Proceedings of the 21st ICSMGE, Vienna, Austria, 14 – 19 June 2026. Pistrol, Adam & Schweiger (eds.)
Published by: ÖGG, Austrian Society for Geomechanics, Salzburg, Austria, ISBN 978-3-9503898-4-5
https://doi.org/10.53243/ICSMGE2026-617

The perception and communication of geotechnical risk

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ABSTRACT: All civil infrastructure and building projects involve some element of geotechnical risk. There are, however, numerous examples where the impact of failing to appreciate geotechnical risks by non-geotechnical professionals has resulted in poor project outcomes. This often includes project programme and cost overruns but could also include political and reputational damage. This paper presents the results of research that has been undertaken through a survey of mostly Australian construction professionals to gauge the perception of geotechnical risk by those who work in the geotechnical field as well of those from other disciplines. These include employees of contractors, government, and consultancies, and covers a broad range of experiences – both in years and specialization. The authors provide some interpretation of the survey data and commentary based on their experience in the Australian context.

In addition, based on the survey responses, a range of methods that can be implemented to improve the communication of geotechnical risk on projects have been proposed. These include how to improve design drawings and geotechnical reports in a manner that should greatly increase risk understanding.

KEYWORDS: geotechnical risk, survey.

1 INTRODUCTION

Geotechnical risks (a hazard and its likelihood of occurring) can be defined as any ground related risk, be it natural or manmade, that can impact a target of that risk. Any construction project that involves interaction with the ground will, therefore, involve some geotechnical risk. Although these risks are often managed through the geotechnical team, it is likely that major decisions are by others. Thus, it is important that geotechnical risk be communicated effectively to ensure that appropriate decisions are taken.

Exploratory research is currently being undertaken to understand the factors affecting perception of geotechnical risks and how these perceptions impact project outcomes. This paper presents part of this research and details a review of literature on the geotechnical causes of project delays and cost overruns, followed by the preliminary findings of a survey of construction professionals which was undertaken to gain an understanding of how geotechnical risk is perceived in the industry. The survey consisted of a multipart questionnaire.

2 LITERATURE REVIEW

There is limited published literature on geotechnical risk perception. An examination of published papers in which surveys of industry professionals were undertaken to identify the causes of project delays and cost overruns has, therefore, been considered as a useful alternative source of data. Although not specifically addressing geotechnical causes, some of that literature narrows down into individual risk elements within projects – see Table 1, for example.

In most of the literature, where ground related issues were mentioned, the impacts of these issues were rated highly. In most cases the opinions of the contractual parties – client, consultants and contractors – are similar. In other case, they are significantly different (Shebob et al., 2012).

The impact of geotechnical risks on individual projects can be significant. Recent major examples include: Nicholl Highway collapse in Singapore in 2004 (Committee of Inquiry, 2005a, Committee of Inquiry, 2005b), M6 tunnelling works in Sydney, Australia (Muscat, 2024) and Yeager Airport reinforced slope failure in West Virginia, USA, in 2015 (VandenBerge et al., 2021, Collin et al., 2021).

Smaller projects can be similarly impacted. For example, a bridge crossing a river in Canada collapsed within six hours of opening due to a foundation failure. It came to light that no site investigation had been undertaken within the river (Reech, 2023, Leo, 2018). The replacement bridge cost over six times as much as the failed bridge and the engineer responsible was fined and placed under supervision for three years.

In general, the common themes identified across much of the literature can be narrowed down to a small number of causes:

- a lack of appreciation of the geotechnical risks (Morgenstern and Geotechnical Engineering Office, 2000)
- ignoring specialist advice (Health and Safety Executive, 2000)
- a lack of knowledge (either of the individual or of the site) (Committee of Inquiry, 2005a, Committee of Inquiry, 2005b, Health and Safety Executive, 2005)
- a risk management process failure (Health and Safety Executive, 2000)
- a lack of action when warnings occurred (Health and Safety Executive, 2000, Committee of Inquiry, 2005a, Committee of Inquiry, 2005b, Health and Safety Executive, 2005, Berg et al., 2020)

3 METHOD

The survey questionnaire was distributed through LinkedIn posts and personal networks. It was carried out under the ethical procedures reviewed by Queensland University of Technology. The survey participants were self-selecting in that they could choose to respond or not. Data was collected using the Qualtrics survey platform and was anonymised, with no personal identifiers such as name, location or date of birth recorded.

