



NORDIC GROUTING SYMPOSIUM 2019

SUCCESSFUL GROUTING OF WEST METRO

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AGENDA

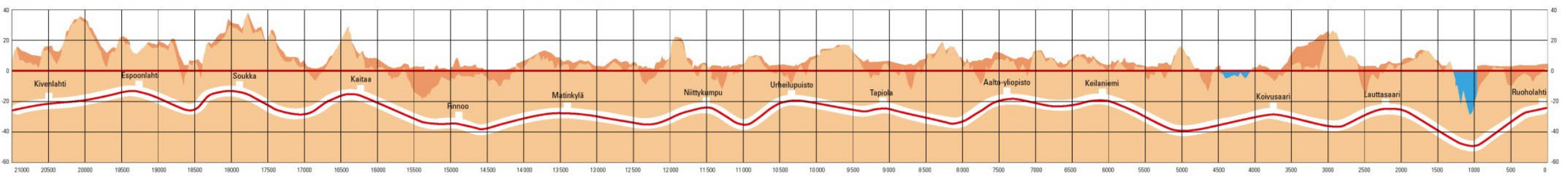
- **Presentation of project**
- **Principles of grouting management**
- **Basic grouting design**
- **Grouting drawings**
- **Cost of grouting works**
- **Development to the next time**

MATINKYLÄ – KIVENLAHTI

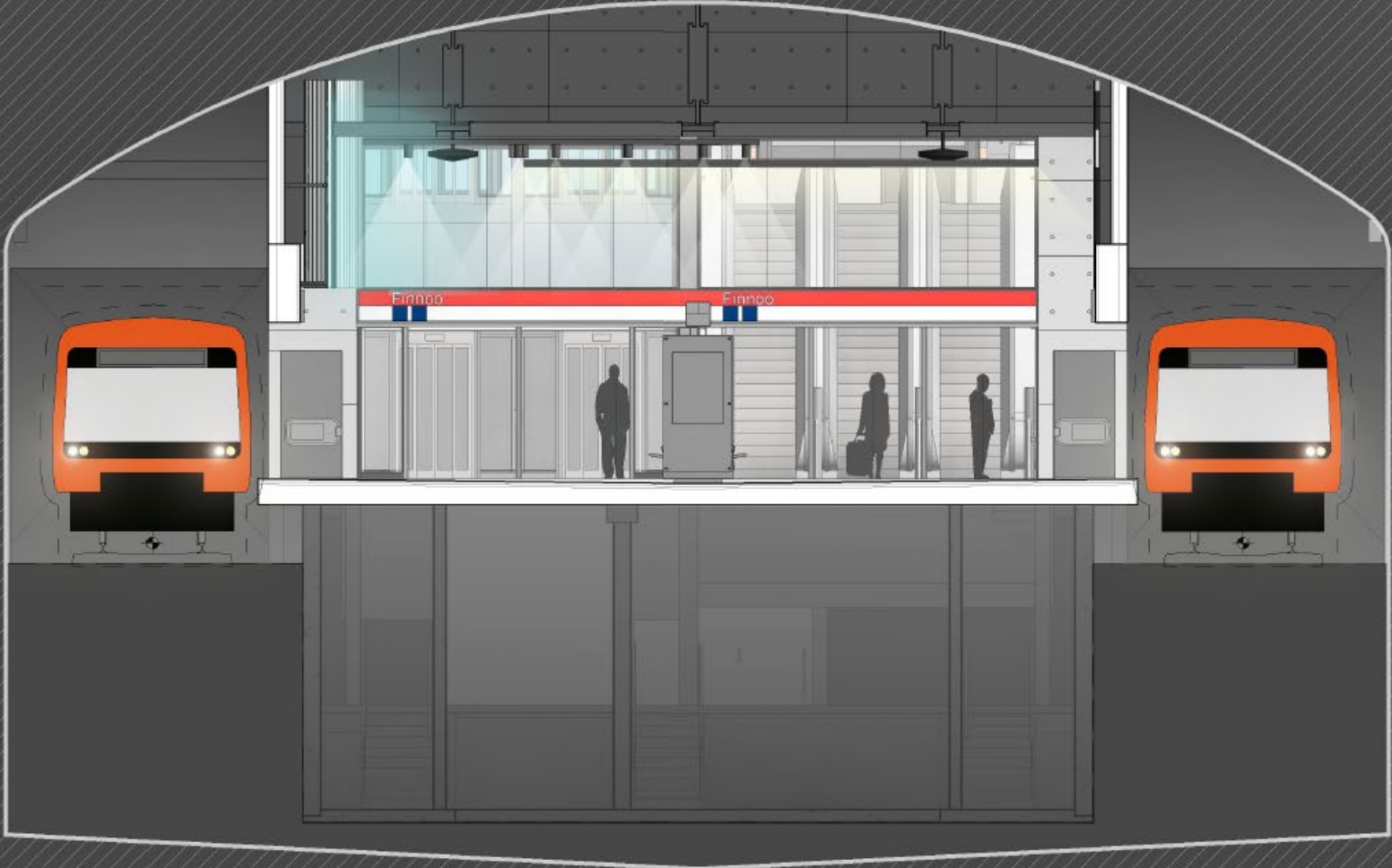
- 7 km twin tunnels
- 5 stations
- depot

