# DEVELOPMENTS IN THE TUNNELLING INDUSTRY FOLLOWING INTRODUCTION OF THE TUNNELLING CODE OF PRACTICE

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Munich RE

# Agenda

- The Code then and today ( 2000 to 2011 )
- Experience with tunnelling insurance in the last decade
- current trends
- The Tunnel Code of Practice
- reference projects

# Major tunnel losses since 1994



| PROJECT | CAUSE | LOSS | DELAY |
|---|---|---|---|
| 1994 Great Belt Link, Denmark | Fire | US$ 33m | - |
| 1994 Munich Metro, Germany | Collapse | US$ 4m | 10 months |
| 1994 Heathrow Express Link, GB | Collapse | US$ 141m | 14 months |
| 1994 Taipei Metro, Taiwan | Collapse | US$ 12m | 12 months |
| 1995 Los Angeles Metro, USA | Collapse | US$ 9m | 15 months |
| 1995 Taipei Metro, Taiwan | Collapse | US$ 29m | 18 months |
| 1999 Hull Sewage Tunnel, UK | Collapse | US$ 55m | 26 months |
| 1999 TAV Bologna – Florence, Italy | Collapse | US$ 9m | - |
| 1999 Anatolia Motorway, Turkey | Earthquake | US$ 115m | 36 months |
| 2000 Taegu Metro, South Korea | Collapse | US$ 24m | 9 months |

# Major tunnel losses since 1994



| PROJECT | CAUSE | LOSS | DELAY |
|---|---|---|---|
| 2000 TAV Bologna – Florence, Italy | Collapse | US$ 12m | - |
| 2002 Taiwan High Speed Railway | Collapse | US$ 30m | - |
| 2002 SOCATOP Paris, France | Fire | US$ 8m | 6 months |
| 2003 Shanghai Metro, PRC | Collapse | US$ 80m | 47 months |
| 2004 Singapore Metro, S'pore | Collapse | US$ 80m | 36 months |
| 2005 Barcelona Metro, Spain | Collapse | US$ 20m | 24 months |
| 2005 Lausanne Metro, Switzerland | Collapse | t.b.a. | - |
| 2005 Lane Cove Tunnel, Sydney | Collapse | US$ 15m | - |
| 2006 Kaohsiung Metro, Taiwan | Collapse | US$ 10m | 24 months |
| 2007 Sao Paulo Metro, Brazil | Collapse | t.b.a. | 10 months |
| 20 major losses | | Total > US$ 650m | > 280 months |

# Tunnel Loss Experience
## Major Tunnel losses and delays



| Year | Project | Cause | Loss | | Delay |
|---|---|---|---|---|---|
| 1994 | Great Belt Link | Fire | US$ | 33 mio | -- |
| 1994 | Munich Metro, Germany | Collapse | US$ | 4 mio | 10 months |
| 1994 | Heathrow Express link, GB | Collapse | US$ | 141 mio | 14 months |
| 1994 | Metro Taipei, Taiwan | Collapse | US$ | 12 mio | -- |
| 1995 | Metro Los Angeles, USA | Collapse | US$ | 9 mio | -- |
| 1995 | Metro Taipei, Taiwan | Collapse | US$ | 29 mio | -- |
| 1999 | Hull Yorkshire Tunnel, UK | Collapse | US$ | 55 mio | 26 months |
| 1999 | TAV Bologna-Florence, Italy | Collapse | US$ | 9 mio | -- |
| 1999 | Anatolia Motorway, Turkey | Earthquake | US$ | 115 mio | -- |
| 2000 | Metro Taegu, Korea | Collapse | US$ | 24 mio | 9 months |
| 2000 | TAV Bologna-Florence, Italy | Collapse | US$ | 12 mio | -- |
| 2002 | Taiwan Highspeed Railway | Collapse | US$ | 30 mio | -- |
| 2003 | Shanghai Metro, PRC | Collapse | US$ | 80 mio | 47 months |

# Tunnel Loss Experience
## Major Tunnel losses and delays



| Year | Project | Cause | Loss | | Delay |
|---|---|---|---|---|---|
| 2003 | Detroit Tunnel | Flood | | | |
| 2006 | Viamala Tunnel | Fire | | | |
| 2006 | Big Dig Boston | Failure of false ceiling | US$ | 166 mio | |
| 2006 | Petrus Tunnel | Cracking of segments | EUR | 19,5 mio | |
| 2008 | Stromoyka Tunnel Prague | Collapse | | | |
| 2008 | Hangzhou Metro | Collapse | | | |
| 2008 | Glendoe HEP | Collapse | EUR | 32,5 mio | |
| 2008 | Guangzhou Metro Line 5 / cross passage | Collapse | | | |
| 2008 | Cicle Line 4 Singapore | Collapse | | | |
| 2008 | Tunnel Pécs – M6 | Collapse | EUR | 10 mio + | |
| 2009 | Brightwater sewer | Collapse | US$ | 48 mio | |

