GEOCONSULT

NATM Applications in Singapore Ground Conditions

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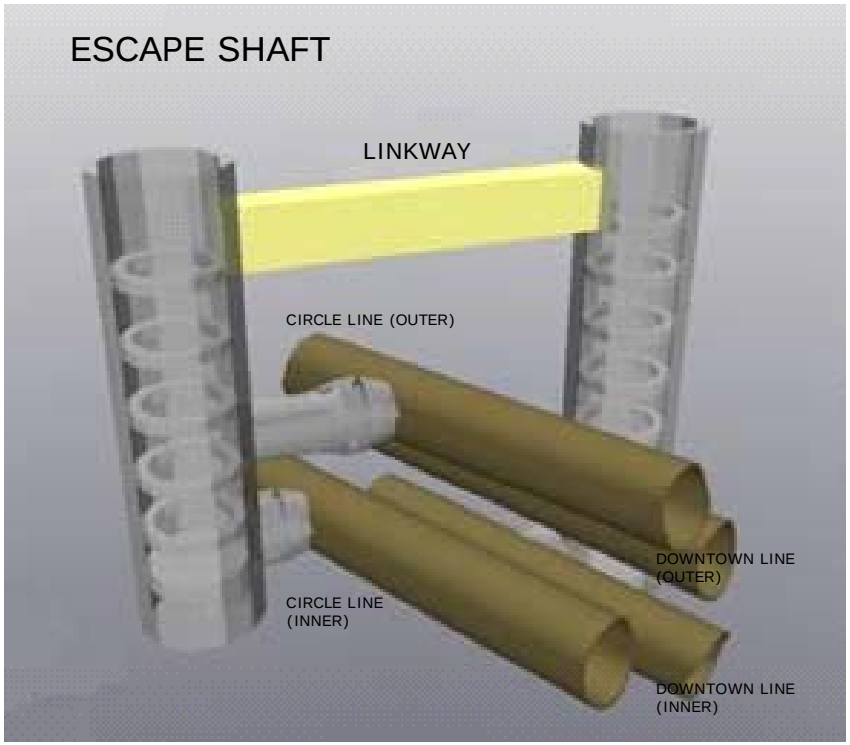
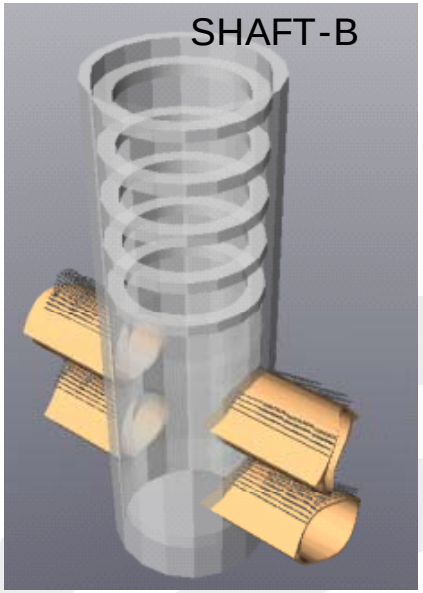
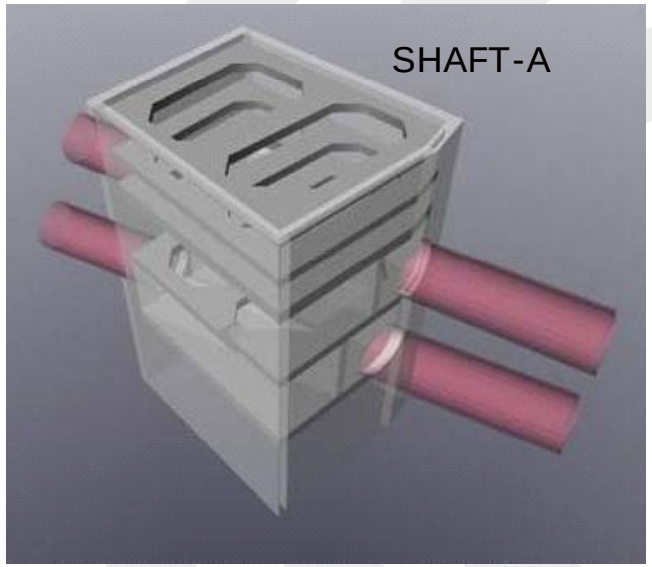
Geoconsult Asia Singapore

Mined Tunnels



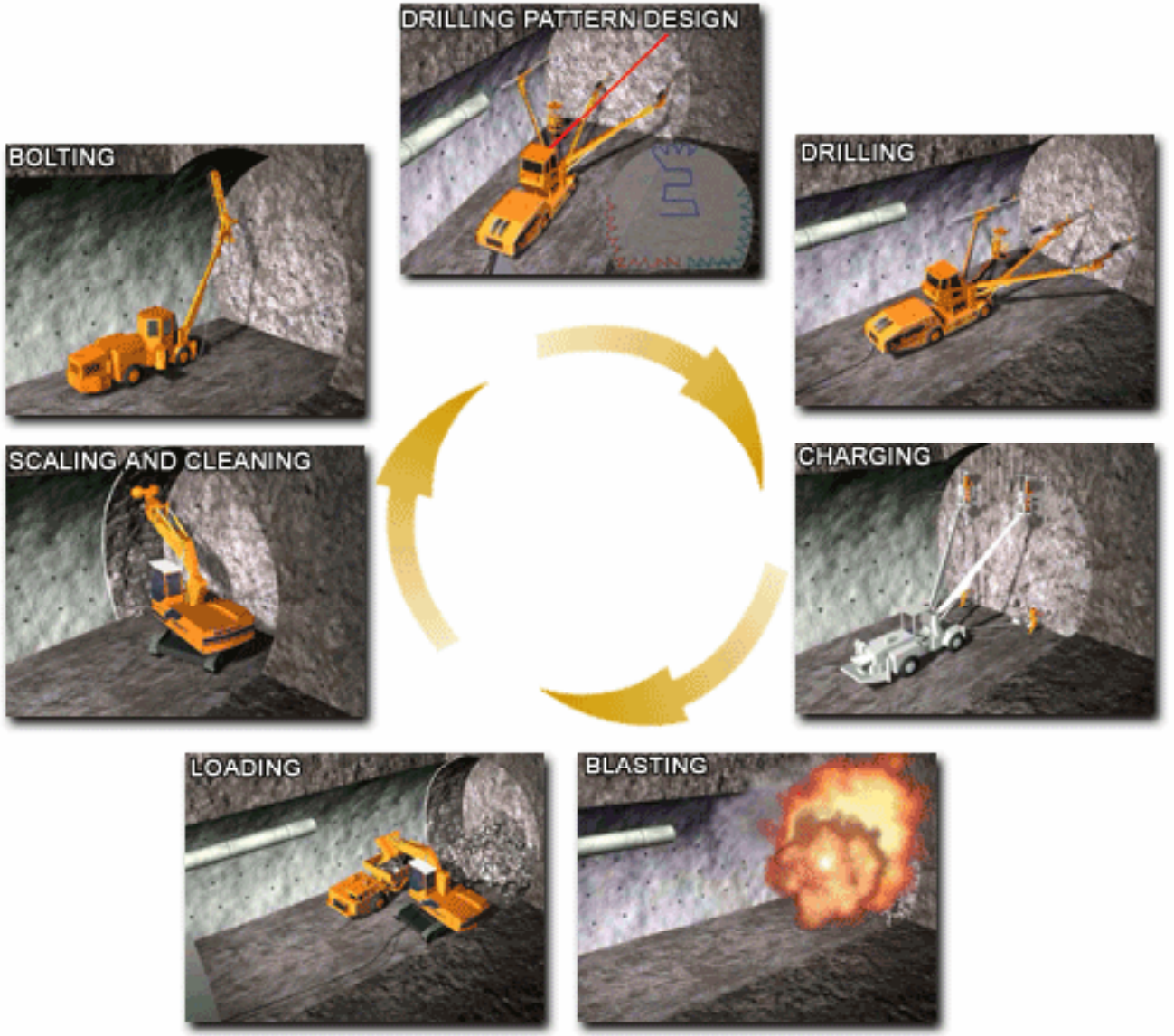




Design Issues

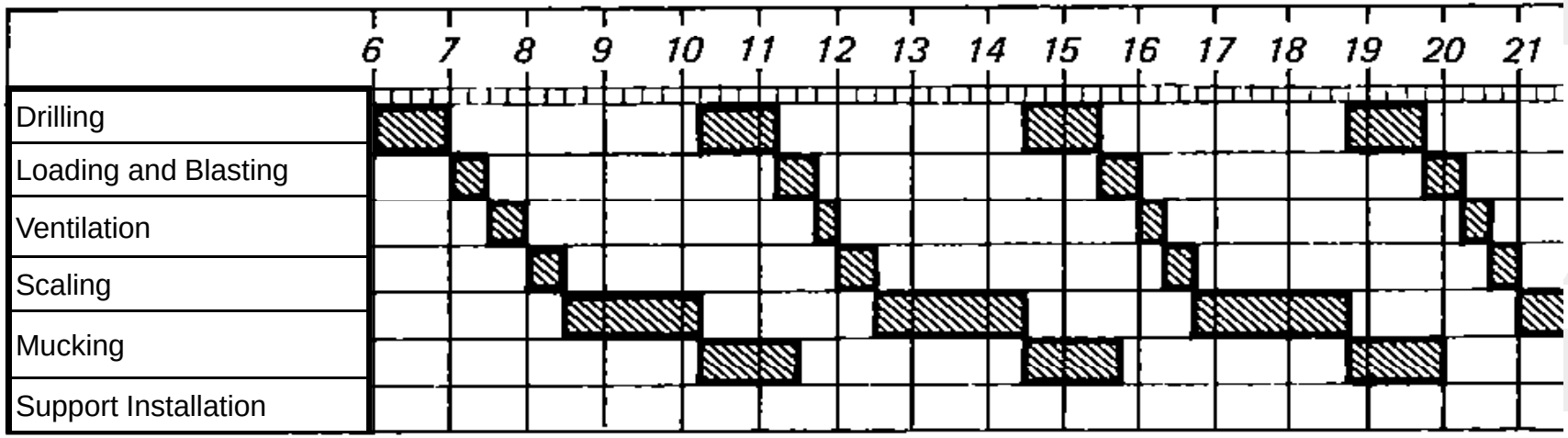
- Understand sequence of works and stage the excavation & support application
- At all times maintain stability of the excavation face
- Design should extend into the construction phase

Excavation Cycle

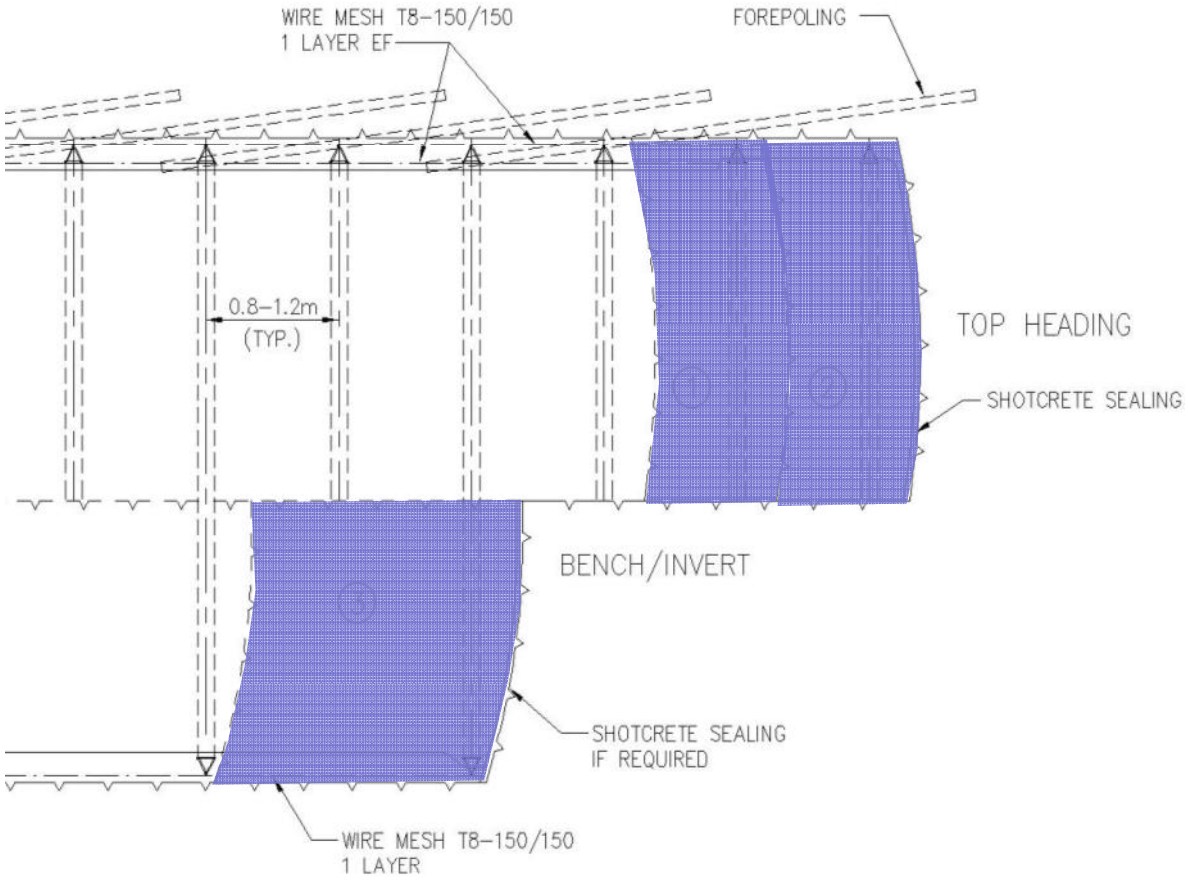


Cyclic Activities in Tunnelling

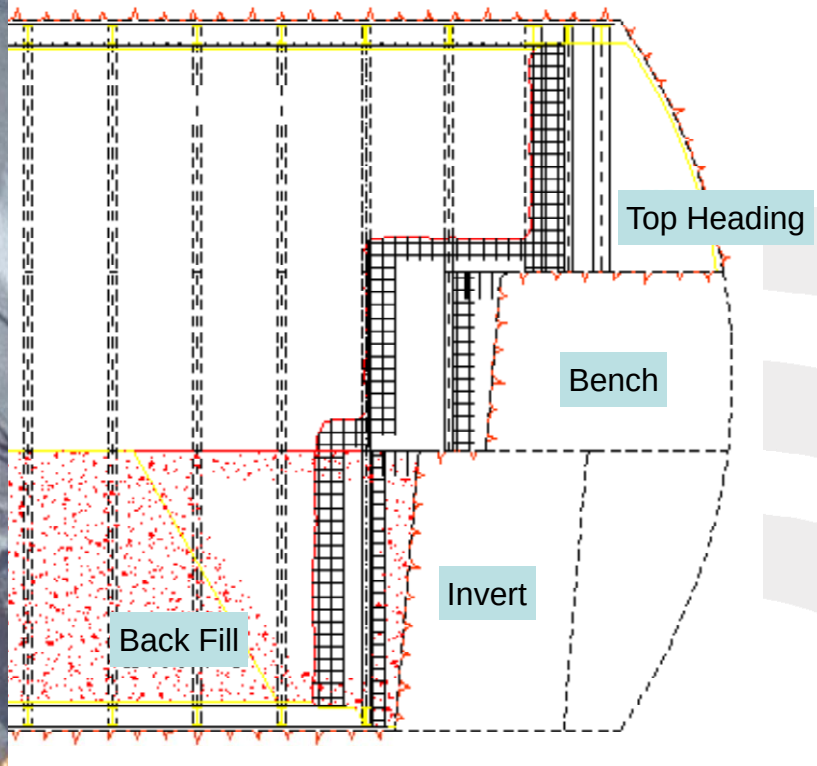
- Activities (excavation, loading, mucking, support installation) are performed in sequence with specific equipment
- Typical work cycles correspond to defined excavation steps and support systems
- Collapses happen during temporary stages



