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CAR Design Cover for Unforeseen Ground Conditions in Tunnel Construction Risks

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Introduction

Part I:

- Observations on tunnelling in general
- Different types of tunnel projects and their inherent risks

Part II:

- Design Definition: What is intended cover granted by CAR
- Examples of frequent design cover/exclusion wordings in CAR Policies
- Application of wordings in relation to losses by way of example using case studies.

Part I:

- Observations on tunnelling in general
- Different types of tunnel projects and their inherent risks

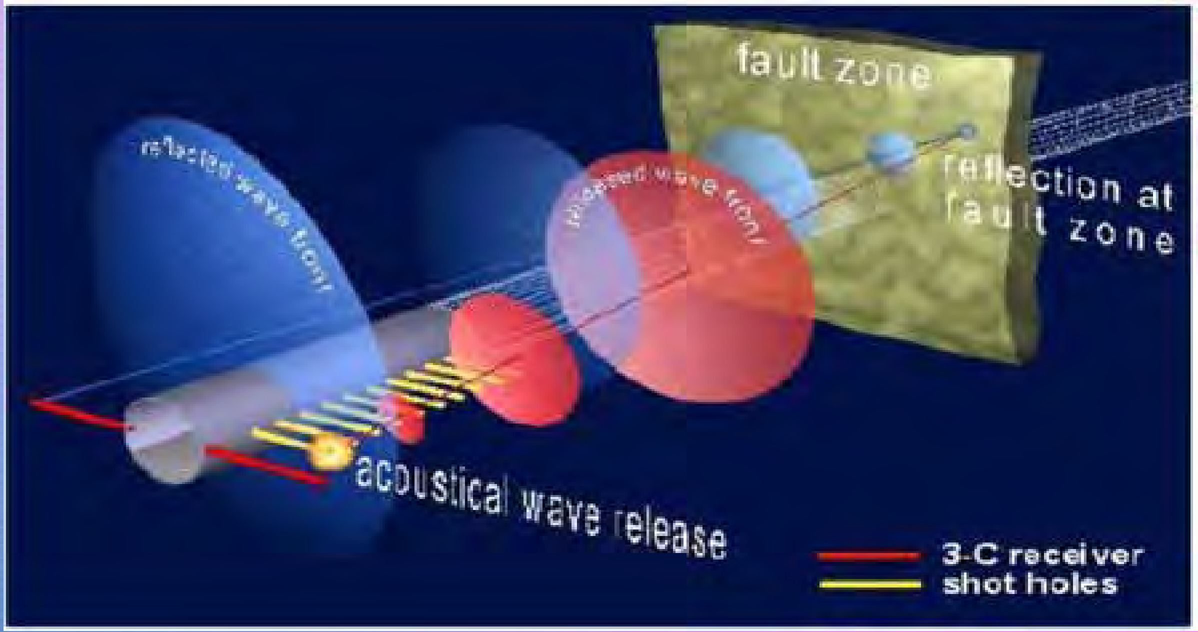
Observations on Tunnelling in General

Observations on Tunnelling in General

- Experience gained in 1860s during construction of London metro.
- Construction of London Jubilee line and current research for London Crossrail project

Different Types of Tunnelling Risks

- Due to cost constraints, current predictability of geology along tunnel alignment only approximate (TSP method)
- Insurance of tunnelling risks requires specialised / extensive technical knowledge and underwriting skill.



Tunnel Seismic Prediction method

Different Types of Tunnelling Risks

- Metro Tunnels & Shafts
- Sewage Tunnels
- Drainage Tunnels (Floodwater)
- Utilities
- Hydroelectric Headrace Tunnels/Surge Shafts
- Motorway & Rail Tunnels
- Submerged Tunnel Projects (different risk)

Metro Tunnels & Shafts

Depth of tunnel determined by financial/political considerations e.g. Escalator length

- 90m long / 65m deep escalator in Prague Metro
- Significantly deeper in Moscow
- Longer escalators can save 100’s of millions of dollars / years of construction time…by reaching “economic” rock formations

