

## TUNNEL INSURANCE - FACTS AND TRENDS

### EXECUTIVE SUMMARY

This paper aims in providing a brief review of the challenges confronted with by the tunnel Underwriters in their day to day business, seen from the perspective of an international senior loss adjuster and geotechnical engineer specialized in tunneling losses. Following discussion of the recent trends in the tunnel industry and the common procedures and approaches presently in use in the insurance market, it attempts to provide some hints and recommendations that could assist Underwriters in their work. These hints and recommendations focus mainly on the enhancement of the underwriting process in conjunction with the application of an improved risk monitoring during the construction stage. The paper concludes with the presentation of a case study referring to a recent tunnel loss in Turkey.

### INTRODUCTION

The acceptance of tunneling risks is one of the most challenging ones in the wide spectrum of engineering insurances due the great number of uncertainties inherent in this type of works, compared to many other construction projects carried out on the ground surface. As it is depicted from the brief overview provided in the following table,

PROJECT TYPE	COMMONLY CONSTRUCTED IN	GROUND UTILIZATION AS	IMPORTANCE OF PROJECT/GROUND INTERACTION	THIRD PARTY EXPOSURE
A. <u>On the Ground Surface</u> such as:  * Motorways * Airports * Dams * Bridges * Industrial Complexes * Power Plants	Non Residential (i.e. outside urban) Areas	Foundations Medium	Crucial but not Decisive	Moderate to Low
B. <u>Underground</u>  * Tunnels (Traffic, etc.) * Caverns	Urban Areas, mainly	Incorporating Medium	Most Crucial	High

*Tab.1: Basic differences in the requirements addressed by the 'on the ground' and 'underground' construction works*

- ✓ The construction of motorways, bridges, dams, airports, industrial plants, etc. usually takes place outside urban areas, for the ground being used mainly as foundation medium. Their execution typically involves a restricted volume of surface excavation whereby the requirements addressed to the designers and the contractors in predicting the anticipated interaction between the ground and the project are relatively easier to handle. Even if it goes wrong, the vast majority of the losses concern the project itself for the third party exposure remaining within reasonable levels.
  
- ✓ Most of the tunneling works to date refer to the construction of traffic tunnels being carried out almost exclusively in urban areas with a high population density. In this case, the works do not simply use the ground as foundation medium, but are rather incorporated therein. Their design and workmanship shall ensure that they become fully integrated into the given conditions of the ground without inducing undesired disturbances seriously affecting both the integrity of the works and the overlying third party properties.

The achievement of this task solely depends on the accuracy of the prediction of the interaction between the ground and the method employed in the excavation as well as the ability of the contractor and their appointed designers to closely monitor the progress of the works and timely react in terms of undertaking the necessary proactive actions.

### **BRIEF HISTORICAL BACKGROUND**

The history of tunnel construction fades back to ancient times, but its relevance for the insurance industry in modern times begins in 1860 with the implementation of the first underground railway connection between the stations Paddington and Farrington in London. It is since that time when tunneling started to become a sovereign and autonomous branch within the civil engineering discipline, accompanied by comprehensive scientific research done by a number of reputable practitioners in this field providing an extraordinary pioneer work that never lost in actuality.

Notwithstanding the huge experience and technological advancements accumulated in the meantime by the tunnel construction industry, tunneling insurance was proven to be a risky business as revealed by the great frequency of major tunnel losses reported in the interim period. More especially, the increased number of the costly tunnel construction disasters since the early 90's, indicated in Table 2 below, started creating serious 'headaches' to the insurance community, as they threatened to reverse in medium terms the insurance of tunneling risks to unprofitable business.

Year	Project/Location	Type of Loss	Cause	Quantum (USD)
1994	Heathrow Express Link, London, UK	Collapse	Bad Workmanship	141 million
1994	Great Belt Link, Denmark - Sweden	Fire	Faulty Design?	33 million
1994	Great Belt Link, Denmark - Sweden	Flood	Bad Workmanship	34 million
1994	Munich Metro, Germany	Collapse	Faulty Design	4 million
1994	Taipei Metro, Taiwan	Collapse	Bad Workmanship	12 million
1995	Taipei Metro, Taiwan	Collapse	Bad Workmanship	29 million
1995	Los Angeles Metro, USA	Collapse	Bad Workmanship	15 million
1999	Bolu Tunnel (Anatolian Motorway), Turkey	Collapse	Earthquake/Faulty Design	115 million
1999	Hull Yorkshire Tunnel, UK	Collapse	Faulty Design	55 million
1999	TAV Tunnel Bologna-Florence, Italy	Collapse	Faulty Design/Workmanship?	12 million
2000	Taegu Metro, South Korea	Collapse	Faulty Design	24 million
2000	Porto Metro, Portugal	Collapse	Bad Workmanship?	?
2001	Porto Metro, Portugal	Collapse	Bad Workmanship?	?
2002	Autoroute A 86 - Socatop Tunnel, Paris/France	Fire	?	8 million
2002	Taiwan High Speed Railway	Collapse	?	30 million
2003	Shanghai Metro, China	Collapse	Faulty Design	80 million
2004	Singapore Metro, Singapore	Collapse	Bad Workmanship	?
2005	Kaohsiung Metro, Taiwan	Collapse	Bad Workmanship	?
2005	Barcelona Metro, Spain	Collapse	Bad Workmanship?	?
2005	Lausanne Metro, Switzerland	Collapse	?	?
2005	Lane Cove Tunnel, Sydney, Australia	Collapse	?	?
2009	Cologne Metro, Germany	Collapse	Faulty Design/Workmanship	?
2009	Cairo Metro, Egypt	Collapse	Faulty Design/Workmanship?	?
2012	Ankara – Istanbul High Speed Railway, Turkey	Collapse	Faulty Design/Workmanship	29 million
2012	NYC Harbor Siphons Project, USA	Flood	?	?
2015	Doha Metro Red Line, Qatar	Flood	?	?

**Table 2: Indicative summary of known tunnel losses**

As revealed by the close examination of the losses listed in the above table, the

- overall reported costs for the major tunnel losses known so far amounts to USD 621 million. However, when taking into consideration a reasonable margin for the non-quantified losses indicated in the table, the actual total costs may be well in excess of USD 800 million
- vast majority of these losses are attributed to tunnel collapses (nearly 81%), for the remaining ones being due to flood (11%) and fire (8%)
- most frequent causes of these losses were the (a) insufficient ground investigation and/or interpretation, (b) faulty design and/or workmanship, and (c) lack of appropriate measures or procedures in place which would enable the timely recognition of imminent problems and hence the implementation of the appropriate corrective actions as to ensure compliance with the acknowledged rules of the tunneling practice.

