SWOT analysis Observational Method applications

Analyse FFOM à l'implémentation de la méthode observationnelle

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ABSTRACT: The paper analyses the strengths, weaknesses, opportunities and threats (SWOT) for the application of the Observational Method in civil engineering practice. International cases, many of which are well known in literature have been analysed along the lines of the SWOT methodology. A specific number of cases has been analysed, having typical Dutch conditions, to determine country specific aspects as well. This paper describes the evaluation of the cases. This results in conditions under which the application of the Observational Method is best suitable and conditions in which it is best to avoid the observational method.

RÉSUMÉ : Cet article présente les résultats d'analyses Forces, Faiblesses, Opportunités, Menaces (FFOM) effectuées pour appliquer la méthode observationnelle au domaine du génie civil. L'analyse FFOM est appliquée à des réalisations internationales, bien connues dans la littérature et pour lesquelles la méthode observationnelle a été mise en œuvre. Un certain nombre de cas est analysé sous les conditions néerlandaises, afin de déterminer les éléments spécifiques pour ce pays. Cet article décrit l'évaluation des cas. Les résultats de cette évaluation sont des situations dans laquelle l'application de la méthode observationnelle est la plus appropriée et des situations dans laquelle il est préférable d'éviter la méthode observationnelle.

KEYWORDS: Observational Method, SWOT, cases.

1 INTRODUCTION

The Observational Method (OM) can produce savings in cost and programme on engineering projects, without compromising safety, and can also benefit the geotechnical community by increasing scientific knowledge. In some countries the use of OM is common practice, see for example Britain with famous papers by Powderham (1994) and Patel et al. (2007) and the CIRIA report 185 (Nicholson et al., 1999) and France with the Irex-RGCU guideline by Allagnat (2005). In many other countries, such as The Netherlands, the method is used in specific cases only and/or more reluctantly. Many papers in literature have described procedures on implementing the OM such as Powderham and Nicholson (1996) and the guidelines mentioned above, but very little attention is usually paid to the conditions in which the OM is most adequate. With use of a SWOT analysis this papers aims to provide such an overview of hurdles and conditions.

This research is performed as part of "Geoimpuls" in the Netherlands; a joint industry programme, with the ambitious goal to half the occurrence of geotechnical failure in Dutch civil engineering projects by 2015. The measures proposed were clustered into five themes by Cools (2011): geo-engineering in contracts, implementing and sharing of existing knowledge and experience, quality of design and construction processes, new knowledge for Geo-Engineering in 2015 and managing expectations. The observational method is seen as a means to obtain robust en cost-effective projects based on measurements in combination with risk-based scenarios. The method provides projects with the possibility to benefit from uncertainties in soil conditions, which results in opportunities.

2 ANALYSIS OF CASE HISTORIES

The paper illustrates the results of a SWOT analysis based on various projects reported in case histories. The focus of this analysis is on the conditions in the projects that make them suitable for the application of the OM. By collecting these aspects, one can check whether for a new project the application of the OM may bring benefits. If this is the case, the authors of this paper wishes to refer to the use of Eurocode 7 and specific guidelines for the correct and optimal procedures. Those procedures are not part of this paper.

Geotechnical monitoring is an essential part of the Observational Method, and if used separately mostly aims to control the construction processes and design assumptions. As part of the OM monitoring is used for design purposes as well. If the monitoring shows that a design can/must be changed with less/more conservative assumptions this is foreseen in the OM. In the SWOT analysis monitoring is also considered, as it is part of the OM. Parts of the SWOT analysis can therefor be used for geotechnical monitoring.

It must be mentioned that for a true SWOT analysis the internal (Strength, Weaknesses) and the external (Opportunities and Threats) must be clearly distinguished. In the case of the application of the OM, this may not be so evident, especially if we consider the soil conditions. In this paper, the soil is considered an internal part of the project. Furthermore, the SWOT analysis focusses on the application of the OM from the start of the project ('ab initio') and not as the 'best way out', when unwanted events already have appeared.

Strengths (S)
Some project characteristics can be seen as strengths for the application of the OM. If the following characteristics exist, OM could be considered as a serious option. .

