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The synergy between theory and practice in geo-engineering

La synergie entre théorie et pratique dans "geo-engineering"

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ABSTRACT

Abstract text GeoBrain is a facility at GeoDelft with the purpose to provide society with all relevant geo-engineering knowledge and experience in a structured way. On the basis of the available knowledge and experience engineers, decision makers and construction supervisors can come to a fast, reproducible and objective choice, taking into account the consequences. The paper presents examples from the GeoBrain experience databases and forecasting models developed for foundation engineering and directional drilling, or: "GeoBrain Foundations" and "GeoBrain Drilling".

Brain is closing the gap between theory and practice. It is aimed directly at reducing uncertainty and the costs of failure, thereby ining the quality of profession and minimising the risk in geo-engineering works.

RÉSUMÉ

GeoBrain est un équipement de GeoDelft, qui pourvoit la société des connaissances importantes et de l'expérience structurée de 'geo-engeneering'. Avec la connaissance et l'expérience disponible des ingénieurs, décideurs et contremaîtres peuvent prendre des décisions rapides, renouvelables et objectives, tenants compte des conséquences.

Cet essai présente des examples des bases de donnés d'expérience et des modèles de prévision de GeoBrain, développés pour la création des fondations et le forage directionel, soit : 'GeoBrain Foundations' et 'GeoBrain Drilling'.

GeoBrain réunit la théorie et la pratique. Il cherche à atteindre la réduction de l'incertitude et du coût de l'échec, en outre augmentant la qualité du profession et réduisant le risk aux projets 'geo-engeneering'.

1 FOUNDATIONS AND DRILLING TECHNOLOGY

In current engineering practice, the reliability of proposed foundation solutions such as sheet piles, prefab concrete piles, steel tubes and other kinds of foundation elements, in drilling projects horizontal directional drillings and micro-tunnels is disappointing. Often sheet piles do not reach their planned depth or run out of their locks. Similarly, theoretical prediction of ground movements and performance using mathematical and computational models is generally poor. The consequences for many works are very serious, leading to cost and time overruns. This lack of reliability has caused loss of confidence in the profession and damaged the image of the construction sector.

The causes are largely in the considerable gap between theory and practice in geo-engineering. Many factors such as the length of the foundation element, the characteristics of the chosen element, the type of equipment used and the soil affect the performance. The skill and experience of the operatives on site and the designers also play an important role. Although from calculation results the outcome may be positive concerning the stability and bearing capacity of the construction, the buildability of the proposed design is often not taken into account. Similarly, ground movements in practice may be excessive or adverse compared to those theoretical predicted affecting surrounding utilities and structures.

This gap stems from the fact that there has been, hitherto no possibility of systematic learning from case histories of completed projects. Practicing engineers have, from time to time, proposed ad-hoc rules and equations based on experience and field observations but no unified framework of disseminating has been available to engineers till now. In recent years, the development of the tools of computational intelligence such as fuzzy logic and artificial neural networks etc. make it possible for engineers to analyze field or 'monitored' data of construction and truly apply 'observational' methods as recommended by various codes of practice. Up to now geotechnical institutes and engineers have concentrated on the development of computational and analytical models (equations) to simulate the observations of engineering practice with limited success. GeoBrain aims at bringing the vast experience on various aspects of foundation construction together and make it available to design and practicing engineers in the form of readily usable tools for closing the gap between theory and practice.

2 OBJECTIVES OF GEOBRAIN

The general objectives are to decrease risk in construction projects, reduce losses, improve the image of contractors and geo-engineers, improve working conditions, ensure completion of these projects without unforeseen delays and last but not least the reduction of insurance fees. Especially in foundation engineering and the drilling technology it is hard to insure projects. The fees for a policy are very high and most of the times the policy does not cover major failures.

GeoBrain is addressing these problems directly by developing an experience database from case histories and disseminating these experiences via the Internet. This database, complemented with expert knowledge, can be used to make predictions with an Artificial Intelligence (AI) based methodology. There are therefore at least two kinds of output from the total GeoBrain system: experiences and predictions (Figure 1).

