# Means and Methods – In the Engineer's Domain?

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## Abstract

The line between engineering design and means and methods of construction has become blurred as the underground industry has matured. There are a multitude of reasons for this blurring of means and methods responsibility including but not limited to cost overruns, differing site condition claims, and protracted litigation.

If an owner and engineer consider means and methods in a limited fashion to come up with a reasonable mix of prescriptive and performance specifications, there is normally not a problem with ownership of the same. If there is an over encroachment on means and methods and/or over prescription of the design (overly conservative or overly stringent requirements), then there can be significant ramifications such as high bid scatter, greatly reduced bidder pool, diminishment of contractor innovation, dulling of a contractor's competitive edge, and implied warranty issues. The bottom line is that the more restrictive, the more prescriptive, the contract documents are in terms of means and methods, the more that "ownership" of the performance can rest with the owner and engineer. In technical terms this is called an implied warranty. This paper will endeavor to shed light on the subject of performance and prescriptive specifications, articulate the bases (and wisdom) for predominantly contractor derived means and methods, highlight the risks of engineers overprescribing a project during the design phase including the risk of implied warranty, and provide the results of a contractor survey highlighting some examples where the owner and/or design engineer overprescribed the design or encroached too far into means and methods of construction.

## Introduction

Besides many roles over the years including assignments relating to tunnel construction, my early engineering career included oversight of multiple and varied infrastructure construction projects and direct employment with a pipeline contractor that provided invaluable insight on means and methods. This experience gave me a unique perspective on what a contractor focuses on versus an engineer during design. During one of those early construction projects I had the "privilege" of being exposed to a superintendant who felt at ease always expressing his opinion. At the time as a young engineer, I took offense to the perceived irreverence about my "esteemed engineering education". Yet looking back on this, I often realize the wisdom and profound fortune I had in hearing that superintendent tell me to *stop trying to be a contractor*. He had some other nice euphemisms that would engender a smile but I will spare those details and leave it for another venue.

As my career evolved into tunnel engineering, those "kind" words about stopping my attempts at trying to be a contractor gave me insights I could have never obtained without that experience. What did he really mean? What he meant was that he is the expert on means and methods and in the best position to decipher how to "build" the project.

Del Nero and Hunt, 2012 indicate that *"Traditionally, means and methods of construction have been the sole domain and exclusive responsibility of the construction contractor primarily because the contractor was viewed as the party best suited to decide what works and what does not work in the construction of the intended facilities and the most experienced in determining and designing what temporary facilities are required to construct the end-product.*" Hatem, et. al. 1998 puts it this way, *"The Contractor has the skill and experience to devise the means and methods of construction; he or she is in control of the construction work, and his or her competence in performing that role provides the contractor with the best prospect to control the risks of construction and the opportunity to win bids and reap profits."*

Even with such clear position statements for contractor ownership of means and methods, the trend is actually for the engineering community to diverge from that traditional approach and take on heavy involvement in means and methods. So much so, that one could make a case that there is potentially an over encroachment by engineers and owners into means and methods specification in tunnel contract documents. The major reasons for this trend is that the tunnel industry, in my estimation, includes approximately 75% of the total cost is in the means and methods of construction and only 25% related to pipe materials (primarily water and wastewater tunnels). Also, Del Nero, 2012 explains that the criticality of means and methods has created a heightened awareness that the means and methods are where the project is won or lost from the standpoint of fiscal success and constructability. Although that paper gives some perspective on why owners and engineers are indulging more and more into means and methods, the extent of that indulgence is so much so that many times undesired and/or unintended results are being experienced. A dilemma is thus created for owners, designers and contractors because the question of how much is too much becomes relevant.

## Means and Methods Definition

Before delving into the main body of the paper and the risks of taking on the traditional contractor roles, following is a short primer on means and methods. The means simply stated are the instruments or equipment used to accomplish something. The methods simply stated are the techniques or procedures used to accomplish an end. It is worthy to note that the phrase means and methods of construction most likely originated with the construction insurance industry to help define lines of responsibility; lines of responsibility in this case that are normally connected to the contractor.