### **ACTIONS TAKEN BY THE INSURANCE INDUSTRY TO TACKLE THE PROBLEM**

It was in 2002, when the British Tunneling Society (BTC) was formally advised by the Association of British Insurers (ABI) of their intention to stop offering insurance on tunnel projects *“until something could be done to improve the situation”*.

As a response to this initiative, a team comprising of representatives from mainly British Insurers and the tunneling industry started working for almost two years on the development of a “Joint Code of Practice for Risk Management of Tunnel Works in the UK” aiming in ensuring, as declared, that tunneling works remains insurable. This Code was first launched in the UK in September 2003. However in January 2006, this code was in fact replaced by a more extended version issued by ITIG (International Tunneling Insurance Group) titled “Code of Practice for Risk Management of Tunnel Works”, intended for international use. This version of the Code was acknowledged and also supported by ITA (International Tunneling Association) and IMIA (International Association of Engineering Insurers).

Notwithstanding the widespread acceptance of this code since its first introduction in 2003, the skepticism in the insurance community regarding its applicability in the daily tunnel practice continued to persist even after the first revision of this code in January 2006. This skepticism prompted MRe in their presentation at the ITA conference in Seoul in April 2006, to the following objective judgments and rather pessimistic predictions:-

#### **1. General Trends in the Tunneling Industry**

- *High risk type construction methods*
- *Trend towards design + build contracts*
- *Unilateral contract conditions*
- *Tight construction schedules*
- *Low financial budgets*
- *Fierce competition in construction industries.*

## 2. Consequences for the Insurance Industry

- High frequency of major tunnel losses
- Insufficient premium income to pay for all losses
- Wide scope of cover indemnifies far beyond repair costs
- Repair costs exceeding original construction costs
- Insurance was cheapest risk management tool
- Tunneling insurance notoriously unprofitable business

## 3. Options for Insurers/Reinsurers & Consequences

### Options:

- Stop offering insurance and reinsurance for tunneling projects
- Increase rates, deductibles, restrict cover
- Tackle the problems with a professional approach, sustainable for all parties

### Consequences:

- Still an option for many market players
- Is insurance cover still affordable and worthwhile to buy for the customer?
- Risk Management: Joint Code of Practice

As confirmed by the persisting loss history in the almost 9 years that elapsed since this presentation, the vast majority of the trends and consequences described therein seems not to have lost their actuality. Even today the tunneling industry continues moving along the same trends, whereas the insurance community continues suffering from the same consequences as outlined in items 1 & 2 of this presentation. How does it stand with regard to the options suggested in item 3 of the MRe's presentation?

### a. "Stop offering insurance and reinsurance for tunneling projects"

Indeed, since 2006 a quite not negligible number of Insurers and Reinsurers, traditionally involved in this field, started to abstain from writing tunneling risks. But even this development did not help the remaining players to sufficiently improve their loss records.

### b. "Increase rates, deductibles, restrict cover"

Even though this measure was occasionally proven to be helpful, it did not really assist Insurers in reducing their exposure to reasonable levels in spite of the continuing trends in the tunneling industry. Worse, the increasing capital flood in the insurance market in recent years in conjunction with the growing competition, decrease in premiums and the appetite for new business associated herewith, in fact resulted in voiding this option.

### c. "Tackle the problem with a professional approach, sustainable for all parties"

Whereas the previous two options suggested in the MRe's presentation are rather defensive minded, it is only this third and last one which counts with the active involvement of the clients, however for the sole focus being actually given only on the compliance by the client with the risk management procedures specified in the "Code of Practice" of 2006. However and whilst looking back in the time, there are not too many examples suggesting that even this option really did assist in sufficiently "tackling the problem", as originally anticipated.

Major tunnel losses continued occurring with an unreduced frequency also after the formal introduction of this Code on a global level in January 2006, despite the interim launch of the

- 2<sup>nd</sup> and slightly revised edition of the Code by ITIG, ITA and IMIA in May 2012
- additional “*Tunnel Works Clause*” by LEG (London Engineering Group), also supported by ITIG and IMIA, in June 2014.

Following, we will take these Codes and Clauses in turn and briefly discuss their applicability and limitations in the day to day construction and insurance practice.

### **THE CODE OF PRACTICE FOR RISK MANAGEMENT OF TUNNEL WORKS**

The declared objective of this code is “*to promote and secure best practice for the minimization and management of risks associated with the design and construction of tunnels, caverns, shafts and associated underground structures...It sets out practice for the identification of risks, their allocation between the parties to a contract and Contract Insurers and the management and control of risks through the use of Risk Assessments and Risk Registers*”.

It is further stipulated in both editions (2006 & 2012) of the code that

- “*The adoption or recognition of this Code is voluntary. Contract Insurers are free to decide their own policy on risk management and underwriting and offer different policy conditions to their clients.*”
- “*Where this Code of Practice uses the words ‘shall’ and ‘must’, the procedure to which it applies is compulsory. Where the word ‘should’ is used then the procedure is recommended best practice”.* (our underlining).

As indicated by its title, the main focus of this Code is on the definition and systematic description of the risk assessment and management procedures to be applied in the various stages of the project. Its core constituents are the accurate identification of the hazards (alias **risk matrix**) and the establishment of a **risk register** functioning as a ‘live’ document, dealing with the allocation of responsibilities (ownership of risks) as well as the control, mitigation and management of the risks inherent to the project.

Following elucidation of the “*Client Role and Responsibilities*” (project owner), it provides detailed guidelines outlining the particulars and applicability of the risk assessment and management procedures to be employed both by the owner and the contractor in each individual stage of the tunnel works as follows:-

#### **1. Project Development Stage**

- Site and Ground Investigations
- Assessment and Evaluation of Project Options
- Project Development Design Studies

## 2. Construction Contract Procurement Stage

- Preparation of Contract Documentation for Tendering Purpose
- Selection of Pre-qualification of Contractors for Tendering Purpose
- Time for Tendering
- Tender Risk Register

## 3. Design Stages

- Transfer of Information Between Designers
- Design Process
- Design Checks
- Constructability Issues
- Validation of Design During Construction

## 4. Construction Stage

- Pre-construction Activities
- Risk Management Procedures (regular monitoring & review of the risk register)
- Contractors' Staff and Organization (selection criteria & duties of key personnel)
- Constructability (frequent reviews of construction progress with the designers)
- Methods and Equipment, Equipment, Inspection and Test Plans
- Management Systems
- Monitoring of the Construction Processes (auditing/reviewing the inspection & test plans)
- Management of Changes (design, method statement, equipment, ground conditions, etc.)

