Review of submitted contributions to Discussion Session 1.2

Revue des contributions pour la Séance de Discussion 1.2

Antun Szavits Nossan
University of Zagreb, Zagreb, Croatia

ABSTRACT
A review of contributing papers to Discussion Session 1.2. „Proactive foundation design. Observational method in urban areas“ is presented after some brief comments on the Observational Method.

RÉSUMÉ
La revue des articles pour la Séance de Discussion 1.2 „Conception proactive des fondations. Méthode observationnelle“ est présentée après les commentaires brefs sur la Méthode observationnelle.

Keywords: proactive design, foundations, observational method, urban areas

1 COMMENTS ON THE OBSERVATIONAL METHOD

Conventional geotechnical design of a structure, or more generally of civil engineering works, is usually finalized prior to commencement of construction activities. It is based on inevitably more or less limited knowledge of soil conditions and resistances characterized by various ground uncertainties. To deal with these uncertainties, the geotechnical engineer must identify risks and establish bounds on possible ground behaviour for which he can design a sufficiently safe and economical structure. The greater the risk the more conservative design is to be expected. In dealing with ground related risks, the engineer may be guided by codes which try to establish, usually indirectly, acceptable risk levels.

Due to various uncertainties in natural ground conditions conventional design is based on conservative interpretation of available ground data. In this approach monitoring and observations during the construction process may be provided but only as a means to verify the assumptions about ground conditions made in the design and to check that the structural behaviour is within the acceptable limits predicted by design calculations. A possible better knowledge of ground conditions acquired by observations during construction is not used to adapt a less conservative design. If unexpected ground conditions are found, or if the actual structural behaviour falls outside acceptable limits, an emergency situation occurs which requires actions usually not provided for in the design. To avoid such unwanted situation designers adopt conservative design assumptions.

With respect to ground behaviour and soil-structure interaction, every construction process is an experiment at a one-to-one scale. By proper observations and monitoring much valuable insight into ground and soil-structure behaviour may be gained during construction in excess of that acquired during the ground investigation at the preconstruction design phase. In some situations these knowledge may be adopted to arrive at a more economical or safer design and construction process. Such course of actions is usually known as the Observational Method.

The Observational Method has developed from the need to avoid highly conservative assumptions about ground properties in geotechnical design when faced with unavoidable uncertainties of natural ground conditions. The learn-as-you-go approach, as opposed to the conventional learn-then-go approach, was used more intuitively than formally by many engineers in the past but was recognized by Terzaghi (Terzaghi and Peck 1967) as the observational procedure. The method's formal ingredients and name were laid down by Peck in his Rankine lecture (Peck 1969).

The success of Terzaghi's approach, and particularly its formalization by Peck, drew much attention by the geotechnical community. A whole range of opinions emerged, from the one that the method is an element of a geotechnical assurance and safety system; to the one that it allows for less intensive site investigations, up to the view that it stimulates introduction of innovations and that it is one of the most powerful weapons in the civil engineering arsenal. And more importantly, starting with a more optimistic initial design, as Peck proposed, and then changing it during construction if adverse circumstances occur, may tend to create concerns about safety and this, according to Powderham (1998), may inappropriately be associated with uncomfortably low safety margins which have discouraged a wider use of the method. Powderham (1998) in addressing this issue developed the method further by advocating a more conservative initial design which is than progressively modified in small and well controllable steps as more data and their trends become available by observations during construction, most probably in the direction of saving costs rather than introducing very unpopular contingency measures, keeping or even decreasing agreed risk levels. For various aspects of the Observational Method and for an extended bibliography the work of Nicholson et al. (1999) can be consulted.

It seems that most ambiguities, disputes and opposing opinions about the ingredients and proper use of the Observational Method may be resolved if one recognizes that geotechnical design is generally based on the available knowledge of ground conditions and on agreed risk levels. The later are usually given indirectly in codes, as e.g. in Eurocode 7 by introduction of characteristic values of ground parameters and material partial factors related to ultimate limit states. When knowledge of ground behaviour or soil-structure interaction becomes less uncertain, as may be the case during construction due to proper interpretation of observational data, design may be changed but only to the extent allowed by the new knowledge, provided there is sufficient time and means to change the construction process. This setting of the Observational Method into the context of general design requirements then gives proper perspective for the Powderham's proposal of a more conservative initial design which may be progressively adapted during construction in small and well controllable steps as observational data became available. Observational Method is then nothing more than a properly planed continuation of the design process into the construction phase driven by newly acquired, possibly more precise, knowledge of ground conditions through observations and monitoring during construction to the extent allowed by new knowledge, available means, time, agreed risk levels and contractual constraints (Szavits-Nossan 2006). Since changing design in midst of construction strains all parties involved as well as imposes additional costs, implementing the Observational Method in design makes sense only if sufficient benefits are anticipated and if possible bounds of ground conditions are well understood and can be dealt with economically during construction. In addition, a beneficial side effect of adopting the Observational Method in the initial design, as opposed to conventional design, may be a greater preparedness during construction for unexpected ground conditions and for timely application of Peck's best-way-out procedure (Peck 1969).

