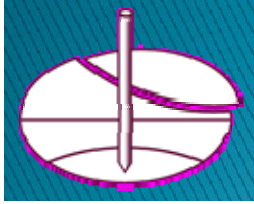
# Introduction to ETC10 Design Examples 2

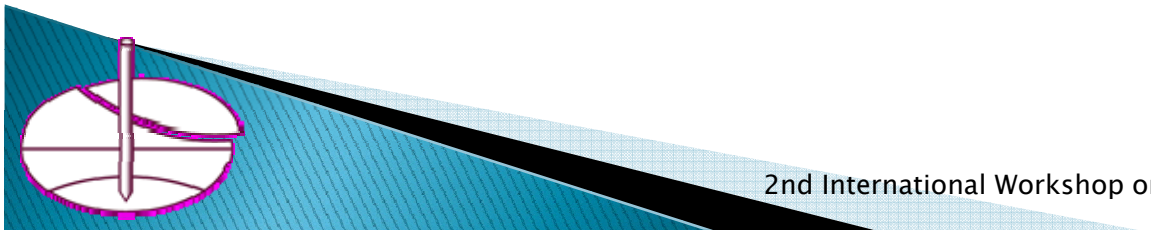
Andrew Bond



2nd International Workshop on Evaluation of Eurocode 7, Pavia, Italy, April 2010

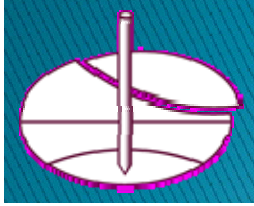
# Introduction to ETC10 Design Examples 2

- ETC10 Design Examples 1
- Survey procedure for Design Examples 2
- Contributions received
- Confidence in the designs
- Variation in the results
- Programme for tomorrow

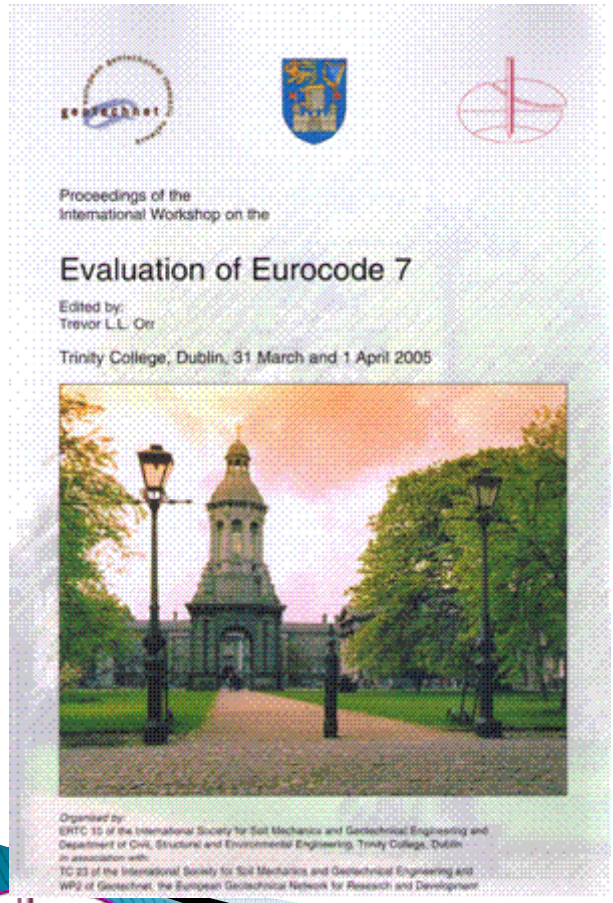


# ETC10 Design Examples 1

## Introduction to ETC10 Design Examples 2



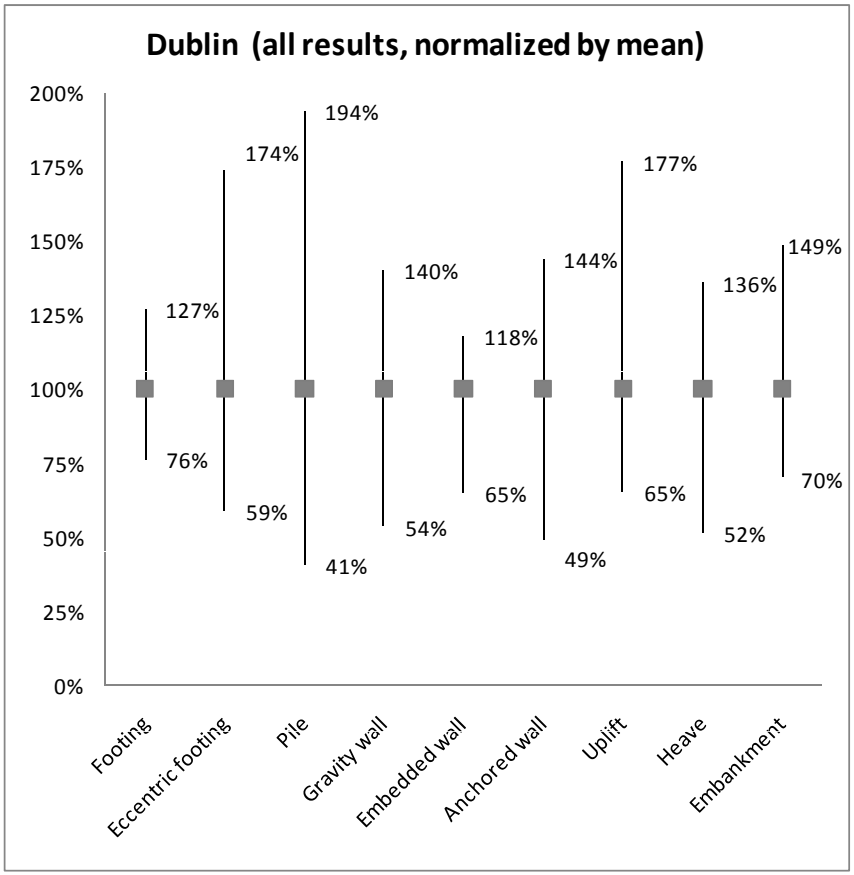
# 1st International Workshop on Evaluation of Eurocode 7, held in Dublin in 2005

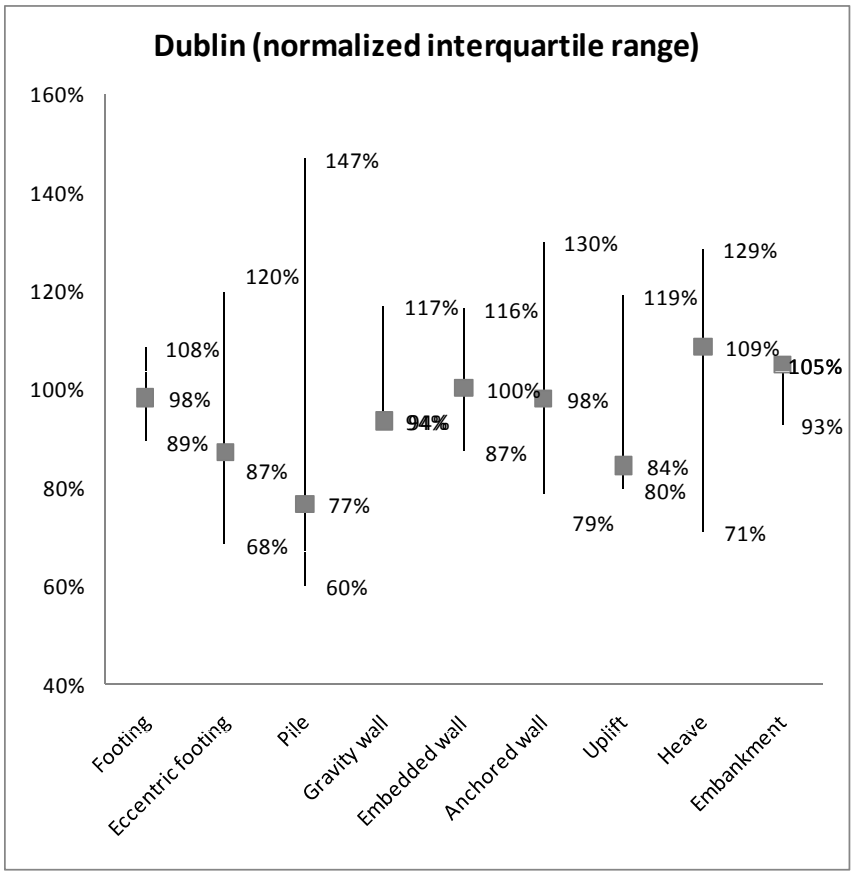



10 examples & 'model solutions':

1. Pad foundation with vertical central load
2. Pad foundation with inclined eccentric load
3. Pile foundation designed from soil parameter values
4. Pile foundation designed from pile load tests
5. Cantilever gravity retaining wall
6. Embedded retaining wall
7. Anchored retaining wall
8. Uplift of deep basement
9. Failure by hydraulic heave
10. Road embankment on soft clay