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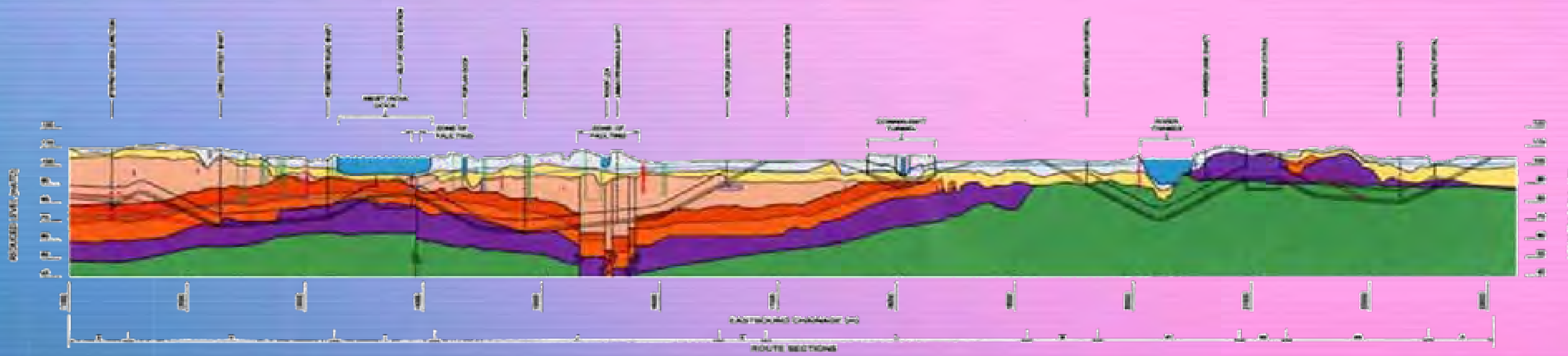
Metro Tunnels & Shafts

- Large diameter / cross section
- Geology usually complicated closer to surface etc
- Third party considerations: Proximity to other tunnels / services / building foundations
- Archaeological finds

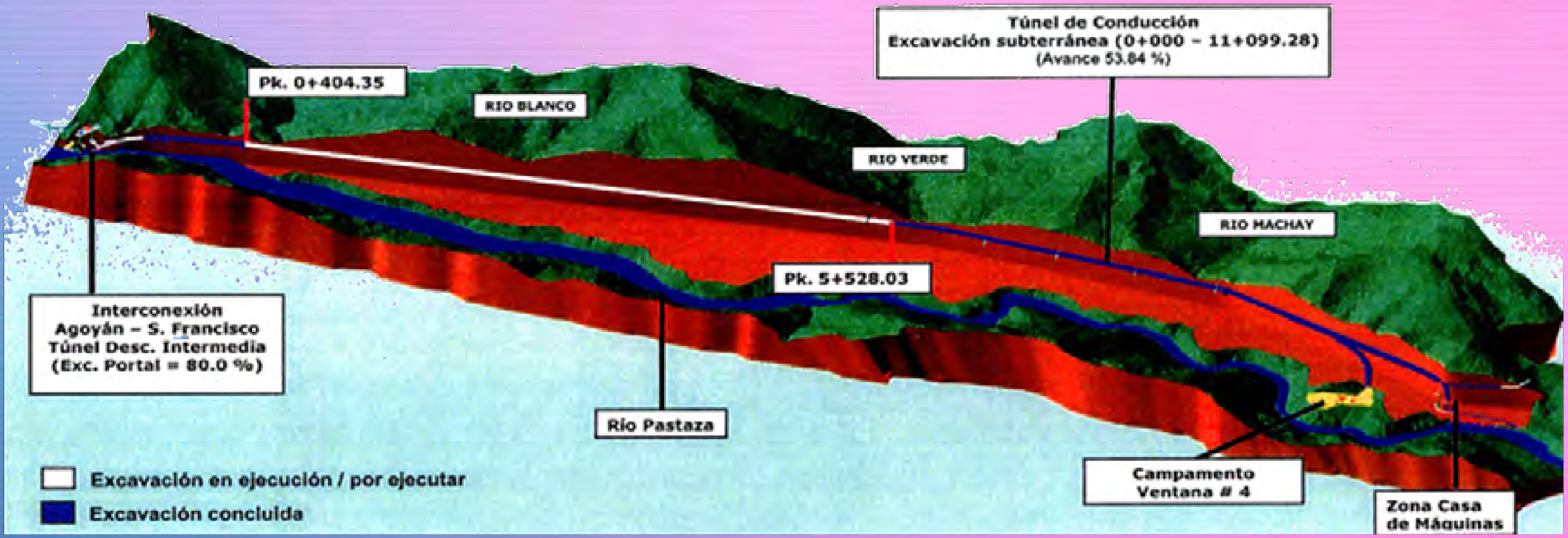


Sewage Tunnels/ Service Tunnels

- Generally smaller diameters
- As with metro tunnels at surface and subject to similar problems with geology and proximity of other tunnels/service installations