To sum up, the “Code of Practice for Risk Management of Tunnel Works” is indeed an almost perfect manual meticulously covering all issues and aspects needing to be considered or dealt with in the daily tunnel practice, being also incrementally endorsed in the insurance policies. However, it is because of the enormous technical and administrative work required for the full compliance to all rules and obligations stipulated in this Code that it appears to be practically impossible for the parties involved to respond in the anticipated manner. In addition, it remains highly questionable whether any breach or deviation from these rules and obligations from the part of the Insured, would legally relieve Insurers from liability in case of a loss or damage to the works or the adjacent third party properties.

### **THE NEW TUNNEL WORKS CLAUSE BY THE LONDON ENGINEERING GROUP (LEG)**

As stated in its introduction, the scope of this clause is to define the extent of cover for tunnel works to be provided under a Construction All Risks (CAR) policy. The reason for introducing this new clause is said to be the variety of tunnel clauses in use in the market with broadly similar exclusions, but different approaches to indemnity resulting in a general lack of clarity and disputes over the level of cover offered. This in turn led LEG to the decision “to draft a new benchmark tunnel clause with the aim of providing greater clarity whilst not restricting the level of cover currently available” indented to “be inserted as an Exclusion to the Section of the CAR policy covering damage to the works”.

This new “Tunnel Works Clause” (TWC) is structured into the following three distinct sections:-

- *Exclusions*
- *Limits*
- *Definitions*



## 1. Extensions

From the variety of clauses claimed to be presently in use in the market, this section of the new TWC focuses only on the MRe Endorsement 101 by providing a number of amendments in order “to reduce ambiguity”, for the suggested revised version being drafted as follows.

*“It is agreed and understood that otherwise subject to the terms, exclusions, provisions and conditions contained in the Policy or endorsed thereon, the Insurers will not indemnify the Insured in respect of:*

a)

*i) alterations in the construction method*

*ii) unforeseen ground conditions or obstructions*

*iii) improving or stabilizing ground conditions or sealing against water ingress*

*iv) dewatering*

*unless necessarily and reasonably incurred following indemnifiable physical loss or physical damage.*

b) *overbreak or over-excavation in excess of the design profile and/or for refilling of cavities resulting therefrom.*

c) *damage due to breakdown of the dewatering system if such damage could have been avoided by the use of standby facilities.*

d) *loss of bentonite, suspensions, or any media or substance used for excavation support or as a ground-conditioning agent.*

e) *the abandonment of sections of Tunnel Works that are not subject to indemnifiable physical loss or damage.*

f) *the abandonment or recovery of Tunnel Boring Machines”.*

## 2. Limits

In brief terms, this section of the clause provides a choice of limits for the indemnification, expressed either in a percentage or monetary fashion which allows, even in the absence of any breakdown of the sums insured in the policy, that a limit of indemnity, in the event of an indemnifiable physical loss or damage during the tunnel works, can still be calculated (our underlining).

However, no mention is made either in this section or elsewhere in this clause as to the criteria to be applied for the definition of the “*indemnifiable physical loss or damage*” being the pre-requisite for the application of the clause.



### 3. Definitions

This section deals with the definition of the various termini used in this clause such as “Tunnel Works”, “Period of Insurance”, “Percentage Limit”, “Immediate Damaged Length”, by also providing guidelines for the quantification of the parameters relevant to the calculation of the percentage and/or monetary limits for the indemnification stipulated item 2 of the above.

From the above it is evident that the main intension of this clause is to (a) more adequately specify the MRe Endorsement 101 by introducing a number of reasonable exclusions, and (b) establish certain useful criteria or guidelines for the calculation of the indemnity in the event of an *indemnifiable physical loss or damage*. Even though this new clause constitutes a useful tool for underwriting purposes, it still leaves a number of crucial issues unresolved which, in the opinion of the writer, are essential for the intended reduction of the claimed “*general lack of clarity*” within the “*range of tunnel clauses in the insurance market....leading to disputes over the cover offered*”. For example, it fails to specify which are in the opinion of LEG the criteria for a physical loss or damage to be considered as being indemnifiable?

Shall these criteria be the ones outlined in the MRe Endorsement 115, then which is the most suitable and less confusing interpretation or definition of the terms “*defective material and/or workmanship and/or faulty design*”, as well as “*correctly executed items*” this endorsement refers to? In other words, which are the precise criteria for the undisputable definition of these terms? As revealed by the loss adjusting practice, there is a general lack of clarity as far as the interpretation of these termini is being concerned, allowing for a wide range of rather subjective interpretations when it comes to judging on the cover and the indemnification of a claim. Hence and as long as no widely accepted criteria for the definition of these terms have been introduced both the usability of the MRe Endorsements 101 & 115 as well as of the new “Tunnel Works Clause” (TWC) will remain standing on tipsy legs.

### **SOME USEFUL FACTS TO THINK ABOUT WHEN UNDERWRITING TUNNELING RISKS**

Most of the tunneling projects in our days form an integral part of larger infrastructure projects being co-financed by the owners (mainly public entities) and a number of lenders. Usually, the Owners have years to plan the project, perform preliminary geotechnical investigations and designs and also deal with the regulatory agencies and the third parties abutters, for the works being usually assigned to the lowest bidders on a design & built contract basis.

The contractors, on the other hand, are in business to make money. At the tender stage of the project, they must accept the preliminary budget, investigations and designs provided by the owners as given and in the space of a few months come up with a cost to perform the work and bid out all other contractors participating in the tender. Their calculation of the bid shall include a provision to cover the expenses needed to supplement the geotechnical exploration, draft the final designs by also reserving a reasonable amount for contingencies, based on experience with similar projects.