Hatem, et. al., 1998 describes the means and methods of construction as, *"the means and methods, sequences, techniques, and procedures of construction, as well as any associated safety precautions and programs, and all incidental or temporary devices required to construction the project."*

## Prescriptive and Performance Specifications

Del Nero 2012 explains that a prescriptive specification boils down to defining a "recipe" with specific ingredients for the contractor to follow in the execution of the work. The recipe and ingredients often characterize what means and methods are to be used in a construction contract. The recipe might include some specific machine characteristics that are required on or in the machine or which type of mining machine is required. Put another way, it is actually specifying the methods the contractor is to use in the construction of the intended facilities or the means when it has to do with MTBM equipment.

A performance specification simply describes the end-result/end-product desired and leaves the "recipe" to the contractor. A more formal definition for a performance specification is that it is a statement of required results with criteria for verifying compliance but without unnecessary limitations on the methods for achieving the required results. The scales of justice below are emblematic of the balancing act required to address means and methods on an underground project.

*Prescriptive Specification*
*(Engineer's "Recipe")*

*Performance Specification*
*(Contractor's "Recipe")*

A synopsis of both approaches as applied to tunnel boring machine design is provided by Reilly, 1997.

> *"The prescriptive approach fully defines the type and characteristics of the tunnel boring machine and the sequence of tunneling and ground support operations."*

*"The performance approach requires only that the contractor meet key project performance requirements and leaves substantial freedom of choice to the contractor, regarding machine types, methods and sequence of operations - so long as he meets his contractual requirements."*

Having two different recipes raises many difficult questions for the underground construction community including, but definitely not limited to, 1) is it possible to be too prescriptive in a prescriptive specification; 2) to what extent is the "low-bid" competitive environment responsible for the trend towards more engineer specified means and methods;
3) to what extent do more prescriptive specifications tend to increase bid prices and final project costs including the cost of change orders and differing site condition claims; 4) to what extent does an engineer's means and methods design discourage contractor innovation; 5) to what extent does an engineer's means and methods design dull a Contractor's competitive edge; and 6) to what extent does the owner/Engineer team "own" the means and methods specified? Several of these questions are difficult to answer with consensus across our industry, but the discussions in this paper will help to provide some wisdom on the various subjects addressed in these questions.

### Hybrid Specifications

Before leaving the subject of various types of specifications, it is important to note that most specifications used in the underground industry are a blend between prescriptive and performance specifications. These can be characterized as hybrid specifications. The balance between prescriptive and performance requirements is often achieved with hybrid specifications written on a project specific basis.

## Bases for Contractor Derived Means and Methods

Although this section will primarily highlight the benefit of using conventional wisdom and assigning means and methods to the contracting community, there are varied positions that one could take to diverge from that approach. An abbreviated position statement for each approach to means and methods is provided by Reilly, 1997.

*"The basis for the prescriptive approach is that the owner, advised by tunneling, geotechnical, and other expert, has the time, knowledge and ability to determine the best machine type, machine characteristics, methods and sequence of operations project requirements."*

*"The basis for the performance approach is that the contractor, with his experience, is best able to determine the most appropriate methods and techniques, using practices that best suit his equipment and experience. This should result in a bid that represents the best price for the underground work."*

These points provide poignant perspectives for each approach, but there are numerous other viewpoints especially in regard to staying with conventional wisdom on the subject. Below are several considerations that should be factored into the decision on whose recipe is best.

