Guidelines on Contractual Aspects of Conventional Tunnelling

ITA - Working Group N°19
Conventional Tunnelling

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>> About this document

In 2009, the International Tunnelling and Underground Space Association (ITA) published a general report on conventional tunnelling [1]. The contractual aspects of conventional tunnelling were treated only in a general way. In 2011, ITA published the Contractual Framework Checklist for Subsurface Construction Contracts [2].

These two documents form the basis of the present guideline for the preparation of contracts for underground construction using conventional tunnelling methods.

This document supplements references [1] and [2] to address in more detail contractual aspects of conventional tunnelling and follows the structure of reference [2].

The present document as well as the documents under references [1] and [2] define the basic principles and recommendations of ITA regarding the drafting work on a new form of contract for underground constructions using conventional tunnelling.

1 >> Introduction

Underground construction is clearly different from any other type of construction since the properties of the construction material – the ground conditions – cannot be precisely known. Unforeseen conditions, dependency on the means and methods, and unavoidable construction risks are typical for underground construction in general, and specifically for conventional tunnelling. Contracting practices for tunnels and underground structures must therefore be dealt with differently from other types of construction.

Conventional tunnelling is the cyclical process of tunnel construction by repeated steps (rounds) of excavation by drilling and blasting, or by mechanical excavators (except full-face Tunnel Boring Machines (TBM)), followed by application of the relevant primary support [1]. Conventional tunnelling allows a fast response to changes in the ground conditions and the application of a wide catalogue of auxiliary construction measures dues to the normally comparatively easy access to the working areas at the excavation face.

Fast response to changed conditions such as changing the excavation sequence and/or method, adaptation of the of the round length[1] and/or the excavated cross-section, changing the number and/or type of support elements, and the application of additional auxiliary construction measures, is only possible if the contract makes provisions for such responses.

The following guideline highlights the special requirements recommended for conventional tunnelling contracts to allow this fast response and to realise the full advantages of conventional tunnelling.

[1] *Length of an excavation step in conventional tunnelling*

Fig. 1: Conventional tunnelling by drill an blast

Conventional tunnelling is performed in a cyclical execution process of repeated steps (rounds) of excavation followed by application of the relevant primary support. Both of these work steps (excavation and support of each round) depend on the existing ground conditions and on the ground behaviour. An experienced team of tunnel workers (miners), using standard and/or special equipment, execute each individual cycle of tunnel construction.

Conventional tunnelling allows either the full-face or partial excavation of the tunnel cross-section. The design engineer must define the appropriate excavation sequence based on the expected geotechnical conditions, the results of his modelling and the structural (ground support) analysis and his personal experience.

Following the basic principles of risk allocation (discussed in Chapter 4), the choice of the excavation method (drill and blast or mechanically assisted excavation by excavators, road headers, buckets, pick hammers) should be the Contractor's responsibility, as long as there are no compelling reasons for the Owner to restrict the choice. The Owner may tender alternative excavation methods on an equal level. In the event that only one method is tendered, alternative methods should be allowed as additional Contractor's alternatives. The Contractor would make its decision based on the Owner's description of the ground conditions (Geotechnical Baseline Reports (GBR[2])) and the limits set by the design engineer.

The Owner has to be aware of the high importance of adequate geological investigations in advance of the invitation to the tender. Low investments for the pre-investigation stage by the Owner can lead to higher cost contingencies in the Contractor's bid and to higher costs in the Owner's risk budget.

The ground conditions and ground behaviour may be different or change within a short distance even in cases of extensive previous site investigations. There may also be a need for the adaptation of the excavation method and/or the sequence and number and/or type of support measures to master the changed conditions. It is recommended these be anticipated in the contract.

Conventional tunnelling allows access to the tunnel excavation face at almost any time. The conventional tunnelling method is very flexible and well suited to such situations that require changes in the excavation process and in the support measures due to changed ground conditions. Conventional tunnelling allows a fast response to changed ground conditions if necessary highlighting the importance of contractual provisions which promote such dynamic responses.