Underground works are expensive, linear and sequential obeying tight construction schedules, limited financial budgets and frequently also unilateral contract conditions transferring all risks and responsibilities to the contractor. Being faced with the dilemma of protecting their profit margin, but also to maintain their competitiveness, the contractors have no other choice than to try saving costs in most instances including the ones related with the supplementary ground exploration, design and workmanship by also attempting, if something goes wrong, to recover any unexpectedly occurring extra expenses or additional construction costs from the owner or the Insurers of the project. This of course is not an accusation, but a natural consequence of the business mainstream.

Here it is essential to point out that for the vast majority of the contractors, the term “unexpectedly” has a broadly embedded meaning than the one traditionally assigned to by the insurance industry and this is one of the root causes for the many disputes and frustration arising during the handling of major losses.

Almost all major contractors involved in tunneling works enjoy an international reputation, being staffed with highly qualified and experienced project engineers and worksite managers. This also applies with regard to most of the engineers in charge of the various designs. For anyone of them, acting as professionals, it is not easy to accept or admit having made a mistake in terms of having issued a “faulty design” or even applied “bad workmanship”, more especially when such accusation is addressed after the loss. In their language the terms “unexpected” and “unforeseen”, usually means an accident due to something, which was possibly not adequately considered beforehand in the approved design or workmanship, without for this something being necessarily predictable. It is the ambiguity in the interpretation of these termini which, in the vast majority of the cases, gives rise to disputes regarding the policy liability, thereby making the further handling of the claim by the lawyers inevitable.

### **THE CHALLENGE**

As evidenced by the previous elucidations also coinciding with the general trends discussed in the MRe’s presentation at the ITA Conference in Seoul in 2006, the differences in the priorities set by the tunnel industry and the insurance community are too substantial as to be easily overcome only with the enforcement of meticulous codes of practice and vaguely worded endorsements or clauses allowing ambiguous interpretations.

Obviously, this circumstance requires a more radical rethinking from the part of the insurance community aiming in the enhancement of their approach in accepting and managing tunneling risks. It seems reasonable for such rethinking to focus on the possible adaptation of two supplementary approaches of equivalent importance running almost in parallel, i.e. the “enhanced” underwriting and the systematic risk monitoring by tunnel experts instead of the “desktop” underwriting in conjunction with only occasional site visits of in-house engineers, as it is the common practice today.

## THE “ENHANCED” UNDERWRITING

### Principal Considerations

Usually at the time of the application for insurance, the project has only a virtual existence for its specifications, designs, method statement/workmanship, etc. existing mainly “on paper”. As a rule, the information forwarded to the Underwriter is compiled by the captive or external Broker, who however personally lacks the expertise to confirm or assure the accuracy and the completeness of same. So, it frequently occurs that the meaningfulness of the information provided, at least as far as the technical aspects are concerned, is not always what it should be.

On the other hand, most of the Underwriters are not necessarily experts in tunnel engineering and therefore they become overextended when it comes to judge on a number of crucial issues such as the accuracy of the geological and geotechnical exploration and interpretations, the suitability of the method statement (i.e. type or version of the TBM or NATM) chosen and its predicted interaction with the ground during the excavation and so forth. Therefore and bearing in mind that the vast majority of the problems or disputes confronted with in the event of a major loss roots in the underwriting stage, it is advisable already at this point of time for the Underwriter to seek obtaining the opinion from a qualified in-house engineer or external tunneling expert as to the consistency of the information provided together with an even quick rating of the risk exposure of the project.

A further issue needing special attention, is the frequently reoccurring circumstance that the description of the ‘risk details’ provided for in the insurance proposal are either incomplete or too general, whereas it is only in the appendixes that some of the missing details are only fragmentarily presented. This is a serious shortcoming which, when adopted in the same disorderly fashion in the policy may give rise to serious disputes when interpreting the policy liability in the event of a loss, more especially in the case of a CPM policy. It is of significant importance that the precise type and description of the machine employed in the excavation is always given in the preamble of the policy and not only in the appendixes.

The most essential plant or equipment used in tunnel works are the TBMs and road headers of various specifications and capabilities depending on the characteristics of the ground they shall be deployed. In the case of a TBM, the differentiation in the type is expressed by the denotation given by the manufacturer such as “single shield hard rock”, “slurry” or “earth pressure balance” (EPB), for this denotation also specifying the categories of the ground each of these types are compliant to. Hence, it is because of this ‘exclusive’ relationship between the type of the TBM and the ground that generalized expressions in the policy wording such as “a TBM to be used in the project...” shall be strictly avoided as they impose the risk for the policy cover to be legally interpreted as referring to any type of TBM whether compliant with the given ground conditions or not. It is though reminded that the vast majority of tunnel collapses resulting in serious damages also to the TBMs are just due to the incompatibility of the type of the TBM chosen for the excavation.

There are plenty of tunneling projects underwritten in emerging countries being governed by the local law. This implies that any dispute or matter, which requires reference to a court, arising out of or relating to an arbitration tribunal or falling outside of the arbitration clause, shall be submitted to the exclusive jurisdiction of the courts of the specific country.

This is an essential circumstance needing special attention by the Underwriter (Insurer or Reinsurer) more especially when it comes to the interpretation by the Judge of a number of issues or clauses such as the “*accidental or unforeseen*” occurrence of a loss, the “*misrepresentation of the risk and/or non-disclosure of material facts*” and/or “*defective material and/or workmanship and/or faulty design*”. There are many examples confirming that the interpretation of these issues and clauses by the local Judge may differ substantially from those commonly anticipated in Europe. Obtaining an early advice from the in-house legal department in these matters would certainly assist the underwriter in minding serious handicaps.

