19th Australasian Tunnelling Conference – Acosta-Martínez, Stewart and Hudson-Smith (Eds.)
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Important considerations when assessing options to manage ground risk on tunnelling and underground works

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ABSTRACT: How best to manage ground risk is one of the most important considerations when developing the procurement strategy for tunnelling and underground works. When addressing this question, how physical condition risks will be shared, evaluated and remedied under the terms of the contract needs to be carefully thought through. To assist in the decision-making process, a comprehensive assessment of potential ground risks should be completed prior to developing the procurement documentation. Careful consideration also needs to be given to how much flexibility will be given to tenderers to modify the concept design and proposed construction methodology during the tender and detailed design phases, along with how the risk sharing mechanisms will be practically administered during construction. If these items are not given sufficient consideration, the effectiveness of the adopted risk sharing mechanisms can be significantly diminished.

1 INTRODUCTION

If not managed well, the delivery of tunnelling and underground works can be confrontational, litigious and dispute driven, as opposed to collaborative and outcome driven, despite everyone's best intentions at the start. While there are many non-ground related issues that can be responsible for this, encountering unexpected ground conditions can be one of the more significant reasons. It is also important to understand and accept that uncertainty will always exist, as we can never fully eliminate it when attempting to predict the conditions which will be encountered underground. However, it is also equally important to always be asking the question what else can we readily and practically do to reduce this uncertainty when planning and executing tunnelling and underground works?

Fortunately, there are many ways to mitigate and reduce ground risks on projects, provided adequate project planning has been done beforehand. These measures include:

- Undertaking a comprehensive site investigation using a phased approach.
- Development of a well-considered, constructable concept design prior to developing the procurement strategy.
- Adopting an observational approach to excavation and support design.
- Rigorous risk management using the guidelines published by the International Tunnelling and Underground Space Association and International Association of Engineering Insurers (ITA and IMIA, 2023).
- Use of appropriate contract packaging, contractual models and risk sharing between the parties.

The remainder of this paper expands on these points, as often not enough attention is given to each, including how the assessed ground risks will be effectively managed under the contract.

2 PROJECT PLANNING

An early focus on developing the conceptual ground model and identification of the potential ground risks for a project are critical for its ultimate success, as the early planning stage is when many risks can be reduced or mitigated without significant cost. To be able to do this effectively requires an early investment in gathering quality site investigation information, as the concept design and options of how it might be constructed start to develop. It also requires early contractor involvement, so the concept design and proposed methods of construction form a robust basis on which the procurement strategy can be built, the necessary environmental approvals sought and the initial cost estimates and schedules for delivery developed.

It is also at this stage that an understanding of the required design development, environmental planning and procurement timelines for the project starts to form. These timelines need to be compared to the development time available, and if the available time is less than what is required to adequately mitigate project risk, what alternative strategies can be put in place to reduce the potential for significant cost and schedule overruns later, due to insufficient time being allowed for project planning.

2.1 *Site Investigation Planning and Execution*

Having a comprehensive understanding of the expected conditions and how they are likely to impact the design and methods of construction, are essential to effectively assess the potential ground risks and develop appropriate mitigation strategies. At the early stages of design, focusing on these items is more important for the Geotechnical Engineer, than undertaking detailed numerical analysis and calculations, given the immature state of the design's development.

As with all projects, it is important to approach the site investigations in a phased way, so the investigation scope can be optimized as the ground model develops and the ground risks become more apparent. All of this can take a significant amount of time, so the planning of the site investigation campaign should be started early and continuously progressed through the project planning phase, with the aim of having a comprehensive database of quality geotechnical, groundwater and environmental information available by the time of tender. Many projects are still planned and taken to market with inadequate site investigation, and it is not surprising that they subsequently run into difficulties, when unexpected conditions are encountered during delivery.

While the costs associated with these early site investigation phases may seem expensive relative to other early cost items, they are typically less than 0.5% of the project's final capital cost. As such, they typically pay for themselves many times over during project procurement and delivery, with the savings achieved in the form of reduced ground risk premiums needing to be added to bids to account for ground related uncertainties, as well as the potential for reduced ground-related claims and disputes.

2.2 *Design Considerations*

The level of maturity of the concept or reference design at the time of tender is another important consideration when developing the project's procurement strategy. Ideally the design should be well developed and be able to demonstrate how the Owner's project requirements can be fully achieved based on the design and construction assumptions made.

Sometimes however it is not possible to achieve this for a range of reasons. In such circumstances it is important to understand the limitations and deficiencies of the design, flag these limitations and deficiencies with tenderers as areas requiring improvement and think through how potential changes to these items might impact the assumptions on which the procurement strategy has been based.

