PERFORMANCE BASED DESIGN: WHY AREN'T WE LEVERAGING IT TO ITS FULL POTENTIAL? MANAGING OPPORTUNITY, SAFETY, AND CONTRACT RISK

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ABSTRACT

The Observational Method is fundamental to the art of subsurface engineering, yet contract methods for effectively leveraging it to its full potential remain limited. This paper demonstrates the advantages of performance-based design, with case histories from the past 50 years to illustrate the economic and risk management benefits from leveraging performance-based design methodologies safely and effectively. The paper describes the risk that specification-driven design parameters can have on design economy, constructability, and schedule, and outlines proposed tendering approaches for incorporating performance-based designs into contracts, while limiting risk for owners and contractors.

Keywords: Observational Method, performance-based design, contract risk, collaborative contract

INTRODUCTION

Risk is inherent to work in the field of subsurface engineering and many contract approaches have become so focused on shedding risk that they leave no room for one of the best tools in our industry, the Observational Method. Its development in subsurface engineering owes its foundation to Karl Terzaghi and Ralph Peck through their respective works dating back as early as *Soil Mechanics in Engineering Practice* published in 1948 and *Advantages and Limitations of the Observational Method in Applied Soil Mechanics* in 1969. Throughout their fundamental works, a strong argument for use of the Observational Method is made:

"...the potential for savings of time and money without sacrifice of safety is so great that every engineer who deals with applied soil mechanics needs to be informed..." (Peck 1969)

Not every project will benefit from its use, but in today's risk management focused world, projects and contracts should be set up to allow for its use, while sharing the risk clearly and equitably between all parties. Without a proper contractual mechanism to leverage its use, perceived management of "risky unknowns" will override substantive application of the method, and significant benefits may be lost as a result. As Terzaghi said "*A vast amount of labor goes into securing only roughly approximate values for the physical constants that appear in equations... Therefore, the results of computations are not more than working hypotheses, subject to <u>confirmation or modification</u> during construction.*" It is our collective view that subsurface engineers should take this task of confirmation and modification seriously. We should use the Observational Method to derive performance-based designs that deliver design economy, constructability, cost, and schedule advantages without sacrificing safety or quality. <u>Collaborative style contracts provide a framework to approach shared risk and opportunity with appropriate incentives for the individual parties.</u>

Fundamentals of the Observational Method

<u>Terzaghi and Peck 1948:</u>

"Base the design on whatever information can be secured. Make a detailed inventory of all the possible differences between reality and the assumptions. Then compute, on the basis of the original assumptions, various quantities that can be measured in the field." "On the basis of the results of such measurements, gradually close the gaps in knowledge and, if necessary, <u>modify the design during construction</u>."

<u>Peck 1969:</u>

"Although the Observational Method often offers the best way out of difficulties that have already developed, its intended <u>use from the inception of a project</u> offers even more opportunity for imaginative planning and may lead to the best possible design from the points of view of safety, economy, and time."

Why then, do we still have difficulty utilizing the Observational Method to its full potential from inception of a project?

- While mostly straightforward, it is not tidy. You can't button it up into a conceptual set of drawings, standards, specifications, or a contract simply. However, we ultimately must accept that there are always unknowns in subsurface engineering, and we can only find the best way to manage them.
- People take comfort from the perception that they are controlling risk. Limiting the potential for contract or scope changes reduces contractual risk, whereas the Observational Method aims to control technical risk and increase safety. Myopia for contractual risk and schedule may obscure physical and technical risk and the opportunities associated with it.
- It takes time — to think about the variables, to monitor, to review, to plan the potential outcomes. We must agree with Ralph Peck: subsurface engineering is an art as much as it is a science. Observation and performance-based design — informed by experience-honed judgement and creativity as much as calculation — should be understood as such, and its practitioners should be given the respect and time the process deserves. Subsurface engineering, as an industry, will only benefit.

The flexibility for inclusion of the Observational Method from inception of a project, and the rigor involved in the process, will ultimately depend on the type of owner: private developers, publicly traded companies with procurement rules, or government entities with mandatory procurement processes (attempting to ensure fair competition). A clear and fair contractual framework is necessary to allow all owners to participate in procurement of performance-based designs. As designs and contingencies for the Observational Method become more complex, the increased risk becomes prohibitive for any single party to hold. But non-traditional contract frameworks can be utilized to properly mitigate risks with this approach and align all parties to take advantage of the Observational Method.

RISK OF PRESCRIPTIVE DESIGNS

Prescriptive criteria do not alone make a design safe. Regardless of the parameters assumed, proper evaluation of the design cases, validation of design parameters and project assumptions, and observation of construction are all critical to ensuring project safety. This is why performance-based designs provide a safer alternative. There are a variety of other risks with a prescriptive design approach to projects, the most obvious being conservative approaches that lead to heavier designs with increased material and installation costs, increased installation schedules, and increased safety risks due to increased risk exposure duration and increased installation labor. In the Toronto area, this has led to designs 2–3 times heavier than similar designs utilizing the observational method.

Conservative soil models can create a myriad of issues, including giving a false sense of security and blindness to critical issues and failure mechanisms. For example, prestressing loads that are too high can lead to performance problems due to overstressing the soil behind the wall and consolidation/creep, ultimately leading to tieback de-stressing or heaving of nearby structures. This conservatism in the design can also lead to the construction team taking greater risks on site because they believe everything is overdesigned. This can manifest itself in dangerous ways, including over-excavation past support levels, less emphasis paid to timely or accurate monitoring of shoring and neighboring structures, and less respect paid to design restrictions. Issues with respect to design performance can escalate quickly under these circumstances creating real life safety concerns.

