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MECANIQUE DES SOLS

ARTICLES REVIEW

This file contains three texts about deep foundation. The first one "Investigation of Pile Behavior Using Embedded Piles" written by H.K.Engin and R.B.J. Brinkgreve is a report on a new numerical methods to describe piles behavior. The second one "Large diameter casing piles, design testing and monitoring" written by J Brinkman, J.G van de Water and E. de Jong deals with the use of new larger piles in foundation of bridges in Nederland. The third text "Prediction, monitoring and evaluation of performance of geotechnical structures" written by Arsenio Negro Jr, Kjell Karlsrud, Sri Srithar & Max Ervin and Eduard Vorster is about prediction, designing and performance of deep foundation.

In the first part of our study, we made a summary of each article in order to understand the important results and analysis. Afterwards, we tried to find the great questions that these texts raised and done a critical analysis of them. In the first part, we talked about the main methods used by engineers to predict the behavior of foundations and how they use them. In the second part, we showed the main issues that these methods meet and we tried to explain why these problems happen. Finally, in the third part we opened a discussion on the future of geotechnical engineering and ideas to fallow for a brighter one.

Part 1: Short summary of the articles

The first article is untitled “investigation of pile behavior embedded piles” and mainly presents a program, called Plaxis 3D Foundations, which enable us to model a 3d pile in the soil. The finite element model has become rather popular in the past ten years, but many problem still occurs, like long time calculation or difficulty to model particular cases. The program in question is modeling the piles like beams elements, represented as line. Two main advantages about this choice, first particular cases like inclined piles are easier to model, second the pile is not a volume in the model only a line, which does disturb the defined volume of the soil, simplifying the calculation and so saving time. For the model to be efficient, the soil/pile interaction is modeled has a mesh dependent behavior of the stiffness and load capacity of the pile, based on the virtual modeled skin of the pile. This model is called the embedded pile model.

To validate the model, test on real piles has been made to be compared with the results of the model. Bored pile in compression case has been easily validate, another test was made, tension tests, on pored piles in Kuwait and result came out positive for the embedded model. Other methods were also used like the Poulos-David method that showed that our model was as efficient as other. The second battery of test were made on a pile raft foundation of a building in Frankfurt. Load capacity, skin friction and axial force distribution force all these tests were made and a part of the existing piles. Results are reasonably in close to measured behavior. Skin friction and tip resistance are well predicted, however the load is sometime over predicted.

Still the main advantage of the model is its fast capability to give results, giving it a great future in the modification of a large number of pile in a foundation.

The second article is the study on a project using large diameter casing piles. An extension of the railway between major cities in Dutch land required a sequence of bridges. Large casing piles were proposed as an alternative to the original proposition which was a large number of driven precast piles supporting a large slab. This more economical solution, had to support load more than 12000kN per pile and most important have a deformation of less than 10mm when a train passed. The solution found was to use a grouting device injected after the hardening of the concrete of the piles.

The main difficulties came from the fact that these kind of piles are designed using combination of experience, ground conditions and static load tests, and many data were lacking in the Netherlands. So tests had to be made, tree piles were chosen and tested on their load displacement behavior. Measures were made on the top of the pile but also 12 and 17 m meter below the head of the pile cap. The results helped the engineer redesigned some of the piles and some piles were monitored for a year. The result after one year concluded that the new predicted design was more close to reality than the first one confirming the need to test these first piles.

Tree year's later bigger piles had to be design for the project. Using the former result and a few loading test, the engineer had reached a very good understanding of the ultimate bearing capacity and the load-settlement of the casing piles.

This last article is making a review of the tree main domains of geotechnical engineering: prediction, monitoring and evaluation. It introduced the problematic with the obsessing need for the human race to predict any action they make. Today construction engineering has become a science of excellence in prediction, or more exactly a science that is willing to be like that. It criticize the fact that most of the methods are applied on empirical correlation and that there is a real reluctance of geotechnical practitioners to use new methods. Many geotechnical experts on the other hand, urge for a revision of these data and present codes and norms more as a barrier than a stimulus to better engineering.

Evaluating a prediction, is part of the everyday day of an engineer and is needed due to all uncertainty of the design. Tree piles test are presented, the technique used, the test made and the evaluation of the results. The authors underlined the difficulty to choose the good way to interpret these data, but moreover the fact that many data are ignored due to hard complications, like in the case were foundations are not respecting the minimum load and the construction of the upper structures are already under way. Two examples of existing foundations are then presented, one were foundations were badly designed because the pile interaction factor was not enough analyzed, the second about a tower in Melbourne were the soil data was not well collected leading to pile not reaching the maximum load and where a hard new study of the soil had to be done.

Part 2: Reflection on exposed methods

I. The most common methods of prediction

As it is said in the third article "Prediction, monitoring and evaluation of performance of geotechnical structures", humankind has always wanted to predict the behavior of its constructions. In order to do that, humans developed several methods of prediction, particularly in deep foundations.