- If pre-qualification of tunnel contractors is used, the owner has some assurance that the best means and methods will be implemented so there is far less need for engineer derived means and methods;
- Keeping means and methods in the contractor's domain promotes contractor innovation – they have an incentive to innovate;
- Keeping means and methods in the contractor's domain actually reduces owner risk. The EJCDC General Conditions discussed later on clearly point toward contractor responsibility for means and methods;
- Excavation support is often linked with the equipment and means and methods being used so it can't reasonably be fully prescribed and forecasted by an engineer;
- A well accepted motto for risk management is to assign risk to the party best able to control the risk. Who better to control ground risk than the contractor who is the party actually mining the ground. Difficult to make a case against that point. The contractor can use the observational method to monitor ground conditions and behavior and readily adjust to a Plan B if Plan A is not working;
- Mechanized tunneling methods have become more and more sophisticated and therefore the selection and design of these systems should be conducted by the equipment manufacturer and the tunnel contractor who actually has to operate the equipment;
- Engineers simply do not have the depth of experience in actual operation of construction mining equipment;
- The owner typically forces a strict consulting contract with limited scope, LOE and fee. This provides a disincentive for the engineer to spend effort to think outside the box (more work) or be innovative. When engineers on a lean budget are asked to include prescriptive requirements to help level the playing field and hopefully reduce owner's risk (of DSC claims), such engineers may not have the budget to fully investigate options, evaluate risks and develop the most effective prescriptive specs. There are simply not enough fees to evaluate the risk/reward scenario when considering prescriptive specifications. The result may be either more costly than necessary specification requirements, overly conservative requirements or worse, unachievable prescriptive requirements;
- Construction constraints associated with noise, vibration, ground and structure settlement, muck disposal, dewatering, and staging are so intrinsically connected to the construction phase that an engineer is challenged to consider the impact of an engineer derived means or method to all these factors;
- Means and methods provide options for a contractor to innovate and to influence a competitive tender; and
- In a survey depicted in Tirolo & Almeraris (2005), only 15% of heavy construction contractors believe the introduction of suggested methods of construction in the contract documents actually improved constructability.

## Legal Implications, Implied Warranty, and General Conditions

The legal implications of engineer specified means and methods were alluded to earlier in the paper, but it deserves further consideration because of the gravity of the issue. In a course on construction contract specifications and law during my master degree at Syracuse University, I learned that legal rulings have great bearing on the construction industry and specifically in the areas of specifying means and methods and the implied warranty concept. The sources of law that impact construction include the constitution, legislative enactment, administrative regulations/law, and court decisions. Although the most significant source of legality and associated requirements for construction come from administrative law, the most significant source of legality regarding means and methods and specifications are court decisions/rulings. The weight of court rulings on the issue of specifications, means and methods and implied warranty is substantial. The reason for this is that this country's legal infrastructure is significantly influenced by the precedence system. Put simply, prior court decisions affect new cases and sway the opinions of judges and juries. Germane to this paper is that many court rulings clearly point towards the owner and engineer taking on legal responsibility for designer derived means and methods that are specified in specifications or drawings. Specifically, if tender documents prescribe and/or specify certain means and methods that include significant design characteristics, there is a body of case law that indicates the engineer and/or owner "owns" the potential substandard performance of said means and methods.

The primary concept that provides framework for much of the case law alluded to on this subject is the implied warranty principle. The concept of an implied warranty is a legally proven principle that has endured for almost 200 yrs. The relevance to the subject of this paper is that prescriptive specifications, otherwise known as design specifications or means and methods specifications, are intrinsically related to implied warranty. The preeminent court ruling on implied warranty is the 1918 case of the United States vs. Spearin. The impact of this single case on construction contracts has endured since its rendering. In short, this case involved a contractor, Spearin, building a Navy dry-dock and sewer in Brooklyn, NY for the US Navy, FindLaw, 2012. The findings in the case, often referred to as the Spearin Doctrine in modern rulings, revolved around what party to the contract was responsible for a breakage in a relocated sewer after construction was finished. The seminal renderings from the case are:

> *"But if the Contractor is bound to build according to the plans and specifications prepared by the Owner, the Contractor will not be responsible for the consequences of defects in the plans and specifications."*
>
> *"the insertion of the articles (in the subject contract) prescribing the character, dimensions and location of the sewer imported a warranty, that if the specifications were complied with, the sewer would be adequate."*

Although the subject of this case appears to be far removed from the subject of this paper, in actuality, the "imported a warranty" language above has direct relevance to the use of prescriptive specifications in the underground industry. Specifically, if a contractor is directed to use specific means and methods during construction, there is an implied warranty the said means and methods will work and if they don't the contractor is more than likely entitled to compensation. Basically, if the prescribed means and methods do not work, then the applicable means and methods specification, it can be argued, are defective. As a side note, it is worth noting, this case also has great bearing on ownership of ground risk during construction of tunnel works.