Hydro Electric Headrace Tunnels / Surge Shafts

- Usually located in mountainous terrain/depths of 70 – 100m+
- Subject to ‘squeezing’ / ‘rock spalling’ / geological faults
- Talwegs (river crossings) very shallow depths / associated risks (leakage, weathered ground etc)



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Motorway Tunnels

- Larger cross-sections
- Similar to Metro Tunnels when traversing mountains: squeezing, geological faults
- Land slides and rock fall at entrance and exits
- Substantial operational risk

Tunnelling Methods

- Cut & Cover
- Conventional Drill and Blast
- New Austrian Tunnel Method (NATM) in UK Sprayed Concrete Lining (SPC)
- Tunnel Boring Machine (TBM)
- Raise boring
- Perforex Pre-vault Excavation System

Part II

Design Definition:

- What is intended cover granted by CAR policy?

Examples:

- Frequent design cover/exclusion wordings used in CAR Policies

Application:

- Wordings in relation to losses by way of example using case studies.

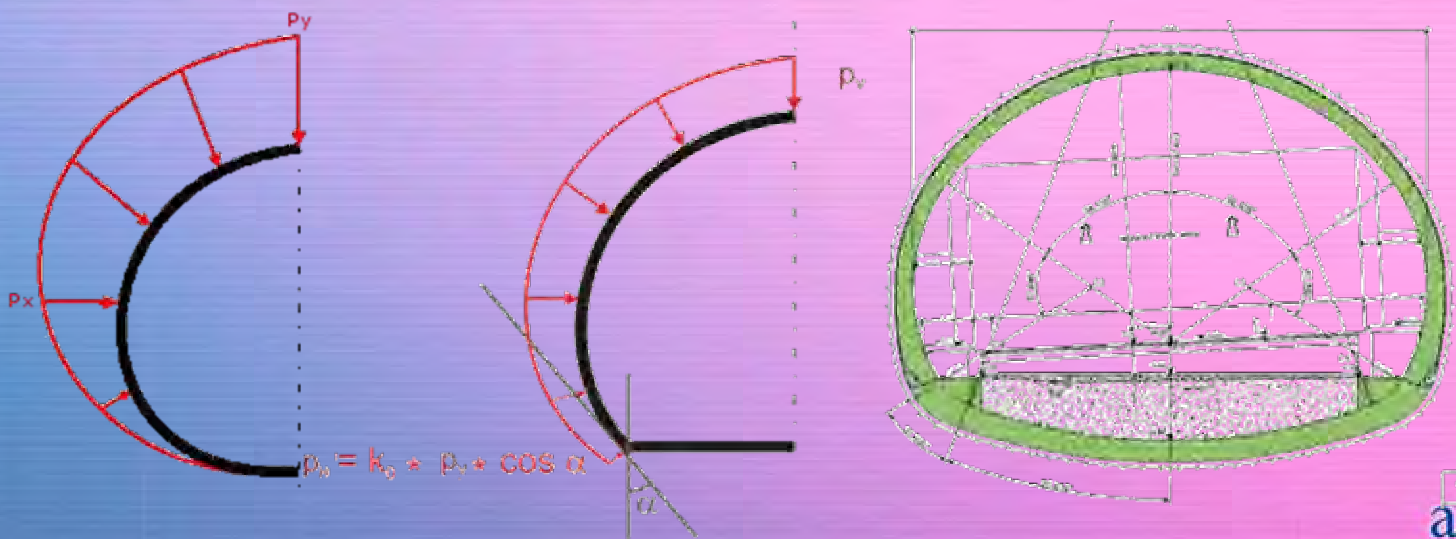
Question!

If tunnel collapse not due to **earthquake, flood** or other **natural peril**, or **external cause**, and no **defective material** / **workmanship** and 'Project Design' is free of error (e.g. calculations/specifications)… why did tunnel collapse?

Design Definition

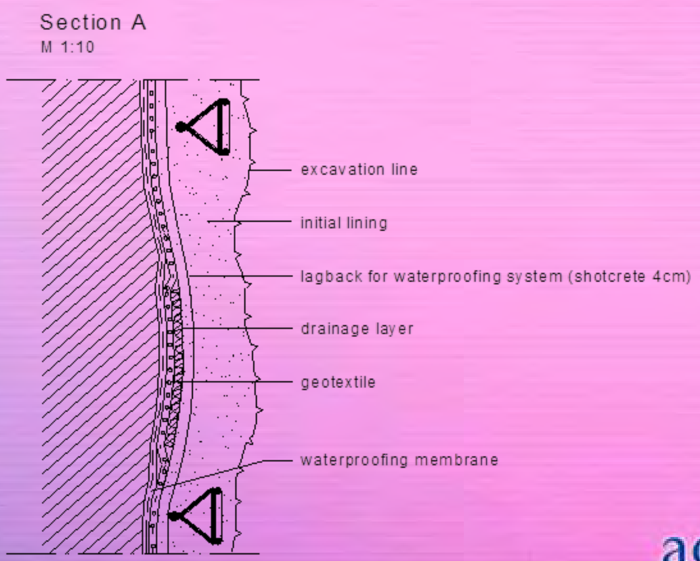
To what 'Design' does the cover/exclusion refer?

