles	Driven spiles	m		0.5	
	Non-grouted spiles	m	75.29	0.6	45.18
	Friction spiles	m		0.8	
	Grouted spiles	m		0.9	
	Self drilling spiles	m		1.3	
	Grouted hollow bar spiles	m		1.6	
Grouting in excess of 10kg per m of bolt, spile, footing micropile		kg		0.1	
Wire mesh	Outside with steel arch	m ²	17.68	1.0	17.68
	inside with steel arch	m ²	17.68	1.5	26.52
	Outside without steel arch	m ²		2.0	
	Top heading invert	m ²		0.8	
	Additional reinforcement, face wire mesh	m ²		2.0	
Arches and wall beams		m	10.40	2.0	20.80
Shotcrete	Top heading and bench headings	m ³	3.54	20.0	70.72
	Top heading invert, top heading footing (elephant footing)	m ³		12.0	
	Face	m ³	1.56	14.0	21.77
	Filling spandrels and over excavation	m ³	0.50	14.0	7.00
Deformation gaps	without ductile elements	m		3.5	
	with ductile elements	m		5.0	
Steel-Sheet forepoling		m ²		5.5	
Footing micro piles	micropiles dia. ≤ 38mm	m		4.5	
	micropiles dia. > 38mm	m		5.0	
Partial face excavation		ST		22.0	
Top heading footing (elephant's foot)		m		50.0	
Demolition of top-heading invert arch during bench excavation		m		50.0	
Summation					234.37
Rating area					47.52 m²
Support number					4.93

Tunnel "Example"

Standard support type: 6/1 (top heading)
 Round length: $>1.00\text{m}$ & $\leq 1.30\text{m}$
 Multiple-drift tunnelling: Top Heading / Bench / Invert
 Excavation method: drill and blast
 Ring closure distance: $< 120\text{m}$ behind face of top heading excavation
 ⇒ Tunnelling Class 6/4.96



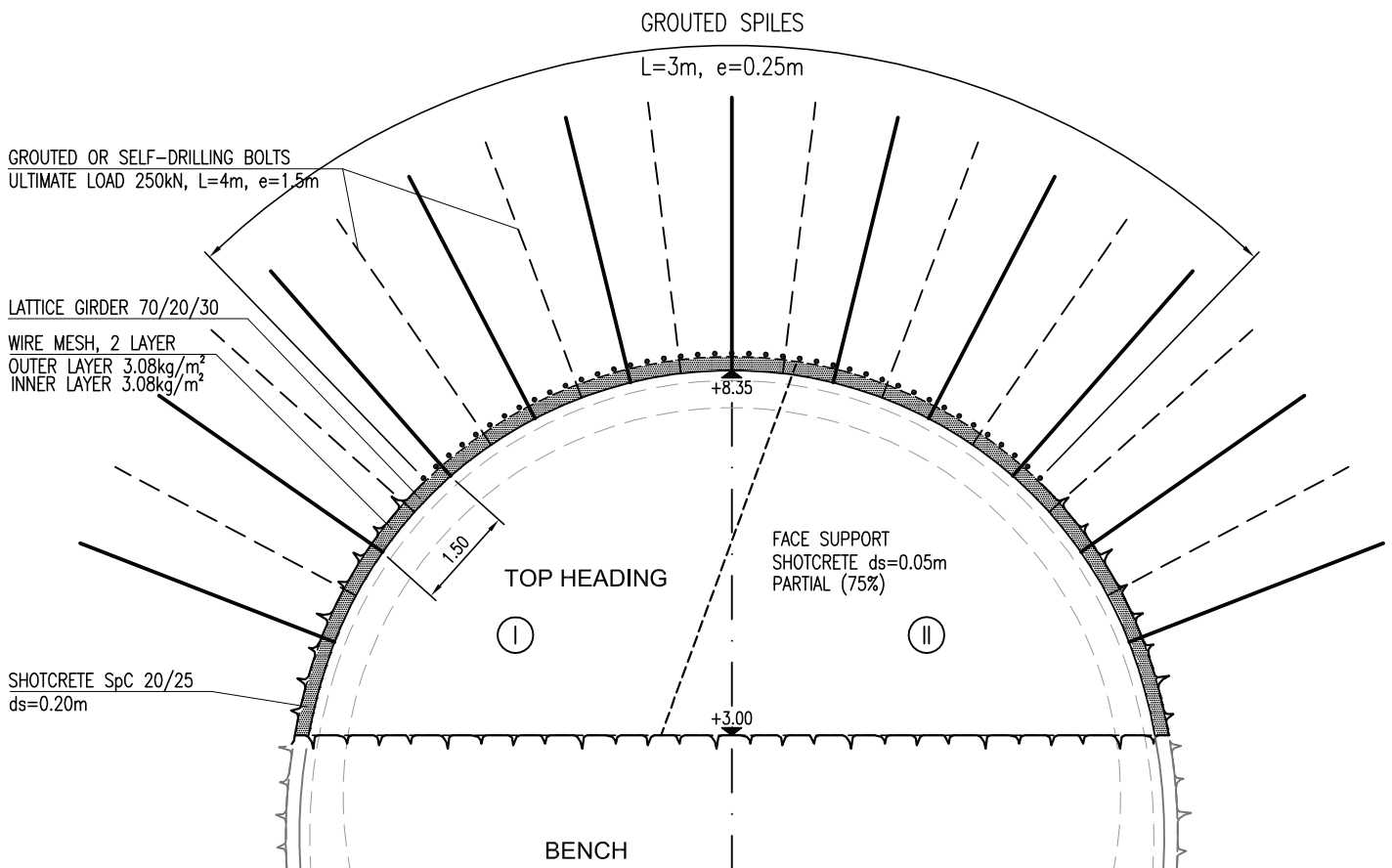
Tunneling Class Top Heading		Round Length up to / ùm			
TC 6/4.96		Top Heading	1.3m / 0.05 m		
Installation site	installation time	Support elements (for 1 m of Tunnel)		Volume/ round	Volume/ m of tunnel
Top heading					
T	before excavation round	Grouted spiles	L= 3 m	36.00 m	27.69 m
T	immediately excavation round	Filling spandrels		0.50 m³	0.38 m³
F	immediately after excavation round	Shotcrete SpC 20/25	ds= 0.05m (50%)	0.01 m³	0.01 m³
T	immediately after excavation round	Shotcrete SpC 20/25	ds= 0.2m	4.60 m³	3.54 m³
T	immediately after excavation round	Wire mesh 1.96cm²/3.08kg/m²	1 outer Layer	22.98 m²	17.68 m²
T	immediately after excavation round	Wire mesh 1.96cm²/3.08kg/m²	1 inner Layer	22.98 m²	17.68 m²
T	immediately after excavation round	Lattice girder	YES	17.68 m	13.60 m
T	max. 2 excavation rounds behind top-heading face	Self-drilling bolts	Ultimate Load 250 kN, 0 m	15.00 m	11.54 m
T	max. 2 excavation rounds behind top-heading face	Grouted bolts	Ultimate Load 250 kN, 0 m	15.00 m	11.54 m
Excavation volume				68.73 m³	52.87 m³