### **Preferred Application of “The Code of Practice”**

As mentioned earlier in this paper, it is because of the enormous technical and administrative work required for the full compliance with all rules and obligations stipulated in this Code that it appears to be practically impossible for the insured parties to respond in the anticipated manner. As an effort to overcome this deficiency by still ensuring the Insured’s principal and efficient conformance with this Code, it is suggested for the Underwriter considering the inclusion of the following crucial provisions as a condition precedent to the acceptance of liability under the policy:-

- (a) appointment of a **risk management team** comprising of qualified engineers, including the worksite manager(s) and the designers, for each member being assigned with well-defined tasks and obligations related to the continuous monitoring of the progress of the works, the quality control, the validation of the assumptions made in the designs, as well as the elaboration of emergency action plans
- (b) drafting of a **risk matrix** dealing with the identification and rating of the potential hazards that might affect the integrity of the project and its surroundings. This matrix shall rate the risk consequences so that the choice can be made as to which to ignore, which to watch, and which to deal with or eliminate. It shall also form the basis to decide which one, out of the identified risks, will be borne by the project owner, passed on to the contractor or given to the insurance
- (c) elaboration of an ‘actionable’ **risk register** used to catalogue the events that may take place at the project, and the probability and consequences if they occur. In addition, it shall also be used as a ‘live’ document or tool to compare the risks, catalogue the mitigation measures chosen to either lessen the probability that the events occur or to lessen the consequences should they occur
- (d) holding of frequent **workshops** between the members of the risk management team to discuss any issues giving rise to concerns and also agree on the corrective actions and/or revisions needing to be timely implemented either on the designs or the method statements in place. Detailed tracking of all issues discussed and actions decided to be taken in the course of these workshops together with their follow-up, shall be kept in the risk register as well as in the corresponding MoM, both of which shall be accessible to the Insurer upon demand.

### **Technical Information to be included in the Insurance Proposal**

It would be beneficial to arrange for the underwriting information to be provided for the acceptance of the risk, to include a certain amount of technical information which, apart from the substantiated assessment of the risk, will also assist in creating a reliable platform for the systematic risk monitoring by the Insurer as from the date of inception of the policy. As revealed by experience, the most suitable way in achieving these goals is to revise the insurance questionnaire as to ensure the mandatory provision by the Insured of the following minimum technical information:-

1. Time schedule of the project. Precise location and dimensioning of the tunnel and number of branches it comprises of. Axial distance between the branches and average advance length between them during the excavation. Maximum and minimum heights of the overburden and their chainage.
2. Geological profile along the approved tunnel alignment advising the number, location and depth of the boreholes and other exploration means it is based on.
3. Summary of the assessed geotechnical parameters of the various geological formations anticipated to be encountered during the excavation.
4. Method statement or workmanship to be employed in the excavation (TBM and/or NATM). In case of alternative utilization, to mention the chainages of the corresponding stretches.
5. Plant and Machinery to be used:-
  - TBM: a. Type, specifications and manufacturer  
b. New or refurbished (overall usage/operating hours)
  - NATM: As above (roadheader?). Is the usage of explosives (blasting) foreseen and where?
6. Brief description of third party properties in the immediate vicinity of the works (type of construction, usage, number of floors). Has a dilapidation survey taken place?
7. Copies of the Risk Matrix, the Risk Register in place along with the organogram of the risk management team appointed by the Insured.

Selected parts of the information referred to in items 1, 4, 5, 6 & 7 shall be preferably incorporated in the policy, whereas the entirety of this information shall be used by the Underwriter and his risk engineer/appointed tunnel expert

- for the quick rating and hence the substantiated assessment of the risk
- as a point of reference for the systematic risk monitoring to be implemented by the Insurer for the duration of the project.

## **THE SYSTEMATIC RISK MONITORING**

As revealed by the loss adjusting experience, the genuine unforeseen and accidental losses do not exceed the mark of 20%, for the remaining 80% of the cases being attributed to human omission and mistakes. Also, in the vast majority of the cases, the adverse circumstances giving rise to major losses do not arise overnight, but are rather well known to the contractors and their designers several days or even weeks ahead. Generally, these adverse circumstances are never reported to the Insurers, but come to light only in the course of the post-loss investigations by the loss adjusters.

As a rule, Insurers insist on the submission of monthly progress reports from their Insured and also delegate from time to time their own risk engineers to visit the worksite(s) in order to obtain a more accurate picture of what is happening on the spot, but as frequently confirmed by the daily practice, this does not seem to be enough.

Typically, the progress reports delivered to Insurers are identical with the ones drafted for the consideration of the owner and/or the lenders of the project. For obvious reasons, no detailed information is contained in these reports in respect of any adverse circumstances or technically driven problems possibly encountered. On the other hand, the Insurer's own risk engineers usually assigned for this purpose either do not have sufficient worksite & claims experience or even lack the necessary in-depth knowledge of the crucial technical aspects inherent in the subject matter of their inspection. It is because of such shortcomings that the risk engineer's report, not quite infrequently, misses to recognize key issues of concern and also to suggest the timely execution of reasonable recommendations.

This by far unsatisfactory situation, which may result in catastrophic losses, can be successfully overcome only through the implementation of a systematic risk monitoring program, involving desktop examination and sample site visits, to be driven by an experienced qualified engineer in negotiation with the interested Underwriter.

In principal terms, the particulars and extent of such monitoring program shall be defined in accordance with the size and complexity of the project. Usually, most of the monitoring activity can be performed on a desktop basis subject to the regular submission by the Insured (at least on a monthly basis) of the

- TBM progress reports
- regularly updated fashions of the risk matrix & risk register
- minutes of meetings (MoM) held by the risk management team and other relevant exchange of correspondence with the designers, project owner and the TBM manufacturer
- monitoring records i.r.o. the adjacent third party properties, possible deviations of the TBM from its anticipated drive, possible over excavations, undesired drop-down of the target face pressure, usage of additives for ground conditioning, variations in the volume of the grouting material used for the filling of the annular gaps behind the segmental rings, etc.

Depending on the consistency and the completeness of these submissions as well as on the actual progress of the works, the time intervals for the site inspections by the tunnel expert should preferably not exceed the period of 6 months.



## THE CASE STUDY

The Project in reference concerns one of the extensions of the Istanbul Metro presently in progress in the eastern part of the city on the European side.



*Photo No. 1: Satellite view of the project*

It comprises of several underground sections which, depending on the ground conditions, are being excavated either by EPB-TBM or conventionally (NATM). The section we are dealing with in this case consists of two tubes with inner diameter of 5.7m, running almost parallel with an axial distance between 35m and 50m underneath a densely populated area.