RUOHOLAHTI – MATINKYLÄ

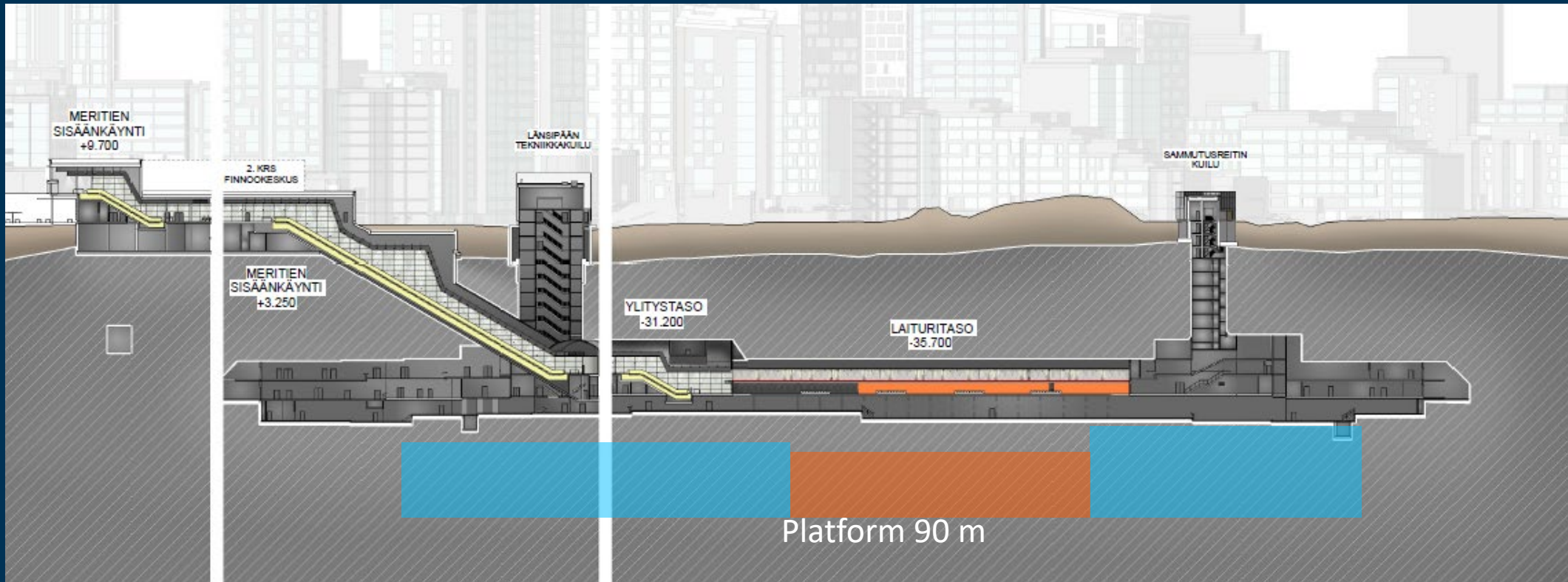
- 14 twin tunnels
- 8 stations



Station width some 25 m and max height 20 m



Station, total length some 200 metriä



PRINCIPLES OF GROUTING MANAGEMENT

- **all contracts (55 pcs) similar basic design**
 - Must be simple and clear
 - Large amount of consulting companies, how to uniform design
- **large field investigation period, all material published**
 - Low rock cover stations (10-20 m)
 - Investigations focused to stations and weakness zones
 - Rock quality more than 80% good
- **client gives all rock quality information and estimated grouting quantities in tender documents**
 - According general conditions for building contracts (YSE, AB04...)