Tunnel "Example"
calculating Tunnelling Class 6/4.96
Top heading

Top heading		üm=0.05 m	6/4.96		
Excavation profile	52.87 m ²	Round length	up to 1.3 m		
Support elements (for 1 m of Tunnel)		Unit	quantity	Rating factor per unit of quantity	Ratio
Bolts	Friction bolts (Swellex or equivalent)	m		0.8	
	Grouted bolts	m	11.54	1.1	12.69
	Self-drilling bolts	m	11.54	1.7	19.62
	Tube bolts	m		2.0	
	Prestressed grouted bolts	m		2.5	
Face Bolts	Number of bolts in the face	ST		8.0	
	Installation of face plates	ST		1.7	
	Installation of face plates plus prestressing	ST		5.0	
Spiles	Driven spiles	m		0.5	
	Non-grouted spiles	m		0.6	
	Friction spiles	m		0.8	
	Grouted spiles	m	27.69	0.9	24.92
	Self drilling spiles	m		1.3	
	Grouted hollow bar spiles	m		1.6	
Grouting in excess of 10kg per m of bolt, spile, footing micropile		kg		0.1	
Wire mesh	Outside with steel arch	m ²	17.68	1.0	17.68
	inside with steel arch	m ²	17.68	1.5	26.52
	Outside without steel arch	m ²		2.0	
	Top heading invert	m ²		0.8	
	Additional reinforcement, face wire mesh	m ²		2.0	
Arches and wall beams		m	13.60	2.0	27.20
Shotcrete	Top heading and bench headings	m ³	3.54	20.0	70.72
	Top heading invert, top heading footing (elephant footing)	m ³		12.0	
	Face	m ³	1.02	14.0	14.23
	Filling spandrels and over excavation	m ³	0.38	14.0	5.38
Deformation gaps	without ductile elements	m		3.5	
	with ductile elements	m		5.0	
Steel-Sheet forepoling		m ²		5.5	
Footing micro piles	micropiles dia. ≤ 38mm	m		4.5	
	micropiles dia. > 38mm	m		5.0	
Partial face excavation		ST	0.77	22.0	16.92
Top heading footing (elephant's foot)		m		50.0	
Demolition of top-heading invert arch during bench excavation		m		50.0	
Summation					235.89
Rating area					47.52 m²
Support number					4.96

Tunnel "Example"

Standard support type: 6/2 (top heading)
 Round length: $>1.00\text{m}$ & $\leq 1.30\text{m}$
 Multiple-drift tunnelling: Top Heading / Bench / Invert
 Excavation method: drill and blast
 Ringclosure distance: $< 120\text{m}$ behind face of top heading excavation
 ⇒ Tunnelling Class 6/6.45

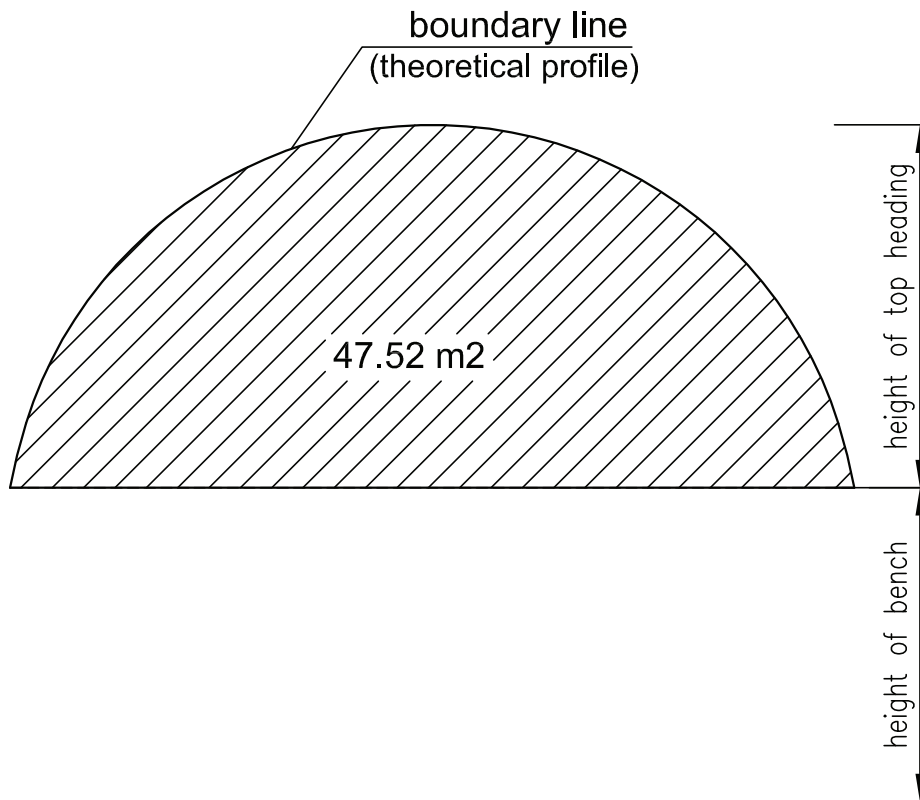


Tunneling Class Top Heading		Round Length up to / \ddot{u} m				
TC 6/6.45		Top Heading	1.3m / 0.1 m			
Installation site	installation time	Support elements (for 1 m of Tunnel)		Volume/ round	Volume/ m of tunnel	
Top heading						
T	before excavation round	Grouted spiles	L= 3 m	90.00 m	69.23 m	
T	immediately excavation round	Filling spandrels		1.57 m ³	1.21 m ³	
F	immediately after excavation round	Shotcrete SpC 20/25	ds= 0.05m (75%)	0.02 m ³	0.02 m ³	
T	immediately after excavation round	Shotcrete SpC 20/25	ds= 0.2m	4.64 m ³	3.57 m ³	
T	immediately after excavation round	Wire mesh 1.96cm ² /3.08kg/m ²	1 outer Layer	23.19 m ²	17.84 m ²	
T	immediately after excavation round	Wire mesh 1.96cm ² /3.08kg/m ²	1 inner Layer	23.19 m ²	17.84 m ²	
T	immediately after excavation round	Lattice girder	YES	17.84 m	13.72 m	
T	max. 2 excavation rounds behind top-heading face	Self-drilling bolts	Ultimate Load 250 kN, 0 m	21.00 m	16.15 m	
T	max. 2 excavation rounds behind top-heading face	Grouted bolts	Ultimate Load 250 kN, 0 m	21.00 m	16.15 m	
				Excavation volume	69.93 m³	53.79 m³