Qualified site engineers from the Owner and from the Contractor determine jointly the round length, the type and amount of support measures to be used, taking into account the detailed design based on the modelling and static calculations of the design engineer and their personal experiences as well as advice from the Owner's geotechnical engineer and/or geologists.

Clear rules should also be made in the contract for the resolution of disputes between the Owner's representatives and the Contractor's representatives. Such provisions provide certainty of competence for such important technical function.

[2] *The Geotechnical Baseline Reports (GBR) is the interpretive report on the ground conditions described in the Owner's Geological Documentation, which includes also the Geological Data Report (factual report). It is the main purpose of the GBR to establish a contractual statement of the geotechnical conditions to be encountered during underground construction by application of the Owner's construction method (Design Report).*

3 >> Construction Contract

Fast response to changed ground conditions is only possible if allowed by the contract. If the contract does not include such provisions, there is a high risk of prolonged discussions without timely decision-making causing additional difficulties for the tunnel construction.

Based on experience from many countries, the following approach is recommended for conventional tunnelling contractual agreements and practices:

- The recommended project delivery approach is the **design - bid - build**[3] model. This project delivery system fits best to the widely accepted principles of risk sharing for underground structures (chapter 4). The adaption of the design in case of changed ground conditions remains the responsibility of the Owner's engineer.
- **Unit price contracts** (chapter 6) are recommended to guarantee the highest flexibility for changed or varied ground conditions.
- The contract should also contain:

- **A standard balanced risk allocation** (e.g. [5], [7]) should be part of each contract of conventional tunnelling based on following principles:
    - Every risk must be allocated to one or other party,
    - Allocate risks to the party best able to manage them,
    - Allocate the risk in alignment with project goals,
    - Share risks when appropriate to accomplish project goals.
- Clear regulations on **making changes** and **implementing value engineering** including a detailed change procedure description.
- A catalogue of **auxiliary construction measures.**
- A clear **regulation on the geomonitoring process.**
- A **comprehensible time sheet** for calculation of the contractual construction time (to be discussed in Chapter 3).
- A clear **regulation on time-dependent costs** (Chapter 6).
- A **Differing Site Conditions clause** (DSC).
- Each contract of conventional tunnelling should contain a detailed claim management system and **standard insurance policy.**
- A **method for dispute resolution**, typically the installation of a Dispute Resolution Board (DRB) is found most beneficial

During the tender phase, the Owner provides to the bidders all available factual information about the ground conditions, such as any Geological Data Reports. In the Design Report, he describes the Owner's view of the construction method. The Owner's interpretation of the ground behaviour related to foreseen construction methods, is documented in an additional, contractually binding, report such as the Geotechnical Baseline Report (GBR) made available to the bidders.

The GBR is incorporated in the contractual documents that define the specific ground conditions to be considered by the Contractor as baseline conditions in preparing bids. The contract should also establish a procedure for adjustments of the contract price when the ground conditions during construction are different than the conditions defined in the contract documents.

The Owner should also show some likely variations in the distribution of the excavation and support classes resulting from the uncertainties of the ground conditions to facilitate the evaluation of the remaining risks.

It is recommended that within the contract the Owner classifies the excavation sequence and method, and the corresponding support measures, by the definition of a classification system (excavation and support classes) for different ground conditions. The classification system can be based on national standards or elaborated on a project-specific basis. It is not recommended to relate the excavation and support classes to rock classification systems based on index values like Q and RMR, which are obtained by the multiplication or addition of different physical parameters or ratings. Such classification systems are not suitable for assessing the rock mass behaviour or to dimension the excavation support because they do not take into account the hazard scenarios of the project specific ground conditions.

The expected distribution of the excavation and support classes will be used for the Contractor's time and price calculation and the real distribution for the final payment.

Fig. 2: Size of a contract for a large underground construction

[3] Design–bid–build is a project delivery method in which the owner signs separate contracts with different legal entities for the design (fully developed by the owner's engineer) and the construction of a project. The design engineer assists the owner in the tender process.