1. 'Project Design' on which the insured contract works are based, i.e. physical manifestation of intellectual property?
2. Design in widest sense i.e. not *only* physical manifestation of project design but design in absolute sense extending outside project design incorporating ground conditions not identified or considered in the project design?



Design Definition

- If intended cover is that of **2)** it follows that design exclusion would be applicable to damage due to unforeseen ground conditions and therefore offering considerably more relief to underwriters than that of **1)**
- In offering cover for ‘Design’ it is crucial underwriters are clear on intended cover and on the consequences of this cover.



Frequent Tunnel Design Covers/Exclusions

Vary from outright design exclusion to entire design cover (with exception for betterment):

- Munich Re Outright Exclusion / Design Exclusion 1
- Munich Re Endorsement 115
- Design Exclusion 3
- LEG2/96
- Design Exclusion 5

Outright Exclusions

DE1 and LEG1 Munich RE

- The most straightforward to apply
- The most restrictive cover
- Damage "due to defect" and not caused by an external source

Observation:

- Absolute exclusion of damage due to defective design

Munich Re End115 – Cover for Designers Risk

Munich Re 115 excludes:

- Items immediately affected by defective material workmanship faulty design but buys back cover for correctly executed items damaged in consequence

Observations:

- Faulty design excluded
- Cover for resultant damage

DE 3 – Limited Defective Condition Exclusion

DE 3 :

- Permits cover for damaged property free of the defect
- Excludes cover for the defective part and any part damaged in order to rectify the defect

Observation:

- Specific reference to property insured or *any part*
- Addresses access costs – often exceeds cost of damaged item

Leg 2/96 – "Consequences" Defects Wording

LEG 2/96 excludes:

- No express exclusion for defective part
- Rather excludes cost of repair necessary to rectify defect

Observations:

- Theoretical remedial measure excluded
- Application difficult for tunnelling risks with dispute over extent of defect and measures required to rectify defect

DE 5 – Design Improvement Exclusion

DE 5 excludes:

- Property defective in design plan specification materials or workmanship
- Property damaged to enable repair
- In event of damage exclusion is limited to work and cost associated with improvements

Observation:

- Everything covered except improvements

Application of Wordings – Case studies

Case Studies:

- Rail Tunnel Czech Republic
- Rail Link Tunnel Spain
- Metro Tunnel Brazil

Railway Tunnel Czech Republic

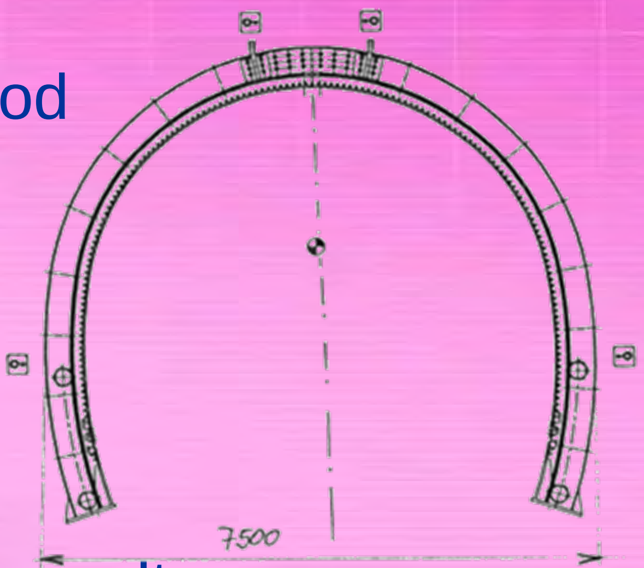
Risk:

- Rail line diversion Prague - Chomutov with 1.7 km tunnel
- Tunnelling predominantly in plastic clays and claystone
- Area affected by undocumented coal mining activities
- Use of Perforex or “Pre-vault” Tunnelling Method

Railway Tunnel Czech Republic

Tunnelling Method

- Perforex “Prevault” Tunnelling Method
- 20cm thick 5m long slits cut along tunnel circumference
- Slits then filled with sprayed concrete