Tunnel "Example"
calculating Tunnelling Class 6/6.45
Top heading

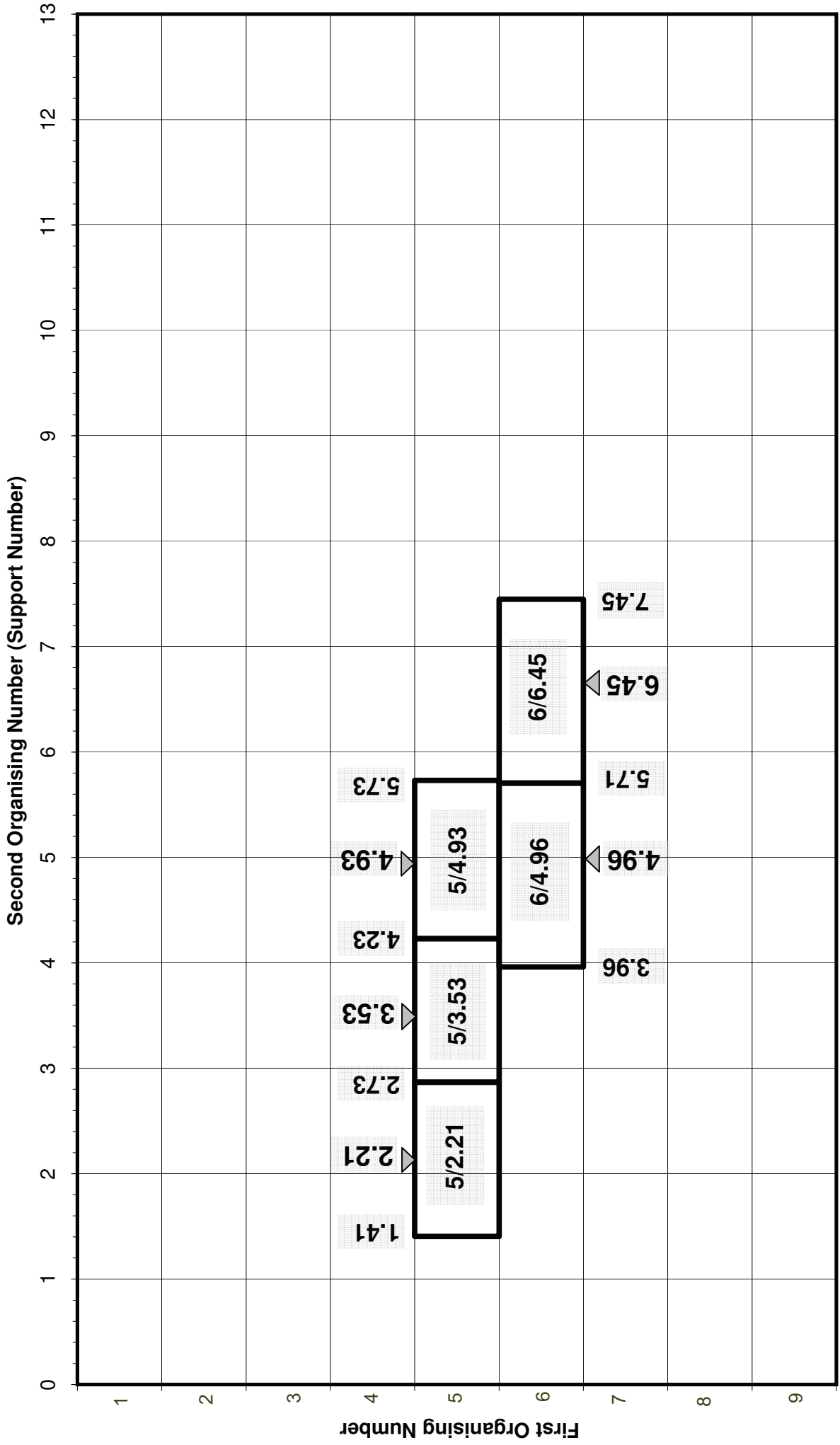
Top heading		$\bar{u}m=0.10\text{ m}$	6/6.45		
Excavation profile	53.79 m ²	Round length	up to 1.3 m		
Support elements (for 1 m of Tunnel)		Unit	quantity	Rating factor per unit of quantity	Ratio
Bolts	Friction bolts (Swelllex or equivalent)	m		0.8	
	Grouted bolts	m	16.15	1.1	17.77
	Self-drilling bolts	m	16.15	1.7	27.46
	Tube bolts	m		2.0	
	Prestressed grouted bolts	m		2.5	
Face Bolts	Number of bolts in the face	ST		8.0	
	Installation of face plates	ST		1.7	
	Installation of face plates plus prestressing	ST		5.0	
Spiles	Driven spiles	m		0.5	
	Non-grouted spiles	m		0.6	
	Friction spiles	m		0.8	
	Grouted spiles	m	69.23	0.9	62.31
	Self drilling spiles	m		1.3	
	Grouted hollow bar spiles	m		1.6	
Grouting in excess of 10kg per m of bolt, spile, footing micropile		kg		0.1	
Wire mesh	Outside with steel arch	m ²	17.84	1.0	17.84
	inside with steel arch	m ²	17.84	1.5	26.76
	Outside without steel arch	m ²		2.0	
	Top heading invert	m ²		0.8	
	Additional reinforcement, face wire mesh	m ²		2.0	
Arches and wall beams		m	13.72	2.0	27.45
Shotcrete	Top heading and bench headings	m ³	3.57	20.0	71.36
	Top heading invert, top heading footing (elephant footing)	m ³		12.0	
	Face	m ³	1.55	14.0	21.72
	Filling spandrels and over excavation	m ³	1.21	14.0	16.91
Deformation gaps	without ductile elements	m		3.5	
	with ductile elements	m		5.0	
Steel-Sheet forepoling		m ²		5.5	
Footing micro piles	micropiles dia. \leq 38mm	m		4.5	
	micropiles dia. $>$ 38mm	m		5.0	
Partial face excavation		ST	0.77	22.0	16.92
Top heading footing (elephant's foot)		m		50.0	
Demolition of top-heading invert arch during bench excavation		m		50.0	
Summation				306.50	
Rating area				47.52 m²	
Support number				6.45	