A recent court case in 2002 affirmed the application of the subject doctrine. In White vs. Edsall, Kutil, et. al., 2007, the court was considering whether or not the contractor was responsible for failure of a tilt-up canopy door system which included a 3-point pick arrangement. Although not a case involving underground work, the findings provide insight for the underground industry and subject discussion. The case boiled to whether the door system was a design specification or merely a suggested option. Ultimately, the court opinion said that the door system was a design specification because the drawings incorporated "significant design characteristics." Interestingly, the court used the Spearin Doctrine to outline the basic propositions of law. This case also involved related disclaimers used in contract documents, so the author encourages further study of this ruling. The author also makes the case that the more design characteristics relating to means and methods that are provided in tender documents regarding excavation support and tunnel boring machines, the higher the chance the owner and engineer takes on responsibility for performance of the corresponding means and methods. Baring language to the contrary, ownership of means and methods can easily shift, sometimes unintentionally, away from the contractor. Further study of the case law regarding the concept of implied warranty can be found at www.constructionrisk.com along with a host of other references in various tunnel industry conference proceedings.

**General Conditions**

This paper would be remiss to not highlight some of the general conditions language provided by the Engineers Joint Contract Document Committee (EJCDC) that expressly addresses means and methods in contract documents. Contract conditions, typically including general conditions and supplementary conditions, are integrated with the technical specifications and have significant bearing on legal issues revolving around means and methods of construction. Importantly, standardized general conditions may be in conflict with a means and methods specification because they often declare contractor responsibility for means and methods. This is because the primary purpose of contract conditions is to define the rights, responsibilities, and relationships of the parties involved and the definitions in most standard forms clearly place the demarcation of means and methods responsibility on the contractor. In addition, the general conditions frequently include the primary clauses that establish how the project is to be administered. The most common form of general conditions in the USA, those promulgated by the EJCDC, mandate that the contractor be solely responsible for means and methods of construction. The following clauses from the Standard General Conditions from EJCDC, 2002 clearly allocate the distinct roles and responsibility of the owner, engineer, and contractor relative to means and methods.

***Paragraph 6.01 A***

*"Contractor shall be solely responsible for the means, methods, techniques, sequences, and procedures of construction. Contractor shall not be responsible for the negligence of Owner or Engineer in the design or specification of a specific means, method, technique, sequence, or procedure of construction which is shown or indicated in and expressly required by the Contract Documents."*

***Paragraph 8.09 A***

*"The Owner shall not supervise, direct, or have control or authority over, nor be responsible for, Contractor's means, methods, techniques, sequences, or procedures of construction, or the safety precautions and programs incident thereto, or for any failure of Contractor to comply with Laws and Regulations applicable to the performance of the Work."*

***Paragraph 9.09***

*"Engineer will not supervise, direct, control, or have authority over or be responsible for Contractor's means, methods, techniques, sequences, or procedures of construction, or the safety precautions and programs incident thereto, or for any failure of Contractor to comply with Laws and Regulations applicable to the performance of the Work."*

These clauses confirm the general and customary division of authority and ownership of the means and methods of construction if they are not explicitly written otherwise in the construction contract. These form, to a certain degree, a legal basis for why engineers are admonished in professional practice to avoid entering the means and methods arena.

