Reliability benchmarking of Eurocode 7 design examples

Eurocode 7 (EN 1997), the European standard (i.e. code of practice) for design of geotechnical structures, is currently undergoing revision. The Eurocodes are reliabilitybased and the second generation of Eurocodes (including EN 1997) will include significantly more explicit reliability elements compared to the first generation. Currently, a CEN task group is working on a guideline document to facilitate the use of reliability-based methods in geotechnical engineering in practice. This graduation topic has been defined to support the work of the task group and to produce material for the guideline document.

The objectives of this thesis topic are:

- 1. To carry out (full probabilistic) reliability analysis on Eurocode 7 design examples;
- 2. To benchmark the performance of different reliability methods;
- 3. To investigate the reliability levels achieved by Eurocode 7 design requirements.



The main challenges for the envisaged MSc-graduation project are:

- 1. probabilistic characterisation of the uncertainties;
- 2. reliability analysis of design examples with different reliability methods (using existing software, e.g. Probabilistic Toolkit PTK)

This project will be carried out at TU Delft or Deltares, and in collaboration with the European task group for reliability-based methods in geotechnical engineering (TG-C3). We are looking for strong candidates with a background in geotechnical engineering and an interest in probabilistic design.

Supervising committee:

Dr. ir. Bram van den Eijnden (assistant professor, TU Delft): <u>A.P.vandenEijnden@tudelft.nl</u> Dr. ir. Timo Schweckendiek (Deltares & TU Delft, chair TG-C3): <u>timo.schweckendiek@deltares.nl</u>



Reliability analysis of Eurocode 7 design examples

Eurocode 7 (EN 1997), the European standard (i.e. code of practice) for design of geotechnical structures, is currently undergoing revision. The Eurocodes are reliabilitybased and the second generation of Eurocodes (including EN 1997) will include significantly more explicit reliability elements compared to the first generation. Currently, a CEN task group is working on a guideline document to facilitate the use of reliability-based methods in geotechnical engineering in practice. This graduation topic has been defined to support the work of the task group and to produce material for the guideline document.

One of the core elements of the envisaged guideline is to provide front-to-end examples of reliability-based verification of limit states for the design geotechnical structures. Examples of structures are:

- railway or road embankments
- retaining structures
- pile foundations etc.

Front-to-end reliability examples will comprise:

- Probabilistic site characterization (ground properties)
- Probabilistic modeling of other uncertainties (e.g. loads, models)







- 3. Full probabilistic reliability analysis (with methods like FORM, Monte Carlo simulation or others)
- 4. Reliability assessment (comparison of obtained reliability with target values)

The examples are meant to demonstrate complete reliability assessment in the Eurocode framework, specifically for geotechnical structures (i.e. EN 1990 and EN 1997). The candidate will need to reflect on possibilities and limitations, and on the impact of practical assumptions to make the problem tractable.

This project will be carried out at TU Delft or Deltares. Candidates who would rather like to do their project in an engineering consultancy firm are encouraged to explore interest for this topic with potentially interested companies. The envisaged supervisors (see below) can help in establishing contacts.

The work will be coordinated with the European task group for reliability-based methods in geotechnical engineering (TG-C3). We are looking for strong candidates with a background in geotechnical or hydraulic engineering and an interest in probabilistic design.

Supervising committee:

Dr. ir. Bram van den Eijnden (assistant professor, TU Delft): <u>A.P.vandenEijnden@tudelft.nl</u> Dr. ir. Timo Schweckendiek (Deltares & TU Delft, chair TG-C3): <u>timo.schweckendiek@deltares.nl</u>



Reliability targets for geotechnical structures

Eurocode 7 (EN 1997), the European standard (i.e. code of practice) for design of geotechnical structures, is currently undergoing revision. The Eurocodes are reliabilitybased and the second generation of Eurocodes (including EN 1997) will include significantly more explicit reliability elements compared to the first generation. Currently, a CEN task group is working on a guideline document to facilitate the use of reliability-based methods in geotechnical engineering in practice. This graduation topic has been defined to support the work of the task group and to produce material for the guideline document.

When reliability assessment for geotechnical structures is carried out fully probabilistically, the calculated reliability needs to be compared with target reliability values (i.e. $\beta \ge \beta_T$). Eurocode 0 (EN 1990) proposes target reliability values, yet these are based on considerations for buildings and bridges, and it is unclear if they are appropriate for use with geotechnical structures.

The objective of this thesis topic is:

To investigate target reliability values for geotechnical structures in the Eurocode framework.