Rating Area Top Heading

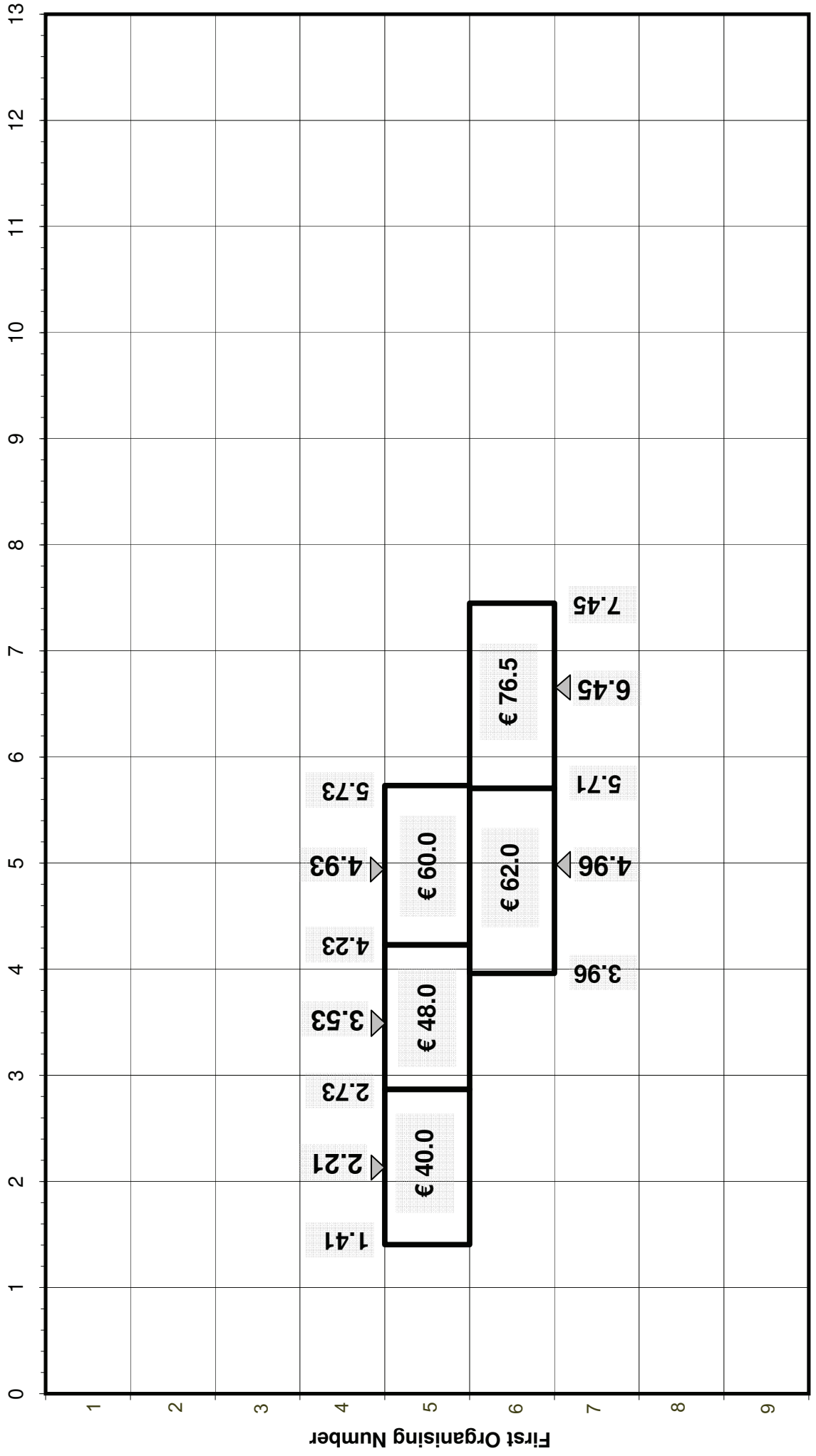


TOP HEADING						
	Excavation profile (m ²)					Line 1a
ds (cm) üm (cm)	10	15	20	25	30	
0	50.16	51.06	51.96			17.55
1	50.34	51.24	52.14	53.06		17.55
3	50.70	51.60	52.51	53.42		17.62
5		51.96	52.87	53.79	54.72	17.68
7			53.24	54.16	55.09	17.74
10			53.79	54.72	55.65	17.84
15						

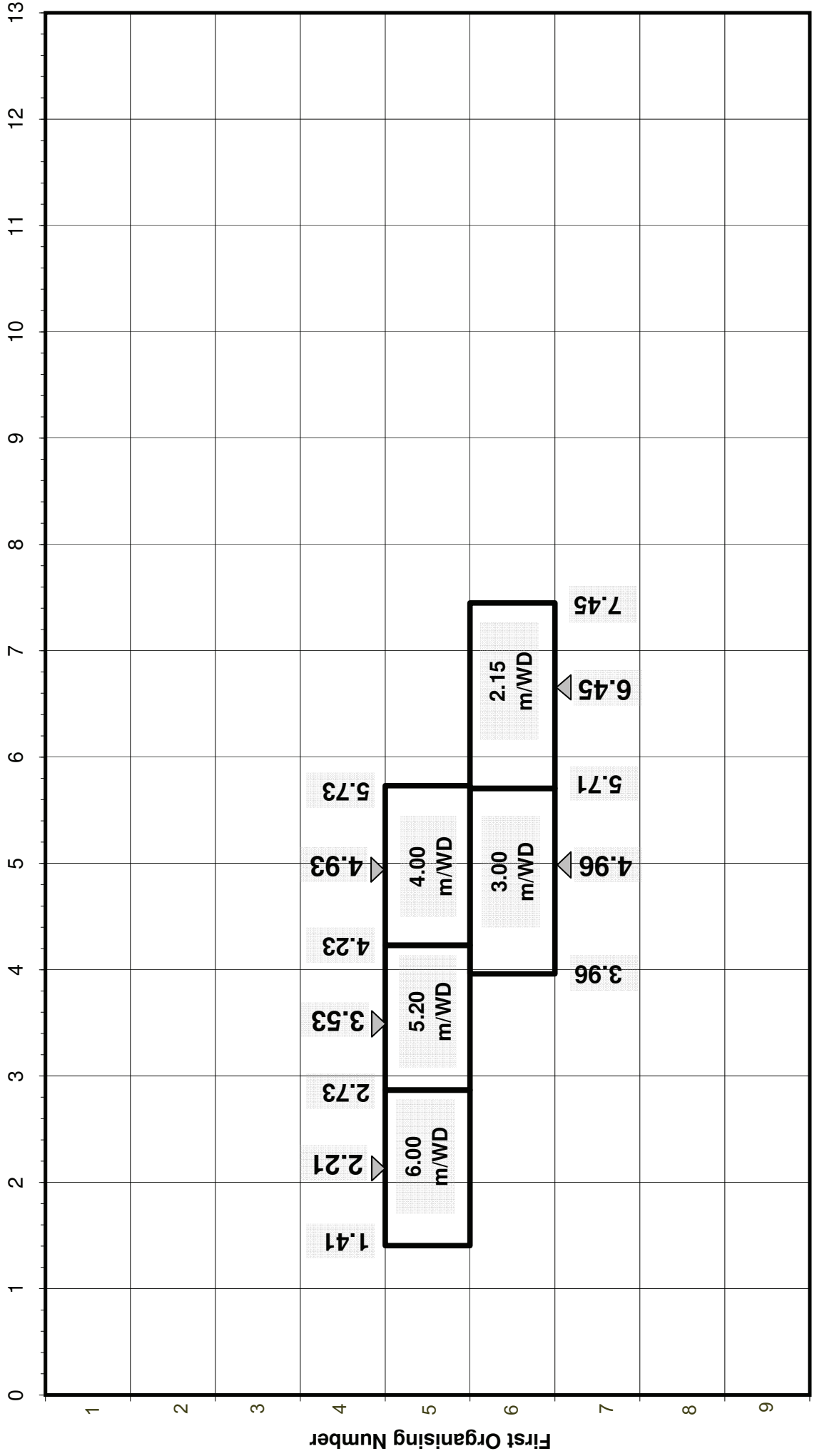
Tunnel "Example"
Tunnelling Class Matrix for projected support types
Top Heading TC 6/xx & 7/xx



Tunnel "Example"
Excavation cost € per m3
Tunnelling Classes 5/xx and 6/xx
Second Organising Number (Support Number)



Tunnel "Example"
excavation advance rates m per workday
Tunnelling Classes 5/xx and 6/xx
Second Organising Number (Support Number)

