ALOP/DSU coverage for tunnelling risks?

This paper deals with potential Anticipated Loss of Profit / Delay in Start Up “ALOP/DSU” losses based on past property damage loss experience

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0 Editorial summary

Over the past decade, CAR insurers suffered major tunnel losses totalling nearly €600m (property damage only). Their reaction was to introduce tunnel clauses and publish a code of practice for tunnelling risks. The losses led to huge delays in completion (on average 19 months). Although these delays were not covered by an ALOP/DSU policy, the total loss of revenue or loss of profits which would have resulted can be estimated at roughly the same as the total amount of property damage losses. An as-if analysis of such major losses shows that the premium necessary to grant this cover is barely affordable, clearly proving the very high exposure of ALOP/DSU for tunnelling risks.

As nowadays tunnel projects worldwide are increasingly privately financed, the demand for ALOP/DSU coverage is growing steadily. At the same time, this type of financing results in higher constructional risks due to the choice in some cases of the cheapest bidders and to the shifting of responsibility from public bodies to constructors. Insurers are therefore faced with new challenges and must be aware of the enormous loss potential.

If ALOP/DSU cover has to be granted, there should be very efficient risk management measures in place and the delay to be indemnified should be strictly limited.

1 Historical background

1.1 Material damage

1.1.1 Underground risks – Construction

In 1860 underground construction work was started on a subterranean connection between the London stations Paddington and Farringdon. This, the first underground railway, was opened in 1863.

The construction of underground connections entails many special hazardous situations, which can be broken down into two main areas:

- Material damage to the construction works, construction machinery and facilities
- Material damage and bodily injury to third parties

Possible losses are:

- Collapse of the trench wall because of failure to adapt risk security measures adequately to the geological circumstances or to assess the geological circumstances properly
- Damage to third-party property, i.e. telecommunications lines, electricity cables, water pipes, caused directly by construction machinery equipment

Current tunnelling projects make use of new technical developments such as *automated electronic drilling rigs* with higher performance and greater accuracy that are easier to handle and require less experienced manpower
but,
involving installation that is more expensive and repair and maintenance that are more sophisticated.
Also new forms of *explosives* (emulsion types) are safer to handle, give off less toxic fumes and cause lower residues in muck, but involve more expensive installation and are more demanding in terms of handling and managing.

New support systems for difficult ground conditions (face bolting, jetting, pipe roof etc.) offer higher performance in difficult ground (larger headings, standardised working procedures) and higher degree of ground stability, but are more expensive installations and more demanding technically/organisationally.

New shotcrete concepts (fibre-reinforced shotcrete, shotcrete robots) lead to higher performance (less working steps, higher production rate) and a higher degree of safety, but normally are technically more demanding (concrete technology, maintenance).

New concrete concepts (self-compacting concrete) offer higher performance (no compaction, standardised concrete) and mostly slimmer constructions (linings, etc.) but the materials are more expensive and technically more demanding (concrete technology).

New installations for logistics ("backup systems") ensure higher overall performance (optimisation of logistics) and separation of heading and invert construction in combination with installations close to the face, but are more expensive installations that require more sophisticated levels of maintenance and repair.

Developed geotechnical measurement technologies lead to a better understanding of tunnel/rock interaction and to a higher safety level. Advanced measurement technologies (probing ahead of tunnel face) offer a better awareness of oncoming ground conditions and facilitate planning of excavation and support work.

Trends in tunnelling entail larger sections (for example triple-lane tunnels) in more difficult ground conditions such as loose ground, groundwater, poor rock conditions and close to the surface. Urban tunnelling under overbuilt areas (city areas) and close to the surface entails higher risk exposures. The projects become larger – longer tunnels – with difficult auxiliary projects parts. The application of alpine rock tunnelling methods even in "non-alpine" types of ground requires special risk assessments.

Risk assessment

New technical developments generally lead to a higher degree of mechanisation and automation, more costly installations, higher performance and less manpower (reduction of human factor).

"Wrongly chosen" or "experimental" installations will lead to *higher risks*, with a high impact on costs, a larger quantity of bound capital, greater pressure on costs and schedules, and increased dependency on highly skilled and trained personnel.

1.1.2 Major loss history

The table below gives an overview of some major tunnel losses that have occurred since 1994.

Although the total of the known losses amounts to €536m, the current estimation of the total loss amount including the "t.b.a." is in excess of €570m.

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

1.1.3 Reactions of the markets

Prompted by this tremendous loss amount, many insurers now refrain from underwriting CAR tunnel risks in the same way as they did in the past; instead, they have come up with wordings for new tunnel clauses and have published a Code of Practice for Risk Management of Tunnel Works, which can be found on the IMIA website (link). The objective of this code is to promote and secure best practices for minimising and managing risks associated with the design and construction of tunnels, caverns, shafts and associated underground structures.