- Overlapping slits form protective pre-vault
- Full face excavation follows by invert closure

Railway Tunnel Czech Republic

Perforex chain saw and back-up

Railway Tunnel Czech Republic

Circumstances:

May 2003 prevault 196 collapsed triggering 80m collapse at 27m depth

Railway Tunnel Czech Republic

Cause:

Loss considered to be **“faulty design”** since model used to verify tunnel geometry did not:

- Reflect soil conditions encountered
- Correspond to structure specified on design drawings
- Adequately model the construction sequence

Observation:

- Insured argued cause **“sudden and unforeseen geological conditions”**

Railway Tunnel Czech Republic

Policy Coverage:

- Outright Design Exclusion

Observation:

- Design 1) loss potentially covered as actual ground conditions differed to project design (conditions unexpected)
- Design 2) loss excluded as design did not contemplate actual conditions therefore defective
- Litigation in Czech Republic – **Insured awarded damages**

Collapse Northern Tunnel Entrance Rail Link Spain

Risk

- 550m tunnel for High speed Rail Link Barcelona- Lleida Spain
- Tunnelling predominantly in plastic clays and claystone
- Area affected contained known geological slickenside fault

Collapse Northern Tunnel Entrance Rail Link Spain

Tunnelling method:

- North side of fault- Open Cast,
- South side of fault- Drill & Blast
- Initial design (insured) specified construction of ‘False Tunnel’ at foot of slope prior to excavation through fault zone
- Original design changed during construction: fault zone excavated prior to false tunnel completion

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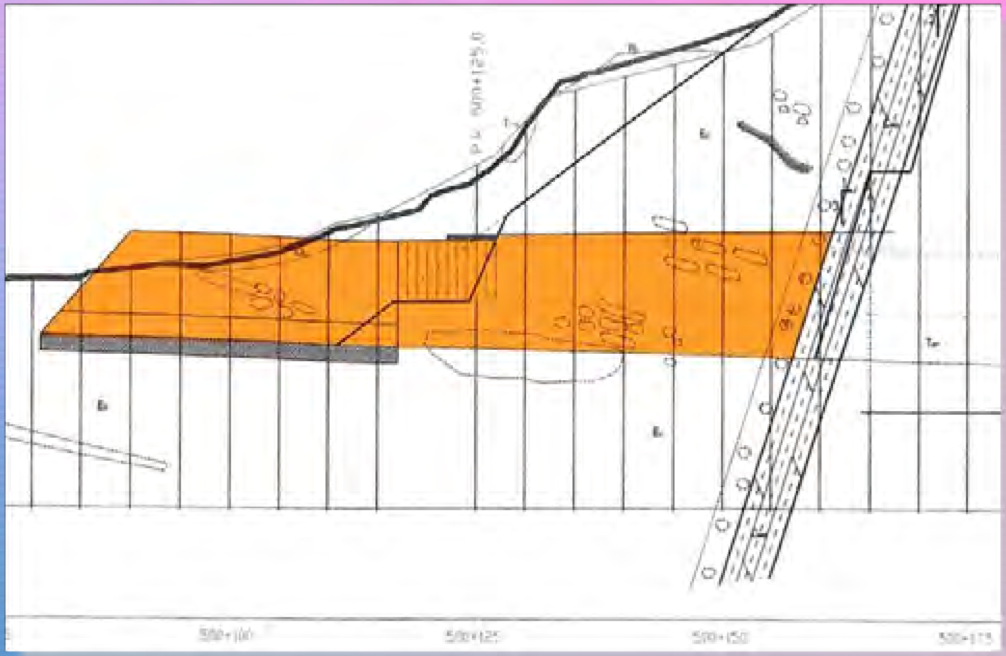
Collapse Northern Tunnel Entrance Rail Link Spain

Circumstances:

- Following a period of heavy rain and tunnelling advance of 40m, northern tunnel entrance collapsed

Collapse Northern Tunnel Entrance Rail Link Spain

Original Design:



- "Cut and cover system" 30m from northern tunnel entrance
- Construction of "False Tunnel" (Reinforcement tunnel arch by reinforced concrete) up to geological fault crossing tunnel route at 60m
- Tunnel excavation through solid material up to geological fault from southern direction