Prescriptive designs should not be used as a broad brush for public infrastructure projects. This approach would be most appropriate where reliable methods for measuring or observing the performance of a structure are not available. For example, prescriptive designs may be appropriate on remote sites with intermittent site visits or projects with missing or unreliable monitoring data, making observations and design adjustment decisions problematic but with relatively low risk from adverse performance.

CASE HISTORIES

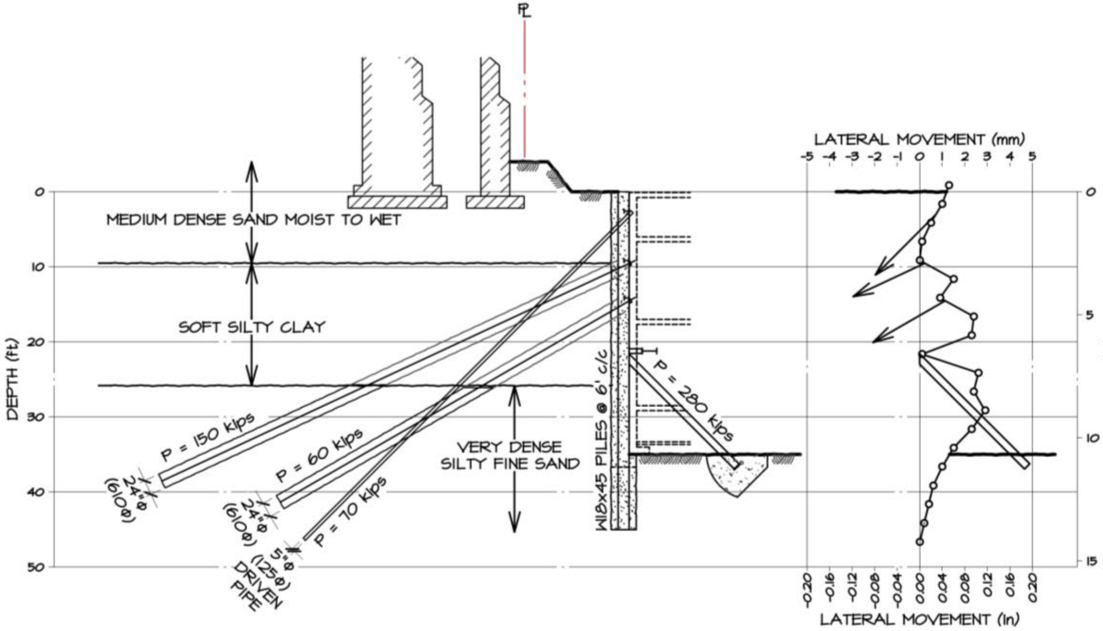
The following are several case histories from the Greater Toronto Area (GTA) where the Observational Method was used successfully, and lessons learned from each:

St. Paul's Anglican Church (1976)

St. Paul's Anglican Church is a cathedral sized church in Toronto's midtown. An apartment building with four underground basement levels was built adjacent, with shoring within 1.5 m (5 ft) of the church's spread footings. The footings were founded on moderately dense sand overlying dense clayey silt glacial till, but during design of the adjacent building, these footing loads were deemed to be exerting higher bearing stress than 1970's design standards would permit. The church already had prominent cracks and signs of settlement, with a large, round, stained glass window casement in the stone wall closest to the proposed shoring already showing signs of movement in the perimeter stones.

Based on the sensitivity of the church structure, "*a serious attempt was made to achieve zero shoring movement in the critical soils below the footings*" (Isherwood 1990). The initial design called for two levels of rakers, as tiebacks were still in the early adoption stage in Toronto, but permission was obtained to use tiebacks shortly before the start of construction. A redesign replaced the upper level of rakers with two levels of tiebacks.

Inclinometers, which were also new to local industry at that time, were installed on the shoring piles and the monitoring results guided decisions to modify the excavation staging and bracing. This ultimately resulted in a third level of soil anchors to achieve the excellent movement results shown in Figure 1, far better than would have been achieved without an observational approach.



a) b)

Figure 1: a) Shoring design cross section adjacent to St. Paul's Church showing the final bracing as installed and b) inclinometer plot of shoring performance

Governor's Hill Condominium Tower (1987)

The proposed condominium tower was built at the base of a 15 to 25 m (50 to 80 ft) tall curving slope with homes ringing the crest of the hill. The underground excavation was a concern for the neighbouring homeowners. Intense debate between the design team and peer review consultant regarding the soil slope conditions and shoring load slowed progress on the project.

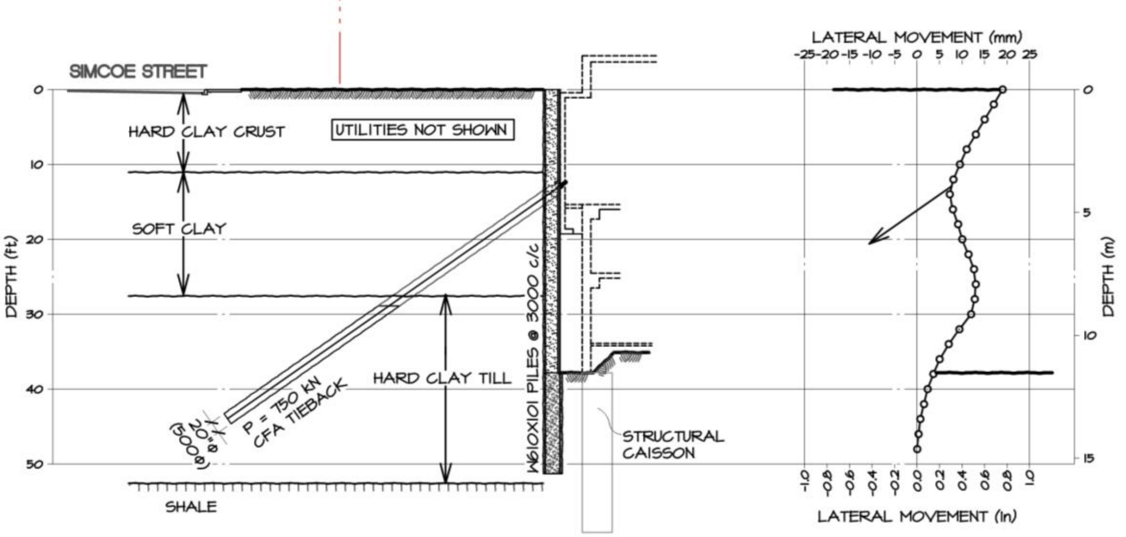
A third-party geotechnical engineer was brought in to perform a secondary analysis of the site. This supplementary report outlined two design scenarios: use of standard apparent earth pressure loading diagrams (0.65KγH), or lesser loading with a rigorous monitoring program *"whereby loads and displacements of the retaining wall system are regularly measured for the purpose of adjusting and/or augmenting the system in response to measured behavior…"*