Typical Sequencing

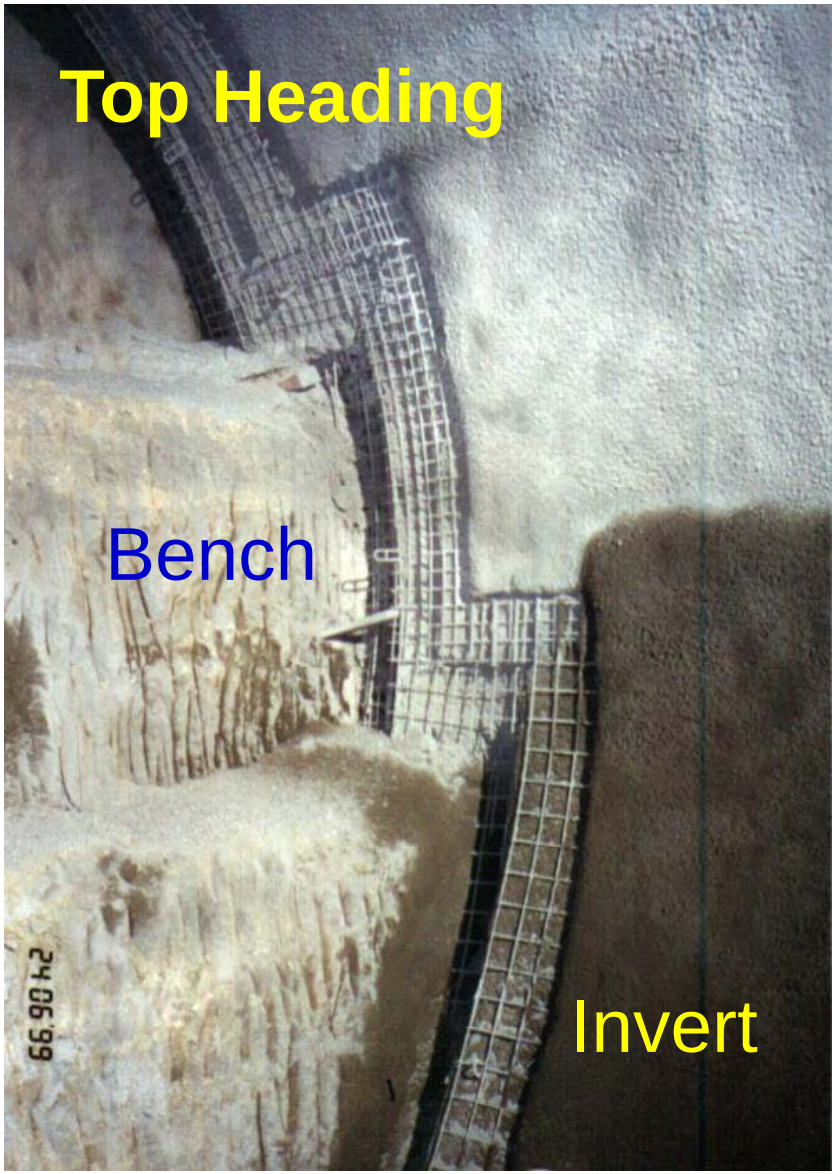


Sequencing – C705 DTSS Advance Tunnel



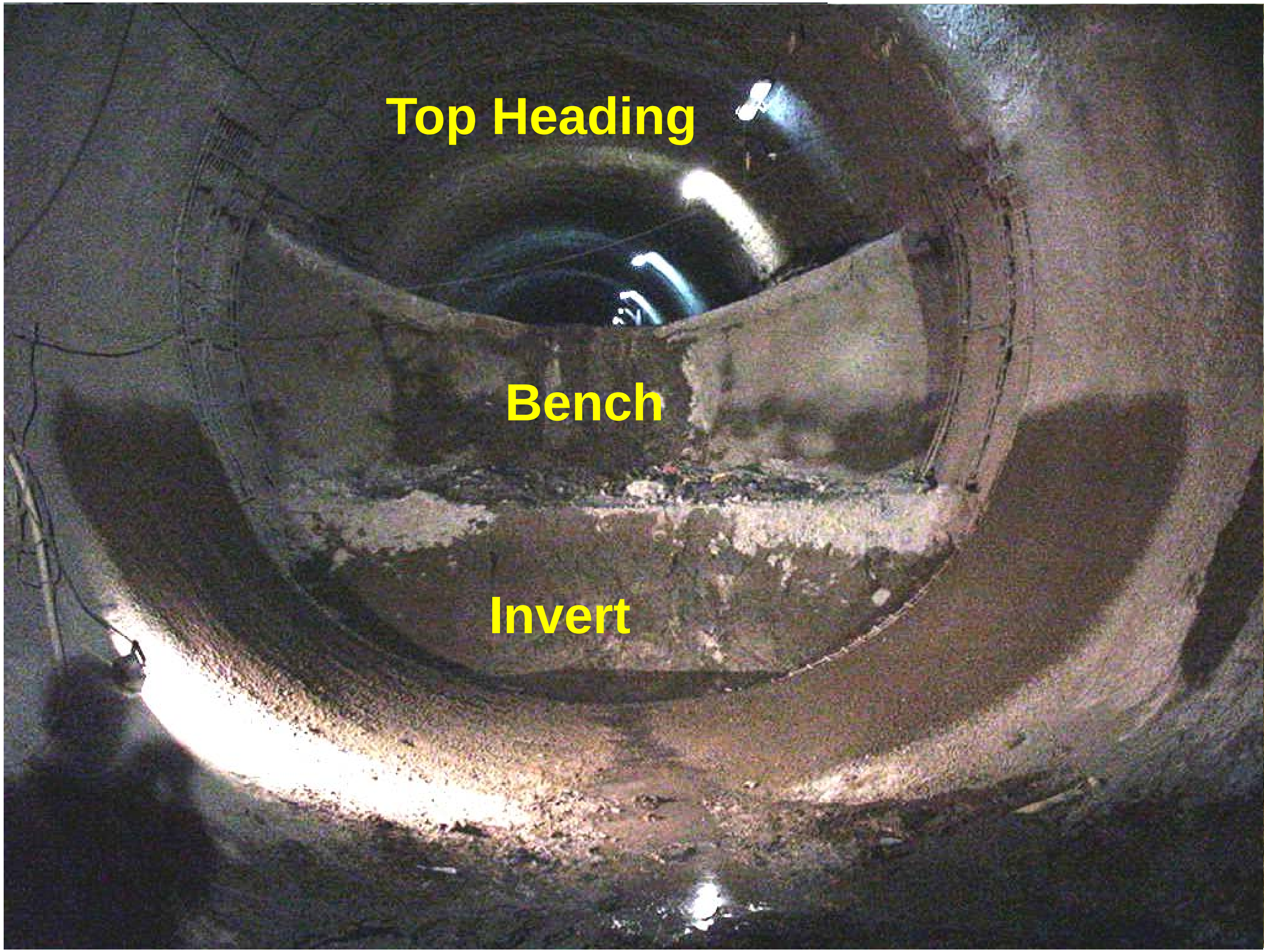
- Staged Excavation
- Lattice girder, full round
- Shotcrete & wire mesh

Detailing – C705 DTSS Advance Tunnel



Sequencing - CCL1 C825 Overrun Tunnels

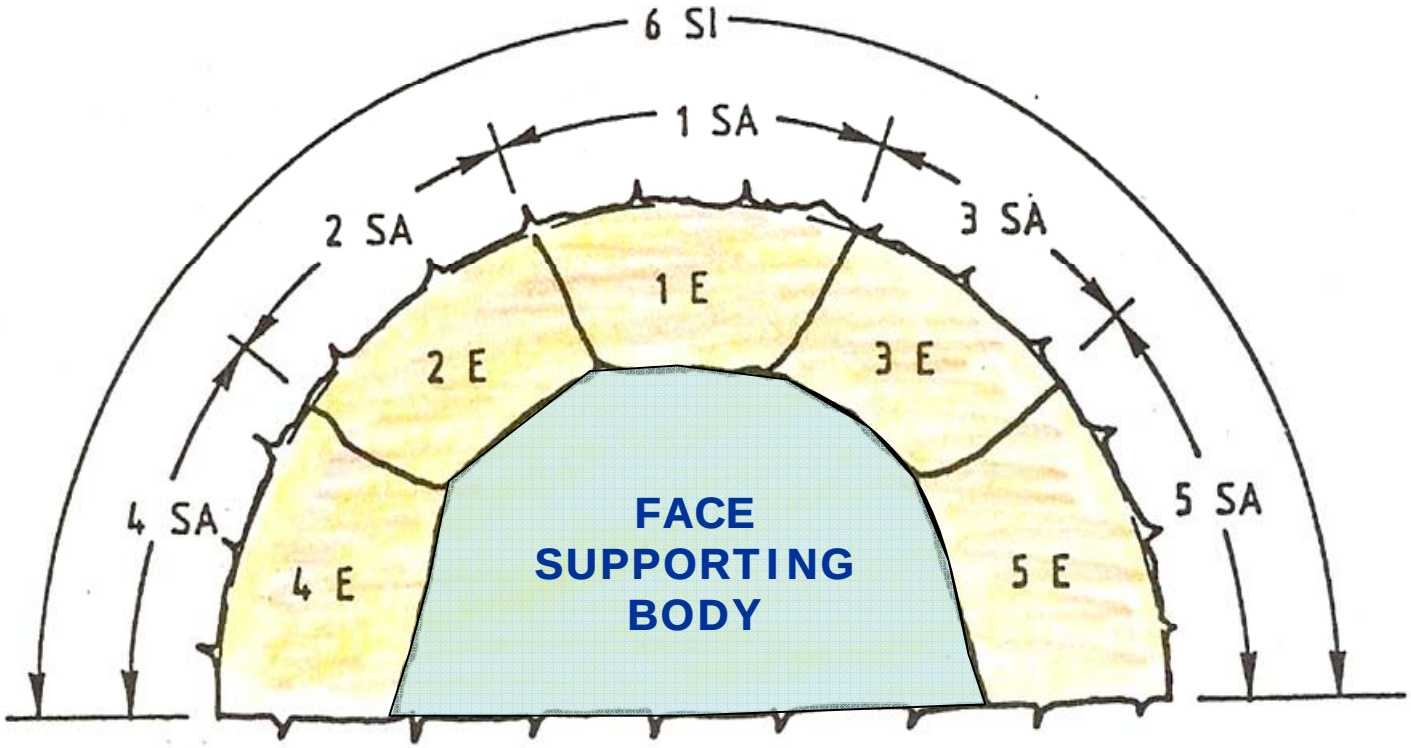
Sequencing - DTSS/T03 TBM Launching Chamber



Sequencing – DTL1 C905

Sequencing

Excavation Sequencing within the Face



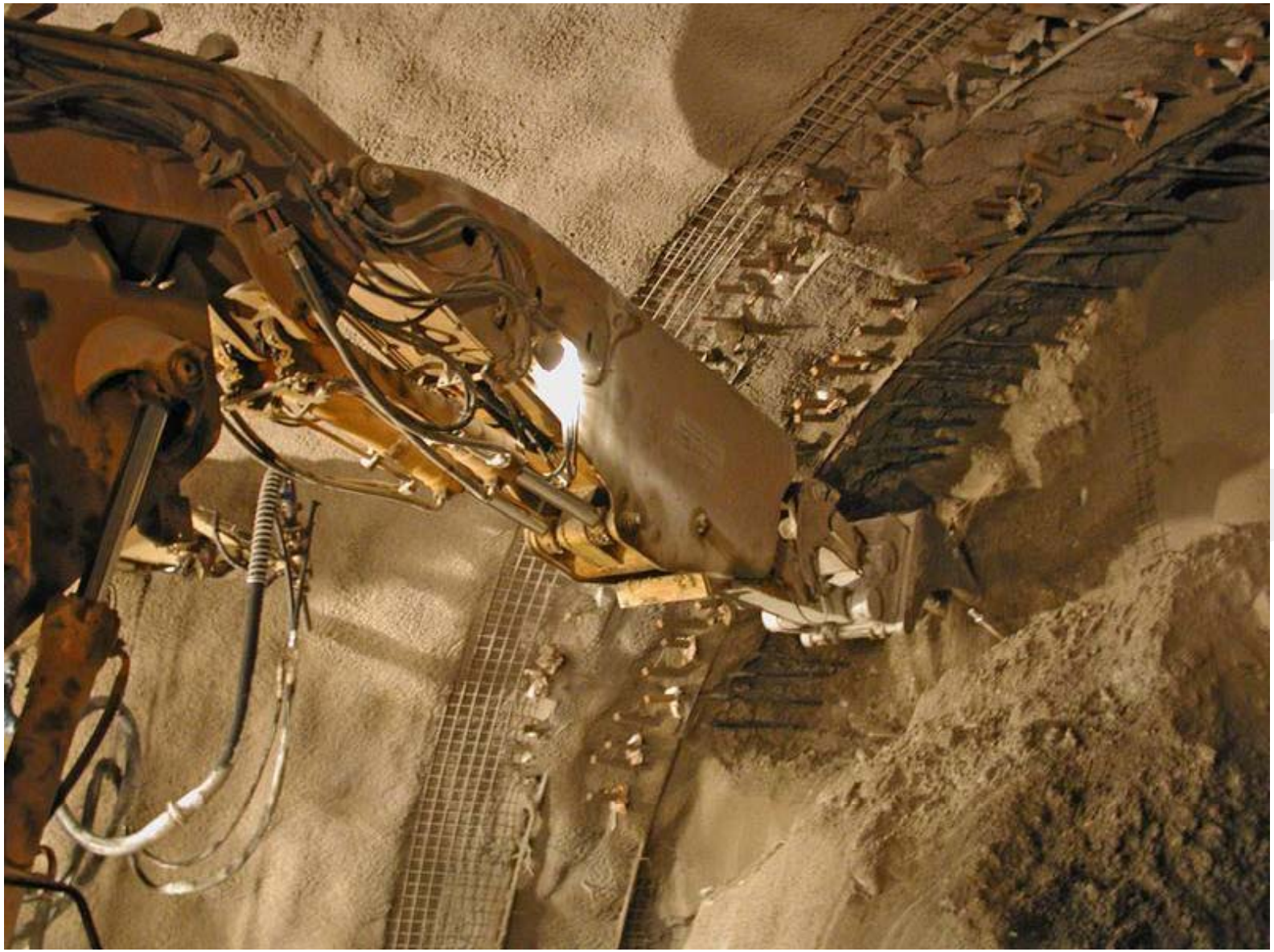
» **Increase immediate Support by reduction of excavation area**

