Ole Eiesland

Implementation of random finite element method in Plaxis Using API / Python scripting

With examples on slope stability problems

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PROJECT THESIS: TBA4510

Main supervisor: Professor Yutao Pan

Department of Civil and Transport Engineering

Norwegian University of Science and Technology (NTNU)

NTNU – Trondheim
Norwegian University of
Science and Technology

Preface

As a prestudy for my masters thesis this project work is presented as final deliverable in the subject "TBA4510 - Geotechnical Engineering, Specialization Project" at the Department of Civil and Transport Engineering, NTNU during the spring semester of 2021. The course is 7.5 SP credits.

The project was suggested and superviced by Yutao Pan, NTNU.

Here, you give a brief introduction to your work. What it is (e.g., a Project thesis in geotechnics at NTNU as part of the MSc in Civil and Environmental Engineering or Geotechnics and Geohazards), when it was carried out (e.g., during the autumn semester of 2013). If the project has been carried out for a company, you should mention this and also describe the cooperation with the company. You may also describe how the idea to the project was brought up.

Trondheim, 2021-12-20

(Your signature)

Ole Eiesland

Acknowledgment

I would like to thank Yutao Pan for supervising during the project work.

O.E.

Summary and Conclusions

Soil is a complex medium. Its inhomogenous nature means that the physical parameters of soil vary spatialy both vertically and lateraly. Traditionally soil properties is modeled with a representative value, usually some kind of mean value or simmilar. In probabilistic methods, this variability, or uncertainty is taken into account by treating the soil as a random variable sampled from a probability distribution. By using random field theory and statistics one can try to describe how the soil parameters are distributed in space and how they vary with distance. In a slope stability problem, the spatial distribution of the soil strength governing parameters has a direct impact on the development of the failure surface, the falure mechanism and therfore the over all stability of the slope. To simulate stability a finite element program can be used with the soil model parameters input to the finite element mesh based on statistical spatial correlated random fields. To simulate variability and uncertainty, the modeling is repeated many times with different random fields. This is the random finite element method.

Current modern soil modeling software do not support random finite element method, and published reasearch random finite element software code do not have the advanced functionality as modern comercial geotechnical software. How ever, since the random finite element method does not change the way the problem is simulated, only the input parameters change, modern software packages can be used if a way to specify the input and the simulation run parameters can be controlled in an efficient manner. Plaxis, a modern software package devolped by Bently, has capabilities like this through its application program interface and python scripting.

In this project work I present a method to run the random finite element method in Plaxis geothechnical software package using python API scripting interface, and demonstrate the random finite element method on a slope stability problem.

Contents

Chapter 1

Introduction

The first chapter of a well-structured thesis is always an introduction, setting the scene with background, problem description, objectives, limitations, and then looking ahead to summarize what is in the rest of the report. This is the part that readers look at first—*so make sure it hooks them!*

1.1 Background

Soil is a complex medium. Its inhomogenous nature means that the physical parameters of soil vary spatialy both vertically and lateraly. Traditionally soil properties is modeled with a representative value, usually some kind of mean value or simmilar. In probabilistic methods, this variability, or uncertainty is taken into account by treating the soil as a random variable sampled from a probability distribution. By using random field theory and statistics one can try to describe how the soil parameters are distributed in space and how they vary with distance. In a slope stability problem, the spatial distribution of the soil strength governing parameters has a direct impact on the development of the failure surface, the falure mechanism and therfore the over all stability of the slope. To simulate stability a finite element program can be used with the soil model parameters input to the finite element mesh based on statistical spatial correlated random fields. To simulate variability and uncertainty, the modeling is repeated many times with different random fields. This is the random finite element method.

In this section, you should present the problem that you are going to investigate or analyze; why this problem is of interest; what has, so far, been done to solve the problem, and which parts of the problem that remain.

Problem Formulation

Current modern soil modeling software do not support random finite element method, and published reasearch random finite element software code do not have the advanced functionality as modern comercial geotechnical software. How ever, since the random finite element method does not change the way the problem is simulated, only the input parameters change, modern software packages can be used if a way to specify the input and the simulation run parameters can be controlled in an efficient manner. Plaxis, a modern software package devolped by Bently, has capabilities like this through its application program interface and python scripting. It is of great interest to research on spatialy varying soil modeling to utelize the anvanced functions of existing software. Gaining this ability will expand the compexity of the problems alowed to be simulated by the RFEM method.

You should define your problem in a clear an unambiguous way and explain why this is a problem, why it is of interest—and to whom. It is also important to delimit the problem area.

Literature Survey

You should here present the main books and articles that treat problems that are similar to what you are studying. If you, later in your thesis, describe the "state of the art" – with a detailed literature survey, you may just give a very brief survey here (approx. a quarter of a page). If this is the only literature survey, you need to go into more details. An objective of the literature survey is to show the reader that you are familiar with the main literature within your field of research – so that you do not "reinvent the wheel."

References to literature can be given in two different ways:

- As an *explicit* reference: It is shown by Grimstad and Degago [2010] and partly also by Emdal et al. [2007] that ....
- As an *implicit* reference: It is shown [e.g., see Degago et al., 2011, Chap. 4] that ....

In the example above, we have used "author-year" references, which is the preferred format. It might be wise to use a program like EndNote to keep track on the references. NTNU has licenses for EndNote. When you refer to the scientific literature, you should always write in *present* tense. Example: Grimstad and Degago [2010] show that . . . .

Remark: You may include a link to the Internet in the text by using a command like: `http://www.ntnu.edu/`.

What Remains to be Done?

After you have defined and delimited your problem – and presented the relevant results found in the literature within this field, you should sum up which parts of the problem that remain to be solved.