The second scenario allowed the intended shoring design to proceed with a monitoring program that included load cells on the tiebacks — an astute application of the Observational Method. The final shoring system had a maximum of 4 rows of tiebacks for the deepest 18.5 m (60 ft) cut and is estimated to have saved $1 million CAD ($2.5M CAD adjusted for inflation) over the conservative approach advocated by the peer review consultant.

Canada Life Building (1992)

In the early 1990's, the Canada Life insurance company built a 16-storey tower with 3 basement levels next to their Toronto campus. The tender documents used 2 rows of anchors extending to rock 17 m (55 ft) below grade. The shoring contractor, Deep Foundations Contractors (now Green Infrastructure Partners, GIP) hired Isherwood to collaborate on a redesign to CFA soil anchors, expecting a single row of bracing would be sufficient for the 12 m (40 ft) deep excavation in clay till. Based on the depth of the cut, inclinometers would be relied upon to measure shoring movements and a contingency second row of bracing would be added if needed.

The shoring contractor priced their bid to cover the cost of a second row and was successfully awarded the contract. The redesign was completed with one row of anchors and inclinometer readings confirmed acceptable performance; see Figure 2 for a typical as-built section and corresponding inclinometer results. In this case, although the owner received a competitive price and expedited schedule, the risk of installation of the second row of anchors, and associated reward in deletion, was borne solely by the contractor.



a) b)

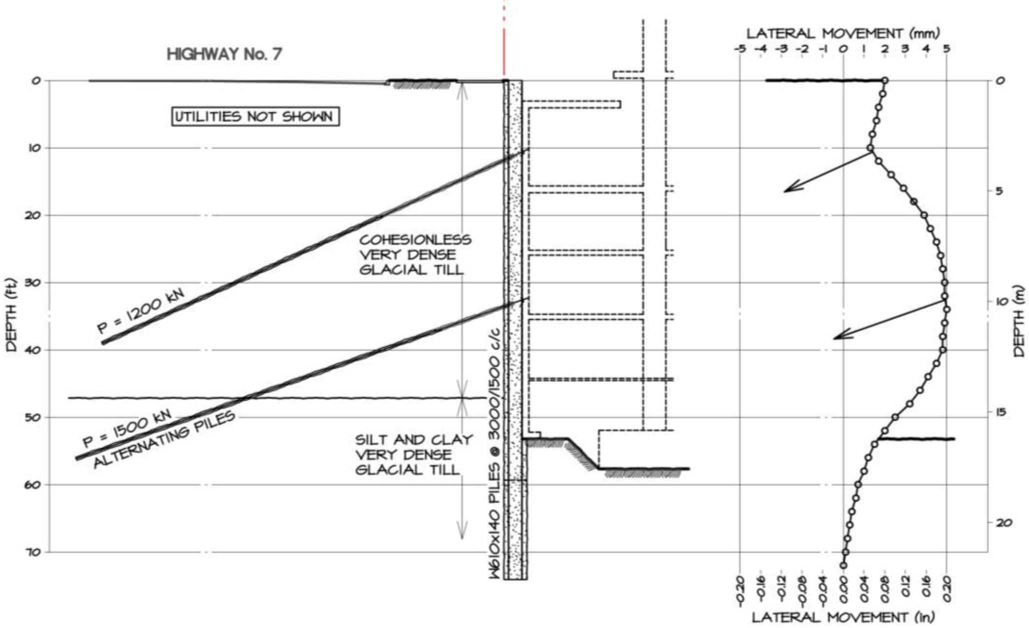
Figure 2: a) Typical shoring cross section for the Canada Life building and b) inclinometer plot of the shoring performance

Vincent Condominiums (2023)

'The Vincent' project has a pair of condominium towers with 4 levels of underground parking, situated in very dense, but variable, glacial till. The original design proposed using 2 rows of tiebacks for the 18 m deep excavation, with a secant wall to cut off water (see Figure 3). However, significant uncertainty existed over whether the excavation would be subject to water pressure in the dense tills. Similar deposits in the project neighborhood are known for having unpredictable sand and gravel channels that carry large quantities of water.

During the bidding process, the shoring contractor's value engineering proposal included possible reductions to the tieback loads where dry conditions were found. To manage the soil and water pressure unknowns, the design engineer left the tiebacks unchanged prior to construction, but the shoring contractor gave separate pricing for the second-row tiebacks. The decision to reduce the tiebacks could then be made based on the shoring monitoring and the actual soil response, with potential tieback savings given back to the owner at a predetermined market rate. This approach to sharing risk and savings is what helped secure the project.