Excavation Sequencing within the Face

Excavation Sequencing – C704 CP3

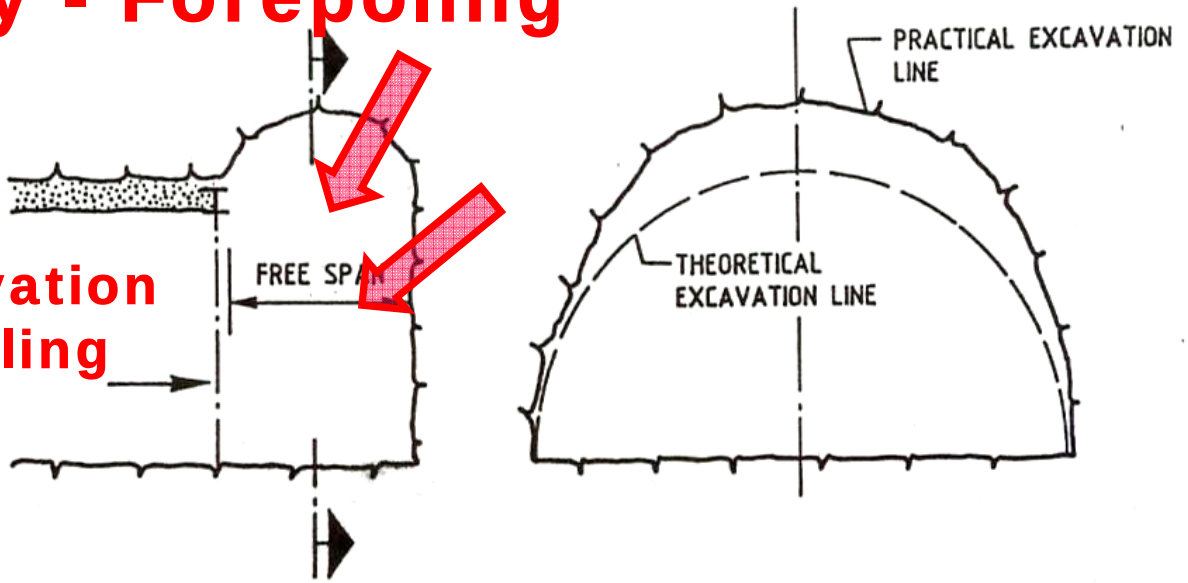
Special Equipment – Tunnel Excavator

Special Equipment – Tunnel Excavator



Face Stability - Forepoling

Shape of excavation *without* forepoling

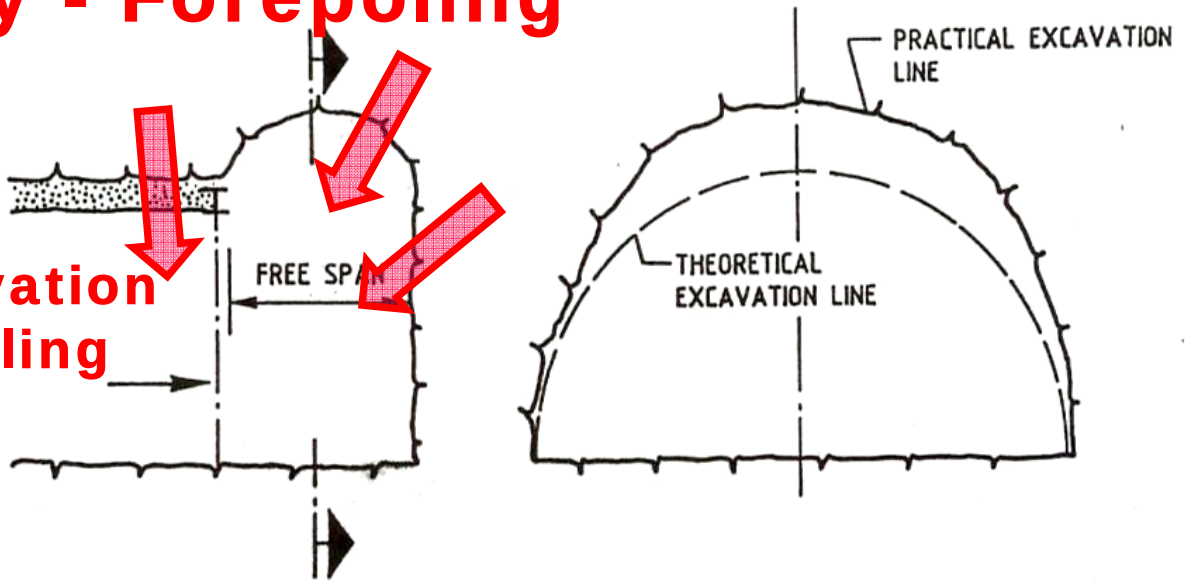


Forepoling

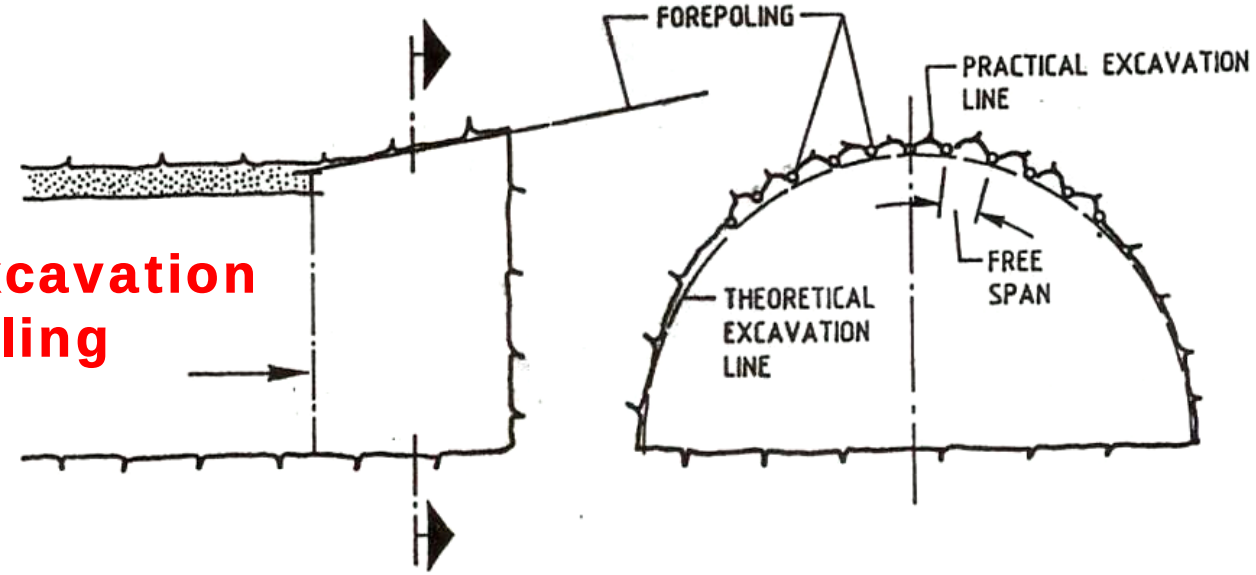
- Advance support ahead of excavation face
- Provides support for the free span = unsupported excavation surface = indirect face support
- Needs support element on its own (soil and lattice girder)
- Effective only for initial support
- Normally no permanent function at all

Face Stability - Forepoling

Shape of excavation *without* forepoling



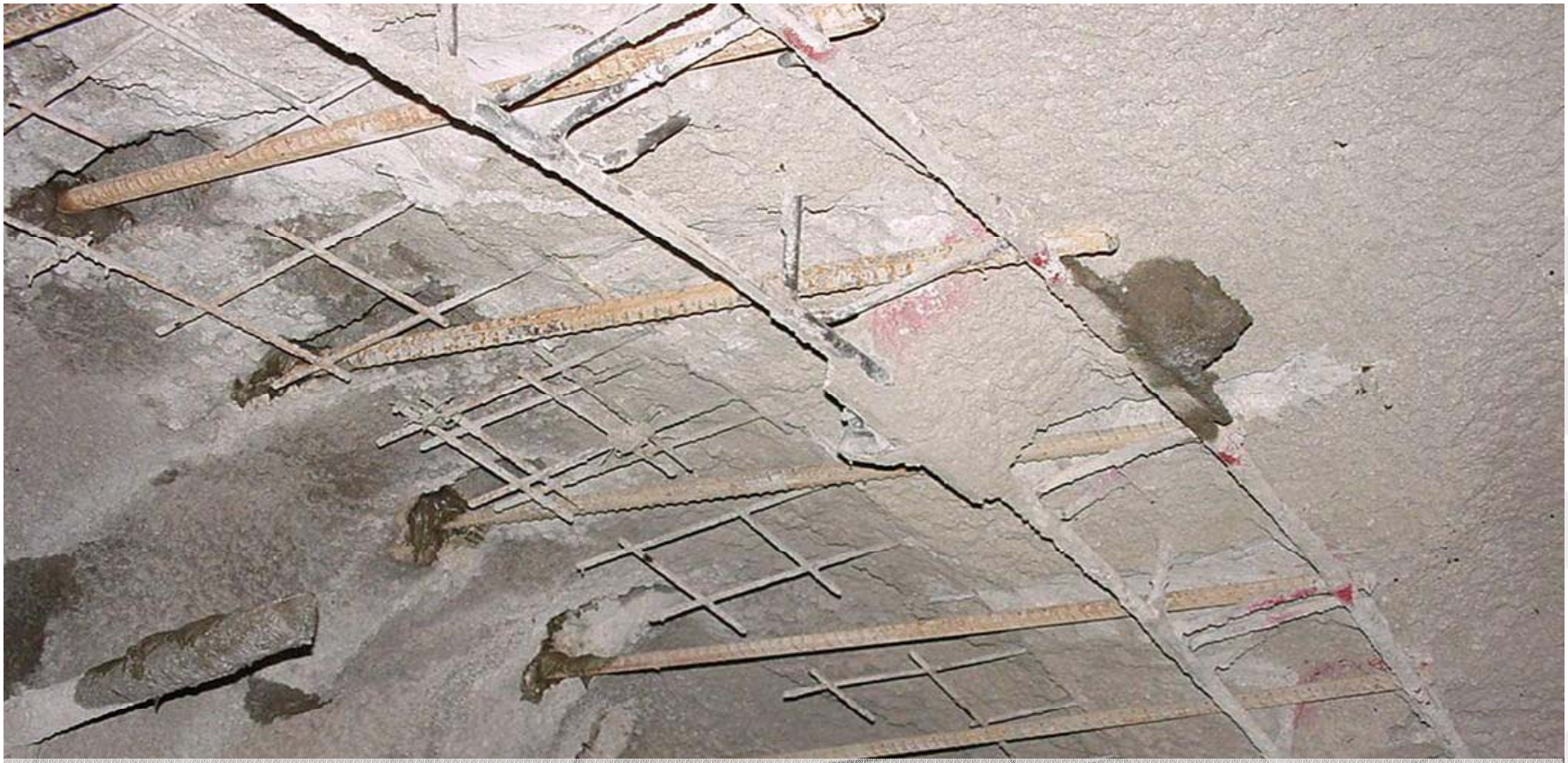
Shape of excavation with forepoling



Forepoling

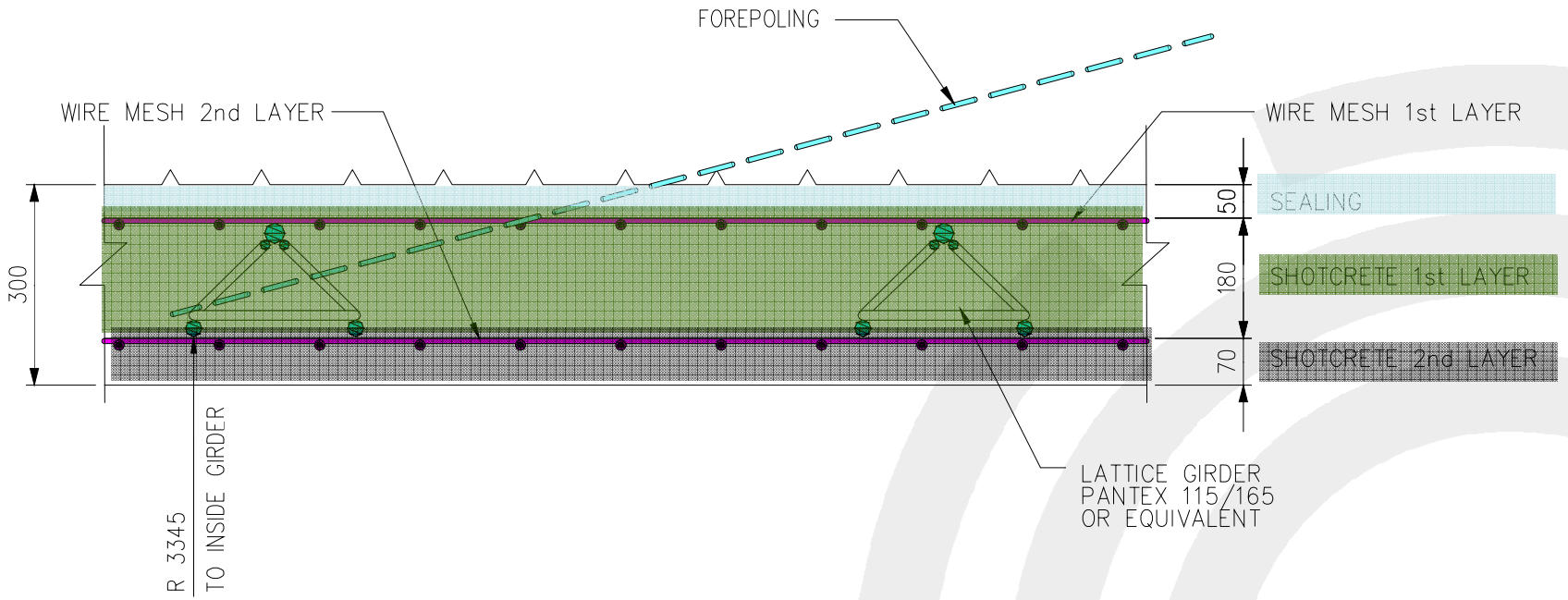
- Forepoling needs support element on its own (otherwise cantilever action)
- One end in soil (adequate rebar length)
- Other end rests on lattice girder (connect rebar to girder)
- Adequate spacing is an important parameter

Face Stability – DTL 1 C905



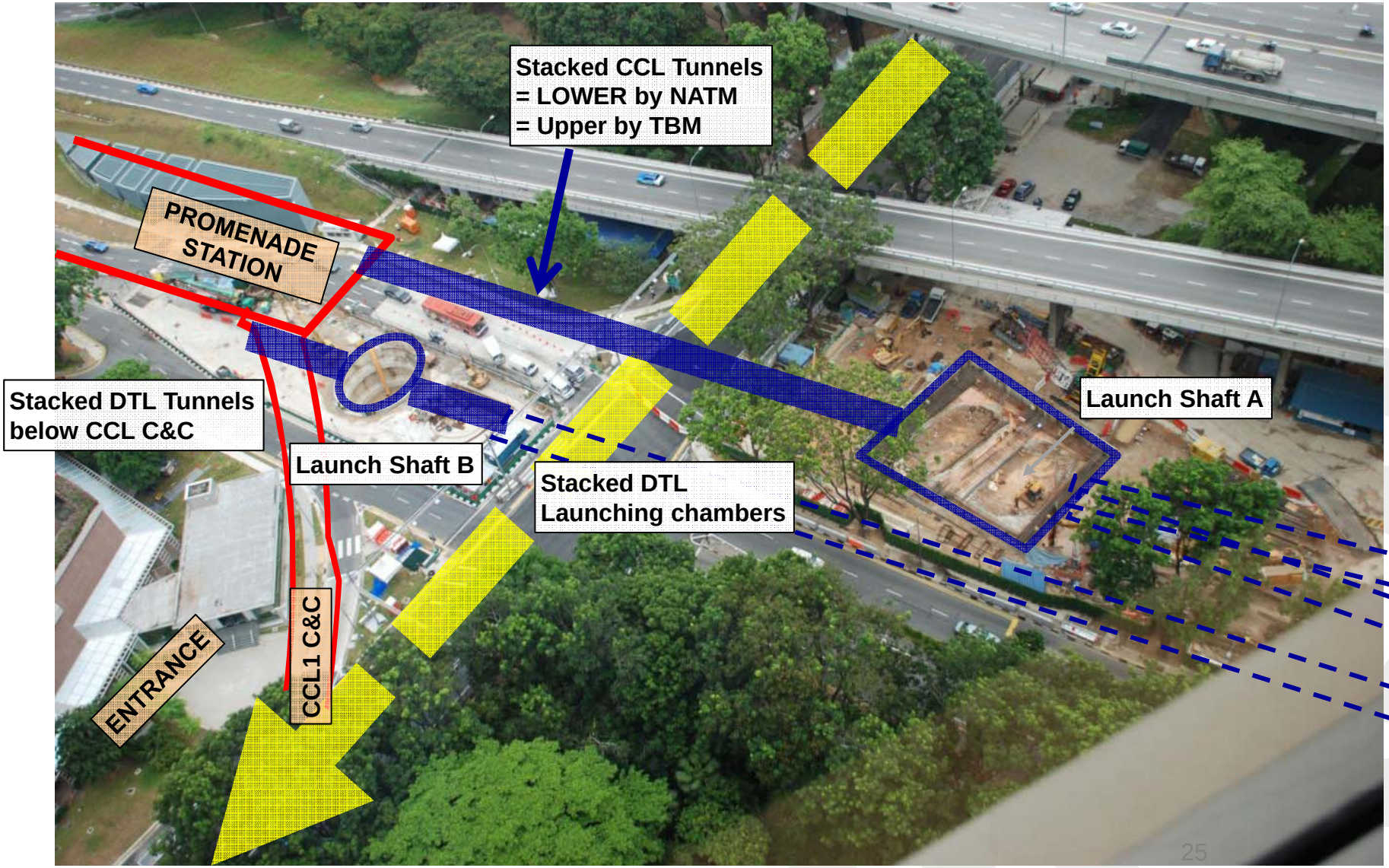
Advance support ahead of excavation face
Provide support for exposed round
Needs support (soil and lattice girder)

Face Stability – DTL 1 C905

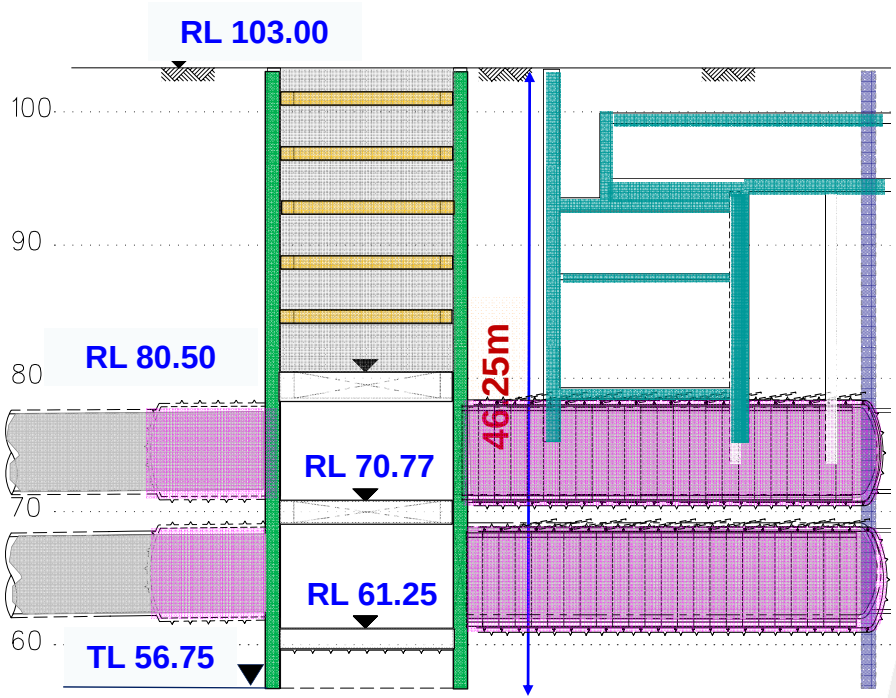


Forepoling

DTL 1 C905


Stacked CCL Tunnels
= LOWER by NATM
= Upper by TBM
PROMENADE STATION
Stacked DTL Tunnels
below CCL C&C
Launch Shaft B
Stacked DTL
Launching chambers
Launch Shaft A
ENTRANCE
CCL1 C&C