Therefore consideration should be given to the front-end documents relating to means and methods review, approval, and most importantly, responsibility. To proceed with an underground contract, in a state of ignorance regarding this issue is a risky proposition to say the least. In fact, a quote that captures the often taken approach to the legality associated with means and methods is "Ignorance is bliss, but it won't stand up in court (anonymous)." Engineers and owners must be cognizant of the potential legal implications of delving too far into the specification of a contractor's means and methods without proper consideration of the risk and potential liability that exists. A case can be made that some degree of burden of performance and resulting legal obligation is assumed by the specifier/designer when a prescriptive specification is used.

Even with the potential risk associated with the implied warranty concept, the author is not saying engineer derived means and methods should never be considered but that they should be considered carefully and with the understanding of potential legal implications. If the design team is not familiar with potential legal implications of prescriptive specifications and how to modify contract conditions relative to the same, an attorney specializing in contract law is recommended.

## Contractor Survey of Overprescribed Designs and Over Encroachment of Means and Methods

In the author's experience there are definite examples of an engineer's over indulgence into means and methods on tunnel projects. There is no better proof of the designer "going too far" than hearing what kinds of requirements have been included in actual tunnel construction contract documents across the United States. In that light, a survey of prominent North American contractors was conducted to provide some ground truth to this important and potentially risky trend. The survey highlighted several owner/engineer derived means and methods and overly restrictive specifications that reflect potential over-encroachment into the contractor's primary domain. Additionally, the survey revealed several contractually related items that plague the industry and are therefore added because of their importance. The highlighted items are elaborated on to further describe the specifics. *As an overarching comment, many contributors to the survey indicated that technical specifications are being promulgated in tender documents that look more like "gotcha" specifications instead of technical specifications.* This unfortunate trend is likely because of an owner or engineer over-correcting or over-reacting to a hiccup on a previous project.

### *Specification of the Type of Tunnel Boring Machine and Ancillary Equipment*

Specification issues related to boring machines was by far the most common concern highlighted by contractors. The specific issues raised by contractors on the subject varied in type and degree. Below is a summary of the topics related to boring machine specifications, procurement and other related issues.

#### *Improper Terminology*

Often a "closed-face" machine is specified. This requirement is inadequate and in fact, incorrect. A cutter-head is never "closed" because it has openings for the material to come in to the plenum through. The only type of machine that is truly closed is a LOVAT type machine with flood doors, which are closed to mitigate unstable soils. No mining can be conducted with the flood doors closed.

#### *Pressurized vs. Open-Mode EPBM Operation Requirements*

One contractor reported overly conservative requirements on EPBM operation. A specification required the EPBM to be operated in earth pressure mode 100% of the time. Yet over 80% of the alignment could have been completed in open-mode. A lack of experience with the machine technology, lack of understanding of ground behavior, and the tendency to be overly conservative likely contributed to this onerous requirement. One obvious impact is an unnecessary escalation of construction cost.

### *Requirement for Specific Type of Pressure Balanced Machine*

It was reported that one recent project required either an EPBM or slurry shield. Modern technology includes variable density shields and dual mode machines for instance. Simply requiring an EPBM or slurry shield is therefore inadequate with modern technology. Another reported the term pressurized face being used in specifications. A pressurized face does not mean that it can balance the earth pressure otherwise the contractor could claim a compressed air shield is pressurized face. If there is a need on a project to manage active and passive load on a project, the terminology to require a machine with that capability is a pressure balanced shield. In another situation on a major tunnel project, an EPBM was specified by the design engineer and after contractor derived investigations, post-award, it became clear that an EPBM would not be appropriate for the entire alignment. A sizeable change order and protracted negotiations were the result of the inappropriate specification. One of the real risks for a designer in this regard is the potential that an owner could file a lawsuit against the engineer under an errors and omissions clause.

One contractor reported a project where an EPBM shield was required in fairly good rock conditions. The subject owner did allow a change to the type of machine but then required continuous probing and grouting. Overly conservative requirements like this only add unnecessary cost to the project.