During secant wall installation, the drilling crew noted dry conditions that could have been drilled without liners, indicating no unexpected granular channels and a large reduction in the applied shoring load. When the excavation level reached the second-row tiebacks, the excellent shoring performance (see inclinometer results in Figure 3) confirmed the reduction in load, and as a result, the tiebacks were only installed on every other pile, a 50% reduction.



a) b)

Figure 3: a) Typical shoring cross section from Vincent Condominiums and b) inclinometer plot of the shoring performance

As this opportunity for shared savings was discussed during contract negotiations between the owner, designer, and shoring contractor, the owner was able to participate in the savings for the tieback deletion, and the contractor was able to share some of the risk associated with assuming better geotechnical performance than reported in the soils report, while capitalizing on their experience in the area.

Cedarvale Subway Station (2013–2022)

The Eglinton Crosstown Light Rail Transit project was completed in three contract phases. It had a series of launch and exit shafts built as part of two separate advanced tunnelling contracts, followed by the contract for the excavation and construction of the new ‘Stations, Rail, and Systems’ (SRS). Cedarvale station was one of the stations, Launch Shaft 2 (LS2) to the east, which was part the previous advanced tunnel contract.

The advanced tunneling contract was based on a conceptual design for the support of excavation systems, governed by a prescriptive design specification that included constraints around the required loading diagrams, shoring stiffness, and maximum support spacing, leaving little room for observation, optimization, or engineering judgement. LS2 was specified to have a 10-year design life and would be handed over to the SRS contractor(s) during that timeframe.

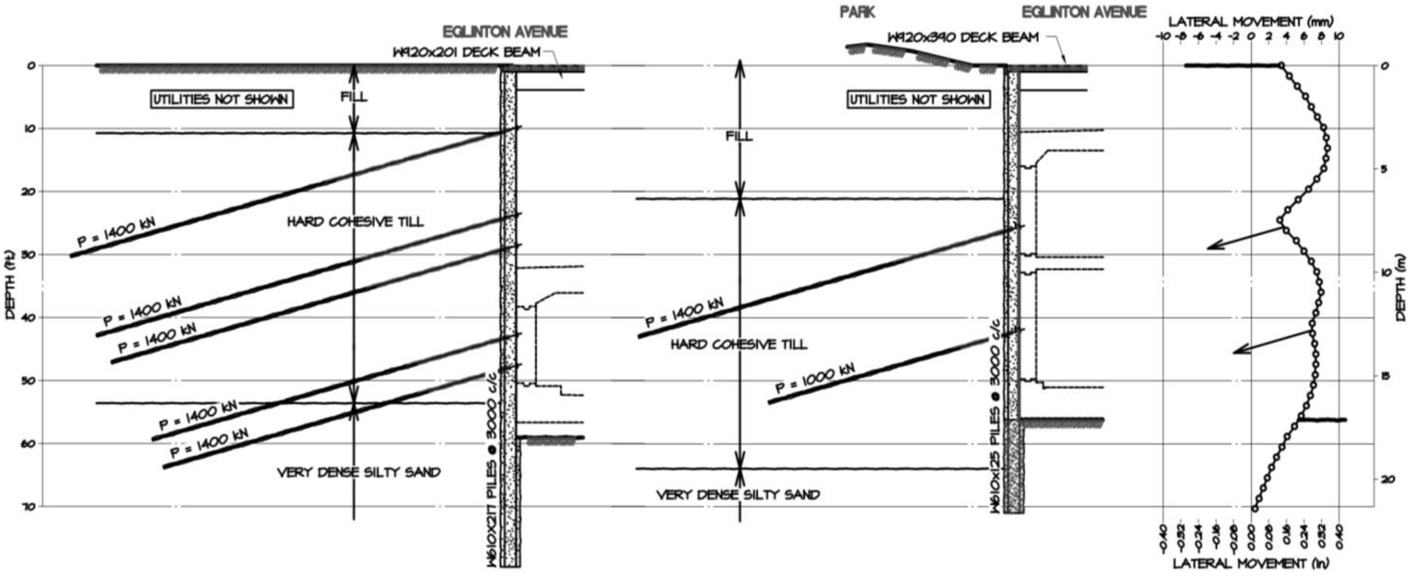
In contrast, the station shoring contract used a design-build process, with a reference concept design showing the proposed station geometry, without shoring, as the starting point for discussions. The performance-based design specifications allowed more design flexibility, using local experience to create a more efficient shoring design.

Together, Isherwood and GIP proposed a shoring scheme to meet the performance requirements (i.e. shoring wall movement limits), creating preliminary sketches showing planned locations of soldier pile & lagging versus secant wall, typical pile layout, expected pile sizes, sample sections showing excavation depth, tieback levels and loads, and toe depth.

Design Comparison

At the interface between the prescriptively designed launch shaft and performance-based designed station excavations, the difference in shoring systems can be directly compared. Figure 4 shows the launch shaft shoring design and station shoring design. Pile target monitoring results for the shaft showed a maximum of 8 mm (5/16”) into site movement, while inclinometer results for the station (figure 4c) showed a maximum of 7 mm into site movement, a negligible difference. The prescriptive LS2 shoring was designed with three times the bracing load due to specification requirements, resulting in shoring almost 90% more costly than the performance-based design of Cedarvale station, with <u>no improvement in shoring performance</u>.