1. Multiple stages or parts in a project. Patel et al. (2007) suggest that for a good application of the OM it is necessary

to have some sort of a variation between parts or stages of the construction. This is essential to make it possible to learn from previous behaviour, which is the essence of the OM. Both projects that are multistage or that are executed according to an incremental construction process are suitable for application of the OM.
Multistage projects for example include a staged excavation or staged application of loads. These provide good possibilities for the OM. Subsequent stages of loading can be based on results measured in previous stages. Examples include the excavation after collapse of the Heathrow terminal described by Hitchcock (2003) and the raising of the embankment of the Betuweroute Cargo Rail on very soft soils as described in the Geotechnet report by Huybrechts (2000). Using the multi-stage construction process, reliability can be controlled by interpreting monitoring of the previous stages and by taking subsequent actions if necessary. Also excavations that progress in depth, for which the struts can be pre-stressed according to the rate of deformation, or when additional struts or soil nails can be installed depending on the deformations, may possess good characteristics for the use of the OM.
Another strength characteristic is present in projects with an *incremental construction process*. These projects are flexible in the speed with which they progress or consist of several steps. An example may be in NATM tunnelling work, or vibratory installation of (sheet) piles, where the rate of advancing can be controlled based on the monitoring results. Also projects with a long length (in similar soil conditions) for example line infrastructure projects such as roads and rail can provide a good basis for the OM, such as for example described for the Limehouse Link by Glass and Powderham (1994).
2. Short project duration in relation with beneficial short term behaviour of soil. In some cases short term soil behaviour may be a strength,, such as when the undrained strength of soils is larger than the drained strength and only short term loading conditions are applicable which have diminished before drainage takes place. Here also the NATM method could be mentioned.
3. Displacements as leading design characteristic. Projects where displacements govern the design are by nature often suitable for the use of the OM. Deformations can usually be monitored accurately and extensively and provide good indication of the mechanisms that have to be controlled. When deformations of adjacent buildings are important, projects can be suitable for the OM, but it must be mentioned that the possible measures and variations might be limited to a specific and tight range of acceptable expected impact, thus giving less space for its application. It can however be considered a strength in the sense of this SWOT if a project relates to existing structures or conditions that are difficult to assess, such as the stability of an existing embankment (Lee, 2012) or old existing structures with unknown response (Chapman and Green, 2004). The application of the OM in those cases might solve otherwise unknown response of the structure. In general projects where epistemic uncertainties, which originate from insufficient knowledge of a property, can be decreased by the use of monitoring might be suitable (Nossan, 2006).
4. Integrated responsibility for both design and construction. Cases where a strong connection exists between design and construction teams and in which good communication between parties is assured, have a strong case for the use of the OM. The OM works well with an alliance contract in which risks (and opportunities) are shared between client and contractor, see section 3 of this paper.
5. Flexible and risk based culture. It can also be considered a strength if the culture of each organization involved is open to some flexibility but also very strict with regard to risk management and monitoring. If staff members are sufficiently experienced and had proper training, preferably related to the use of the OM, this is a main benefit. A management commitment to implementing the OM approach at all levels is also an organizational strength.
6. High ground heterogeneity and or uncertainty in failure mechanism. In cases with high uncertainty a 'standard' (non OM) design approach forces the designer to make conservative design assumptions, leading to costs that possibly are not necessary and can be avoided. This leads to a potentially high cost differences between a 'standard' design and an OM design. It is the advantage of using the OM to justify a set of more favourable assumptions leading to a more cost effective design. This for instance can be the case when a decision needs to be made between a shallow foundation and a piled foundation, as has been experienced by GeoImpuls participants for a LNG terminal with high demands for dissimilar settlements, or in geological heterogeneous areas (for instance close to rivers).
Two combinations of variability are especially suitable for the OM. First, the soil strength or stiffness is not well known or has a large spread, but the load that will be presented is relatively well known (for example in NATM tunnels or deep excavations as described by Kamp (2003) or the railway example by Lee (2012). Secondly, if the opposite is the case and the load is relatively unknown but the soil strength is well known, for example in the case of deep foundations and embankments described by Peck (1969) and many others, the method could also work well. If both are known, or both are unknown, the OM is not suitable and this should be considered a threat.