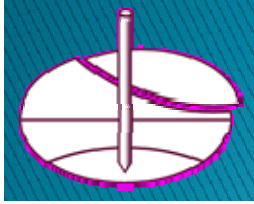
# Results of Dublin Workshop



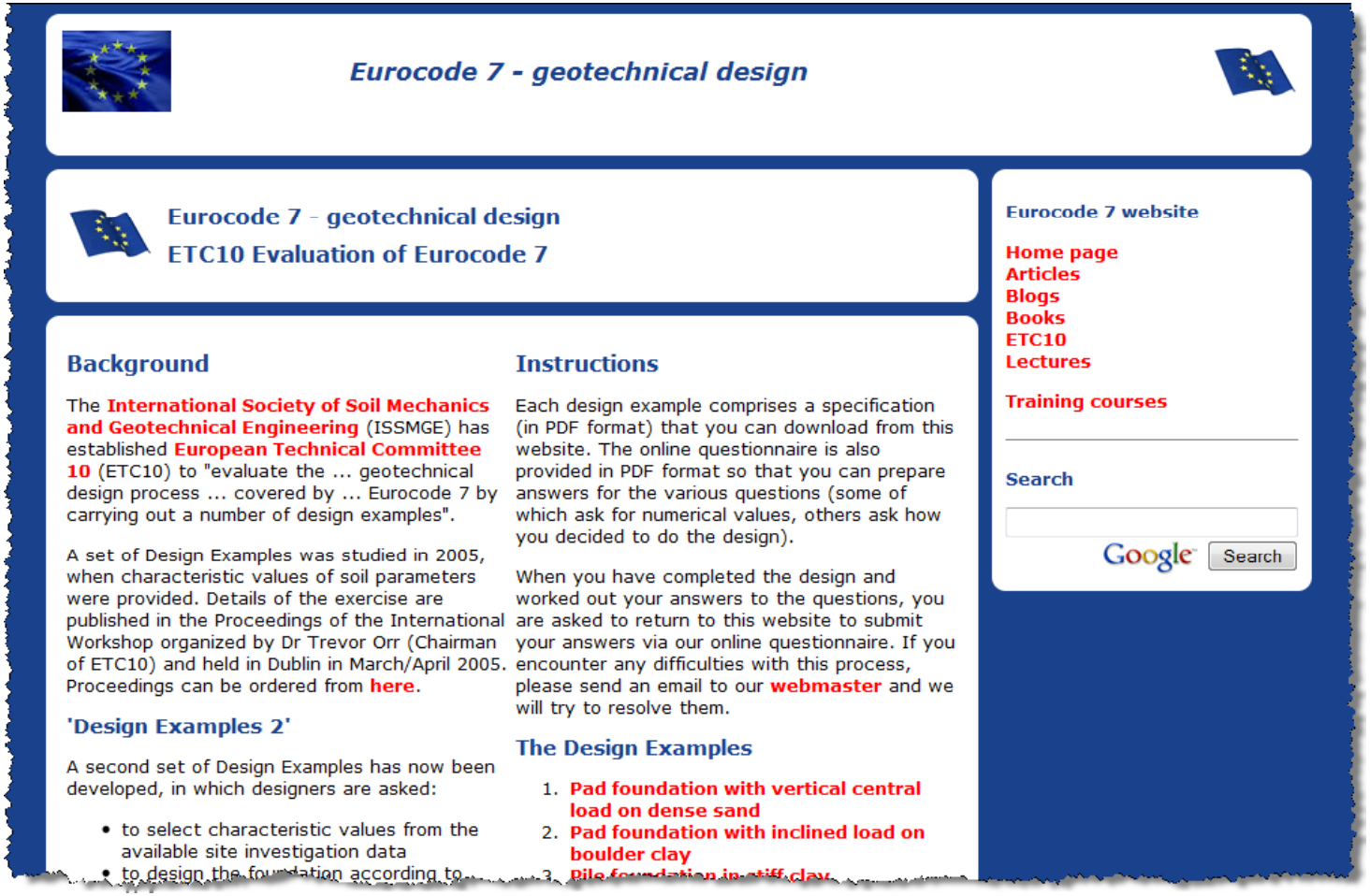



# Survey procedure for Design Examples 2

## Introduction to ETC10 Design Examples 2



# ETC10 micro-site established at www.eurocode7.com



*Eurocode 7 - geotechnical design*

**Eurocode 7 – geotechnical design**
**ETC10 Evaluation of Eurocode 7**

## Background

The **International Society of Soil Mechanics and Geotechnical Engineering** (ISSMGE) has established **European Technical Committee 10** (ETC10) to "evaluate the ... geotechnical design process ... covered by ... Eurocode 7 by carrying out a number of design examples".

A set of Design Examples was studied in 2005, when characteristic values of soil parameters were provided. Details of the exercise are published in the Proceedings of the International Workshop organized by Dr Trevor Orr (Chairman of ETC10) and held in Dublin in March/April 2005. Proceedings can be ordered from **here**.

## 'Design Examples 2'

A second set of Design Examples has now been developed, in which designers are asked:

- to select characteristic values from the available site investigation data
- to design the foundation according to

## Instructions

Each design example comprises a specification (in PDF format) that you can download from this website. The online questionnaire is also provided in PDF format so that you can prepare answers for the various questions (some of which ask for numerical values, others ask how you decided to do the design).

When you have completed the design and worked out your answers to the questions, you are asked to return to this website to submit your answers via our online questionnaire. If you encounter any difficulties with this process, please send an email to our **webmaster** and we will try to resolve them.

## The Design Examples

1. **Pad foundation with vertical central load on dense sand**
2. **Pad foundation with inclined load on boulder clay**
3. **Pile foundation in stiff clay**

**Eurocode 7 website**

**Home page**
**Articles**
**Blogs**
**Books**
**ETC10**
**Lectures**

**Training courses**

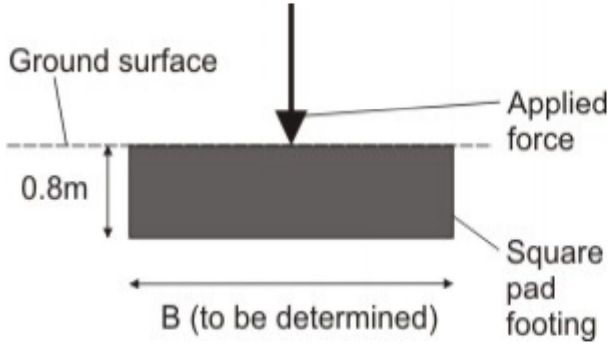
**Search**

Google Search

# Separate page for each of 6 Design Examples

## Design Example 2.1

The purpose of this design example is to investigate the way engineers design a pad foundation subject to vertical central loading and resting on sandy soil.




## Specification/downloads

**Specification of Design Example 2.1 (PDF)**
**Cone penetration data (Excel spreadsheet)**

## Questionnaire 2.1

Download a **Word copy of Questionnaire 2.1** to complete in draft before submitting your answers via the online questionnaire given below.

When you have decided on your answers to the questionnaire, please submit them to us using the online form **Questionnaire 2.1**.

Thank you for your contribution!

## Phase 2: benchmark exercise

Phase 2 of the exercise involves re-designing the foundation with benchmark characteristic values supplied to you in **this document**.

When you have re-designed the foundation, please submit your new answers using the following (modified) online form **Questionnaire 2.1 benchmark**.

Thank you once again for your contribution!

# Specification, raw data, and questionnaire provided for each Design Example

ETC10 Design Example 2.1 (version 07/06/2009)

**Example 2.1 Pad foundation with vertical central load on dense sand**

Note: this is a persistent design situation; for simplicity, accidental design situations do NOT need to be checked.

The square pad foundation shown in Figure 2.1a is made from concrete with a weight density of 25 kN/m$^3$ and has an embedment depth of 0.8 m. The ground surface shown can reliably be assumed to be below any topsoil and disturbed ground.

The foundation is required to support the following characteristic loads:

| | | |
|---|---|---|
| Permanent: | Vertical | $G_{k,1}$ = 1000 kN, excluding weight of foundation |
| | Horizontal | $G_{k,1}$ = 0 |
| Variable: | Vertical | $Q_{k,1}$ = 750 kN |
| | Horizontal | $Q_{k,1}$ = 0 |

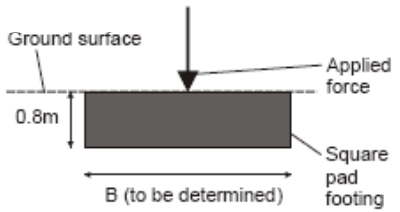



Figure 2.1a: Pad foundation (square on plan)

The soil consists of a very dense fine glacial outwash sand with a mean particle size of 0.14 mm. The soil has a bulk weight density of 20 kN/m$^3$ and close to 100% relative density. The ground water level is 6 m below ground level. The water content above the water table is 11% and the degree of saturation is 71%. Bedrock underlies the sand at 8m depth.

A plan of the site is given in Figure 2.1b showing the locations of four CPT tests carried out on the site with respect to the centre of the proposed foundation. The results of the four CPT tests are plotted separately in Figures 2.1c (1-4) and all the $q_c$ values are plotted together in Figure 2.1d and listed in Table 2.1a.

