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Consultants, clients and contractors: A seventy-year revisit

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ABSTRACT: In 1958, Karl Terzaghi published a paper in the Journal of the Boston Society of Civil Engineers, following a presentation he had made at a joint meeting of the BSCE and the Massachusetts section of ASCE. The paper, titled *Consultants, Clients and Contractors*, detailed Terzaghi's experiences as a consultant on large infrastructure projects, with a particular focus on factors that could lead to partial or complete project failure. Among these factors, Terzaghi highlighted the importance of casual observations, the qualifications of personnel supervising the works, the contractor's attitude towards their work, and the lack of communication between design and construction departments. The paper quickly prompted several engineers to contribute to the discussion.

In this revisit paper, the author aims to analyse whether the situation has fundamentally changed nearly seventy years later. In the age of digital communication, artificial intelligence, more complex organizations and increasingly stringent contracts and codes, have we made any progress in communicating efficiently, ensuring the proper transfer of information, and adequately controlling and documenting operations? Have these advancements resulted in a reduction of failures and conflicts on large or small projects? Furthermore, have we succeeded in gaining a better understanding and consideration for the particularities of deep foundations and soil mechanics issues, and the importance of adequate knowledge and experience, both in design and construction activities ?

In this conference dedicated to the memory of the father of soil mechanics, who was also a very practically-oriented field consultant, the author believes that this revisit may demonstrate Terzaghi's enduring vision on the complex relationship between clients, consultants, and contracting organizations, but also help us to try defining the contours of a better future for our profession.

KEYWORDS: Karl Terzaghi, consultants, contractors, deep foundations, communication, qualification, collaborative contracts .

1 INTRODUCTION

In 1958, Karl Terzaghi published a seminal paper titled 'Consultants, Clients and Contractors' in the Journal of the Boston Society of Civil Engineers. It was published after a talk he held at a joint meeting of the BSCE and the Massachusetts section of ASCE in October of 1957. 'His talks usually drew continuing public debate, fuelled by his correspondence with friends and personal invitations to prepare written discussions in order to air additional perspectives; this popular subject launched sixteen published discussions from informed engineers' (Goodman, 1999), some of which we will refer to later in this paper. Drawing from his extensive experience as a consultant on large infrastructure projects, Terzaghi identified several human and organizational factors that could lead to project failure. These included the importance of casual observations, the qualifications of supervisory personnel, the contractor's attitude, and communication gaps between design and construction teams.

This paper humbly intends to revisit Terzaghi's insights in light of contemporary engineering and contracting practices, and reflects on whether the profession has evolved in addressing these challenges. It is developed with a perspective informed by the various input and discussions with DFI and EFFC colleagues and by the author's John Mitchell lecture held at the DFI-EFFC conference in Berlin (Bottiau, 2022), which was aiming at offering a framework for more ethical and collaborative engineering practice.

Figure 1. K. Terzaghi in August 1957 with A. Casagrande and L. Bjerrum.

2 TERZAGHI'S 1958 OBSERVATIONS

Terzaghi's 1958 paper was a candid critique of the systemic issues he observed in engineering practice. He emphasized that technical soundness alone could not guarantee project success. Instead, he highlighted the critical role of human judgment, field experience, and inter-stakeholder communication. His observations were grounded in real-world consulting experience and resonated with many engineers of his time, prompting widespread discussion.

2.1 *Importance of communication*

Throughout his paper, Terzaghi emphasized the critical role of clear and effective communication among consultants, clients, and contractors. He believed that misunderstandings and miscommunications could lead to project delays, cost overruns, and disputes. He stressed how important it was to align the objectives of design and construction department, and to involve consultants and inspectors, as early as possible in process but also through the entire construction process.

2.2 *Qualification of personnel supervising the works*

'Design assumptions may be utterly at variance with reality', Terzaghi noted. He clearly identified the upmost importance of qualified inspectors and supervisors to detect 'conditions which (…) require local modifications of the original design'. 'The consequences of these conditions depend on the qualification of the personnel engaged in the supervision of the construction operations'.

2.3 *Important consequences of casual observations*

Terzaghi observed that 'quite often the most essential services (he) rendered to (his) clients had no relationship to the original assignment. They grew out casual observations (he) made while inspecting the site.' More than once, he would stress the importance of looking beyond theory and design assumptions and the necessary balance between observation, experience and theory.