As is clearly illustrated in this example, the huge material, cost, and schedule savings paired with the equivalent movement control of the pared down station shoring is a strong argument for the economic success of the Observational Method and resulting performance-based design. What is often missed is the <u>increase in safety</u> that a performance-based design process provides: proper implementation requires more stringent validation of assumptions, performance, and associated design monitoring than one simply coded with ‘conservative’ design assumptions. This is a key distinction that more owners, and owner’s representatives, should be aware of.



a) **b)** **c)**

Figure 4: a) LS2 cross section, b) Cedarvale station cross section, c) Cedarvale station inclinometer plot

Contract Notes

The risk on this complex design-build project, where there were many geotechnical and interface risks, was dealt with using the open-book, target price contract method to properly motivate all parties to make best-for-project decisions for the station shoring. Based on the proposed shoring scheme sketches, an open book estimate was created for the base design target price, with labor rates and profit agreed upon and included. The work was billed according to the actual time and materials utilized. Contingency amounts above the base target price were built based on the known highest-value risks to assign a budget against, for example — geological risks (boulders), production risk (estimated overages in time and materials), and quality risks (redrilling). Of interest - the contingency pool was not exclusive to the items used to generate its value, it was to cover any project risks which were not a result of three exclusions: changes to shoring type, shoring geometry, and geotechnical parameters.

The general contractor and shoring subcontractor were incentivized to minimize use of the contingency through two mechanisms: any contingency amounts not used were split between the contractor and the subcontractor, while any overages were paid at a reduced, pre-negotiated rate. This created an efficient mechanism to share the risk of cost overruns between parties. For this target price agreement, up to half of the contractor’s agreed profit margin could be used to cover any initial overages beyond the contingency budget, and the rest would be paid at a time and materials rate with zero profit. (See Figure 5 and Table 10 for an example breakdown of this contract type.) This is one example of a contract set up appropriately to leverage the Observational Method and performance-based design. However, the nuances of each individual project’s risk profile are unique and are not fully captured by a single contract model.

USING THE OBSERVATIONAL METHOD IN CONTRACTS

Allowing for tendering of large projects using performance-based designs from project inception requires a large investment of time, which may not be practical during the bid stage of the project. This is where collaborative contract models could improve the design development process. While recent collaborative contract improvements have tried to close the gap between owners and contractors by promoting risk-sharing, significant challenges still exist to substantive use of observation-driven, performance-based designs. Primarily, current alternative contract models focus on the owner/contractor relationship. This often does not incentivize the Observational Method’s use, as the risk is still borne disproportionally at the subcontractor and designer level. For example, certain progressive design-build (PDB) contracts allow for early contractor involvement at the design stage of the project. However, without guaranteed construction scope, there is little draw for contractors to share all their best ideas, which could then be market priced to avoid sole sourcing as required by most public agencies. Introducing risk and opportunity sharing principles between owners, contractors and subcontractors will allow greater opportunity for use of the Observational Method.

The final step of integrating the Observational Method onsite is to incentivize the project stakeholder group's participation. Sharing the potential benefit and risk of unknowns is paramount to owner/contractor/designer trust and engagement. There are schedule and commercial risks associated with this design approach and, as demonstrated in the case histories, substantial reward. Though risks will remain, they can be mitigated like any others: with proper planning, preparation, monitoring, and timely action. It is important to remind everyone again, as stated by Peck: if done correctly the Observational Method is the safest method of design, and an opportunity to get the design exactly right by confirming assumptions along the way. A conservative design without the same level of validation is not *de facto* safer, especially in the uncertain world of underground engineering.

Collaborative contract types cover a spectrum of risk-sharing methods. On the more simplistic end, with one or two parameters of variability, contract levers can be added to trigger additional work by actual performance levels. As the risks become more convoluted, or should more fairly be borne by multiple parties, contract types can become more complex and involve target pricing, progressive design methods, or owner/contractor alliances.

CONTRACT IMPLEMENTATION

Once an opportunity to use the Observational Method has been identified, additional contract mechanisms should be discussed beyond the usual design alternative proposal or Design-Build contract model. Due to the resulting new assignment of risk to parties in the contract, the project stakeholder group will be subject to a new set of potential costs based on the observed performance onsite. It is important to remember, as shown in the prior case histories, that the Observational Method base cost is lower than the non-observational base cost, otherwise the design alternative would not be proposed. In addition, the total cost after implementing observational techniques and executing some associated contingencies has the potential to show substantial savings versus a non-observational cost and should provide more certainty over the required spend as compared with an intentionally conservative design as the design is adjusted only as necessary to achieve *in situ* performance. This is because a conservative design tries to account for all possible worst-case scenarios, whereas a performance-based design adjusts for what is present on site, good or bad.

Procurement methods can fall into two general categories, public and private. Private procurement typically comes with wider latitude from the project owner on how to engage with contracting parties, and laws around open and competitive procurement may not apply. Public procurement will typically involve a formal process for the demonstration of competition and the fair commitment of public funds. There are opportunities to enter into a collaborative risk-sharing contract in either method.

Private Procurement

In a private contracting environment, opportunities can be identified and discussed at any stage in the process. With less formality a trusting relationship between the parties involved is fundamental. Ideas and potential opportunities will be shared and discussed, requiring protection of the intellectual property of the sharing party. While non-disclosure agreements are good practice, practically speaking they are hard to enforce.

The simplest form of agreement in a private contracting scenario would be a trigger type clause added to the standard bid-build contract. An opportunity for use of the Observational Method to redesign a project would be highlighted, with a separate price given for the additional contingency measures (for example, additional bracing). If this method properly shares the incentive, then all parties can benefit: the owner can share in the risk and opportunity, while the contractor can execute the competitive redesign while not bearing the entire risk.

As the alternative approaches or risk sharing become more complicated, or if the value of the change is high as a proportion of the work, more complex agreements can be used. It is necessary to set out clear contractual baselines and contingency triggers at the time of contracting. The owner, contractor, designer, and any other necessary project team members must be involved in this discussion. Attempting to negotiate these terms and response levels during construction will undermine the process, waste time, and skew the risk sharing as stakeholders may try to renegotiate their position or disagree on necessary actions.

