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Effective communication to manage geotechnical risk

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ABSTRACT: In selecting a suitable topic for this paper, written towards the end of my career, I considered the important lessons I have learned since first exposed to civil engineering in the UK in 1976. There are already many valuable and informative technical papers addressing topics such as piling, ground anchoring and retaining walls so I see little value in covering these subjects here. In recent years my work has been focused on Forensic Engineering, Expert Witness, training and review. It has become obvious to me that effective communication is the most important aspect of managing geotechnical risk. This paper presents details of some technical and construction challenges that I have encountered, explains how communication gaps have caused or exacerbated the observed problems and shares my thoughts on how communication can be made more effective in helping manage geotechnical risk.

1 MANAGING GEOTECHNICAL RISK

1.1 Main areas of risk

Geotechnical risk can be defined as *the risk posed to construction by the ground or ground water at a site*. In the context of this paper geotechnical risk can be considered to relate to an unintended project outcome such as delay, increased costs, loss of function, reduced durability or contractual disputes that result from a ground or ground water related hazard that has not been adequately mitigated.

The ICE publication *Managing Geotechnical Risk*, (Clayton, 2001) provides an excellent description of the risks associated with engineering in, on or under the ground and confirms that ground conditions are a common cause of significant project cost and time overruns and contractual disputes. It is interesting to note that the suggested key areas of focus, to facilitate better management of geotechnical risk, are: *committed leadership, customer focus, integrated processes and teams, quality driven agenda and commitment to people*. These five key drivers are all very closely connected to and rely upon efficient and effective communications.

To help clarify the criticality of communication I have considered that the key aspects of geotechnical risk management fall into three main categories, technical, constructability and commercial.

1.2 Technical

Technical hazards include ineffective or inadequate assessment, use and documentation of ground models, design parameters, analytical models and documentation of the adopted design solution. Design codes, established analytical methods and robust review, both internal and external, generally combine to adequately manage this aspect of geotechnical risk. In my experience it is rare for design parameters and analytical methods to be the primary cause of project problems.

The development and understanding of relevant and appropriate ground models, and the incorporation of the ground model into the relevant design process is a common cause of difficulty. The ground model is often developed by a site investigation team focused on the relevant engineering geology. The design model is commonly developed and processed by the geotechnical engineers in the design team. These teams may work very closely together or may operate within separate entities. Effective communication between the ground modeling and design teams is critical if adequate risk management is to be achieved.

Drawings, reports, specifications and contract terms combine to define the design results and describe the adopted solution. Lack of clarity and incomplete details with the final documentation can cause problems during the design and construction of the works as well as causing delays, increased costs and contractual disputes.

1.3 Constructability

On *construct only* work packages it is common for the geological modelling and geotechnical analysis/design to be carried out with little or no input and review from the construction team. The adoption of *design and construct packages*, to facilitate close connection and understanding between the design and construction teams, is frequently adopted successfully for specialist geotechnical works.

Where adequate understanding of constructability constraints is not maintained design solutions can incorporate materials that are not available or cannot be transported to site and may require equipment that cannot access the site. Consideration of durability, cost and program restrictions can also become problematical and lead to inefficient solutions if the design team are not adequately informed of and appreciate relevant practical project requirements.

An adequate understanding of design considerations by the construction team is essential if site processes are to achieve the required outcomes.

These aspects of geotechnical risk management can only be addressed where adequate understanding of design and construction constraints are effectively communicated and understood between the two teams. The designers must have an adequate appreciation of relevant construction limitations and similarly the construction team must appreciate the critical issues from the design process.

1.4 Commercial

Project contracts are written to define the roles, responsibilities and liabilities of the parties involved in the works. Commercial and program requirements, and processes to address risk management and dispute resolution, are generally defined in detail.

Where the contract terms and conditions do not adequately address the roles and responsibilities, and related technical and construction issues, this can cause confusion and may restrict the ability to effectively manage geotechnical risk. This can be particularly problematical when the contract places liability for ground related risk with parties who do not appreciate or cannot effectively manage that aspect of the process.