To this end, the student will consider:

- 1. Life safety recommendations;
- 2. Economic considerations (cost-benefit analysis involving the risk of failure);
- 3. Reliability achieved with Eurocode 7 requirements (empirical safety).
- 4. Target reliability levels recommended in related domains (e.g. structural engineering, flood risk, quay walls etc.)

This project will be carried out at TU Delft or Deltares, and in collaboration with the European task group for reliability-based methods in geotechnical engineering (TG-C3). The results can have a direct impact on future recommendations in European guidelines. Hence, we are looking for strong candidates with a background in geotechnical or hydraulic engineering and an interest in probabilistic design.

The MSc project will be jointly supervised by the sections Geo-engineering and Hydraulic Engineering.

Supervising committee:

Dr. ir. Bram van den Eijnden (assistant professor Geo-engineering): <u>A.P.vandenEijnden@tudelft.nl</u> Robert Lanzafame, PhD (lecturer Hydraulic Engineering): <u>R.C.Lanzafame@tudelft.nl</u> Dr. ir. Timo Schweckendiek (Deltares & TU Delft, chair TG-C3): <u>timo.schweckendiek@deltares.nl</u> Dr. ir. Alfred Roubos (Port of Rotterdam & TU Delft): <u>aa.roubos@portofrotterdam.com</u>



Reliability of existing geotechnical structures

Eurocode 7 (EN 1997), the European standard (i.e. code of practice) for design of geotechnical structures, is currently undergoing revision. The Eurocodes are reliabilitybased and the second generation of Eurocodes (including EN 1997) will include significantly more explicit reliability elements compared to the first generation. Currently, a CEN task group is working on a guideline document to facilitate the use of reliability-based methods in geotechnical engineering in practice. This graduation topic has been defined to support the work of the task group and to produce material for the guideline document.

The reliability of existing geotechnical structures is of importance for future guidelines for two reasons:

- 1. Assessment of existing structures will enter the scope of the Eurocodes in the next generation, because ageing (infra)structures become increasingly important;
- 2. Reliability analysis of existing (geotechnical) structures provides insights in the reliability levels achieved by Eurocode designs (and previous/other codes of practice).

Furthermore. the reliability analysis of existing structures differs from the design of new structures because more information is available to reduce uncertainties. Examples of such information are measurement and monitoring data from the construction phase, or performance data obtained during operation/service.



The objectives of this thesis topic are:

- 1. To assess the reliability of one or several (existing) geotechnical structures;
- 2. To make use of relevant additional data on the structure(s) besides ground investigation (e.g. proven performance);
- 3. To relate the obtained reliability levels to design (code) requirements.

Candidate applications are: railway or road embankments, retaining structures, pile foundations etc.

This project will be carried out at TU Delft (section Geo-Engineering) or Deltares. The results can have a direct impact on future recommendations in European guidelines. Hence, we are looking for strong candidates with a background in geotechnical or hydraulic engineering and an interest in probabilistic design.

Supervising committee:

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Probability distributions for geotechnical properties

Eurocode 7 (EN 1997), the European standard (i.e. code of practice) for design of geotechnical structures, is currently undergoing revision. The Eurocodes are reliabilitybased and the second generation of Eurocodes (including EN 1997) will include significantly more explicit reliability elements compared to the first generation. Currently, a CEN task group is working on a guideline document to facilitate the use of reliability-based methods in geotechnical engineering in practice. This graduation topic has been defined to support the work of the task group and to produce material for the guideline document.

When reliability assessment for geotechnical structures is carried out fully probabilistically, geotechnical the properties such as undrained shear strength are modelled as probability distributions. For example, lognormal distribution often chosen since is it excludes negative values. However, studies that utilize actual soil or rock data to investigate which probability distributions would be suitable have been rather limited.



The objectives of this thesis topic are:

- 1. To perform a review on most commonly selected probability distributions in geotechnical reliability assessment
- To carry out distribution fitting using large geotechnical datasets (e.g., site-specific datasets extracted from the 304dB database collection compiled by The Engineering Practice of Risk Assessment and Management Committee of the ISSMGE, TC304)
- 3. To derive recommendations for the probability distribution selection regarding various geotechnical properties

This project will be carried out at TU Delft or Deltares, and in collaboration with the European task group for reliability-based methods in geotechnical engineering (TG-C3). We are looking for strong candidates with a background in geotechnical engineering and an interest in probabilistic design.

Supervising committee:

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