DTL 1 C905 – Underpassing CCL C&C

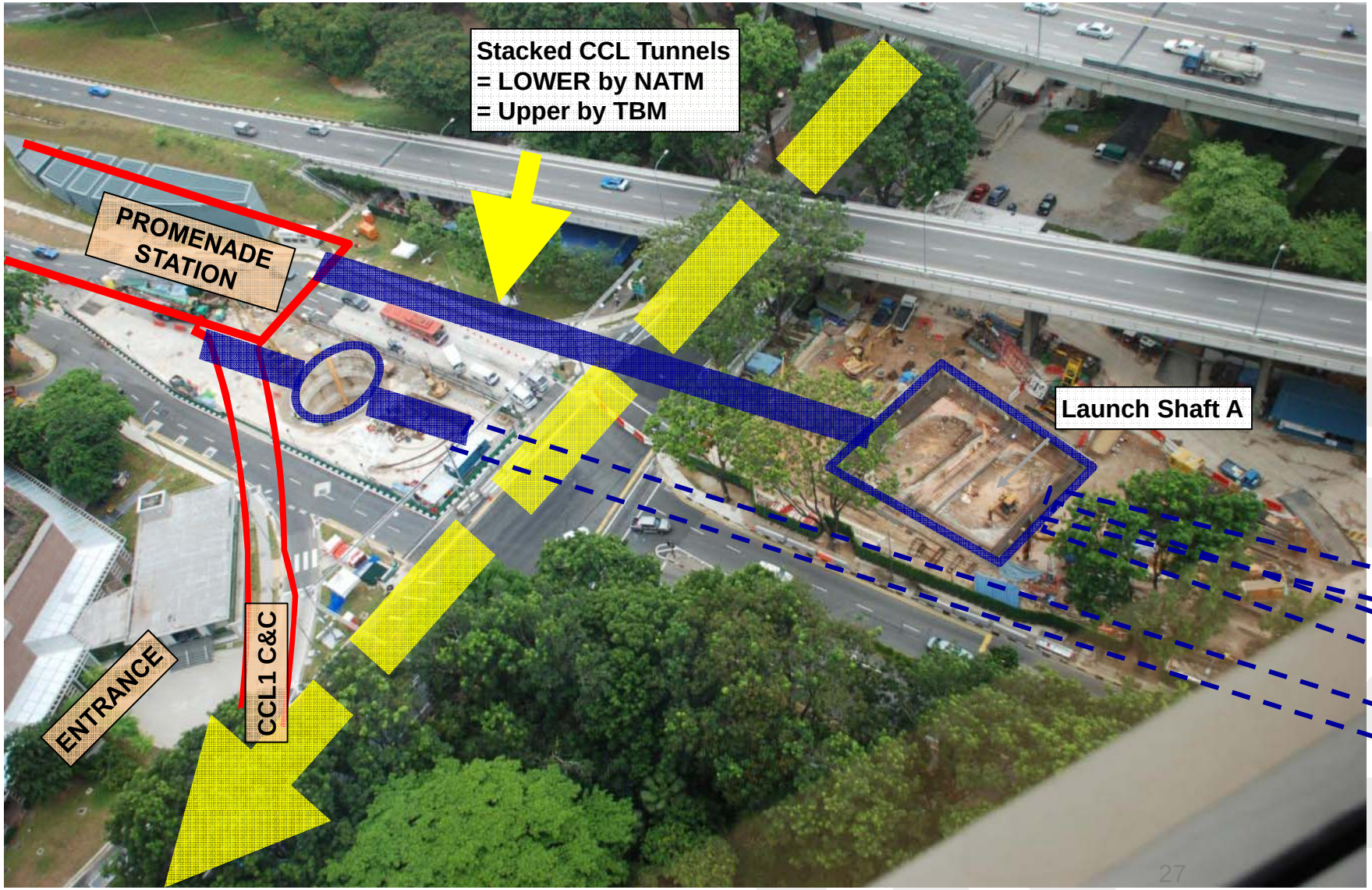


Reclamation

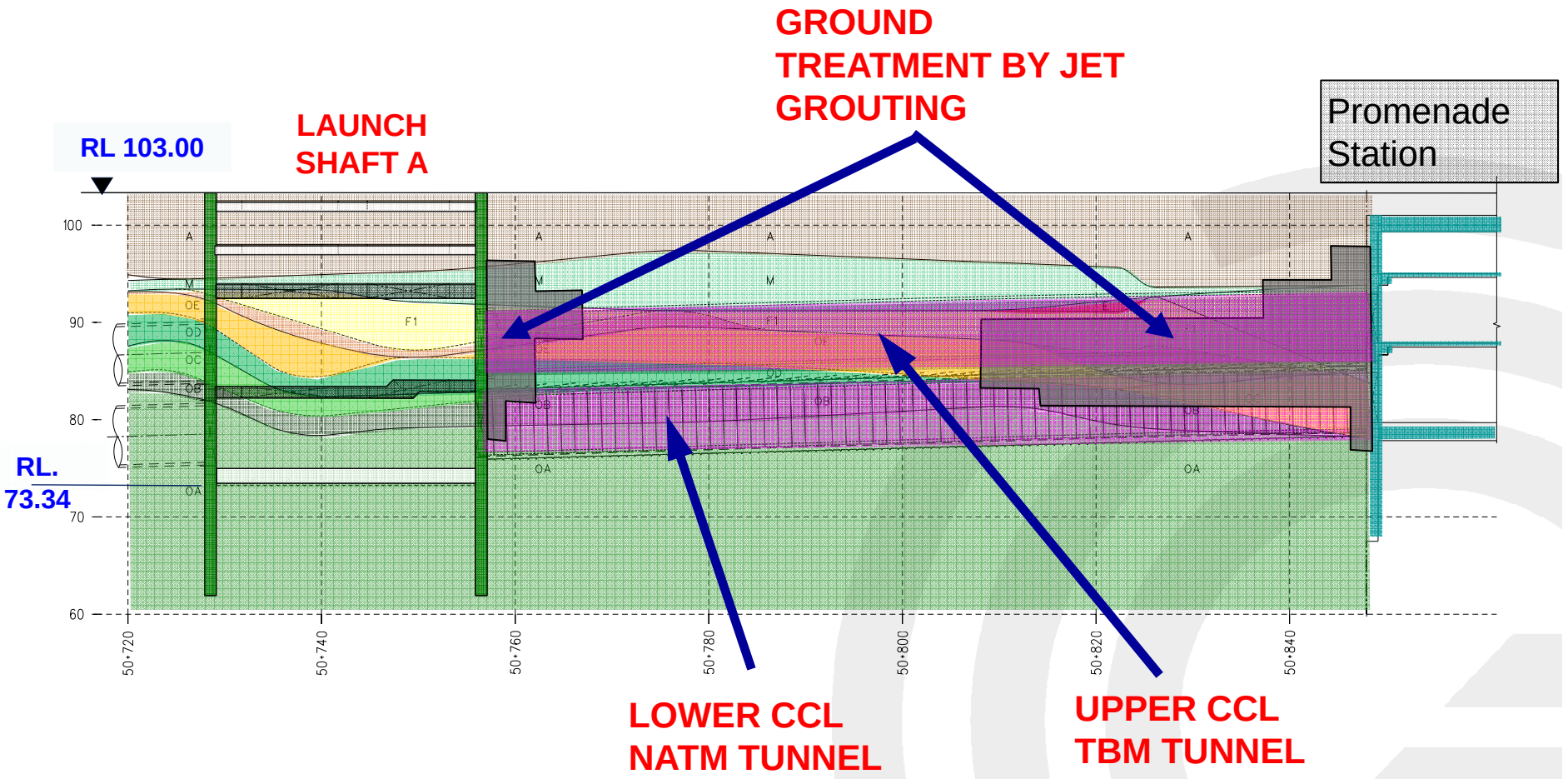
Kallang Formation

Old Alluvium

DTL 1 C905


Stacked CCL Tunnels
= LOWER by NATM
= Upper by TBM
PROMENADE STATION
Launch Shaft A
ENTRANCE
CCL1 C&C

DTL 1 C905 – NATM with ground treatment



Face Stability – DTL 1 C905

Pipe Roof – Heavy Forepoliong

- Support free span (unsupported length) at the face
- Pipe roofs are longer and heavier than forepoling and of larger size
- Typically applied in difficult ground and/or for tunnelling with low overburden

Pipe Roof

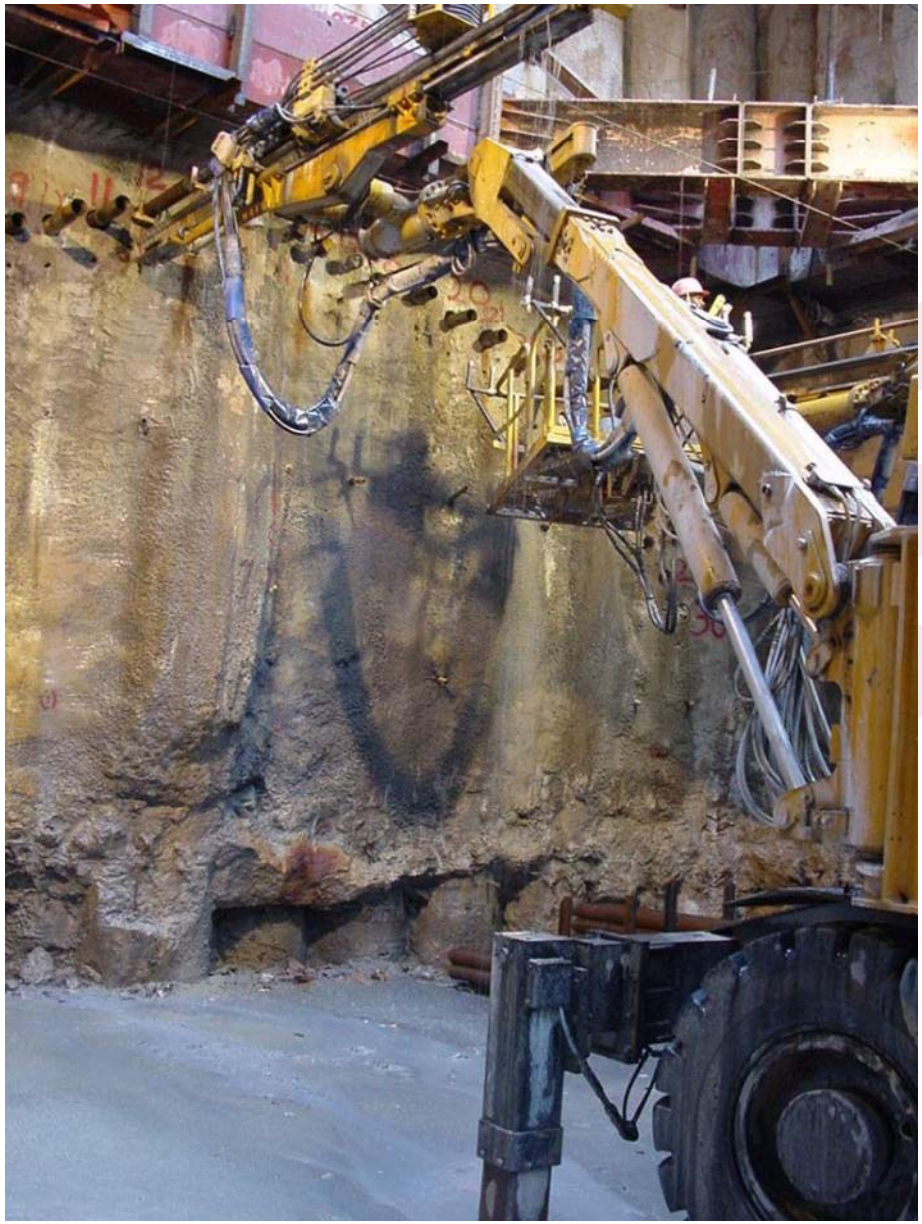
Pipe Roof – NEL C704 TBM Launching

Pipe Roof – CCL 3 C852 Advance Tunnel

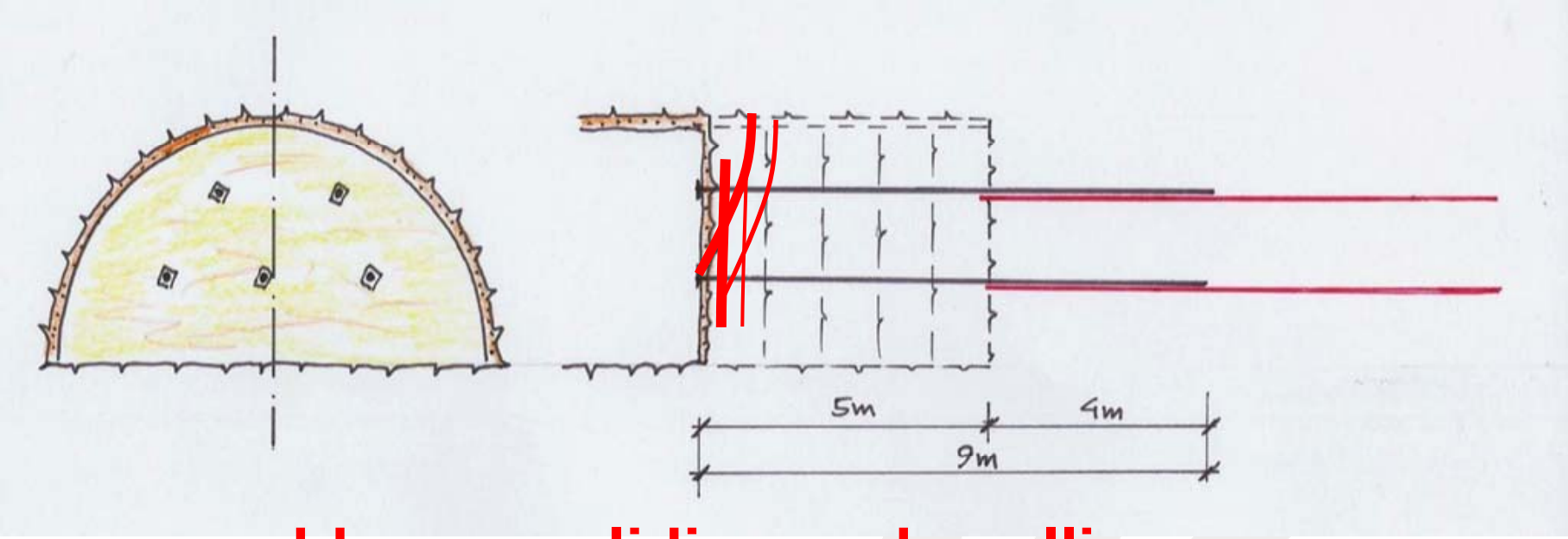
Pipe Roof – CCL 4 C855

Equipment

Drilling Jumbo



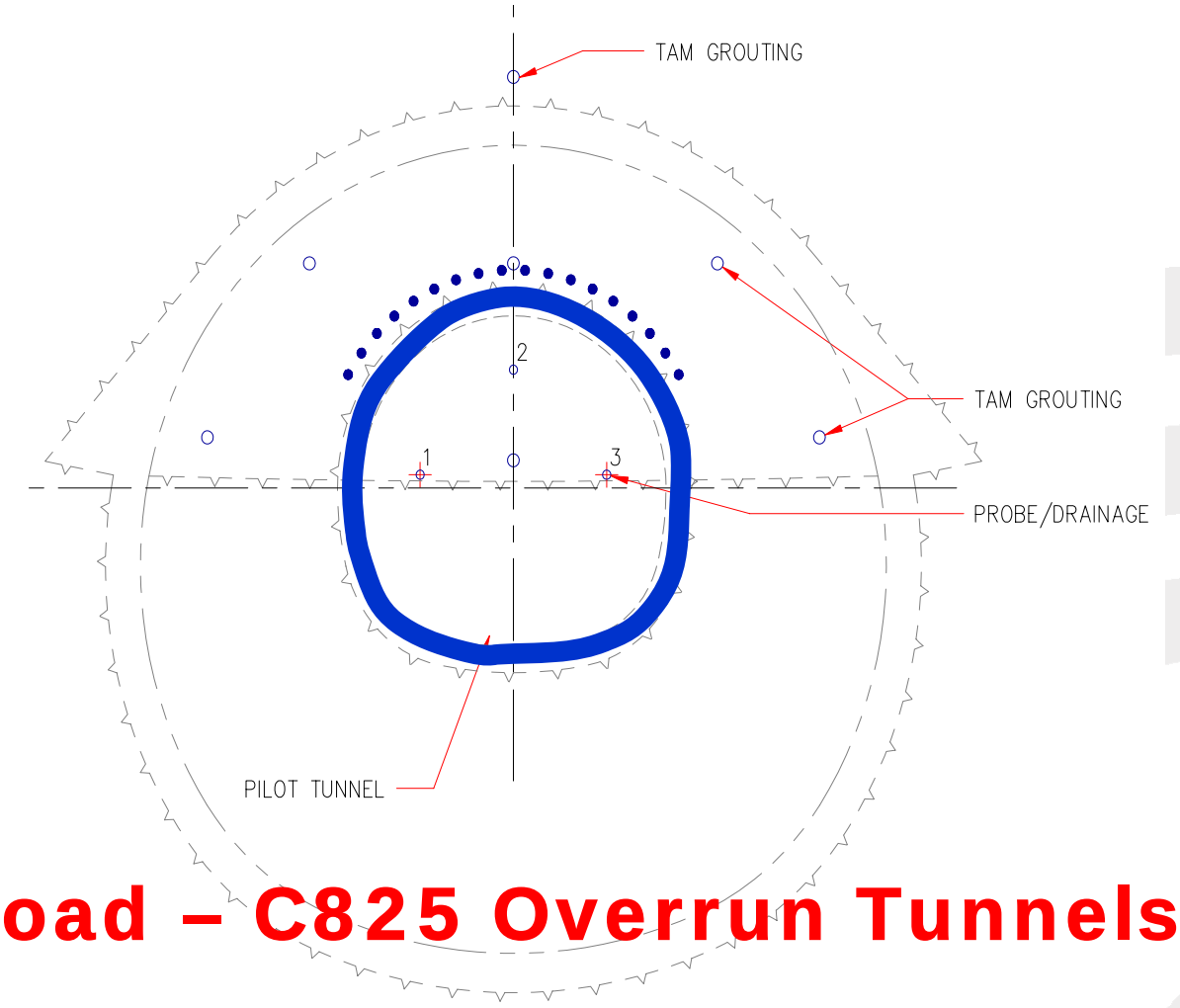
Face Support – Face Bolting



- addresses sliding and spalling
- cut back after each advance
- continuous thread