The foundation is to be designed to Eurocode 7 to determine the foundation width when the maximum allowable settlement is 25 mm. There is no need to consider any effects due to frost or vegetation. The foundation's design working life is 50 years.

| | D | E | F | G |
|---|---|---|---|---|
| | on 09/05/2009) | | | |
| | **n vertical central load on dense sand** | | | |
| | CPT 2 | | CPT 3 | |
| | qc (MPa) | fs (MPa) | qc (MPa) | fs (MPa) |
| | 5.41 | 0.018 | 8.78 | 0.0091 |
| | 9.37 | 0.0456 | 9.89 | 0.0256 |
| | 10.1 | 0.0928 | 10.05 | 0.0453 |
| | 8.94 | 0.0959 | 8.96 | 0.0616 |
| | 9.14 | 0.0751 | 8.38 | 0.0633 |
| | 10.1 | 0.0679 | 9.27 | 0.038 |
| | 9.78 | 0.0829 | 10.78 | 0.0533 |
| | 9.38 | 0.0811 | 12.17 | 0.0883 |
| | 8.95 | 0.1003 | 13.42 | 0.1222 |
| | 10.18 | 0.1098 | 13.63 | 0.1603 |
| | 10.82 | 0.1156 | 12.03 | 0.1362 |
| | 11.48 | 0.1239 | 14.79 | 0.1366 |
| | 11.81 | 0.1266 | 17.5 | 0.167 |
| | 11.69 | 0.1309 | 15.68 | 0.1789 |
| | 13.58 | 0.1363 | 13.83 | 0.1326 |
| | 17.3 | 0.1596 | 13.7 | 0.1224 |
| | 16.51 | 0.157 | 14.51 | 0.1214 |
| | 13.15 | 0.1806 | 13.03 | 0.1272 |
| | 12.81 | 0.186 | 12.15 | 0.1256 |
| | 13.49 | 0.1805 | 12.87 | 0.1252 |
| 28 | 2.1 | 13.68 | 0.1963 | 12.98 | 0.1863 | 16.76 | 0.1384 |
| 29 | 2.2 | 14.45 | 0.1812 | 14.21 | 0.1973 | 16.24 | 0.1452 |
| 30 | 2.3 | 13.91 | 0.1863 | 14.36 | 0.1902 | 17.48 | 0.2689 |
| 31 | 2.4 | 13.24 | 0.1997 | 14.38 | 0.1819 | 16.16 | 0.2628 |

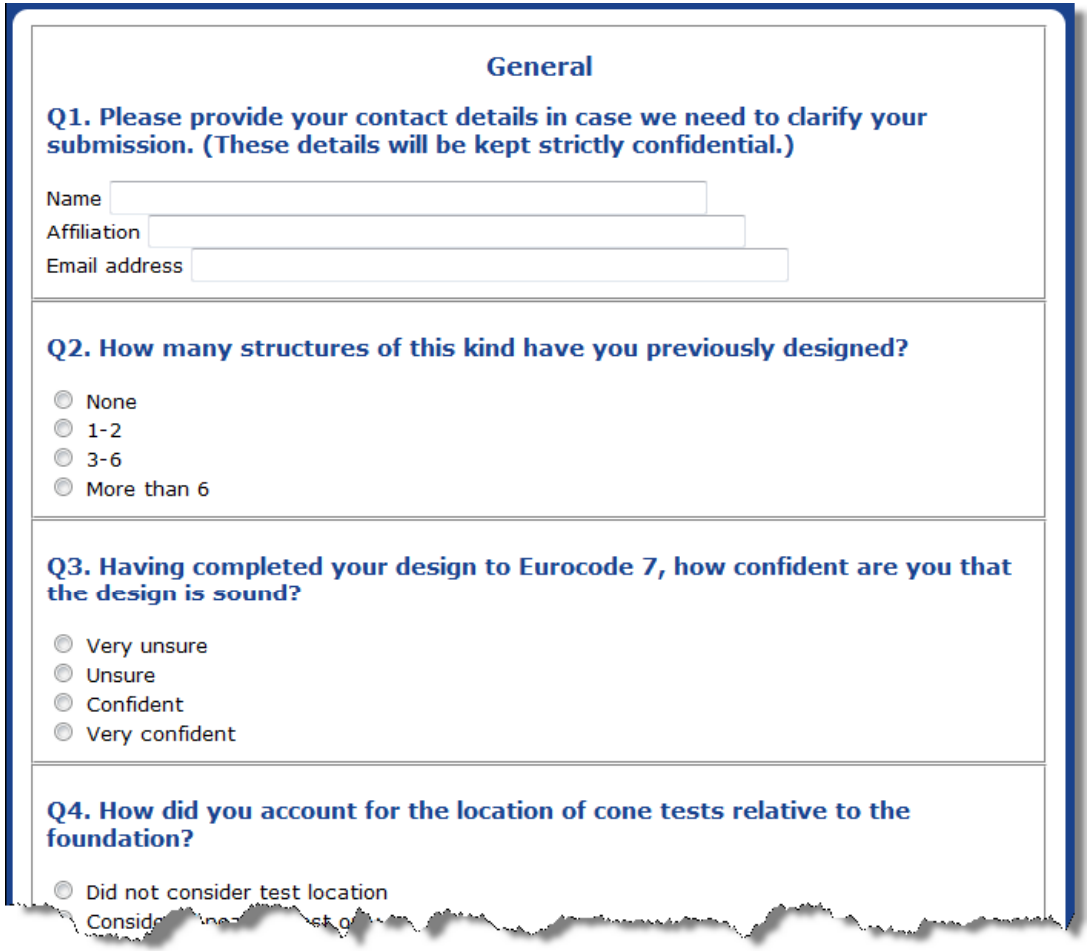
Sheet1 Sheet2 Sheet3

ETC10 Questionnaire 2.1 (version 07/07/2009)

**Example 2.1 Pad foundation with vertical central load on dense sand**
Note: this is a persistent design situation; for simplicity, accidental design situations do NOT need to be checked.

| | Question | Instruction | Answer |
|---|---|---|---|
| | **GENERAL** | | |
| 1 | Please provide your contact details in case we need to clarify your submission* | *Will be kept strictly confidential | Name<br>Affiliation<br>Email address |
| 2 | How many structures of this kind have you previously designed? | Tick one | ☐ None ☐ 1-2 ☐ 3-5 ☐ More than 5 |
| 3 | Having completed your design to Eurocode 7, how confident are you that the design is sound? | Tick one | ☐ Very unsure ☐ Unsure ☐ Confident ☐ Very confident |
| 4 | How did you account for the location of cone tests relative to the foundation? | Tick one | ☐ Did not consider test location<br>☐ Considered nearest test only<br>☐ Considered 'average' of all tests<br>☐ Considered trend of all tests, biased towards nearest<br>☐ Other (specify) … |
| 5 | Please explain the reasons for your answer to Q4 | Free text | |
| | **SERVICEABILITY LIMIT STATE** | | |
| 6 | Which parameters did you use for the SLS design of the spread foundation? | Tick all that apply | ☐ Cone resistance $q_c$ ☐ Cone sleeve friction $f_s$<br>☐ Young's modulus of elasticity E' ☐ Poisson's ratio ν<br>☐ Shear modulus of elasticity G<br>☐ Other (specify) … |
| 7 | What correlations did you use to derive soil parameter values (if used) for the SLS verification? If more than one, please list others below | Free text | Description:<br>Author:<br>Title:<br>Pages: |
| 7a | Any other correlations? (please give same info as above) | Free text | |
| 8 | What assumptions did you make in choosing these correlations? | Free text | |
| 9 | How did you account for any variation in parameters with depth? | Tick one | ☐ Ignored variation with depth ☐ Assumed linear variation<br>☐ Assumed bi-linear variation ☐ Assumed stepped variation<br>☐ Other (specify) … |
| 10 | Please explain the reasons for your answer to Q9 | Free text | |
| 11 | What is the characteristic value of $q_c$ at these depths? | Provide values in units of MPa | At 1 m : $q_c$ = At 2 m : $q_c$ = At 4 m : $q_c$ = |
| 12 | What is the characteristic value of E' for a linear elastic calculation at these depths? | Provide values in units of MPa | At 1 m : E = At 2 m : E = At 4 m : E = |
| 13 | How did you assess these values? | Tick all that apply | ☐ By eye ☐ By linear regression ☐ By statistical analysis<br>☐ From an existing standard (specify) …<br>☐ From a published correlation (specify) …<br>☐ Comparison with a previous design<br>☐ From the soil description, not using the data<br>☐ Other (specify) … |
| 14 | Which calculation model did you use to determine settlement? | Tick one | ☐ Annex F.1 from EN 1997-1 ☐ Annex F.2 from EN 1997-1<br>☐ Annex D.3 from EN 1997-2 ☐ Annex D.4 from EN 1997-2<br>☐ Annex D.5 from EN 1997-2<br>☐ Alternative from national annex (specify) …<br>☐ Alternative from national standard (specify) …<br>☐ Finite element analysis ☐ Finite difference analysis<br>☐ Other (specify) … |
| 15 | What width does the foundation need to avoid a serviceability limit state? | Provide value in m | $B_{req}$ = |
| | **ULTIMATE LIMIT STATE** | | |
| 16 | Which parameters did you use for the ULS design of the spread foundation? | Tick all that apply | ☐ Cone resistance $q_c$ ☐ Cone sleeve friction $f_s$<br>☐ Angle of shearing resistance φ' ☐ Effective cohesion c'<br>☐ Angle of interface friction δ<br>☐ Other (specify) … |