This perspective on the Observational Method will be adopted in reviewing papers submitted to this session of the Conference.

2 REVIEW OF SUBMITED CONTRIBUTIONS

There were 19 contributions submitted to the Session. Authors came from 16 countries: China, Belgium, Denmark, Finland, France, Greece, Germany, Hungary, Italy, Ireland, Netherlands, Poland, Russia, Slovakia, Sweden, UK and USA. Some contribution are directly related to the use of the Observational Method in foundation design in urban areas while others deal with other aspects of foundation design. The review follows by alphabetical order of the first author with the paper title in brackets.

Barounis, Orr, Barrounis and Nerantzis (Modulus of subgrade reaction for foundations on clay from consolidation tests) propose a method to derive the modulus of subgrade reaction, k (kN/m^3) for soil-structure interaction calculations for structures with shallow foundations. They derive k from the oedometer modulus, E_{oed} (kN/m2) by adjusting k_{oed} (kN/m^3) = $a\ E_{oed}$ for foundation width and length, a (m^{-1}) being a correlation constant. The modulus k_{oed} was calculated as the ratio of vertical effective stress and specimen settlement in an oedometer test. By these definitions a appears merely to be the reciprocal of the oedometer sample height and not a material parameter. Furthermore, authors use a constant k in their example soil-structure calculations which may grossly err on unsafe side, particularly for raft foundations. If used in soil-structure interaction calculations, k should reflect not only soil stiffness but also contact pressure distribution p between the foundation and the ground as well as the foundation settlement s in the usual form of $k = p/s$. Modulus k is then not constant along the foundation-ground interface. An iterative calculation scheme for soil-structure interaction analysis would be much better suited with the first iteration often been sufficient for routine applications.

D'Onza, d'Onofrio and Mancuso (Study of the effects of soil suction on the unsaturated soil behaviour and its importance on seismic response) present interesting data on the influence of suction on small shear strain shear stiffness and damping ratio of unsaturated clayey silts compacted at Proctor optimum water content, as measured in RC tests, as well as a parametric study of the influence of suction in a soil profile on acceleration and frequency amplification under seismic excitation. It is clearly shown that the unsaturated soil state and particularly the resulting suction profile has considerable influence on response of soil deposits under seismic loading. Suction influences the response by increasing soil stiffness and decreasing soil damping.

England (World record bi-directional load testing of CFA piles) presents very interesting results on bi-directional testing of Continuous Flight Auger piles by use of single, and in one case, double Osterberg cells. Mobilized loads reached were up to 46 MN for 900 mm pile diameter and 36 m pile length in soft rock formations of SE Florida. Details of O-cell installation are presented. O-cell testing, being much cheaper than conventional pile load tests, greatly facilitates wider use of large diameter and large load capacity CFA piles.

Fernie, Pedley, Vaziri and Hartlib (Movement Prediction and Control of a major construction site on the South Bank – London) present an interesting and complex case history of a major underground basement construction site where tender typically required an absolute lateral movement control limit of 20 mm on the wall. This limit was found too restrictive and mostly meaningless since a major part of measured movements come from sources other than that predicted from excavation. A control manual with predicted wall movements was produced and amber and red trigger values defined. An array of instrumentation controls was installed. Observational Method was used to control excavation and wall propping. Clear cooperation of all parties involved are emphasized. Unfortunately, limited space available makes the presentation condensed and sometimes hard to follow.

Gaszyński and Gwóźdź–Lasoń (FEM Analysis of Reinforced Subsoil Under Shopping Centre) present a case history employing large number of vibro replacement gravel piles to improve foundation soil, consisting mostly of soft clay and mud, beneath a shopping centre structure. Prediction of settlements and bearing capacities were performed by FEM using elasto-plastic soil models. Analysis was calibrated to a load test experiment of limited extent. Insufficient data were given to asses predictive capabilities of the method.

Kellezi, Denver, Kudsk, and Stadsgaard (FE skirted footings analyses for combined loads and layered soil profile) present 2D and 3D finite element analyses of bearing capacity of skirted footings on layered soils encountered in offshore industry when subjected to combined vertical, horizontal and moment loads. The soil model used was of a simple linear elastic – ideally plastic (Mohr-Coulomb) type. The analyses demonstrate that complex 2D and 3D foundation problems can be successfully solved by available commercial software.

Kempfert and Becker (Empirical axial resistances of driven sheet piles) present a statistical analysis of measured axial resistances of driven piles from a large number of pile load tests. Pile tip and pile shaft resistances are correlated to cone penetration data from CPT tests. About 1000 pile load test results were analysed. Adjustments were developed for sheet piles. Derived data are presented with several confidence levels. Results may be very useful for soils where CPT tests can be performed.