PRINCIPLES OF GROUTING MANAGEMENT

- **all grouting works unit prices**
 - gives client freedom to modifications during tunneling
- **separate price for all different grouting methods**
 - No need to ask additional prices after tender
- **client determine grouting classes in tender documents**
 - Easier for contractor to give (reasonable) tender
- **chemical grouting in severe conditions**
 - No long delays for excavation
- **environment**
 - Tunnel goes under sea several km
 - Groundwater table is not extremely sensitive, GW is not used for domestic purpose, but there are large clay areas and danger for settlement exist

BASIC GROUTING DESIGN

- **environmental classes**
 - AA < 2 l/min/100 m; WPT limits 0,2/0,4 Lug walls/bottom
 - A < 5 l/min/100 m; WPT limits 0,3/0,5 Lug
 - B < 10 l/min/100 m; WPT limits 0,3/0,6 Lug
- **systematic pregrouting or pregrouting according as water pressure test (L)**
- **Several grouting rounds if necessary**
 - method A 1. pregrouting - probing - WPT -2. pregrouting if needed - WPT- 3. if needed - WPT- excavation
 - method B 1. pregrouting half of the holes- hardening- pregrouting other half- probing - WPT -2. pregrouting if needed - WPT- 3. if needed - WPT- excavation
- **mainly microcement, heavy leakage chemical grouting**
- **w/c 2,0 - 0,6**

BASIC GROUTING DESIGN

- **probing 15-24 m, overlapping 5 m with previous round**
- **8 hours waiting for hardening**
- **Large surface ground water observation holes on-line monitoring (several thousands)**
- **leakage inspection and floor flow measuring dams (too often too late)**
- **tunnel has own geologists and site rock engineer by designers**
 - follows grouting work in tunnel regularly
 - contractor sent daily grouting records
 - rock engineer modify basic design if needed

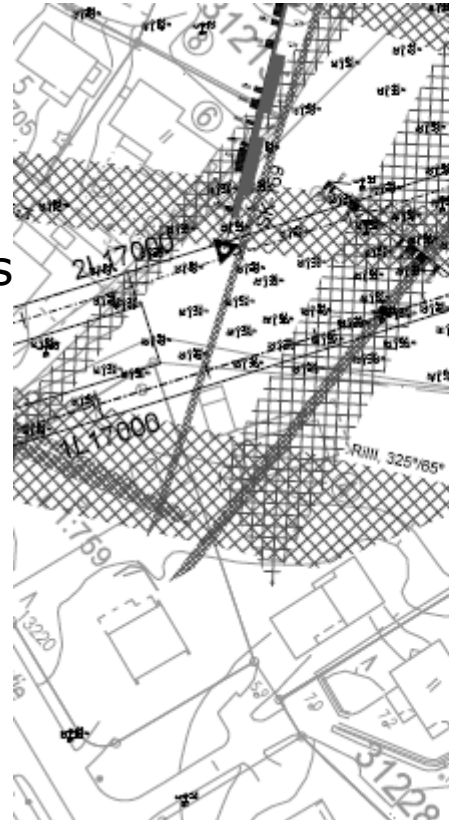
BASIC GROUTING DESIGN

- **Drainage of tunnels**
 - There is a rock drainage system between rock and shotcrete which leads leakage to floor horizontal drainage
 - There are several water basins which collect water and via it is pumped out
 - Volume of basins are equal to 24 hours leakage
- **Authorities**
 - Authorities has determined the maximum allowed leakage
 - Continuous reporting

GROUTING DRAWINGS GEOLOGY

- Map of investigations 1:500

- Geological mapping
- Probing
- Seismic velocity measurements
- Core drillings
- Rock stress measurements
- Water pressure tests