I.1 The numerical method

This method is used in the first article "investigation of piles behavior using embedded piles". This method consists in developing a model of behavior to describe the real behavior of piled foundation. In this document, the author develops a finite element method and an elasto-plastic hypothesis to describe the behavior at skin and tip surfaces: means of line to volume interface and point to volume interface. This method is new and has to be proven: in fact, we will see if hypothesis made to establish the method could be false and that's why the numerical results have to be compared with the reality. Thus, experimental results are used to compare with the data obtained with numerical results. First, we compared the model for one embedded pile. When it is compared to the experiment, we can see that there is a little difference in results but there are not significant according to the author. Indeed, experimental results can vary a little because of reading mistakes or measures mistakes. Also, the method is validated by experiment. After, the method is used to describe the behavior of several embedded piles used for the same building in Frankfurt. The author used the same mean to compare numerical and experimental results and valid the method for several piles. This numerical method could be used to understand the behavior of important foundation and simplify the way to calculate: this method is used on computer with software which reduces the time of buildings design. This method will be able to be used for further study as other methods which are used in this study to obtain the new method.

I.2 The experimental method

Another method which is used is the experimental method. This method is not a numerical method: it consists in testing in laboratory or in situ the property of the material we will use. It is used principally when there are not numerical methods which are applicable to the case. The example is given in the second article "large diameter casing piles, design, testing and monitoring". In this case, Dutch engineers used new piles with a large diameter 1,65 meters to improve the resistance of bridges and to reduce the number of piles. In place of 80 small piles, they used 6 big piles. However, these piles are new and never used in this kind of environment. Also, they have to use a method of prediction different of the numerical method. They also used en experimental method. They applied loads on the piles to see the resistance of the pile. They expect that piles will resist at a charge of 12000 kN, and the experimental results show that piles could support 20000 kN. Thus, these piles could be used to support the new bridges in place of smaller piles. The experimental results can be used in special cases to design structures.

I.3 By using texts and norms

Sometimes, engineers don't use methods but texts and norms to design their structures. These norms and texts shows the main structures which are used for buildings. Also we use these structures because we know them. In the third text, it is explained that lots of structures which are built which norms. Actually, these structures are often very resistant, maybe too much: lots of these structures are even overdesigned. This is the main problem of these structures as we will see after. However, these structures are very economical to design because they don't need lots of studies. Thus, there are lots of structures which are looking like to the others because they are very easy to build.

In fact, for all these methods, engineers have to take in account lots of conditions. As it said in the third text, in order to design appropriate foundation they have to know the general geology of area and the different stratas which can affect the foundation and its history, the hydrologic conditions, condition and method of construction of piles, and of course behavior of these foundation in labs, in situ and in other constructions.

II Limits and disadvantages of these methods

Although these methods are very used, they are not always the best methods which can be employed. Sometimes, these methods are not good methods and lead to failure of the structure.

II.1 Over prediction

The first problem that we met with these methods is that they are often over predicted. In fact, the foundation can often support more as than it was expected to support. As is it said in the third article, constructions are designed to support loads of extreme conditions which happened very rarely. It is caused by security norms but they are often too large for the construction. This over prediction leads to expensive building/construction. Indeed, in order to support more load, the construction need lot of materials, more than required.

For this case, the third text suggests that foundations have to be designed in order to support the most probable case. This could lead to cheaper foundation and to more freedom in the building design. For example, in the second text, although the new piles are cheaper than the others, they could support 20 000kN while they have to support only 12 000 kN. This is a proof to show that constructions are often over dimensioned even if it is a non-common construction. The solution to solve this issue would be to propose over solutions of foundation with the same piles or thinner piles like ones with a diameter of 1,5 m. Maybe engineers could find a better solution and more appropriated with the effective load.

This problem is also due of common construction. In fact, lots of constructions are dimensioned like this because there are other constructions which have ever been built like this. The problem is that not all foundation has to be dimensioned in the same way. For example, if the soil is just a bit different, it could lead to over predicted foundation and also to loss of money for the constructor.

But, it is better to over predict the foundation as to under predict it, because in this case it can lead to failure and serious accidents.

II.2 Failure

The other issue that could happen is the failure of the structure and in this case of foundation. But as it said in the third article, most of the failures are not due to bad prediction in design. In fact, construction can often carry more that it was supposed to do as we said in the first part. But the real problem is in the evolution of the conditions of the structure or of the soil. According to Peck in 1981, 90 % of failure was due to oversight that could and should be avoided. The issue is that construction and conditions are not enough verified. In order to reduce these failures, Peck suggested using another method after construction: it's looking. In fact, he say that if we are often looking after the construction and the condition of soil, we could predict failures and maybe prevent them.

