

Emerald Book FIDIC – A Path to Fair Risk Allocation in the Construction of Underground Works

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ABSTRAKT: The FIDIC Emerald Book is one of the latest contractual conditions for underground construction (2019). It currently represents the greatest progress in the (fair) distribution of risks between the Client and the Contractor in the Design & Build construction method. One of its key documents is the Geotechnical Baseline Report (GBR), which contains a definition of the foundation conditions at the site of the work and a specification of key criteria for risk distribution. The article describes the procedure for applying selected provisions of the FIDIC Emerald Book in the specific conditions of the Homole tunnel on the D35 motorway (for the first time in the Czech Republic), presents previously unknown annexes to the contract documents, specifies the reasons for selecting individual key criteria and their values, and summarizes the first experiences from the application of these contractual conditions during implementation.

1. INTRODUCTION

This article presents a current perspective on the construction of an underground work involving the implementation of selected elements of the FIDIC Emerald Book, using the excavation of the Homole Tunnel on the D35 motorway as a case study. The paper indirectly builds on the professional discussion initiated by the article “The Emerald Book and the FIDIC Golden Principles” by Ing. Michal Uhrin and JUDr. Lukáš Klee, Ph.D., LL.M., MBA, published in *Stavebnictví* 8/2024, as well as on the author’s earlier paper “First Experiences with Selected Elements of the FIDIC Emerald Book during the Construction of the Homole Tunnel on D35” published in *Stavebnictví* 12/2025.



Figure 1: Global layout

Attention is devoted to the fundamental technical parameters of the structure, a description of selected Emerald Book provisions applied in the project, and an evaluation of the construction process from the viewpoint of geotechnical conditions and contractual relationships. Emphasis is placed on the definition and significance of the Geotechnical Baseline Report (GBR), one of the key documents of the FIDIC Emerald Book, which directly influences the allocation of risks between the Employer and the Contractor.

1. HOMOLE TUNNEL: BASIC PROJECT INFORMATION

1.1 GEOMETRY AND SPATIAL ARRANGEMENT

The Homole Tunnel is designed as a pair of separate one-way tunnel tubes of category T 9.5, each with an approximate width of 12.1 m. The two tubes are separated by a rock pillar roughly 17 m wide, which ensures sufficient stability and minimizes mutual influence during excavation. The overburden in the mined sections varies significantly: above the right tunnel tube, approx. 8.5–19 m, above the left tunnel tube, approx. 8.7–24 m.

At the crossing of the existing I/17 road, which currently accommodates transit traffic on the future D35 expressway, the overburden decreases to just about 13.5 m, practically equal to the width of the excavation itself. The tunnel passes beneath this road at a relatively sharp angle of approximately 30°, increasing the demands on temporary stabilization measures during construction.

1.2 PRIMARY LINING AND EXCAVATION TECHNOLOGY

In the mined sections, the primary lining consists of sprayed concrete C 20/25 – X0, with strength development corresponding to curve J2. The lining is reinforced with steel ribs and welded steel meshes made of B 500B steel. The lining thickness varies between 200 and 300 mm, depending on the NATM technological class.

Excavation is carried out using a horizontally staged excavation sequence, with individual advance rounds of 1.0–1.75 m. In areas with minimal overburden or in unstable ground conditions, a protective canopy made of micropiles is used, supplemented by cement based or resin-based injections.

1.3 SAFETY AND OPERATIONAL CROSS-CONNECTIONS

The two tunnel tubes are interconnected by a single mined cross passage, serving both for evacuation and emergency response access. At both portals, combined emergency and service areas are designed to accommodate the needs of the Integrated Rescue System, the Police of the Czech Republic, and the tunnel operator.

1.4 WATERPROOFING, DRAINAGE AND OPERATIONAL NICHES

The waterproofing system is designed as a vaulted waterproofing membrane, combined with foot drains running along both sides of each tunnel tube. The drainage system is accessible through inspection niches located at intervals of up to 50 m.

In accordance with common European safety standards, the tunnel is equipped with: combined inspection niches with SOS cabinets (right side in the direction of travel), fire hydrants placed in every second niche on the left side.

1.5 SURFACE WATER DRAINAGE

Roadway drainage is provided by slot curbs, which discharge water into a collection sump located near the western portal. This sump also serves as a containment chamber for hazardous spill events, preventing such substances from entering the public stormwater system — a standard requirement for modern motorway tunnels.