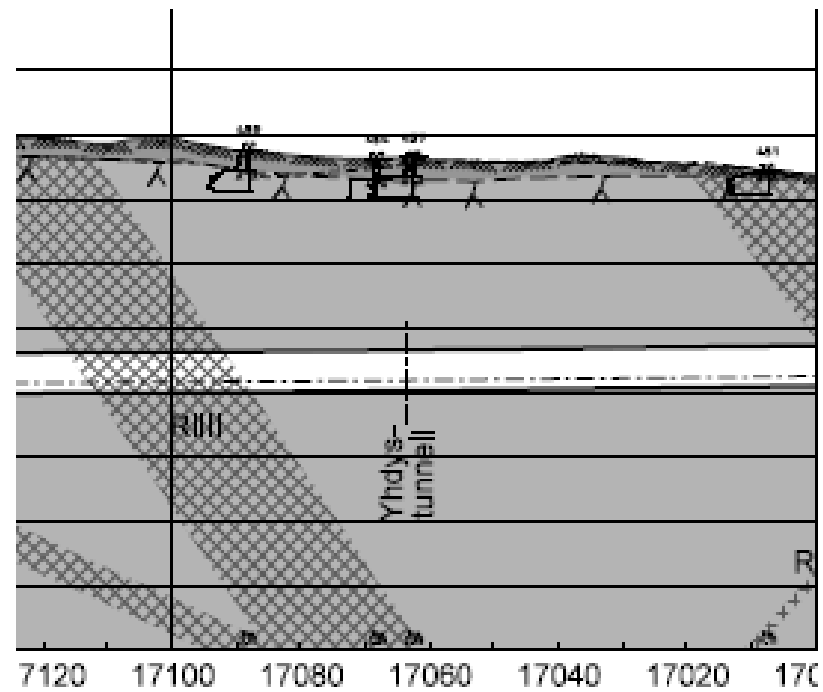
MERKINTÖJEN SELITYKSET

	Kalluperän arvittu rikkinäisyysdyvyke Rikkinäisyysdyvykseen luokka (RC-luokitus), suunta ja kaltevuus
	Avokallioalueen raja Rakennusgeologiset karttustiedot
	Retrospektiivinen luotauksen ja liikuttamisen, pinnan, ja seismiset nopeudet
	Kallontyöntekijän Pöytäkirja, alkuperäiset ja muutokset, todetut rikkinäisyydet ja vesimerkit
	Kallontyöntekijän ja liikuttamisen pöytäkirja
	Avokallioalueen tehty kallio- pinnan rakentaminen Pöytäkirja, kaiteen suunta ja suuruus asteissa, rakotus (k/m)
	Avokallioalueen tehty kallio- pinnan rakentaminen Läpikäytävien rakotus (k/m)
	Avokallioalueen tehty kallio- pinnan rakentaminen Läpikäytävien suunta ja suuruus asteissa
	Porekokeet Maankorkeus, paine, kovuus, ja muut ja kallionpinnan korkeusaste

Geologinen kartta, joka sisältää tutkimuskohteiden sijainnin ja tutkimustulokset.

