

ADVICE FOR CONDUCTING FULL SCALE FIELD TRIALS FOR JET GROUTING

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ABSTRACT

A Full Scale Field Trial (FSFT) is typically conducted before production jet grouting commences. The FSFT allows the Contractor to commission his means, methods, and equipment, and allows him to demonstrate that his choice of jetting system and parameters will provide treated elements which satisfy the specified requirements. However, such FSFT's often do not have a satisfactory outcome either from the technical or contractual viewpoints. Given that an FSFT will typically be on the critical path of a project, any problem encountered can have an impact on the overall project far greater than its actual cost.

This paper provides advice to Owners, Engineers, and Contractors involved in the design, execution, analysis, and acceptance of FSFT's. It is not a specification, but more a commentary on good and sensible practice, designed to avoid disputes. The paper is based on a compendium of personal observations and experiences – good and bad – and so does not cite specific projects.

INTRODUCTION

A Full Scale Field Trial (FSFT) invariably precedes a jet grouting project. Given that it is practically impossible to conduct a “bench scale” test of relevance for jet grouting (other than to mechanically blend soils with grouts to obtain samples providing an index of strength and/or permeability of the soilcrete) it is only in the field that a Contractor can demonstrate that his own particular choice of jetting system and parameters will satisfy the performance parameters as laid out by the Engineer-of-Record. In this regard, most jet grouting applications require the individual elements to overlap completely, such as when forming a vertical or (more challengingly) a horizontal water barrier. Hence the demonstration of the diameter actually achieved – in *all* soil types indicated to be present – is vital. Similarly, strength and homogeneity are typically critical goals, and permeability will also be an acceptance criterion, depending on the application of the jet grouting.

Whereas many publications refer to FSFT's in their accounts of jet grouting case histories, little attention is usually devoted to the challenges of designing, executing, and analyzing such programs since the heft of the paper is the account of the subsequent (and invariably successful) production works. Similarly, it is interesting that otherwise comprehensive, excellent guidelines for jet grouting, such as the “Guide Specifications” Document of the ASCE GeoInstitute Grouting Committee (2008, Revised 2016) which strongly influences North American practices, devotes barely 2 of 35 pages *directly* to FSFT's. Hardly coincidentally, this content ratio is not dissimilar to the ratio of FSFT to production and mobilization /demobilization prices in a typical jet grouting project. However, the FSFT is absolutely critical to the success of the overall project and is a gate through which neither Engineer nor Contractor should pass unless both are convinced that the outcome of the FSFT is technically acceptable. Unfortunately, it has been the author's experience in several jet grouting projects to which he has been called in a forensic and/or dispute resolution role, that an FSFT has not yielded the results adequate to give comfort to all parties before production works are due to commence. In plain language, the jet grouting contractor, under severe schedule pressure from the General Contractor, often proposes to proceed into production “at his own risk” soon after the trial columns are installed, and before the definitive testing for conformance is completed. On the other hand, the Engineer, very mindful of the Owner's timetable, will often choose to allow this “at risk” option to be accepted, comfortable that he has in effect, transferred the contractual risk. In such situations, both parties are wrong.

It is an understandable dilemma. Jet grouting usually represents a small percentage of the cost of the overall project, especially when conducted for urban foundations and tunneling applications. However, it is typically one of the first major activities on the site, following surface preparation, utility relocation, and usually lies on the General Contractor's critical path: excavation for the foundation box, or tunneling activities, cannot commence until the production jet grouting is completed. There is therefore pressure "from above" to have the jetting completed in the shortest practical time, a period including the FSFT. Ideally, there should properly be a period of "dead time" between the installation of the FSFT elements, their verification, and their acceptance. Unfortunately, both the General Contractor and the jet grouting contractor often see this "dead time" as a period to be compressed to the limit: the jet grouting contractor is usually complicit in this approach as it reduces the equipment and labor costs he is bearing during the "dead time". The danger arises in cases where the results of the FSFT have not been properly evaluated and the production jet grouting commences with parameters which are not proven and potentially inadequate. The resulting inadequacy of the grouting will then only be revealed when further routine Verification Testing is conducted (typically at 28 days soilcrete age) and/or when the excavation proceeds, especially beneath the water table. Given typical jet grouting production rates, and the average size of an urban jet grouting project, it is entirely feasible that a large proportion of the scope will have been completed by the time the inadequacy is realized. Remedial works – with or without jet grouting – will ensue, but invariably with a considerable impact on overall project time and schedule.