1.2 ALOP/DSU

1.2.1 List of tunnel projects with ALOP/DSU coverage

Although the losses mentioned above led in many cases to tremendous delays in completion, most of these projects were not covered by an ALOP/DSU insurance. Nevertheless, we below mention some major projects either completed or still under construction for which an ALOP/DSU insurance had been placed or is still in force:

Channel Tunnel (completed)
Airport Link Company, Sydney (completed)
Heathrow Express Link (completed)
Eastern Harbour Crossing, Hong Kong (completed)
Cross-City Tunnel, Sydney (completed)
Taiwan High Speed Railway (due to be completed in October 2006)
Kowloon Southern Link, Hong Kong (under construction)
KCRC East Rail extension, Hong Kong (under construction)
Lane Cove Tunnel, Sydney (under construction)
Perpignan–Figueras, France-Spain (under construction)
DLR Woolwich Arsenal, London (under construction)

1.2.2 Financing of projects/Responsibility for delays

BOT – Build-Operate-Transfer

“A builder builds you a house – a BOT builder builds you a home”

“Normally you go for the cheapest, but with BOT it is different. For the first time in the history of construction, there is an actual incentive for quality improvements. The long term operation ensures that you can produce quality so you do not have to put the same level of finance into the future maintenance”.

In Europe, it started during the late 1980s when some governments realised that a public-private financing system can bring advantages to public services. For political reasons, tax-funded operations are often short-changed in terms of public investment in new facilities. Most of the time, funding is only sufficient for minor extensions or refurbishments.

BOT means Build-Operate-Transfer – an unusually large project where the grantor (often a nation or a government board) gives a private company a concession to build and operate the project within its jurisdiction for a term (invariably long) of the concession, receiving revenues from the income of the project output purchaser (and not directly to the consumers/end users) and transferring the project assets to the grantor at the end of the concession.

By the very nature of a BOT project – involving sovereign countries, private international investors, huge costs, long duration and other complex issues – there is bound to be a plethora of legal, commercial, political, social and economical aspects that assume importance. These are nowhere else better reflected in the sheer numbers of parties involved and the number of documents that record their relationships.

Here follows a short summary of the current situation:

BOT projects mean that governments accept two things – in certain aspects of serving their citizens, they have no choice but to seek external assistance (whether in the form of finance, technology or otherwise); and secondly, in several aspects it is commercially prudent to swallow your pride and let the private sector take over.

There are a number of parties involved – the grantor, input supplier, lenders, offtake purchaser, operator, project company, project participants, shareholders and/or investors, insurers, etc.

Similarly, there are a number of documents that record these arrangements – financing agreement, shareholders’ agreement, concession agreement, offtake purchase agreement, input supply agreement, construction contract, operation and maintenance agreement and other direct agreements.

The trend is global and very clear. The public financing possibilities for large infrastructure projects are limited and will probably decrease. Public authorities both in developed and undeveloped countries have to find new financial solutions. Here you can see forms like BOT, BOOT (Build-Own-Operate-Transfer), PFI (Public Finance Initiative), PPP (Public Private Partnership), which all mean more or less support of private financing. However, it also means a giant outsourcing from state and city controlled projects to private actors.

The large international construction companies are definitely important actors in this game, sometimes under internal divisions called “concessions”. The trick is to find win-win solutions for both public investors and for the private actors. The United Kingdom could be mentioned as one of the pioneer countries, where BOT or PPP (Public Private Partnership) or PFI (Public Finance Initiative) started.

BOT, PPP, PFI, etc. are parts in a larger trend where the major construction companies are increasingly becoming service providers. The construction companies are upping their involvement in construction, part owning and operation, and will be involved in facility management.

BOT has proven its ability to boost development in many countries to fulfil the needs, requirements and expectations of so many different parties or interest groups.
The long-term aspect of BOT projects is perhaps the most important distinction between BOT and “normal” business. The provider is responsible for delivering services for sometimes as much as 50 years; it is important to take seriously the notion of life-cycle design and management in the physical facilities.

The world’s largest BOT project

The Taiwan High Speed Rail Project is currently the world’s largest BOT project, with a total cost of more than €13bn.
The Taiwan High Speed Rail Project is a high-speed railway with twin tracks, with a maximum speed of 350 km/h. The project began in May 2000 and inauguration is planned for autumn 2006.