# Tunnel Loss Experience
## Major Tunnel losses and delays



| Year | Project | Cause | Loss | | Delay |
|---|---|---|---|---|---|
| 2009 | Metro Cologne | Collapse | EUR | 365 mio | |
| 2009 | Thirre Tunnel | Collapse | EUR | 6,4 mio | |
| 2010 | Cairo Metro | Collapse | EUR | 20 mio | |
| 2010 | Blanka Tunnel Prague | Collapse | | | |
| 2010 | Ettendorfer Tunnel | Collapse | EUR | 1 mio + | |
| 2010 | Leak Mead Tunnel | Flood | | | |
| 2010 | Gilbe II HRT | Collapse | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

# List from IMIA paper 2006



| O/C Y | Project | Type of contract | Method | Type of loss | Cause of loss | €m |
|---|---|---|---|---|---|---|
| 1994 | Great Belt Link, Denmark | | TBM | Ingress of water | | 32 |
| 1994 | Munich, Germany | | NATM | Collapse | Faulty design(soil) | 2 |
| 1994 | Heathrow Express Link, UK | | NATM | Collapse | Faulty workmanship | 150 |
| 1994 | Taipei Metro, Taiwan | | TBM | Ingress of water | Faulty workmanship | 12 |
| 1995 | Los Angeles Metro, USA | | TBM | Collapse | Faulty workmanship | 16 |
| 1995 | Taipei Metro, Taiwan | | TBM | Ingress of water | Faulty workmanship | 30 |
| 1999 | Hull Yorkshire Tunnel, UK | design and build | TBM | Collapse | Faulty design? | 64 |
| 1999 | Anatolian Highway, Turkey | | | E/Q | E/Q | 121 |
| 2000 | Taegu Metro, Korea | | Cut and Cover | Collapse | Faulty design/work | 13 |
| 2000 | TAV Bologne – Florence, Italy | | NATM | Collapse | | 5 |
| 2002 | Taiwan High Speed Railway | design and build | NATM | Collapse | | 11 |
| 2002 | Autoroute A86 – Rueil, France | | TBM | Fire | | 11 |
| 2003 | Shanghai Metro | | Freezing | Collapse | Faulty workmanship | 69 |
| 2004 | Singapore Metro, Singapore | design and build | Cut and Cover | Collapse | Faulty design/work | t.b.a. |
| 2005 | Barcelona Metro, Spain | | NATM | Collapse | | t.b.a. |
| 2005 | Lausanne Metro, Switzerland | | | Collapse | | t.b.a. |
| 2005 | Lane Cove Tunnel, Sydney, | | NATM | Collapse | | t.b.a. |
| 2005 | Kaohsiung Metro, Taipei | | TBM | Collapse | Faulty workmanship | t.b.a. |
| | 18 major losses | | | | Total | >570 |

TBM = Tunnelling Boring Machine
NATM = New Austrian Tunnelling Method

# Tunnel Loss Experience
## Major Tunnel losses and delays



| Year | Project | Cause | Loss | | Delay |
|---|---|---|---|---|---|
| 2004 | Singapore Metro, Singapore | Collapse | US$ | 80 mio | 36 months |
| 2005 | Barcelona Metro, Spain | Collapse | US$ | -- | 24 months |
| 2005 | Lausanne Metro, Switzerland | Collapse | US$ | -- | -- |
| 2005 | Lane Cove Tunnel, Sydney | Collapse | US$ | -- | -- |
| 2006 | Kaoshiung Metro, Taiwan | Collapse | US$ | -- | 24 months |
| 2007 | Sao Paolo Metro, Brazil | Collapse | US$ | -- | -- |
| 2009 | Metro Cologne, Germany | Collapse | US$ | -- | -- |
| 1996 | Eurotunnel, France / UK | Fire | US$ | 375 mio | 7 months |
| 1999 | Montblanc  Tunnel, CH/A | Fire | US$ | 525 mio | 36 months |
| 1999 | Tauerntunnel,  Austria | Fire | US$ | 42 mio | 3 months |
| 2001 | Gotthard Tunnel, CH/I | Fire | US$ | -- | 2 months |
| 2002 | SOCATOP Paris, France | Fire | US$ | 8 mio | 6 months |
| 2008 | Eurotunnel, France / UK | Fire | US$ | 450 mio | -- |