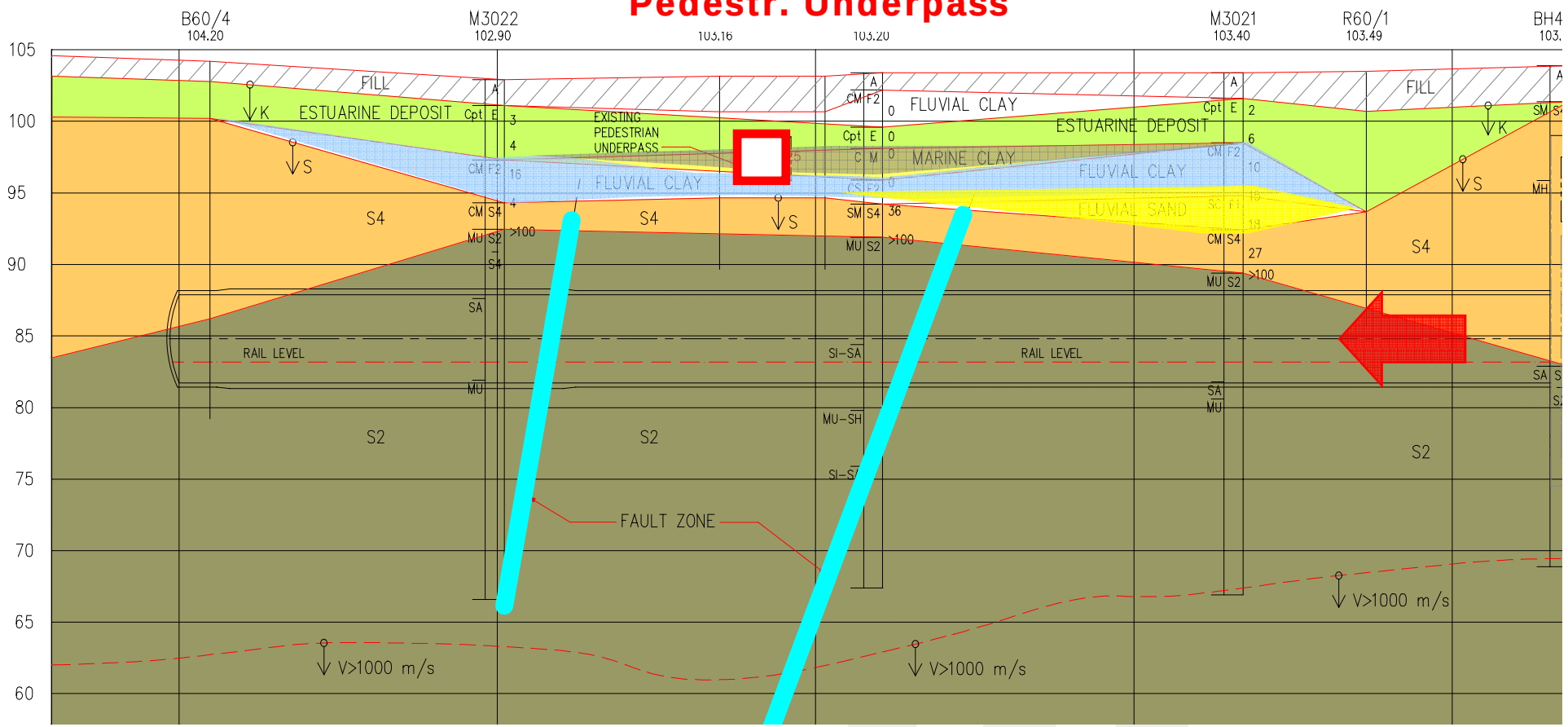
Sequencing with Face Bolting

Construction Concepts – Pilot Tunnel

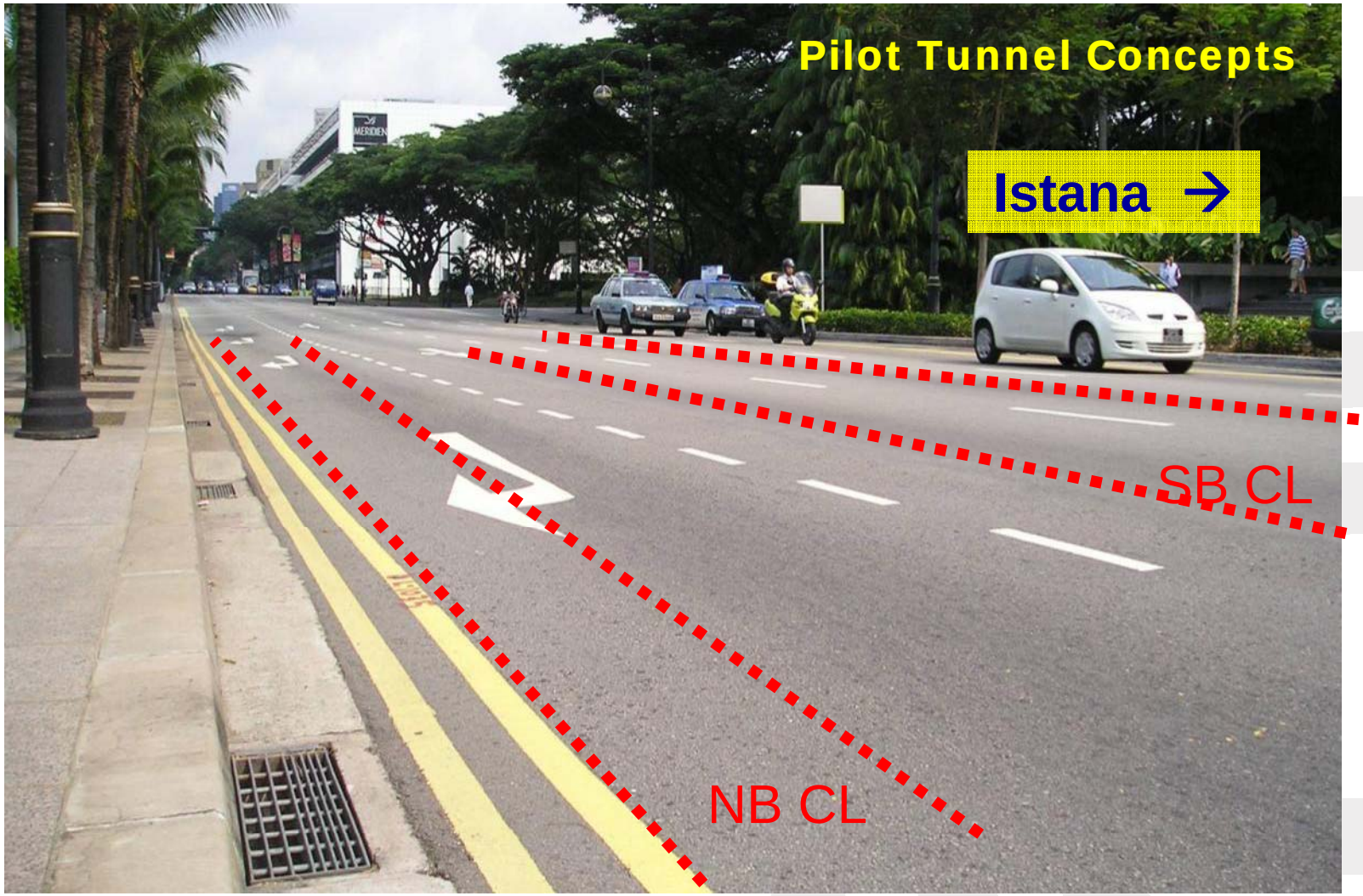


Orchard Road – C825 Overrun Tunnels

Geotechnical Longitudinal Section

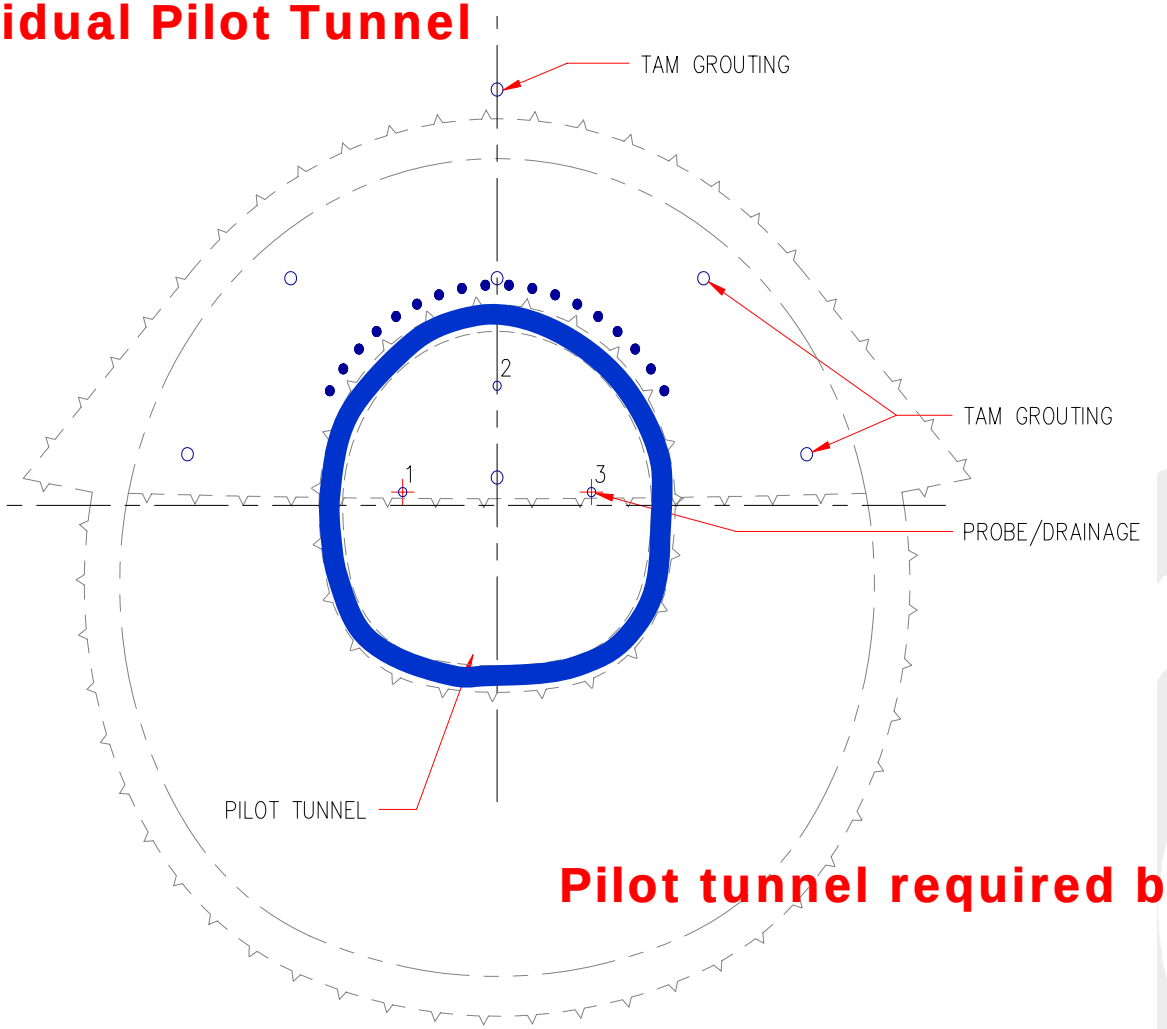


Orchard Road – C825 Overrun Tunnels



Construction Concepts – Pilot Tunnel

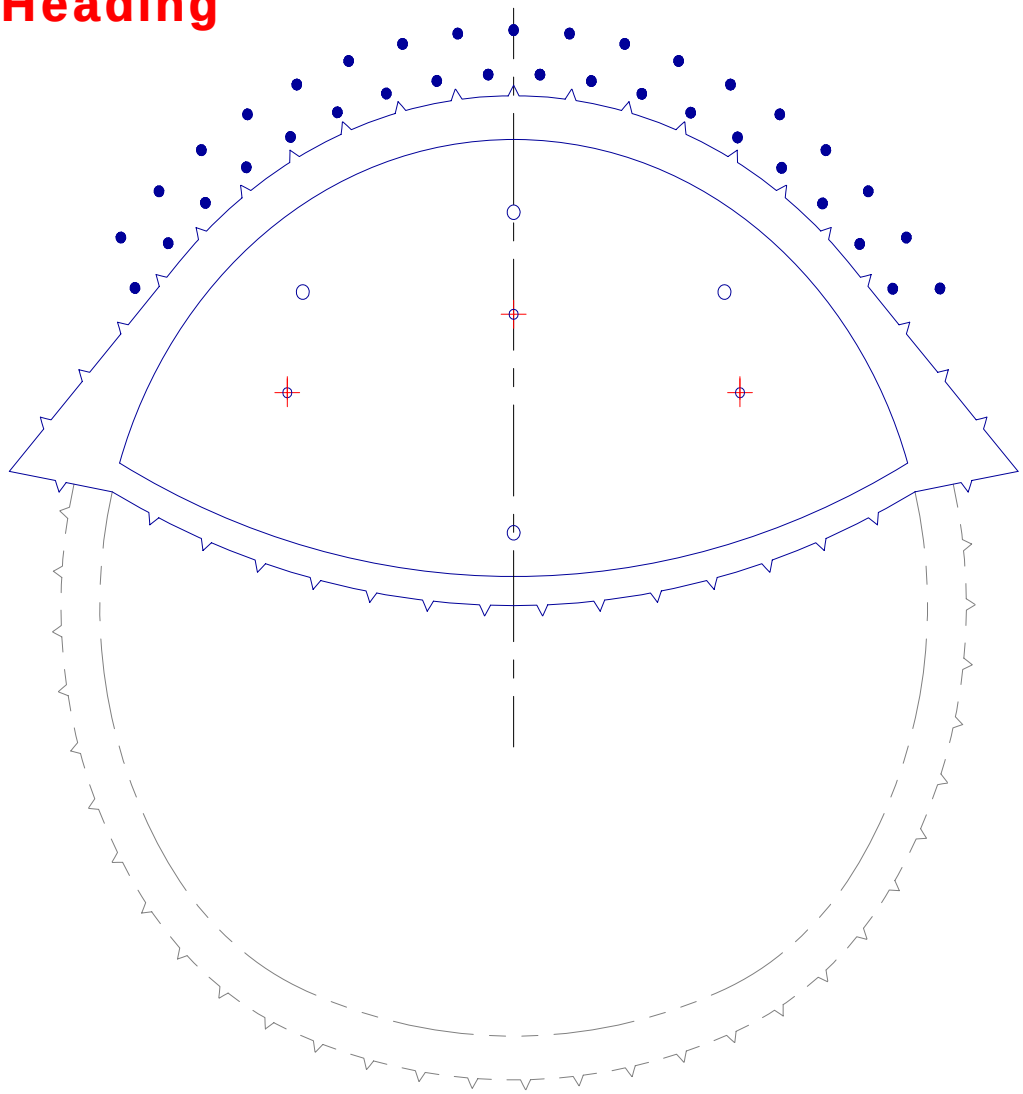
#1 Individual Pilot Tunnel



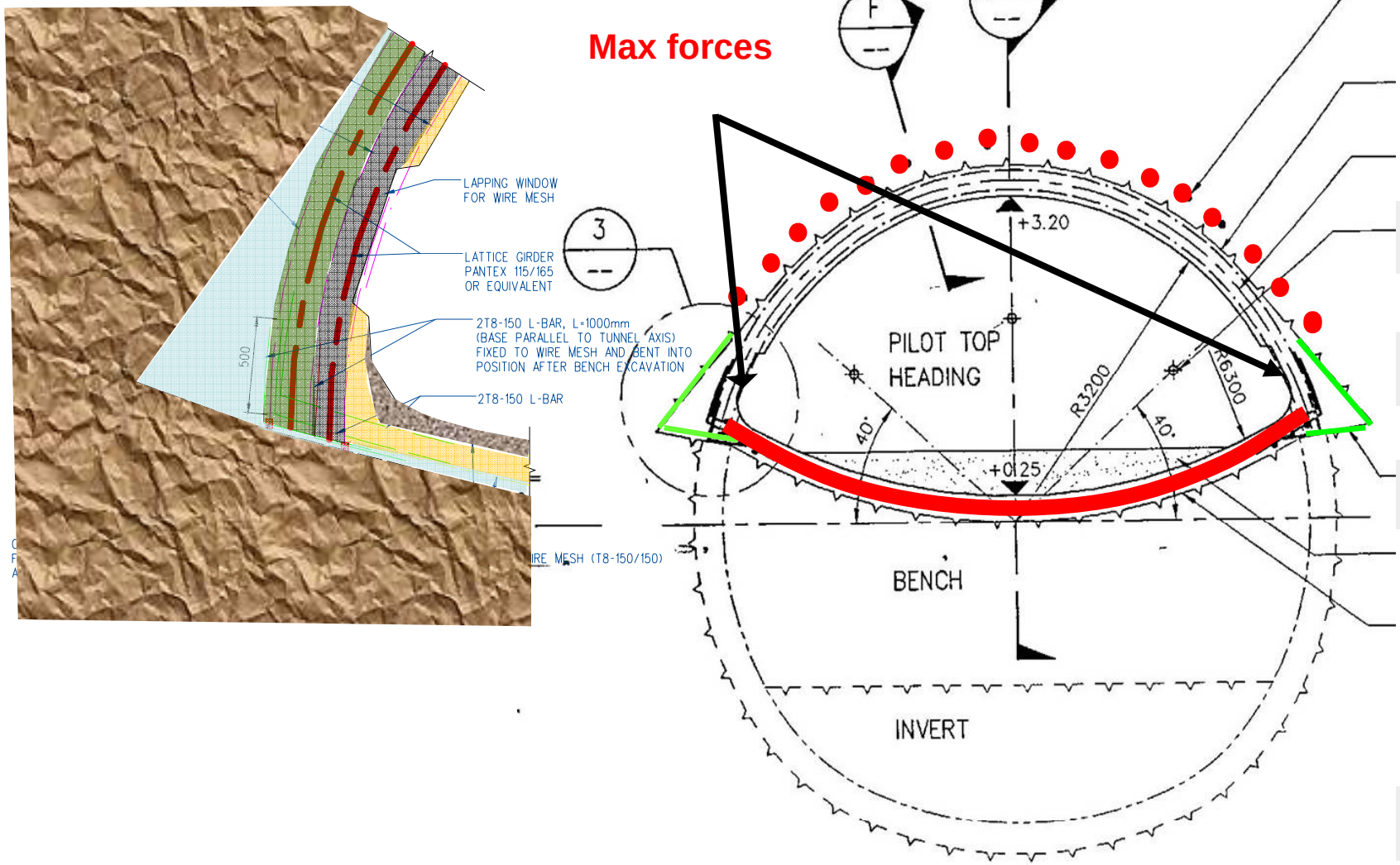
Pilot tunnel required by PS

Construction Concepts – Pilot Tunnel

#2 Pilot Heading



