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Geotechnical Engineering, Techniques and Methods

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Index

Chapter 1
Geotechnical problems

1.1. Introduction

Any practitioner who develops their activity on the design, construction or exploitation of infrastructures is aware of the influence that the ground has on the cost and the viability of their activities. From foundations to slope stability issues, the field cover by Geotechnical Engineering is quite wide and unlike the structure of a bridge or the façades of a building, the output of solving the engineering problem is nearly in all cases completely hidden (i.e. not visible). This leads to the generally misunderstood concept of "saving", as many investors (including the State itself) do not want to invest money where no one will see it. However, a great disproportion usually exists between those saving and the cost of repairing the damages caused by the lack of suitable geotechnical measures.

Solving a constructive issue which involves a geotechnical problem could in most cases be considered a kind of handicraft. Combination of experience and a series of techniques (which may be more or less accepted) are therefore needed, and they should always be used together with some inspiration.

In Geotechnical Engineering almost any problem cannot be solved using the same solution as used before and the same problem is often addressed by different practitioners with different solutions. Fortunately, a series of rules and principles may be identified to reach a technically and reasonable solution. An approach may be therefore established which can be used to adequately face and address geotechnical problems.

1.2. Addressing the problem

1.2.1. Main principles

The approach to solve a geotechnical problem, despite not being possible to standardize a general procedure, should be based on three main principles:

- The *experience* of the practitioner who addresses the new geotechnical problem. This is needed for identifying the geological environment, proposing a proper ground study and different alternatives, selecting the appropriate calculation method and analyzing the results obtained.
- The *quality* of the work conducted. This includes the scope and aim of the geological and geotechnical investigation, the parameters to be obtained, and the adjustment of the techniques and methods to use.
- The *safety* of the proper solution to perform. This should be based, rather than on a simple final ratio, on an assurance of each and every of the phases of the work developed.

1.2.2. Conditioning factors

Infrastructure works are characterized by being frequently subjected to some conditioning factors which may sometimes result in, consciously or unconsciously, an incomplete evaluation of the geological and geotechnical risks.

Lack of resources is the most important and common conditioning factor. The lack of a budget for geotechnical investigation, the lack of time to perform it, the limitations of the works themselves, or even the need to perform the works at certain times, makes the proposals not be developed in the ideal conditions of "quality-safety", even though the practitioners have the required experience.

Sometimes is the experience required the factor scarce on the work site. This might be the consequence of not possible to have the right person, either by time or by term. Under those circumstances the site work practitioners are forced to tackle a problem for which they are not especially skilled, but whose solution is pressing.

For all these reasons, it is very important to have the tools to overcome the lack of time and the resources to ideally develop the "experience-quality-safety" principles that should guarantee any engineering work.

1.2.3. Good practice rules to ensure the success of the works

1.2.3.1 *Experience*

To ensure an approach based on experience, the first and main principle, the following guidelines should be followed when facing a geotechnical problem:

- If the practitioner is not an expert in the problem, the most direct and easy solution would be to contact a specialist in the topic. Unfortunately, this is not always possible because of economic reasons or because of temporal or geographical unavailability.
- In order to partially overcome that absence, one should make use of the previous experience kept in existing documents and bibliography, such as:
  - Designs and maps.
  - Aerial photos.
  - Previous studies of nearby areas.
  - Technical texts.
  - Technical articles (however, it is well known that obtaining texts in the geotechnical field is difficult and sometimes even their practical application in complex problems is unreliable to inexperienced practitioners).
- Consulting the current legislation, standards and guidelines is essential, since they reflect the previous experience accepted by the technical authorities in the country and because it ensures, or at least partially covers, the responsibility of the practitioner.
- The engineering team should include those practitioners from other specialties that are necessary in the project and/or execution of the infrastructure/building.

1.2.3.2 *Quality*

In order to ensure the quality of the work, an aspect which should never be taken for granted, the following measures should be addressed:

- Proposing a geotechnical investigation and exploration in accordance with the existing ground and the typology of the works to be constructed, which should consider:
  - Types of investigations and explorations.
  - Scope, number and magnitude.
  - In-situ and laboratory tests.
  - Performance conditions of each investigation and test.
- Having adequate resources to carry out the proposed geotechnical investigation without too many restrictions.
- Conducting the geotechnical investigation by experienced staff and accredited companies.

- Supervising the geotechnical investigations on site by technicians and practitioners specialized in these kinds of tasks.
- Rearranging and/or complementing the initial investigations when any possible information gap is detected, as well as when inconsistencies or doubts about the results initially envisaged arise or when any change in the typology of the projected works occurs.

1.2.3.3 *Safety*

Safety of the proposed solution should be based, besides and beyond the simple definition of a “coefficient”, in other important aspects such as:

- Ensuring the representativeness of the results obtained on site and in laboratory tests.
- Identifying the main values of the materials properties.
- Selecting the appropriate design model.
- Contrasting the assumptions adopted in the design phase with the “real-scale” observations in the implementation phase.
- Contrasting the expected results by monitoring the works, either by instrumentation or by direct observation.

1.2.4. Regulations in the field of Geotechnical Engineering and foundations

Standards and guidelines are a tool of untold value. In fact, these are reference documents that bring together and collect the experiences of other experts. Regardless of its scope or level of exigency, the existence of these documents is recognized for facilitating the work of the practitioners and for determining the success of their actions. Obligations and restrictions, safety margins, rules and regulations regarding control as well as similar aspects, must be understood as the result of experience, and not as mere caprices of the legislators or practitioners who wrote it and demand their application.