2.4 *Performance by the Contractor*

Contractors obviously play a crucial role in the execution of a project. Terzaghi pointed out that their expertise and practical experience should be valued and integrated into the planning and design phases. He believed that a collaborative environment where the knowledge and skills of all parties are respected and utilized would lead to better project outcomes. He warned for the impact of the contractual conditions on the contractor's attitude during the performance of the works.

3 CONFRONTING TERZAGHI'S THEMES WITH MODERN PRACTICE

3.1 *Communication: from letters to Large Language Models (LLM)*

Terzaghi lamented the lack of communication between design and construction departments. He stressed the importance of a strong relationship between design engineers and teams on the field: 'in the realm of earthwork and foundation engineering the absence of continuous and well organized contacts between the design department and the men in charge of the supervision of the construction operations is always objectionable and can even be disastrous' (Terzaghi, 1958).

In modern practice, paradoxically, this challenge remains crucial. It has become commonplace to say that the current proliferation of communication tools broadly result in the lack of effective communication between people, entities, or spheres of influence. This is because digital communication tend to place the focus on transactions rather than on interaction (more informal conversations), which were a big part of the communication (Bottiau, 2022; Williams, 2002). Moreover, and because of the increased complexity of our environment, we have been cutting the problems in pieces, each party specializing in still more narrow topics. 'Geotechnics is genetically a complex discipline, since geotechnical engineering practice requires working with a very limited set of information on complex materials whose state can radically change over short distances and over time (Marr, 2006). Therefore, the collaboration of experts from different disciplinary sub-areas is often required' (Cardoso, 2015). But this is hardly the case. On the contrary, we developed as apart entities, more isolated and specialized, communicating primarily through digital systems which leads to the lack of transfer of a lot of unformal information and experience (Bottiau, 2022). And the absence of continuous contacts between the departments as highlighted by Terzaghi, has therefore even worsened.

Another factor is the explosion of the amount of data produced, collected and transmitted which we have observed in recent years (Bottiau, 2022):

- increasing volumes of specifications, recommendations, standards, made available through web-platforms or share points, often unsorted and named with codes and numbers only clear for the people who drafted them.
- increasing amount of raw and untreated data: soil investigation, output of machine monitoring systems,
- exponential volumes of scientific research and reports.

We could hope that digital tools such as Building Information Modelling (BIM), Common Data Environments (CDEs), and instant messaging platforms and even more recently the advent of AI and LLMs would help here. AI-powered tools can indeed analyse vast amounts of data, generate insights, and facilitate real-time communication across different stakeholders. However, integrating these new tools into existing workflows and systems can be challenging. 'The large data streams made possible by improved sensing capabilities will require new approaches to management of data, database structures, computer models for understanding and prediction of geomechanical behaviour, and multispatial, temporal modelling, and visualization of the geosystem' (Long, 2006). Moreover, while AI and LLMs can provide valuable insights and automate many tasks, over-reliance on these technologies can lead to a lack of critical thinking and (human) judgment. It's important to strike a balance between leveraging technology and maintaining oversight to ensure that decisions are well-informed and consider all relevant factors. For all these reasons, there is a risk that information remains fragmented across systems or entities, and critical insights from the field may not reach the design office (or vice-versa) in time to influence decisions. This could become even worse when externalisation of design activities further complicates effective collaboration. Nowadays, it's indeed not uncommon that a German designer works for a British consultancy on an Italian project with a Belgian contractor. How can communication between the design department and the field team be optimised in such scenarios?

A final, paradoxical observation is warranted. In contemporary business practice, the prevailing sense of urgency necessitates that decisions and corresponding actions be immediate. Communication tools such as email are now expected to deliver messages instantaneously, with recipients responding in real time. This elimination of any buffer between decision-making and implementation can result in critical information arriving too late for construction teams to respond effectively. While these upgraded tools were intended to enhance communication and the final product by reducing risks and improving planning, in practice they have led to increased flexibility, more frequent last-minute changes and urgent

information creating misunderstanding and miscommunication on the field.