Responsibility for delays – Effects on risks

“Money shortage” due to more private financed projects (BOT, etc.), with contracts awards often going to the cheapest bidder. The client representatives might be less competent due to tunnelling projects also in “non-classical tunnelling countries” (for example Holland, Ireland) and can have an effect on national interests. They are also “new players”.

Highly complex structures and organisations are the cause of very many “satellites” circling around the projects (working groups, boards, specialists, etc.), sometimes with no clear allocation and sometimes with different people having the same responsibilities and duties. These structures and organisations can also lead to the splitting of technical and other responsibilities (contractual, etc.) and also to the increasing influence of lawyers.

The contractors are experiencing overcapacities due to shrinking markets (parts of Europe) and new players coming in from eastern Europe, China, etc. There is high pressure on costs due to creditworthiness and low margins. New forms of contract are coming, such as private financing that include operation and lump sum contracts. In addition, joint ventures with local contractors may lead to higher risks (language, culture, etc.).

Over-regulated contracts and the shifting of responsibilities will mean not only higher risks due to a lack of flexibility but also costs and time overrun owing to a failure to react appropriately as the allocation of responsibilities is unclear.

- *Higher risks are expected from accepting the cheapest offers, from the tendency to “avoid any unnecessary risks” (uneven risk distribution), from compensation by large organisations and from very restrictive contracts.*
- *Higher risks also come from accepting high constructional risks, using a less experienced labour force, cutting back on quality, safety, etc. and risk and claims management.*

Complex organisations, a plethora of law-related contractual conditions and spreading responsibilities widely do not compensate for fair contracts, fair prices and the involvement of experienced people willing to take on the necessary responsibilities.

1.2.3 Reasons for increasing demand for ALOP/DSU coverage

On the one hand, the demand is there to build tunnels in big cities and urban areas to meet the needs of an increasing urban population for utilities and underground transportation systems (new railways in Asian and South American cities, extension of existing railways in North American and European cities). On the other hand, these infrastructure projects, which used to be planned and financed by official bodies some decades ago, are being planned and financed privately to an ever-greater degree due to an increasing shortage of public funds in many countries. This is done by way of BOT contracts (Build-Operate-Transfer) or PPPs (Public-Private-Partnership).
The projects are financed, built, operated, and maintained by a private company under a public-works concession contract. It is of utmost importance that these projects are commissioned on schedule to earn operational revenues in order to reimburse the lenders. Thus the risk of a possible delay in construction resulting in a loss of revenues cannot be taken by private companies. For this reason, they look for ALOP/DSU coverage.

Therefore, the increasing need to build tunnels – combined with a change in their financing – results in a tremendous demand for ALOP/DSU cover. This trend has been observed in all continents over the past few years.

2 As-if ALOP/DSU loss history

The chart below shows the delays (in months) from 14 major tunnels losses over the past decade. It has to be emphasised that for those projects with delays no ALOP/DSU cover had been in force as it had not been requested, with the exception of Heathrow Express Link. The delays are nonetheless known to us and are given here for the sole purpose of enabling us to make an as-if calculation.

Major tunnel consequential losses delays in month

O/C Y	Project	Type of contract	Method	Type of loss	Cause of loss	Months
1994	**Great Belt Link, Denmark**		**TBM**	**Ingress of water**		**12**
1994	**Munich, Germany**		**NATM**	**Collapse**	Faulty design(soil)	**10**
1994	**Heathrow Express Link, UK**		**NATM**	**Collapse**	Faulty workmanship	**14**
1994	**Taipei Metro, Taiwan**		**TBM**	**Ingress of water**	Faulty workmanship	**12**
1995	**Los Angeles Metro, USA**		**TBM**	**Collapse**	Faulty workmanship	**15**
1995	**Tapei Metro, Taiwan**		**TBM**	**Ingress of water**	Faulty workmanship	**18**
1999	**Hull Yorkshire Tunnel, UK**	Design and build	**TBM**	**Collapse**	Faulty design?	**26**
1999	**Anatolian highway, Turkey**			**E/Q**	E/Q	**36**
2000	**Taegu Metro, Korea**		**Cut and Cover**	**Collapse**	Faulty design/work	**9**
2000	**TAV Bologne – Florence, Italy**		**NATM**	**Collapse**		**0**
2002	**Taiwan High Speed Railway**	Design and build	**NATM**	**Collapse**		**0**
2002	**Autoroute A86 – Rueil, France**		**TBM**	**Fire**		**6**
2003	**Shanghai Metro**		**Freezing**	**Collapse**	Faulty workmanship	**47***
2004	**Singapore Metro, Singapore**	Design and build	**Cut and Cover**	**Collapse**	Faulty design/work	**18***
2005	**Barcelona Metro, Spain**		**NATM**	**Collapse**		**24***
2005	**Metro Lausanne, Switzerland**			**Collapse**		**t.b.a.**
2005	**Lane Cove Tunnel, Sydney,**		**NATM**	**Collapse**		**0**
2005	**Kaohsiung Metro, Taipei**		**TBM**	**Collapse**	Faulty workmanship	**24***
	14 major losses with resulting delay				**Total**	**> 271**