GROUTING DRAWINGS GEOLOGY

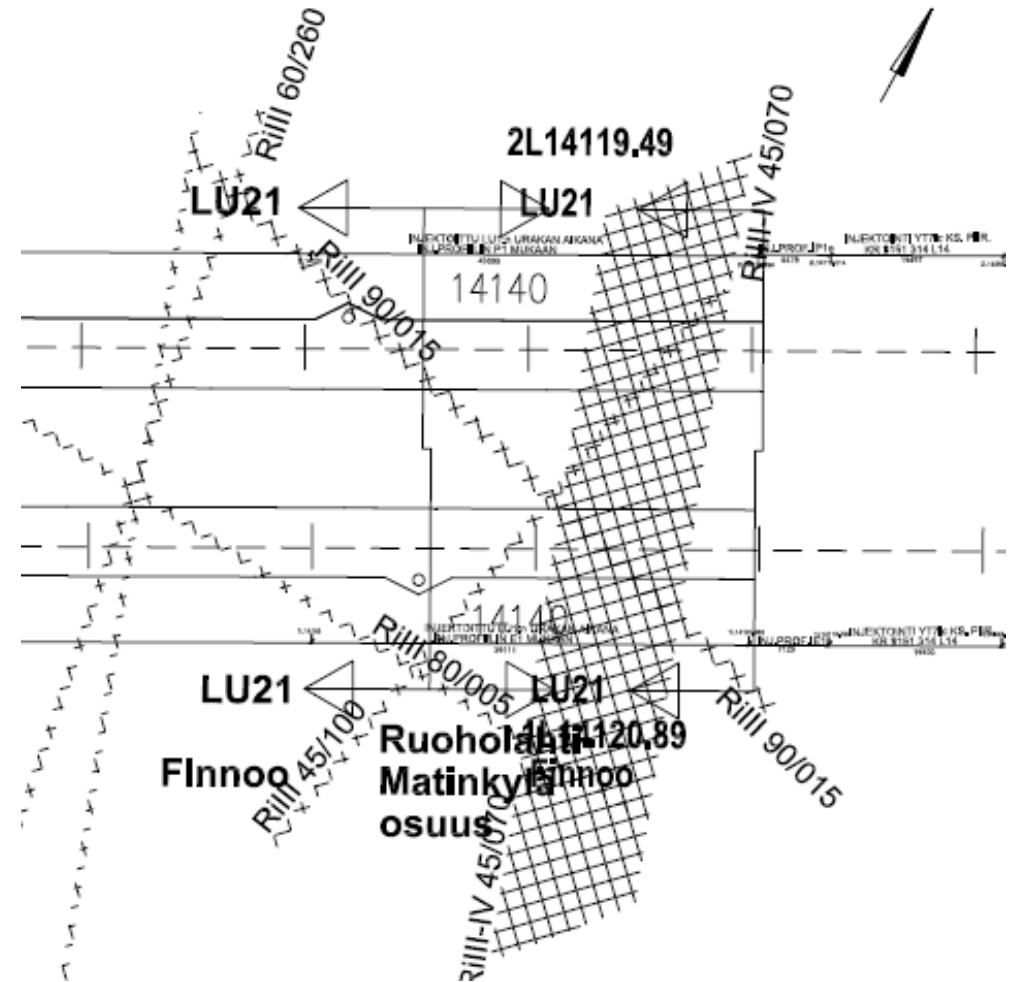
- Map of geology 1:1000
 - Geological investigations
 - Longitudinal profile
 - Q values
 - Environmental classes (AA)