Weaknesses
Opposite to the benefits are of course also weaknesses for the application of the OM. If any of the following characteristics exist, application of the OM may result in additional challenges or may not be suitable.
1. Too little time between measurements and measures. A major weakness exists if mechanisms involved in the project reveal themself quicker than measures can be implemented. In the case of brittle failure monitoring may not provide previous warning. Brittle failure is a no go for the OM, while late appearance may make application of the OM inefficient since savings of necessary reinforcements can not be decided early enough, such as described by (Korevaar, 2012). Examples are non-ductile failures of structural members such as struts/waling connections in multi-propped basements as described by Patel (2007) or the vertical equilibrium of deep excavations.
2. Measurements that cause failure. In some mechanisms, for example related to the pull out capacity of (micro)piles or anchors, monitoring would require failure of the system, which is not acceptable.
3. Failure mechanism/parameter can not be measured. It can also be problematic if the monitoring system is not able to capture the correct mechanism or relevant parameters. This is often the case as stiffness and strength of soils are only weakly correlated, meaning that deformation measurements do not always indicate a possible failure of the strength of a material.
4. Change of failure mechanism during construction. Other weaknesses could be that during the construction process, the failure mechanisms change, for example if shallow failures become deep failures, primary consolidation becomes creep etc.
5. Costs for changes during construction are higher than profits minus costs for monitoring. The use of OM inevitably requires usually costly continuous measurements that have to be taken, interpreted and analysed during construction. During the design more scenarios need to be calculated together with analysis of other cases/experiences in order to know what to expect. These costs needs to be balanced with

expected benefits. Also sometimes measures that might be needed as an outcome of OM are inefficient during construction. This for instance is described by (Schmitt and Schlosser, 2007) for the case of an excavation in Monaco where huge stays bearing on the bottom of the excavation would have caused major consequences for the completion time of the project.
Although it might seem that OM through this weakness is more beneficial in larger projects than in smaller, this not necessarily is the case. For example small embankments lend themselves often for the use of OM.

6. Communication between site and design office. Application of OM requires direct communication between site and design office, being responsible for direct analyses of the measurements. If these different cultures do not find each other easily in a project, this may cause delays in go – no go moments or even proceeding of the work on site without commitment of the design office. However, if communication is planned carefully it can even be considered a strength of OM that is brings design and construction close to each other. Projects where the culture is based on individual profit and loss opposed to mutual benefits, with extremely low bid or difficult market conditions are not suitable for the application of the OM.

Figure 1. Example project with application of OM in Amsterdam, Rokin Station

Opportunities
Opportunities for the use of the OM are present at projects with the following characteristics:

1. Presence of risks with low, but unacceptable a priori probability of exceedance and significant consequences. For the use of OM it is necessary that the full range of possible behaviour is assessed and that it is shown that there is an acceptable probability that the actual behaviour will be within the acceptable limits (Eurocode 7). OM is suitable if the probability is higher than acceptable for a standard design, but is small enough to still have a large chance of successfully completing the project without necessary measures. This also requires the consequences to be large enough to justify the additional costs. Examples can be the impact of vibratory installation of sheet pile nearby a pipeline or possible damage by vibrations to old monumental buildings during driving of piles. The vibrations will most likely be present, but the probability of exceedance might be low enough to use the OM, in order to avoid a priori costly measures in design.
2. Stakeholders. OM lends itself perfectly for good communication with stakeholders involved in the project. For instance a critical attitude of a project's neighbours can be addressed with a proper explanation of the project risks and the way the project is organized to react pro actively if risks seem to occur. It is shown at the North South Line in Amsterdam during the application of OM in the final excavation of Rokin Station that the stakeholders were reassured by the extensive risk based OM approach. Also the application of OM at the A2 Maastricht proved to be a very good way for communication with the stakeholder (Grote and van Dalen, 2012) The uncertainties related to the strength of the limestone and the subsequent response of the excavation wall, see Figure 2, made application of the OM suitable for a good communication strategy. However, it should also be mentioned here that miscommunication of the use of OM is a threat for the project, since it can easily be interpreted wrongly by stakeholders as a way of window-dressing a risky project.
3. Best way out. Although the authors of this paper think OM should be used 'ab initio', OM has proven many times to be a very good opportunity in case unwanted events are (nearly) happening, for instance observed from geotechnical monitoring. Because the original design already is 'in place' and can not easily be changed, an OM approach can still save the project.