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

If we were to assume that each of these risks had had an ALOP/DSU cover with an annual sum insured (SI) of €30m (i.e. €2.5m per month) and with a time excess of three months, then the above-mentioned tremendous loss amount of €570m (PD only) would have been doubled (total as-if ALOP/DSU loss amount €572m), with the probable consequence that some insurers would have stopped writing tunnel risks.

3 As-if calculation of an ALOP/DSU net rate

- Loss frequency

  The first step is to determine the major loss frequency. We will assume that the net tunnel CAR rate should have been 1% over the last decade to achieve a net loss ratio of 100%. Therefore, based on the total PD loss amount we can calculate the total sum insured of all tunnel projects as follows:

  TSI = 570/1% = €57,000m

  The second assumption concerns the average value of a tunnel project.
  Experience over the year 2005 shows €375m.
  Hence the number of projects insured: 57000/375 = 152
  The loss frequency is the number of losses divided by the number of projects insured: Loss frequency = 14/152 = 9.2%

- Average delay = 271/14 = 19.4 months

- Estimate of an “as-if” ALOP/DSU net rate

  In this calculation, we will take into account a six-month time excess.
  The net ALOP/DSU rate would be the result of the multiplication of the loss frequency by the average delay minus six months (per year, therefore divided by 12)

  Net ALOP/DSU rate = 9.2%x(19.4–6)/12 = 10.3% of annual SI

- Conclusion

  Needless to say that such a net rate is not affordable. Even if we were to assume that the average value of a tunnel project was only €250m, the net ALOP/DSU rate would be 6.8%.

  Due to the many assumptions and approximations, a net ALOP/DSU rate can evidently not be exactly determined, but a rough estimate seems to be around 8.5~9% of the annual SI, which still makes the price of this cover hardly affordable.

  This price reflects in fact the very high exposure of this type of cover. For this reason, some market players are nowadays very reluctant to grant this cover.

4 Loss example

We can classify the types of losses affecting tunnelling under the following categories:

1. Natural events
1.1. Earthquake
1.2. Flooding of the tunnel from adits

2. Fire
2.1. Fire spreading from the TBM or other equipment (locomotives, transformers, etc.)

3. Collapses
3.1. Due to faulty design, material, workmanship
3.2. Due to unexpected geological conditions (chimneys, front collapse, etc.)

4. Other type of loss
4.1. Water inlet
4.2. Deformations (squeezing, cracking of lining, etc.)

5. Losses to tunnelling equipment (TBMs)
5.1. Internal breakdown (main bearing, gear boxes, etc.)
5.2. Losses to TBM due to external obstacles found during excavation

In the previous list of 18 major losses referred to in Section 1.1.2, we have only one fire loss, one E/Q loss, three ingress of water, and 13 collapses. We will concentrate below only on collapse losses.

4.1 Hull Sewer Tunnel. Date of loss: 16 November 1999

Description of project

The Hull flow transfer tunnel was constructed for Yorkshire Water to direct sewage flows to a new treatment works. This 10.6 km, 3.6-m-diameter tunnel was bored using an EPB TBM. The tunnel was driven at depths of 15–25 m through water-bearing glacial and alluvial soils under the north bank of the River Humber. The project included ten shafts spaced at up to 1.8 km of 7.5–12.5 m diameter and depths of up to 30 m. The tunnel lining comprised a six-segment, tapered trapezoidal, 250 mm thick conventionally reinforced ring with EPDM gaskets.

Ground conditions surrounding the tunnel comprise alluvial and glacial deposits. The alluvial deposits consist of clay, silt, sand, gravel and peat, which lie on the glacial deposits comprising clay, fine to medium sand and gravel. The upper chalk is at depths beneath the tunnel.

Two aquifers are present along the route. The upper, hydrostatic, aquifer is approximately 2 m below ground level. The second is tidal, situated beneath the laminated clays, in the lower glacial deposit and chalk.

Loss occurrence

The incident occurred after considerable tunnelling was complete, in a section next to a shaft. The section seat of the incident had been completed for eight days.