To reduce fire spread in case of flammable liquid leakage, the slot channels are equipped with fire resistant non return valves at intervals up to 60 m, in line with standard European tunnel design practice.



Figure 2: Support works for the construction pit at the western portal

2. TECHNICAL DESIGN CHANGES

During the procurement process, the bidders were allowed — within the limits defined by the Employer — to modify the technical design when preparing their tenders. The baseline document for bidding was the Reference Design (RD), represented by the Documentation for Building Permit. A total of five bidders submitted their tenders; most of them proposed changes only for the mined sections of the tunnel. For other parts of the structure, bidders kept the original RP solution, which they priced accordingly.

In accordance with the Contract Conditions and the Employer's Requirements (part of the tender documentation), the Contractor submitted — as part of the preparation of the Detailed Design for Construction (DDD) — and is currently implementing the works with the following significant modifications:

- Adjustment of the transverse profile geometry (narrower and higher).
- The tunnel cross section was redesigned to be more compact, reducing excavation volume and optimizing structural behaviour while maintaining the required tunnel clearance. Omission of the second cross passage (CP). The safety concept for the Homole Tunnel allows for only one cross passage. However, its location falls within the most unfavourable geotechnical conditions near the operational I/17 road. Therefore, the original DSP included two separate cross passages to ensure design flexibility. This modification was discussed with the relevant authorities and the building office and is processed as a Change of the Works Prior to Completion.
- Omission of surface-based ground improvement measures. In the most geotechnically complex section, where excavation of the top heading would encounter water bearing cover soils, the RD and the

Contractor's tender originally anticipated jet grouting from the surface. The DDD technical solution replaces these measures with: large scale micropile umbrellas, umbrellas made of IBO self-drilling anchors, systematic ground improvement using cement and chemical grouting, extensive stabilization of individual tunnel faces. This method ensures stability while eliminating the need for disruptive surface works.

- For NATM Class 3, the primary lining includes only one welded steel mesh at the intrados side. This simplified primary lining arrangement — one layer of steel mesh placed near the extrados — is applied where justified by geotechnical conditions.

- Replacement of the cut and cover section of the Left Tunnel Tube near the eastern portal with a “turtle” structure. The original design envisaged a cut and cover tunnel for the Left Tunnel Tube running parallel to the mined section of the Right Tunnel Tube. The Contractor's DDD replaces this with a “turtle” structure, i.e., a mined tunnel excavated beneath a previously constructed reinforced concrete protective shell resembling a turtle's carapace. This method minimizes surface impact and increases stability.

3. CURRENT STATE OF WORKS

Construction of the D35 motorway, section Ostrov – Vysoké Mýto, commenced on 6 May 2024, starting with surface works. The Homole Tunnel is being constructed by a consortium comprising EUROVIA CS, a.s., TuCoN, a.s. (renamed Marti a.s. as of 1 September 2024) and EUROVIA SK, a.s. The contract price amounts to CZK 1.754 billion (excl. VAT), which is nearly CZK 200 million (approx. 10%) less than the control estimate prepared within the DSP documentation (as no detailed Design for Construction had been developed for the project).



Figure 3: Rock excavation at LTT

Based on the expected geological and hydrogeological conditions, the Contractor proposed — in accordance with the tender documentation — a construction period of 960 calendar days. Excavation of the Left Tunnel Tube (LTT) began on 22 November 2024, shortly before St. Barbara’s Day, the patron saint of miners. Excavation of the Right Tunnel Tube (RTT) followed on 13 December 2024. The excavation of: LTT was completed on 2 September 2025,

RTT was completed on 10 November 2025. From Q3 2025 onwards, intensive works have been carried out on the installation of waterproofing membranes and the casting of the secondary lining, following completion of the primary support.

4. DESIGN & BUILD CONTRACTING

As already mentioned, the contract was tendered and is being executed using the Design–Build approach based on the FIDIC Yellow Book, supplemented with selected provisions of the FIDIC Emerald Book. The Emerald Book was prepared by the International Federation of Consulting Engineers (FIDIC) together with the international Tunnelling and Underground Space Association (ITA AITES) in 2019 and is specifically tailored to underground works with geotechnical risk allocation. This project represents the first-ever application of such a contractual model in the Czech Republic. Balanced Allocation of Geotechnical Risks Under this contractual arrangement, geotechnical risks are shared more evenly — and therefore more equitably — between the Employer and the Contractor. The key instrument governing the risk split is a standalone contractual document known as the Geotechnical Baseline Report (GBR). The adopted Design–Build approach also affects several detailed provisions of the Conditions of Contract. Fundamental Difference from the Yellow Book. A major distinction between this hybrid contract (Yellow Book with Emerald Book principles) and the standard Yellow Book is that: Selected parts of the works — in this case, excavation of the construction pits and tunnel excavation — are not paid as lump sum items. Instead, they are measured during construction against predefined criteria included in the GBR.