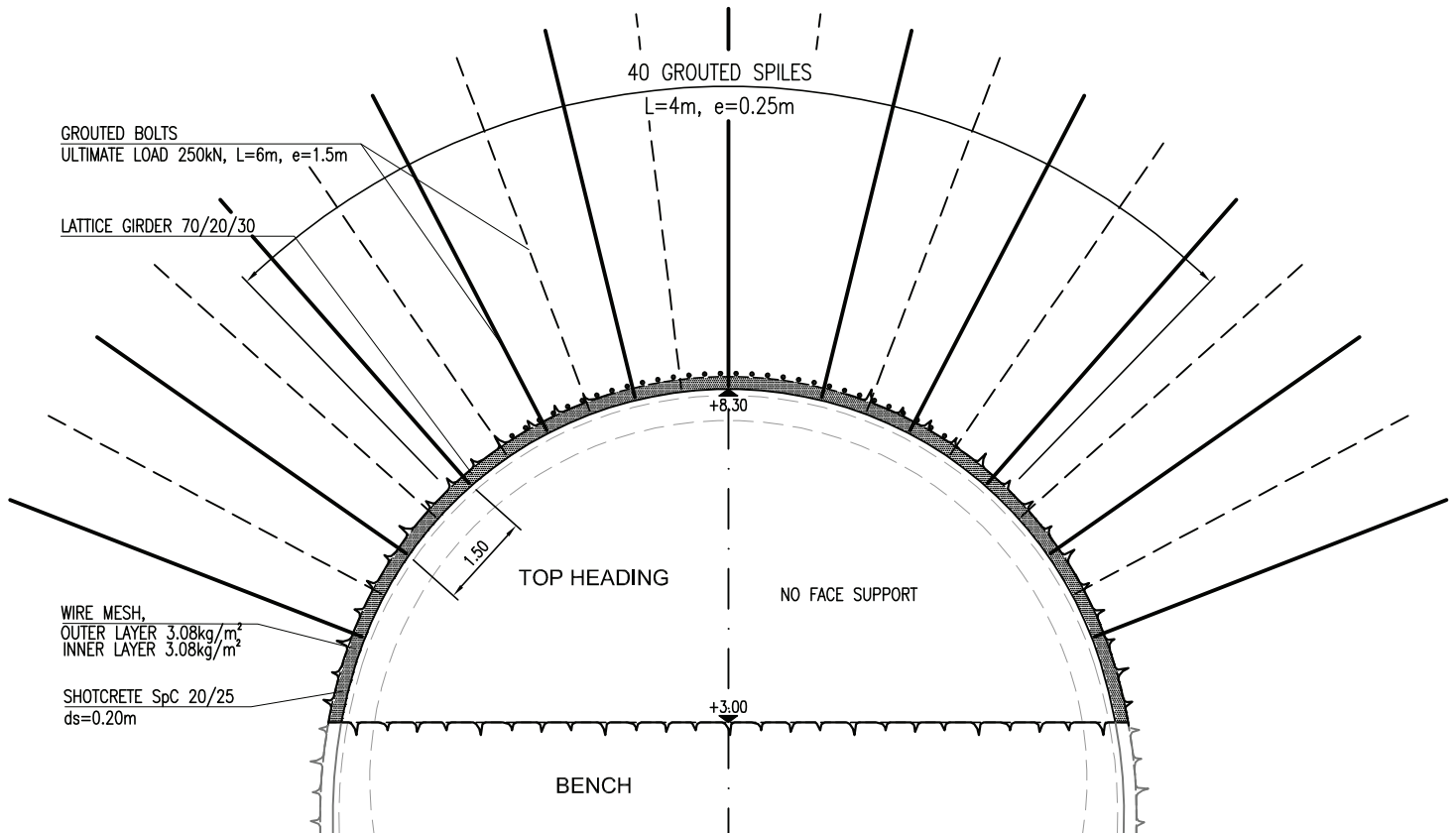


Tunnel "Example"

Installed support elements No.12 (top heading)

Round length: 1.50m

$\ddot{u}m = 0.05m$



Tunneling Class Top Heading		Round Length up to / $\ddot{u}m$		Volume/ round	Volume/ m of tunnel
TC 5/6.14		Top Heading 1.5m / 0.05 m			
Installation site	installation time	Support elements (for 1 m of Tunnel)			
Top heading					
T	before excavation round	Grouted spiles	L= 4 m	160.00 m	106.67 m
T	immediately excavation round	Filling spandrels		1.20 m ³	0.80 m ³
T	immediately after excavation round	Shotcrete SpC 20/25	ds= 0.2m	5.30 m ³	3.54 m ³
T	immediately after excavation round	Wire mesh 1.96cm ² /3.08kg/m ²	1 outer Layer	26.52 m ²	17.68 m ²
T	immediately after excavation round	Wire mesh 1.96cm ² /3.08kg/m ²	1 inner Layer	26.52 m ²	17.68 m ²
T	immediately after excavation round	Lattice girder	YES	17.68 m	11.79 m
T	max. 2 excavation rounds behind top-heading face	Grouted bolts	Ultimate Load 250 kN, 0 m	63.00 m	42.00 m
Excavation volume				79.31 m³	52.87 m³