# As if assumptions



| Major tunnel consequential losses delays in month | | | | | | | with TCoP |
|---|---|---|---|---|---|---|---|
| O/C Y | Project | Type of contract | Method | Type of loss | Cause of loss | Months | Months |
| 1994 | Great Belt Link, Denmark | | TBM | Ingress of water | | 12 | 12 |
| 1994 | Munich, Germany | | NATM | Collapse | Faulty design(soil) | 10 | 0 |
| 1994 | Heathrow Express Link, UK | | NATM | Collapse | Faulty workmanship | 14 | 0 |
| 1994 | Taipei Metro, Taiwan | | TBM | Ingress of water | Faulty workmanship | 12 | 0 |
| 1995 | Los Angeles Metro, USA | | TBM | Collapse | Faulty workmanship | 15 | 15 |
| 1995 | Tapei Metro, Taiwan | | TBM | Ingress of water | Faulty workmanship | 18 | 0 |
| 1999 | Hull Yorkshire Tunnel, UK | Design and build | TBM | Collapse | Faulty design? | 26 | 26 |
| 1999 | Anatolian highway, Turkey | | | E/Q | E/Q | 36 | 36 |
| 2000 | Taegu Metro, Korea | | Cut and Cover | Collapse | Faulty design/work | 9 | 0 |
| 2000 | TAV Bologne – Florence, Italy | | NATM | Collapse | | 0 | 0 |
| 2002 | Taiwan High Speed Railway | Design and build | NATM | Collapse | | 0 | 0 |
| 2002 | Autoroute A86 – Rueil, France | | TBM | Fire | | 6 | 6 |
| 2003 | Shanghai Metro | | Freezing | Collapse | Faulty workmanship | 47 | 47 |
| 2004 | Singapore Metro, Singapore | Design and build | Cut and Cover | Collapse | Faulty design/work | 18 | 0 |
| 2005 | Barcelona Metro, Spain | | NATM | Collapse | | 24 | 0 |
| 2005 | Lausanne Metro, Switzerland | | | Collapse | | t.b.a. | t.b.a. |
| 2005 | Lane Cove Tunnel, Sydney, AUS | | NATM | Collapse | | 0 | 0 |
| 2005 | Kaohsiung Metro, Taipei | | TBM | Collapse | Faulty workmanship | 24 | 24 |
| | 14 major losses with consequential delay (without TCoP) | | | | Total | 271 | |
| | 7 major losses with consequential delay (with TCoP) | | | | Total | | 166 |

TBM= Tunnelling Boring Machine
NATM= New Austrian Tunnelling method
E/Q= Earthquake

# What‘s the conclusion ?



| | A | B | C | D |
|---|---|---|---|---|
| 1 | Year | MD claims | DSU delays | no. |
| 2 | 1994 | 190 | 24 | 4 |
| 3 | 1995 | 28 | 0 | 2 |
| 4 | 1996 | 0 | 0 | 0 |
| 5 | 1997 | 0 | 0 | 0 |
| 6 | 1998 | 0 | 0 | 0 |
| 7 | 1999 | 221 | 65 | 5 |
| 8 | 2000 | 36 | 9 | 2 |
| 9 | 2001 | 0 | 2 | 1 |
| 10 | 2002 | 38 | 6 | 2 |
| 11 | 2003 | 80 | 47 | 2 |
| 12 | 2004 | 80 | 36 | 1 |
| 13 | 2005 | 0 | 24 | 3 |
| 14 | 2006 | 195 | 24 | 4 |
| 15 | 2007 | 0 | 0 | 1 |
| 16 | 2008 | 42,5 | 0 | 7 |
| 17 | 2009 | 54 | 0 | 2 |
| 18 | 2010 | 0 | 0 | 4 |
| 19 | | | | |