Conversely, consider the case where the jet grouting contractor stands his ground and conducts and analyzes his FSFT in accordance with proper scientific experimental principles. Despite having used "conservative" parameters (based on his experience in similar soil conditions) there are occasions when the hoped-for result of the FSFT is not met, due to a Differing Site Condition (DSC). The logical path is to conduct a second FSFT to optimize the parameters. However, each FSFT will involve a period of 3-4 weeks, most of which is "dead time", and such delay may not be palatable to the General Contractor or Owner and will be financially damaging to the jet grouting contractor. It is at such times that a pragmatic "best for project" decision must be agreed by all parties, including the Owner being prepared to consider a DSC-based claim to fairly reimburse the Contractors, and/or a redesign of the grouting program or indeed a re-evaluation of the viability of the jet grouting scheme itself.

This paper provides advice to the parties sharing a jet grouting project. It should however be regarded not as a specification per se, but as a commentary on a typical specification. Many readers will find the observations obvious and even simplistic, but it would be my guess that these same colleagues will never have been involved in a major contractual dispute involving a jet grouting project, and arising from its FSFT.

FOR THE OWNER

While many Owners have a long experience with jet grouting on their projects, many other Owners, especially those in the private sector, may have very little or no direct experience. To the experienced group, the advice would be to be receptive to new developments in the technology, and to avoid falling into the "this is how we did it ten years ago at Trump Avenue" syndrome. A good example of this would be to embrace the considerable advantages of the newer "High Efficiency" jet grouting systems on offer from several specialty contractors.

To the first-time Owner, the advice would be to engage a properly experienced and knowledgeable Engineer-of-Record who will accept the responsibility of evenly explaining to you the process, its advantages and disadvantages, and its inherent risks. This is particularly important when the jet grouting specification is very much of the Performance (as opposed to Prescriptive) type, and/or jet grouting is being offered as a Value Engineering Cost Proposal i.e., as an alternative to the originally designed, probably more "traditional" scheme.

The Owner must ensure that any and all site investigation data are made available at bid stage, including a description of the evolution of the site, with respect to both geological developments and human impacts. These descriptions must include “warts and all”. The Owner must insist on an effective and regular communication process between all parties, before and during the works, even if it does not quite reach the intensity of formal Partnering. The Owner must develop and accept a realistic well-informed schedule, ensuring that sufficient time is allowed for the evaluation of the obligatory FSFT, and that adequate “float” is incorporated for all tasks involving subsurface construction activities especially in cramped, urban sites. He must clearly spell out the project’s goals and list any key considerations or restraints which will impact the Contractor’s choice of means, methods, scheduling and sequencing.

Owners must also realize that even with the best intentions of all parties, problems may arise in the construction of the work: this reflects the natural risk inherent in all subsurface construction. Risk allocation should be clearly defined in the Contract Documents, and full commitment given to fairly and quickly evaluating the merits of an alleged DSC for example. There should be no room for the paradigm that the Owner is out to exploit the Contractor (or vice versa), but there should be acknowledgement that the Owner owns the site and is responsible for its accurate and comprehensive description.

FOR THE ENGINEER-OF-RECORD

Do not consider designing or supervising a jet grout project unless you have a proper depth of experience within all the key engineering levels within your organization and especially regarding design and construction supervision. The nature of jet grouting and its attendant performance risks are such that inexperienced “internet expert” consultants should not participate, notwithstanding the excellent presentations available on many contractor websites. Likewise, having attended a seminar or read a technical paper also does not constitute adequate experience.

An early, fundamental step is to confirm that the grouting is indeed technically and practically feasible for the specific project conditions, since, once it is specified, there is an implied warrantee that it is buildable (the Spearin Doctrine). Beware of “shoehorning” jet grouting – or indeed, any specific technique – into a project.

It is then wise to base the Technical Specifications on the ASCE GeoInstitute’s “Guide Specification” Document (2016) as this is a well-respected and referenceable standard of care. However, please note it is a “Guide” only, and it must therefore be used with original thought and input, especially when detailing the specific scope and requirements for the FSFT program(s), the focus of this paper.