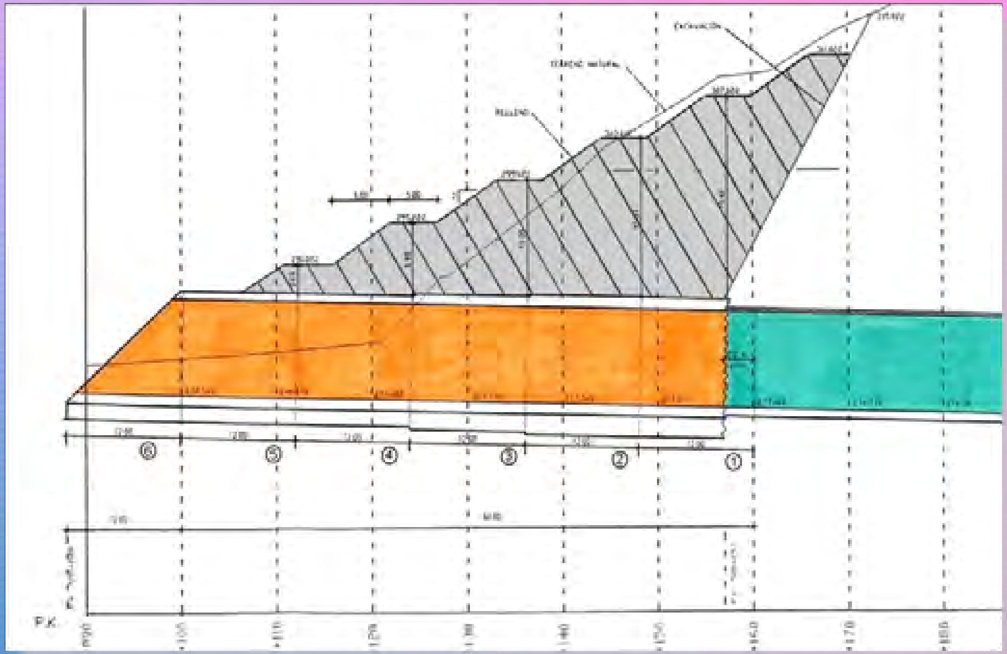
Collapse Northern Tunnel Entrance Rail Link Spain

Alternative design adopted:

- Slope excavation in clay with inclination 3:2 30m from northern tunnel
- Construction of a “False Tunnel” 30m length
- Placement of fill to support lower slope section and lateral tunnel slopes
- Tunnel excavation from southern direction carried out after false tunnel completion/ slope protection

Collapse Northern Tunnel Entrance Rail Link Spain

Tunnel repair followed original design, but more expensive due to:



- Removal of collapsed slope material
- Slope stabilisation at fault zone
- Construction of longer “False Tunnel” up to geological fault zone crossing tunnel route heavy reinforcement steel structure
- Replacement collapsed slope material to original profile

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Collapse Northern Tunnel Entrance Rail Link Spain

Material change in risk

Insured modified original design without notification to Insurers

Cause

Loss occurred as consequence of:

- 30m false tunnel length inadequate
- Failure to provide adequate surface water drainage at geological fault location
- Slope design at northern entrance too steep

In Policy terms: **Defective Design**

Collapse Northern Tunnel Entrance Rail Link Spain

Policy Coverage:

- Munich Re Endorsement 115
- In present case no defective part but erroneous decision
- Resultant damage: section of collapsed built tunnel and shortened toe (replacement of collapsed slope not insured - works not covered)

Observation:

- Design 1) not covered as design insured not followed
- Design 2) similarly not covered

