GROUND CHARACTERIZATION

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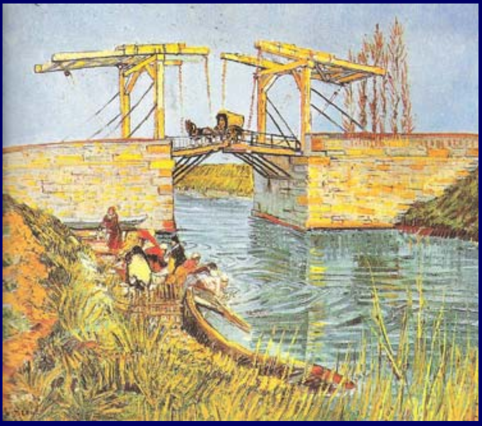


Langlois bridge – Van Gogh 1888

TOPICS

1. Introduction
2. General Basis of EC7
3. Ground Characterization
4. Ground Investigation Report
5. Derived Values, Characteristiques Values and Design Values
6. General Principles for Statistical Evaluations of Materials
7. Physical and Mathematical Modelling
8. Interaction with Other Codes
9. Conclusions

The Journey of a Thousand of Miles Begins With One Step

Lao - Tsze, Maxin 64

EUROCODE 7- GEOTECHNICAL DESIGN

Section 1: General
Section 2: Basis of Geotechnical Design
Section 3: Geotechnical Data
Section 4: Supervision of Construction, Monitoring and Maintenance
Section 5: Fill, Dewatering, Ground Improvement and Reinforcement
Section 6: Spread Foundations
Section 7: Pile Foundations
Section 8: Anchorages
Section 9: Retaining Structures
Section 10: Hydraulic failure
Section 11: Overall stability
Section 12: Embankments

EUROCODE 7- GEOTECHNICAL DESIGN

Annex A (normative) Partial and correlation factors for ultimate limit states and recommended values.
Annex B (informative) Background information on partial factors for Design Approaches 1, 2 and 3.
Annex C (informative) Sample procedures to determine limit values of earth pressures on vertical walls.
Annex D (informative) A sample analytical method for bearing resistance calculation.
Annex E (informative) A sample semi-empirical method for bearing resistance estimation.
Annex F (informative) Sample methods for settlement evaluation.
Annex G (informative) A sample method for deriving presumed bearing resistance for spread foundations on rock.
Annex H (informative) Limiting values of structural deformation and foundation movement.
Annex J (informative) Checklist for construction supervision and performance

monitoring

LIMIT STATES

- Each geotechnical design situation shall be verified that no relevant limit state is exceeded

- Limit states can occur either in the ground or in the structure or by combined failure in the structure and the ground

- Limit states should be verified by one or a combination of the following methods: design by calculation, design by prescriptive measures, design by loads tests and experimental models and observational method.

VERIFICATION OF LIMIT STATES

- Loss of equilibrium of the structure or the ground, considered as a rigid body, in which the strengths of structural materials and the ground are insignificant in materials providing resistance (EQU)
- Internal failure or excessive deformation of the structure or structural elements, including footings, piles, basement walls, etc., in which the strength of structural is significant in providing resistance (STR)
- Failure or excessive deformation of the ground, in which the strength of soil or rock is significant in providing resistance (GEO)
- Loss of equilibrium of the structure or the ground due to uplift by water pressure (buoyancy) or other vertical actions (UPL)
- Hydraulic heave, internal erosion and piping in the ground caused by hydraulic gradients (HYD)

VERIFICATION OF LIMIT STATES

Design by calculation involves:

Actions, which may be either imposed loads or imposed displacements, for example from ground movements;
Properties of soils, rocks and other materials;
Geometrical data;
Limiting values of deformations, crack widths, vibrations etc.;
Calculation models;
The calculation model may consist of: (i) an analytical model (ii) a semi-empirical model; (iii) or a numerical model

SERVICEABILITY LIMIT STATES

- The selection of design values for limiting movements and deformations shall take account of the following:

i) the confidence with which the acceptable value of the movement can be specified;
(ii) the occurrence and rate of ground movements;
(iii) the type of structure;
iv) the type of construction material;
(v) the type of foundation;
(vi) the type of ground;
(vii) the mode of deformation;
(viii) the proposed use of the structure;
(ix) the need to ensure that there are no problems with the services entering the structure.