Tunnel "Example"
 installed support elements heading No 12
 Top Heading

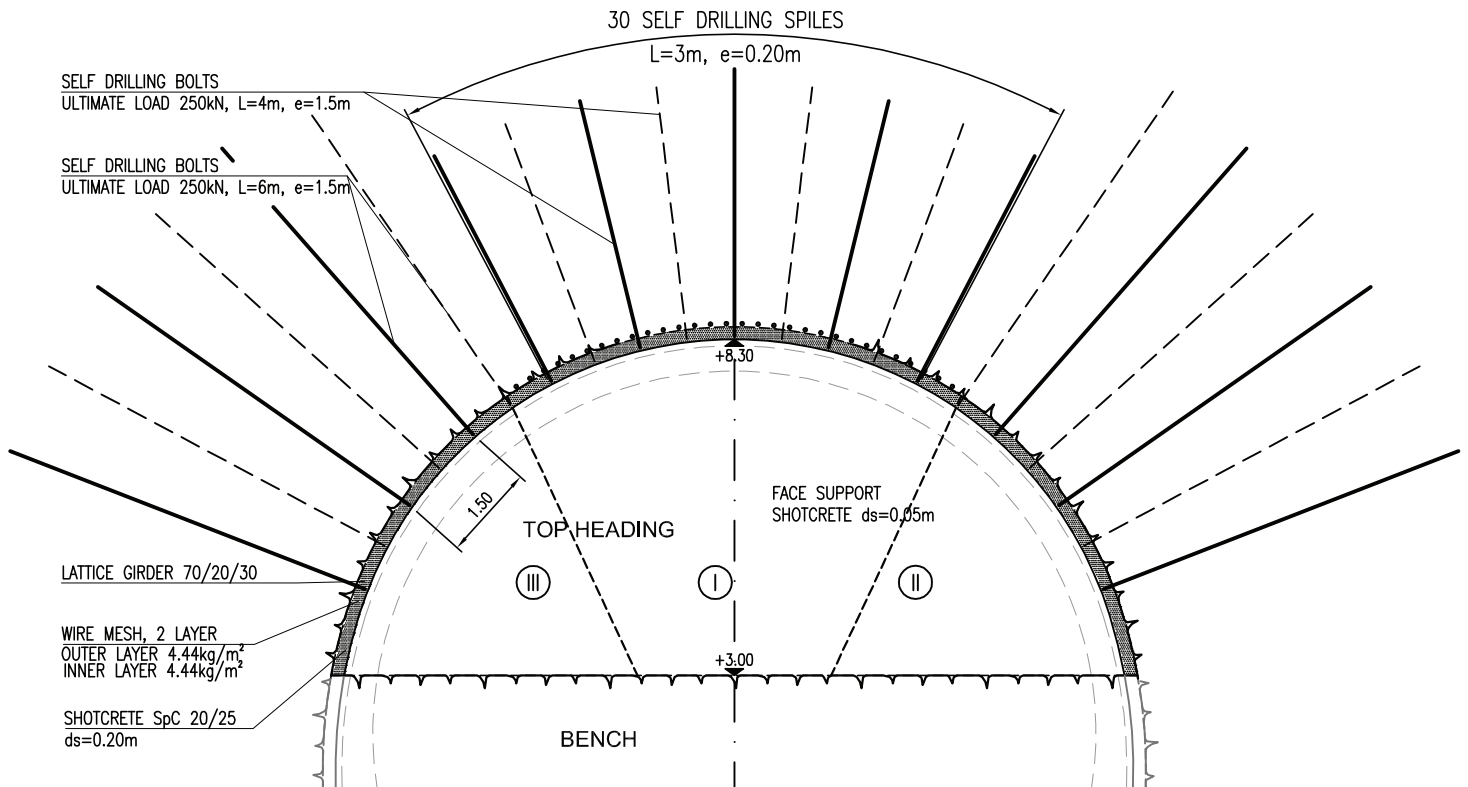
Top heading		ūm=0.05 m	5/6.14		
excavation profile	52.87 m ²	Round length	1.5 m		
Support elements (for 1 m of Tunnel)		Unit	quantity	Rating factor per unit of quantity	Ratio
Bolts	Friction bolt (Swellex or equivalent)	m		0.8	
	Grouted bolt	m	42.00	1.1	46.20
	Self- drilling bolt	m		1.7	
	Tube bolt	m		2.0	
	Prestressed grouted bolt	m		2.5	
Face Bolts	Number of bolts in the face	ST		8.0	
	Installation of face plate	ST		1.7	
	Installation of face plate plus prestressing	ST		5.0	
Spiles	Driven spiles	m		0.5	
	Non-grouted spiles	m		0.6	
	Friction spile	m		0.8	
	Grouted spiles	m	106.67	0.9	96.00
	Self drilling spiles	m		1.3	
	Grouted hollow bar spiles	m		1.6	
Grouting in excess of 10kg per m of bolt, spile, footing micropile		kg		0.1	
Wire mesh	Outside with steel arch	m ²	17.68	1.0	17.68
	inside with steel arch	m ²	17.68	1.5	26.52
	Outside without steel arch	m ²		2.0	
	Top heading invert	m ²		0.8	
	Additional reinforcement, face wire mesh	m ²		2.0	
Arches and wall beams		m	11.79	2.0	23.57
Shotcrete	Top heading and bench headings	m ³	3.54	20.0	70.72
	Top heading invert, top heading footing (elephant footing)	m ³		12.0	
	Filling spandrels and over excavation	m ³		14.0	
	Filling spandrels and over excavation	m ³	0.80	14.0	11.20
Deformation gaps	without ductile elements	m		3.5	
	with ductile elements	m		5.0	
Steel-Sheet forepoling		m ²		5.5	
Footing micro piles	micropile dia. ≤ 38mm	m		4.5	
	micropile dia. > 38mm	m		5.0	
Partial face excavation		ST		22.0	
Top heading footing (elephant's foot)		m		50.0	
Demolition of top-heading invert arch during bench excavation		m		50.0	
Summation					291.89
Rating area					47.52 m²
Support number					6.14

Tunnel "Example"

Installed support elements No.17 (top heading)

