The Observational Method in a Real-Time, Multi-Stakeholder Environment

POT, R a, ROELSE, F.P. a, VAN DER MEER, M.T. a,b, NUSHI, B.R.I. a,b and NELEMANS, J.P. a

a Fugro Onshore Geotechnics, Fugro GeoServices B.V., The Netherlands
b Delft University of Technology

Abstract. The application of the Observational Method can contribute to an economic construction process and effective geotechnical risk management. Current project management practices and control of construction works lead to unfavourable conditions of its application. Throughout the realization of infrastructure, understanding of project risks and effective risk communication are relevant stakeholder responsibilities. In complex or high-risk projects, quick and informed decision-making is critical to prevent failure costs and disruption. A real-time overview of information is a key condition for decision-makers; supports risk communication and helps geotechnical engineers to identify geotechnical risks. To improve conditions in which a construction team needs to operate, GeoRiskPortal is developed. This web-based interface simultaneously presents geotechnical data and time dependent risk in a single viewer. A priori risk assessments, real-time sensor observations, and updated model results provide input for tailor made data visualisations. Colour projections are applied to communicate project risks and opportunities. Stakeholders and geotechnical experts were given access to a prototype of GeoRiskPortal. The application of decision support and interactive data visualisations on maps has proven to be very powerful to engage stakeholders and supported the interaction between geotechnical experts and non-technical stakeholders.

Keywords. Observational Method, Geotechnical Risk Management, Failure Costs, Risk Communication, Monitoring

1. Introduction

Application of the Observational Method (OM) can contribute to an economic construction process and effective geotechnical risk management (Peck, 1967). It depends on project conditions if and to which extend the OM can be applied. These conditions can have a technical or non-technical nature. Technical reasons to apply the OM are high ground heterogeneity, uncertainties in failure mechanisms and the ability to change the design during the project. Apart from economic benefits, non-technical incentives to apply the method are unacceptable (environmental) risks, a critical attitude of stakeholders or staged construction. Contract preferences, inflexibility of authorities or unawareness of the possibilities (often the case in the Netherlands, due to a lack of experience with the OM) might be reasons why the method is not applied (Korff et al. 2013). A successful application of the OM depends on flexibility, preparedness, effective communication, and the ability to act based on field data (Peck, 1967). The later aspects are also pre-conditions for effective Geotechnical Risk Management (GeoRM). The increasing number of (often non-technical) stakeholders adds value to the decision-making process. However, proactive stakeholder involvement introduces new demands for information and requires geotechnical experts to translate technical grammar in understandable language. Traditional information sharing mechanisms do not support effective risk communication and are not suitable to make informed decisions in a multi-stakeholder environment. This complicates practice of the OM. To improve conditions in which a construction team (consisting of technical and non-technical stakeholders) needs to operate, an intelligent web-based decision support system (DSS) is developed and tested. Goal is to map critical conditions -and pitfalls- to improve the decision-making process, aiming to avoid disruption (such as geotechnical failure), reduce failure costs, and optimize project results.
2. The Observational Method, Geotechnical
Risk Management and Project Conditions

The OM is often instinctively applied as “a best way out” whenever during construction an
unexpected development has occurred. Such a
development can relate to unexpected ground
behaviour, if there are threats of damage,
geotechnical failure or calamities. The success of
this approach fully relies on observations. Field
observations (often time dependent) have to be
interpreted correctly and need to be
communicated in such a way, that the right
actions are taken. Depending on the failure
mechanism and consequences, quick decision-
making is required. The OM can also be applied
from the start of a project (ab initio). The
objective of the method is to achieve greater
overall economy, without compromising safety
(Nicholson, 1999).