4 >> Time schedule

In underground construction the construction time depends strongly on ground conditions and the corresponding advance rates. It is recommended to include a time sheet with an analytical calculation of the theoretical construction time following the critical path in the contract.

During the tender process the target of the total construction time is contractually agreed between the Owner and the Contractor. The target construction time corresponds to the critical path in the construction programme and is based upon the Owner's estimate of the relevant quantities in the bill of quantities and the performance rates provided by the Contractor in its bid. The contractual time sheet should also include a commonly agreed time for predefined work standstills.

During the construction the ground conditions may be different from the contractual assumption and the relevant quantities may change. The changed quantities are order changes, which can require an adjustment in the deadlines.

The contractually agreed time sheet is the basis for the calculation of the final contractual construction time. The final contractual construction time is a theoretical time and is calculated after the final breakthrough from the final quantities used, multiplied by the contractually agreed performance rates (table 1). The final contractual construction time must not match the real construction time. The final contractual construction time is the basic parameter for the final payment of the time-dependent costs (chapter 6.6).

Excavation is generally one of the main elements of the critical path for underground construction. In conventional tunnelling, the round-length mainly determines the time of excavation. The round-length depends mainly on the ground conditions and the capabilities of the equipment used. Other factors determining the construction time in conventional tunnelling are the amount of support measures, the amount of probe holes ahead of the tunnel face and the amount of auxiliary construction measures such as drainage measures, pre-grouting, and measures for ground improvement and ground reinforcement.

The Owner shows the distribution of the foreseen excavation and support classes for the expected ground conditions in the tender documents. The tender documents also describe the reasons for hindrances (e.g. probe holes ahead of the face, grouting, etc.) and give the catalogue of auxiliary construction measures according to his project.

The Contractor analyses and describes the expected construction process for each excavation and support class in his offer. Included in the offer is a daily performance rate for each excavation and support class and a detailed analysis of a typical cycle. Additional construction time caused by hindrances and the application of auxiliary construction measures can be added. The Contractor delivers a summary construction timetable with his bid.

CATEGORY OF WORK			PERFORMANCE	CONTRACT		FINAL PAYMENT	
Excavation		Round lenght (m)	(m/WD[4])	Quantity (m)	Time (days)	Quantity (m)	Time (days)
Excavation and support class	A1	5.0	7.5	150	20	90	12
	A2	4.0	5.5	330	60	275	50
	A3	3.0	2.8	280	100	420	150
	A4	2.0	1.6	80	50	40	25
	A5	1.0	1.0	50	50	65	65
Total Excavation time				890	280	890	302
Hindrance							
Exploratory drillings - Percussion drilling - Installation / de-installation - Drilling		Lenght 80 m	1 WD 10 m/hour	14 WD 1000 m	14 4,2	12 WD 960 m	12 4
Pre-grouting			Standstill time		40		0
Total hindrances					58,2		16
Total construction time					**338.2**		**318**

Table 1: Simplified example for evaluation of the construction time (for a more detailed example see references [3], [5])

[4] WD = working day

5. RISK ALLOCATION

The risks of uncertain ground conditions drive time and costs of many underground constructions. These risks can be related to construction means and methods, to the ground conditions and ground behaviour, to unforeseen conditions, or to external factors such as third-party approvals or changes in imposed limitations.

The allocation of risk between the Owner and the Contractor will have a direct relationship on the Contractor's contingency pricing in his bid. A fair and equitable risk-sharing mechanism helps to avoid disputes and finally to reduce the final costs, due to the fact that reasonable low contingencies will be included in the Contractor's bid. From the Owner's perspective a lower reserve fund has to be provided for unforeseen ground conditions, as no premium for additional Contractor's risks has to be covered.

The risk allocation between the Owner and the Contractor should be defined in the contract documents if there is no generally adopted standard solution. Standard solutions can be found in national codes [5], in the FIDIC "Red Book" [7] or in other relevant documents like the ITA recommendations on contractual sharing of risks [8].