# Participants encouraged to submit answers via on-line questionnaire



General

**Q1. Please provide your contact details in case we need to clarify your submission. (These details will be kept strictly confidential.)**

Name
Affiliation
Email address

**Q2. How many structures of this kind have you previously designed?**

- None
- 1-2
- 3-6
- More than 6

**Q3. Having completed your design to Eurocode 7, how confident are you that the design is sound?**

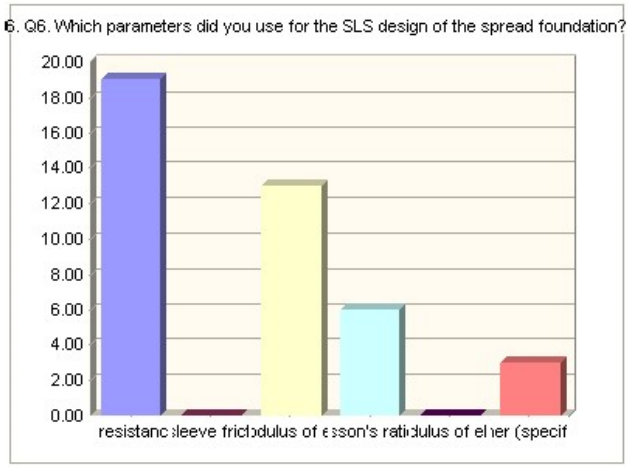
- Very unsure
- Unsure
- Confident
- Very confident

**Q4. How did you account for the location of cone tests relative to the foundation?**

- Did not consider test location
- Consid

# On-line questionnaire enabled automatic generation of result summary

**6. Q6. Which parameters did you use for the SLS design of the spread foundation?**

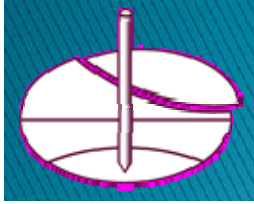



| Response | Count | Percent |
|---|---|---|
| Cone resistance $q_c$ | 19 | 86.36% |
| Cone sleeve friction $f_s$ | 0 | 0.00% |
| Young's modulus of elasticity E' | 13 | 59.09% |
| Poisson's ratio n | 6 | 27.27% |
| Shear modulus of elasticity G | 0 | 0.00% |
| Other (specify) | 3 | 13.64% |

| Response ID | Other (specify) |
|---|---|
| 21 | Eeod |
| 45 | pressure dependet modulus of elasticity according to OHDE |
| 117 | stiffness modulus from the Oedometer-test (Es) |

# Contributions received

## Introduction to ETC10 Design Examples 2



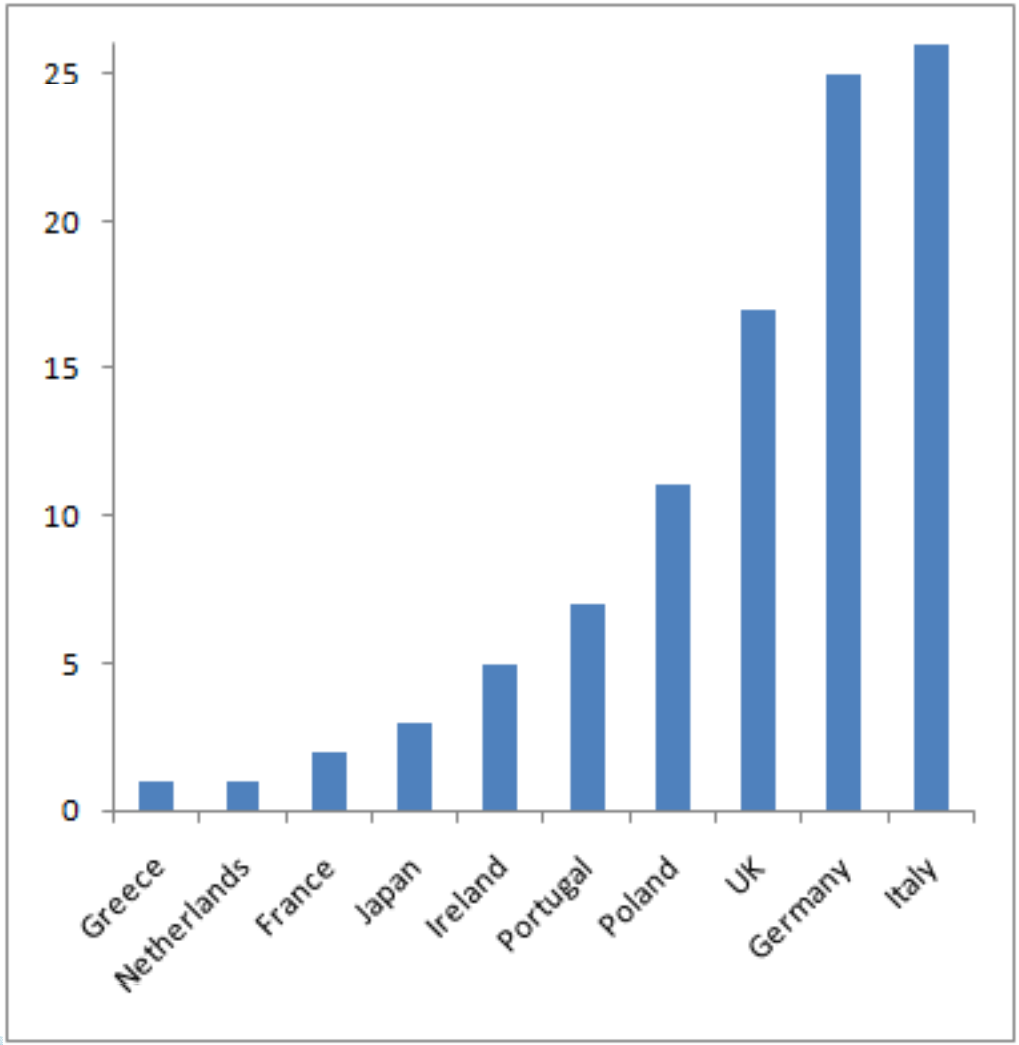
# Number of responses received for each Design Example

| Design Example | Description | No responses | Reporter (MG advisor) |
|---|---|---|---|
| 2-1 | Pad foundation with vertical central load on dense sand | 24 | Carsten Sørensen (Trevor Orr) |
| 2-2 | Pad foundation with inclined load on boulder clay | 15 | Norbert Vogt (Giuseppe Scarpelli) |
| 2-3 | Pile foundation in stiff clay | 17 | Adriaan van Seters (Brian Simpson) |
| 2-4 | Earth and pore water pressures on basement wall | 17 | Hans Schneider (Andrew Bond) |
| 2-5 | Embankment on soft peat | 12 | Eric Farrell (Bernd Schuppener) |
| 2-6 | Pile foundation in sand | 13 | Boleslaw Klosinski (Roger Frank) |
| | *Total* | 98 | |

# Thanks to all these (64) contributors

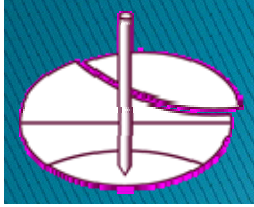
Luigi Albert
Lorenzo Allievi
Tiziana De Angelis
Sean Arnold
Benjamin Aulbach
Marco Balducci
Raffaella Di Battista
Jose Mateus de Brito
Building Research Institute (PL)
David Carlaccini
E. Cattoni
M. Cecconi
Claudio Consorti
Phil Cullen
Alastair Curry
Claus Dannenmann
Tiziana De Angelis
Jonathan Dewsbury
Jeannine Eisenmann
Anita Etz
Silvia Ferrero
Federica Formato
Marco Franceschini
Roger Frank
Beata Gajewska
Paweł Galas
Hans-Georg Guelzow
Takashi Hara
Dirk Heckhoff
Yusuke Honjo
Philip Jenkins
H.-G. Kempfert
ThuyChung KieuLe
Dariusz Kiziewicz
Boleslaw Klosinski
Adam Krasinski
Sylvia Kuerten
Mariusz Leszczynski
Frank Lettko
Judith Lonzen
J. Lueking
Eleonora di Mario
Luca Masini
Jacques Monnet
Paolo Orlandini
Trevor Orr
Isabella Pacek
Roberto Persio
Francesco Petrella
Simona Sacconi
Monika Sawka
Giuseppe Scarpelli
Valentina Schembri
Joerg Schreiber
Bernd Schuppener
Brian Simpson
Panagiotis Sitarenios
Carsten Sorensen
Stephan Stalter
Mario Steinhagen
Fritz Strauss
Elias Tafur
S. Thomas
Oleksandr Zimels