Threats
Threats for the use of the OM are present at projects with the following characteristics:

1. Quickly changing loads. One of the major and most well known threats is the possibility of quickly changing loads (causing brittle failure) such as deterioration of soils caused by intrusion of groundwater. Also external loads such as rainfall induced ground water surges or burst water mains as well as the risk for liquefaction all are potential threats for the use of the OM.
2. Unwillingness of authorities. Another type of potential threat may be the willingness for authorities to allow the method, even though according to Eurocode 7, the method is now regulated. Use of OM almost inevitable requires efforts on communication with the authorities in order to explain what OM is, why it is used, and how is ensured that a safe and sound construction will take place. This especially is the case in countries with little experience with OM, such as the Netherlands.
3. Time restrictions. Making an OM design requires more effort in the design phase. If the design capacity is not adapted this may lead to a longer design period. Projects with high planning demands can therefor be impractical for the use of OM, especially if it is expected that OM will not lead to time savings during construction.
4. Calculation methods and tools do not always allow for proper use of OM, in this case related to the necessary inverse modelling. A large amount of data becomes available during construction and needs to be processed. For instance for settlement prediction software, modules exist in which fitting between model parameters and measurements can take place in order to make better forecasts for stages to come. However, for other mechanisms such as deformations of retaining walls or designs using finite element models this is not easily done. Many calculations may need to be performed in advance in order to use OM properly during the construction. This might lead to inefficient use of OM, causing high design costs or even (if mechanisms happen outside the design expectations) the fact that OM can not be used quickly enough during construction.

It can be concluded from all of the above SWOT conditions that the observational method is best suited for projects that are governed by the serviceability limit states. It is applicable, but less suited, for designs governed by the ultimate limit states with ductile behaviour, and it is unsuitable for the ultimate limit states if brittle behaviour takes place.

3 CONTRACTUAL ASPECTS

When discussing the possibilities of the Observational Method in geotechnical engineering, it becomes obvious that contract requirements should facilitate or, to say the least, should not obstruct its use. In The Netherlands projects are awarded based on the so called UAV (Uniform Administrative Conditions) or the UAV-gc (Uniform Administrative Conditions for integrated contracts). In contracts where the UAV-applies, the client is responsible for the design and the contractor is responsible for the execution of the works (Traditional contract). Since it is virtually impossible to make a design with the Observational Method without expert knowledge of construction methods, there are limitations to the use of the OM in this kind of contracts. Once the contract is awarded, for instance when a contractor is selected based on general conditions and unit prices, it is possible to change the design using the expertise of the contractor.

If the UAV-gc applies the contractor is responsible for both the design and the executions of the works (Design and Construct contract). All though the possibilities for the use of the OM as a design method are significantly greater than compared to the UAV type of contract, there are still a number of challenges to overcome. One of the main challenges is that in order to get the contract awarded, the contractor first has to be selected. Since the only award criterion that is deemed truly objectively is price, a problem arises in selecting the best offer for the works. The cost price resulting from a design based on OM will vary around the cost price of the most probable way of execution of the works. By nature of the method, it is impossible to submit such a price in a bid. In the Netherlands it was concluded that in order to use the OM as a design method from the start, it is strongly advised and beneficial to execute the project in an alliance between client and contractor.

In this kind of contract client and contractor share a common objective, for example the execution of the project in a safe and cost-effective manner with a minimised risk for the surroundings. All the unknowns in a project that is designed using the OM can be a shared responsibility. Both client and contractor will be fully involved in all decision making and will have an equal part in any additional costs or benefits. Part of the Betuwelijn Cargo Rail Line (Huybrechts, 2000) has been successfully constructed in this way. The challenge of selecting the most qualified contractor remains. One of the suggestions to overcome this challenge is to have a “beauty contest” and a known budget price for the total works. In this way the client is able to select a contractor based on value (best value procurement). Contractors are asked to present themselves not only with reference to the projects they carried out in the past (track record), but also with respect to the proposed method of cooperation with the client. The staff that the contractor wants to deploy for the project will be judged not only on their technical know-how, but also on their “soft skills”, since cooperation is the key-word in an alliance type of contract.