This arrangement reflects the nature of underground works, where actual geotechnical conditions can differ substantially from investigations, and measurable items provide a fairer allocation of time and cost risks.

Additional Tender Documentation Components.

Besides the Employer’s Requirements — which define the complete set of requirements for individual structures and systems (with references to relevant Technical Specifications and standards of the Road and Motorway Directorate) — the tender included several additional, atypical appendices:

- Bill of Quantities
- Baseline Schedules
- Payment Schedule
- Schedule for Completion

4.1 GBR – GEOTECHNICAL BASELINE REPORT

Within the Reference Design (RD) — and consequently within individual sections of the GBR — a specific technical solution is defined for each NATM technological class (TC). For each class, the GBR establishes baseline geotechnical criteria, which could not be altered during tender preparation. These criteria form the contractual basis for determining whether encountered ground conditions fall within or outside the baseline ranges, thereby determining which party bears the associated time and cost impacts.

The GBR for the Homole Tunnel defines the following key measurable criteria (k1–k7):

- **k1 — QTS Classification Score (Tesař, 1990)** – For each technological class, the GBR specifies an acceptable range of QTS points, derived from geotechnical characterization of the rock mass (rock mass).

If the actual measured QTS score exceeds or falls below this range, it constitutes a contractual basis for compensation, provided this deviation results in additional costs. This criterion is one of the most

important, serving as an analogue to the technological classification used under the FIDIC Red Book. The score is determined by the Employer's geotechnical engineer based on the geotechnical monitoring (geotechnical monitoring) and recorded geological conditions.

- **k2 — Percentage Representation of Individual Geotypes (Qx, Kx) in the Excavation Face** – For each TC, the GBR defines an expected percentage range of individual geotypes appearing in the excavation face. If actual conditions differ significantly — and this necessitates additional, unforeseen works — the deviation forms a contractual basis for compensation. This criterion accounts for situations where, for example, hard rock is unexpectedly encountered at the bottom of the top heading, increasing excavation time despite not changing the TC classification. Quantification is again performed by the Employer's geotechnical engineer based on face mapping and monitoring during excavation.

- **k3 — Dip and Condition of Rock Layers** – For each TC, the expected dip angle and condition of the rock layers are defined. Changes in layer orientation or the presence of a different dominant system of discontinuities may significantly influence face stability, requiring additional support measures. If these occur outside the defined interval and lead to extra works, they are compensable.

- **k4 — Percentage Occurrence of Tectonic Disturbance Within the Excavation Face** – For each TC, the GBR defines an expected percentage of tectonically disturbed rock mass.

If actual disturbance (faults, sheared zones, intensely fractured zones) exceeds the baseline range and necessitates unforeseen works, this triggers a compensation event. This criterion addresses cases where localized but severe tectonic disturbance significantly complicates excavation, even if the TC classification remains unchanged.



Figure 4: Rock Detachment in the LTT

- **k5 — Overbreak (Geologically Induced, Unavoidable Overbreak)** – Overbreak is defined as the unintended excavation of rock beyond the theoretical excavation line, resulting from the interaction between the excavation method and the mechanical behaviour of the rock mass. It typically occurs due to rock structure, texture, jointing, or other discontinuities, and therefore cannot be fully prevented even when correct excavation procedures are followed. For contractual purposes, the GBR establishes a

maximum allowable value of unavoidable, geologically induced overbreak of: 1 m³ of overbreak per 1 linear metre of tunnel (per partial excavation stage).

- **k6 — Method of Excavation (Mechanical Excavation vs. Drill and Blast)** – The GBR establishes mechanical excavation (mechanical excavation) as the baseline excavation method for all relevant technological classes. Mechanical excavation is assumed to be feasible throughout the tunnel length and therefore forms part of the Contractor’s priced risk.

- **k8 — Deformation of the Primary Lining** – For each NATM technological class (TC), the GBR defines a maximum expected deformation of the primary lining (primary lining) for individual excavation stages (top heading, bench, invert). These deformation limits represent the anticipated structural response of the lining under the geotechnical conditions assumed in the GBR. Deformations are evaluated based on convergence measurements (convergence measurement), using monitoring points installed by the Contractor and measured by the Employer.