# Contributions by country (10 total)

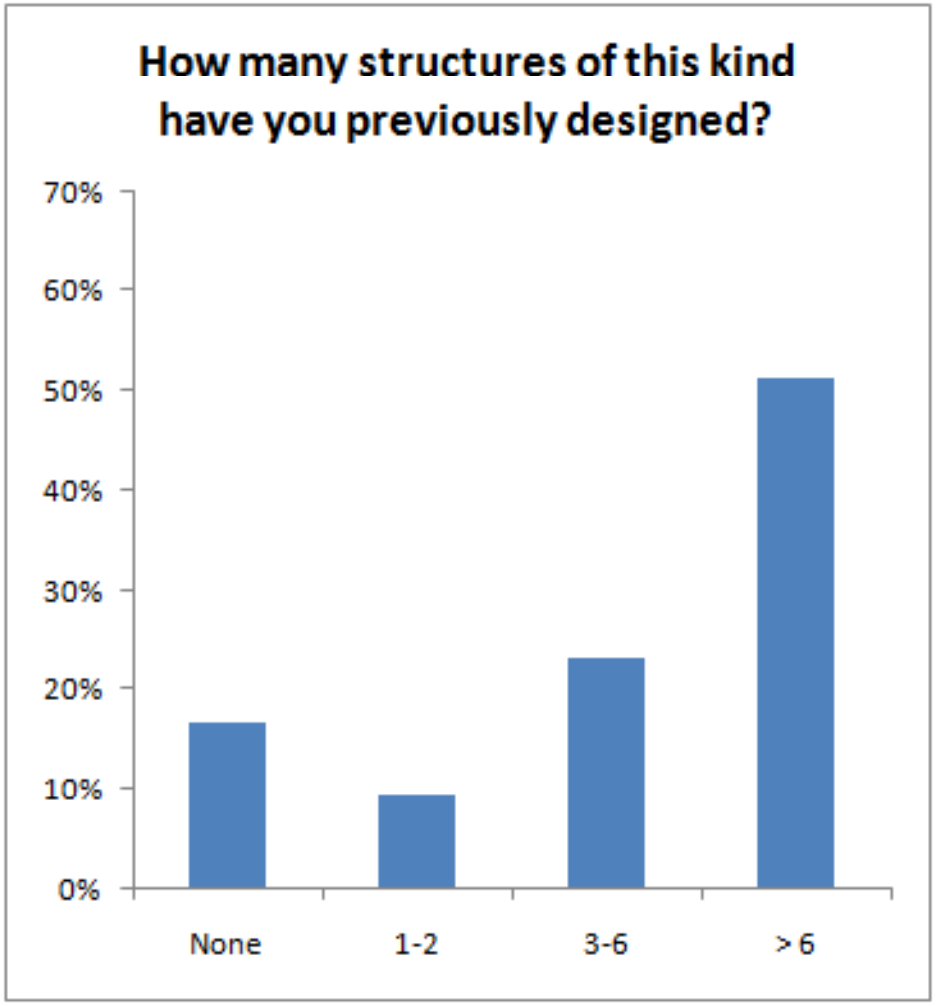


# Confidence in the designs

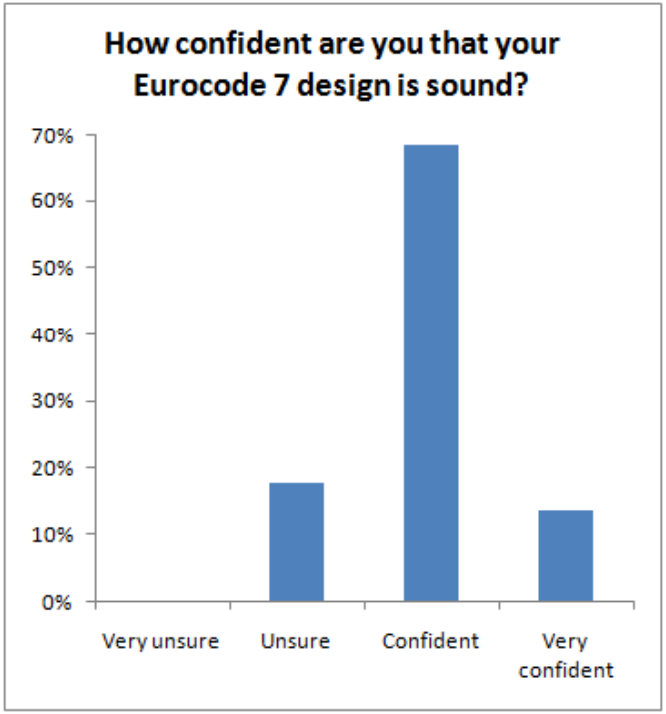
## Introduction to ETC10 Design Examples 2