### *Owner Supplied EPBM's, Spare Parts, and Tunnel Segments*

Several contractors reported concerns regarding the trend for owner procured equipment and materials. In short, this trend escalates projects costs, adds potential for claims and litigation, and takes away a contractor's competitive edge. Eliminating a large portion of the competitive environment by supplying the boring machine and precast concrete segments for example significantly increases contracts costs from day one. Urschitz, 2013 reports that 30 out of 42 machines procured by owners in the subject study were of the EPBM type. Often the justification for this trend is more control over the contractor and schedule constraints. In general, there are many other methods that involved less risk for "controlling" a contractor and meeting schedule requirements. One contractor reported that the success of the excavation of a tunnel with either an EPBM or Slurry shield depends on: 20% of its design + 40% of its manufacturing + 40% of its operation = 100% success. No matter where the opinions fall with regard to how success is achieved, success in large part is still related to operation of the equipment. If that is the case, why should an owner take on the risk of designing and manufacturing of the boring machine? It is important to note that one contractor did indicate an understanding of the need for owner procured machines in certain circumstances and that if those cases do arise, a delivery method should be used that has the contractor engaged in the machine design and procurement process.

Trying to differentiate between ground behavior and a machine's equipment, instrumentation, etc. and operator related activities is a difficult proposition to say the least. A reality owners need to understand is that it is easy for a contractor to simply point towards

boring machine instrumentation, other ancillary equipment, or ground behavior materially different than the baseline as the cause for production issues.

Also, removing contractor innovation in the area of means and methods fundamentally eliminates the possibility that lessons from other projects are mobilized to improve the project. Lastly, the litigation record for projects with owner supplied boring machines indicates this trend is a riskier proposition than almost all other risks inherent in a tunnel project.

Many contracts require a laundry list of spare parts be mobilized on-site. Owners should realize that if the parts are not used, they will be re-stocked for 30 cent per $1. Only critical spare parts should be required on-site such as a main bearing and even then should have a strong basis for such a requirement. Also, certain owners and engineers include this requirement for spare parts but do not indicate what critical parts are required.

***Specification of Mechanically Related Boring Machine Equipment***

One contractor reported that a specification for a pressure balanced shield included very detailed requirements for mechanical equipment including valves and gauges. There is no real value in an engineer going this deep into means and methods and could very well be a cause of claims.

***Pressure Balanced Shield Maintenance and Interventions***

Contractors reported several projects that included requirements for inspection and maintenance of the machine and cutterhead and the number of interventions and timing of such. Contractors indicated that this causes disputes and results in a definite and significant increase in contract price. One contractor indicated it would much more cost effective to simply provide an allowance in hours for interventions related to inspection and maintenance. In an effort to control risk, owners and engineers are writing specifications that add untold cost to the project. The proper use and interpretation of the machine parameters indicates when interventions need to be performed. Mandatory interventions may increase the amount of interventions and costs associated with it. This is an operational decision and should not be part of means and methods specifications.

***Screw Auger Size, Number, and Location in Plenum***

One contractor reported a project where there was a requirement for where the screw auger should be placed but had no correlation with the ground conditions. Going into this much detail in a specification could subject the owner and engineer to significant liability.

***New vs. Used TBM***

Many projects require a new TBM where it is unnecessary. The designer on one project provided input on the subject and strongly recommended to the owner that a new TBM be mandated. In that situation the contractor was able to convince the owner to allow a used, refurbished TBM that was greater than 30 yrs. old and world record production rates were achieved with that machine. There are now so many machines in the marketplace, the requirement for a new machine should be considered only when very unique ground conditions are anticipated. It is important for a design team to do a survey of what machines may be available rather than simply requiring a new machine.

***Precast Concrete Segments and Related Grouting***

One contractor reported that an engineer required approval of precast concrete segment connections, reinforcement, permeability, and durability yet was not experienced in the review and approval of such materials. Further, the project included operation and maintenance of the completed facilities by the builder and concessionaire so these parties have an inherent objective to minimize operational costs. The designer review and approval of the segments represented an unnecessary and risky over encroachment into means and methods. In such circumstances, without proper delegation of responsibility for review of submittals in the contract, an engineer could be held legally responsible for the performance of the lining (including maintenance) for the duration of the operational cycle.