At 00.30 hrs, signs of water inflow at a segment joint was reported at a point some 200 m behind the face of the TBM. The water was carrying fine sand into the tunnel. Despite efforts to stem the flow of material, water and sand inflow levels rapidly increased and the tunnel became destabilised.

At 03.00 hrs the same day, the tunnel was evacuated and subsequently collapsed. The collapse was focused some 6 m to the east of a maintenance shaft. Immediately following the collapse the nearby A63 road was closed and properties evacuated; both as precautionary measures.

At the location of the collapse, the ground surface sank by some 2.5 m within a depression some 60 m in diameter. In total, approximately 100 m of tunnel was affected by the collapse.

Cause of the loss

No immediate cause for the collapse was apparent. The investigation methodology included intensive ground investigation of the collapse location. A three-dimensional model was developed of the soils to assess the possible modes of failure.

The leaks are most likely to have been caused by movement of the tunnel relative to shaft T3, which led to opening up of the circle joints and shearing between adjacent rings, causing local structural failure around the gasket.

The movement was most likely attributable to compression of the peat above the crown, caused by the upward buoyant pressure of the tunnel combined with loosening of the ground by shaft sinking/tunnelling and dewatering of the peat layer by a leak into tunnel or shaft.

Planning the repair

Several options, including tunnel diversion, cofferdam construction, jet grouting and artificial freeze were reviewed for the reconstruction of the tunnel. With the exception of tunnel diversion, all options considered involved stabilising the ground and reconstructing the collapsed section of tunnel along its original alignment.

Supporting the ground by artificial ground freeze and supporting the tunnel with a sprayed concrete lining was adopted, as this was deemed to provide the optimum solution when considering the local ground conditions, safety, programme, build ability and cost.

Repair works

The reconstruction of the collapsed section was conducted in five stages. The length of the construction stages was governed by drilling constraints and ranged from approximately 20–25 m in length. The tunnel axis was at a depth of approximately 15 m below ground level. Each construction stage was supported and closed to the surrounding ground and ground water horizontally with a circular ice wall and vertically with a frozen bulkhead.

A road header, with the capability of using either a rotary cutter or a pneumatic breaker was used for excavation. Hand mining was used to trim the profile. The shotcrete was batched using heated aggregates and hot water. In addition a geocomposite insulating layer was attached to the side of the tunnel prior to spraying the shotcrete.

The overall delay in completion resulting from the time necessary for soils investigations, redesigning and repairing the collapsed section was 26 months.

4.2 Shanghai Pearl Line Stage II Project. Date of loss: 1 July 2003

Description of project

The Shanghai Pearl Line Stage II Project is an extension of the existing Shanghai Metro system. It comprises twin tubes excavated by a TBM with an external diameter of 6.2 m. The distance between the tunnel centre lines is 11 m. The total length of the project is 22 km. The project includes the construction of 17 stations.

The incident giving rise to this claim occurred within the section of the project between stations at Pudong Nan Lu Road and Nanpu Bridge. The distance between these stations is

2,000 m. 440 m of the tunnels lie below the Huangpu River. Both tunnels have been constructed at the same depth, with the deepest section having 37.7 m of cover.

At a point approximately 50 m from the river is a ventilation shaft above a cross-tunnel connecting the two main tunnels.

Loss occurrence

At the time the incident occurred, both main tunnels had been completed between the Pudong Nan Lu and Nanpu Bridge Stations. The box section of the ventilation shaft had also been constructed and work was ongoing on the construction of the cross-tunnel between the main tunnels.

Ground freezing had been undertaken to provide a workable medium through which the cross-tunnel was being excavated by traditional mining methods from the downstream tunnel to the upstream tunnel.

As the excavation works had reached the upstream tunnel and the concrete rings of the main tunnel had been removed to allow the connection of the cross-tunnel into the main tunnel, there was a sudden flow of water and soil into the tunnels. This flow could not be stopped and within a short period of time extensive catastrophic damage had been sustained to the tunnels and to third party properties on surface.

Possible development/Worst-case scenario

The insured and the municipal authorities were faced with a catastrophic situation. The incident occurred at around 3.00 a.m. and by 6.10 a.m. the authorities had appointed Academician Liu Jiansheng to coordinate the efforts of numerous experts in response to the evolving risk. The worst-case scenario was considered to be that the damage to the tunnels could extend to the two neighbouring stations. 2,000 m of tunnels could be totally damaged between the stations at Pudong Nan Lu Road and Nanpu Bridge.

Mitigations measures implemented

The following measures were implemented:

- Cut off the tunnels and inject water into them in order to equalise soil and water pressure
- Reduce extra loads and prevent thrust and vibration to the ground
- Prevent water from Huang Pu river flowing in and increasing damage to the tunnels
- Stabilise the ground
- Provide support services to secure works and ensure safety

These measures were implemented within 15 days.