1.5 Effective communication

We can consider the generalized areas of geotechnical risk described above as being represented by a three-legged stool. The stool will be stable, even on irregular ground, provided all three legs have adequate, though not necessarily equal, capacity and are held together by the seat. The seat is representative of overall effective communication that enables the three legs to operate in combination.

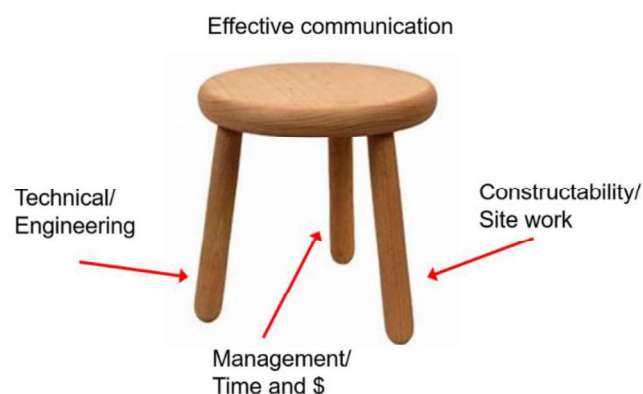


Figure 1. Effective communication to manage risk.

This model demonstrates that each team must have adequate awareness of the entire process to facilitate effective communication with the other teams. Without this communication it is not possible to achieve the necessary common understanding of the geotechnical hazards, the degree of risk and how to best manage them. The designer, constructor and/or project management team working in isolation is a certain route to project problems that will impact on all teams and project outcomes.

2 COMMUNICATION GAPS

The most common examples of communication gaps are where relevant questions are not asked, answers are not listened to, documentation is unclear, or is not seen by all necessary parties, and where changes are not adequately controlled.

Questions such as: *How variable could the ground conditions be?*, *What is the potential seasonal variability in the ground water level?*, *What are the specified allowable deflections?* and *What are the constraints beyond the site boundary?* need to be addressed if effective risk management is to be achieved.

Effective project communications must enable the teams to address and understand the hazards caused by the ground conditions. Important factors including the nature and variability of the ground water, soil or rock strength, stiffness and distribution, permeability, and possible time related changes to these parameters, need to be appreciated.

3 COMMUNICATION CHALLENGES

The most valuable lessons are often learned from consideration and back analysis of failures and near misses. Unfortunately, it is often difficult, if not impossible, to publish actual project details addressing

failures. The typical examples described below are based on actual project experience but are indicative in nature.

3.1 *Not asking the right questions*

Any effective design solution must be compatible with the anticipated ground conditions and likely variability. It is also critical that the design solution reflects the project requirements in terms of deformations, durability and construction constraints.

When specified deformation limits are not provided these values must be considered and resolved with the relevant project team members. If the question *What is the specified deformation limit?* is not asked, and low settlement or deflection limits are required due to structural constraints, the design solution may not be appropriate.

The question *What are the conditions adjacent to the site?* can be critical and needs to be answered in all cases. Temporary ground retention for a basement on an inner-city project in WA incorporated a conventional anchored temporary steel sheet pile wall. The sheet pile wall was partially constructed before it was identified that a reinforced concrete cut and cover tunnel, nominally parallel to the sheet pile wall, was off-set by only 6.0m and so prevented installation of the proposed conventional anchors.

The question *How shallow/strong could the bedrock be?* is important when excavation, dredging or pile installation works are being considered. Generally, in terms of stability, deformations or durability it is conservative to focus on how low the rock strength could be. When considering excavation, sheet pile driving or pile installation, it is necessary to also consider how high the rock strength could be.

Shallow refusal of sheet piles and difficult excavation, when encountering bedrock material discovered at a higher level and with higher strength than anticipated, has caused significant delays and cost increases on a number of major projects.

3.2 *Not listening to the answers*

Asking the relevant questions and not taking note of the answers generally leads to increased geotechnical risk.