Round length: 1.30m

$\ddot{u}m = 0.10m$

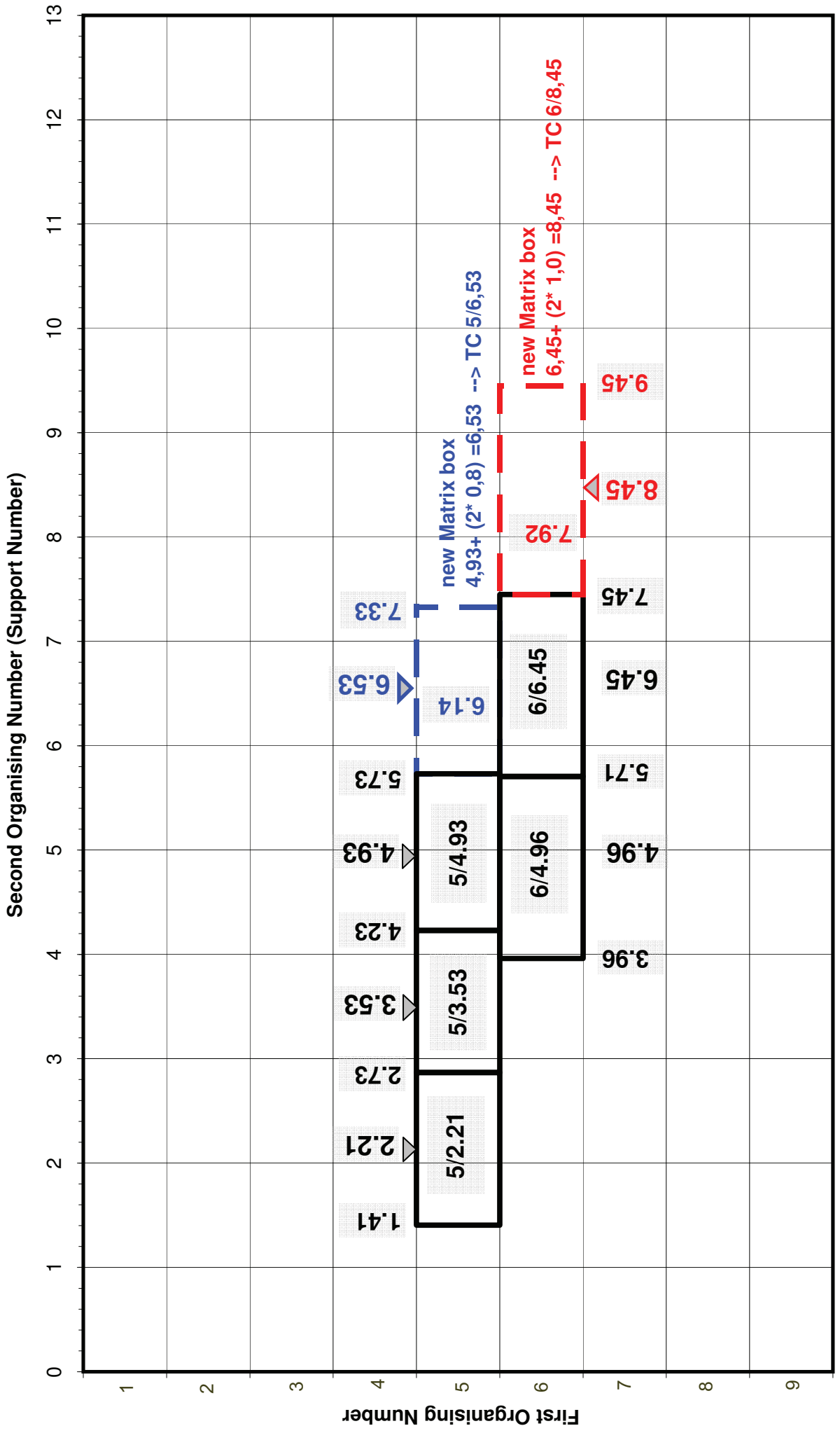


Tunneling Class Top Heading		Round Length up to / $\ddot{u}m$		Volume/ round	Volume/ m of tunnel	
TC 6/7.92		Top Heading	1.3m / 0.1 m			
Installation site	installation time	Support elements (for 1 m of Tunnel)		Volume/ round	Volume/ m of tunnel	
Top heading						
T	before excavation round	Self drilling spiles	L= 3 m	90.00 m	69.23 m	
T	immediately excavation round	Filling spandrels		0.90 m³	0.69 m³	
F	immediately after excavation round	Shotcrete SpC 20/25	ds= 0.05m (100%)	0.03 m³	0.02 m³	
T	immediately after excavation round	Shotcrete SpC 20/25	ds= 0.2m	4.64 m³	3.57 m³	
T	immediately after excavation round	Wire mesh 2.83cm²/4.44kg/m²	1 outer Layer	23.19 m²	17.84 m²	
T	immediately after excavation round	Wire mesh 2.83cm²/4.44kg/m²	1 inner Layer	23.19 m²	17.84 m²	
T	immediately after excavation round	Lattice girder	YES	17.84 m	13.72 m	
T	max. 2 excavation rounds behind top-heading face	---	Ultimate Load 250 kN, 36 m	0.00 m	0.00 m	
T	max. 2 excavation rounds behind top-heading face	Self-drilling bolts	Ultimate Load 250 kN, 36 m	54.00 m	41.54 m	
				Excavation volume	69.93 m³	53.79 m³

Tunnel "Example"
 installed support elements heading No 17
 Top Heading

Top heading		ǖm=0.10 m	6/7.92		
excavation profile	53.79 m ²	Round length		1.3 m	
Support elements (for 1 m of Tunnel)		Unit	quantity	Rating factor per unit of quantity	Ratio
Bolts	Friction bolt (Swellex or equivalent)	m		0.8	
	Grouted bolt	m		1.1	
	Self- drilling bolt	m	41.54	1.7	70.62
	Tube bolt	m		2.0	
	Prestressed grouted bolt	m		2.5	
Face Bolts	Number of bolts in the face	ST		8.0	
	Installation of face plate	ST		1.7	
	Installation of face plate plus prestressing	ST		5.0	
Spiles	Driven spiles	m		0.5	
	Non-grouted spiles	m		0.6	
	Friction spile	m		0.8	
	Grouted spiles	m		0.9	
	Self drilling spiles	m	69.23	1.3	90.00
	Grouted hollow bar spiles	m		1.6	
Grouting in excess of 10kg per m of bolt, spile, footing micropile		kg		0.1	
Wire mesh	Outside with steel arch	m ²	17.84	1.0	17.84
	inside with steel arch	m ²	17.84	1.5	26.76
	Outside without steel arch	m ²		2.0	
	Top heading invert	m ²		0.8	
	Additional reinforcement, face wire mesh	m ²		2.0	
Arches and wall beams		m	13.72	2.0	27.45
Shotcrete	Top heading and bench headings	m ³	3.57	20.0	71.36
	Top heading invert, top heading footing (elephant footing)	m ³		12.0	
	Filling spandrels and over excavation	m ³	2.07	14.0	28.96
	Filling spandrels and over excavation	m ³	0.69	14.0	9.69
Deformation gaps	without ductile elements	m		3.5	
	with ductile elements	m		5.0	
Steel-Sheet forepoling		m ²		5.5	
Footing micro piles	micropile dia. ≤ 38mm	m		4.5	
	micropile dia. > 38mm	m		5.0	
Partial face excavation		ST	1.54	22.0	33.85
Top heading footing (elephant's foot)		m		50.0	
Demolition of top-heading invert arch during bench excavation		m		50.0	
Summation					376.52
Rating area					47.52 m²
Support number					7.92

Tunnel "Example" Extrapolating Tunnelling Class Matrix



Tunnel "EXAMPLE"
 Extrapolation for new excavation costs and advance rates

Extrapolation with 2 existing tunnelling classes in one matrix line: e.g.: for TC 6/8.45

	TC 6/4.96	TC 6/6.45	TC 6/8.45
Excavation costs in €/m ³	62.00	76.50	91.00
Advance Progress rates in m/woi	3.00	2.15	1.30

Extrapolation with 3 existing tunnelling classes in one matrix line: e.g.: for TC 5/6.53

--> extrapolation by using a polynomial best-fit curve : $y=ax^2 + bx + c$

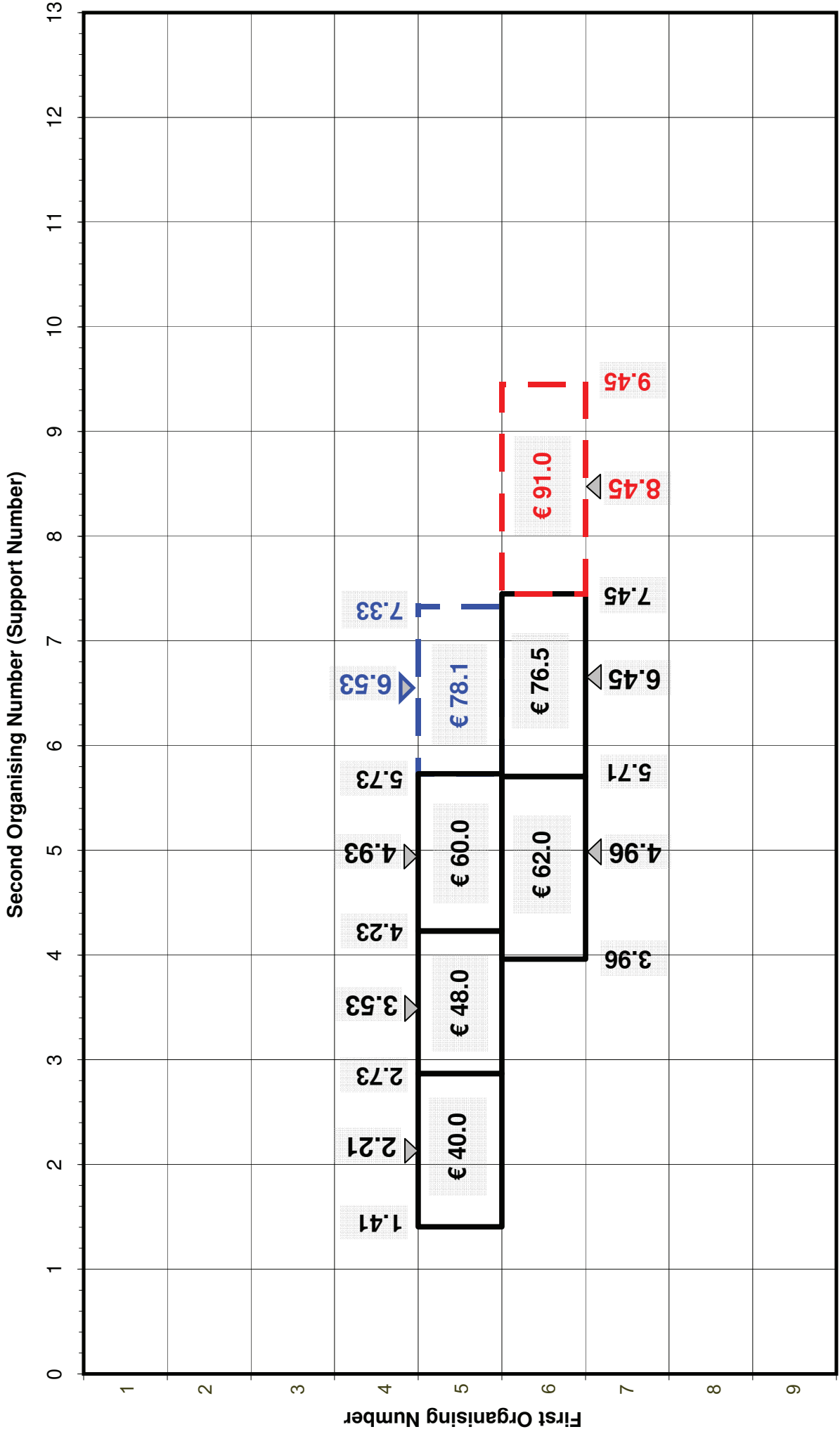
	TC 5/2.21	TC 5/3.53	TC 5/4.93	TC 5/6.53
Excavation costs in €/m ³	40.00	48.00	60.00	78.15
Advance rates in m/working day	6.00	5.20	4.00	2.19