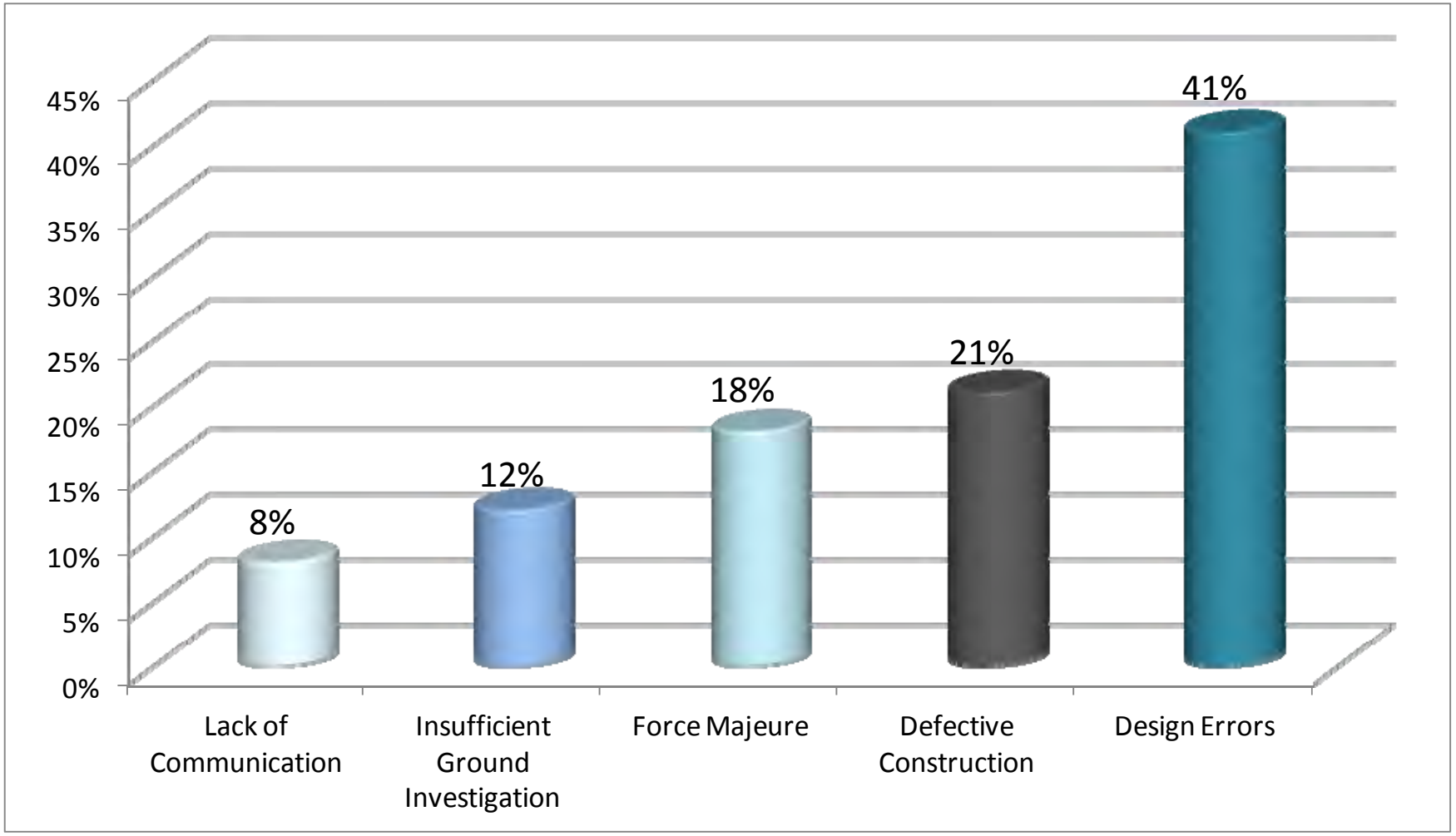
# Statistical data



- Plenty of data available, list sometimes mixed up with operational losses
- Plenty of claims settlements  still pending
- Conclusions are inconclusive
- It‘s all about the perception
- The code has worked if only one major claim has been avoided