3.2 *Supervision and Qualifications*

Terzaghi warned that inadequate supervision could compromise even the best designs. He particularly stressed the difficulty of managing the changing conditions in foundation works: 'If conditions are encountered which require local modifications of the original design, the construction engineer may make these changes in accordance with his own judgment, which he believes is sound, although it may be very poor. Important changes of this kind have even been made on the job without indicating the change on the field set of construction drawings' (Terzaghi, 1958). While modern certification and training programs have improved, hopefully resulting in a better qualification level of the average field engineer or supervisor, globalization has accelerated complexity, as varied factors and interdependencies increasingly shape decisions and actions. As A.S. Cardoso states, 'the increasingly globalized world, where information on whatever occurs wherever it may be, is available almost immediately, is also characterized by a permanent growth in complexity. That is, procedures and actions are conditioned by increasingly diverse factors and growing interdependencies. Complexity also results from the fact that humans face increasingly difficult and global challenges that, years ago, were simply not considered'(Cardoso, 2015).

Modern engineers therefore must contend with heavy administrative, technical, legal or contractual workloads—handling data, emails, documentation, regulations, and meetings. Yet, in our field, their main duty remains making informed decisions in Geotechnical Engineering and Deep Foundations. These rising administrative demands risk overshadowing crucial technical knowledge, impacting not just project managers but also consulting engineers and owner's representatives. As we explained above, isolated and more and more specialized entities primarily communicate through digital systems, which may result in the lack of transfer of specific information and experience. Which is extremely detrimental to the capitalization of knowledge. 'The foundation of engineering practice is indeed the distributed expertise enacted through social interactions between people harnessing the formal and tacit knowledge and expertise carried by a variety of people' (Kaplan, 2013). There is a risk, in our increasingly administrative and complex organizations, that this 'tacit' knowledge gets forgotten.

On the technical side, the increasing reliance on numerical methods and calculation software also can hinder clear communication between design and operations. Construction teams may struggle to fully grasp complex calculations often treated as black boxes, especially when informal interaction with designers is limited, which is increasingly the case, as we have seen above.

A last alarming evolution of the Construction environment is the rise of subcontracting and lean staffing models which often results in underqualified personnel managing complex tasks. As the author developed in his JML, this is the consequence of the evolution of contracting practices. 'An Entrepreneur is, at the origin, an individual, later a company who operates a business, in this case a Construction business. In other words, it is a skilled, professional builder who establishes himself and offers its services. In the 17th and 18th century, under the growing pressure of the administration, particularly in France, it became important to "fix the terms" under which works would be executed and paid. The notion of Contractor raised, mainly under Anglo-Saxon influence. A Contractor, from Late Latin (1540s) contractor "one who makes a contract," is a person, company, or corporation offering services or goods to another party under specific terms outlined in a contract' (Bottiau, 2022). Today, most large Construction Companies are organized as "Contractors", doing less and less themselves, hiring personnel for inspection and supervision tasks and using many subcontractors for the different "packages"; among which specialized deep foundations contractors.

3.3 *Contractor engagement and role*

Terzaghi valued contractors who took pride in their work and collaborated with engineers. But he warned for the fact that this collaboration could be negatively influenced by the contractual conditions on the project. 'If a job is carried out on a contract basis, one more element of uncertainty enters into the operation. It is the attitude of the contractor towards his work.' (Terzaghi, 1958) Although it is not clear what Terzaghi meant by 'on a contract basis', the importance of aligning the objectives of the Contractor with the Project were clearly identified. In the discussion which followed Terzaghi's paper publication, one of the contributors, M.H. Cutler, Chief Structural Engineer, mentioned that these remarks struck a responsive note. 'It is our philosophy, Cutler added, that the best solution to this dilemma lies in a contract under which the interests of these parties are common' (Cutler, 1958). If not, 'the contractor cannot be expected to be interested, or even aware of, the reasoning behind the design. His sole aim is to perform the work covered by the contract at a minimum expense. (Occasional discrete departures from the specifications reduce the cost quite considerably)' (Terzaghi, 1958).

This is of course a severe vision of the Contractor's attitude. But the current business environment may well contribute even more to such behaviour. Current contracting frameworks can indeed foster adversarial relationships. 'Modern (geotechnical) practice takes place in an increasingly competitive and litigious environment' (Peter Day, 2017). And 'clients increasingly favour competitive bidding, based on either too vague or too prescriptive specifications, and strict tendering rules. Public procurement is mainly based on the lowest bidder, and, in their vast majority, promotors take still lesser account of qualification and technical capacities. (…). In addition, contractual prescriptions tend to impose unbalanced impositions and too optimistic schedules and minimize the access to change clauses: change of scope, unknowns,…' (Bottiau, 2022). Geographical, environmental or geological conditions are deemed to be tackled by contract clauses.