Extrapolation of excavation costs: $a=0,923, b=0,762, c=33,807$
 $UP\ new = 6,53^2 \times 0,923 + 6,53 \times 0,762 + 33,807 = 78.15\ \text{€/m}^3$

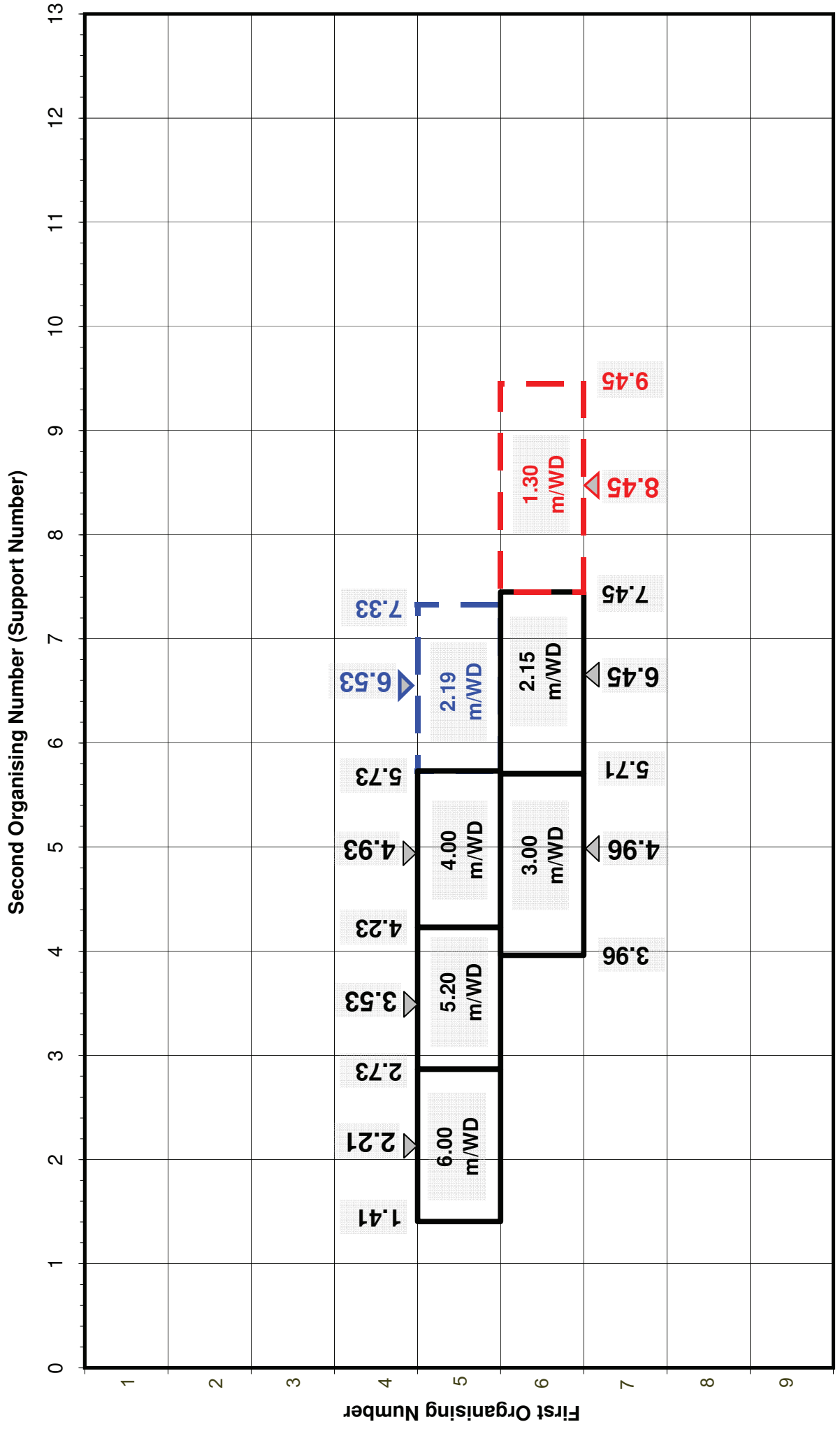
Extrapolation of Advance rates: $a=-0,092, b=-0,076, c=6,619$
 $v\ new = -6,53^2 \times 0,092 - 6,53 \times 0,076 + 6,619 = 2.19$

where TC..... tunneling class
 UP..... unit price
 v..... advance rate m/working day

Tunnel "Example" Excavation cost € per m3



Tunnel "Example" excavation advance rates m per workday



Tunnel "EXAMPLE"
Calculation of construction time and time dependent costs

"WD" means work day

Calculation of offered excavation time (top heading)

Tunneling Classes (TC)	Estimated length of each TC in m	Offered advance Rates	Offered excavation time
TC 5/2.21	24.00	6.00 m/WD	4.00 WD
TC 5/3.53	95.00	5.20 m/WD	18.27 WD
TC 5/4.93	60.00	4.00 m/WD	15.00 WD
TC 6/4.96	124.00	3.00 m/WD	41.33 WD
TC 6/6.45	56.00	2.15 m/WD	26.05 WD
Total	359.00		104.65 WD

Calculation of Contractual Excavation Period (top heading)

Tunneling Classes (TC)	Actual Length of each TC in m	Contractual Progress Rates	Contractual Excavation Period
TC 5/2.21	68.00	6.00 m/WD	11.33 WD
TC 5/3.53	89.10	5.20 m/WD	17.13 WD
TC 5/4.93	76.50	4.00 m/WD	19.13 WD
TC 5/6.53	13.60	2.19 m/WD	6.22 WD
TC 6/4.96	71.50	3.00 m/WD	23.83 WD
TC 6/6.45	32.50	2.15 m/WD	15.12 WD
TC 6/8.45	7.80	1.30 m/WD	6.00 WD
Total	359.00		98.76 WD

Time dependent costs of top heading excavation

Offered lump sum for time dependent costs		€ 996,265.00
Change of lump sum into "costs per work day"	=996.265,00/104,65=	€ 9,519.97
Payment of time dependent costs for actual excavation time	=9519,97 x 98,76=	€ 940,192.37