From a ground risk management perspective, changes by the tenderers to the proposed alignment and proposed method of construction need to be carefully considered, particularly if no site investigation information is available for the proposed new alignment or insufficient or the wrong type of information is available, to allow the ground risks associated with adopting the new construction methodology to be properly assessed.

2.3 *Adopting an Observational Approach*

Given the inherent uncertainties associated with tunnelling and underground work, it is prudent to adopt an observational approach to excavation and support design, whereby a toolbox of design options is prepared to account for the range of expected conditions, with the implemented design being based on the actual conditions encountered. To be effective, the following prerequisites need to be in place:

- Sufficient geotechnical investigation and characterization of the ground have been completed to allow the majority of ground types and geohazards which may be encountered to be anticipated.
- The potential ground behaviours and failure modes associated with the proposed design and construction methodology can be predicted based on past experience in similar conditions.
- The most likely conditions, as well as the potential outliers, can be assessed with reasonable certainty for the purposes of design.
- It will be possible to adequately observe the ground conditions encountered, so an appropriate excavation and support class can be determined prior to taking the next advance, and
- It will be possible to verify the design's performance, and modify the design if necessary, through an instrumentation and monitoring program tailored to the design with alert levels and action plans specified for each of the instruments.

It also requires that these observations are practical to make, are reliable, are relevant for the assessment at hand and can be promptly reported and interpreted prior to the start of the next excavation and support cycle. It also requires that suitable contingency plans are in place if unexpected conditions are encountered and that these measures are sufficient to not allow a rapid and progressive failure to develop, before an alternate excavation and support design can be developed and implemented.

2.4 *Rigorous Risk Management*

The Code of Practice for Risk Management in Tunnel Works is a comprehensive guide jointly developed by the tunnelling and insurance industries (ITA and IMIA, 2023). It aims to reduce the frequency and severity of incidents in tunnel construction projects by promoting best practices in risk management and providing a framework for managing risks on underground works across the planning, procurement, detailed design and construction stages.

From a ground risk management perspective, the code of practice states that a project should have the following principal attributes to deliver on the code’s objectives:

- Sufficient site and ground investigation has been completed prior to project award to identify and quantity ground risks to inform design and construction risk assessments.
- The ground risk assessments and ground reference conditions against which changes will be assessed are included in the contract documents.
- Ground conditions are assessed in the temporary and permanent condition during construction, with the limitations of support designs clearly defined in the design documentation, along with the instrumentation and monitoring required to verify and validate the design’s performance.

These attributes are all closely aligned with the project planning considerations discussed earlier and a review of the guide prior to starting the procurement process for project delivery is a useful way to make sure all of these items have been suitably covered off in the tender documentation.

3 CONTRACT TYPE SELECTION

For design and construct type contracts which are common in Australia, the following contract approaches are typically taken to manage ground risk:

- All ground related risks are placed on the Contractor and none are shared with the Owner.
- The contract contains a latent conditions clause which allows a claim to be made if unexpected conditions are encountered.
- Ground risk is shared within the contract using geotechnical baselines similar to that adopted in the FIDIC Emerald Book.
- A collaborative contracting approach is taken by adopting a target price or alliance contract model and the associated open book pricing and cost sharing arrangements.

Despite its ineffectiveness at preventing ground related disputes, the first approach is commonly adopted by Owners, as it is considered that it will effectively reduce their claim exposure. This rarely proves to be the case, particularly if the unexpected conditions are significantly different from those expected, simply because of the quantum of additional costs which are difficult for one party to bear.

A summary of the alternative risk sharing approaches listed above, where a decision is made by the Owner to share some or all of the ground risk, is provided in the following sections. If there is not local experience with the more sophisticated contractual models, it may also be beneficial to consider a staged introduction, with less complex packages bid first to build up experience, before the more complex packages are procured.

3.1 *Latent Condition Clauses*

Several Australian Standard Conditions of Contract such as AS 4000 – 2025 (Construct Only) and AS 4902 – 2000 (Design and Construct) include latent conditions clauses, which are designed to allocate the risk of unforeseen physical site conditions that could not reasonably have been identified before the contract was entered into, including subsurface conditions.

These clauses typically define latent conditions as physical conditions on the site that:

- Could not have been reasonably foreseen by a competent Contractor;
- Differ materially from those that should have been anticipated based on the information provided and any site inspections completed at the time of tender.

When included, they allow the Contractor to claim time extensions and cost adjustments if latent conditions are encountered. The wording of the latent condition clauses in these standard forms of contracts however can be somewhat subjective, leading to projects still ending up in ground related disputes, given there is often some ambiguity that the unexpected conditions were truly latent and not foreseeable at the time of tender.