Icarus wax Wings conceived by Daedalus

GEOTECHNICAL CATEGORIES

- Geotechnical Category 1 includes small and relatively simple structures
- Geotechnical Category 2 includes conventional types of structure and foundation with no exceptional risk or difficult soil or loading conditions
- Geotechnical Category 3 includes: (i) very large or unusual structures; (ii) structures involving abnormal risks, or unusual or exceptionally difficult ground or loading conditions; and (iii) structures in highly seismic areas

EUROCODE 7-PART 2
FIELD TESTS

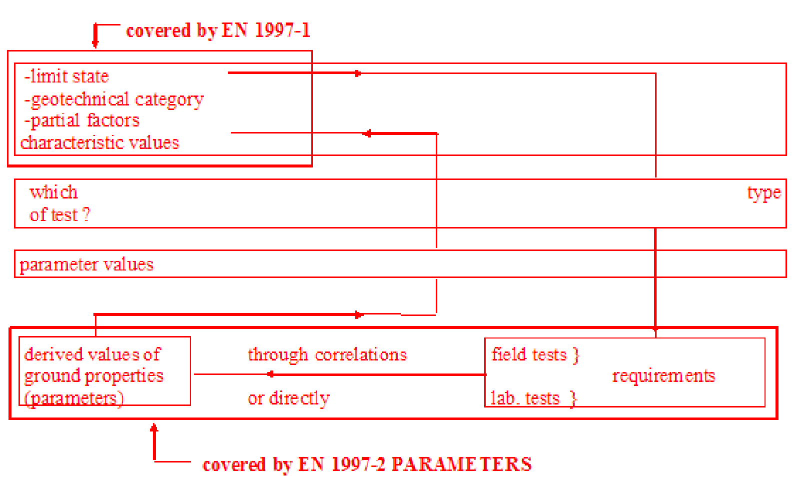
The field investigation programme shall contain:

- A plan with the locations of the investigation points including the types of investigations;
- The depth of the investigations;
- The type of samples (category, etc) to be taken including specifications on the number and depth at which they are to be taken;
- Specifications on the ground water measurement;
- The types of equipment to be used;
- The standards that are to be applied.

EUROCODE 7- PART 2
LABORATORY TESTS

- The laboratory test programme depends in part on whether comparable experience exists.
- The extent and quality of comparable experience for the specific soil or rock should be established.
- The results of field observations on neighbouring structures, when available, should also be used.
- The tests shall be run on specimens representative of the relevant strata. Classification tests shall be used to check whether the samples and test specimens are representative.
- This can be checked in an iterative way. In a first step classification tests and strength index tests are performed on as many samples as possible to determine the variability of the index properties of a stratum. In a second step the representativeness of strength and compressibility tests can be checked by comparing the results of the classification and strength index tests of the tested sample with entire results of the classification and strength index tests of the stratum.

FLOWCHART



covered by EN 1997-1

-limit state
-geotechnical category
-partial factors
characteristic values

which of test ? type

parameter values

derived values of ground properties (parameters)

through correlations or directly

field tests }
lab. tests }
requirements

covered by EN 1997-2 PARAMETERS

Planning of Ground Characterization

- Objectives and scope;
- Prediction of test results
- Specification of test specimens and sampling;
- Loading specifications;
- Testing arrangement;
- Measurements;
- Evaluation and reporting of the tests.

Montaigne stressed that we have the duty to preserve our heritage and our knowledge

All properties and circumstances should be taken into account, including:

- Geometrical imperfections;
- Material properties;
- Parameters influenced by fabrication and execution procedures;
- Scale effects of environmental conditions taking into account, if relevant, any sequencing.

Tests Specimens

- Test specimens should be specified, or obtained by sampling, in such a way as to represent the conditions of the real structure.

Factors to be taken into account include:

- dimensions and tolerances;
- material and fabrication of prototypes;
- number of test specimens;
- sampling procedures;
- restraints.

The objective of the sampling procedure should be to obtain a statistically representative sample.