2.1. Conditions for effective utilization

There are a number of requirements to be
fulfilled before the OM can be applied
successfully. The most important ones are: 1. full
understanding of the project challenges; 2. the
visualization of possible eventualities; 3.
preparation in advance (an appropriate course of
action to meet whatever situation develops); 4.
the ability to observe, interpret and communicate
the actual field conditions; 5. design flexibility
and 6. the ability to act in accordance with the
objective of the method (Peck, 1969). In this
paper Terzaghi and Peck describe its application
in an engineering environment corresponding
with a technocratic decision-making process by
individuals or groups of (technical) professionals,
based on technical input and focussed on quality
and economic design. Correct utilization implies
effective geotechnical risk management.

2.2. Societal relevance of avoiding disruption
and failure costs

The development of infrastructure and real estate
increasingly takes place in an urban environment.
Initiators, contractors and engineers have to deal
with existing infrastructure and buildings in the
near surroundings of the project location. These
circumstances introduce an additional probability
of disruption. Initiators are forced to make
increasing efforts to prevent hindrance and
damage. Within multi-stakeholder environments,
in which the public and bystanders are heard,
political support is lost quickly if projects are
accompanied by excessive hindrance, calamities
or significant failure costs.

Failure costs in the construction industry
have a large economic and societal impact.
Castillo et al. (2010) define failure costs in
construction to be all unnecessary and avoidable
costs incurred throughout the project, due to
product and process deficiencies. Failure costs
manifest themselves as a result of mistakes (in
the (pre)tender, design or construction phase),
inefficiencies, (geotechnical) failure or delays
(Castillo et al. 2010). Often they are related to
unexpected or unforeseen ground behaviour. In
the Netherlands, failure costs are estimated to be
5 - 13 % of construction investments (Van
Staveren and Chapman, 2007), corresponding to
about 3 to 7 billion euros per year. It is estimated
that about half of these failure costs have a
ground related cause (Van Staveren, 2006).

Disruption or failure cannot be expressed in
economic losses alone. Mistakes in projects are
not always detected immediately if verification
of the end product is insufficient. Risk-based
asset management cycles are therefore essential
to guarantee the safety of critical infrastructure
(physical assets that are essential for the
functioning of a society and economy).
Geotechnical failure often leads to unsafe
situations; damage to the adjacent environment
of the building site; loss of reputations, but most
important, it can disrupt the lives of local
residents and businesses. This often results in
political demands and immediate measures. After
damage has occurred, minor additional risk as
assessed by technical experts, often elicits strong
public concerns, contributing to risk
consequences. This phenomenon is called social
amplification of risk (Kasperson et al, 1988) and
is often forgotten in initial budget allocations. It
is recognized that geotechnical failure occurs
often. Studies of failure generally show failure
could be avoided by improving project
management (Sherwood, 2011). This implies
multidisciplinary efforts and inclusion of Geo-
RM in all project phases and consideration of
applying the OM.
2.3. Unfavourable changes of project conditions

Stakeholders, including local residents and politicians are nowadays to a certain level engaged in construction projects. This reflects a mature democratic society in which multiple actors can influence project decisions. In a multi-stakeholder environment, actors have different goals and risk perceptions. Actors generally do not have access to the same information. If they have access to the same information, they have a different way of coping with it as a result of their role, level of understanding, field of expertise and their risk perception (Edwards and Bowen, 2003). This highly complicates decision-making. Figure 1 (after Edwards and Bowen) expresses this reality, showing stakeholders’ engagement and accessibility to relevant project information. Not all actors share relevant information with project management (PM) and/or act in accordance with project goals.