Public Procurement

In public procurement, often at least one stage of competitive procurement must take place to demonstrate value is being attained for public money committed. This is typically further separated into two categories.

Design-Bid-Build Pursuit

Design-build agreements are similar to the private contracting template. The difference is that the design on these projects is at a very early design stage, typically a Reference Concept Design (RCD), which fixes project scope and demonstrates project constructability. A few other metrics need to be put into place, such as geotechnical parameters in a Geotechnical Baseline Report (GBR) and performance tolerances.

When initiating a pursuit using this method, it is best to form a teaming or exclusivity agreement on the project to protect intellectual capital. To achieve the best results, an integrated approach to ensure “best-for-project” decision-making is necessary. The lowest price for each scope is rarely the lowest overall risk-adjusted project cost, so all parties need to plan together. Achieving this is no simple feat and requires a multidisciplinary team to work through an iterative planning process. Setting appropriate incentives for all parties to bring ideas to the table and share in the potential risks and opportunities is key to the success of this approach.

One such incentive is the use of an open book approach to the estimate throughout the pursuit phase, with an exclusivity agreement in place for a guaranteed portion of the work. Then, based on job complexity, the final price can be locked in at an agreed design and estimate stage and converted to a construction contract. This contract could simply be the base construction contract, with trigger levels for observational elements, as previously discussed, or a target price as dictated by project complexity.

Pursuit Without Known Deliverables

The other main approach for a design-build relationship is where some of the baseline information (RCD, GBR, or performance criteria) is not known for the project, therefore a typical technical proposal and price procurement for total cost cannot properly evaluate the proponents as there are too many outstanding variables for adequate comparison. In this case, a qualifications-based procurement approach should be taken with proponents submitting the team qualifications, team experience, and baseline profit assumptions.

In PDB, Alliance, or other collaborative contract types, the engaged parties would then become design partners. At this stage there is no construction contract in place, but there would be a process to convert the design phase to a construction phase. This often includes a preliminary step of "Early Works" construction activities, which can be identified and pulled forward to maintain schedule, while the larger design pieces continue to be developed.

As design partners are awarded the contract very early on in the project compared to traditional contractor engagement, there are many unknowns about the scope of work. These include budget, schedule milestones, and even project scope in some instances. The owner or contracting authority also needs to maintain termination clauses or the ability to opt out of the construction phase if project parameters (financial or technical) are not achieved. On the other hand, the contractor-design team needs certainty that they will be able to complete the construction project if the design phase is successful, as their business model is to construct. Compensation for the contractor's time spent during the design phase, at cost plus a small mark-up, does not cover the lost profit of a construction contract or lost alternative pursuit opportunities. There also remains a risk that the designs are then released for public tender if the design partner and owner cannot come to a construction agreement, making the design party compete on the open market to construct the design that they developed with the client.

Trust and clear communication between parties are key to the success of this contracting model. The parties need to have common goals and be incentivized to work together to achieve them. This is difficult to achieve on the mega projects now prevalent in global construction, as people from multiple disciplines, companies, and cultures must come together to bring these projects to life in a short timeframe. The goal of the collaborative contracting method is to support the development of this necessary trust, as it is impossible to contractually enforce it. Achieving project success from the viewpoint of all project stakeholders requires that all parties come together to work towards a common goal and trust that they will be treated fairly through the process.

DESIGNER MOTIVATION

With flexibility created via the various contract mechanisms described above, experienced designers can use the Observational Method to plan for the most likely soil parameters, with rigorous monitoring programs to alert them when contingencies need to be implemented. The case histories have illustrated how this approach can lead to both improved performance and cost savings, but designers need to be motivated to participate in the shared risk (beyond the satisfaction of resources saved and their own competitive edge) with financial compensation to reflect the value that they add with smarter designs. There should be an opportunity for the design engineer to participate in the various collaborative models and participate in the risk and opportunity sharing.

Designers can be made part of joint venture teams, sharing in the larger overall profit resulting from their design optimizations, but this would generally expose them to outsized financial risk compared to their scope, since engineering fees are small (1-10%) compared to the overall contract. One approach would be to use a portion of the larger profit to have more site personnel to keep better tabs on progress and catch possible issues, but there must be sufficient trust between parties to ensure that issues raised are addressed and that contracting teams maintain accountability for their work.

Alternatively, the designer can remain outside of the joint venture team, but the contract could allocate larger fees and profit to the designer that reflect the value of the expertise and value engineering they provide, or tie it to the design optimizations that are realized. To ensure the designer is appropriately sharing in the project risk, mechanisms could be introduced to claw back profit akin to other contract parties when there are cost overruns, with minimum fees set to cover costs (similar to the Cedarvale Station contract described above). However, there should be clauses to divorce the designer from risks they don't control; for example workmanship problems, changes to design requirements made by the owner, etc. More importantly, success will require trust that the designer's contribution is valued, not just for the hours worked on the project, but the years of experience and learning that made the optimizations possible. If compensation is tied to use of design contingencies, special attention should be given to the key contingency designs and implementation levels during construction. Failure to identify these parameters during the design development phase could lead to a perceived conflict of interest during observation interpretation. Delay in the setting out of actionable observations and necessary actions also creates uncertainty for all involved contract parties, and could inappropriately incentivize riskier decision making than initially intended.

It is worth dwelling on the importance of design verification (field review, monitoring, testing review) for success using the Observational Method, as one needs to be able to detect if an adverse condition is arising. Proper monitoring execution is an essential risk management tool for the design engineer, and they should have control over the monitoring whenever possible, even supplying it via a subcontractor. When this isn't possible, the designer should be cautious about what designs they are willing to execute and consider carrying their own contingencies for independent monitoring of critical items like inclinometer and survey baselines.