Understanding that nowadays not all practitioners have the knowledge or capacity to fully deal with the diversity of problems that arise in the performance of their activities is vital. And sometimes asking for the right person is not easy or affordable, especially in small works. Therefore, one should always take into account the available regulations (both general guidelines and local standards) existing in the field of Geotechnical Engineering, Soil Mechanics and Rock Mechanics.

1.3. The geotechnical study

Addressing and solving a geotechnical problem requires a complex process which includes several actions and activities such as gathering information, planning a series of explorations and investigations, performing such explorations, conducting in-situ and laboratory tests, analyzing the data, interpreting the results and proposing a geotechnical solution. That process is summarized in what is usually referred as “geotechnical study”, which must be always elaborated following the three main principles (experience, quality and safety) and according to the existing standards and regulations.

Typically a geotechnical study covers the following three phases:

- Preliminary study: a compilation and analysis of pre-existing information is carried out. Stratigraphy and basic geotechnical properties may be retrieved from other previous geological (or even geotechnical) studies. This phase should include a study of the different possible alternatives to tackle the problem as well as a preliminary design of the solution, together with the work plan of the geotechnical investigations and explorations.
- Geotechnical investigation and exploration: fieldworks and laboratory tests are conducted according to the geotechnical investigation planned. Works to carry out should be programmed in a document, specifying all that issues considered to be fundamental, relevant or important.
- Geotechnical report: finally, a report is produced. It must collect, summarize and analyze all the previous information gathered and obtained. The report must propose the values of relevant geotechnical parameters and include project recommendations to be used as guidelines and background for future designs and studies.

Chapter 2
Planning a geotechnical investigation

2.1. Introduction

Geotechnical investigations and explorations aim to establish the ground conditions in order to define the viability, design and construction of engineering works. They determine the nature of subsoil materials, allow the study of the geological, geotechnical, hydrogeological and environmental conditions and set the geotechnical properties needed for the design and construction of an infrastructure. Furthermore, in some cases, the geotechnical investigation can be the cornerstone of a project, helping in the selection of the most favorable infrastructure location and identifying potential ground instability problems and possible geological hazards (like expansive clays, landslides and floods).

Thus, geotechnical investigations are used in each phase of a project:

- In previous studies, geotechnical investigations are a part of the informative studies and help in defining the viability of the project.
- In the preliminary project, geotechnical investigations are necessary for selecting infrastructure locations and solutions, and for estimating the project cost.
- In the designing project phase, geotechnical investigations have an influence in the design, in the final definition of solutions and in the budget.

- In the construction phase, geotechnical investigations help in the verification of the project and the control of it, and are used in the study of ground treatments.
- During the exploitation phase, geotechnical investigations can be used for the infrastructure monitoring, surveillance and control.

2.2. Information gathering

A geotechnical investigation always needs information. Two kinds of information sources may be distinguished:

- *Basic data*, necessarily for a correct planning of the geotechnical study and which should exist before any work.
- *Additional information*, gathered in different phases of the geotechnical study and which contributes to the correct interpretation of the existing problems.

2.2.1. Basic data

When any geotechnical study is commissioned or initiated, data should be available, as complete as possible, on the following points:

- Topographic map of the work area.
- Location of the planned structures and works.
- Future use of the planned structures and works.
- Work characteristics.
- Structure typology and materials (e.g. concrete, steel or precast walls).
- A top view of the structural layout.
- Order of magnitude of the loads at the foundation depth.
- Structure tolerances to total or differential movements and service limit conditions.
- Eventual vibrations or thermal effects generated in the use of the structure.
- Expedited earthworks (excavations or fillings).
- Legal problems, accesses problems, availability of water and other similar aspects, which may affect the development of the geotechnical investigations.

Besides, any geotechnical studies performed previously in the area should be always supplied by the person/entity who commissions the study, as well as any other information available that affects any of the points dealt in the following section.

2.2.2. Additional information

Information to gather considered of great interest include:

- Local experience and background, which should reveal:
  - In the specific case of foundations, foundation practices in the area.
  - Possible geotechnical problems reflected in cracks, distortions or movements.
  - Problems of instability, landslides or subsidence affecting the studied area.
  - Previous uses of the site or the area (e.g. orchard, landfill, industry) and especially those activities that may have led to hidden problems (such as quarries, trenches, walls and archeological areas).
- Features of the area and its surroundings reflecting:
  - Provisions relating to the protection of nearby buildings and public services such as communication routes, waterways, pipelines, underground or air utilities.
  - Foreseeable or known obstacles in the area like buried pipes or collectors, underground power lines or subway lines.
  - Type and depth of adjacent foundations and retaining structures.
  - Characteristics of dividing and surrounding structures.
- Local geology, covering the most relevant aspects:
  - The stratigraphic, lithological and structural identification of the formations in the area.
  - The geomorphological characterization (e.g. alluvial plains, dejection cones, moraines, paleochannels, thalwegs).
  - The location of faults, fractures and other accidents that may affect the projected works.
  - The possible seismotectonic activity in the area.
  - Active and/or potential instabilities of natural origin (e.g. landslides, avalanches, subsidence, karstification) and/or artificial (e.g. dumps, leaks of channels/pipes).
  - Existence of organic, expansive and/or collapsible deposits.
  - Erosion and scouring problems.

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