LinkedIn was chosen as it is a platform where individual construction professionals engage with each other. It also has the benefit that there are multiple specialist construction groups with relatively large memberships. These larger groups were all targeted. However, given the nature of the survey, those that

Table 1. Ranking of importance of ground related risks/factors to project overruns (from literature).

Reference	Location	Project Type[4]	Cost or Schedule Overrun [2]
Abdul-Rahman et al. (2006)	Malaysia	C	SO 1st (overall/contractor), 2nd (client/consultant) – foundation / substructure; 1st (consultant), 2nd (client/overall), 3rd (contractor) – piling; 4th (contractor), 5th (overall), 7th (consultant) - dewatering / drainage; 2nd (client), 5th (consultant), 7th (overall/contractor) – earth work; 6th (consultant), 7th (contractor), 8th (overall) - excavation
Ametepey et al. (2018)	Ghana	B/CE	SO - 4th (client/contractor), 5th (overall/consultants) – unforeseen site conditions
Akinradewo et al. (2019)	Nigeria	C	CO - 18th – inadequate site investigation / survey
Atapattu et al. (2023)	New Zealand	CE	CO - 6th – unforeseen ground conditions
Aziz (2013)	Egypt	C	SO - 4th (consultants), 12th (contractors) – inaccurate site investigation
Aziz and Abdel-Hakam (2016)	Egypt	C	SO - 7th (overall), 4th (consultant), 5th (contractor) – mistakes in soil investigation; 12th (overall), 4th (contractor) – faulty soil investigation; 20th (overall), 7th (consultant), 3rd (contractor) – unexpected underground condition
Chan and Kumaraswamy (1996)	Hong Kong	B	SO - 2nd (consultant), 5th (client), 19th (contractor) - unforeseen ground conditions
Faridi and El-Sayegh (2006)	UAE	C	SO - 10th (overall), 31st (contractor), 25th (consultant) – unforeseen conditions – subsurface soil condition
Tessema et al. (2022), Karunakaran et al. (2018)	Malaysia	CE	SO - 4th – poor site investigation
Khabisi et al. (2017)	South Africa	C	CO - 22nd - unforeseen ground conditions
Kumaraswamy and Chan (1998)	Hong Kong	CE B	SO - 1st (consultants) - unforeseen ground conditions SO - 19th (contractors) – unforeseen ground conditions
Lo et al. (2006)	Hong Kong	CE	SO - 1st (consultant/contractor), 2nd (overall), 4th (client) – unforeseen ground conditions
Madhu and Sree Lakshmi (2023)	India	CE	SO - 6th (overall/consultant), 8th (contractor), 9th (engineer) – effects of subsurface conditions; 12th (contractor), 14th (consultant), 16th (overall), 17th (engineer) – differing site (ground) conditions
Mpofu et al. (2017)	UAE	C	SO - 54th (overall) – inadequate site investigation; 86th (overall) – effects of subsurface conditions
Muneera and Joe Maria (2021)	India	B	SO - 1st – unexpected surface and subsurface conditions
Mukuka et al. (2015)	South Africa	C	SO - 4th (external) – effects of subsurface and ground conditions
Park and Papadopoulou (2012)	Asia	CE	CO - 2nd – inadequate site investigation; 3rd - unforeseen site conditions
Rostami and Oduoza (2017)	Italy	C	CO/SO[3] - 3rd – design variations [1] 8th – lack of site information
Sambasivan et al. (2017)	Tanzania	C	SO 4th – unforeseen site condition
Shahsavand et al. (2018)	Iran	C	SO - 4th (contractor), 5th (overall), 8th (client) – effects of subsurface conditions
Sharma and Gupta (2021)	India	C	CO/SO[3] - 4th – unforeseen ground conditions
Shebob et al. (2012)	Libya	C	SO - 25th (contractor), 26th (consultant), 35th (owner) - poor site conditions; 24th (consultant), 31st (contractor) – subsurface site conditions differing from contract documents
	UK	C	SO - 7th (contractor), 8th (consultant), 34th (owner) - poor site conditions; 42nd (contractor), 32nd (consultant), 33rd (owner) – unexpected geological condition; 13th (consultant) - subsurface site conditions differing from contract documents
Shukla et al. (2023)	India	CE	SO - 1st – consequence of sub-surface circumstances
Susanti et al. (2021)	Indonesia	CE	CO – 1st (external) (owner/contractor) – unforeseen soil conditions-
Tessema et al. (2022)	Ethiopia	C	CO/SO[3] - 9th – unforeseen site conditions
Yap and Skitmore (2018)	Malaysia	C	CO – 3rd (consultants), 5th (overall), 8th (clients/contractor) - unforeseen ground conditions (geotechnical issues)-
Yap et al. (2021)	Malaysia	C	SO -11th (consultant), 14th (overall) 15th (client/contractor) – unforeseen site conditions