Nature and extent of damage

Although the most severe settlement at ground level was recorded at 4 m, the greatest settlement of the tunnels occurred directly below the ventilation shaft where 9 m of settlement was recorded. In total, a 250-m length of each tunnel was discovered affected by the subsidence, of which approximately 50 m were beneath the river.

Seven buildings had to be demolished and nine others had to be repaired.
The 120-m-long flood protection wall was severely damaged, a 60 m section collapsed entirely. Nearby roads, a pumping station and public utilities were affected to varying extent.

The accident was caused by the combination of faulty workmanship together with the breakdown of the ground-freezing equipment a few days before, allowing the ground to start thawing. Shortly before the accident occurred, an order was given to remove a wooden sealing board from the excavated face and drill a hole of 0.2 m diameter into the face with a pneumatic drill.

Repair works

The planning of the repair works took place between July 2003 and May 2004 (11 months). After considering different alternatives (including a new route), the less expensive and less time-consuming method was chosen. The repair works are to be executed in open trenches including the section beneath the river, where a river cofferdam platform is to be built. This will be done in two phases to minimise disturbance of traffic on surface. The repair works began in May 2004 and are scheduled to be finished by May 2007.

This is the longest delay (47 months) encountered in tunnel construction loss history.
It can be summarised as follows:

- Two weeks of mitigation and emergency measures
- 11 months of planning followed by
- 36 months of repair works

4.3 Lessons learned: Why is the delay so high?

Generally speaking, when a collapse occurs during tunnel construction the first step is to prevent an extension of damage to third-party property on the surface. This is mainly achieved by pouring all kind of materials (concrete, earth, rock) into the crater and sometimes by flooding part of the tunnel too. These mitigation measures have to be taken very rapidly and are only intended to minimise damage on the surface. This means that first it will make the access to the damaged section more difficult, thus delaying the assessment of the extent of the underground damage, and then the removal of all the materials that were hastily poured in will make the repair works more difficult and more time-consuming.

These mitigation measures are always taken before it is even possible to hazard a guess at the cause of the accident. It will then take a long time to assess the extent of the damaged area and the cause of the collapse. In most cases, additional soil investigations are then necessary to determine the cause of the loss and to plan the repair method.

Very often the repair method differs from the original method, making the repair works more costly and time-consuming. As a tunnel is nothing but a void, the underground repair of any given collapsed section will first have to restore and stabilise a “new soil” through which a new void will have to be re-excavated. The stabilisation measures can include grouting, ground freezing, compressed air. All these additional measures are very time-consuming. If an underground repair is not possible, an open cut or trench has to be dug from the surface. In exceptional cases, a repair will not be possible so that a new route has to be chosen, making the overall delay even longer.

Otherwise as in EAR, especially when the loss occurs during testing, there is no way of reducing the delay by means of extra charges for speeding up the delivery of spare parts or of new machines.

5 Conclusion / Recommendations

5.1 Code of Practice for Risk Management of Tunnel Works

5.1.1 Had the code been in force: Which of the previous losses would probably not have occurred?

As mentioned above in the history part, one of the reactions after the occurrence of major tunnel losses was the publication of the tunnel joint code of practice. One can also reasonably ask what effect the code would have had on this major loss history had it been in force. This is of course a very speculative exercise, but nonetheless we assumed that the TCoP would have probably prevented some of the losses due to faulty design or faulty workmanship. We reviewed all the losses one by one. The losses that would have been prevented according to our opinion are given in the list below.

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

Our assessment was made on basis of the following assumptions. If proper ground investigation and design checks had been done, if risk management procedures had been in force, like laid down in the TCoP, the following losses would probably not have occurred: Munich (insufficient ground investigation); Heathrow (faulty design combined with poor workmanship); Taipei (Inappropriate measures to ensure watertightness during launching and arrival situations of TBM's); Taegu (faulty design of diaphragm wall); Singapore (faulty design of diaphragm wall); Barcelona (insufficient ground investigation and insufficient monitoring of deformations).