So, since Terzaghi's times, no progresses have been made in improving contractual relations, although most of us know that 'classical contracts combined with traditional delivery methods often produce sub- optimal results' (O'Connor, 2009). On the contrary, 'relationships between parties are based on still stricter contracts making reference to stringent codes, and introducing unbalanced risk allocations resulting in adversarial interactions and lengthy disputes' (Bottiau, 2022)

Just as Terzaghi pointed out without referring to any formal framework, we need to promote early engagement of all stakeholders, and collaboration between them. But in order 'to foster true collaborative behaviour – collaboration that can withstand the inevitable challenges presented by complex construction projects – requires the right people performing the right tasks within an environment that promotes trust and mutuality of expectation over shared project outcomes' (O'Connor, 2009). This is why the sector needs to evolve

towards collaborative arrangements, and this passes through new contract forms which have been developed in recent years : Early Contractor Involvement (ECI), Integrated Project Delivery (IPD), or NEC series of contracts are good examples. These new forms of contract have the following features in common:

- A Fixed Price Incentive or (successive) target(s)
- The early involvement of the parties in a process in a spirit of mutual trust and cooperation such as the project delivery method where a general contractor is engaged to provide "preconstruction services" concurrent with design effort.
- An option to engage the construction process if the target is met.
- A clear Risk Allocation, where the risks associated with the project are clearly defined and allocated to the appropriate party
- A change management procedure with successive target price adjustments ensuring fairness and transparency.
- A regularly updated program .
- A clear procedure for resolving conflicts or disagreements.

These contract forms also allow for the transfer of lessons learned from one project to another in a long-term relationship. (…) They seek to answer questions about the "Who" and the "How" early enough in the project development process allowing for the introduction of lean construction methods and techniques aiming at eliminating project waste while resolving any design/construction technical conflicts before they cause a negative impact on the project' (Saad, 2020) and therefore may have a potentially strong positive impact on the Projects timelines (see fig. 2).

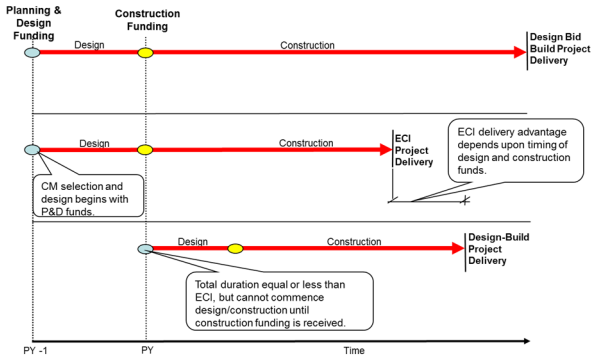

Figure 2. Delivery Timelines Comparison between Standard and Integrated Delivery Projects (EFFC position paper).

In a recent workshop organized during the Bruges DFI/EFFC International Conference on Deep Foundations, we could see how visionary public Authorities try to shape a new collaborative framework for managing projects, emphasizing clear communication, risk allocation, and a collaborative approach to problem-solving. Among other participants, the Corps of Engineers, Lantis and the Port of Hamburg showed clear examples of how the paradigm of contracting can be modified, using one of these new contract forms. As an example, Lantis developed the way they successfully implemented the NEC-4 type of contract for the large civil works on the Oosterweel project currently going on in Antwerp.

These are nice examples, which we would like to see more often, and not only limited to large projects with visionary clients.

4 DEEP FOUNDATIONS AND SOIL MECHANICS

4.1 *Terzaghi – Father of modern soil mechanics*

Terzaghi, as the father of soil mechanics, was acutely aware of the risks of underestimating ground conditions. Starting the discussion section after the publication of Terzaghi's 1958 paper, Arthur Casagrande interestingly summarized: 'Professor Terzaghi has made it quite clear that principal causes of trouble are 1) the fact that the actual subsoil conditions cannot be known exactly during the design stage and that appropriate changes in design must be made as construction proceeds, and 2) the changes that the construction department will make or authorize without notifying the designers. (…) Professor Terzaghi points out that the principal requirement for solving difficulties is a competent soil mechanics department that creates the liaison between the design and the construction departments, and that is empowered by sufficient authority. ' (Casagrande, 1958) Let us analyse the evolution in this respect on two aspects: the advances (?) in site investigation and soil modelling, and the current (in)correct valuation of geotechnical engineers. Prof. J.B. Burland has delivered interesting comments on this topic, and developed a most interesting tool, to account for the 'lack of appreciation of the number of aspects that have to be considered in tackling a ground engineering problem' which he came up with in 1987 after 'after careful study of the opinions expressed by Terzaghi and others, and from (his) own experience' (Burland, 2007): the Geotechnical Triangle.