# Tunnel Loss Experience
## Causes of Underground Failures





# 11 years of the code

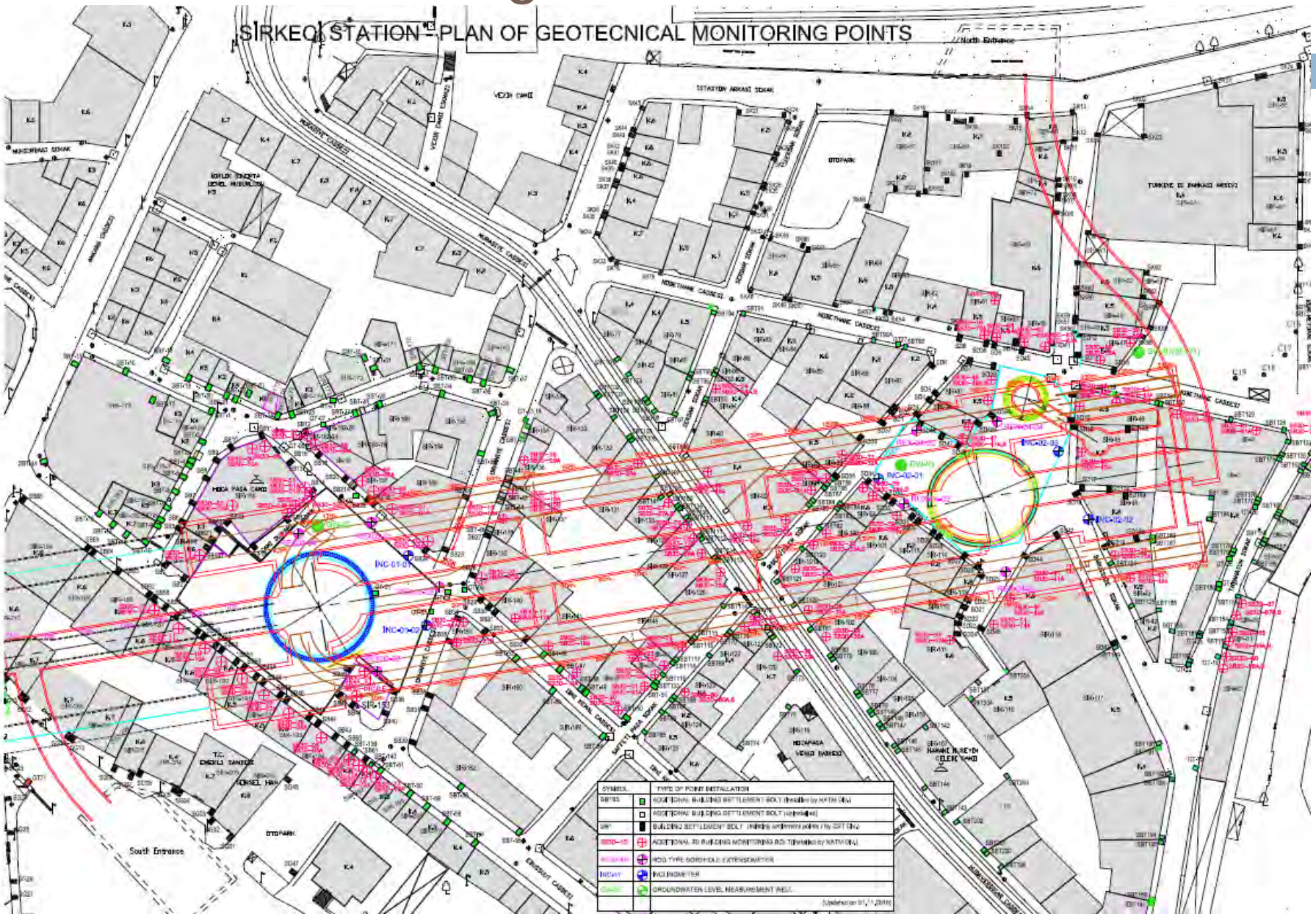
## 2000

- Who pays for it ?
- Who does it ?
- It restricts cover !
- It is time consuming – holds project up !
- It is another unnecessary check list !
- We don‘t need insurance to direct the works !
- This a UK thing only !
- Too complicated to work in all environments !

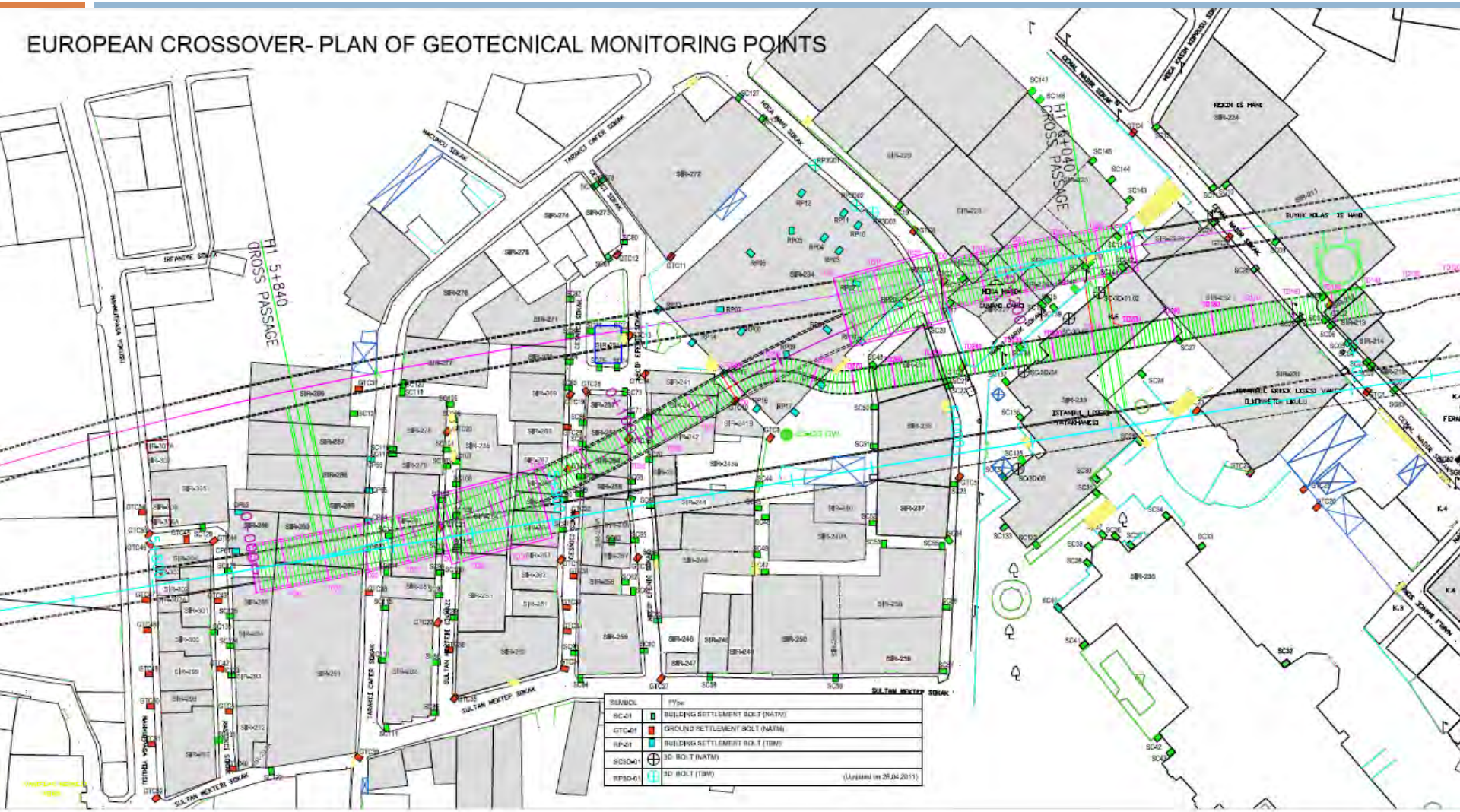
## 2011

- Insurance panel „share“ the cost
- Never even had to threaten with restricted coverage
- Most recommendations are very welcome
- bridges between employer and contractor
- Principals like it – more transparency
- Code is (world)widely accepted, mostly understood and appreciated
- Very few cases where it’s introduction was opposed
- In few cases as a measure stick against similar or better risk management
- Good brokers rather deal with uw‘s applying the code
- Monitoring sometimes inadequate
- Code available in all major languages – on IMIA website !

