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Underpinning the Observational Method through Process Modelling and Procurement

Jason LE MASURIER, PhD, CEng, MICE
Consultant, Observationalmethod.com, UK

Abstract. Geotechnical engineering designs are often predefined before construction commences, in an attempt to eliminate uncertainty. Such predefined design can lead to poor value, either due to waste of resources from over design, when opportunities are missed for optimising the design during construction, or due to the delay and additional cost of dealing with unforeseen ground conditions. The Observational Method (OM) provides an alternative design approach, to proactively manage the uncertainty associated with ground conditions, using a flexible design that is able to be adapted to suit the actual conditions found during construction. Feedback from observations and monitoring allows the designer to maximise the opportunities and minimise the risks. Case studies of applications of this approach are presented to demonstrate the significant benefits that have been derived from managing geotechnical uncertainty in this way. The OM relies on the integration of construction processes and teams, best achieved through a collaborative style of management, rather than under the types of relationship formed under traditional fragmented procurement processes. A synopsis is given of the influence of procurement options on the implementation of the OM. A danger with collaborative approaches to project delivery is that responsibilities are not clearly defined. An example where failure in the management of the process led to a tunnel collapsing during construction is used to illustrate the importance of designing the process and clearly defining responsibilities in a project team that chooses to use an OM design. A process modelling methodology is described which facilitates the definition and mutual understanding of processes and responsibilities in a project team, thus ensuring robustness in the OM process. A further practical example is given of an application of this methodology within a project team using the OM for a deep basement construction.

Keywords. Observational-Method Uncertainty Management Process-models Procurement

1. Introduction

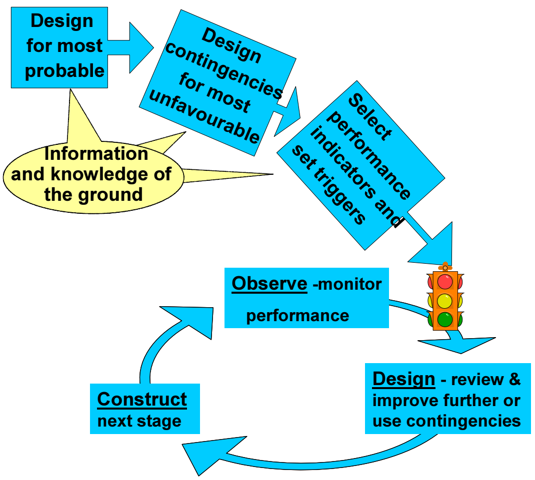

Figure 1. A model of the Observational Method process

The Observational Method (OM), as first described by Peck (1969), provides an alternative to the predefined design approach. A model of the OM process is shown in Figure 1. Designs are developed for the full range of conditions likely to be encountered, based on knowledge of the ground, including design for the most probable conditions and design of contingencies for the most unfavourable conditions. During construction a thorough monitoring and observation strategy is essential in order to check and confirm the actual conditions, with performance indicators selected to represent the areas of greatest uncertainty, for example settlement. Trigger values on the performance indicators (represented by traffic lights) will determine the response to the observed values which could be to use contingencies or to improve the efficiency of construction if more favourable ground conditions are encountered. This process clearly requires coordination and co-operation between all those involved in the design and construction process.

The traditional separation of the design phase from the construction phase encourages the designer to use the predefined design approach, since there is no commitment to ongoing integration of design and construction processes, as required by the OM. A predefined design is also common when there is unwillingness to invest in the design, i.e. if a designer has been selected based partly on lowest price the cheapest option for the designer is to produce a conservative predefined design.

Over the past 20 years there has been a trend in the construction industry towards more collaboration and integration of processes and teams, in particular the integration of design and construction, through new methods of procurement. This trend started with design and build (D&B) contracts in the early 1990s and was followed by partnering and alliancing in the 1990s. Other developments include early contractor involvement (ECI), integrated project delivery (IPD) and the increasing interest in Building Information Modelling (BIM) since the start of this century.

The following examples of integrated design and construction from the 1990s demonstrate how such procurement can promote the use of the OM.