Over the last years several projects in the Netherlands have been awarded in this manner. For the OM to be used within such contracts, all other requirements for the successful use of the OM should also be fulfilled. However, an alliance type of contract comes close to the ideal contract framework that was described as being “utopia” in CIRIA Report 185 (Nicholson et al., 1999).

4 PROJECT ASPECTS

Some project examples are given in this section with their relative appropriateness to the use of the OM. It must be mentioned that each project should be considered in their specific settings, both physically and organizationally. In the examples, only the most common aspects have been considered.

For deep excavations the use of the OM is usually limited to the focus on the settlements in the surrounding structures or soil. In some cases, struts can be optimized but it may not always be possible to decide in time whether a strut layer actually can be omitted. If long cut and cover lengths are present, the subsequent sections may learn from earlier sections. Chapman describes several cases where the use of the OM was successful; whereas Karlsrud and Andresen (2008) state that the OM is not particularly suitable for deep excavations. It can be dangerous if sudden increases in water pressures may happen, accidents such as strut failure or unforeseen loads next to excavation happen. It is rather difficult to apply the OM to assure the vertical equilibrium of deep excavations, although this was actually done in Rokin station for the Amsterdam North South Line, as best way out, see Figure 1. Usually this aspect is considered as a potentially brittle behaviour, but in this specific case the behaviour was expected to be more ductile since the water carrying sand layer causing the possible uplift was very thin.

For deep foundations the method is usually difficult to apply because strength at failure often governs the design. There are however good examples that for the re-use of existing piles (Huybrechts, 2000) the OM shows some good possibilities. For TBM tunnelling the OM is often used to control the settlements, and for example not to design the tunnel lining, where standardization is always more efficient than optimization over shorter lengths. For NATM tunnelling the method is often mentioned and it should be possible if a safe base design is present. (Muir Wood, 1990) and (Kovari and Lunardi 2000) state however that the OM for NATM is actually not working in a correct way.

Embankments are usually well suited for the application of the OM. Examples are mainly related to settlement control and staged construction, but also include the control of stability (Lee, 2012). In a similar way especially suited for the OM seem projects where a surcharge is placed, a tank is filled or similar loading of soil with storage takes place. The flexible use of (pre)loading has proved very efficient in many cases.

Other types of projects suitable for the application of the OM are pipelines when deformation limits are very strict, because the allowable values are difficult to assess in design. Environmental projects (contaminated sites) have been presented by Morgenstern (1994) and drainage works by (Roberts and Preene, 1994).

Very simple structures (‘in the backyard’) are usually not suitable for the OM, because the costs of the additional monitoring are often larger than the benefits for the project.

In all types of projects where buildings are present at short distance, the method may be beneficial because they can be strictly monitored. On the other hand, much more flexibility in the system is present if no such buildings/structures are present. Usually in dealing with stringent deformation limits it is necessary to have a more robust design, which reduces the effectiveness of the use of OM.

5 CONCLUSIONS

Conclusions in this paper are given in the form of Go/No Go items for clients and project initiators, as well as designers in a very early stage of the project, to determine whether or not the OM could be a wise approach in their specific project, given the specific circumstances. These Go/No Go items are listed by importance, based on the opinion of the authors. Some issues form the Go/No Go list may be given facts for a project, some may be project choices that may benefit (or contradict) the use of the OM. Some items should be taken merely as reminders of how to organize the project most efficiently. These items are labelled in the third category ‘To overcome’.

Go:

- Multistage projects and/or projects with an incremental construction process.
- Presence of risks with low, but unacceptable a priori probability of exceedance and significant consequences.

- Integrated responsibility for both design and construction.
- High ground heterogeneity and/or uncertainty in failure mechanism.
- Displacements as leading design characteristic.
- Short project duration in relation with beneficial short term behaviour of soil.
- Flexible and risk based culture.
- Critical attitude of stakeholders related to the project.
- Best way out.

No go:
- Too little time between measurements and measures.
- Quickly changing loads.
- Failure mechanism/parameter is not measurable.
- Change of failure mechanism during construction.
- Measurements only useful after failure.
- Costs for changes during construction are higher than benefits minus costs for monitoring.