$0,4 < Q < 1$	$1 < Q < 4$	
AA		

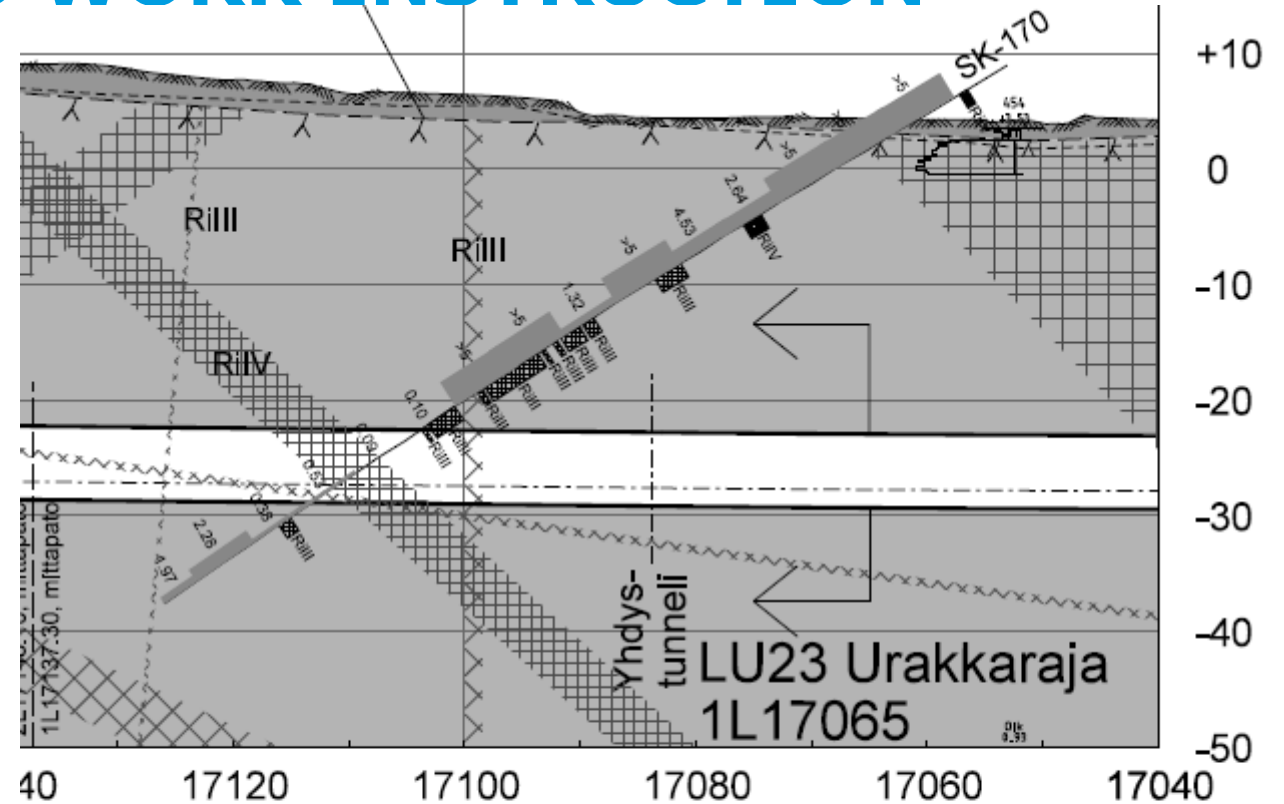
GROUTING DRAWINGS WORK INSTRUCTION

- Map of grouting 1:200
 - Location, chainage
 - Refer to detailed grouting profile



GROUTING DRAWINGS WORK INSTRUCTION

- Profile 1:500
 - Grouting method
 - (rock support class)
 - (shortened tunnel advance)

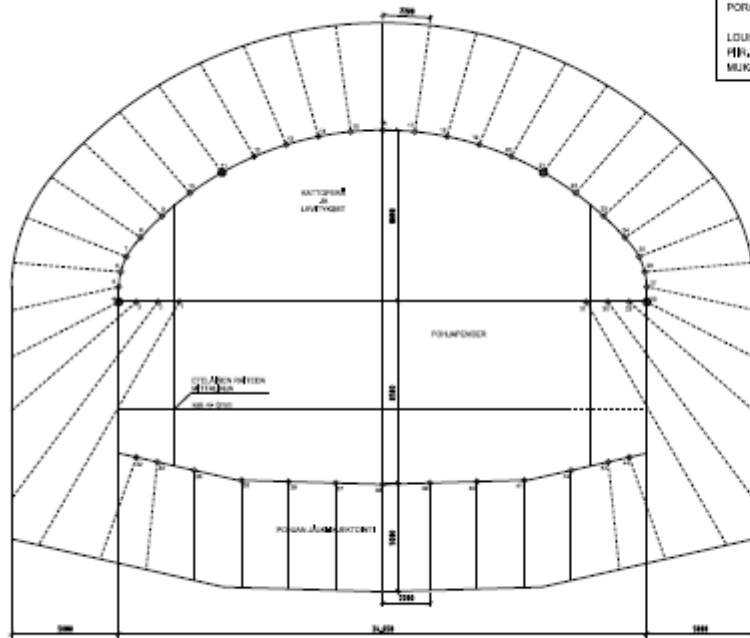


Systemaattinen esi-injektointi vaiheittain. Käytettävä esi-injektointi-profiili tyyppi III. Kts. piirustukset KR 8151_001 ja 003 1L17-18	
D	C
Katkon pituus 3 m. Työn-alkainen lujitus. Kts. piirustukset KR 8152_001...002 1L17-18	