Notes: 1. Rostami and Oduoza (2017) – "In this study, project managers outlined *inadequate site investigation* by designers to obtain reliable design data, and absence of an effective communication scheme among the projects' stakeholders as the reasons for *design variations*." 2. "Construction projects" – non-defined industry in relevant papers. 3. No distinction between cost and time overruns in literature. 4. SO -Schedule overrun, CO – Cost overruns. 4. C – construction, CE – civil engineering, B – building, PC – petrochemical

were most engaged with the industry, or were interested in the subject of the survey, were more likely to respond.

The survey was divided into three parts (Table 2) which covered general demographics of the respondents (Part 1), their risk profile and their perception of their corporate/industry risk (Part 2) and, finally, their views of geotechnical engineers and geotechnical engineering risk, and their experience of geotechnical failures (Part 3). No question was mandatory, and although most questions were closed (yes/no, multiple choice, Likert scale) some questions were open form.

4 RESULTS

4.1 *Respondent demographics*

At the completion of the survey, a total of 253 responses were received. Not all responses were complete, but of the full responses the following breakdown of the respondents professions were identified:

- 96 ground engineering professionals

- 29 project managers / construction management professionals
- 69 civil and structural engineers
- 31 other / not provided

Given the nature of the construction industry, most respondents were male (80%, 180) and 18% (41) female with 2% (4) not given. In terms of age, the largest single group was the 31-40 years old, which matches the industry average of 36 years for civil engineers (Australian Government, 2023) (Table 3).

Table 2. Questionnaire structure.

Part	Question Nos.	Subject
1 - demographics	1-10	gender, age, qualifications, role, experience
2 – risk profile	11, 12	Individual and corporate risk profile
3 – geotechnical risk	13-25, 30-35, 40-45	experience of geotechnical engineers and geotechnical risk

Notes: 1. No question nos. 26-29, 36-39. 2. Questions 19, 25, 35 and 45 were open questions allowing respondent comments.

Table 3. Age of respondents.

Age Range (Years)	No. / Percent	Construction Experience (Years)	No. / Percent
<31	31 / 15.1	<5	29 / 12.9
31-40	72 / 32.0	5-10	38 / 17.0
41-50	64 / 28.4	11-20	73 / 32.6
51-60	33 / 14.7	21-30	46 / 20.5
>60	22 / 9.8	>30	38 / 17.0

Slightly more respondents were born overseas (54.2%, 122) compared to those born in Australia (45.8%, 103). The largest contingents from overseas were from the UK (9.8%, 22), China (5.3%, 12) and New Zealand (4.4%, 10). The country of birth breakdown of respondents closely replicates that of the Australian general and engineering populations (Australian Bureau of Statistics, 2025, Briggs, 2023).

All but 14 of the respondents were degree qualified. Most respondents had civil engineering degrees (59.4%, 133) with 22 (9.8%) having geotechnical or geology-based degrees. Of those that had post-graduate degrees, most (27.7%, 61) had a geotechnical qualification. The respondents appear to be more qualified than the construction industry average (Briggs, 2023) which may mean they are more invested in their career and more engaged with the engineering industry. Most of the respondents were consultants (71.5%, 161) with 15 (6.6%) respondents working for contractors.