1.2 Objectives

The main objectives of this project are

1. This is the first objective
2. This is the second objective
3. This is the third objective
4. More objectives

All objectives shall be stated such that we, after having read the thesis, can see whether or not you have met the objective. "To become familiar with . . . " is therefore not a suitable objective.

1.3 Limitations

In this section you describe the limitations of your study. These may be related to the study object (physical limitations, operational limitations), to the thoroughness of the analysis, and so on.

1.4 Approach

Here you should describe the (scientific) approach that you will use to solve the problem and meet your objectives. You should specify the approach for each objective.

If there are any ethical problems related to your approach, these should be highlighted and discussed.

1.5 Structure of the Report

The rest of the report is structured as follows. Chapter 2 gives an introduction to . . .

Remark: Notice that chapter and section headings shall be written in lowercase, but that all main words should start with a capital letter.

The length of the report is not important, the content is!

Chapter 2

Equations, Figures, and Tables

The content of this chapter will vary with the topic of your thesis.

2.1 Simple Equations

This is how a simple equation is included:

$$F(t) = \int_0^t \exp(-\lambda x)\, dx \tag{2.1}$$

The equations are automatically given equation numbers – here (2.1) since this is the first equation in Chapter 2. Note that you can refer to the equation by referring to the "label" you specified as part of the equation environment.

2.2 Including Figures

Each figure should include a unique caption *label* as for Figure 2.1.

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Figure 2.1: This is the logo of NTNU.

Table 2.1: The degree of newness of technology.

Experience with the operating condition	Level of technology maturity: Proven	Level of technology maturity: Limited field history or not used by company/user	Level of technology maturity: New or unproven
Previous experience	1	2	3
No experience by company/user	2	3	4
No industry experience	3	4	4

2.3 Including Tables

Please see Table Figure 2.1 for an example of a table.

Remark: Notice that figure captions (Figure text) shall be located *below* the figure – and that the caption of tables shall be *above* the table

2.4 Copying Figures and Tables

In some cases, it may be relevant to include figures and tables from from other publications in your report. This can be a direct copy or that you retype the table or redraw the figure. In both cases, you should include a reference to the source in the figure or table caption. The caption might then be written as: *Figure/Table xx: The caption text is coming here [Emdal et al., 2007]*.

In other cases, you get the idea from a figure or table in a publication, but modify the figure/table to fit your purpose. If the change is significant, your caption should have the following format: *Figure/Table xx: The caption text is coming here [adapted from Emdal et al., 2007]*.

2.5 References to Figures and Tables

Remember that all figures and tables shall be referred to and explained/discussed in the text. If a figure/table is not referred to in the text, it shall be deleted from the report.

2.6 Plagiarism

Plagiarism is defined as "use, without giving reasonable and appropriate credit to or acknowledging the author or source, of another person's original work, whether such work is made up of code, formulas, ideas, language, research, strategies, writing or other form", and is a very serious issue in all academic work. You should adhere to the following rules:

- Give proper references to all the sources you are using as a basis for your work. The references should be give to the original work and not to newer sources that mention the original sources.
- You may copy paragraphs up to 50 words when you include a proper reference. In doing so, you should place the copied text in inverted commas (i.e., "Copied text follows ..."). Another option is to write the copied text as a quotation, for example:

  > Two totally different cases, referred to as creep hypotheses A and B, have been used as a basis of discussion to assess the effect of creep during the primary consolidation phase.
  >
  > Degago et al. [2011]

Chapter 3

Summary and Recommendations for Further Work

In this final chapter you should sum up what you have done and which results you have got. You should also discuss your findings, and give recommendations for further work.

3.1 Summary and Conclusions

Here, you present a brief summary of your work and list the main results you have got. You should give comments to each of the objectives in Chapter 1 and state whether or not you have met the objective. If you have not met the objective, you should explain why (e.g., data not available, too difficult).

This section is similar to the Summary and Conclusions in the beginning of your report, but more detailed—referring to the the various sections in the report.

3.2 Discussion

Here, you may discuss your findings, their strengths and limitations.

3.3 Recommendations for Further Work

You should give recommendations to possible extensions to your work. The recommendations should be as specific as possible, preferably with an objective and an indication of a possible approach.

The recommendations may be classified as:

- Short-term
- Medium-term
- Long-term

Appendix A

Acronyms

CPT Cone Penetration Test

CRS Constant Rate of Strain

Appendix B

Additional Information

This is an example of an Appendix. You can write an Appendix in the same way as a chapter, with sections, subsections, and so on.

B.1 Introduction

B.1.1 More Details

Bibliography

S. Degago, G. Grimstad, H. Jostad, S. Nordal, and M. Olsson. Use and misuse of the isotache concept with respect to creep hypotheses a and b. *Géotechnique*, 61(10):897–908, 2011. ISSN 0016-8505. doi: Doi10.1680/Geot.9.P.112. URL <GotoISI>://000295208700007.

A. Emdal, G. Priol, G. Grimstad, and A. Løhren. Numerical analysis of the effect of sleepers on the lateral displacement of railway track. In *Numerical Models in Geomechanics*. Taylor & Francis, 2007. ISBN 978-0-415-44027-1. doi: doi:10.1201/NOE0415440271.ch7510.1201/NOE0415440271.ch75. URL http://dx.doi.org/10.1201/NOE0415440271.ch75. doi:10.1201/NOE0415440271.ch75.

G. Grimstad and S. Degago. A non-associated creep model for structured anisotropic clay (n-sac). In *Numerical Methods in Geotechnical Engineering*, pages 3–8. CRC Press, 2010. ISBN 978-0-415-59239-0. doi: doi:10.1201/b10551-310.1201/b10551-3. URL http://dx.doi.org/10.1201/b10551-3. doi:10.1201/b10551-3.