2. Case Studies

2.1. M6DBFO

The final section of the M6 motorway between central Scotland and the border with England was constructed under a Design, Build Finance and Operate (DBFO) contract. On this project one party was responsible for design, construction and first 20 years of operation and maintenance of the road. Under these circumstances the OM became viable and was used extensively on the project, as described by Everton and Gellatly (1998). Applications of the OM included design of a soil nailing solution for a 1.2 km cutting through soil and rock and excavation and backfilling of an extensive area of peat adjacent to a principal railway. The OM was also used as a novel long term contingency, to manage potential settlement of a bridge bank-seat over the 20 year operation concession. A process of learning and continuous improvement was made possible by close collaboration between the construction team and their designers, facilitated by the DBFO procurement route.

2.2. Hong Kong airport platform

The Hong Kong International Airport was constructed on a platform largely reclaimed from the sea. The finished platform included various types of in-situ and fill materials which will undergo varying amounts of settlement throughout the airport's life. During the initial designs for the airport buildings and facilities, each of the designers made settlement predictions for their own part of the airport which were often incompatible with adjacent facilities. The Airport Authority realized that contractors for the construction works would include contingency sums in their tenders to allow for uncertainty over settlement. To overcome the resulting potential for a significant increase in construction costs, the Airport Authority modified the proposed contract conditions that would otherwise have put settlement risks on to the contractors and took it upon themselves to integrate the settlement design considerations with the construction phase using an OM approach, known as the 'installation levels procedure'. This gave the Airport Authority confidence in the performance of the reclamation and provided reassurance to all stakeholders (Covil and Pickles, 1998).

3. Requirement for process design

The case study examples clearly illustrate the importance of integration of project processes and teams, however a danger with collaborative approaches to project delivery is that responsibilities are not as clearly defined or understood as they are under familiar, traditional relationships. Under such circumstances uncertainty in a process can lead to confusion of responsibilities and unsafe operational practices. The danger is clearly illustrated by the Heathrow Express (HEX) project which suffered a tunnel collapse during construction in 1994. The tunnel construction was attempting to use the 'New Austrian Tunnelling Method' (NATM) which is a variant of the OM and is a very efficient tunnel construction technique when applied successfully. NATM is however a complex process to manage and relies on complete integration of the design and construction processes. Despite the knowledge gained on the ground prior to construction, including a full scale trial tunnel, and the ongoing monitoring and analysis during the main tunnelling works, a collapse of the tunnels occurred. This was not due to poor understanding of the ground variability or information on its response to the construction (subsequent analysis of the monitoring data indicated that a developing collapse could have been foreseen several weeks before it occurred), but the problem lay instead in the *'cultural mind-set (that) focussed attention on the apparent economies rather than the particular risks'* (Health and Safety Executive, 2000). In the HSE enquiry the NATM design was vindicated, however failure of the managerial process was highlighted as follows:

'There were undoubtedly human errors; but these were merely a consequence of foreseeable cultural, organisational and management failures. The causes of the incident were rooted in failures in 'defensive' systems (i.e. preventative management systems) that did not adequately deal with hazard identification, risk avoidance and reduction and the control of the remaining residual risks. There was organisational blindness to the possibility of collapse. As a consequence, human failures were not readily identified and corrected; and mistakes in decision-making were more likely.' (HSE, 2000). Procurement of HEX used the NEC contract and contractor self-certification which were new and unfamiliar to the project participants.

HEX illustrates the need for clarity over roles and responsibilities when using integrated design methods such as NATM and the OM. Such clarity can be facilitated by the team collaboratively designing the processes, to ensure that each party understands their role. The process design can be represented in process models. Several examples of such models are given in Nicholson et al (1999), which substantiates their value in OM. It is surprising therefore that here is no established procedure for the production and use of process models as part of the overall OM design, when it is clear that definition and understanding of processes and roles and their interactions by all players, is crucial for the successful implementation of OM designs. The types of process model that can aid this understanding and a procedure for their production were investigated by Le Masurier (2001). In conjunction with building information modelling (BIM) it is proposed that through facilitated workshops a project team should collaboratively develop a model of the process for implementing an OM design. i.e. designing the project processes, in conjunction with designing the 'product' (which is the traditional focus of design). This approach concurs with 'Management by design' proposed by Muir Wood (2000) whereby design emphasises: '*the essential interaction between product design (the design of the finished product and its operation) and process design (the design of construction and its means).*' There are no specific recommendations for the process design, since like the product the process will be different in each different project. The key point is that the process should be proactively designed and not left to chance (or reactive management if the process fails). The process models so produced by the team should be dynamic i.e. continuously reviewed and updated, in the same way that the model of the ground conditions and the design of the works are updated, based on feedback from the enacted processes. This procedure is described in more detail in Le Masurier et al, (2006), together with a proposed extension of the OM principles to the management of uncertainties more broadly, including management of human behavioral uncertainties of the type that contributed to the collapse of the HEX tunnels.