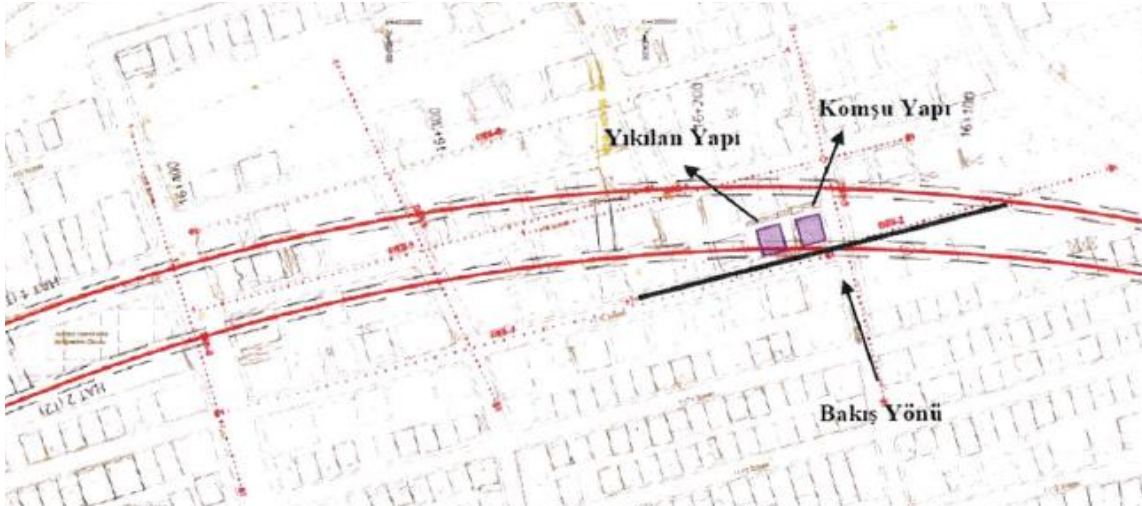
Part of this section runs along a left-curved stretch, passing some 10m-11m below the foundations of 6-storied residential buildings occupying the specific area. The excavation is performed by two EPB-TBM's operating with an advance distance of 50m – 70m. Each of the rings, constituting the final lining, comprises of 5+1 segments with an overall length of 1.40m and width of 0.35m.

According to the geotechnical report, the ground in the area where the incident occurred comprises of a 1m - 1.5m surface layer consisting of fill material followed by non-cohesive coarse grained silty sand. The cover provided under the CAR policy in force is subject to the strict application of the terms and provisions stipulated in the "Code of Practice for the Risk Management of Tunnel Works".

### The Loss

In the early evening hours of the 12 June 2015 and whilst the shield of the TBM 2 had already passed underneath the bldgs. 31 & 29, the residents of bldg. 29 notified the contractor's worksite manager of serious cracking taking place in their premises. Following some period of hesitance, the contractor decided at approx. 22:30hrs to suspend the excavation of this TBM as well as of the TBM 1 which, having already passed the specific location, was continuing its operation some 60m ahead.

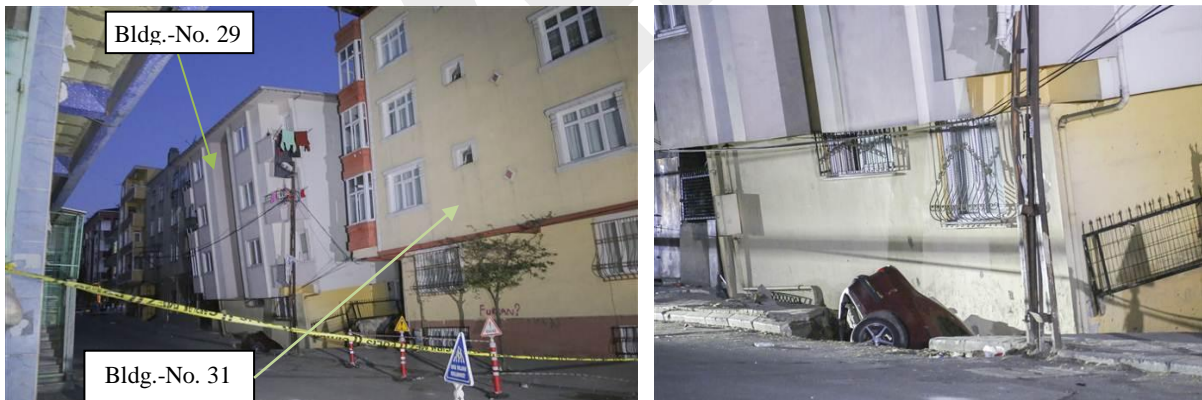




*Fig. No. 1: The location of the incident*

Given that the cracks on the bldg. 29 continued occurring in an almost unhindered fashion, the contractor with the agreement of the municipality, which was alarmed in the meantime, decided to evacuate this building. However, the crew of TBM 2 remained underground working on the completion of the last segmental ring, whose installation commenced at the time of the suspension of the excavation.

At approx. 02:45hrs of the 13 June 2015, a ground collapse took place in front and underneath bldg. 29, causing this bldg. to tilt at some 15° towards the street by also sucking a private car parked nearby.



*Photo Nos. 2 & 3: The tilted building-no. 29 and the sucked car in the cavity in front of the building*

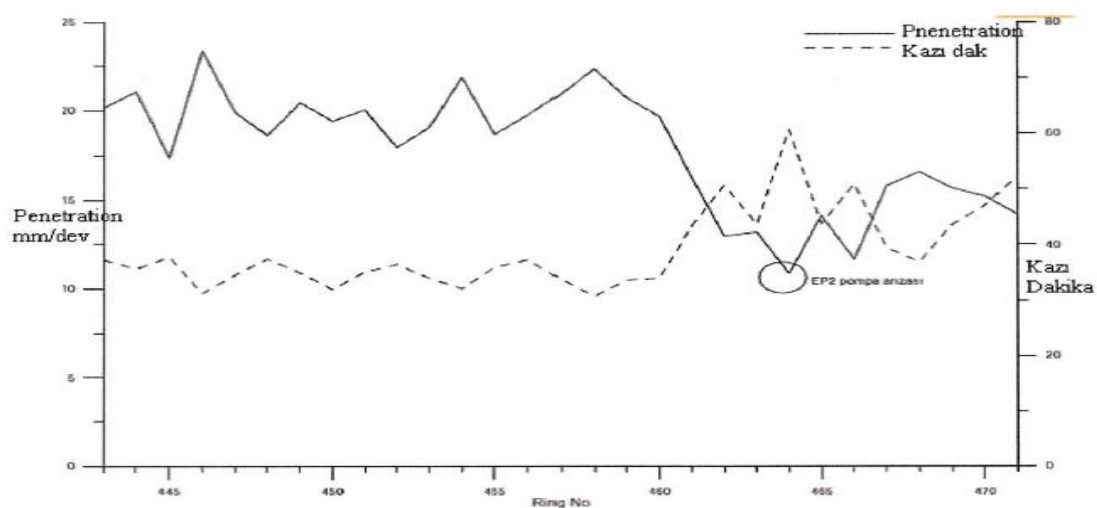
The volume of the cavity created as a result of the ground collapse measured some 125m<sup>3</sup>, which was promptly filled with concrete. As a further emergency measure, it was decided to also evacuate the adjacent bldg. 31 as well as another 6 buildings in the immediate vicinity. Still on the same evening and upon the order of the authorities, bldg. 29 was completely demolished.