In practice, this means that for each of the above-mentioned criteria, the GBR defines specific baseline intervals of the monitored values. If, during construction, the measured parameter remains within its defined interval, the associated geotechnical risks — including all related costs and time impacts — are borne by the Contractor. Conversely, if the parameter falls outside the interval, the risk shifts to the Employer, provided that the deviation actually results in any potential time or financial claims.

4.2 BILL OF QUANTITIES

This is the complete list of works that defines the total contractual price of the project. It is divided into measured items, non-measured (lump sum) items, and time related items for the construction units of the works, which represent complete or subdivided structures and operational systems.

4.3 BASELINE SCHEDULES

This document defines the Contractor’s production rates for activities specified by the Employer during the execution of the works (such as excavation of the top heading of the LTT, excavation of the bench of the LTT, and similar tasks). These production rates form part of the Contractor’s tender and, when multiplied by the anticipated length of the individual NATM technological classes, determine the expected duration of these measured activities.

In addition to production rates (for example, the Contractor advancing 2.25 m per working day in Technological Class 3), the Production Rate Schedules also specify potential delays that may occur during the execution of underground works, such as groundwater inflows, delays associated with geotechnical monitoring, or limitations in advance length imposed by instructions from the Engineer.

During construction, the actual times and delays are recorded and compared with the tendered values. Depending on the actual extent of the encountered NATM technological classes, the originally tendered construction period is adjusted — extended in the case of less favourable conditions or shortened when conditions prove more favourable.

4.4 SCHEDULE FOR COMPLETION

This is an overall programme that consolidates all Production Rate Schedules together with the other key project milestones and defines the revised contractual completion date. It must be emphasised that this date does not represent the actual completion date. Rather, it is an updated contractual date calculated on the basis of the geotechnical conditions actually encountered (the extent of the individual NATM technological classes and the delays). In other words, it is the completion date that the Contractor would have offered at tender stage had the actual excavation conditions and all delays been known in advance.

4.5 PAYMENT SCHEDULE

Invoicing of the works follows two regimes:

- For non-measured construction units, the lump sum price from the Contractor’s tender applies, in accordance with the general principles of the FIDIC Yellow Book. The Engineer certifies that the

construction unit has been fully completed and complies with the requirements set out in the Employer's Requirements.

- For measured construction units, invoicing is based on the evaluation of measurements carried out in accordance with the GBR, which then form the basis for payment.

Invoicing does not occur immediately upon completion of each individual construction unit. In the Payment Schedule, all construction units are grouped into a total of twenty-seven payment milestones. Each partial payment covers several construction units. Until all units assigned to a given partial payment are completed, invoicing cannot take place. The grouping of construction units within each partial payment was determined by the author of the tender documentation, based on their anticipated overall construction schedule.

5. EXPERIENCE WITH THE USE OF SELECTED ELEMENTS OF THE EMERALD BOOK

5.1 ACTUAL CONDITIONS ENCOUNTERED

From the beginning of the excavation works, more favourable geotechnical conditions were encountered than had been anticipated based on the detailed engineering geological investigation. The sandy siltstones and marlstones in the top heading excavated from the western portal were found in weathered to fresh condition, coarsely bedded and disintegrating, with relatively small groundwater inflows on the order of a few tenths of a litre per second. This situation affected the works in particular as follows:

- The excavation time increased, which eventually led the Contractor to consult with the Engineer and subsequently commence excavation using drill and blast methods.
- Occurrence of Technological Class 2, which had not been expected based on the investigation results.

Even in sections where very challenging geotechnical conditions were encountered and parts of the excavation proceeded through clayey soils, the selected construction methods proved effective. The Contractor's technical solution, consisting of protective micropile umbrellas and supplementary stabilisation using cement and chemical grouting, enabled safe execution of the excavation.

With the exception of a single case, no significant complications were recorded under the ongoing geotechnical monitoring.