It is common for a geotechnical design package to require a dilapidation survey in advance of the works, provision of regular monitoring of ground and structure deformations and feedback if any unexpected site or ground conditions are encountered.

Unfortunately, it is not so common for these important aspects of the construction process to be adequately provided in a timely manner. It is too late to conduct a dilapidation survey, clarify the monitoring base line data and consider changed ground conditions after a retaining wall has deflected more than predicted and adjacent structures are showing signs of distortion and cracking.

3.3 *Lack of clarity*

Confusion can easily occur between different project teams if there is any lack of clarity or over complication of the communications.

One very common cause of confusion is misuse of the terms level, depth and datum. Modern GPS based survey systems have reduced the adoption of site datums, but this can still potentially be problematical on smaller projects. It is also possible for project teams to be confused by work onshore to Australian Height Datum (AHD) connecting to nearshore work to Chart Datum (CD). It is essential that all documentation and conversations are based on a clear understanding of which level datum is being referred to.

The construction team can easily be confused by the definition of a *depth* that is actually a *level*. This area of risk can best be addressed by consistently specifying and working only to reduced levels against a specified height datum, such as the Australian Height Datum (AHD).

A similar and still common cause of error arises from confusion between structural and geotechnical design teams over the use of factored and unfactored loads. This is best addressed by consistent adoption of the terminology presented in the relevant design standards.

Ground related works such as underpinning, grouting and piling are often required to be carried out in a specified sequence. If not clearly specified and understood by site personnel, it is easy for the sequence to be ignored or changed without a full appreciation of the implications. Formation of new piles, near adjacent fresh piles, can damage the uncured pile if interconnection in soft or loose soil occurs.

Providing clarity on what is known and required should be relatively routine. What is not always so apparent, and can be critical, is to adequately clarify what is not known. For example, if the design is of limited scope, the ground model is of limited depth, and/or site access or project program constraints are not defined, these issues must be effectively communicated to all project teams.

3.4 *Scale*

A very common cause of geotechnical problems is the selection and awareness of the relevant scale to be adopted in modelling and analyzing the issue under consideration. The ground and design models must be compatible and must address potentially critical issues that may range from a regional scale of many kilometers, down to site and construction details at a scale of millimeters.

Focusing on the geometry and stability of a platform, with a nominal cut depth of 4m below the surface of an existing shallow slope, was adequately addressed at a local/site scale of around 60m on plan and to a depth of around 12m. The project team did not

develop a ground or design model on a local/regional scale of several kilometers and so did not consider overall slope stability and more onerous ground strata at greater depth. The local cut face on the upslope side of the platform was stable but significant deep-seated down slope movement distorted the platform and damaged recently constructed structures.

The grout underpinning solution shown in the first sketch below could be considered appropriate until appreciating the implications of the adjacent batter slope to be cut in sand as shown in the second sketch at a larger scale.

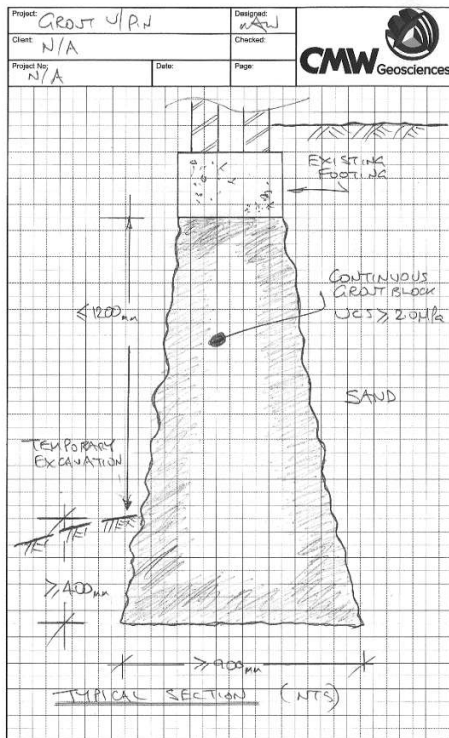


Figure 2. Grout underpinning block.