THE OBSERVATIONAL METHOD IN PRACTICE – ADDITIONAL NOTES

The following are suggested considerations for implementing the Observational Method successfully, incorporating the lessons discussed above.

Suggested Procedure for OM Project from Inception (with inspiration from Peck):

1. Conduct geotechnical investigation(s) sufficient for project scope.
2. Create the geotechnical baseline report (GBR)[1] to outline the range of conditions to be expected based on geotechnical investigation. No additional geotechnical investigation is required — this document outlines what is included in the contract as a known condition versus a change in condition based on the investigation conducted.
3. Create the "base design" based on the most probable conditions (leverage local experience).
4. Decide on performance indicators to be observed during construction to validate assumptions and the method of observation/accuracy required. For example: Movement/settlement thresholds, bracing loads, etc.)
5. Create "contingency designs" based on the range of conditions up to the most unfavorable conditions outlined by the GBR (one or several contingency design steps). For example: Additional row of bracing.
6. Outline triggers for contingency measures during construction and action plans for swift implementation onsite. For example: Additional struts available onsite for installation if loads exceed thresholds.

Figure 5 below shares an example of how a target price contract framework could be built to include risk/benefit sharing between the owner and contractor, with supplemental information in Table 1, as described in the Cedarvale Station case example above. The share percentages, start/stop stages, and minimum/maximum values can all be negotiated to suit different project profiles.

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[1] For GBR reference documentation please review the *Geotechnical Baseline Reports: Suggested Guidelines* prepared by the Task Committee on Geotechnical Baseline Reports of the Construction Institute of the ASCE (2022)

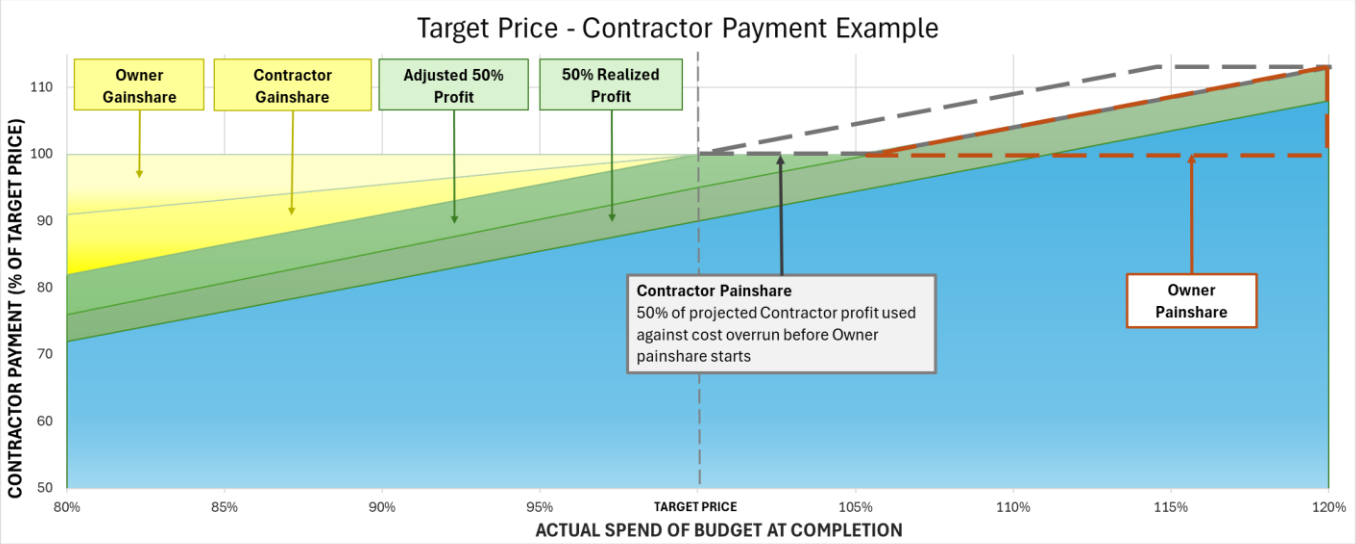
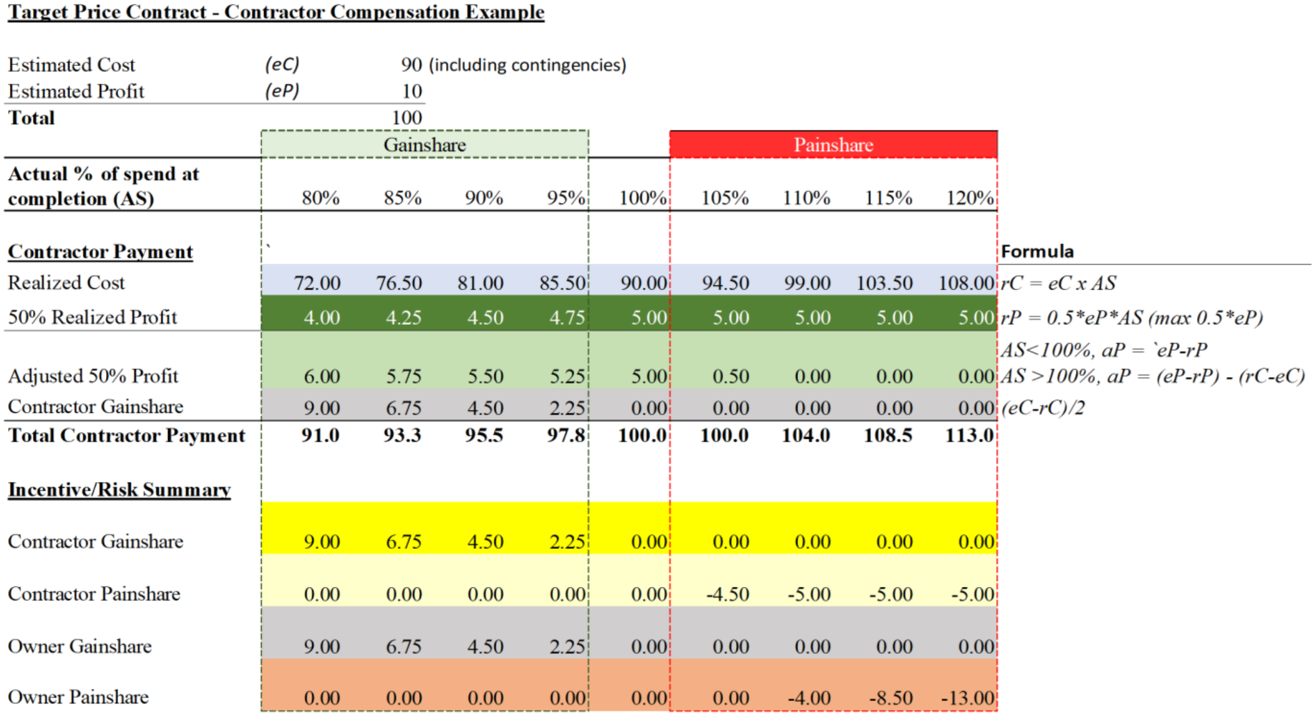