3.2 *Baseline approaches*

To overcome the types of difficulties described above, FIDIC in cooperation with the ITA, developed a set of Conditions of Contract specifically for Tunnelling and Underground Works (FIDIC and ITA, 2019) and elements of it have now started to be adopted on major infrastructure projects in Australia. The fundamental risk sharing principles assumed in the contract are:

- Unexpected ground conditions risk should lie with the Owner.
- Performance risk should lie with the Contractor as the party who can best handle expected conditions.

These concepts are then integrated into the contract using a Geotechnical Baseline Report (GBR) and a Baseline Schedule. The GBR sets out the contractually agreed anticipated ground types, ground behaviours, excavation methods, support types and their spatial distribution upon which the contract price is based. The baseline schedule then documents the anticipated work items, activities and production rates upon which the contractual time to completion is based. These items are all subsequently monitored and remeasured during construction to establish the final contract cost using the agreed contractual mechanisms. The contract model is therefore closely aligned with the observational approach and is ideal for the delivery of excavation and

ground support packages of work. With this form of contract, difficulties however can arise if the scope of work, design or method of construction on which the contract was based changes materially during delivery.

3.3 *Collaborative Contract Arrangements*

For projects where the Owner wishes to take a more collaborative approach to project delivery, target price contracts and alliance agreements are becoming more frequently adopted in Australia. They also provide the advantage of being more interactive during the tender period and therefore allow the Owner to gain a better understanding of how the parties are likely to work together during delivery.

3.3.1 *Target Price Contracts*

Where a project is complex and will require significant collaboration between the Owner and the Contractor to successfully deliver it, a target price contract can provide a good risk sharing model to help manage the identified risks, including ground risk. It blends elements of both fixed-price and cost-reimbursable contracts, aiming to align the interests of both parties and encourage cost efficiency. A target cost is negotiated during the tender period which includes direct costs (labour, materials) and indirect costs (overheads, profit), along with a pain/gain mechanism to share the savings or cost overruns should the actual cost be less or more than the target. The contract also specifies which party bears the risk for different types of ground conditions, with often known risks priced into the target, while unknown or latent risks are shared or retained with the client. A portion of the budget is also typically set aside to cover unexpected ground conditions, either within the target price or through a separate contingency fund.

3.3.2 *Alliance Agreements*

A project alliance is where the Owner and Non-Owner Participants (Designers, Contractors, Suppliers) work as an integrated team to deliver a project under a contractual framework where the commercial interests of all parties are aligned with the desired project outcomes. Under this model risks and opportunities are jointly shared and managed, with behavioural expectations between the parties managed through an Alliance Charter. It differs from traditional forms of contract where each party has and must fulfill its own separate obligations and risks are allocated to each party. Compensation is based on a target cost arrangement using project reimbursable costs, Non-Owner Participant fees and normal profit and a risk / reward amount using a pain / gain formula, with adjustment events used to manage variations. It is particularly useful on projects when significant value can be added by the Owner during final design and delivery and where there are:

- Complex interfaces and / or unpredictable risks
- Complex stakeholder issues and / or external threats to the project
- Very tight timeframes
- Difficult to define scope and/or likely scope change.

Because of the joint sharing and managing of risks, ground risks are not allocated to one party, but the alliance instead collectively owns them. Costs arising from ground conditions are therefore absorbed by the alliance and factored into the overall project performance. If ground conditions change, the alliance can adjust scope, budget, or schedule without formal claims or disputes, with decisions made based on a best-for-project basis.

4 DEVELOPMENT OF PROCUREMENT STRATEGY

Where a shared approach to ground risk management is adopted, a phased approach to procurement and contractor selection should also be developed, with sufficient time given to tenderers in each phase to fully develop their bids. The phased approach should be structured at high level along the following lines:

- ***Prequalification Stage:*** Establish a shortlist of qualified bidders using a pre-qualification

process. As part of the pre-qualification process, commentary should be invited on the concept or reference design, the proposed construction methodology and the Owner's assessment and proposed allocation of risk. The opportunity should also be given to provide feedback on areas for improvement and where some targeted value engineering could provide a better solution. This feedback should be used to finalise the procurement strategy and tender documents prior to progressing to the tender stage.