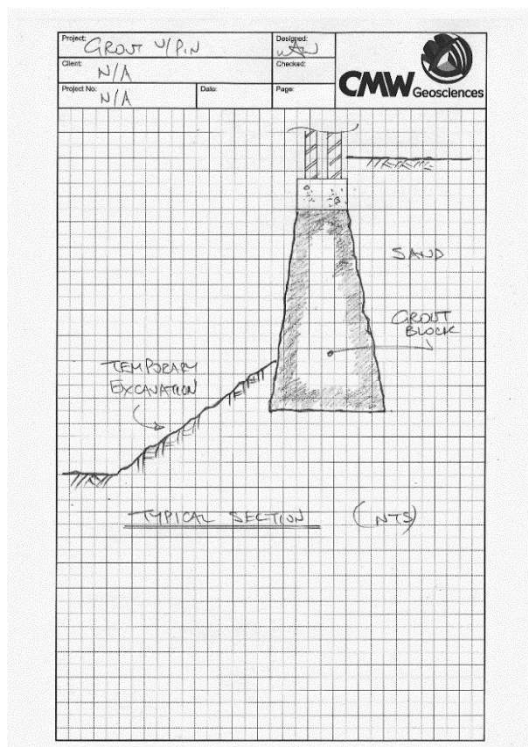


Figure 3. Grout block and adjacent excavation batter.

3.5 Seasonal variability

When conducting a geotechnical investigation it is standard practice to establish the level of the ground water beneath and around the site. In some instances, it is critical to note, question and further investigate potential seasonal variations in ground water levels.

Proposed basement excavations, nominally above a water level measured at the end of summer, could be assumed possible without dewatering. If excavation in late winter encounters higher ground water, delays and increased costs associated with dewatering and approvals will occur.

3.6 Explain what is essential

Some aspects of a design solution or construction methodology may be optional, and some will certainly be essential. It is critical that appropriate terminology, that can be easily understood by all teams and individuals responsible for the process, is used.

If an action, property, tolerance or construction sequence is essential it is not adequate to state *It should be done* or *It is recommended that*. The most appropriate and simplest way to avoid confusion is to consistently use the terms *Must* and *Must not* to describe items that are required or are to be avoided.

Consider the difference between, *In Australia you should drive on the left* and *In Australia you must drive on the left*.

4 EFFECTIVE COMMUNICATION

4.1 Talk, listen and think

Discussions between teams and individual team members are extremely valuable to identify areas of confusion or gaps. Time and financial constraints can lead to an overreliance on the very efficient electronic communications now available to us. Investment in early face to face discussions, review of drawings and collective site observations can provide significantly improved understanding and so facilitate hazard identification effective risk management.

Relevant discussions and effective listening are important, but of limited value, without the time and commitment to think about the issues being addressed. Question and answer sessions, review of project documentation and assessment of design models are only effective if the information presented is thought about in sufficient detail. It is likely that assuming the issues under consideration are routine, simple and *the same as the last job* will lead to incomplete understanding and inadequate development of the design solution or construction methodology.

4.2 Drawings and sketches

Engineering drawings are an effective and essential aspect of any project design and construction documentation. Conventional engineering and architectural drawings typically contain a large amount of information, are prepared in a computer-based CAD system, and can be overly detailed for geotechnical purposes.

The adoption of CAD and other computer systems has reduced the use of hand drawn sketches. There are a number of fundamental and critical benefits from producing a hand drawn sketch to scale on a single A4 or A3 sheet of paper.