GROUTING DRAWINGS WORK INSTRUCTION

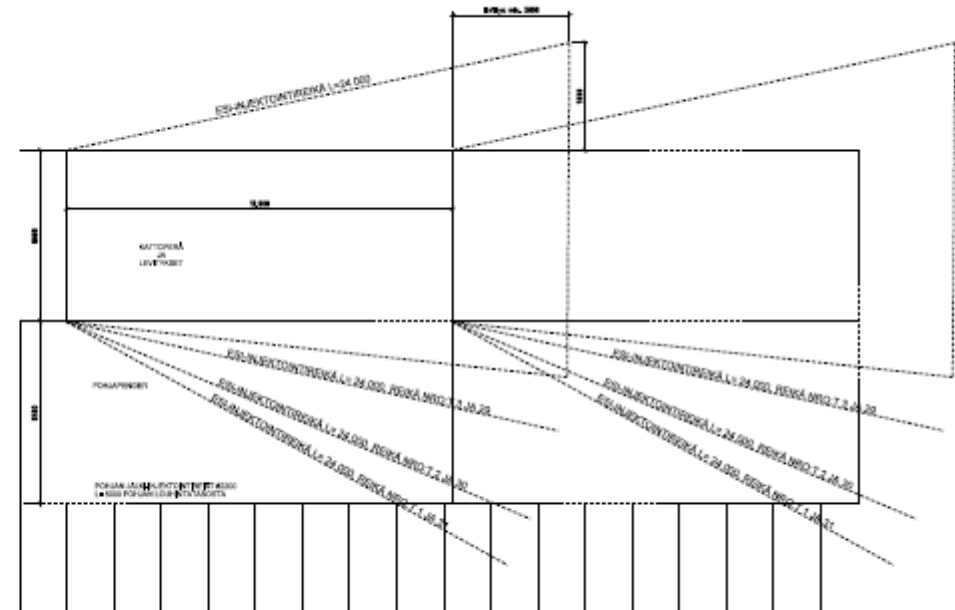
- Grouting profile
 - Stations (one example)
 - Drilling pattern ,amount, length, angle, location, max deviation

PROFILI SOUKI
Ei4/1000/1000/1000
• kokonaispituus 24 m
• 31 reikää
• kokonaispituus 764 m
• 4 kunnostusvaihetta (reitit 4, 11, 21 ja 28)
• 3 kunnostusvaihetta (reitit 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 29, 30, 31)
Pöytä 2014/1000/1000/1000
• 13 reikää 1000x1000
• kokonaispituus 60 m



KATTOPÄÄ JA LEVITYKSET
LOUHIKKAAN SAMALLE PAALULLE
ENNEN ESIMUOKOTIN KAIKKIEN
PORAUSTIA.

LOUHIKKAAN VAIHESTUS
R10, KR 619, 718 SOU
MUKAAN.



GROUTING DRAWINGS WORK INSTRUCTION

- **Grouting profile**
 - Matrix of grouting pressures and advance (one example)

pregrouting according as water pressure test
grouting treshole limit 0,25 Lug in any hole
all holes drilled in one go

Advance	1.	2.	3.	4.
w/c	1,2	1,0	0,8	0,6
kg max/hole	10	20	30	50
Cement	micro	micro	micro	micro
max pressure Mpa	4,0	4,0	4,0	4,0

after grouting
probe holes 3 pcs
WPT probe holes 3 pcs
ending after 0,25 Lug or new advance

COST OF GROUTING WORKS

- Real costs of three different contracts (M€)

KAITAA	all	station	access tunnel	tunnels	shaft 1	shaft 2
excavation	21,0 €	10,6 €	1,2 €	6,3 €	1,1 €	1,7 €
pregrouting	3,0 €	1,2 €	0,2 €	1,4 €	0,1 €	0,1 €
postgrouting	0,5 €	0,2 €	0,0 €	0,3 €	0,0 €	0,0 €
whole contract	35,0 €	16,5 €	2,0 €	13,1 €	1,5 €	1,9 €

FINNOO	all	station	access tunnel	tunnels	shaft 1
excavation	22,3	16,9	0,8	3,3	1,3
pregrouting	3,2	1,2	0,3	1,7	0,07
postgrouting	0,5	0,4	0,03	0,1	0,02
whole contract	36,8	24,2	1,7	9,1	1,7

SOUKKA	all	station	access tunnel	tunnels	shaft 1
excavation	17,0	9,9	1,7	5	0,3
pregrouting	2,4	1	0,3	1,1	0,02
postgrouting	0,2	0	0,03	0,1	0
whole contract	30,0	16,2	2,9	10,1	0,8

COST DISTRIBUTION OF CONTRACT

Average of several contracts

excavation fixed price	60 %
grouting unit prices	10 %
rock bolting unit prices	7 %
shotcreting unit prices	13 %
other unit prices	11 %