4.2 *Respondents risk profile*

Respondents were asked a series of questions related to their attitude towards risk. Respondents were generally risk adverse. Most respondents *think safety first* (91%, 160), prefer to *avoid risks* (69%, 127), *like to know what is going on* (57%, 104), do not view themselves as *risk takers* (53%, 88) and *do not take risks* regularly (57%, 104). There appeared to be minor differences in responses between genders, but younger respondents appear to be slightly more risk adverse than the older respondents (41 years and older).

Respondents were also positive about corporate and industry attitudes to safety, with female respondents slightly more positive than male respondents. For example, most agreed that risks are adequately addressed on construction sites (60.3%, 137) and felt comfortable about working on construction sites (81.9%, 150). Team leaders' behaviours with respect to safety were seen positively in several separate questions - commitment to safety (87.9%, 160), expresses satisfaction when safety is considered by respondents (83.1%, 162) and talks about the importance of safety (88.7%, 173).

4.3 *Attitudes to geotechnical engineers and geotechnical risk*

Geotechnical engineers tend to be well regarded by the respondents, with most agreeing that geotechnical engineers are well educated (83.1%, 157), good communicators of geotechnical risk (54%, 101) and can be trusted (79.1%, 148). However, they also believe that geotechnical engineers should improve their risk communication (63.6%, 119) and vary greatly in quality (63.1%, 118). Proportionally, more civil engineers (73.5%, 25) thought geotechnical engineers were good communicators of geotechnical risk, whereas geotechnical engineers were considerably more convinced that geotechnical engineers needed to improve their communication (73.3%, 55).

Most respondents (72.4%, 127) agreed that geotechnical designers were conservative, with only 20 (10.6%) disagreeing. When compared to other disciplines, geotechnical engineers were considered to be the same or slightly more conservative than structural, highway, civil and environmental engineers (all approximately 70% of responses). They were also considered slightly more or more conservative when compared to project managers, architects, construction managers and site engineers (all above 70% of responses).

4.4 *The impact of geotechnical risk on projects*

Respondents were asked if they believed geotechnical risks impacted projects and were also asked if they had encountered any geotechnical incidents during their careers. Each respondent could enter up to three cases.

Approximately 50% of respondents felt that unforeseen geotechnical risks caused an increase in project cost or caused delay on some projects (6% to 25% of projects). Approximately 30% of respondents felt that these were frequent (26% to 50% of projects). Only 10% thought they occurred on most projects (>50% of projects) with another 10% thinking they rarely occurred (≤5% of projects).

Respondents identified 186 incidents of which two-thirds were in Australia. Of these incidents, just over one-third (36%, 67) involved an impact to a third party. In 15% of the incidents an injury or fatality occurred. In only about a quarter of the incidents was the outcome foreseen by the respondent or project geotechnical engineer. The impacts of these incidents to project costs and delays are detailed in Table 4.

4.5 *Discussion of results*

The respondents were generally representative of the industry in Australia in terms of gender, age, country of birth and qualifications. The respondents were generally risk adverse and believe the industry and their organizations are safety focused.

Based on their experiences, respondents indicated that geotechnical risks resulted in project delays and increased costs with 30% of respondents indicating that more than 25% of projects were impacted. This was highlighted by the large numbers of examples detailed in responses and confirms the concerns raised in the literature identified in Table 1.

Respondents also indicated a general trust in geotechnical engineers and recognition of their qualifications. However, there are mixed results around geotechnical risk communication and a general view that geotechnical engineers are conservative.

Table 4. Magnitude of impact to project delays and costs.

Increase in time / cost**	Cost* (No./%)	Delay* (No./%)
Very high (>20%)	41/23.2	44/24.9
High (15%-20%)	23/13.0	29/16.4
Medium (10%-14%)	38/21.5	28/15.8
Low (5%-9%)	34/19.2	37/20.9
Very Low (>5%)	41/23.2	39/22.0

Note: *(No./%) = number of respondents / % of respondents; **increase over original project programme or budget

5 COMMUNICATION OF GEOTECHNICAL RISK

"*The major part of the college training of civil engineers consists in the absorption of the laws and rules which apply to relatively simple and well-defined materials, such as steel or concrete. This type of education breeds the illusion that everything connected with engineering should and can be computed on the basis of a priori assumptions. Unfortunately, soils are made by nature and not by man, and the products of nature are always complex.*" (Terzaghi, 1936).