One contractor reported that they were permitted to grout outside the TBM rather than through the segments but then required holes to be drilled in the segments for grout confirmation. It is important that grouting and confirmation of such be consistent in terms of approach.

Specification of grouts was also reported as an issue. There is much more art than science in grouting materials and specifying a two component grout or a standard granular-cement mix for instance should be the choice of the contractor. There is not a clear limit between the two types in regards to the soil and the field of application overlaps quite a bit. Depending on grout quantities it can have a significant impact on project cost.

***Gassy Ground Classification and Related Equipment Requirements***

One contractor reported a project where the ground was classified as potentially gassy while at the same time equipment requirements were specified for gassy ground. Specifically, “permissible” diesel equipment was required for some of the sequential excavation method equipment, which added hundreds of thousands of dollars to the project. Project costs could have been significantly reduced by allowing normal diesel equipment and increased ventilation to address encountering explosive gas conditions. Considering most contractors do not have a long list of equipment that is suitable in ground classified as gassy, the unnecessary requirements for “permissible” equipment in potentially gassy ground puts a heavy burden on the contracting community and inflates projects costs.

***Restrictive Tolerances on Temporary Shaft Support***

Temporary shaft are just that, temporary. More than one contractor indicated that shafts tend to be fairly shallow and short-lived in-terms of how long the shaft will be used but often the contract documents frequently have vertical tolerances that relate to permanent shaft support. The impression given in contractor discussions was that specifications were taken from other projects with the shaft wall acting as temporary and permanent support and applied to shafts that are short-lived and temporary only.

***Overly Conservative Engineering Parameters for Temporary Shaft Support Design***

One contractor reported that in some cases owners issue pressure diagrams that are extremely conservative for temporary shaft support. The temporary shafts as a result are significantly overdesigned and result in far greater construction costs than necessary. It would be far better to mandate that the contractor hire a licensed engineer to design and seal the temporary shaft support and base that design on a geotechnical data report than to issue or baseline design parameters that are too conservative. The other related concern expressed was the use of the same pressure diagrams for a region rather than developing them for project specific conditions. The problem with the latter goes without saying.

***Geotechnical Baselines not Measurable in the Field and Too Many Baselines***

The primary purpose of the baseline concept is to establish a framework for consideration of differing site conditions. As such, in theory every baseline should be established in large part to do its ability to be measured during construction. If not measureable, the variable or parameter adds little value to the project. Also noted by contractors is the trend to baseline any number of parameters regardless of their importance to tunnel construction. In reality, this trend actually increases owner risk as explanations can be developed to explain why such and such a parameter impacted means and methods. It is prudent to only baseline parameters that facilitate selection of means and methods and that are measureable in the field. Also, production is the primary barometer for profit on an underground project so parameters that impact the prediction of production should also be considered for baseline. As noted earlier, baselines are sometimes provided for the design of temporary support, which is reasonable, but these baselines also need to be realistic.

***Professional Seal on Extraneous Technical Information***

The requirement for professional seal on various documents generated by the contractor or even equipment supplied by the contractor has become common in the industry. The downside of this trend though is to require a seal when there is little value in doing so. Multiple contractors reported the requirement for a seal on extraneous types of information that goes far beyond a seal on the design of temporary support, which is often done.

A related concern highlighted is where a seal is requested but the seal has to come from the state where the project is located. Considering that many tunnel projects are constructed by out of town contractors this type of requirement places unnecessary burden on the contractor. The question that

should be investigated by the engineer of record is whether a professional engineer licensed under NCEER will suffice. In most if not all cases, it will. That way a professional engineer from another state can seal the document.