Pilot Heading



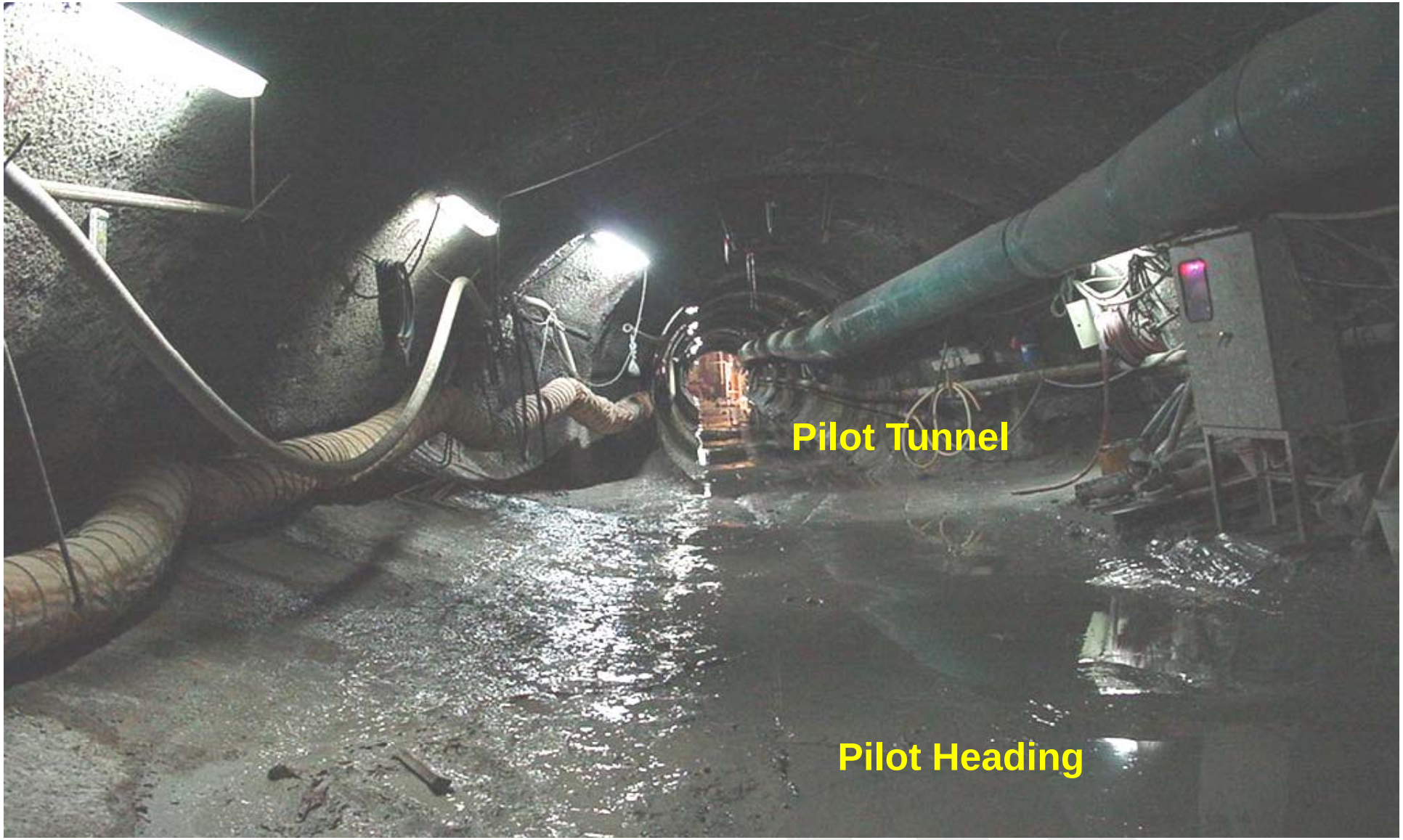
Horizontal Core Drilling Results

Pilot Tunnel – CCL C825

Pilot Tunnel – CCL C825

Breaking of Pilot Tunnel during Topheading Excavation

Pilot Tunnel – CCL C825



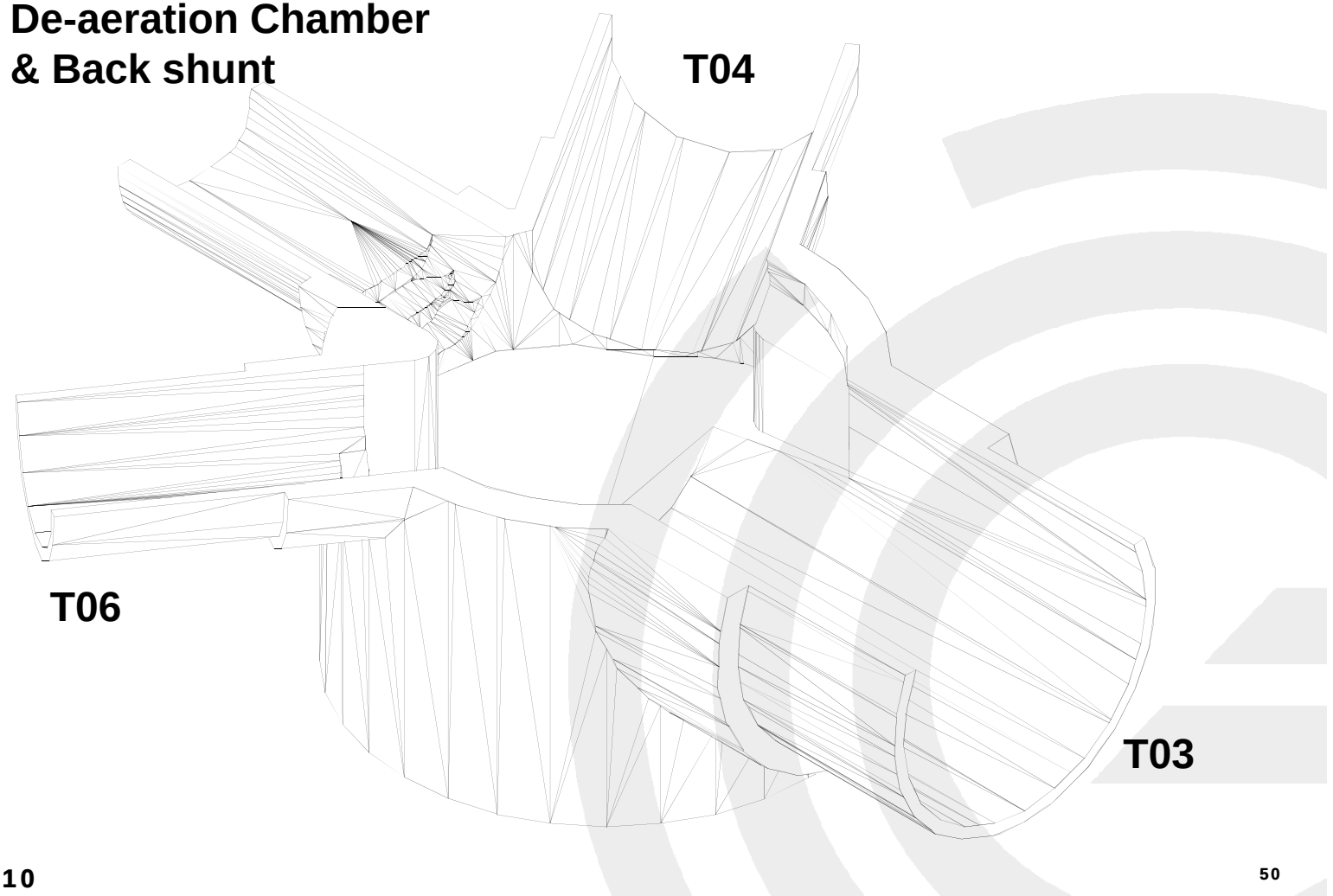
Enlargement to Final Size & Shape

Ventilation Cross Tunnel

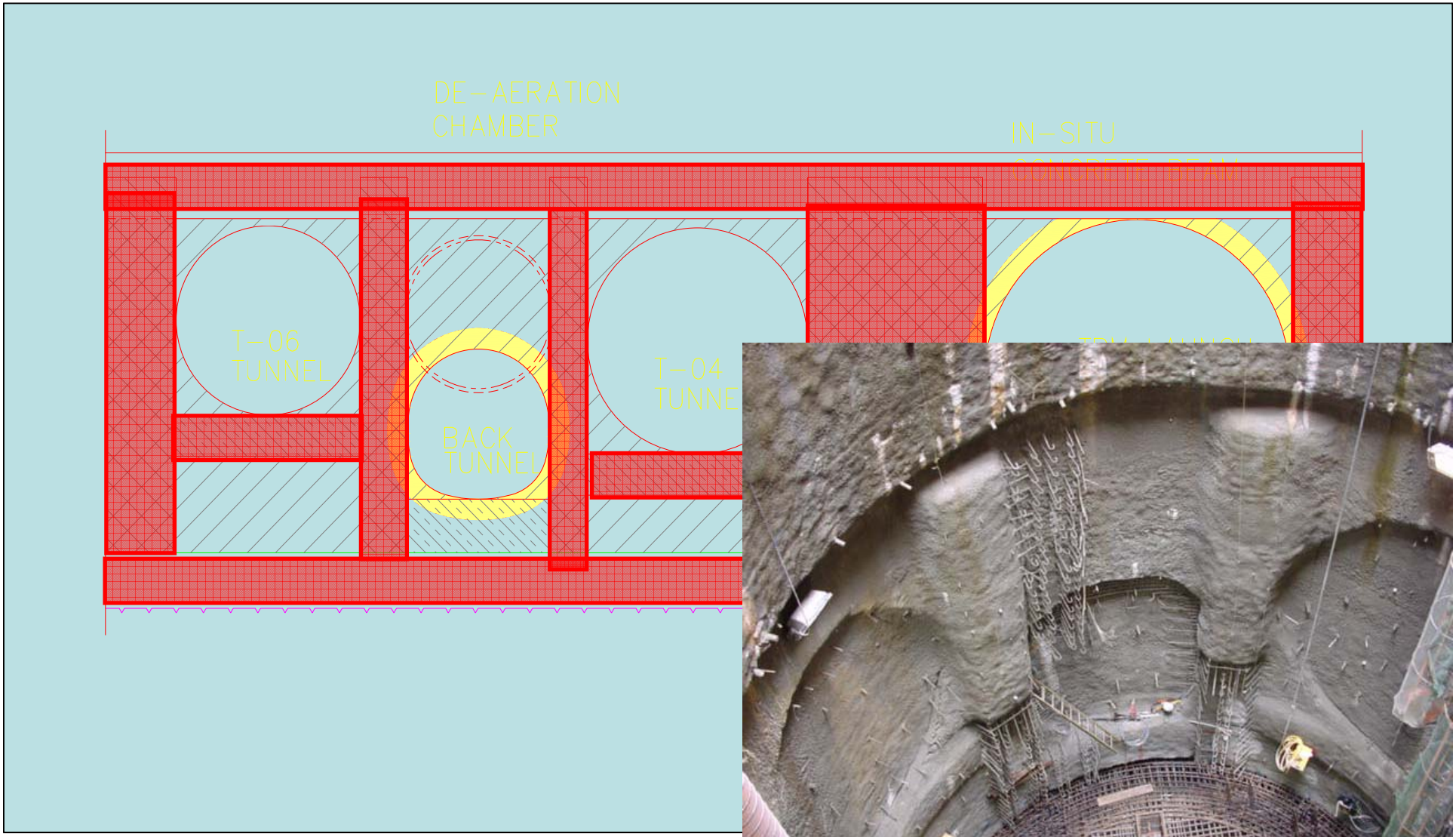
Ventilation Cross Tunnel

Special Application – DTSS, Shaft E

» 5 Tunnels intersecting the Shaft structure



Design of Shaft Lining with Tunnel Eyes