Figure 5: Target price contract framework showing contractor incentive (gainshare) and profit claw back (painshare)

Table 1: Sample Target Price Contract – Contractor Compensation Summary



Target Price Contract - Contractor Compensation Example

Estimated Cost	(eC)	90 (including contingencies)	
Estimated Profit	(eP)	10	
Total		100	

	Gainshare					Painshare				
Actual % of spend at completion (AS)	80%	85%	90%	95%	100%	105%	110%	115%	120%	
Contractor Payment	`									**Formula**
Realized Cost	72.00	76.50	81.00	85.50	90.00	94.50	99.00	103.50	108.00	*rC = eC x AS*
50% Realized Profit	4.00	4.25	4.50	4.75	5.00	5.00	5.00	5.00	5.00	*rP = 0.5*eP*AS (max 0.5*eP)*
Adjusted 50% Profit	6.00	5.75	5.50	5.25	5.00	0.50	0.00	0.00	0.00	*AS<100%, aP = `eP-rP* *AS >100%, aP = (eP-rP) - (rC-eC)*
Contractor Gainshare	9.00	6.75	4.50	2.25	0.00	0.00	0.00	0.00	0.00	*(eC-rC)/2*
Total Contractor Payment	**91.0**	**93.3**	**95.5**	**97.8**	**100.0**	**100.0**	**104.0**	**108.5**	**113.0**	
Incentive/Risk Summary										
Contractor Gainshare	9.00	6.75	4.50	2.25	0.00	0.00	0.00	0.00	0.00	
Contractor Painshare	0.00	0.00	0.00	0.00	0.00	-4.50	-5.00	-5.00	-5.00	
Owner Gainshare	9.00	6.75	4.50	2.25	0.00	0.00	0.00	0.00	0.00	
Owner Painshare	0.00	0.00	0.00	0.00	0.00	0.00	-4.00	-8.50	-13.00	

Note that the rates, percentages and risk levels in the example above can all be adjusted to suit the specific project and relationships between the necessary parties.

Other Contract Inclusions to Consider:

<u>Contingency sharing mechanism</u>: Incentivizes the contractor to not use the entire contingency for additional work. Alternatively, any contingency work conducted could be done on a cost-plus basis to limit additional profit from contingency work. This limits the risk to the contractor of inheriting the sole risk on an efficient performance-based design and having to do additional work, while limiting the risk to the owner by not providing a blank cheque for any changes. As illustrated in the preceding Cedarvale station case study.

<u>Market Pricing:</u> In a qualifications-based engagement where contractors are engaged to provide early design advice, such as in a PDB project, and market pricing is required by the regulatory agency, consider creating a separate set

of concept drawings that limit detailed information created in collaboration with the preferred contractor but provide enough for budget pricing. Alternatively, mutually agreed sections of the project could be competitively tendered, while maintaining critical scopes with the main contracted entities. This allows the owner to get a market range to compare with the detailed pricing by the preferred contractor engaged in the early design phases, while protecting the contractor's intellectual property.

Evaluation of bids: With the base and contingency model, competitive evaluation of bids becomes more complex for the owner. To simplify the process and to avoid the potential pitfall of unbalanced base/contingency allocations, we recommend adding a “probability of contingency expenditure” factor to the bids received. A contingency expenditure factor could be derived from a technical proposal score or pre-qualification rating then applied as a factor against the estimated contingency. Similarly, for agencies that maintain a ‘Contractor Rating’ for the traditional bidding group this score could also be used for a contingency expenditure factor.

CONCLUSION

Commercial risks and opportunities are embedded within the specific geotechnical environment where a project is executed — this the nature of subsurface engineering. The Observational Method is a powerful tool for driving performance-based designs that can optimize these risks and create opportunities for design, constructability, cost, schedule, and safety benefits. The collaborative contracting principles discussed provide the opportunity to fairly distribute those risks and the associated opportunities among the project team. Trust is essential to this process to de-risk and apportion the available opportunities to benefit to all parties involved. As these types of contracts highlight, and the Observational Method requires, all relevant parties must be fairly rewarded to achieve success. If there is an imbalance in the contractual division of risks or opportunities, then the parties may not be incentivized to decide according to a “best-for-project” principle.

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