To be overcome:
- Communication between site and design office.
- Unwillingness of authorities.
- Time restrictions.
- Calculation methods do not always allow easy use of OM.

Figure 2. Application of OM in Maastricht for A2Maastricht tunnel (photo Reen van Beek)

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7 REFERENCES

Allagnat, D. (editor). 2005. *La Méthode observationnelle pour le dimensionnement interactif des ouvrages*. (The observational method for the interactive design of structures). Guide Technique, Presses de l'ENPC

Chapman, T. and Green, G. 2004. Observational method looks set to cut city building costs. *Proceedings of ICE Civil Engineering* 157, 125–133 Paper 13416

Cools, P.M.C.B.M. 2011. The Geo-Impuls Programme reducing geotechnical failure in the Netherlands. *ISGSR 2011* in Vogt, Schuppener, Straub & Bräu eds Bundesanstalt für Wasserbau

Glass, P.R. and Powderham, A.J. 1994. Application of the observational method at Limehouse Link. *Geotechnique* 44, No. 4, 665-679.

Grote, B.J.H. and van Dalen, J.H. 2012. Onzeker kalksteen in grip met Observational Method, *Land + Water*, 12

Hitchcock, A. 2003. Elimination of temporary propping using the observational method on the Heathrow airside road tunnel project. *Ground Engineering Magazine*. Vol. 36, No. 5, 30-33

Huybrechts, N. 2000. Design Tools in Geotechnics – Observational Method and Finite Element Method. *GeoTechNet Project GTC2-2000-33033, WP3: Innovation*

Kamp, R.A.J. van de. 2003. *Observatiemethode voor diepe bouwputten* (In Dutch). MSc. Thesis Delft University of Technology

Karlsrud, K. and Andresen, L. 2008. Design and performance of deep excavations in soft clays. *6th international conference on case histories in geotechnical engineering*, Arlington, VA. Paper No 12.

Korevaar, M. 2012. *De Observational Method, Onderzoek naar een veilige toepassing van deze methode voor bouwkuipen* (In Dutch). MSc. Thesis Delft University of Technology

Kovári, K. and Lunardi, P. 2000. On the observational method in tunnelling. *Proceedings of the GeoEng 2000: an International Conference on Geotechnical & Geological Engineering*, 19-24 november, 2000. Vol. 1, 692-707, Melbourne, Australia.

Lee, S. 2012. Application of the observational method for railway earthwork stabilisation in the UK. *Presentation DGF Geoteknisk monitering og observationsmetoden, Kopenhagen*.

Morgenstern, N. R. 1994. The observational method in environmental geotechnics. In: *Proc. of 1st International Conference on Environmental Geotechnics. Edmonton*, 965-976.

Muir Wood, A. 1990. The observational method revisited. In: *Proceedings of the 10th Southeast Asian Geotechnical Conference*, Taipei, 2, 37-42.

Nicholson, D., Tse C.-M., Penny, C. 1999. *The Observational Method in ground engineering: principles and applications*. CIRIA, London, Report 185.

Nossan, A.S. 2006. Observations on the Observational Method. *XIII. Danube-European Conference on Geotechnical Engineering.* Logar, J., Gaberc, A., Majes, B. (ed). - Ljubljana : Slovenian Geotechnical Society. 171-178

Patel, D., Nicholson, D., Huybrechts, N. and Maertens, J. 2007. The Observational Method in Geotechnics. *Proceedings of the 14th ECSMGE:* Madrid, Spain. Vol. 2, 365-370.

Peck, R. B. 1969. Advantages and limitations of the observational method in applied soil mechanics. *Géotechnique*, 19 2, 171-187.

Powderham, A. J. 1994. An overview of the observational method: development in cut and cover bored tunnelling projects. *Géotechnique* 44 (4), 619-636.

Powderham, A.J. and Nicholson, D.P. 1996. *The Observational method in geotechnical engineering*. ICE, Thomas Telford, London.

Roberts, T.O.L. and Preene, M. 1994. The design of groundwater systems using the observational method. *Géotechnique* 44 (4), 727-734.

Schmitt, P. and Schlosser, F. 2007. La méthode observationnelle : du suivi géotechnique au dimensionnement interactif (in French)*).* *Travaux* (Paris) Y. 2007, No. 844, 99-106