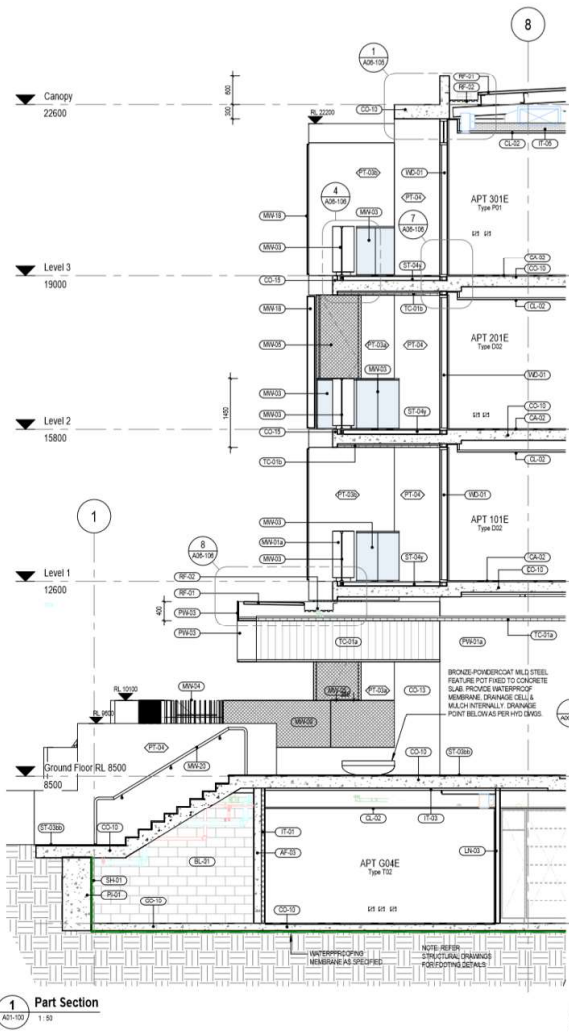


Figure 4. Typical drawing of basement wall and structure.

Before being able to commence the sketch, it is necessary to consider and clarify the optimum scale of the issue being addressed. As the sheet of paper cannot be increased in size, and the scale of the sketch cannot be adjusted at the click of a button, the initial thought process and the communications necessary to complete it must resolve the likely extent, location, depth and nature of the works being addressed. This scaling process forces the engineering geologist and geotechnical engineer to consider the big picture, nature and scope of the solution being documented.

The sketch must be drawn to scale to avoid misleading impressions being presented. Even with limited experience most competent engineers develop a feel for the appropriateness, or otherwise, of a proposed solution that can quickly be assessed in general terms from review of a simple sketch. If the sketch is not to scale the impression given can lead to inadequate understanding of the critical issues being considered.

The sketch will typically require details such as the ground model, reduced levels, ground water levels, adjacent conditions, construction procedures and access constraints. Preparation of the sketch forces communication about these potentially critical issues thereby dramatically reducing the possibility of confusion, error or omission.

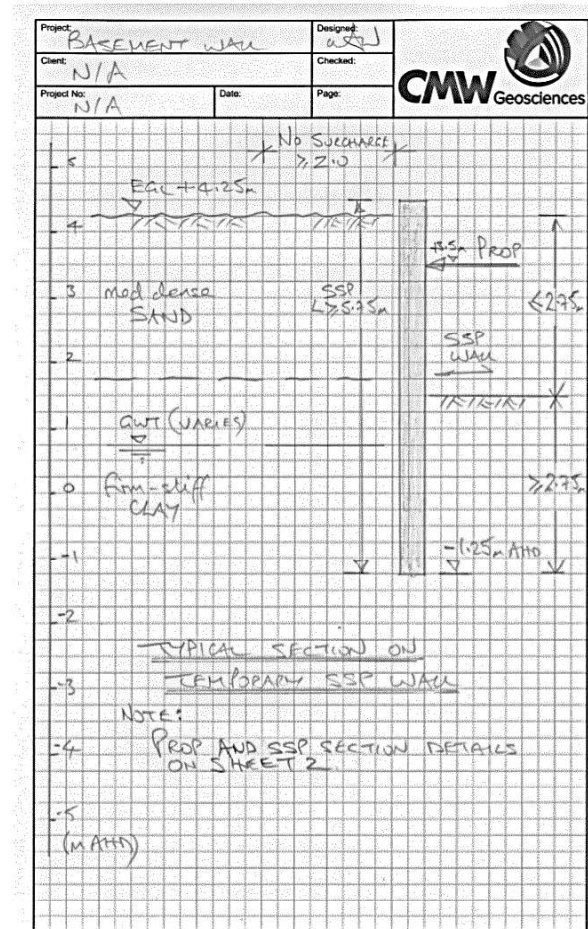


Figure 5. Indicative retaining wall sketch.