![Figure 1: Access to project information.](image)

Within organisations, the composition of project teams has changed as well. To professionalize process management, teams have become multidisciplinary to address complex juridical aspects, contract management and environmental aspects. An example of this is the adoption of the Integral Project Management (IPM) model by Rijkswaterstaat and the Dutch Provinces. Over the last decade decision-making in construction projects has evolved from a technocratic process towards a multi-dimensional process. Conditions to apply the OM in a technocratic decision-making process are different in comparison to a real-time multi-stakeholder environment. The increasing number of actors and different compositions of project teams has enhanced the influence of non-technical actors on project decisions. In order to make informed decisions, they require different (tailored) information about projects risks. Risk communication between experts and non-technical experts is recognized to be difficult (Leung et al., 2008). The concept of geotechnical risk is generally supported by complex graphs and calculations that tend to thwart stakeholders understanding. Understanding field conditions, updating of premises and the principles of (the ab initio) OM are not obvious for non-technical actors. Its application implies taking into account different scenarios, flexibility and continuous gathering of field data but easily sends out a very different message. Therefore it is essential that geotechnical engineers inform and engage their co-decision-makers in advance and throughout the project. Non-technical stakeholders have a responsibility to demand understandable information to make better decisions aiming to avoid disruption and failure.

2.4. Efforts made to improve Geo-RM

In 2010 a joint industry program called Geo-Impuls was launched in the Netherlands to raise awareness and reduce geotechnical failure costs with 50% in 2015 (Cools, 2011). To manage risks in construction projects, Rijkswaterstaat has implemented the RISMAN approach (Well-Stam, Lindenaar et al. 2003). To improve Geo-RM practices, Deltares developed the GeoQ methodology (Van Staveren, 2009). Both concepts focus on a step-by-step approach and can be applied easily. Geo-Impuls has stimulated sharing of best practices, published guidelines and developed valuable Geo-RM tools. The use of such (decision support) tools in geotechnical projects remains limited, especially in multidisciplinary project teams. It might be of influence that current information sharing mechanisms solely focus on technical end-users. Traditional information sharing practices are often not suitable for real-time performance during execution of projects or team decisions. In a potential calamity situation, decision-makers, very much like crisis management workers, need quick access to field information. This requires a
quick translation of (real-time) monitoring data to understandable information.

3. GeoRiskPortal for Decision Support

To support teams to apply the Observational Method and practice Geo-RM in a multi-stakeholder environment, GeoRiskPortal is developed. This web-based decision support system is designed to: improve communication on geotechnical risk, support end-users to make informed decisions, and provides access to field observations and (risk) visualizations. The information sharing mechanism is targeted towards reducing the cognitive load needed to share, interpret and access information. The portal integrates field data, interpretations and time dependent risk in a single viewer using a layered approach.

In figure 2 this layered approach is incorporated in a decision-making model. Stakeholders have access to relevant information corresponding to their role. The portal serves multiple user groups: geotechnical experts, operations, decision-makers and local residents. Geotechnical engineers are required to actively take part in the decision-making process (their traditional role); however, they also need to fuel the system with information that supports (non-technical) stakeholders. A priori risk assessments, sensor observations and model results provide input for tailor made data visualisations with the goal to engage non-technical stakeholders. Users get insight in settlement or stability calculations which can be updated throughout the project. As a base layer satellite data from USGS’s Landsat is used. On the base layer real-time observations are made accessible using GeODin Portal Server. This allows Cone Penetration Tests, borehole logs, time series of geotechnical monitoring to be presented in a single viewer. The visualisation of sensor-based data acquisition enables insight in ground behaviour and the effects of building activities. Keyhole Markup Language (KML), dynamic charts and dashboard functions are applied to visualize field conditions. To prepare end users for unwanted events, scenarios are applied to visualize uncertainties of ground behaviour. Comparisons of field conditions and (updated) model results are made using state indicators and colour codes. Users can collaborate by making digital annotations and remarks. GeoRiskPortal is accessible online. To use the interface no prior knowledge is required.

4. Experience in Projects

The concept of the GeoRiskPortal as decision support system was tested with the goal to receive feedback and to engage end-users. These tests consisted of an internal technical user group and non-technical stakeholders. An operational prototype was tested alongside traditional consulting services in three cases: a levee reconstruction project (preoperational phase, effects on vulnerable structures), embankment heightening (visualisation of settlement calculations) and field observations of a building pit (monitoring). This chapter shares user
experience, requirements for successful application and lessons learnt from the development team. Its utilization is discussed from the perspectives of the contractor and public authorities.

