

# GEOTUTOR: SOFTWARE CREATED AS AN EDUCATIONAL RESOURCE FOR GEOTECHNICAL ENGINEERING

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## Abstract

Innovative software applications may prove to be advantageous in a teaching environment. It has been proven that technological teaching produces better achievement in class and an increased interest in the relevant field of teaching. Software that is able to produce a basic geotechnical report will give civil engineering students an insight into the field of geotechnical engineering and an understanding of the relevant inputs required and the outputs generated. A fundamental understanding of site investigations and related reports is an important aspect of geotechnical engineering training.

**Keywords:** Geotechnical Site Investigations, Computer-aided Learning, Innovative Teaching.

## 1. INTRODUCTION

Many young civil engineering technicians, technologists and engineers are involved with planning and design of new structures. Each new structure requires a geotechnical investigation to identify possible geotechnical constraints and to give guidance on designing for any constraints found. Typically young technicians, technologists and engineers are not familiar with geotechnical reports because they have never been exposed to geotechnical investigative report which leads to a situation where the wrong questions yield fruitless answers. Foundation design is absolutely dependent on a good, sound geotechnical report. The outputs given on geotechnical reports should be part of the primary inputs for foundation design, but it is not. Foundation design has become a matter of familiarity where foundation types are paired with structure types and the soil on which the structure will stand is ultimately not considered in depth.

Geotechnical Engineering is concerned with the engineering properties of in-situ soil and bedrock upon which structures such as roads, bridges and buildings are founded. Geotechnical Investigations is the process by which geological, geotechnical and other information which may affect the performance or construction of a structure is gathered (Clayton, 1995).

Typically geotechnical investigations are undertaken by Geotechnical Engineers (Civil Engineers specialising in soils) or Engineering Geologists (Geologists with an interest in the relevance of geology to civil engineering).

Site investigations date back centuries and a paper by Mayniel (1808) refers to Bullet noting the importance of trial holes in order to determine the different beds of soil beneath a site. Many advances have been made in the field of Geotechnical Engineering and typical standards today indicate the following objectives: (Codes of Practice – BS CP2001:1950, 1957;BS 5930:1981)

- 1.1 Site selection. Based on any available area, there exist more economically feasible and less feasible areas. Problem soils can easily escalate construction costs and it is therefore important that site selection be applied.
- 1.2 Foundation and earthworks design. Once a site is selected, any geotechnical problems must be solved to allow a safe and economical design to be prepared.
- 1.3 Temporary works design. In some cases the loads applied to the soil during construction would exceed those of the final structure. While excavations for foundations are made, steep slopes may collapse due to the ingress of water. These are temporary difficulties which must be considered during the investigation.
- 1.4 The effects of the proposed project on its environment. The construction process may cause structural distress to neighbouring structures. A lowering water table might leave neighbours without water. The effect of the project needs to be considered during the investigation.
- 1.5 Investigation of existing construction. Observations with regards to current structures subject to the same conditions can often give more valuable insight than laboratory testing.
- 1.6 The design of remedial works. Site investigations can be used if a structure seems to be failing in an attempt to take remedial measures.
- 1.7 Safety checks. Site investigations can be used to determine whether earth dams, sludge dams and other similar structures are in condition for continued use.

GEOTUTOR aims to familiarise students with geotechnical investigations by forcing students to enter information deemed necessary to record on site during investigations. The software will give guidance and additional literature to give background and support wherever necessary. There are many different types of Geotechnical Investigations, as listed in Table 1. GEOTUTOR will focus on the most typical geotechnical investigations which are foundation investigations for single and double storey houses, as is described in Table 1.

## 2. LITERATURE REVIEW

A study of current academic software available focussed on Geotechnical Investigations proved that many products are available for commercial use and to a lesser extent academic use. Typically applications available for academic use are only a limited edition of similar commercial products available with little to no guidance. The software available on the internet relies on users' fundamental understanding of geotechnical investigations, something that most civil engineering students do not yet possess.