Two days later, two more ground collapses occurred on the sidewalk of bldg. 31, each measuring some 30m<sup>3</sup>, causing severe structural damages also to this building and hence leading to the decision for this building to also be demolished. It is worth mentioning that no damages at all were reported having been sustained by the works as a result of these incidents.

### Investigations as to the Cause

There was no doubt, that the cumulative volume of more than 180m<sup>3</sup> of the three cavities formed as a result of the above mentioned ground collapses was the result of an extensive “ground volume loss” having taken place during the drive of the TBM in the captioned area.

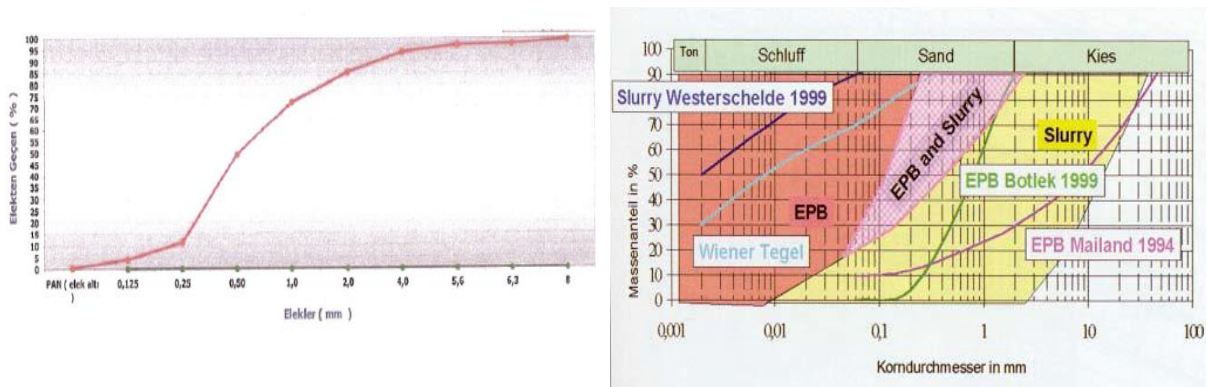
The whereabouts of the missing 180m<sup>3</sup> of earth corresponding to the volume of the cavities, in first instance could not be verified, but it is believed that over a period of time it had been flowing into the excavation face and then removed as surplus to the nominal earth quantities collected during the excavation process. This assumption could not be directly verified due to the unfortunate circumstance that the contractor did not keep accurate records in respect of the excavated material. However the outstanding evidence was finally obtained from the close examination of the (a) penetration rate of the shield vs. time, and (b) values of the actual face pressures recorded during the critical hours prior to the incident.



*Fig. no. 2: Penetration rate of the shield versus time*

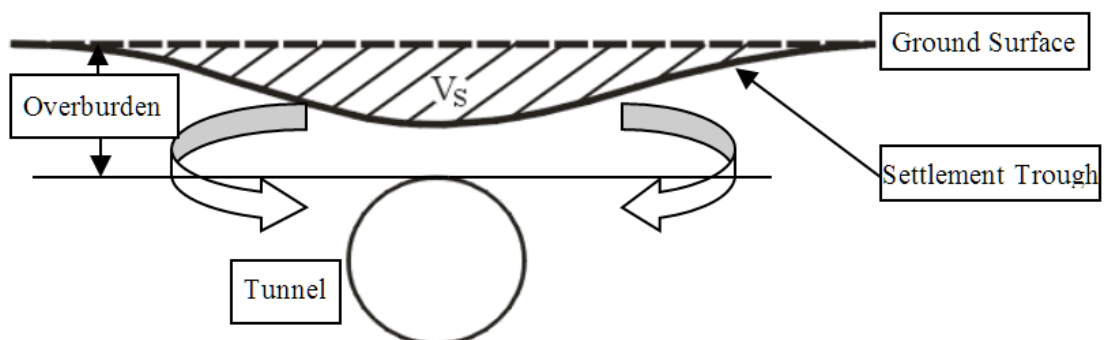
As it may be seen from the above graph, some 20 hours prior to the first ground collapse, the penetration rate of the shield started decreasing drastically being accompanied by a significant increase of its progression time. Evidently, the ground in this area consisted of non-cohesive silty sand without containing any boulders or other obstacles which could impede the excavation progress. Insofar, the only explanation for the ‘struggling’ in the progress of the TBM during this period can only be reasonably attributed to the almost continued inflow of the surrounding sand into the excavation face.

This conclusion is also supported by the fact that during the same critical period, the shield had never managed to maintain the designed face support pressure at the desired level of 1.4 bar operating only between 0.8 & 1.0 bar. This level of support pressure in the given soil material was by far insufficient in keeping the excavation face stable. As it may be seen from Fig. No. 2 below, the average grain size of the non-cohesive sand in this area was in excess of 1mm, which in fact constitutes the upper limit for its unobstructed excavation by an EPB-TBM.



**Fig. No. 3:** Grain size distribution of the surrounding sand (left), limits of applicability of EPB-TBM depending on the soil consistency (right)

This circumstance led to extreme disturbances in the surrounding ground during the TBM drive, initiating a redistribution of the stresses initially prevailing therein. Looking for a new equilibrium condition, the soil started moving into the freshly excavated hole thereby significantly increasing the volume of the earth material needing to be removed from the excavation front. For the excavation face itself being also destabilized through this process, it was no more possible for the shield to maintain the anticipated face support pressure, which therefore started decreasing. This mechanism, known in the tunnel practice as 'ground volume loss', progressively results in the formation of a so-called 'settlement trough', which in case of a relatively thin overburden ( $\leq 15\text{m}$ ) may reach the ground surface thereby seriously affecting the integrity of third party properties.