Not much has changed since this statement was made, and it highlights the challenge faced by geotechnical engineers in communicating risk to other construction professionals. However, before a geotechnical engineer can attempt to communicate the geotechnical risks on a project, they first need understand them themselves.This means they need adequate resources, leadership and technical competence to do the job, as well as sufficient support and understanding from senior management on a project. Failure to do so can lead to increased levels of risk on a project (Bridges, 2019, Bridges, 2024).

The questionnaire results highlight that most respondents believe that geotechnical engineers are conservative. From a geotechnical engineer's perspective, a degree of conservatism may be prudent given, for example, the lack of data and / or geotechnical variability typical on most projects, especially in the early stages. This perception of conservatism, however, may affect the recipients view the information received from the geotechnical engineer. Clear communication of risks, however, can improve relationships and develop trust in the engineer and the information provided. The following sections provide some recommendations for clear communications of risk.

5.1 *Reports and advice*

The primary method of communication by a geotechnical engineer is a report. These reports can be highly technical in nature and that can be a barrier to clear risk communications. Although geotechnical engineers, in writing, are trying to cover their own corporate risk, that should not distract from the fact that they need to think about their target audience, which means they should be:

- using a language which is as simply as possible to understand
- clearly identifying risks and challenges that may be relevant to the project
- identifying uncertainties
- avoid using words such as "conservative", "non-conservative" or "aggressive" when referring to parameters (alternatives such as "appropriate")
- using executive summaries

Ultimately, when speaking to contractors, it is quite common to find that no one has read the relevant report, and problems occur on site that were foreseen in the geotechnical report. One possible tool is the use of a geotechnical risk card that provides graphical identification of risks that are discussed in the report (Figure 1). This could be added to the drawings or executive summary of a report.

Finally, geotechnical engineers should ensure that any relevant information from the report is transferred to the drawings.

5.1 *Drawings*

The main method of communication in construction is using drawings. However, these are very rarely utilised effectively as a geotechnical risk communication tool. The main risk controls are construction sequencing and monitoring. Construction sequencing is used to control the contractors work, for example, in excavations (Figure 2), to reduce the likelihood of excessive movement or destabilisation. These can be through a detailed sequence of works, or through a series of hold points where inspections are required.

Another control is through the use of a monitoring regime with trigger levels. These are employed on a variety of projects where performance needs to be guaranteed – embankments on soft soil, for example – or where impacts on adjacent stakeholders need to be controlled. The trigger levels act as hold points should excessive or unexpected movements occur.

Behind all these controls is the project risk register, however, the risk register is rarely included as part of the drawing package. It may be contained in the project documentation, but how many site engineers read these documents? Having it at the front of the drawing package raises these issues to the front of mind and helps to show why these other controls are in place.

The most effective measure, however, is to front up to the construction team, explain the risk and challenges and build a relationship with the aim to build trust between the parties.