Design of Shaft Lining with Tunnel Eyes

Application – DTSS Shaft E

DTSS T06 – Shaft / Tunnel R2

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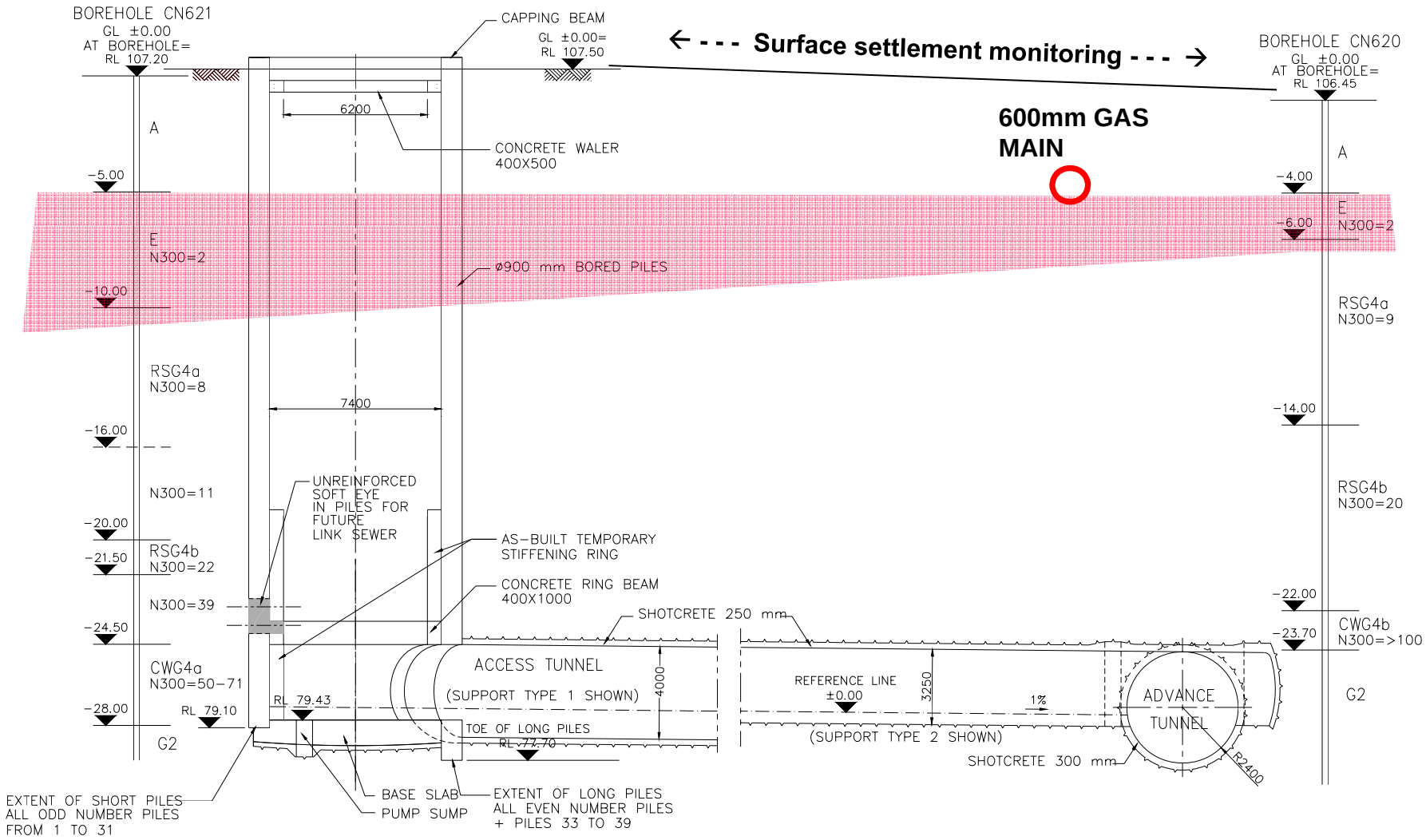
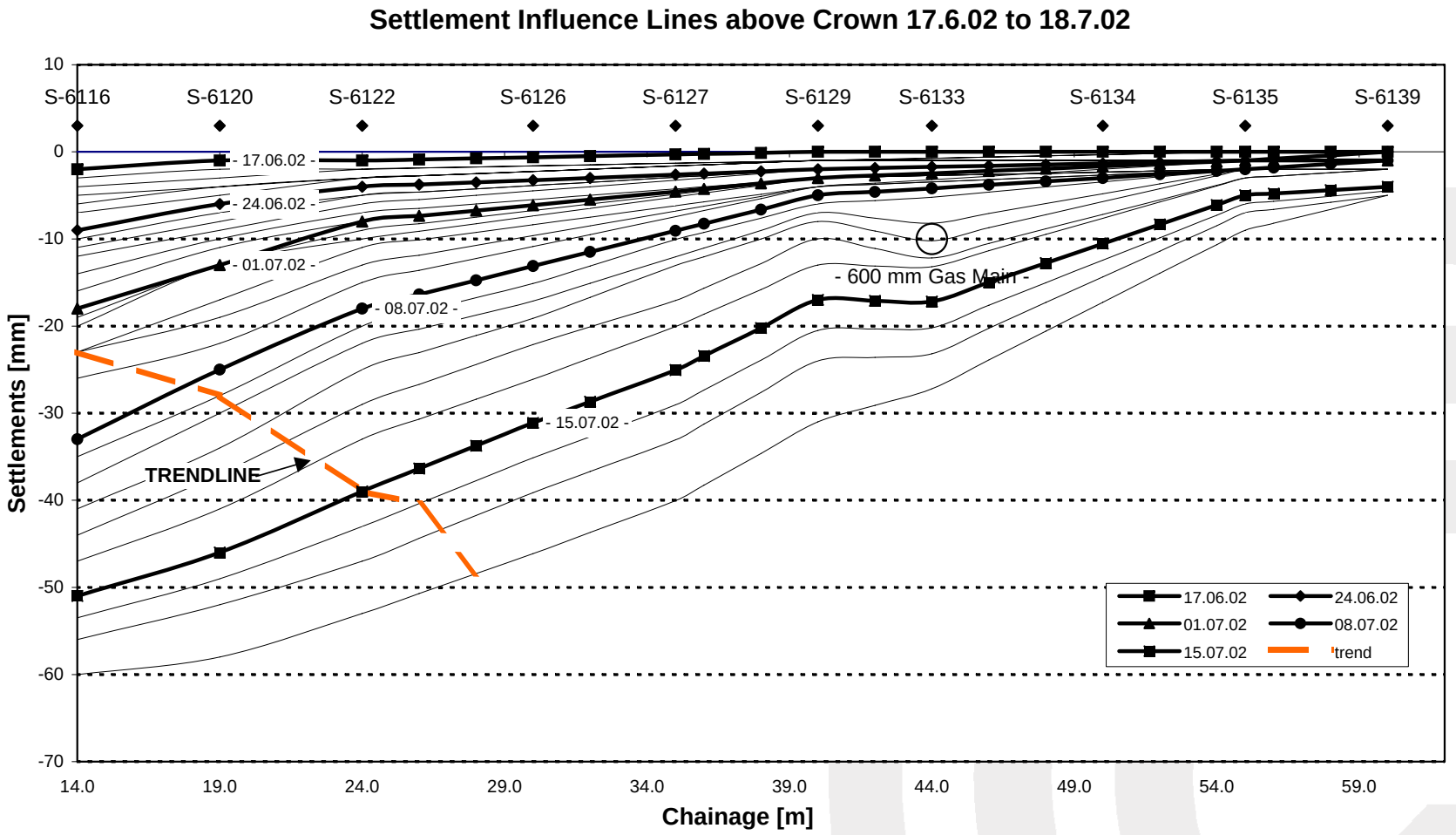


DTSS T06/R2 – Influence Lines



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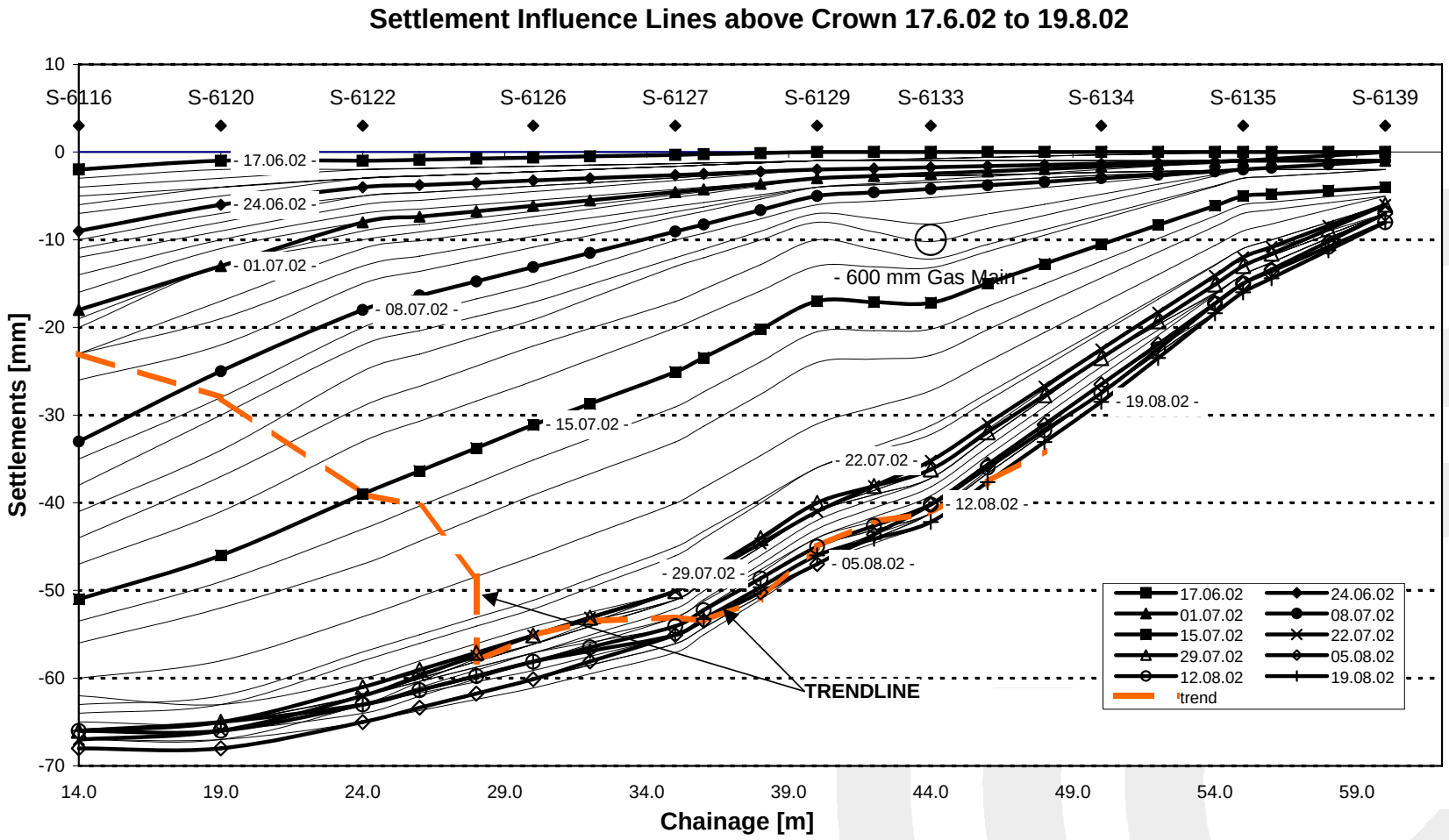

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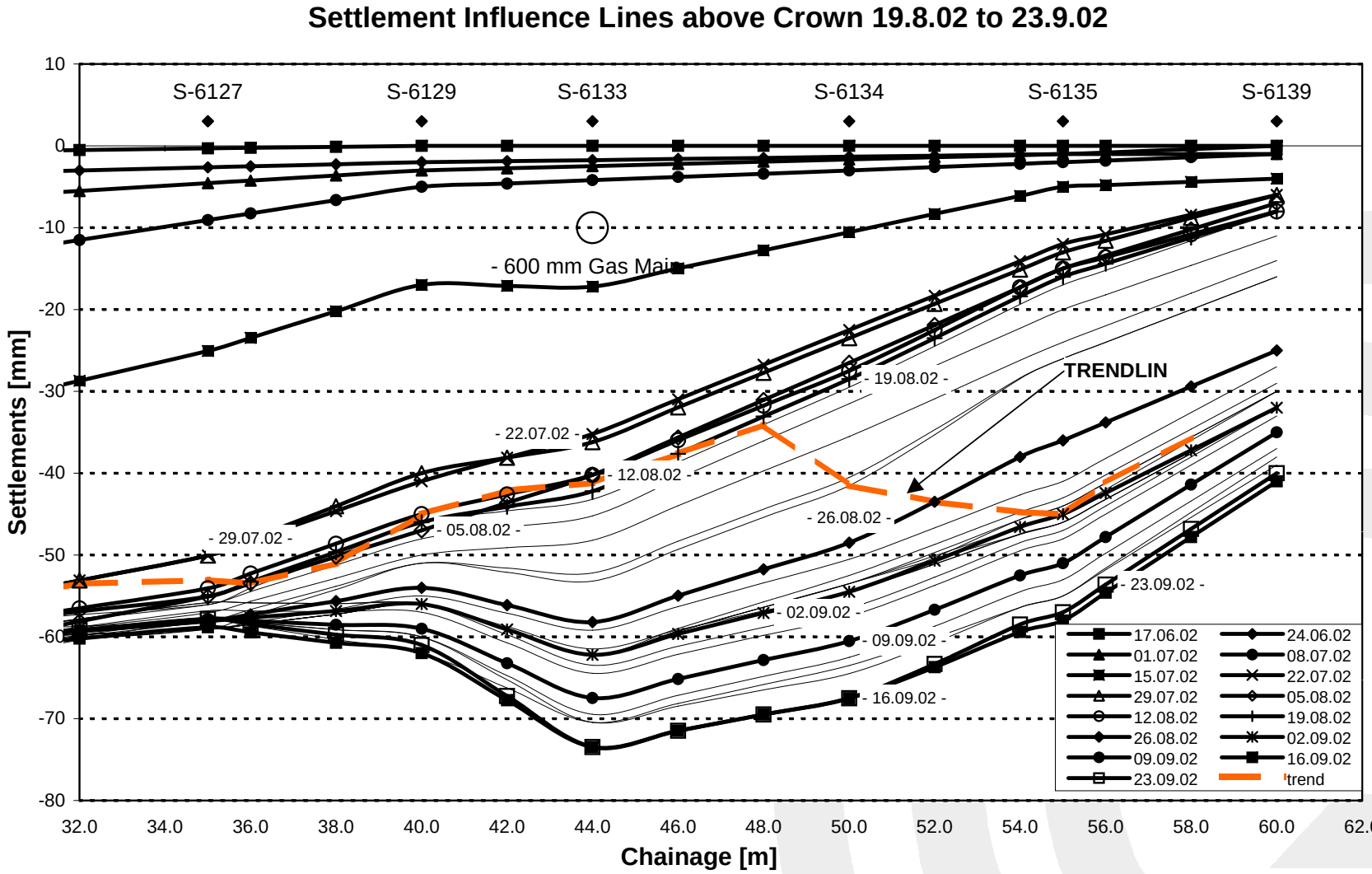
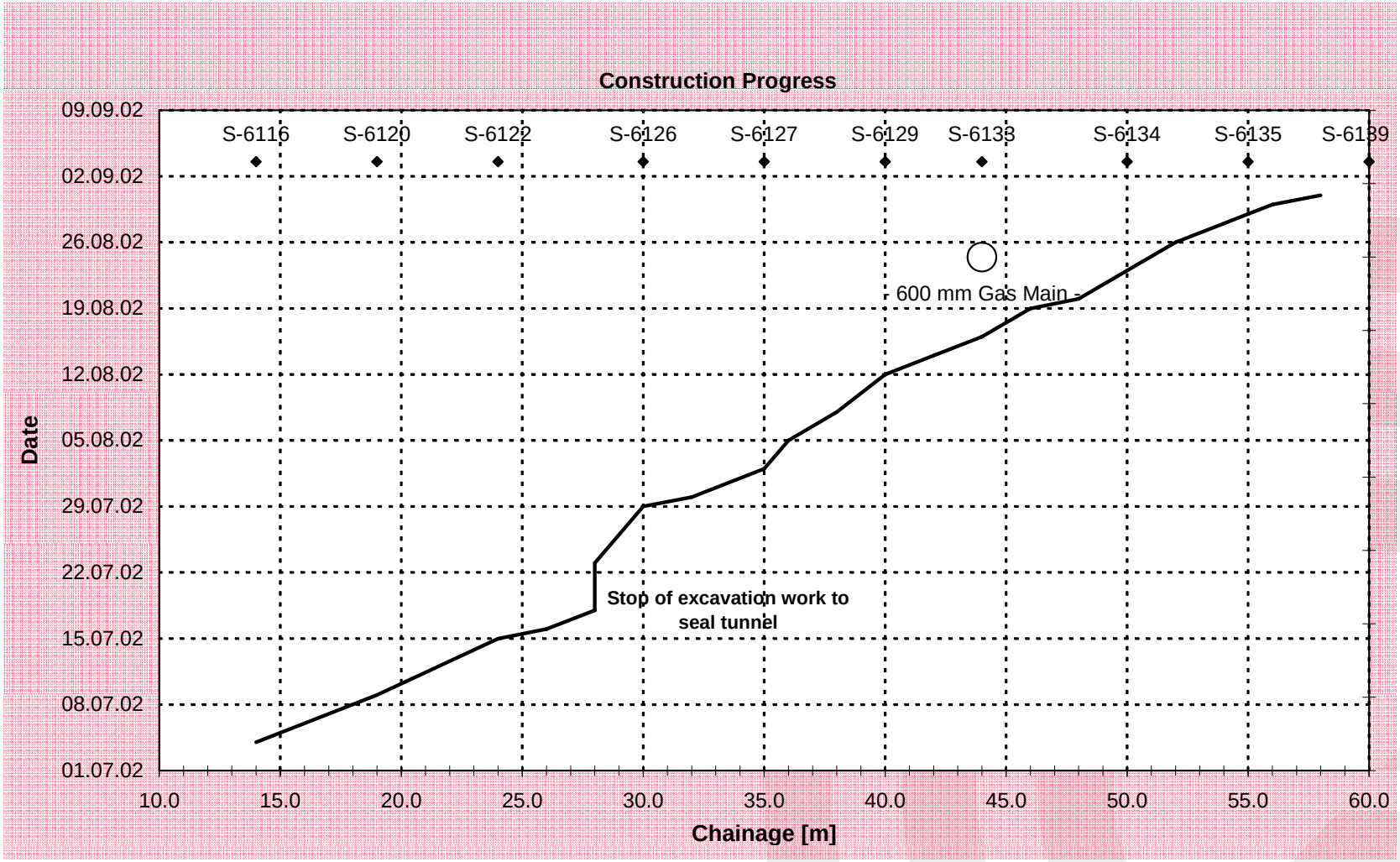
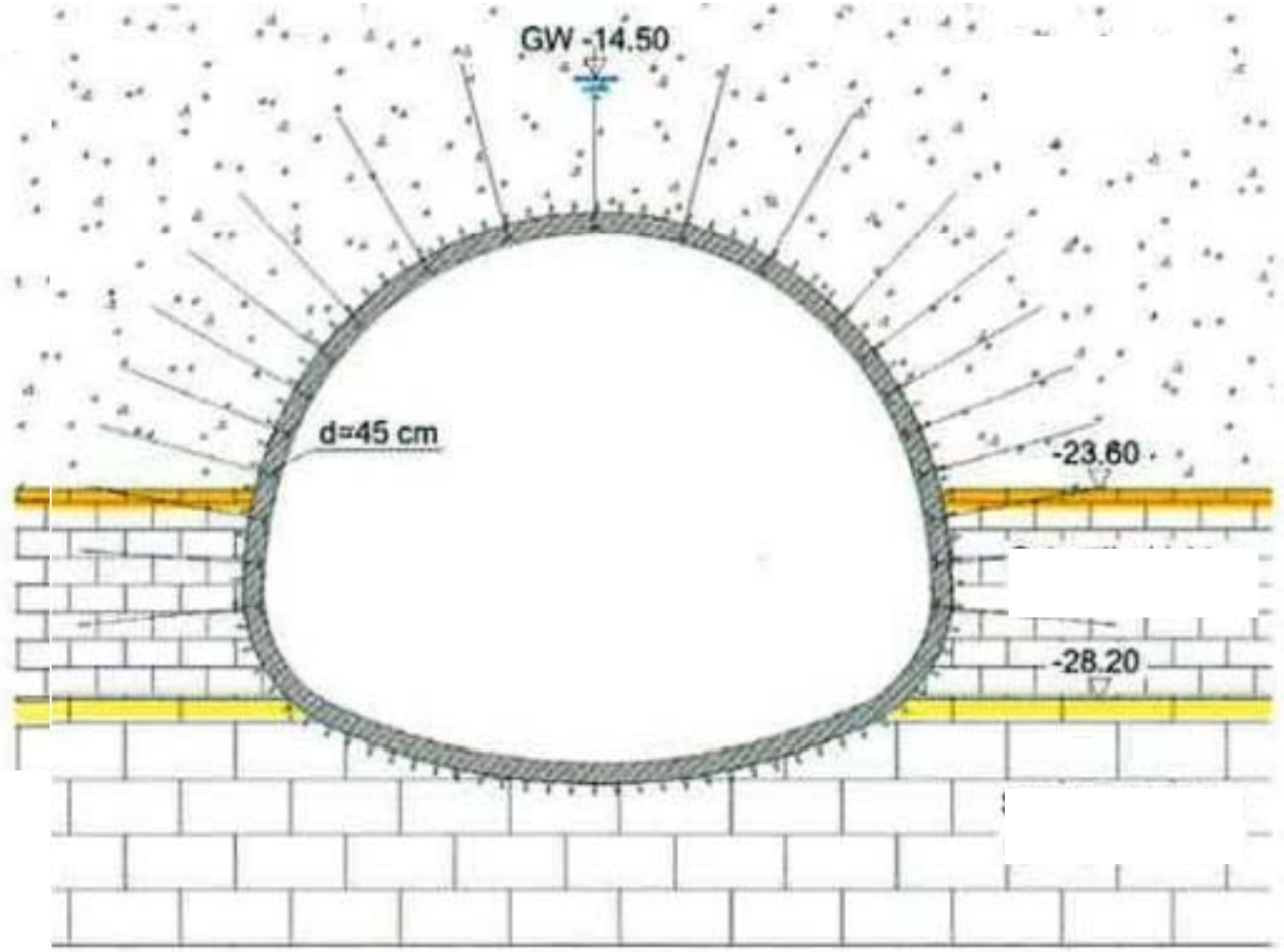