'Because of his work in developing the scientific and theoretical framework of soil mechanics and foundation engineering, Terzaghi is often regarded as essentially a theoretician. In the teaching of Soil Mechanics it is all too easy to leave the student with the impression that the subject is now an exact science and that everything can be calculated, emulating the older discipline of structural engineering. Nothing could be further from the truth' (Burland, 2007). And indeed, despite advances in geotechnical modelling and site investigation, subsurface uncertainties remain a major source of conflict in many projects. One of the reason is that the site investigation phase is still often dramatically underestimated with sites being insufficiently characterized and contextualized. 'Geoengineering is burdened by a lack of adequate characterization of the geomedia and paucity of necessary information, which contributes to some extent to the unavoidable uncertainty in design' (Long, 2006).

But more generally, the complexity of soil behaviour is still too poorly communicated to non-specialists, and geotechnical expertise is often undervalued until problems arise.

4.2 *The Geotechnics triangle*

At a recent symposium held in Copenhagen (*Successes and Failures, what did we learn?*- DFI Europe and DGS, Copenhagen, April 2024), Tony O'Brien purposely referred to the Geotechnical triangle, which offers an excellent framework to understand the interaction between the different elements to be considered, and how the balance between the different aspects of the Triangle should be given proper attention to avoid failures.

Five key elements should be considered for practical applications (O'Brien, 2024):

- site geology/hydrogeology/history
- ground behaviour (both for design + construction)
- appropriate models - both conceptual + analytical
- well winnowed experience
- link design to construction (key observations/tests during works).

In this presentation, the Geotechnical Triangle (Fig.3) was modified in order to account with the construction process, emphasizing the importance of construction processes in foundation engineering and the potential impact of those processes on key design assumptions, which is a topic we find particularly important. But even important is the danger caused by the inadequate current focus on calculations and computations, rather than on fundamental understanding of the ground behaviour and on the quality of the site investigation.

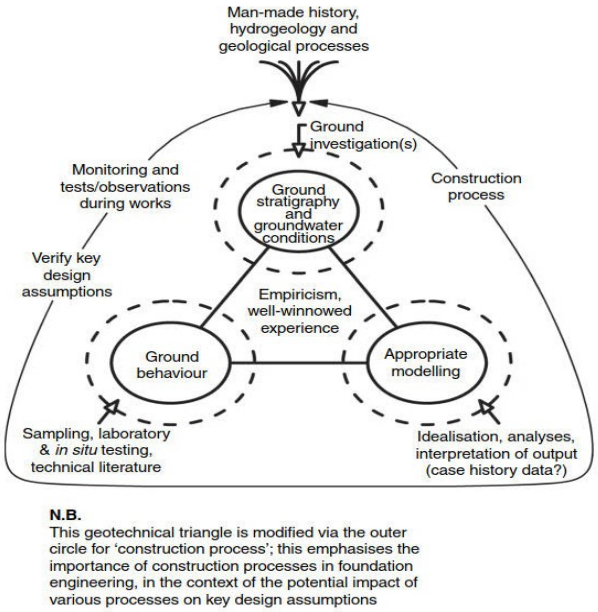

Figure 3. Modified geotechnical triangle (O'Brien, 2024)

In modern geotechnics, O'Brien says, too much focus is given on analysis with inadequate attention to conceptual models. Analysis will not predict a failure mechanism if the conceptual model is flawed, he adds. (Bottiau, 2024)

With the advent of AI and its – not yet fully envisaged - impact it is even more essential that information remains interpreted on the basis of the strong understanding of fundamental principles of Ground Engineering. In the Preface of the Third edition of Soil Mechanics in Engineering practice (Terzaghi, Peck and Mesri, 1996), Ralph Peck wrote:

> 'In the half-century since (the preface to the First edition by Terzaghi in 1948 was) written, research in sampling and testing has continued unabated, and a vast literature has accumulated about the properties of soils, much of it directed toward advancing one or another school of thought concerning the idealized conception of soils behaviour. During the same time, remarkable advances in electronic calculation have made theoretical forecasts possible for problems involving complex boundary and stratigraphic conditions. Thus it may no longer be true that, (as stated by Terzaghi), if forecast cannot be made by simple means it cannot be made at all. In exchange of this progress, however, it has become increasingly important that the choice of soil properties used in the analyses be based on a fundamentally correct knowledge of the soil behaviour.'