4.1. Perspective from public authorities

The department of civil engineering of a medium size municipality reviewed the use of GeoRiskPortal in the preoperational phase of a levee reconstruction project (effects of the installation of a sheet pile wall). The team has budgetary responsibility, arranges project guidance and frequently communicates with citizens that might be affected during the execution of the work. In this case the possible level of disruption, damage and measures to mitigate the problem were investigated. Colour codes were applied to indicate the risk of damage based on intervention values and a basic assessment of structural integrity.

Figure 3 shows a similar visualization aiming to support risk communication. For publication purposes, dummy data was used. In conversation with decision-makers and citizens, civil servants experience on a daily bases difficulties to translate technical information into understandable language. The use of visualisations was beneficial to create an overview of project information and supported the conversations and decisions. Fast access to project information and the ability to make annotations were mentioned as key advantages compared to traditional information sharing mechanisms. The allocation of colour codes based on intervention values) resulted in discussions about warning- and intervention levels. Transparency about the applied parameters and benchmarks was marked to be essential for end-users. The use of scenarios in could have supported the project team in advance.

4.2. Perspective from the contractor

Contractor got access to monitoring data and modules to map ground behaviour (settlement calculations and stability of embankments). Field observations were used to update settlement predictions. Colour codes showed the difference between the anticipated settlements and stability and the situation in the field using settlement plate observations and pore pressure meters. The ability to access all this data in one viewer supported the execution and the conversations with the client. Users that were confronted with the visualisations requested full insight into the colour code allocation, a notification of status updates and a log book functionality.

4.3 Lessons learnt and critical conditions

The internal user group (geotechnical experts) valued easy access to relevant project data. The ability to steer a project (in a critical phase) based on a DSS such as GeoRiskPortal, depends fully on the reliability of field observations, fast data access, and the availability of metadata. The application of data visualisations has proven to be powerful. Colour codes can engage stakeholders but are able to influence decisions easily. Transparency about the underlying data, benchmarks, and preparedness is therefore essential. Its application resulted in a large
amount of substantive questions. It is therefore important that geotechnical engineers are prepared and capable to support non-technical stakeholders. In the three cases the DSS improved communication about uncertainties, field conditions and geotechnical risks.

5. Conclusions

A number of conditions present in today’s construction industry are unfavourable for effective Geotechnical Risk Management (Geo-RM) and the application of the Observational Method (OM). Terzaghi and Peck have described application of the Observational Method in a technocratic environment. This environment has changed. Nowadays multi-disciplinary project teams make project decisions. They are often exposed to a large number of (non-technical) stakeholders. To fulfil preconditions for successful application of the OM and effective Geo-RM it is important to engage stakeholders and to support project teams to make informed decisions. Full understanding of project challenges, effective communication of field conditions, design implications, and preparation in advance are therefore required. Geotechnical engineers need to take responsibility to engage non-technical stakeholders by translating technical grammar to understandable language. Decision support systems can be support this with the aid of data visualisations. They can be valuable to improve conditions to apply the OM and practice Geo-RM in a multi-stakeholder environment. With caution we suggest project teams to consider the use of decision support systems to improve risk communication and decision-making. They can speed up and rationalize (critical) decisions in construction projects.

Acknowledgements

We would like to acknowledge FloodControl-IJkdijk for providing a scientific research and development environment that was beneficial for the development of GeoRiskPortal. The development has been inspired by the Geo-Impuls programme in the Netherlands. Geo-Impuls is a five year long, joint industry programme which aims at reducing geotechnical failure substantially in 2015. Special thanks go out to our team of skilled programmers, test engineers and end users who were willing to give valuable feedback.

References


Leung, S. W., Mak, S., & Lee, B. L. (2008). Using a real-time integrated communication system to monitor the progress and quality of construction works. Automation in Construction, 17(6), 749-757.