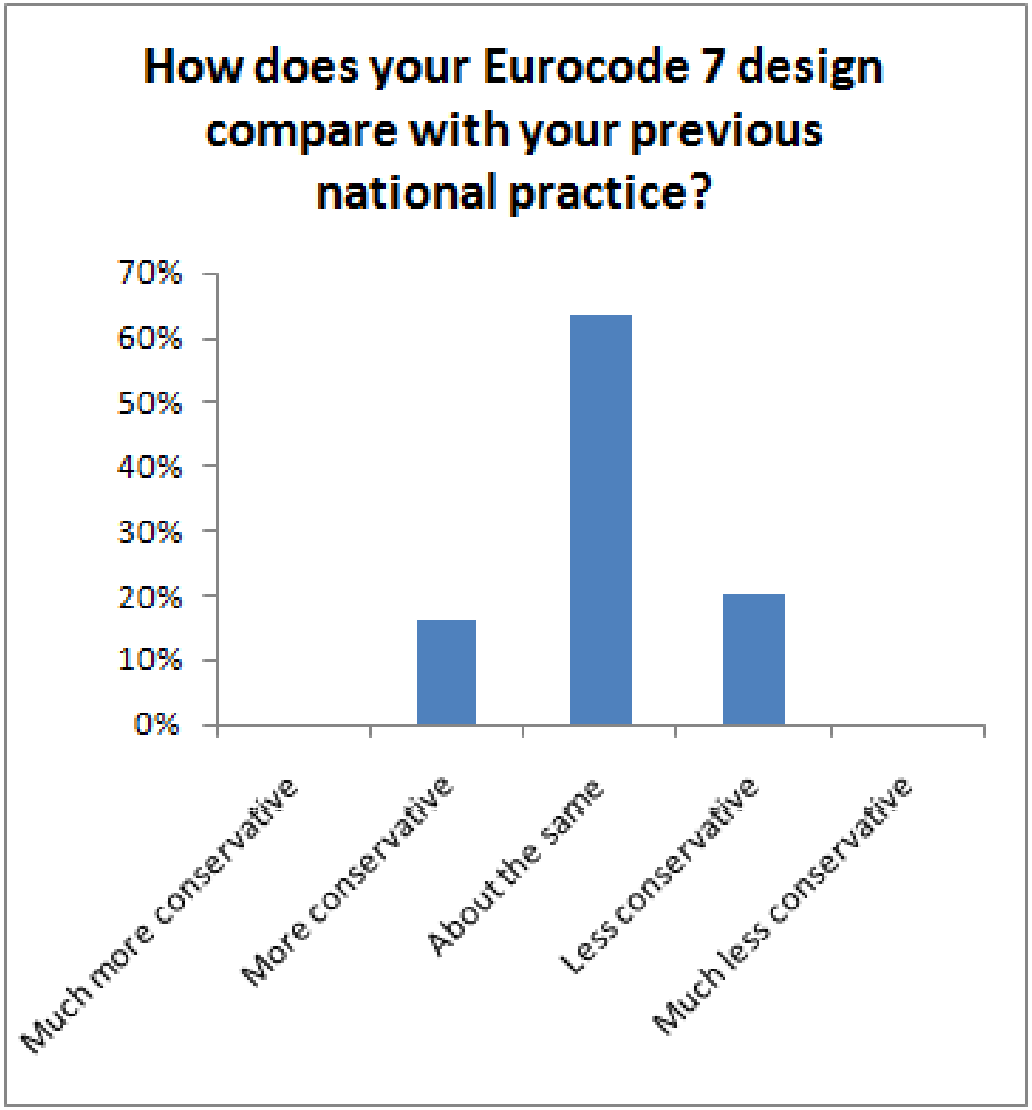


# Respondents' experience of designing the specified foundations

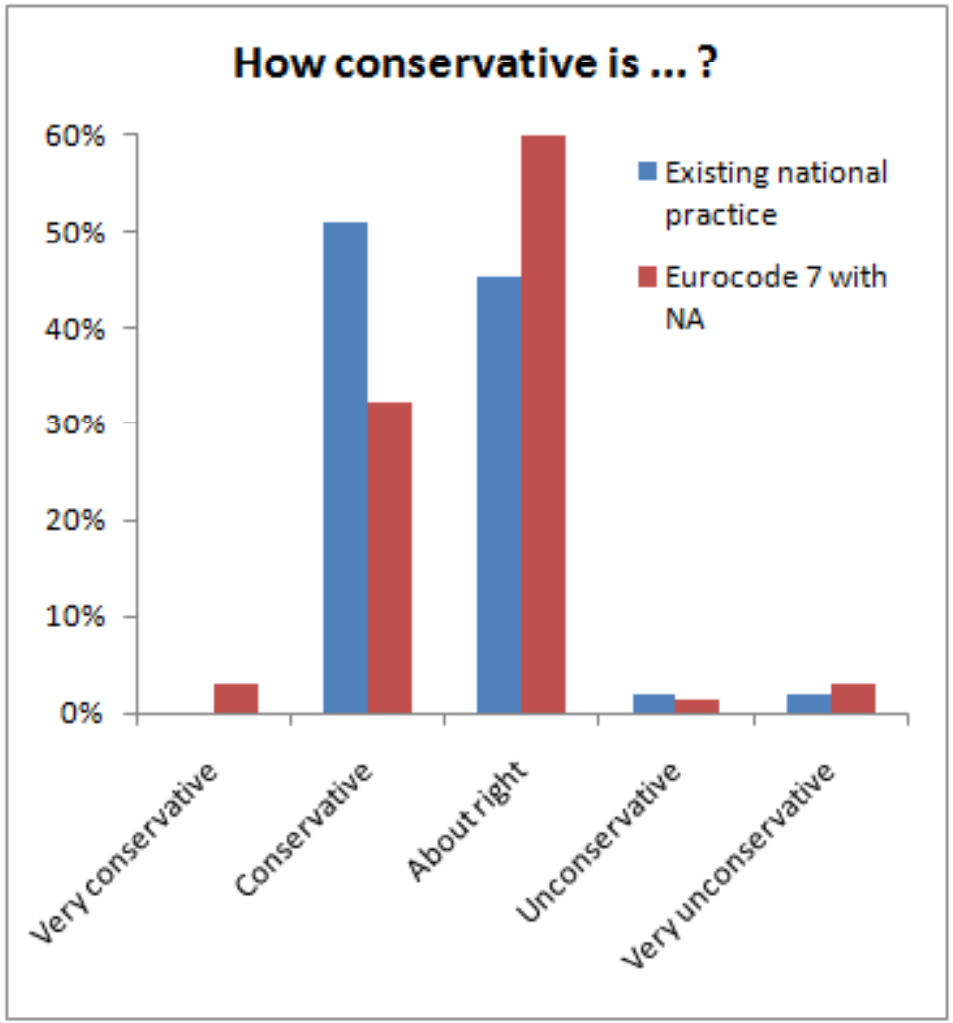


# Respondents' confidence in their Eurocode 7 designs



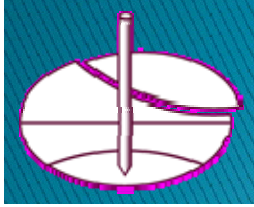



# Respondents think that Eurocode 7 is less conservative than existing national practice

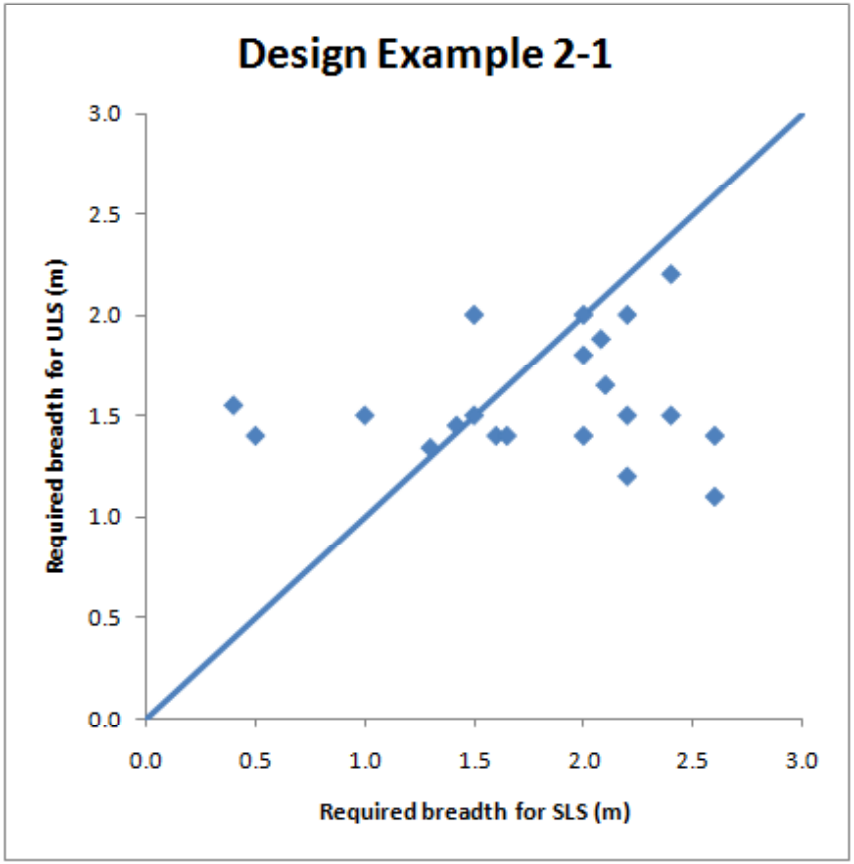


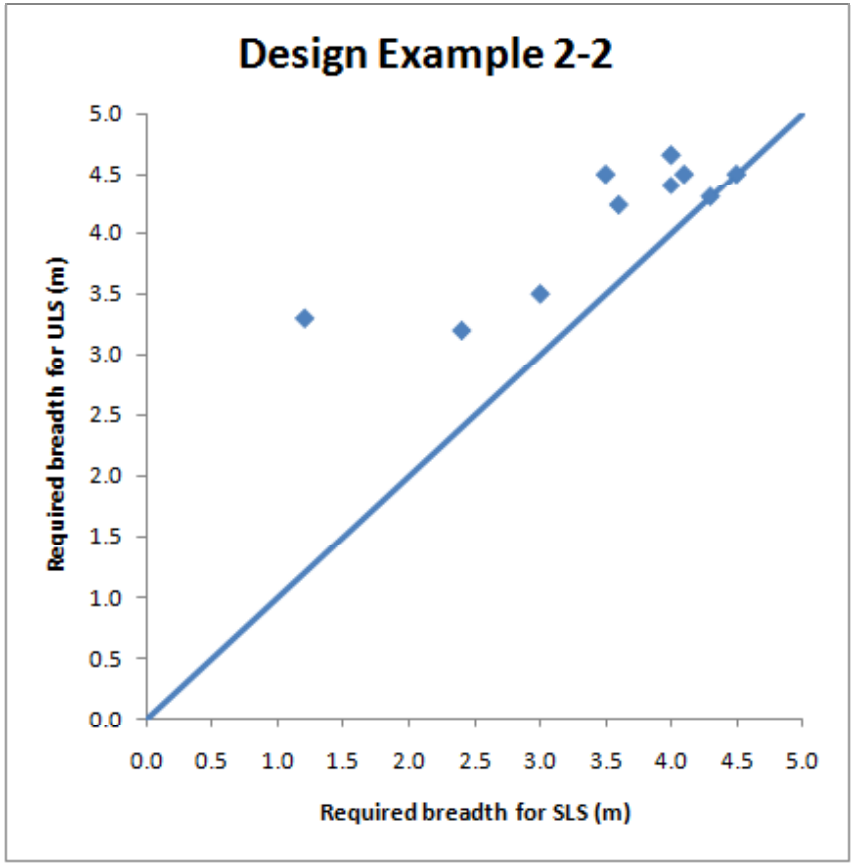
# Variation in the results

## Introduction to ETC10 Design Examples 2

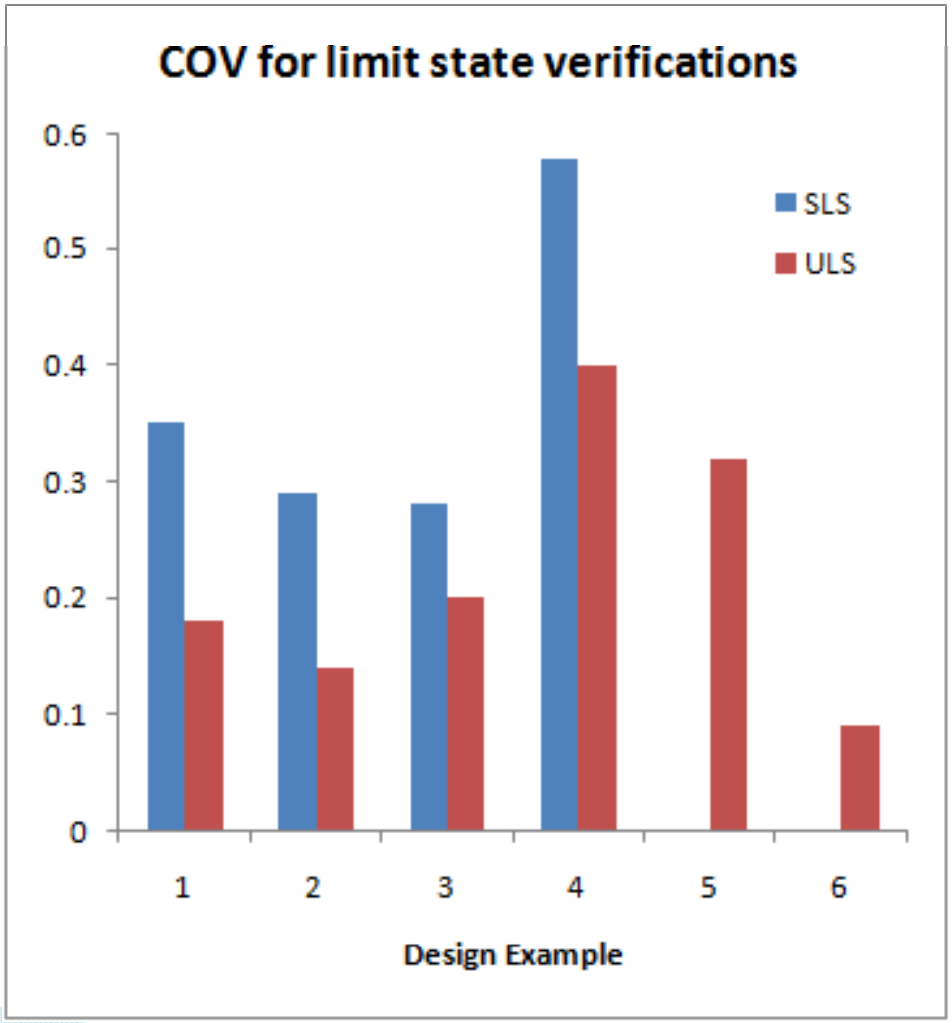


# Required foundation width B for Design Examples 2–1 and 2–2

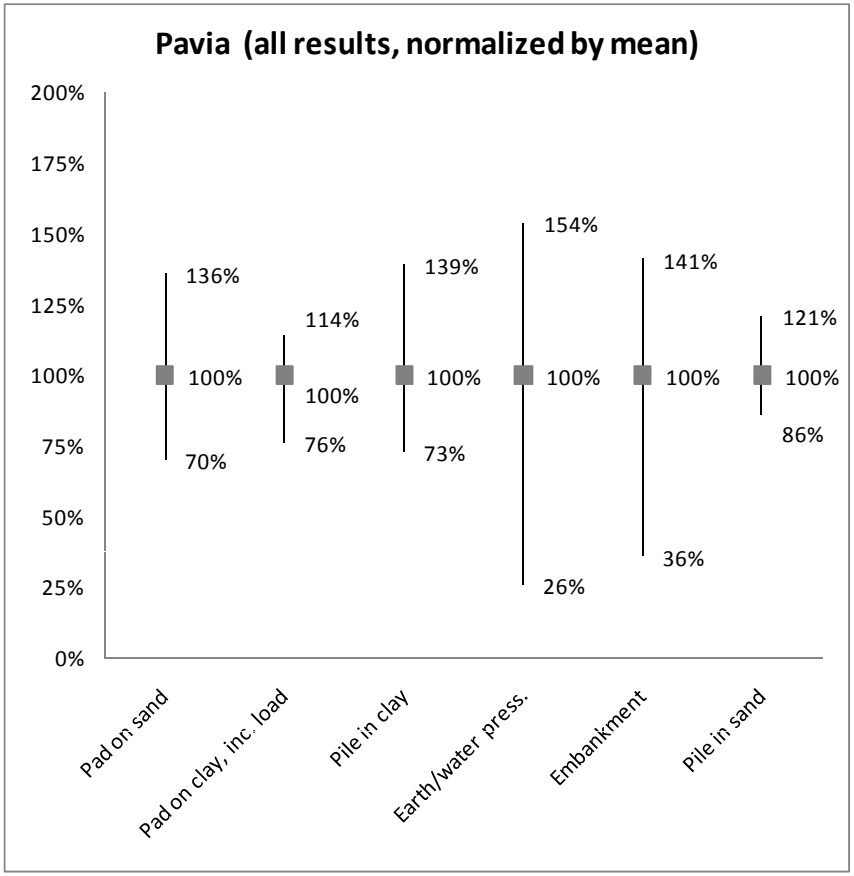


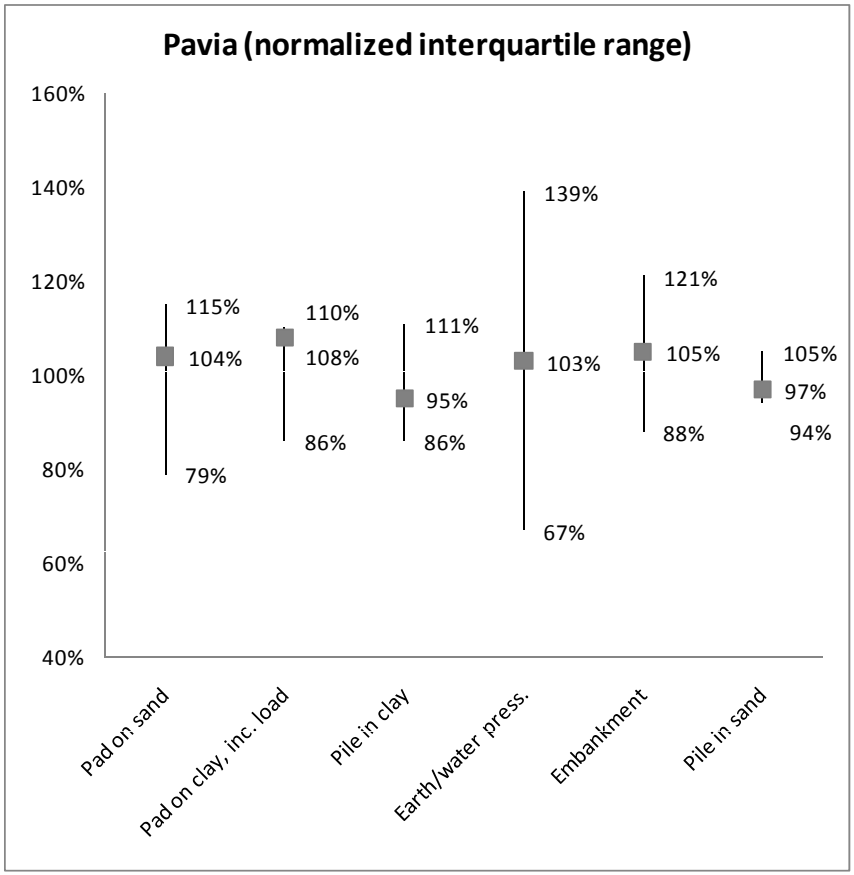



# Coefficient of variation is greater for SLS than for ULS verifications

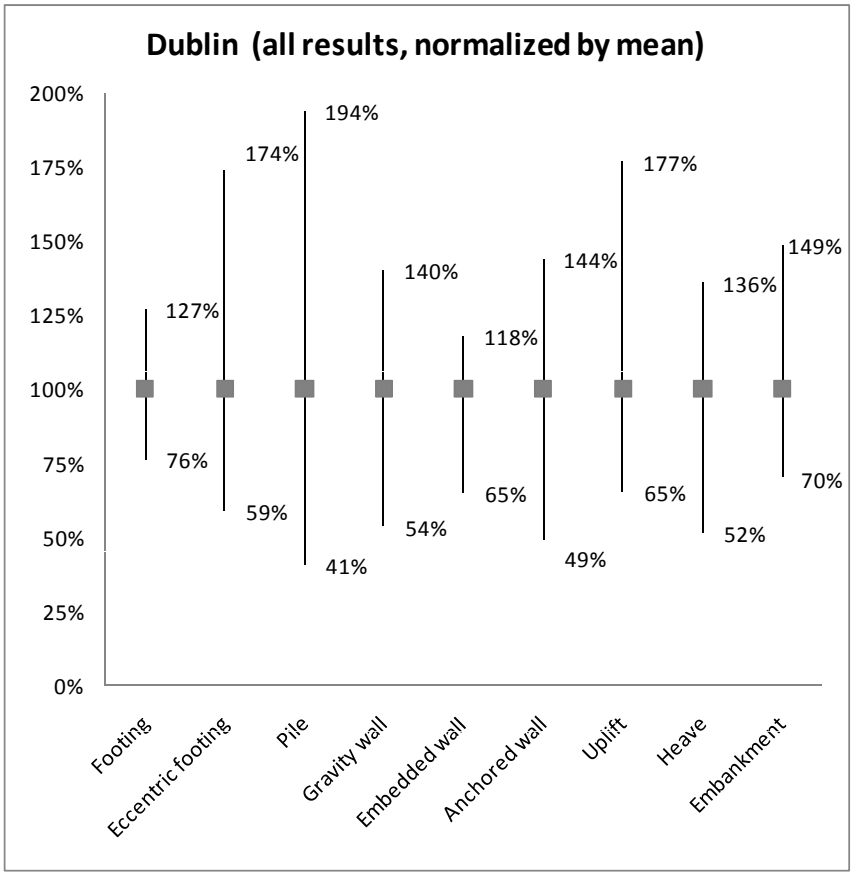