The FSFT is obviously the chance for the Contractor to demonstrate the suitability of his equipment system and parameters in the ground to be jetted. In this regard:

- The Contractor’s ability to maintain an open annulus around the drill rod during jetting should be regarded as an integral acceptance condition.
- The location and depth of the trial should be as representative of the foreseen production works as is practical, and the trial elements should be permitted to be part of the final works – subject to any replacement or remediation of non-compliant elements.
- It is clear that the most definitive demonstration of element size, shape and continuity is by exposure. However, in the vast majority of cases, exposure is practically impossible bearing in mind ambient water levels, requirements for safe excavation, and impact on schedule. While it is the Contractor’s responsibility to produce elements of compliant geometry and properties, the Engineer should stipulate exactly how these properties are to be established in the FSFT. If the bidders object, and/or have additional or different methods or techniques, then let these ideas be resolved in the submittal process so that, by the time the FSFT is about to be implemented, all parties are crystal clear about how these issues are to be monitored and evaluated.

- The Engineer must stipulate the *minimum* number of test elements to be installed, together with their layout. It is most typical to have at least three groups of three elements in a triangular formation, each hopefully overlapping, and each group installed with different parameters. The Contractor should be allowed to install additional elements if he so chooses, to better calibrate his concepts, provided he does not negatively impact the project schedule. It is typical that FSFT's are billed as a Lump Sum, and so the financial risk is principally with the jet grouting contractor.

Prior to the FSFT being conducted, the Engineer should convene a technical coordination meeting, at which the Contractor's proposed (and by now, accepted) FSFT scope is explained. Bearing in mind that the Engineer's supervision of the FSFT is usually in the hands (and eyes) of relatively junior, and often inexperienced engineers, then the Contractor's proposal should be explained and debated, step by step, and the normal foreseeable vagrancies of construction (such as breakdowns or loss of spoils return) should be openly discussed. At this meeting, the Engineer should re-emphasize the contractual burden placed on the Contractor with respect to data recording and timely reporting. This cooperation should be enhanced through daily debriefing meetings, which need not be prolonged, so that all parties are satisfied – in real time! – that the implementation of the FSFT is proceeding in accordance with the Work Plan, and is reacting, when necessary, to unexpected findings in the soil. During such meetings, the parties should bear in mind that the frequency of equipment malfunctions tends to be higher in FSFT's due to "learning curve" factors, including fast mobilization of equipment which may well have been idle for some time beforehand or not fully serviced before arriving from a recently completed jobsite.

Notwithstanding the commercial pressures discussed above, and in an ideal world, the Engineer should not permit the Contractor to proceed – even "at risk" – with the production works until he is satisfied that the FSFT has been conducted and analyzed in compliance with the Contractor's Work Plan, and in satisfaction of the design requirements. The process should include a timely review of the Contractor's obligatory FSFT report, and a formal declaration that the Contractor's conclusions from the FSFT are acceptable as a basis for progressing into production. This step is increasingly a grey area in risk allocation. This is a step that should not be abrogated or conveniently ignored. It is a fundamental "hold point" in the process.

Also, the Engineer should be receptive to technical input from all corners in technical debates, including the Contractor's consultant(s), whom they should not dismiss as "hired guns", or mere mouth pieces in the event of disputes. These consultants have the ability to provide unbiased professional input into such debates, even if their fees are, of course, paid by the Contractor.

FOR THE JET GROUTING CONTRACTOR

Most jet grouting projects are conducted as sub-contracts, although the exceptions are notable (Bliss, 2005). Most General Contractors pass through, as are they indeed contractually obliged, the proposals, reports, and correspondences of the specialist jet grouting contractor. Without in any way discounting the role of the General Contractors, who, after all, are typically required to provide a myriad of services to the specialist, including hauling away of spoils and provision of office, storage, and sanitary facilities, the following remarks are addressed to the Jet Grouting Contractor.