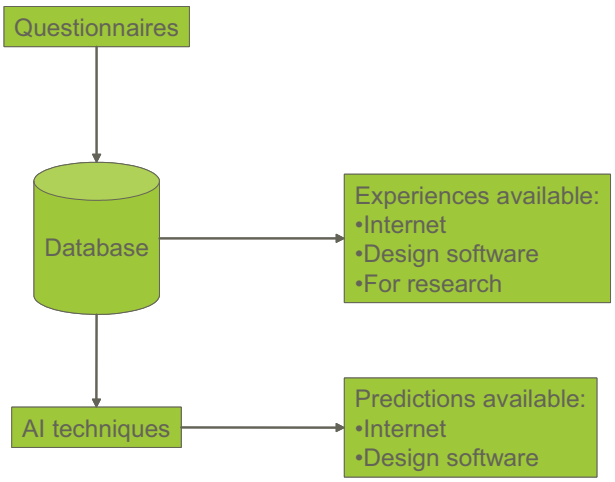

Figure 1 Using questionnaires the experiences are collected in a database. The experiences are directly available via the internet and in design software. In a later stage we will implement them in our design software such as Msheet and other M-Series software. The predictions, based on an Artificial Intelligences methodology, are also available via the internet and will be in design software.

3 WHAT IS AN EXPERIENCE?

In setting up GeoBrain, one of the first challenges was to define exactly how experiences could be captured. Our intention was to bring real case history experiences to the designer or engineer. In this context an experience is a collection of data systematically describing the cause of consequences induced by an act, for example installing sheet piles. The experience must also include the solution adopted to mitigate the consequences. An experience database therefore has to have the following structure: act, consequences, causes and solutions.

The definition of an act is the execution of a technique leading to a particular set of consequences are solely to blame to that act. A leak in a building pit can have many causes, which cannot be blamed solely on one act, such as problems with installing the sheet-piles. Other causes may also be to blame, such as the lack of an adequate confining clay layer. This decision, to collect experiences based on acts, is fundamental to the GeoBrain approach. In the GeoBrain system we collect experiences based on a particular act, which leads to consequences. We do not collect experiences based on consequences for which causes have to be found.

A project can have more then one experience. An experience is uniquely defined by the type of element (sheet-pile or prefab concrete pile), the type of equipment used and the soil conditions. If one of these alter in a project this leads to a new experience. This way the differences between material, equipment and soil can be seen. In a lot of cases contractors use another type of vibrator if the first one did not give the desired result. In some cases the soil conditions or the type of sheet pile alter, resulting in different consequences.

4 QUESTIONNAIRES

To get the appropriate input for the experience database questionnaires have been used. Different questionnaires for different acts. Up to now we tackled five acts: the installation of sheet piles, prefab concrete piles, vibro-(combination) piles, the extraction of sheet piles in foundation engineering and horizontal directional drillings in the drilling technology. Other techniques are being addressed such as microtunnelling at the end of this year. The questionnaires consist of different subjects, mainly to be categorized by: general information, facts about the subsurface, the installation method, the type of material (sheet piles etc.), the influence the act had on the surroundings, the solutions to any problems (if any) and finally the consequences of the act. The causes of the consequences lie in the questions asked. There is also a possibility to give a cause for every consequence, but since this is a text field containing a personal interpretation it is difficult to rely on this input.

A short description of some typical questions is given below.

- General information about the project: information about the location (X-Y coordinates), type and scale of the construction and the name of the project.
- Detailed facts about the soil. For instance if there are any gravel layers, stiff sand and weak clay layers. It is obligatory to upload a CPT from the location in GEF format, which is the standard format in The Netherlands for CPTs (http://www.delftgeosystems.nl/en/page6728.asp). This way the different layers are automatically characterized and the cone resistance and friction are known.
- Act: detailed facts about the method used. In the case of the installation of sheet piles facts about the type of vibrator, hammer or pusher (Silent Piler etc.) can be chosen from a specially developed database with all types used in The Netherlands and with all relevant technical specifications; facts about the use of fluidation or jetting, predrilling or predigging, type of lock indicator, lock resistance reduction, experience of the operating group and more.
- Detailed facts about the materials used. In the case of the installation of sheet piles facts about the type, to be chosen from a database with all types of steel sheet piles known, with accompanying characteristics and specifications, if the sheet piles were used previously and the state they are in (corroded, bent), single, double or threesome sheet piles, types of locks, steel quality, the lengths and if they have been used in combination with steel tubes and or H-profiles.
- Detailed facts about the influence the act had on surroundings, such as buildings. The amount of settlement, directly near the element, 1 m from and 3 m from the element. If there are any marks, such as cracks in surrounding buildings, the damage scale, the type of surrounding construction and if there have been any complaints from the inhabitants of the neighbourhood.
- Detailed description of the consequences of the act on the elements. In the case of sheet piles: have they reached their planned depth, were they damaged, did they run out of their locks, etc.