DTSS T06/R2 – Influence Lines



Side Galleries

Side Galleries



Side Galleries

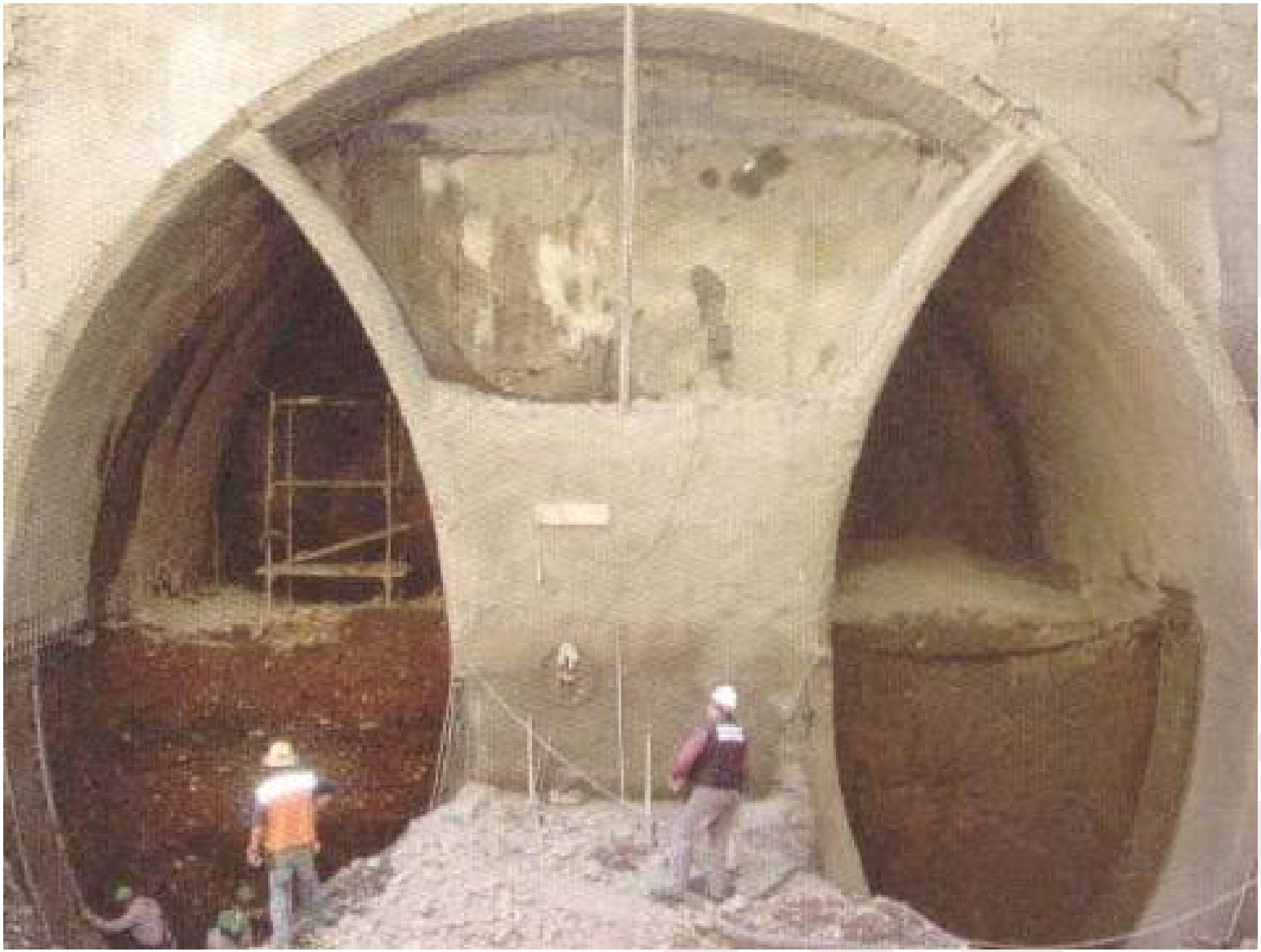
- »Reduce size of excavation face
- »Face stability
- »Control of Settlements

Side Galleries

»Make sequence only as complicated as necessary

»Avoid additional (structural) complications

Side Galleries – Common “Design Trap”



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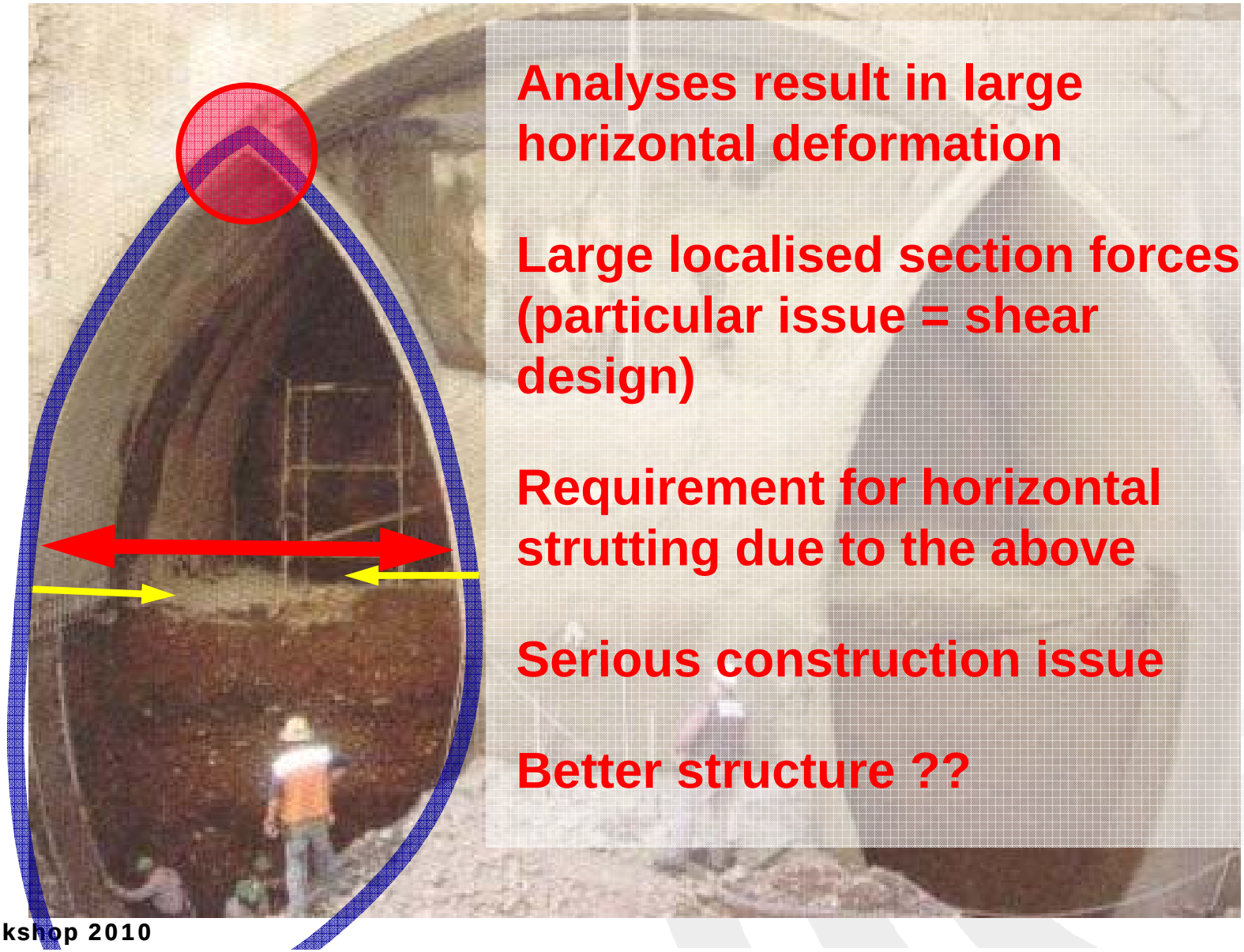


Analyses result in large horizontal deformation

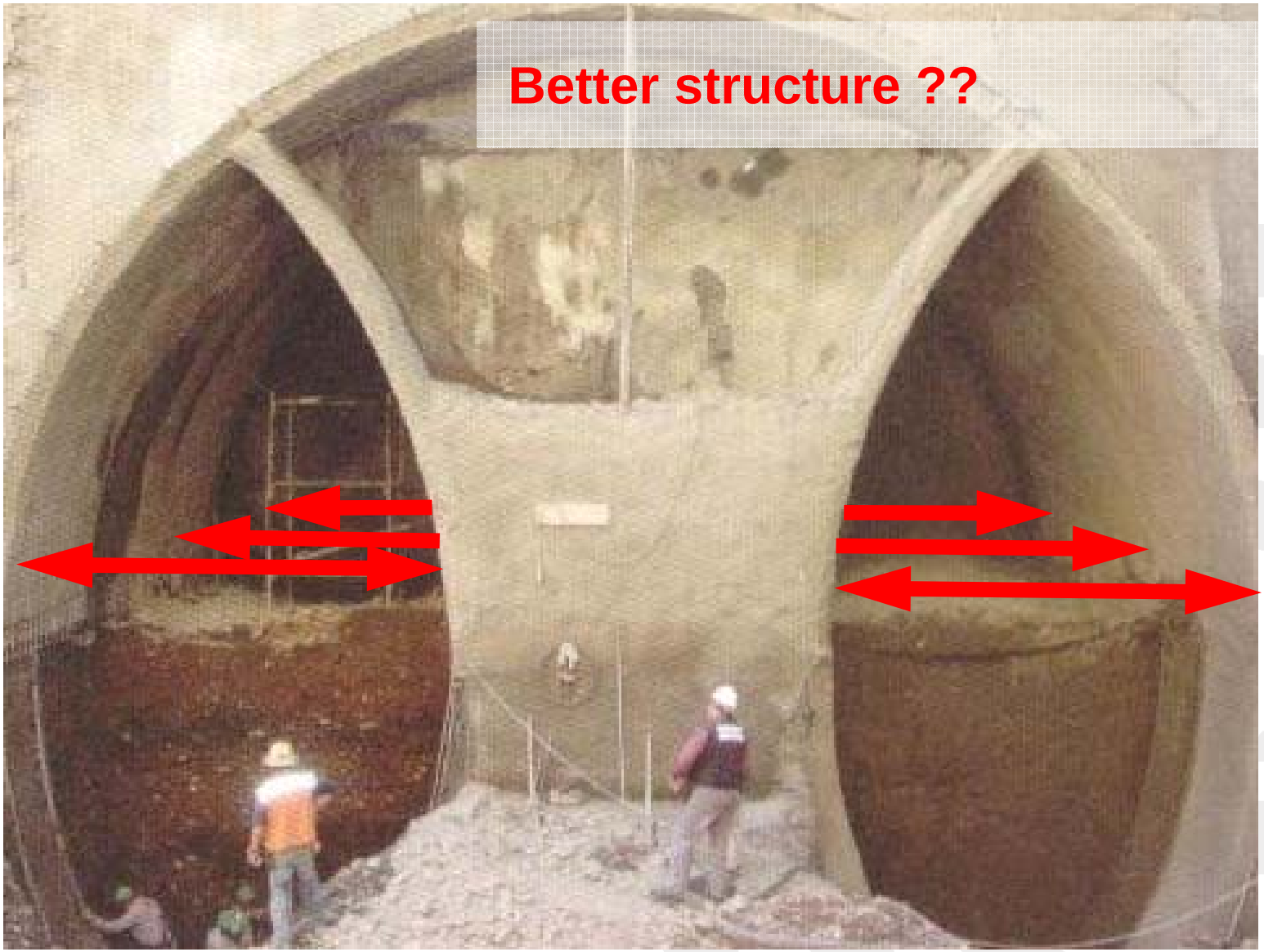
Large localised section forces (particular issue = shear design)

Requirement for horizontal strutting due to the above

Serious construction issue

Better structure ??

Side Galleries – Common “Design Trap”



Side Galleries

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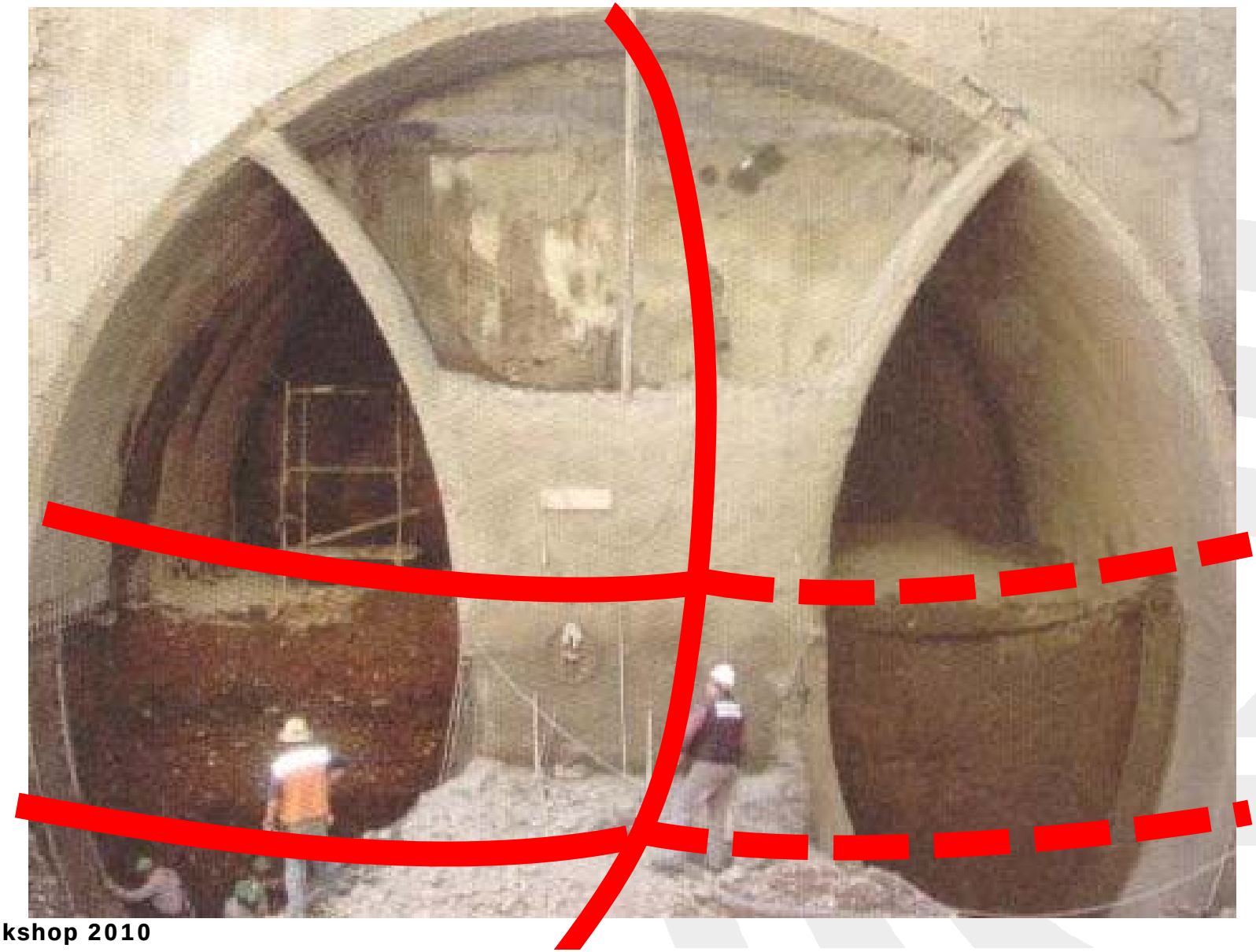

Side Galleries

Thank You

And Glück Auf