# Settlement management



# Geotechnical monitoring



# Geology + exploration drillings

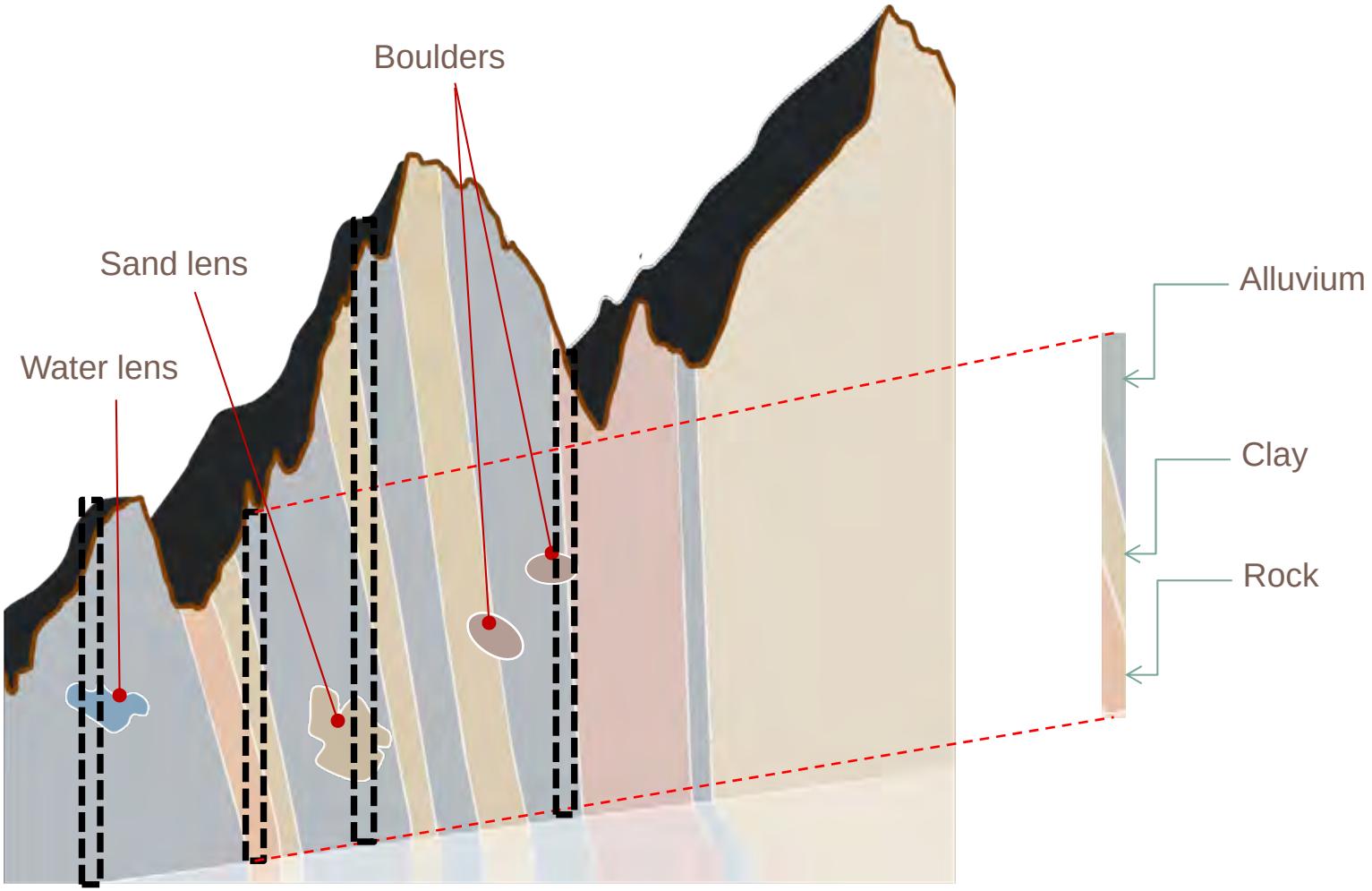