5.1.2 New as-if calculation of an ALOP/DSU net rate

As before, we have to calculate the new loss frequency (number of losses divided by number of insured projects):

- Loss frequency = 7/152 = 4.6%
- Average delay = 166/7 = 23.7 months
- Estimate of an "as-if" ALOP/DSU net rate

We will again take into account a six-month time excess, the net ALOP/DSU rate being the result of the multiplication of the loss frequency by the average delay minus six months (per year, therefore divided by 12):

Net ALOP/DSU rate = 4.6%x(23,7 – 6)/12 = 6.8%

Even if we were to assume that the average value of a tunnel project was only €250m, the net ALOP/DSU rate would be 4.5%. A rough estimate seems to be around 5.5% of annual SI, which still makes the price of this cover hardly affordable

5.2 How can ALOP/DSU for tunnelling risks be covered?

To make this cover affordable (and therefore insurable), the net ALOP/DSU rate on annual SI should be in the range of 2.5% or more. Based on the known losses and assuming the TCoP will be complied with, this would mean that the indemnity period has to be limited.

5.2.1 Limitation of the indemnifiable delay

To reduce the indemnifiable delay, one should first exclude such delays caused or aggravated by the following:

- Loss or damage to TBMs or other mechanical equipment
- Stoppage of works due to enquiries from any authorities (e.g. losses involving casualties)
- Time needed to re-design and agree changes in the geological model, tunnel supports, method of excavation
- Measures required for special ground treatments in crossing faults or other areas involving particular difficulties (change in ground condition, water inlet, etc.)
- Construction of caverns or shafts required to free or repair a damaged TBM
- Use of special solutions (compressed air, ground freezing) in the event of works carried out under water table

Then it should be useful to limit the indemnity period to a maximum of … months. In line with the calculation given above (Section 5.1.2), a maximum of 12 months would permit to obtain an "affordable" net rate.

Furthermore, one could think of linking the indemnifiable delay and the length of the immediate damaged section.

5.2.2 Example of endorsement

Section III – ALOP/DSU
Special conditions concerning projects involving the construction of tunnels and galleries

For the purpose of this Section, the indemnifiable delay in the commencement of full Commercial Operation of the Project attributable to each occurrence of Damage is the delay directly due to and not exceeding the time taken to complete the repair or reinstatement of each occurrence of Damage to its condition prior to such occurrence without taking into account any further delay attributable to :

- Loss or damage to TBMs or other mechanical equipment
- Stoppage of works requested by any authorities
- Measures needed to stabilise the ground condition immediately after the loss occurrence
- The time needed to design the repair method and to redesign the further excavation method
- Measures which become necessary to improve or stabilise ground conditions before the repair can be done
- Construction of caverns or shafts to free or repair a damaged TBM

The indemnifiable delay in days attributable to occurrences of Damage affecting tunnels and galleries shall in addition be limited to x days per metre of the immediate damaged section.

Maximum recommended indemnity period: 365 days

5.2.3 A specific issue: ACOW and ICOW

Besides DSU coverage, which indemnifies the insured for loss of revenue resulting from delay in completion, CAR policies can also provide cover for costs incurred to prevent or reduce this delay. Among these clauses, the following are discussed below:

- Additional cost of working (ACOW)
- Increased cost of working (ICOW)

ACOW coverage is sometimes provided under Section 1 of the policy for the benefit of contractors. It provides cover for additional costs incurred by the contractor (with an adequate sublimit) for the purpose of preventing or minimising a delay following an indemnifiable loss, so he can meet his contractual requirements for completion.
It is an extended form of the expediting expenses cover: where the latter solely indemnifies overtime, night work etc., ACOW provides wider cover for additional costs of construction, e.g. costs incurred following changes in the work programme or in the method of working.

An example of wording for that clause is:

The Insurers shall indemnify the Insured in respect of the additional costs necessarily and reasonably incurred for the sole purpose of preventing or minimising the interruption of or the interference with the carrying out of the Project/Contract in the event of delay in completion of the Project/Contract due solely to loss or damage to any of the Property Insured for which liability has been admitted under Section 1 of this Policy.
(…)

The reference to the project or contract completion is important: if the project is already delayed due to other unrelated events, then the impact of the loss on the project schedule may be nil, whereas its impact on the contract schedule may be significant.

ICOW coverage is provided under the Advance Loss of Profits Section for the benefit of the principal. It provides cover for additional costs of construction incurred to reduce a delay resulting from an indemnifiable loss under Section 1 of the policy. The indemnity is capped by the loss of profits thereby avoided, and therefore this coverage is in principle mutually beneficial to the principal and to the insurers.

The clause usually reads as follows:

The Insurers will indemnify the Insured in respect of the increased cost of working (…).
The amount payable as indemnity shall be:
The additional expenditure necessarily and reasonably incurred for the sole purpose of avoiding or diminishing the reduction in turnover which, without such expenditure, would have taken place during the indemnity period, but not exceeding the sum obtained by applying the rate of gross profit to the amount of the reduction in turnover thereby avoided.
(…)

In the case of large infrastructure projects involving tunnels, many questions can arise about the way these clauses operate. The construction period being usually several years, the impact of an incident on the construction schedule can be difficult to assess.