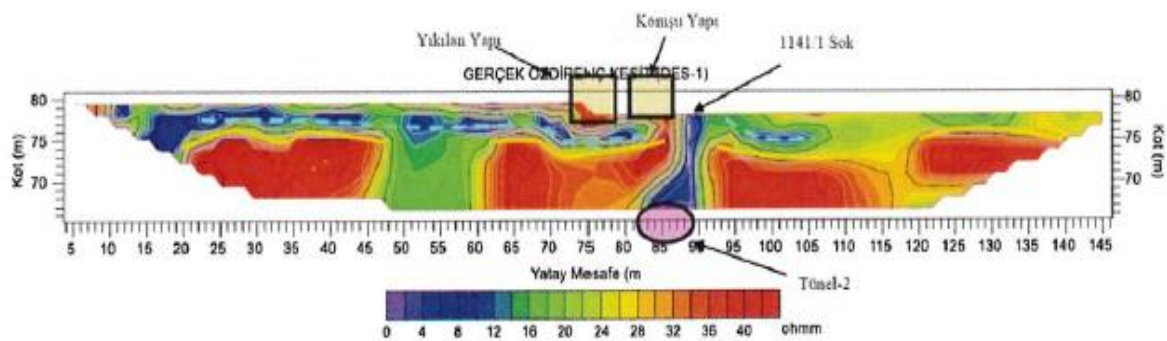


**Fig. No. 4:** Schematic diagram of a 'settlement trough' due to ground volume loss during the tunnel excavation

The excessive disturbance of the ground and hence the formation of the cavities, would most probably have been avoided if the contractor had timely reacted by means of using the appropriate additives for the conditioning of the ground.

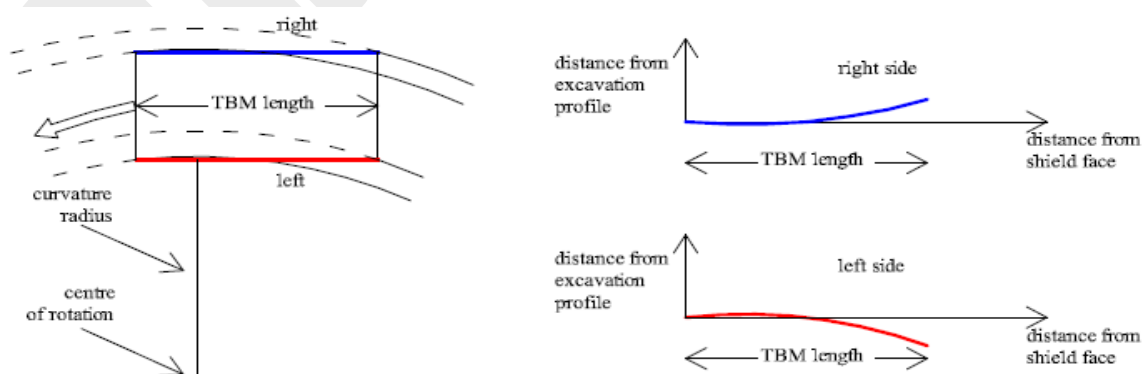
Apart from the above unfavorable circumstances, the following additional issues were found also having contributed to the ground collapses and hence to the damages to the overlying third party properties:-

- It was known to the contractor that in the immediate vicinity of the route there are a huge number of old wells some 180 out of which were filled with concrete prior to the passage of the TBMs through this area. However and as revealed by the post-loss geophysical examination of the area, apart from the wells, there is also a shallow old river bed passing some 2.5m underneath the foundations of the damaged bldgs. This old river bed functioned as water supply source for the wells existing in the area. It is not clear why the contractor and their designer failed to recognize the consequences arising therefrom (increased water pressure) in their assessment of the stability condition of the sandy formation and the target support pressure to be applied by the shield on the excavation face along this critical section of the project.



*Fig. No. 5: Geophysical profile along the excavation stretch underneath the damaged buildings indicating the location of the old wells and the shallow river bed*

- As depicted in Fig. No. 1 above, the area where the ground collapses occurred is within a left-curved section. For the shield progressing in the curve at certain advance stages or lengths, equivalent to the nominal length of the rings, the surrounding soft soil enters into an angular interaction with the shield. Given the snake-like motion of the EPB-TBM, there are certain sections of the shield where the surrounding soil is compressed and others where it is relaxed. Such asymmetric interaction, disrupted by frequent long lasting intervals/stoppages in-between, needed for the assembly of the rings, unavoidably induces repeated, unevenly distributed displacements in the surrounding ground.



*Fig. 6: Schematic repetition of the TBM's drive along curved stretch (D. Festa, W. Broere, J.W. Bosch, World Tunnel Congress Geneva, 2013)*



As indicated in the above graphic, as a result of this asymmetric interaction on the left hand side, the surrounding soil is compressed along the 1<sup>st</sup> half of the shield length, whereas on the 2<sup>nd</sup> half the soil becomes simultaneously relaxed. The opposite situation appears along the right-hand side of the shield. This mechanism also called “erratic advance”, giving rise to the additional loosening of the ground, seems to have also contributed in the excessive “ground volume loss” and the subsequent ground collapses in the specific area.

### **Conclusions**

As previously mentioned, the cover provided under the police is subject to the adherence by the insured contractor to the procedures and duties stipulated in the ‘Code of Practice for the Risk Management of Tunnel Works’. However and as confirmed by the previous elucidations as to the cause, this adherence was fulfilled only halfway being limited mainly in the formalities rather than to the core (i.e. appointment of risk management team and drafting of a risk matrix and risk register). As further revealed by the subsequent examinations,

- both the risk matrix and risk register were never updated as to reflect the observations made and proactive measures possibly taken during the excavation to (a) minimize the probability of any of the originally identified hazards to occur, and (b) timely recognize and also respond to previously mentioned critical situations confronted with during the TBM drive
- also the only few MoM issued over the period by the risk management team appointed by the contractor, did not contain convincing evidence confirming the enforcement of a consistent and suitable monitoring of the progress of the works accompanied by the coherent analysis and cross checking of the actual findings made during the drive with the ones assumed in the design and the workmanship.

It is the author’s opinion that if the contractor had properly complied at least with the above crucial requirements of the Code, then this loss would have probably been avoided.

**Dr. Stavros G. Artopoulos**  
**Geotechnical Engineer / Executive Loss Adjuster**