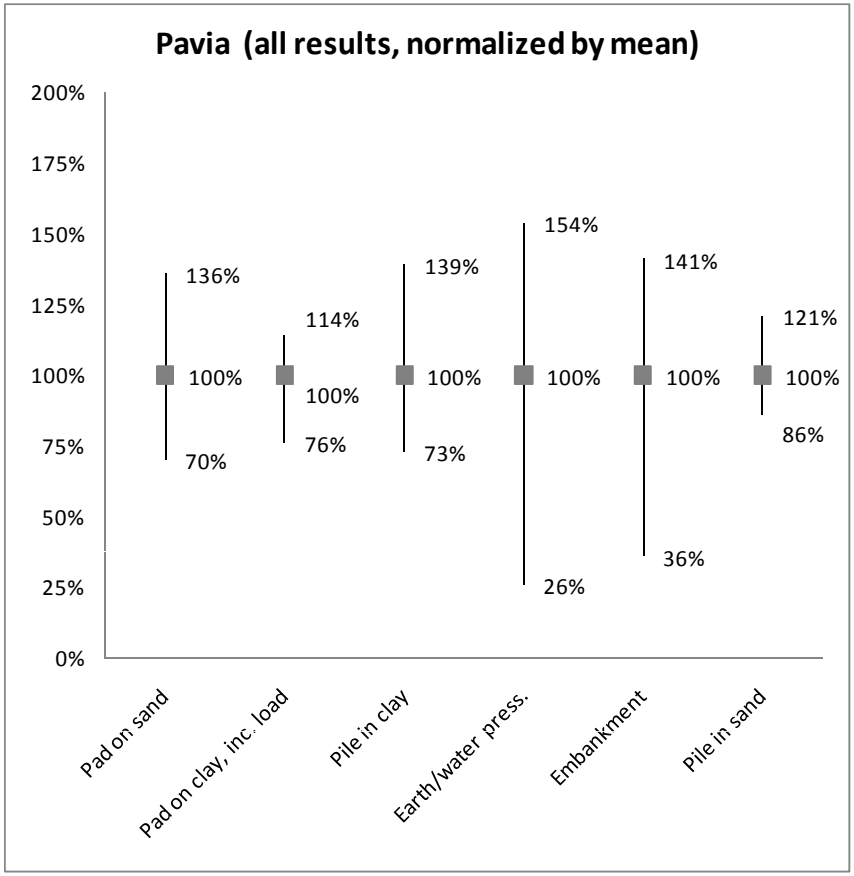
# Results of Design Examples 2



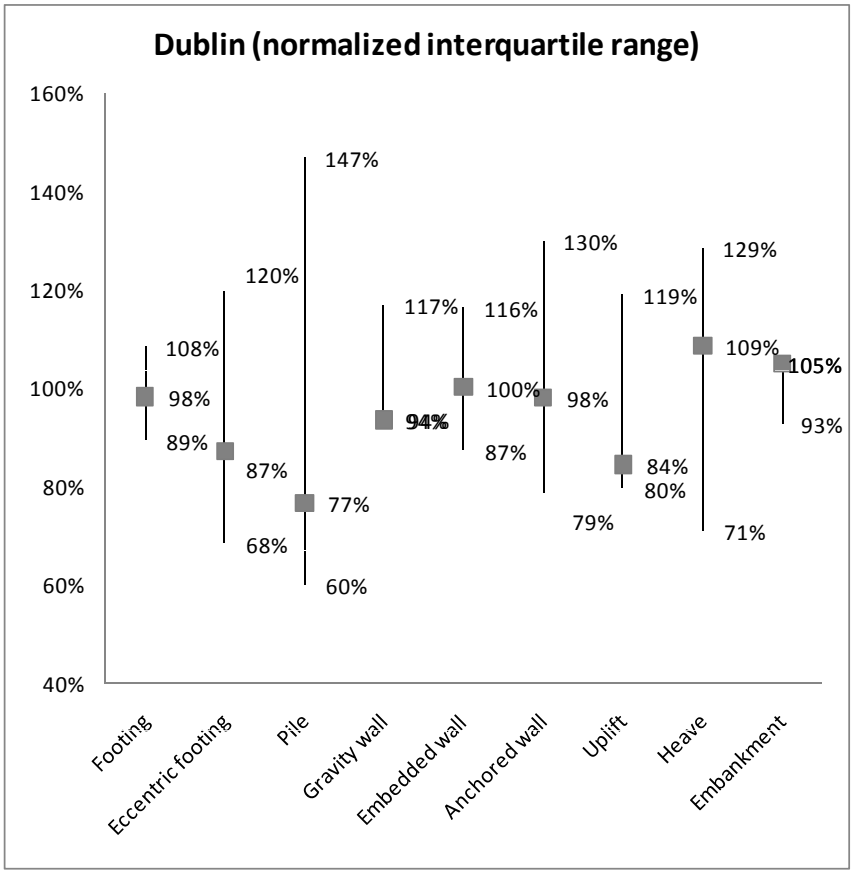



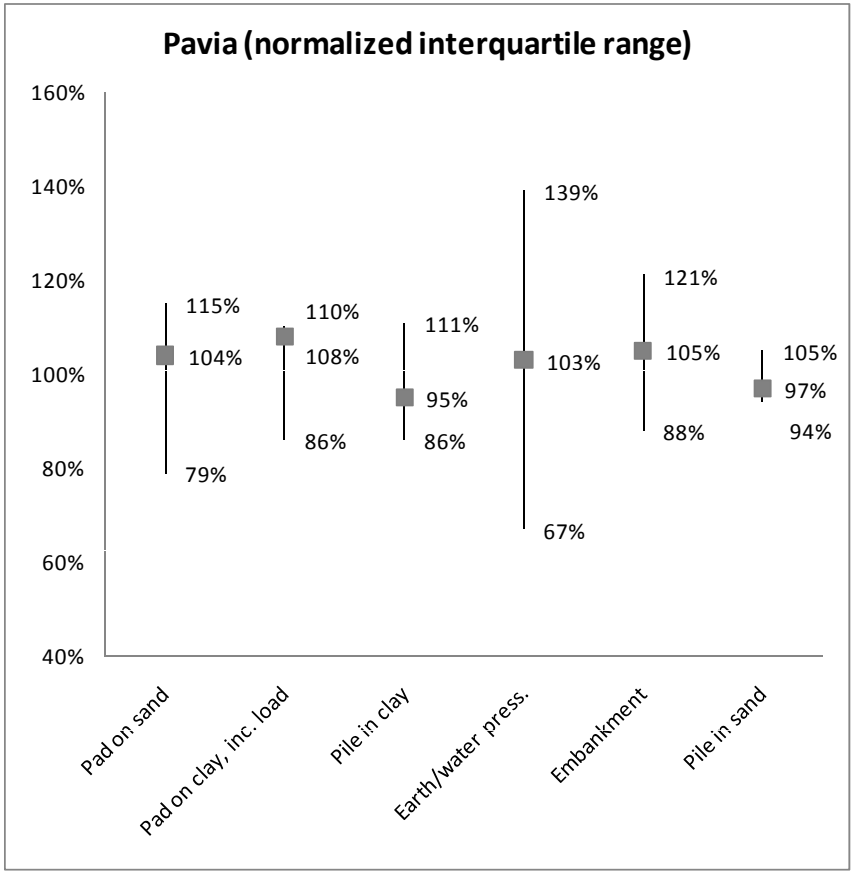
# Dublin and Pavia compared – all results



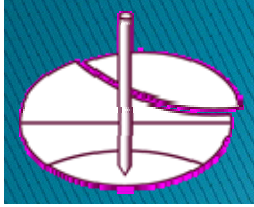
# Dublin and Pavia compared – interquartile range



# Programme for tomorrow

## Introduction to ETC10 Design Examples 2



# Presentations on Day 2 – morning

## Session 2 (Chair: Giuseppe Scarpelli)

09.00 Report on Design Example 2.1 – Foundation with central vertical load (Carsten Sørensen)

09.30 Report on Design Example 2.2 – Foundation with inclined load (Norbert Vogt)

10.00 Discussion of Design Examples 2.1 and 2.2

10.30 Coffee break

11.00 Report on Design Example 2.4 – Earth & pore water pressures on basement walls (Hans Schneider)

11.30 Eurocode 7 designs for water pressures and review of survey (Brian Simpson)

12.15 Discussion on Design Example 2.4 and water pressures

13.00 Lunch

# Presentations on Day 2 – afternoon

## Session 3 (Chair: Trevor Orr)

14.00 Reliability analyses of the Design Examples (Yusuke Honjo – former Chairman TC23)

14.40 Report on Design Example 2.5 – Embankment of soft peat (Eric Farrell)

15.10 Discussion of Example 2.5

15.30 Coffee break

16.00 Report on Design Example 2.3 – Pile foundation in stiff clay (Adriaan van Seters)

16.30 Report on Design Example 2.6 – Pile foundation in sand (Boleslaw Klosinski)

17.00 Discussion of Design Examples 2.3 and 2.6

17.30 Closure

19.30 Workshop Dinner