**Table 1:** Types of site investigations

| <b>Type of Investigation<br/>(Broadly defined)</b>     | <b>Considerations</b>   | <b>Reference</b>                       |
|--|---|--|
| Roads  | Determination of the current engineering parameters of the existing road materials ( <i>in-situ</i> ) and its suitability for future use in proposed new road construction.   | (SANRAL, 2004), (COLTO, 1998)          |
| Single and double storey houses (NHBRC specifications) | Evaluation of problem materials in the area, the feasibility of proposed areas for development and a proposal of foundation design types. (such as raft foundations, strip footings, etc...)  | (NHBRC, 2014)                          |
| Commercial structures                                  | Determination of the <i>in-situ</i> bearing capacity and/or bearing capacity of bedrock. Depth of bedrock and the water-table are typically important parameters. Depending on the size and shape of the building piling may be considered which needs to be investigated specifically per pile type.                                       | (Byrne & Berry, 2008)                  |
| Bridge structures                                      | Bridges are typically piled and would require parameters associated with pile foundations such as the friction angle, undrained consolidation and various other engineering parameters. Bearing capacity of the <i>in-situ</i> material and the bedrock is vitally important.   | (SANRAL, 2011)                         |
| Warehouse structures                                   | Because of the large floor areas typically associated with warehouses. They are vulnerable to heaving clays, collapsible sand and compressible soils. Typically the portal frames exert a much higher load than an unloaded floor which will result in differential loading and ultimately differential settling.                           | (Clayton, 1995)                        |
| Cemeteries   | Contamination of ground water and/or surrounding water-bodies is probably the most important consideration; this would include parameters such as permeability and the electrical conductivity and pH of the soil. Other important considerations include the excavatability of the materials on site and the site topography and drainage. | (Richards & Croukamp, 2004)            |
| Land fill sites  | Typically the considerations are similar to those of cemeteries with a different set of specifications.   | (DWAF, 2003)                           |
| Earth dams   | Earth dams typically have clay cores in order to prevent seepage through the dam walls. Because of this dispersion is an important factor. Dispersion can lead to piping which could ultimately lead to a collapse in the dam walls.  | (Clayton, 1995)                        |
| Other site investigations not listed                   | Investigations for harbours and coastal structures have other important factors such as saline water causing corrosion.<br><br>Investigations for soil retention, marine foundations, soil improvement, remedial works, safety checks and under-water structures each have site specific concerns.  | (Clayton, 1995), (Byrne & Berry, 2008) |

The approach to civil engineering problems by structural engineers differ from that of geotechnical engineers which often leads to a lack of understanding and difficulties in communication. (Burland, 2006) Burland further noted that much can be done to improve the understanding of the geotechnical engineering approach.

Geotechnical engineering is a wide field of interest ranging from different structures, different construction types and different fields of interest ranging from design, construction to field exploration. Site investigations range from simple to complex as illustrated in table 1.

Based on various research papers, notably a paper by Becker (1994) and Kulik (1994), computer-based education has proven to score on the 64th percentile compared to the 50th percentile for those without computers. Kulik's conclusions included that students were found to enjoy the classes more and were able to learn more in less time. A paper prepared by Professor Jeffrey T. Fouts for the Bill and Melinda Gates Foundation made various arguments for and against the use of computers for educational purposes, but states that the interactive nature of teaching offered by computers contributes greatly to better understanding of the subject matter. (Fouts, 2000)

Research by Sivin-Kachala (1998) reviewed 219 research studies from 1990 to 1997 to assess the effect of technology on learning across all learning domains and found that students in technology rich environments experienced positive effects on achievement in all major subject areas. Furthermore, a paper by Schacter (1999) reviewed more than 700 empirical research studies and concluded that students with access to computer assisted instruction, integrated learning systems technology, simulations and software that teaches higher order thinking, collaborative network technologies or design and programming technologies showed positive gains in achievement on researcher constructed tests, standardised tests and national tests.

A geotechnical conference was held in Denver, Colorado, to discuss several issues with regards to teaching geotechnical engineering to students (Proceedings of sessions of Geo-Denver 2000, held in Denver, Colorado, August 5-8, 2000. Sponsored by the Geo-Institute of ASCE). During this conference several authors suggested that technology be better utilised for educational purposes. It was suggested that the newest technologically advanced teaching methods be introduced to classrooms including the use of multimedia and innovative applications. Various research papers reviewed by the author have proven that software used as an educational tool will provide better achievement which directly implicates better understanding. It is on this premise that the decision was made to research the possibility of creating educational software to improve the general understanding of Geotechnical Engineering reports with Civil Engineering students.

### 3. RESEARCH METHODOLOGY

Practical research in the industry identified that several civil engineering consultants and contractors are unfamiliar with geotechnical reports on investigations undertaken. Structural engineers are ignoring the very ground that structures they design will stand on because of a lack of understanding of geotechnical reports. This may, however, not be true for larger engineering firms who rely on senior engineers for all major engineering decisions, but it is true for smaller up and coming engineering firms. This problem has been identified by various professionals working at materials laboratories throughout the country. Various geotechnical engineers have discussed their dismay at the lack of understanding of geotechnical reports by structural engineers.

A descriptive-qualitative research approach was followed with various professionals in the civil engineering naming a lack of understanding of geotechnical reports as a contributor to structural failure. The following steps were taken as part of research methodology:

Step 1: Deciding what to research – Research questions

1. The lack of understanding of geotechnical reports is a problem many engineers face. How do you understand something you have never encountered before?
2. How do you expose students to geotechnical investigations and geotechnical reports when it is practically almost impossible to do so?
3. What do students fundamentally need to understand in order to create a platform upon which they, themselves, can build on?
4. There are several types of geotechnical investigations, some which occur frequently and others less so, to which types of investigations should students be exposed to?

Step 2: There exists a wide range of different geotechnical reports; this was identified in table 1.

Step 3: It was decided to focus on one specific type of geotechnical report to narrow the scope. Due to the frequency of the investigation type, geotechnical reports on single and double storey houses were selected.

Step 4: The specific objectives and inputs required for a typical geotechnical report for single and double storey houses were identified.