***Requiring a TBM to be Capable of Mining in all Potential Ground Conditions***

This requirement basically means the TBM has to be capable of mining in all conceivable ground conditions. One specification was referenced that required the TBM to be capable of mining in rock, relic rock, boulders, and obstructions of man-made and natural origin. An "all" ground TBM simply does not exist. A very basic explanation is that a cutterhead that is tooled to deal with soft ground is not suited to properly address full-face rock.

***Various Specification and Contracting Practices***

The following concerns relating to various specification and contracting practices were raised by multiple contractors.

- Tender periods are often too short
- A lack of understanding of large diameter TBM costs and the need for contract provisions that compensate the contractor for higher mobilization costs than other types of infrastructure
- Prequalification that are very subjective
- Prequalification shortlist includes too many contractors
- A no change order philosophy
- A lack of provisions covering cost escalation during construction period including but not limited to fuel and metal pricing
- Specifications for TBM's and pressure balanced shields are looking more and more like operation and maintenance manuals
- GBR's that specify a specific type of boring machine but the specifications pointed towards multiple machines. The overarching comment here is that the technical specifications are not consistent with the GBR and in fact are not a compliment to the GBR.

It is likely many of the above requirements are well intended, yet the results in many cases include "collateral damage" to the project including excessive costs. In my experience over the years in the underground business it is my perception that overly burdensome contract requirements do not get upheld in courts. That point deserves far more elaboration, but just the same, it is incumbent on the owner and engineer to be deliberate about what is made prescriptive in a tender. If there are certain project conditions that seem to point towards a means and methods or prescriptive specification, serious consideration should be given to prequalification of tunnel contractors. Del Nero and Hunt, 2012 highlight a method to assess if a construction item should be prescriptive or not.

As a professional courtesy, the paper does not highlight the individual contractors who contributed the above cases but a hearty shout of appreciation goes out to those who contributed. Their generosity in sharing information and experiences greatly improves our industry. Various

contributions were also provided by Jim Peregoy Construction Services and Mr. Gil Garcia. The author acknowledges their important contributions.

## Conclusions

The over-prescription and over-encroachment by engineers into means and methods reflected in the contractor survey is a wake-up call to the industry. It is recognized that a bad project may tend to cause owners and engineers to overreact and therefore over specify a project. It is likened to over steering in a car. Over steering may be feel right at first, but at the end of the day may cause far more damage than it is worth. In a real way, trying too hard to control the outcome of a tunnel project is likely the cause of overprescribed project designs.

The flip side of this issue is that contractors need to understand our clients are our revenue stream and since we are most often living and working in the same community as our clients, if we lose a client from a bad project it can put an office in peril. Having worked with a contractor before, the author knows there is almost always a counter argument and in this case, it might be that every contractor is always one bad job away from going out of business.

To answer the question posed by the title of this paper, deviating from contractor derived means and methods by engineers does have some limited justification in the author's opinion, but should be done carefully and strategically. The conventional wisdom of keeping means and methods with the contractor still has the greater merit. As pointed out in Del Nero 2012, there are situations and conditions that justify an engineer derived means or method, but again, careful consideration and communication to the owner of the additional risk must be part of the decision process.

As highlighted by the EJCDC General Conditions, ownership of means and methods points to the contractor. The quote below, framed by the author, encapsulates the primary risk in specifying the means or the methods (over steering) that forces the contractor's hand.

*"He who directs contractor means and methods may inherit significant responsibility (and liability) for them."*

This must be taken into consideration when engineers and owners want to "play contractor" to an extreme. Over-encroachment of the traditional roles regarding means and methods can impart unwanted and unrealized risk. When a decision is made to encroach on this traditional domain of a contractor, sobriety is needed and the conduct of a succinct risk/reward evaluation mandated. That way a fully educated decision can be made. Lastly, taking on these traditional contractor roles without considering modifications, if necessary, to standard general conditions may have significant legal implications including protracted litigation from the resulting implied warranty.

Various elements of the underground industry may disagree, viscerally, with certain parts of this paper, but all of us can agree that the best projects are always those that involve a close and trusting relationship between the owner, engineer, and contractor. Nothing else is more important in the final outcome.

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