The level of risk allocation is a major factor in deciding the type of procurement practice to be implemented. The contract must define the limits of the Contractor's responsibility.

The ground normally belongs to the Owner. It is therefore customary for unforeseen ground conditions outside the contractual limits to be the Owner's risk.

Means and methods within the contractual limits of the ground conditions are generally the Contractor's responsibility. The risk of inability to perform under the prescribed/known conditions must be borne by the Contractor.

6. RESOURCES

The Owner, the Contractor and their responsible engineers must be well experienced in underground construction. They must make their decisions taking into account their own experience but also the science of engineering.

The foremen and workers (miners) in conventional tunnelling must also be an experienced team of tunnel workers, able to assess the general ground conditions after the excavation of each round.

It is desirable that state-of-the-art equipment and plant must be used for the execution of conventional tunnelling (for further details see [1]).

Experienced staff and state-of-the-art equipment are key factors for the successful management of underground constructions, especially if changed ground conditions occur and should be clearly defined award criteria.

Fig. 3: Tunnel reconstruction due to unexpected high convergences

7 >> Payment

For conventional tunnelling the payment based on the measurement of each item (excavation, rock support, impermeabilisation, inner lining etc.) listed in detailed bill of quantities is recommended ("unit-price contract", Chapter 2). The bill of quantities is the basic document for the detailed description of the work and the payment. Each item in the bill of quantities and the corresponding unit price must be clearly defined.

7.1. STRUCTURE OF THE BILL OF QUANTITIES

The bill of quantities for a contract for conventional tunnelling should contain unit prices for at least the following activities, which are not limiting:

- **Installations/equipment** and plant (including mobilisation and demobilisation).
- **Quantity-dependent activities**, such as
  - Excavation
  - Support measures
  - Drilling and grouting
  - Waterproofing and drainage
  - Ventilation and cooling (if necessary, e.g. energy consumption)
  - Inner lining
  - Other auxiliary construction measures.
- **Time-dependent activities**, such as
  - Operation and maintenance of the equipment
  - Services and support
  - Dewatering (e.g. hours of pumping).

Each item in the bill of quantities has its own unit price. The contract should show the limits for which the unit prices remain fixed and the rules for adapted prices if the initially defined limits are exceeded.

7.2. EXCAVATION AND SUPPORT

The costs of excavation and support should be paid per unit of excavated material or support measure installed.

The most powerful instrument for a transparent time and cost evaluation in the design and tender phase is the definition of excavation and support classes (e.g Table 2). Excavation and support classes describe the excavation method and the required amount of support measures for typical ground conditions.

Although national standards in many countries provide excavation and support classes (e.g. [3], [5]), project-specific definitions must also be considered, for example in cases with an extremely large variation in ground conditions.

	EXCAVATION					
Support measures per round	**Method**	D&B	D&B	D&B	D&B	Mechanical
	Sequence	Full face	Full face	Full face	Full face	Full face
	Round lenght	Up to 5 m	Up to 4 m	Up to 3 m	Up to 2 m	Up to 1 m
	Cross section	60-70 m^2	60-70 m^2	60-70 m^2	65-80 m^2	70-100 m^2
	Class	**A**	**B**	**C**	**D**	**E**
Bolts and meshes for safety (protection of the excavation surface	**1**	A1	B1	C1	D1	E1
Bolts and dowels in vault, meshes	**2**	A2	B2	C2	D2	E2
Bolts in vault and face, partial support with shotcrete	**3**	-	B3	C3	D3	E3
Steel arches	**4**	-	-	-	D4	E4
Bolts and/or steel arches and shotcrete, ring closure after each round, spiles, pipe umbrella	**5**	-	-	-	D5	E5

Table 2: Simplified example of a definition of excavation and support classes (matrix)

7 >> PAYMENT

Irregular excavation surfaces are characteristic for conventional tunnelling due to geological and technical overbreak (described in 7.3 below). Payment for excavation should be made per volume unit of theoretical excavation (or design line).