- ***Tender Stage:*** Based on the project complexity, the prequalified tenderers should be given sufficient time to develop a well-considered tender design, on which their commercial proposal will be based. This should include a series of interactive workshops, with some of the allocated time focused on discussing the identified ground risks and how they are proposed to be shared, so both parties have a better appreciation of each other's position. The aim of these discussions should be to make sure the material risks have been identified and fully understood, so the Owner is better informed going into the evaluation stage.
- ***Tender Evaluation and Award Stage:*** Based on the results of the tender evaluation and negotiations, the contract documentation will need to be finalised and the contract price and the Owner's contingency allowances set. If tender interactives and submission requirements have been well planned, this is the time where certain risk items can be bought back by the Contractor if they are better able to manage them or the risks further assumed by the Owner if the uncertainty is resulting in very high contingencies in the Contractor's pricing. Where a baseline approach has been taken, the baselines in the GBR can be adjusted based on the agreed outcomes of these negotiations. Depending on the complexity of the project and flexibility which has been given to change the design and construction methodology, this final stage can take some time, particularly if the preferred tender solution differs from the reference design. It is important therefore that these updates are not rushed and sufficient reviews are completed to make sure all the contract documents reflect the agreed changes and link properly prior to contract award.

5 GBR DEVELOPMENT AND ADMINISTRATION

When a baseline approach to ground risk sharing is adopted, the reference ground conditions for the shared risk model are incorporated into the contract using a GBR. The most widely recognised reference for the use of GBRs in tunnelling and underground works is the ASCE Suggested Guidelines (Essex, 2022). This originates from, and is targeted at, the North American (i.e. USA and Canadian) construction industries, but the majority of the content provides a useful set of principles and guidance for adoption in many common law jurisdictions. CIRIA Report C807 (Davis et al, 2023) is also a useful reference and documents best practice in the adoption of GBR's, based on a cross-section of industry expertise, including extensive experience from within and outside of the UK.

For the Design and Construct type of contracts which are common in Australia, the GBR needs to be prepared using the three step GBR-A, B and C process outlined in the guidelines. When preparing initial version (GBR-A), it is important for the Owner and their advisors to think through what ground risks the project faces, which of them could have a material impact on the project, which make sense for the Owner to share and how they should be baselined. When doing this both "foreseeable" systematic and non-systematic conditions should be considered (the known unknowns), as the "unforeseeable" ground risks (the unknown unknowns) should be addressed through an appropriate latent conditions clause.

For the risks which will be shared, geotechnical baselines need to be selected, which are clear, unambiguous and easily measurable. It is also advisable to include direction in the report on how the baseline is to be measured and to specify the information required to validate a claim of exceedance. If there is a need for Baseline Statements to refer to an equation, graphical plot of data and/or a geological section or plan, then these should be included in the GBR and not cross referenced to other project documents or external publications.

Baseline Statements are also commonly divided into either Material or Behavioural Baselines – a division that attempts to address either "cause" or "effect" of encountering variable ground conditions. Material Baselines usually address the extent of various geological/geotechnical strata or the engineering properties of materials. Behavioural Baselines are often easier to implement

but are usually specific to an assumed form of construction. The Behavioural Baseline Statements can address the effect of variation in some of the fundamental material properties by baselining the effect of the variability. Examples include the type of ground support class which should be installed for a given encountered condition in a mined excavation or the number of interventions which should be allowed for to deal with natural or man-made obstructions in a TBM excavation.

It is also important to focus the GBR on just the material ground risks rather than all of the assessed ground risks, otherwise the data collection and contract administration requirements can become overly complex and burdensome. Each selected baseline condition should also be reflective of the risk and the risk level the parties have agreed to share. The report should also be clear these baselines have been set for contractual purposes and are not necessarily reflective of the actual conditions expected to be encountered. If a GBR is poorly written this distinction can become blurred and lead to the baseline conditions being inappropriately used for the purposes of design.

Lastly it is important to make sure the GBR is fully integrated into the Contract and is appropriately cross referenced and linked to those clauses in the Conditions of the Contract that deal with entitlement for extensions of time and additional cost. This should happen both when preparing the tender documents and when finalising the contract documents prior to award, with both the legal and technical teams being involved in the drafting and reviews.

6 CLOSING STATEMENTS

Even with all of this planning and preparation, it is inevitable that there will still be disputes on large complex underground construction projects and the adoption of a shared ground risk model will not eliminate this from happening. However, by adopting the practices outlined in this paper the number and size of ground related disputes should be reduced, and when they do occur, it should be more efficient to assess and administer them. In this regard, consideration should also be given to including a Dispute Avoidance / Adjudication Board (DAAB) into the contract, as in the author's experience the use of a DAAB is an efficient way to reduce the number of disputes which are initially raised, as well as limit the potential for those that are raised to escalate further, once the board recommendations have been made.

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