Image source: Die Zeit

# you can be unlucky too !

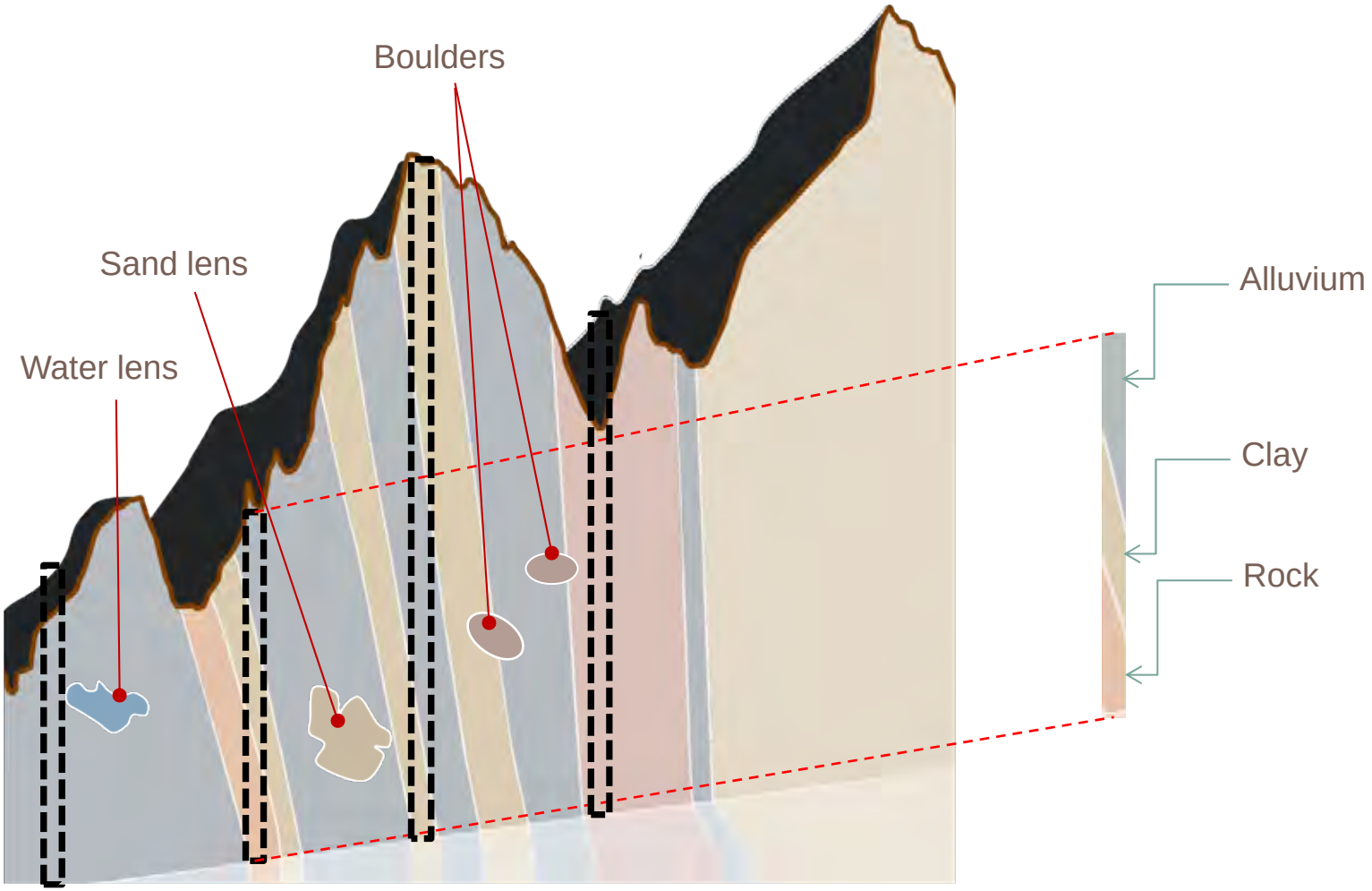
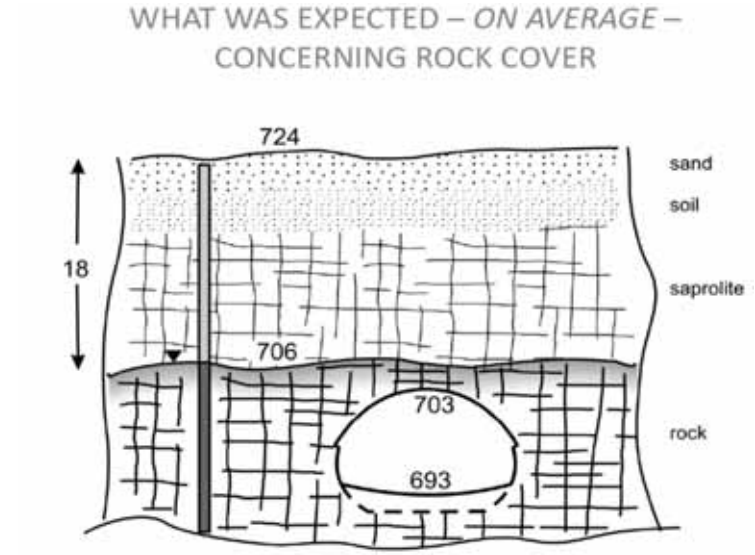