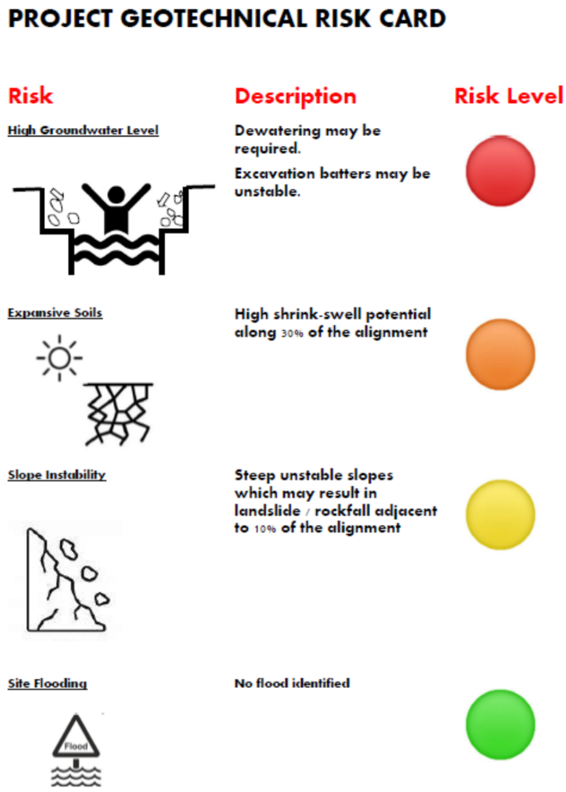

Figure 1. Example risk card

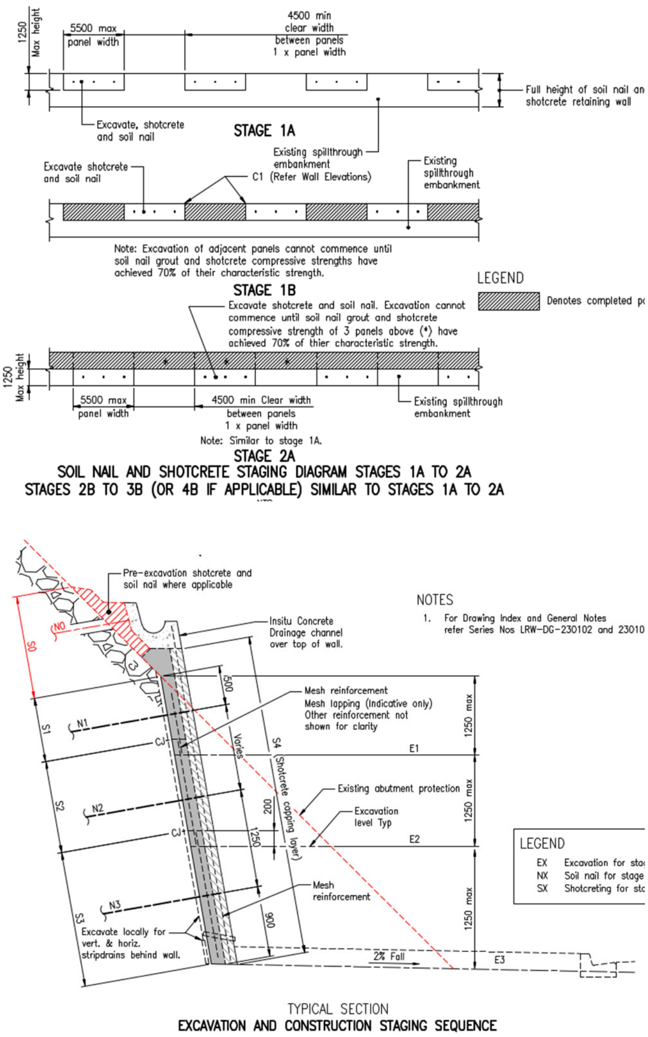

Figure 2. An example of construction sequencing – soil nailed excavation

6 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A survey of construction professionals, predominantly in Australia, identified that the respondents felt that geotechnical engineers were generally well qualified, trusted by their fellow professionals, but conservative when compared to others. Although they were typically seen to be good communicators of risk, a large proportion of respondents - especially geotechnical engineers - thought that their risk communications needed to improve.

Many respondents identified that geotechnical risks impact project outcomes, with up to 15% of reported cases involving injury or death. In terms of increased costs and delays, most respondents agreed that geotechnical risks had an impact which could be substantial, with 40% of respondents identifying that the over 25% of projects were affected. A literature review also identified that geotechnical risks were considered by consultants, contractors and clients to be of concern on projects, although this varied by industry and region.

Although only about 25% of geotechnical incidents identified in the respondent's case studies were foreseen, it is likely that with better communication to the construction team on site, the number of these incidents can be reduced. The authors have identified several solutions that can assist in these communications. However, the impact of the perception of geotechnical engineers as conservative should not be underestimated in preparing risk communication. Geotechnical engineers should, therefore:

- build relationships with other professionals to develop trust
- avoid wording that implies conservatism in design and development of parameters
- produce communication that provides clear information on risks and uncertainty

7 FUTURE STUDIES

This research is part of a larger exploratory study aiming to identify how geotechnical risk perceptions are impacted by experience and how these perceptions impact future project outcomes.

Once complete the authors will undertake workshops with industry to identify methods of improving geotechnical risk communication.

8 ACKNOWLEDGEMENTS

The authors would like to thank the respondents to the survey, who gave their free time to assist with this research.

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