Apart from the promotion of collaborative working, BIM offers further assistance to applications of OM, through the sharing and updating of all ground related data throughout the life of a project, the importance of which is illustrated in Figure 1.

4. Process design in practice

To test the proposed process modelling methodology, the author was seconded to the project team for an OM design application, selected for a deep basement construction project in the City of London, as described in Chapman and Green (2004).

With regard to the procurement route on this project it is interesting to note that the designers

(Arup) were first employed by the client to develop the complete structural and geotechnical design. At this initial stage, without a guarantee of their continuing involvement, the design team was obliged to produce a traditional predefined design based on standard conservative soil parameters. However, after award of the construction contract the main contractor (HBG) employed Arup Geotechnics independently as geotechnical designer. At this point, with an assured ongoing involvement in the construction phase and with their good understanding of the ground conditions and structure, Arup Geotechnics identified an OM opportunity and working with the contractors were able to develop a design resulting in an alternative construction sequence, involving fewer separate stages of excavation and slab construction than in the predefined design, thus providing cost and time savings. Arup Geotechnics carried out the design and produced a comprehensive report covering all aspects of the OM; in particular this included design of the construction processes. Through regular meetings between engineers from Arup Geotechnics, HBG and the excavation and structural sub-contractors, design of the construction process evolved to suit the requirements of all parties. Once all parties understood the OM design process, the whole team participated in developing the monitoring and contingency plans for each stage of the construction sequence, the definition and allocation of roles and responsibilities and the ongoing improvement of the construction sequence through design modifications. A key component of the process design was a process model. A preliminary process model for the project was based on a generic model developed by Le Masurier (2001). The model included process interaction charts and role interaction charts, details of which are given in Chapman and Green (2004).

The construction team members refined this model at project review meetings, where the various models and charts proved useful in dialogue within the construction team, to agree on the allocation of roles and responsibilities. Several iterations were made to identify and name process owners and other roles and define responsibilities.

A process interaction chart was developed as shown in Figure 2. This shows the key processes associated with construction control. Column headings denote the process owners (parties responsible) for each of the processes in the columns below. Associated with each of the key monitoring processes, roles and associated responsibilities were defined and negotiated.

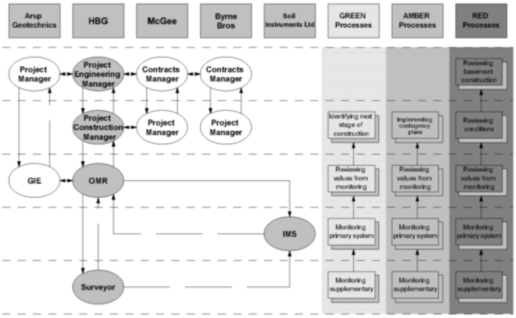

Figure 2. Role interaction model of the OM process (GIE, OMR and IMS are abbreviations for various roles responsible for monitoring and review).

5. Conclusions

Case studies show the OM provides significant benefits over the more common predefined design approach to manage geotechnical uncertainty. The use of an OM design is facilitated by a procurement approach that integrates the design and construction processes. When an integrated, collaborative approach is adopted it is essential to ensure that roles and responsibilities are clearly defined. This is particularly important if working under a novel procurement route, as was the case in procurement of HEX and is currently the case on many projects when participants may be unfamiliar with working in the integrated manner promoted through BIM procurement. Clarity leads to mutual understanding which reduces the likelihood of confusion or disputes. The basis of a process modelling methodology has been presented which allows a team to collaboratively design the processes alongside BIM and define the roles for implementing an OM design.

The increasing trend towards collaborative working and BIM means conditions for OM design are becoming more conducive, and applications of OM in ground engineering would be expected to increase.

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