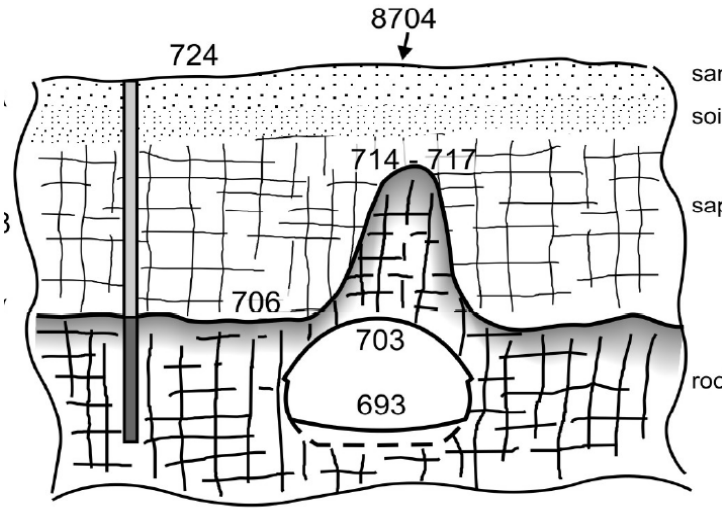

Image source: Die Zeit

# Marmaray Project, Turkey



# Pinheros


WHAT WAS EXPECTED – *ON AVERAGE* –
CONCERNING ROCK COVER
724
18
706
703
693
sand
soil
saprolite
rock


8704
724
714 - 717
706
703
693


POÇO
TUNEL VIA

# General trends in the tunnelling industry



- High-risk-type construction methods
- Trend towards more complex tunnels, bigger diameters
- design + build, fixed-price contracts, PPP’s
- risk transfer from project owner to contractors
- Tight construction schedules
- insufficient financial budgets of (public) project owners
- Fierce competition in construction industries (globalisation!)

# Consequences for the insurance industry



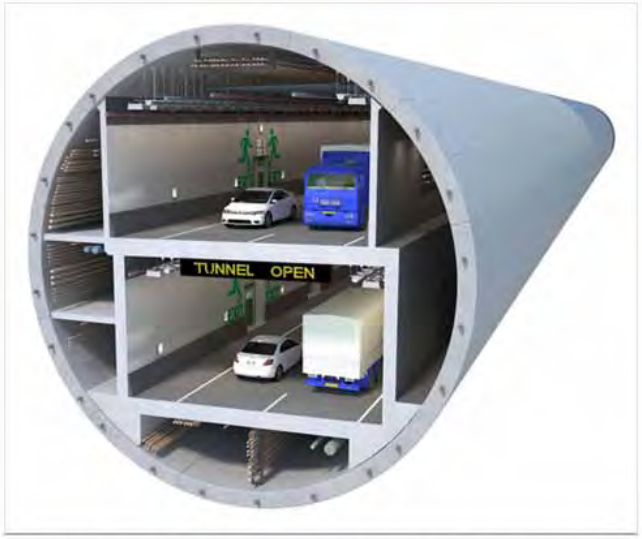
- Insufficient premium income to pay for all the losses
- Repair costs always exceed original construction costs
- Wide scope of cover indemnifies far beyond repair costs (e.g. debris removal, professional fees, loss minimisation, improvements, more adequate construction methods)
- Very long delays in completion
- Insurance is a "cheap risk-management tool"
- Tunnelling insurance in the spot light due to high claims amounts

# Tunnelling has become a high tech industry




**Machine Technology**

- EPB Shield
- Mixshield
- Slurryshield
- Single Shield TBM
- Double Shield TBM
- Gripper TBM
- Shield with Partial Face Excavation
- HDD Rig




a

A mighty 17.5m or 58ft diameter tunnel will replace Seattle's double-decked waterfront viaduct

If the code is opposed or not acceptable ?

# Risk Management Process


**Project will acknowledge the Code and adopt best practices for the benefit of the project and underwriters.**

**Formal adoption of the Code is not possible for multiple reasons.**

## 6.3 Risk Management Program

Risk management activities are scheduled as follows (gre
Chart under 6.2):

| Activity | Date | Main Focus |
|---|---|---|
| Desktop Review | October 2011 | Review of all available information as requested by risk engineer |
| Site Survey | November 2011 | Establishing relationships with project management team, insurers role, project and program review, risk management (implementation of TCoP), H&S plan |

- Implementation of International Construction Codes (e.g. ITIG-Code of Practice)
- Health & safety management
- Security and access control
- Plant Use

# Conclusions



- Tunnel construction is a journey into the unknown and hence risky
- Loss experience is at an unsustainable and unpredictable level
- Professional risk-management strategies were missing
- TCoP was developed jointly by construction and insurance industries
- More suitable tunnelling clauses are worked upon
- The Code or equivalent risk management tools shall be compulsory to procure CAR cover for future tunnel projects
- Cut and Cover tunnels and boxes collapse too
- TCoP must be professionally monitored !
- Risk mitigation is possible, but it comes at a price and is cheaper than cleaning up afterwards

# open box structures



- Cologne Metro Germany - 2009

# Cut & cover structures




- Singapore Metro
  Singapore - 2004

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THANK YOU VERY MUCH
FOR YOUR ATTENTION

Hartmut Reiner

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