For example, if the material damage loss occurs long before the anticipated date of completion of the project, should increased costs of construction be incurred although there is no certainty that other insured or uninsured events will not cancel out the impact of the loss on the construction schedule?

The following example illustrates the difficulties in applying these clauses:

On a major infrastructure project involving ten civil contracts running simultaneously, a major tunnel collapse occurs three years before completion.

The material damage claim is adjusted according to the policy conditions and a limit of x% of the original cost of construction is applied, thereby causing a shortfall in the recovery of the repair costs by the contractor.

The contractor then seeks compensation under the ACOW clause of the policy (Section 1) for the increased costs experienced in completing the undamaged remainder of the tunnel. As stated above, the clause considers costs incurred to minimise a delay which is “due solely to loss or damage to any part of the Property Insured”. Should ACOW apply only to the repair works or should it extend to cover undamaged items as well?

In addition, the principal posts an ICOW claim under Section 3 (DSU) of the policy.

The ICOW claim comprises three elements:

- An amount (mainly for grouting works) paid to the contractor
- The cost of accelerating works under other contracts in order to minimise the overall delay
- The principal’s own costs

For them to be indemnified, each of these elements must be

- necessarily and reasonably incurred;
- incurred for the *sole purpose* of avoiding or diminishing delay to the scheduled date of commencement of the insured business;
- not in excess of the sum calculated by applying the formula of the Operative Clause.

The key issues are first the nature of the costs incurred and claimed, and second the situation of the project in respect of the contractual construction schedule.
In the present case, the grouting works constituting the first element of the ICOW claim are part of the reinstatement measures of the collapsed section and as such indemnifiable under

Section 1 of the policy. These costs cannot be considered as being “incurred for the sole purpose of diminishing delay”.

Concerning the second element of the ICOW claim, it can be argued that at the time the decision to incur increased costs of working was made, the delay of the project was within the time excess under Section 3 of the policy and that therefore the economic test (point 3 above) is not met. In other words, it was the principal’s decision to incur these costs to avoid a loss, but at that time the loss was at the principal’s risk.

These examples show the complexity involved in applying the ACOW and ICOW clauses and the potential disputes which can arise during the adjustment of claims. When providing this type of coverage, one should pay attention to the following:

- ACOW coverage is provided under the Material Damage Section of the policy. Any payment under this clause should be considered as part of the overall settlement of the MD claim. In particular for tunnel risks, the ACOW sublimit should be included in the limit of indemnity (usually expressed as a percentage of the original cost of construction of the damaged section), in the same way as the sublimit for debris removal.
- ICOW coverage is provided under the DSU Section and as such is subject to an economic test. For lengthy infrastructure projects, many of which include tunnelling works, a thorough follow-up of the construction schedule is necessary to determine at the time of the loss whether increased costs of working should be incurred or not.

5.3 General conclusion

Up to now there has not been any ALOP/DSU loss to our knowledge. Some insurers seem not to be aware of the tremendous loss potential of ALOP/DSU coverage for tunnelling risks and have shown some appetite for this kind of risk.

The risk assessment should take into account the following elements:

1. Contractual conditions
1.1. Have any contractual provisions been included that would have the effect of adjusting prices in line with actual geological conditions (are there any provisions in this sense or is the contract a lump-sum one)? In the event of a fixed-price contract, what geological uncertainties have been taken into account in estimating the price?
1.2. Who is responsible for the geological information used in estimating the contract price?

2. Geological information available
2.1. Source and reliability
2.2. Extent of the geological report
2.3. Remaining uncertainties (faults, presence of water, presence of squeezing or other phenomena requiring particular solutions)

3. Designer experience

4. Method of excavation to be used

5. Contractors’ experience with the method of excavation to be used

6. Monitoring of works and quality control at site

7. Contingency measures available to minimise risk exposure. Flow chart for decision-taking in the event of an emergency

8. Buffer time available in the event of a loss / Position occupied by tunnel activities in respect of the critical path

Before granting an ALOP/DSU cover for a tunnelling risk, the underwriter should bear in mind that besides the general underwriting considerations given above, which are of course of enormous importance, once a tunnel collapse loss has occurred normally no mitigation measures can be taken to reduce the delay.

Therefore, from our point of view it is of the utmost importance on the one hand to try to reduce the probability of a loss occurrence and on the other hand to limit the indemnifiable delay.

This can be achieved by way of full compliance with the Code of Practice for Risk Management of Tunnel Works and by stipulating the above endorsement.