COST OF GROUTING WORKS

- Relative costs of different locations of grouting of whole contract

	Average of all locations	station	access tunnel	tunnels	shaft
pregrouting	8 %	6 %	13 %	13 %	4 %
postgrouting	1 %	1 %	1 %	1 %	1 %

COST OF GROUTING WORKS

Relative costs of unit prices for grouting for tunnels, stations and shafts

RELATIVE COST FOR GROUTING	STATION	SHAFT	TUNNELS
MATERIAL CEMENT	26 %	3 %	30 %
pregrouting rapid cement	0 %	0 %	0 %
pregrouting mikro cement	24 %	3 %	27 %
pregrouting ultra cement	1 %	0 %	1 %
plasticiser	1 %	0 %	1 %
MATERIAL CHEM	9 %	5 %	15 %
chem grouting material	8 %	4 %	15 %
silica	1 %	0 %	0 %
1 PREGROUTING WORKS CEMENT	24 %	9 %	28 %
1 pre grouting drilling cement	13 %	4 %	14 %
1 pregrouting work cement	11 %	4 %	13 %
1 PREGROUTING WORKS CHEM	2 %	45 %	2 %
1 pre grouting drilling chem	0 %	2 %	0 %
1 pregrouting work chem	2 %	43 %	2 %

	STATION	SHAFT	TUNNELS
2 PREGROUTING WORKS CEMENT	12 %	3 %	12 %
2 pre grouting drilling cement	6 %	1 %	7 %
2 pregrouting work cement	6 %	2 %	5 %
2 PREGROUTING CEMENT other	7 %	3 %	7 %
pregrouting test holes drilling	5 %	2 %	6 %
pregrouting test holes water pressure test	1 %	2 %	1 %
POSTGROUTING WORKS CEMENT	3 %	13 %	5 %
post grouting drilling cement	2 %	9 %	3 %
post grouting work cement	1 %	4 %	2 %
POSTGROUTING CHEM	14 %	8 %	2 %
post grouting drilling chem	1 %	3 %	1 %
post grouting work chem	13 %	5 %	1 %

COST OF GROUTING WORKS

Relative costs of unit price groups for grouting for tunnels, stations and shafts summary

RELATIVE COST FOR GROUTING	STATION	SHAFT	TUNNELS
CEMENT	26 %	3 %	30 %
DRILLING (CEMENT)	25 %	16 %	29 %
GROUTING WORKS (CEMENT)	19 %	10 %	20 %
GROUTING WORKS MAT+WORK (CHEM)	24 %	57 %	19 %
WATER PRESSURE TESTS	1 %	2 %	6 %

COST OF GROUTING WORKS

Unit prices of grouting page 1(2)

PRICES FOR TUNNEL GROUTING FINNOO 2 x 1080 m km					
definition	unit	amount	unit price €	tot price €	price/m
rapid cement	kg	21 300	0,30	6 390	3
mikro cement	kg	1 074 620	0,45	483 579	224
ultra cement	kg	21 170	1,00	21 170	10
super plastizer	kg	10 940	2,00	21 880	10
polyuretan	kg	8 250	32,00	264 000	122
silica	litre	1 000	8,00	8 000	4
drilling I cement	drill m	64 520	4,00	258 080	119
grouting work I cement	h	2 160	110	237 600	110

COST OF GROUTING WORKS

Unit prices of grouting page 2(2)

drilling II cement	drill m	21 950	6	120 725	56
grouting work II cement		740	125	92 500	43
drilling chem	drill m	100	22	2 200	1
grouting work chem	h	100	290	29 000	13
WPT	pieces	630	42	26 460	12
postgrouting drilling cement	drill m	2 985	17,00	50 745	23
postgrouting work cement	h	120	295,00	35 400	16
post grouting drilling chem	drill m	995	17,00	16 915	8
post groutnig work chem	h	40	355	14 200	7
				1 688 844	782

DEVELOPMENT FOR THE NEXT TIME

Focus to tunnel ahead (not passed)

Strengthen the co-operation: geological prediction - tunnel work – documentation – decision making by tunnel engineer – supervision – machinery – material – motivation, too often they do not know each others

Push energy to tunnel work

Avoid too many spreadsheets and office speculations

How well it is possibility to measure in reality: mixture / pressure / joints / water leakage > we easily give too exact designs

Chemical grouting is the future

THANK YOU AND LET'S GROUT AGAIN