Korff, van Tol and de Jong (Risks related to CFA- Pile walls) present a simple risk analysis related to possible water leaking problems with various types of Continuous Flight Auger pile walls in clayey and sandy soils, particularly with high ground water levels. This risk analysis led to a decision making tree for selection of the most appropriate wall type. The analysis proved very useful in reducing costly remediation works for water leakage and related problems.

Mahler (Settlement prediction of CFA piles based on CPTu results) presents an analysis of bearing capacities and settlements of CFA piles and correlated them with CPT data taken at 23 test sites with different ground conditions. Pile base and pile shaft resistances were obtained and related to pile settlements which facilitates predictions of pile load-settlement curves.

O'Brien (Raising the 133 m High Triumphal Arch at the New Wembley Stadium, Risk Management via the Observational Method) describes the application of the Observational Method to pile group behaviour. The application of the Observational Method to pile behaviour is unusual and thus the presented case history shows how the Method can be successfully extended even into this new area. The Method has primarily been used to control eventual overstress of piles in pile group foundations carrying the arch bases, jacking bases and turning strut bases used in the complex mechanism of lifting the arch with a 315 m span and 133 m height. Precise displacement and rotation measurements were taken and amber and red trigger values for employing contingency measures were determined. The operation presents a marvel in precision rare in geotechnical engineering.

Patel, Nicholson, Huybrechts and Maertens (The Observational Method in Geotechnics) present a study on the Observational Method, its principal features and operational details, as well as shortcomings of its coverage in Eurocode 7. The presentation is based on a detailed study carried out under GeoTechNet, a European funded geotechnical forum which maintains a web site with several case histories employing Observational Method. The paper elaborates on the differences between original Peck's approach (starting construction with a design based on most probable ground conditions) and the approach advocated by Nicholson et. al. (1999), and earlier by Powderham (1998) who advocate to start construction with a more conservative design. As stated in the introduction to this review, setting the Observational Method under the context of general design requirements may clarify the issue. The paper is otherwise a useful overview of the Method.

Pedley, Fernie, Cabarkapa, St John and Daynes (Design & construction of high capacity large diameter bearing piles for top down construction in the London basin) present an interesting case history of design and construction of large diameter bored piles for top down construction of a basement of a high rise building in London. The construction is related to contribution (4) in this Session. Predicted tensile strains in piles due to ground heave during excavation compared well to strains measured by optical fibres. Predictions were based on well established soil stiffness profile.

Popsuenko and Zaitsev (Application of the impact-free piling technique during construction of exhibition pavilion «Expocenter» in constraint urban environment in Moscow) present an analysis of pre cast piles driven by static force. The analysis is based on less known Russian code and Russian references and is difficult to follow.

Ravishankar (Time Dependent Behaviour of Pile Capacity and Pile Penetration Resistance) addresses the soil set up after pile driving leading to an increase of pile bearing capacity with time. Fifteen 12 to 19 m long tapered test piles were driven into a soil deposit fill, peat and soft clay underlain by coarse to fine sand and clayey silt. Pile capacities were analyzed by pile driving analyzer (PDA) immediately during driving and one to four days after initial driving. Bearing capacity increased by 15 % to 95 % generally increasing with time. The increase was attributed to consolidation of pore pressures.

Robert, Moreau, Lavisse and Schmitt (Deep excavation in a sloping urban site of Monaco: the contribution of the interactive design method) present a case history of a deep excavation secured by an anchored Berlin wall. Wall displacements were predicted in design and monitored during construction. Trigger values of displacements (absolute and differential) were established. Contingency measures were prepared in case measured values would exceed trigger ones.

Ryhänen, Ylönen, Luomala, Kolisoja, Mäkelä and Halkola (Continuous Ground Movement Measurements) describe the design and use of a automatic multi-sensor inclinometer for measuring ground movements. The instrument works automatically and sends data to the Internet server. There data can be presented graphically and also alarm limits can be set. The accuracy of the instrument is about 2 mm/m.

Smith, Bengtsson and Holm (Three-dimensional numerical analyses of a full-scale instrumented railway embankment) present 3D numerical analyses of stress distribution and displacements in a railway embankment under dynamic loads of high velocity trains. The results were compared with published data from pressure cells installed in a railway test embankment. The study shows good agreement between numerically obtained pressures and those measured in the field. Some general conclusions about the influence of train velocity were drawn.

Turček and Súľovská (Using the observation method for foundation of high-rise building) present an settlement analysis of the foundation of a high rise building. Predicted deformations were compared to values measured beneath the foundation. Not sufficient details were given to comment the quality of predictions. It is, however, to be emphasized that Observational Method in usual sense was not used.

Venmans and Lehnen-de Rooij (Decision support systems: success or failure?) describe the development of interesting decision support systems for the construction of local roads on soft soils. It was shown that the success of both systems depends on recognizing user needs, participation of involved parties, establishment of Communities of Practice to keep the participants involved and availability of specific supporting computer applications accessible for non expert users through www.

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