5.2 GBR

From the perspective of the GBR, several criteria were found to fall outside their defined baseline intervals:

- **k1** – Conditions were encountered which, according to the applied tunnelling classification system, resulted in QTS scores exceeding 64 points (by several units). For the given excavation width, this corresponds to classification into Technological Class 2, which had not been anticipated in the tender documentation or in the DDD. The issue was resolved by establishing a new class, recorded by the mining designer in the site diary (longer advance lengths, excavation carried out using drill and blast methods).
- **k2** – At several tunnel faces, a significantly higher than expected proportion of weathered rock (by several tens of percent) and even fresh rock (not expected at all) was encountered. This was the direct reason for the transition to drill and blast excavation.
- **k5** – At some tunnel faces, due to coarse bedding and the unfavourable intersection of discontinuity systems, increased formation of geologically induced, unavoidable overbreak was observed (rock spalling from behind the theoretical excavation profile, falling out spontaneously during excavation). The current average value for the LTT is 2.5 m³ per advance, and approximately 4.2 m³ per advance for the RTT. The GBR sets the threshold for overbreak at 1 m³ per 1 m of tunnel.

- **k6** – The Contractor is legitimately excavating using drill and blast, or a combined mechanical and drill and blast method. The GBR, however, assumed mechanical excavation only.

For the Homole Tunnel, it was not possible to revise the GBR. As a result, the GBR had to be prepared in a highly detailed and conservative form, addressing all potential design modifications the Contractor might propose in the tender, to ensure that the underlying principles of the GBR could not be circumvented.

Current experience indicates that a more advantageous approach would be to prepare the GBR for tendering purposes and, following selection of the Contractor, jointly define a fair and balanced GBR for execution of the works.

5.3 BILL OF QUANTITIES

When dividing the works into measured and non-measured parts, it is necessary to consider the potential technical solutions that the Contractor may propose in its tender. For certain structures in which measurement may appear unnecessary in the tender documentation (for example, supplementary stabilization works), measurement may in fact be more appropriate—or fairer—depending on the Contractor’s proposed technical solution. Subsequent changes to the extent of measured and non-measured parts of the works are not permissible from a legal standpoint.

5.4 PRODUCTION RATE SCHEDULES

No major difficulties arose in evaluating the schedules during execution. For future projects, however, it will be necessary to explain certain items in greater detail to avoid disputes between the Employer and the Contractor. An example is the item “Delay related to geotechnical monitoring carried out by the Employer”, where the Employer’s Requirements anticipated its use only in exceptional cases involving extraordinary delays (such as the need to perform additional tests or measurements). The Contractor, however, when preparing the tender, considered this item applicable to any delay, for example to the time required for face documentation by the geotechnical engineer as part of the classification into the respective NATM technological class. When resolving the dispute, it had to be acknowledged that, based on the wording included in the Employer’s Requirements, the Contractor’s interpretation at the tender stage could not be excluded.



Figure 5: Equipment for installing micropile umbrellas

5.5 PAYMENT SCHEDULE

Ideally, this appendix to the Employer's Requirements should not be created at all. However, omitting it results in more frequent invoicing, depending on the number of construction units included in the project, which—depending on the project's scope—may reach several tens or even low hundreds.

An alternative is to retain the appendix, define only the total number of payments, and allow the Contractor, during tender preparation, to assign individual construction units to each payment. When the assignment is defined in advance by the Employer, based on the anticipated construction schedule prepared by the designer of the tender documentation, it may result in significant complications in cases where the Contractor executes the works in a different sequence or by a different method. This may lead to situations where completion of a single construction unit (for example, one with a negligible lump sum value) prevents invoicing of several tens of millions of Czech crowns.

6. CONCLUSION

The first experiences with the application of selected principles of the FIDIC Emerald Book in the construction of the Homole Tunnel can be evaluated as clearly beneficial. This contractual framework allows for more effective management of geotechnical risks and enables a more balanced allocation of responsibilities between the Employer and the Contractor. Moreover, the progress of the excavation demonstrated that actual geological conditions were, in some sections, more favourable than expected, which made it possible to adjust the construction methodology, including expanding the use of drill and blast excavation.

It has also been confirmed that a properly structured GBR represents a key instrument for managing deviations from the anticipated geotechnical conditions within a binding contractual relationship. It enables objective assessment of the time and financial consequences arising from real excavation conditions. Unforeseeable physical conditions were primarily classified as unexpected changes in rock composition, excessive geological overbreak, or the need to employ different methods of rock mass excavation.

These findings confirm that a precisely prepared and clearly defined GBR is an essential pillar of the contractual conditions for projects with elevated geotechnical risk. The experience gained during the construction of the Homole Tunnel therefore provides valuable feedback for future projects in which the use of the FIDIC Emerald Book is anticipated in the Czech environment.

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