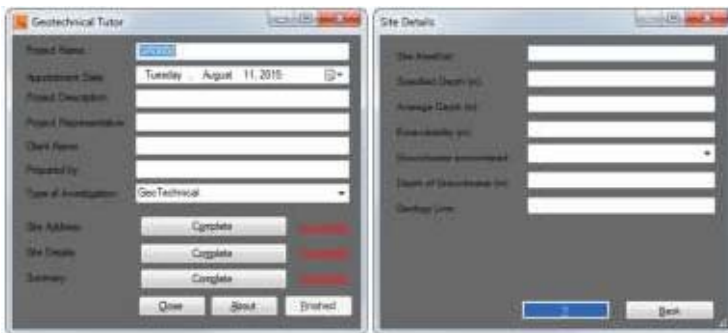
Step 5: Geotechnical reports vary according to various factors, these factors needed to be limited in order to create a general type of geotechnical report that will contain enough information to be used as a platform for future geotechnical reports and offer students enough information to generally understand geotechnical reports and the approach thereto.

Step 6: The objectives were checked and verified and modified where necessary.

Step 7: The decision was made that enough information is available and that research on the subject can continue.

#### 4. FINDINGS AND DISCUSSION

GEOTUTOR is an innovative application designed and programmed to teach civil engineering students about geotechnical engineering investigation reports. It is vital for civil engineers to correctly interpret the findings of geotechnical reports. This software aims to provide the necessary background and understanding to achieve this. Figure 1 below shows typical input parameters required as part of the final report.



**Figure 1:** Screenshots of the current version

Using a pilot version of the planned software it was found that the software will have academic value and commercial value. Technical personnel using the software were found to have an increased understanding of how a geotechnical investigation should be conducted and had a better understanding of the importance of several input parameters. Several factors that are often omitted during geotechnical investigations that were deemed of lesser importance are now recorded as the software does not allow any important factors to be ignored. This has improved the quality of the final geotechnical reports created using this software.

Several shortcomings have been noted and will insofar possible be addressed with the following version of the software. These include:

- The reports generated are generic and not site specific.
- There exist shortfalls in the final layout of the report. The software is dependent on a lot of manual user corrections, inputs and formatting.

The following methodology has been employed to create GEOTUTOR:

Step 1: In order to give proper guidance on geotechnical reports research needed to be done to avoid a “blind leading the blind” scenario. Experience in the industry and involvement in a research group specifically focussing on geotechnical investigations helped the author to achieve sufficient research on the matter.

Step 2: Geotechnical investigations entail a large scope of work. This scope needed to be narrowed in order to specifically focus on the type of investigations most typically done. The focus of the software is on single and double storey housing due to the national importance and drive towards housing the population of South Africa. In order to conform to national standards and typical expectations the software is based on several NHBRC approved geotechnical reports. As the NHBRC is the regulatory body for housing developments, this was considered ideal.

Step 3: Identify what the software should address in terms of the subject matter. The software is intended to teach and not spoon-feed. This software won't serve as a nationally accepted template of what a geotechnical report should look like, and would be of little use commercially. The intention of this software should be to educate students on the processes of a geotechnical investigation. Students should realise that each investigation is unique, there is no “one size fits all” solution to geotechnical investigations.

Step 4: Acknowledge your own short-comings. Microsoft Excel was initially used to program the software, but it proved to be limited in certain aspects and it became apparent that a programmer needed to be consulted. Upon his guidance Microsoft Visual Studio, C#, was decided on.

Step 5: Process control. To transfer ideas from one person to the next is almost impossible; no person shares your exact vision. It is important to stick to your convictions to achieve the final product you envisioned. Try not to compromise on the ideals you have set.

Step 6: Evaluate the product. Test the software with various input parameters and verify that the findings made by the software are consistent and correct.

Step 7: Correct and re-evaluate. It is inevitable that the initial product will not meet satisfactory standards. The short-comings were identified, corrected and re-evaluated until satisfaction was achieved.

Step 8: Publish the software and accompanying documentation. This is still in process.

## **5. CONCLUSION AND FURTHER RESEARCH**

The objective of GEOTUTOR is to familiarise students with geotechnical investigations in a practically achievable way. It is vital that students gain a fundamental understanding into the importance, function and content of geotechnical reports to ensure that the important input factors contained therein is designed for in future.

GEOTUTOR is an interactive teaching tool that creates geotechnical reports using inputs given by the user. The user (student) will be asked for various inputs from a geotechnical investigation which will be provided by the lecturer. The inputs are what should typically be recorded during a site investigation and where interpretation is needed, that too will be asked of the student. With the students reviewing the inputs required of them, and reviewing the final report created by the software, it is believed that the students will gain enough understanding of geotechnical reports to make better engineering decisions thereon in future.

The software has definite commercial value in that a geotechnical report can be created to be technically sound in a fraction of the time it would take a geotechnical engineering team, saving both time and money.

From an academic standpoint, students will gain an understanding of what a geotechnical investigation is, why it is necessary and how the results and findings of laboratory test results can be interpreted.

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