- He should try not to adopt a superior or aggressive posture at any phase of the award and submittal process, even though he is the specialist, and possesses so much more specialist knowledge than the General Contractor, and probably the Engineer-of-Record also. He should share the knowledge openly, for the betterment of the project.
- As far as disclosure of "proprietary" information permits, the Contractor should be as transparent as possible in terms of the logic behind the selection of jetting systems and parameters. Reference to the project GDR, case histories in similar soils and/or local projects of relevance should be provided. This open approach not only is a positive contribution to site cooperation,

but it also clearly illustrates what was in the Contractor's mind approaching the FSFT. In other words, a contractual and technical baseline is declared up front, which will be invaluable in the case that the results of the FSFT differ significantly from those foreseen, and a Differing Site Condition may have been discovered.

- The Contractor and the Engineer must fully agree the scope of the FSFT and how it is to be monitored, controlled, and analyzed. In particular, the number, timing, and type of column diameter measurement methods which the particular site permits should be agreed. Possible methods include "blind" drilling and probing with rotary water flushed methods (including testing the pH of the water return, and using phenolphthalein solution, both to detect the presence of cementitious materials), core drilling, piezo-cone testing, geophysical methods, and the prior installation of slotted PVC pipes in boreholes at various distances around the column being installed. When probing or drilling, it should be recalled that it is not unusual for the uppermost part of columns to be of larger diameter than the lower parts, due to the normal tendency of soils to be more erodible towards the surface and vertical confinement being less. Coring should be focused on exploring column intersections and in particular, triple point intersections when three or more columns are installed in a group. In this regard, it is common to find the scope of an FSFT includes at least three trial groups, each of three columns. This will permit the Contractor to experiment systematically with different jetting parameters, bearing in mind always that there should be only one variable changed in moving between the successive columns, or groups of columns. There is no real reason for conducting diameter tests only at 28 days. As long as there is sufficient strength contrast between soil and soilcrete, testing should be permitted at fewer days of curing.
- The Contractor should consider installing a limited number of "preliminary" columns, in advance of the formal FSFT columns. These need not be conducted within the "pay zones" but will allow the Contractor to commission and demonstrate his equipment, instrumentations, and QC processes, as well as gaining a preliminary feeling for the specific site conditions.
- The Contractor is best served by placing the technical supervision of the FSFT under the control of an experienced jet grouting engineer even if that person will not subsequently oversee the production works. That person must ensure that all possible real-time observations and records are maintained – both within and beyond the requirements of the specification. Valuable information can often be obtained from wet samples of the soilcrete, both from return spoils and from deep grab samples (where feasible). Such data may not typically be used as an acceptance criterion but will contribute to real-time as well as post-action understandings and analyses.
- The FSFT Report should be as comprehensive and timely as possible. The analysis of the data need not be voluminous since much of the data can be dropped into appendices. However, the Report must address clearly the conclusions insofar as they relate to the specified acceptance criteria. Again, in the ideal world, failure to satisfy these criteria should result in the Contractor being permitted to conduct a second FSFT. Otherwise, all parties will move into the production works carrying considerable additional potential risks. As noted above, testing only after 28 days of curing is a burdensome paradigm.
- The Contractor should be proactive in scheduling, contributing to, and recording regular technical meetings with the other parties as the FSFT progresses. In particular, he should describe the logic of any "on the fly" changes he proposes – or had implemented – so that there is no room for misunderstandings when the FSFT has been completed and the Report is being reviewed by the Engineer-of-Record.

CLOSURE

It is clear that a major element of a successful FSFT is close cooperation and communication between the respective parties throughout its planning, implementation, and analysis. Problems and disputes relating to an FSFT usually arise from a failure of one or more of the parties to sensibly and conscientiously discharge its respective duties and responsibilities. The lower the quality level of an FSFT, the more risk there will be to all parties in the subsequent production works. These risks will apply in different ways and amounts and will have technical, financial, schedule, and/or performance implications. In the worst case, the relatively small expenditure inherent in a typical FSFT may ultimately have an impact that is far greater in all these areas of concern, and litigation will ensue. It is hoped that the simple advices contained in this paper will help avoid such litigations and disputes.

REFERENCES

Bliss, M. (2005). Jet Grouting for Seismic Remediation of Wickiup Dam, OR. *Journal of Dam Safety* 3 (1).

ASCE GeoInstitute Grouting Committee Task Force (2016). *Jet Grouting Guide Specifications*, 35 pp.