Adaptation of the excavated cross-section according to the ground conditions is one of the characteristic aspects of conventional tunnelling. Payment per volume allows fast payment of changed cross-sections according to the ground conditions.

The excavation and support class matrix shows project-specific combinations of excavation and support measures. The bill of quantities should distinguish between the different excavation methods, which are:

- drilling and blasting
- mechanical excavation by excavator, road header, bucket, pick hammer.

It is the Owner's responsibility to define typical excavation and support classes in relation to the various ground conditions, showing the foreseen round-length, the foreseen excavation sequence, and the method and typical amount and location of placement of the support measures.

All support measures such as dowels, rock bolts, wire mesh, shotcrete, steel arches, lattice girders, etc. should be paid according to the quantities placed.

The bill of quantities should contain the price list of all the necessary support measures.

7.3. OVERBREAK

The occurrence of overbreak is inherent to conventional tunnelling and is a special aspect of conventional tunnelling to be regulated in the contract.

According to the general risk-sharing policy a distinction must be made between:

1. "Geological" overbreak due to the ground conditions (belongs under Owner's risks)
2. "Technical" overbreak due to Contractor's means and methods (belongs under Contractor's risks)

The Owner's and the Contractor's on-site representatives may take contradictory note of the reasons for the overbreak.

The contract must provide rules for compensation for the mucking of the overbreak and the excess consumption of filling concrete for "geological" and "technical" overbreak. The concrete for filling of technically caused overbreak is often paid for by reduced unit prices. National standards (Chapter 8) provide standard solutions for the payment of overbreak.

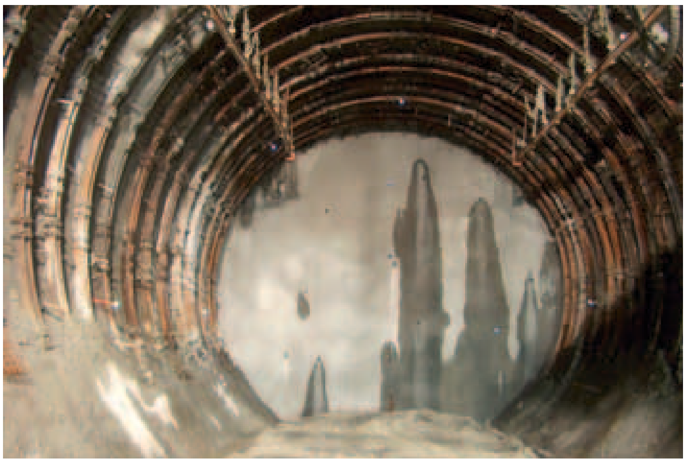

Fig. 4: Conventional tunnel drive (full face excavation by drill and blast, support with steel ribs, spiles, shotcrete and rock bolts)

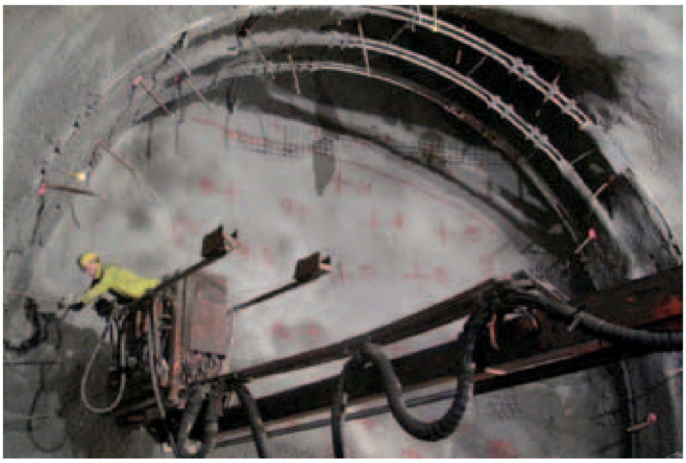

Fig. 5: Geological overbreak

7.4. COMPENSATION FOR HINDRANCES

Compensation for hindrances such as the execution of probe holes, drainage measures, pre-grouting, and other measures for ground improvement or ground reinforcement, must be regulated by special conditions in the contract.