There is another reason of these failures maybe. It is the lack of attention taken during the designing of the foundation. For example, we can see in the first article that the new method was not tested on all type of soil: only on sand and clay soil. Besides Enkin and Brinkgreve the two scientists, did not us the same soil in order to valid their method for one pile behavior and several piles behavior. In fact they did their tests on sand soil and valid the system for this type of soil. After that, they use the hypothesis that the method is valid for one pile and they applied it into several piles foundation. But this application is made on a real structure and on a different soil, the clay. We can wonder if they would better have to test a one pile foundation in clay before to verify it in several piles foundation. In fact, in this case, it has not a great importance because the method describes very well the behavior of the foundation and also it didn't lead to a failure. But maybe it could have been lead to lots of problems. Also in order to develop a numerical model, scientist have to be more precise on the condition of application of this method and to say how they valid their method.

III Reflection on the optimization of geotechnical construction.

We have seen the different steps a geotechnical engineer has to do fallow to succeed in the design of good foundations. But still different data are scattered, methods differs from a country to another, and FE models is always on the edge between fast calculation and efficient models. Geotechnical engineering is far from perfection, and a lot could done. We will try to open the discussion to where this science has good opportunity to improve its self.

III.1 The inventory of data

Soil data, experimental data, reports on existing building, all these are precious for an engineer but they are all scattered. The article on the pilling in the Netherland clearly showed us the lack of data. We are aware that the soil in this country is quite particular but still it appeared strange any data couldn't be collected from a place of similar soil for that type of piling. And moreover, it's a country part of the European Union so it's even more surprising that contacts with other country couldn't not be done, or if they tried, it seems it failed. The eurocodes helped, but still we have seen in the article making a review of the geotechnical field that many method and data need to be review or, at least, could be improved. After build drawing of an infrastructure must be given to the client afterward, which includes foundation, which is a great step knowing the problem engineer have when constructing a building were a former building existed and that had deep foundation. On top of that taller and bigger infrastructure are more and more needed, requiring heavier foundation and at a great past. No wonder the first article talked about test made in Kuwait. Nearby countries like Dubai build extraordinary buildings on a soil were few data existed. No need to mention buildings like the Burj Dubai, but it seems like these are going to be a formidable huge scale laboratory on building behavior, considering how much the soil was transformed in so little time.

But let's get back to our busyness, the foundation of a building is a public safety concern. Norms are of course compulsory but the free accessibility of collected data on an infrastructure should also be. Measures, experiences, behavior reports all these data if there were accessible to any researcher, would help a lot in the advances of the comprehension of foundation behavior. Of course it's an utopic will, these data are a source of income for many and the hard competition in the construction busyness does not help. It's a bit like if we ask the pharmaceutics company to freely give their researches. Still if we wanted to have a reasonable solution, it could be a very good thing to force Construction Company to deliver a minimum of data after they finish a project. I know some data are compulsory to prove that norms are respected but more could be done.

III.2 The golden age of numerical model

Recent studies shows that the calculation power of the common personal computer doubles every 18 months. The first article presented this program, Plaxis 3D Foundation, and what was the main advantage? Faster than the common program. The simplification in its model, the pile represented as a line beam, reduce distortion and so the numbers of calculation. But this an alternative to the real physic phenomena, and by all these simplifications and little tricks, we may gain on efficiency but not on accuracy. In our present time it is a just exchange, but as we said to introduce, we are not far from a future where billions of calculation will be affordable. The rush we know today in the advance of computer efficiency as for consequence that a revolutionary program in FE model can become obsolete 2 or 3 years later. Creating fast efficient model is of course needed to respond to the present demand but we can afford to really concentrate on a complex, but realistic real physic phenomena model, no matter if it is a glutton calculation program.

Of course you could always argue on what is exactly this close future? What length of time does it represent? Well it doesn't matter. My point is that we must today believe in the future high accuracy of numerical program, mainly because it will become cheaper than automatically doing tests and experiences on construction site, but also because when this time comes we need to be ready for it, for the first one to efficiently use this technology while the king of the field (on a pure economical point of view). And for that it may be more interesting to focus for now on another horizon: soil data survey. Let us clarify: we are waiting for more powerful calculation tool, at accessible price, supercomputer are out of the idea, but for a top shape model to be efficient, we need all the soil data we can collect. We need new fast way to collect them and with an absolute quality, this is what needs to be done for now. The futur of this next generation of geoengineering FE models resides in the quality of our soil data.

Conclusion

Geotechnical engineering, is a field that as greatly evolved the last century but that still have a long way to go. Prediction, monitoring and evaluation, three very different action of the field but very much interconnected, working as a vital circle. We have overviewed different examples, from an efficient finite element model of pilling, to the monitoring of large scale pile, and a criticism of different aspects of the field. The main subject we have seen, which is mainly on deep foundations, helped us understand the many errors or lack of data, even little ones, that are common problems on construction site. Great advances has been made as we said, but the need of more efficient method to design these foundations are greater. We tried despite our lack of experience to discuss possibility or opportunity to improve the field or foreseen the future, may be considered as a futility, but this is not what there is to remember. The main think that we can extract from this review is that there is a great deal of opportunity to improve the field, and the best of it, is that these improvements are a walk away from us. Deep foundation and other field of geotechnical engineering is going to need lot of hand, and that is why it's an interesting field, it's because it's full of promises.