Nearly thirty years later, this statement has even gained in importance and is not limited to soil properties but also to models, theories and codes. We could write indeed that, in exchange of the progresses made, it has become increasingly important that the choice of soil properties and conceptual models, and the application of codes used in the analyses be based on a fundamentally correct knowledge of the soil behaviour.

4.3 *The necessary recognition of Geotechnical engineers*

As highlighted by F. Marston, another contributor to the discussion about Terzaghi's 1958 paper : 'Much of the paper could have been titled, 'The Importance of Soil Mechanics in Foundation Engineering"' (Marston, F.A, 1958). A. Casagrande, as recalled above, confirms that Terzaghi emphasized the need for a competent soil mechanics department (…) that is empowered by sufficient authority. This leads us to an important question: is Soil Mechanics better recognized today as a key component of the Construction process? Did the role of the Geotechnical Engineer, as a profession, evolve towards more recognition over the last decades? This is all but certain.

Firstly, the selection of all categories of engineering services has not evolved in the good direction. As reported by Peter Day, 'over the last three decades, the procurement of professional engineering services has changed significantly. In the past, the person or entity calling for such services either had some knowledge of the services required or relied on trusted professionals to propose a suitable scope of services. The value of employing a reputable professional was recognised. In recent times, procurement of engineering services is often done by commercial or project management personnel by way of open tender, with little or no specification of the services required or who should provide them (Day, 2017). Secondly, the understanding between structural and geotechnical engineers continue to be at stake. Prof. Burland extensively developed this topic in another interesting paper. 'Interaction, he says, always takes place between a structure and its foundation…whether or not the designer allow for it.' And further 'structural engineers tend to work and think in terms of forces and stresses, geotechnical engineers are much more used to working in strain and deformation' (Burland, 2006).

'Geotechnical engineering is one of the first technical and scientific fields to intervene in any infrastructure or urban development project and, in many cases, it is the most important' (Cardoso, 2015). Promoting greater recognition of our role is essential not only for our profession but also for society as a whole. It is equally important to emphasize the unique characteristics of our discipline by communicating to stakeholders that 'soils are made by nature and not by man, and the products of nature are always complex... As soon as we pass from steel and concrete to earth, the omnipotence of theory ceases to exist. Natural soil is never uniform. Its properties change from point to point while our knowledge of its properties are limited to those few spots at which the samples have been collected. In soil mechanics the accuracy of computed results never exceeds that of a crude estimate, and the

principal function of theory consists in teaching us what and how to observe in the field.' (Terzaghi,1936 in Goodman, 1999) Which, despite the progresses in modelling and the capacity of current computers, still remains valid. 'We must explain to decision makers the uncertainty in geotechnics and raise awareness of the social and economic benefits that derive from risk reduction' (Barends, 2005).

5 CONCLUSIONS

Seventy years after Terzaghi's landmark paper, many of the issues he identified remain unresolved, or even have been amplified . While technology and regulation have advanced, the fundamental challenges of communication, supervision, contractor engagement, and geotechnical understanding persist.

Rather than proposing procedural fixes, we advocate for a cultural shift in engineering practice—one that emphasizes ethical alignment, mutual accountability, and professional recognition. We call for engineers, contractors, and clients to move beyond contractual compliance and embrace shared responsibility for better project outcomes. This is more than just a philosophical message. It is a necessary evolution which will shape a new paradigm in the whole Construction sector and renew the vision of the external world. As Jane Long states, 'if we do not find better ways to solve our traditional problems, economic and environmental concerns will push these solutions further and further out of reach' (Long, 2006).

Joining our efforts through all professional organisations in our field, we urgently must:

- Recognise the unique aspects of Geotechnical engineering and invest in educating both our teams and our clients.
- Use balanced contracts that fairly manage risks and responsibilities, including mechanisms for addressing unexpected issues and prompt compensation.
- Foster increased transparency within the profession by openly sharing both failures and achievements. Utilize advanced monitoring technology to enhance documentation and comprehension, thereby contributing to the maturation of the industry.

We believe this vision aligns with Terzaghi's emphasis on the human dimension of engineering, but extends it by proposing a proactive, values-driven approach to collaboration and decision-making.

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