4.3 Reports, memos and emails

Documentation should enhance and support effective risk management by clearly identifying hazards and the assessed degree of risk, stating what is not known or has not been addressed and defining required actions and processes. It is critical that the documentation is presented in a manner that can be understood and utilized by all teams in the project delivery. Critical aspects of design or construction buried inside a long and complex technical report may not be noted by the site team operating at the coal face.

Executive summaries, drawings and sketches provide details in a summarized format are very valuable, but it must be remembered that, in some cases, these may be the only parts of the document that are read and referred to by other team members.

Emails provide an extremely easy and instantaneous form of communication. When used effectively emails can facilitate efficient communication particularly when working across large distances or time zones. It is critical to note that quickly written, lightly considered or unreviewed email communications can cause confusion, inefficiency and conflict or worse. Where it is not practicable to get an email reviewed independently, it is recommended that it be closely reviewed after a break of an hour or more and ideally overnight before sending.

It is relevant to remember that if the project geotechnical risk management is inadequate, problems occur and claims are made, every email communication will be analyzed in detail to assess the legal ramifications of what was, and was not, stated.

4.4 *Independent Review*

Adequate management of geotechnical risk is only achievable when effective communication enables appropriate review. The designer, constructor and project manager require assessment of their thoughts, work and documentation, by adequately experienced independent reviewers, to provide a sanity check, gap analysis and process review.

It is also critical that documentation is independently reviewed as issues obvious to the writer who has carried out the work may be confused, hidden or missing from the report or drawings. These issues can usually only be identified by the fresh eyes and thought processes provided by an independent reviewer.

4.5 *Follow up and feedback*

Effective risk management requires continued involvement, review and feedback across the project teams until, and often after, the construction process is complete.

Geotechnical works are, of necessity, based on assumptions and predictions about likely ground conditions and behaviors. Most geotechnical works incorporate some form of testing, monitoring, site observation and control measures to check that what is encountered is compatible with the ground and design model and analytical processes that have been adopted. Effective feedback from the site construction team to the designers and project managers is essential if successful project outcomes are to be achieved and the effects of any variability on site minimized.

4.6 *Independent Observation*

Effective and efficient quality control and risk management measures typically require self-scrutiny and checking/monitoring by the site construction team. The independent inspection roles of a Clerk of the Works and/or Resident Engineer are virtually unknown in the modern construction industry.

Effective communication of risks, site conditions, monitoring and changed circumstances is often much more effective if the site observation and reporting process can be carried out by a suitably experienced individual who is independent of construction management and the achievement of target production rates. This independence allows the person to observe the bigger picture, compare site works to anticipated conditions and procedures and so enhances the effectiveness of on-site risk management.

5 CONCLUSIONS

Effective management of geotechnical risk requires relevant and adequate ground models, analysis, design, construction and project management. Many experiences of problematical projects, Forensic Engineering investigations and Expert Witness work have shown that a common cause of problems is inadequate communication, causing lack of understanding, consistency and/or compatibility, within and across the various teams that contribute towards each project.

Effective risk management is not achieved by limiting or reallocating geotechnical risk and the liability for it. Effective risk management is achieved when all parties collaborate to identify, address and manage the significant ground related hazards that are inherent in geotechnical engineering works to minimize the likelihood of avoidable problems occurring.

It is apparent that, no matter how well the design, construction and project management functions are delivered, the geotechnical risks will remain poorly managed unless effective and robust communication is maintained within and between all project teams.

REFERENCES

- Clayton, C.R.I. 2001. Managing Geotechnical Risk. ICE and DETR, Thomas Telford Publishing, London.