Sao Paulo Metro Tunnel Collapse

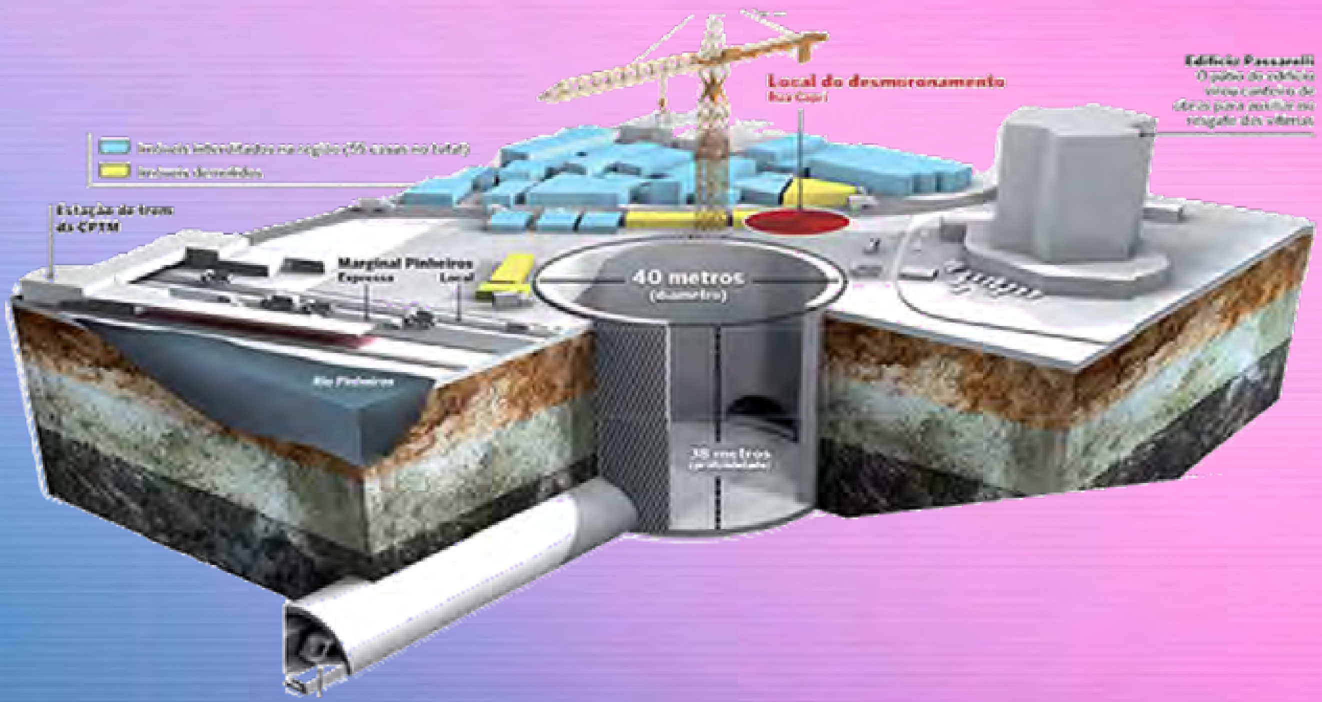
Risk:

- 12.8 km of tunnels and 11 stations

Sao Paulo Metro Tunnel Collapse

Tunnelling Method:

- Tunnels – TBM
- Stations – NATM (loss occurred in Pinheros Station)



Cutaway section through Pinheros station shaft

Sao Paulo Metro Tunnel Collapse

Circumstances:

- Convergence readings increased over Christmas break
- Collapse of tunnel, 8 people dead, extensive TP damage