The number of questions are different for each type of act, ranging from 100 to 200 questions. Most of them are obligatory. In order to make it easy to give the answers, most answers can be chosen from a dropdown list or using check boxes. The reason for this is not only to help the user, but also to guarantee consistency in the answers. Different ways of describing acts or processes, or even different spelling or vocabulary can be a major handicap for the interpretation of the answers.

The questionnaires can be reached via the internet and are protected from unwanted use by a login and password.

5 PREDICTIONS

The basic idea is to make predictions with an Artificial Intelligence based methodology from experiences. For this purpose a lot of experiences are necessary, taking into account the number of representative factors influencing the consequences of an act. We consider that at least 200 experiences per act are needed to provide statistical reliability.

This GeoBrain system makes predictions using a Bayesian Belief Networks (BBN), which can be built from expert knowledge and validated using the real case experiences. During sev-

eral Electronic Boardroom Sessions the basis for the network was made and questions were asked in a way that the probability tables, which lay behind the network, could be completed. The questions are more or less asked in a fuzzy logic kind of way. Neural Networks will also work, but are not suitable to back-analyze the network and expert knowledge. For example, if you want a certainty of 95 % that the sheet piles have to reach their planned depth, the outcome of the BBN can be that you have to use at least a certain type of hammer. In addition a BBN needs much less data then a Neural Network. At this time we can make predictions for sheet piles. The next step is to validate the network. This can be done with the collected experiences. We will also make BBN's for the other acts.

6 OUTPUT

The Internet is the ideal medium to display the experiences and the results of an prediction. Searching can be done either on act type or via a map to search on location (Figure 2). Afterwards the query can be refined. The predictions can be made on the same website. For example for sheet piles, you have to choose a type of sheet pile, its length and a type of vibrator, hammer or pusher. Finally a CPT has to be uploaded in GEF format. The CPT wile be processed and the thickness and cone resistance of the sand and gravel layers will be used by the prediction model together with the other data. The model will run and give an answer about for example the probability that the sheet pile will reach its planned depth.

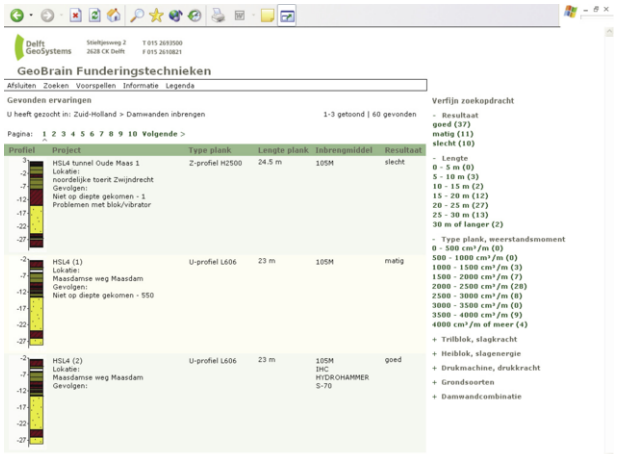

Figure 2 Shows the website (www.geobrain.nl) where the user searched for experiences.

7 PARTICIPATION AND ROLES

The participating work groups for foundation engineering and drilling technology consist of several contractors and experienced people from engineering consultancies. Together we made the questionnaires and experts deliver their knowledge for the prediction models, the BBN's.

On the input side the clients stimulate the contractors to deliver their data. This is done via the specifications of projects and standard contracts. In The Netherlands most projects are carried out with standard specifications, called the RAW. From April 2005 there will be a clause integrated in this specification, such that the contractor is required to deliver their data to the experience database.

On the output side the main stimulators are the insurance companies. If a contractor or a client can prove with the use of the prediction models and experience database that there is less risk involved in his project, the insurance companies have a better insight in their risk and are therefore sooner willing to insure the project against a lower fee and or a lower own risk rate.

The users of both the database and the prediction models are: engineers working in client organisations, consultants and contractors, the operating contractor, expertise agencies and risk controllers.

Based on the collected experiences the evidence of failure to surrounding utilities and foundationelements is present in at least 40% of all cases. GeoBrain does promise to make a real difference in geo-engineering and will help the designers to design a buildable construction with the use of experiences. Future plans for GeoBrain are to widen the topics and to internationalise the use.

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