Structural Reliability Applications

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Background

Civil engineering at City University London is a part of multidisciplinary School that includes mechanical engineering, aerospace engineering etc.

Courses include 3-year BEng, 4 year MEng and 1 year MSc courses in Civil Engineering Structures and Construction Management
My background

Structural reliability applications

Sample failure scenario

\[ M = R - S \]

- Assessment of highway bridges
- Design optimization
- Probabilistic life cycle performance estimates
- Reliability assessment of variety of structures
- Optimization of inspection regimes
- Acceptable risk level
Secant Pile Wall

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JISC-funded project

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FORM analysis, parametric study

Reliability index

D=600mm
D=750mm
D=900mm
D=1050mm

\( P_f = 10^{-3} \)

Sensitivity factors

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Sensitivity factors

- Sensitivity parameters reflect the importance of specific variables as expected.
- Sensitivity factors can be further used for decision making.

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What could be considered

- Section shape factors, to acknowledge deviation from the design shape. These can reflect the difference between primary piles that are drilled through undisturbed soil and secondary piles. Both effects of differing stiffness and drilling conditions would contribute to variation in uncertainty.

- From site data, improved modelling can be developed to account for size effects (tolerance for all section sizes is the same at present) and direction effects (we have introduced a simplified, linear, out of plane component for both primary and secondary pile).

- Target reliability level. This notional value can be established to reflect specific problem. For example, target value can be established as a value of the reliability index associated with a particular set-up that has performed adequately.
Structural Reliability Methodology

• Limit state consideration
• Probabilistic modelling
• Approximate evaluation of event probability (reliability)
  FOSM (H-L method)
  Simulation
• Probabilistic optimization
• Reliability profiles for changing climate
I Infrastructure Monitoring Data

- Time related “events” that define structural behaviour are often defined
- Many techniques are available for monitoring of structures and detection of particular conditions
- Technology is racing ahead (and will be even faster in the future) so more parameters will become available.
- Data is everywhere (maybe too much of it and possibly at too high price)
- It is becoming difficult to establish a rational processing mechanism for data from monitoring
- Methodologies are limited that enable decision makers to take advantage of technology advancement
II Acceptable Risk Levels

Functional
number of users, planning requirements, purpose of the structure, required space, speed of construction…

Environmental
use of materials, pollution, noise, re-cycling, energy consumption, maintenance requirements…

Safety
risk to users, from all life cycle stages (during construction, in service, during maintenance rehabilitation, …..)

Economy
limit on particular costs, at a given stage (equally applies to all life-cycle stages…….)

Other structure specific criteria
aesthetics, innovative material, site specific data…..
III Design optimization

\[ \text{A} \quad \min w(d_i) \]

s.t.

\[ f_j(d_i) \leq 0; j = 1, \ldots n \]

\[ d_i^l \leq d_i \leq d_i^u \]

\(w(d_i)\) objective function (e.g. minimum weight of the structure, minimum cost, etc.)

\(f_j(d_i)\) constraints (such as ultimate and serviceability limit states).
\[
\begin{align*}
\text{B} & \quad \min \ w (d_i, X_1) \\
\text{s.t.} & \quad \beta_j (d, X) - \bar{\beta}_j \geq 0; j = 1, \ldots n_j \\
& \quad d_i^L \leq d_i \leq d_i^U;
\end{align*}
\]

\(w(d_i, X_1)\) objective function (e.g. minimum weight of the structure, minimum cost, etc.)
\(\beta_j (d, X)\) reliability indices associated with relevant limit states.
\(\bar{\beta}_j\) target reliability indices.
General remarks

• The methodology is ideally placed for inclusion climate scenarios.
• The methodology is versatile and applicable for a variety of circumstances and problems
• Industrial applications are always possible
• Provides crucial data for risk evaluation
Thank you

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