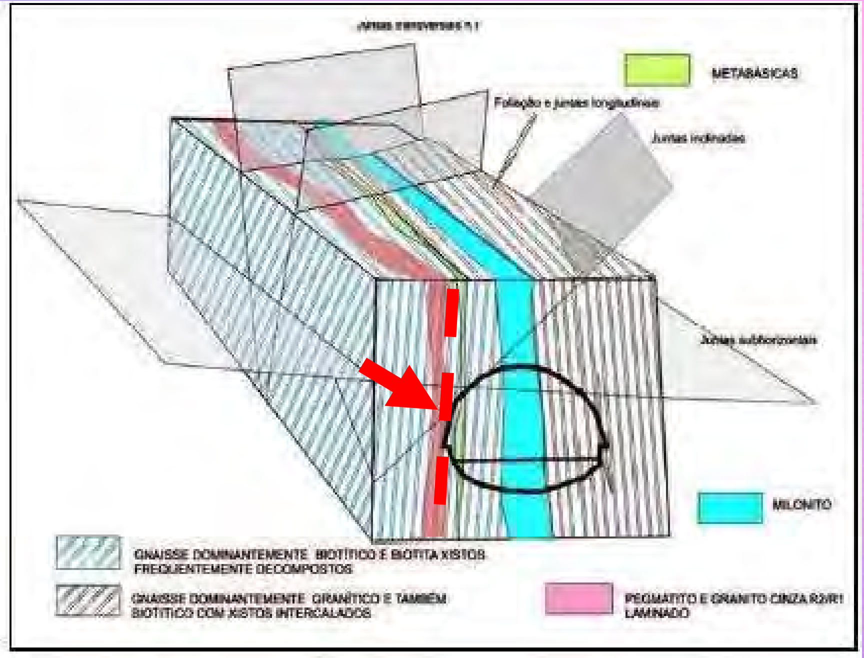
One week before collapse

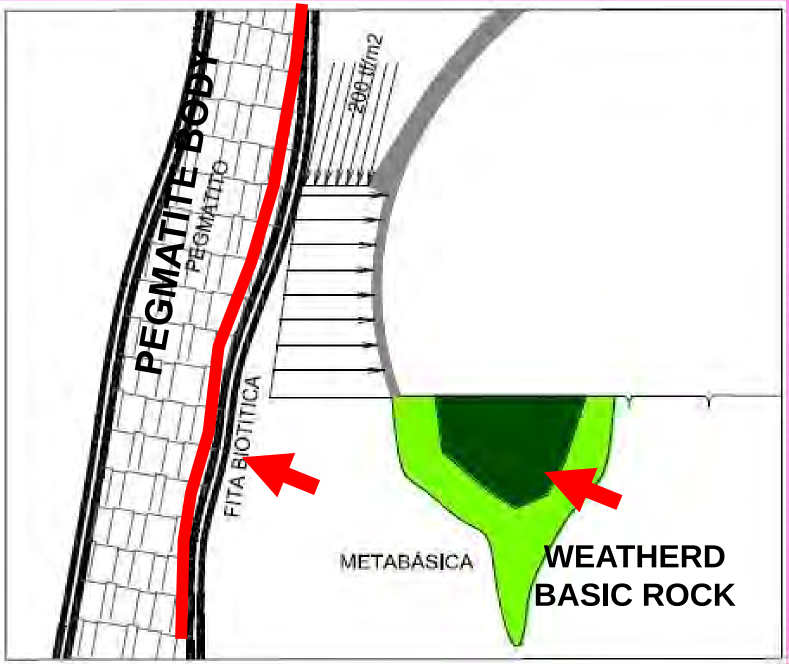
Day of collapse

Sao Paulo Metro Tunnel Collapse

Cause:

- Unforeseen adverse geological conditions
- Weak micaceous weathered layer within lateral rock mass

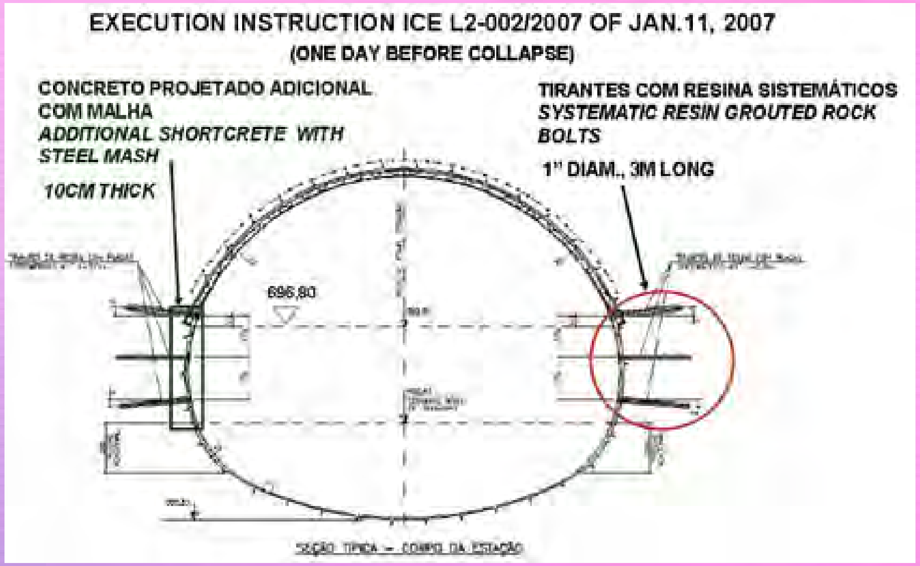




Sao Paulo Metro Tunnel Collapse

Meeting with designer day before failure on 11th January 2007:

- Designers recommended installation of 3 lines of rock bolting each side with 10cm mesh reinforced shotcrete



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Sao Paulo Metro Tunnel Collapse

Cause

- Unforeseen geology

  "*combined effect of a number of geological features, some of which were known at the time of the design some not foreseen, probably not foreseeable*"

- Insured failed to install rock anchors to walls of the first bench required for (foreseen and unforeseen) ground conditions encountered at this section

Sao Paulo Metro Tunnel Collapse

Policy Coverage:

- Design Exclusion DE3
- Tunnel wall (defective part if design 2)
- Resultant damage was collapsed of entire access shaft and TP property

Observation:

- Design 1) loss covered as geology unforeseen and design in strict sense error free
- Design 2) defective tunnel walls excluded, resultant damage covered

Conclusions

- Tunnelling is not an exact science
- Only experienced underwriters should insure tunnelling risks
- Underwriters should be familiar with the main considerations in the construction contract
- Most tunnel losses involve dispute in application of Design Cover /Exclusions
- Clear mutual (Insurers/Insured) understanding of extent of Design Cover/Exclusions, should be attained at inception of cover.

Thank you!