It is recommended to separate quantity-dependent costs (e.g. drilling metres, grout volume, etc.) and time-dependent costs (additional standstill time).

Fig. 6: Hindrance by a preventer protected core drilling

7.5. AUXILIARY CONSTRUCTION MEASURES

Auxiliary construction measures can be dealt with in the same way as excavation and support. Unit prices should be fixed for the necessary catalogue of auxiliary construction measures for quantity-dependent activities (such as spiles, drainage drillings etc.) and time-dependent activities (such as pumping-hours).

The influence of the additional standstill time due to the application of auxiliary construction measures is paid according to the rules of Chapter 6.6.

7.6. TIME-DEPENDENT COSTS

Changes in the ground conditions normally cause changes in the construction schedule. In the event of changed ground conditions, major changes in the construction schedule may result.

The contract should contain detailed rules on how to compensate the time-dependent costs for equipment and the costs for the Contractor's personnel for services and management.

The bill of quantities should contain daily, weekly or monthly rates for the additional costs for equipment, services and management.

The Owner should pay for additional time-dependent costs only if the reason for the longer construction time belongs to the Owner's risks. Likewise, if the cost savings result from a shorter construction time due to better ground conditions, the Owner should be entitled to the savings.

The inability of the Contractor to perform under prescribed contractual conditions is no reason for additional payment.

8 >> Conclusions

Based on the previous guidelines of ITA Working Group N°19 "General Report on Conventional Tunnelling Method" [1] and of ITA Working Group N°3 "Contractual Framework Checklist for Subsurface Construction Contracts" [2] ITA, Working Group N°19 comes to the following conclusions:

1. Design - bid - build contracts are recommended for conventional tunnelling.

2. The use of the standard terms and conditions and use of the technical standards is recommended for conventional tunnelling projects.

3. Unit price contracts are recommended for conventional tunnelling with clear regulations for quantity-dependent activities and for time-dependent activities.

4. A differing site conditions clause should be part of each contract of conventional tunnelling.

5. A standard balanced risk allocation ([5],[7],[8]) should be part of each contract of conventional tunnelling based on following principles:
    - Every risk must be allocated to one or other party,
    - Allocate risks to the party best able to manage them,
    - Allocate the risk in alignment with project goals,
    - Share risks when appropriate to accomplish project goals.

6. Each contract of conventional tunnelling should allow making changes and implementing value engineering including a detailed change procedure description.

7. Each contract of conventional tunnelling should contain a detailed claim management system and standard insurance policy.

8. Each contract of conventional tunnelling should regulate the geomonitoring process.

9. For projects of conventional tunnelling, experienced decision-makers should be responsible at all levels on the Owner's and the Contractor's side.

10. The implementation of a Dispute Resolution Board is recommended for conventional tunnelling projects.

9 >> References

[1] General Report on Conventional Tunnelling Method (Report of ITA WG N°19), ITA-AITES, 2009

[2] The ITA Contractual Framework Checklist for Subsurface Construction Contracts, (Report of ITA WG N°3), ITA-AITES, 2011

[3] Austrian Standard B 2203-1 (2001), Conditions of Contract for Works in Underground Construction

[4] Swedish Standard AMA AF (2010), Guidance for the Preparation of Particular Conditions for Building and Civil Engineering Works and Building Services Contracts

[5] Swiss Code 118-198 (2004), General Conditions for Underground Construction Work

[6] US Federal Highways Administration, Handbook of Tunnelling:Technical Manual for Design and Construction of Road Tunnels

[7] FIDIC “Red Book”, Conditions of Contract for Construction (1999)

[8] ITA Recommendations on contractual sharing of Risks (1988, 1992)

This report contains contributions by the various Members of Working Group N°19 and Working Group N°3 over the period 2009 – 2012. Heinz EHRBAR, Animator (Switzerland), Robert GALLER, Vice-animator (Austria), and Markus THEWES, Tutor (Germany) were leading the Working Group N°19 during the time of.

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