Attention should be drawn to any difference between the test specimens and the product population that could influence the test results.

Location of Investigations Points

a) the stratification can be assessed across the site.

b) investigation points for a building or structure should be placed at critical points

c) for linear structures, investigation points should be arranged at adequate offsets to the centreline

d) for structures at or near slopes and excavations, investigation points should be arranged outside the project area,

e) investigation points are arranged so that they do not present a hazard to the structure, the construction work, or the surroundings

f) the area considered extends into the neighbouring area to a distance where no harmful influence on the neighbouring area is expected, for example 1.5 times the expected excavation depth.

g) for groundwater measuring points the possibility of using the equipment installed during the ground investigation for continued monitoring during and after the construction period is considered.

Recommendations for Depth of Investigations

a) For high-rise structures and civil engineering projects.

$za \geq 6$ m and $za \geq 3.0 \cdot bF$, where bF is the smaller side length of the foundation.

For raft foundations $za \geq 1.5$ bB, where bB is the smaller site length of the structure.

b) Embankments and cuttings.

1) For dams: $0.8\,h < za < 1.2\,h$ and $za \geq 6$ m, where h is the embankment height.

2) For cuttings: $za \geq 2.0$ m and $za \geq 0.4 \cdot h$, where h is the dam height or depth of cutting.

Sharing for the Fourth Dimension – Salvador Dali 1979

Recommendations for Depth of Investigations

c) Linear structures.

1) For roads and airfields: $za \geq 2$ m below the proposed formation level.

2) For canals and pipelines: $za \geq 2$ m below the invert level and $za \geq 1.5 \cdot bAh$, where bAh is the width of excavation.

d) For small tunnels and caverns: $bAb < za < 2.0\,bAb$, where bAb is the width of excavation.

e) Excavations.

1) Where piezometric surface and groundwater table are below the excavation base: $za \geq 0.4 \cdot h$ and $za \geq t + 2.0$ m, where t is the embedded length of the support and h is the excavation depth.

Table 1: Quality classes of soil samples for laboratory testing and sampling categories to be used

Soil properties / quality class	1	2	3	4	5
Unchanged soil properties	x	x	x	x	
particle size, water content	x	x	x		
density, density index, permeability,	x	x			
compressibility, shear strength	x				
Properties that can be determined sequence of layers	x	x	x	x	x
boundaries of strata – broad	x	x	x	x	
boundaries of strata - fine	x	x	x	x	
Atterberg limits, particle density, organic content	x	x	x		
water content,	x	x			
density, density index, porosity, permeability	x	x			
compressibility, shear strength	x				
Sampling category according to EN ISO 22475-1	**A**				
			B		
					C

Table 2 Static Field Tests

Test	Parameters for stress state				Strength Parameters				Parameters for deformation		
	γ	I_d	K_o	OCR	S	S_u	c	ϕ	E	G_{max}	M
CPTU	x	x	x	x	x	x	x	x	x		x
SPT		x			x	x	x	x	x		x
Vane shear			x	x	x	x	x		x		
Pressiometer			x			x	x	x	x		
Penetrometer						x	x	x	x		
Dilatometer	x	x		x		x		x	x	x	x
Plate load						x			x		

Table 3 Static Laboratory Tests

Test	Strength Parameters			Deformation Parameters		
	S_u	c	ϕ	E	G_{max}	M
Direct shear		x	x			
Uniaxial compression				x		
Triaxial	x	x	x	x		
Odoemeter						x

Table 4 Dynamic Field Tests

Tests	Parameters		
	V_p	V_s	G_{max}
Refraction	x	x	x
Uphole	x	x	x
Downhole	x	x	x
Crosshole	x	x	x

Table 5 Dynamic Laboratory Tests

Tests	Parameters			
	G	E	δ	G_{max}
Resonant Column	x	x	x	x
Cyclic Triaxial	x	x	x	
Cyclic simple shear	x	x	x	
Cyclic torsional shear	x	x	x	

Ground Conditions and Soil Investigations

Subsoil class A – rock or other geological formation, including at most 5 m of weaker material at the surface characterised by a shear wave velocity Vs of at least 800 m/s;

Subsoil class B – deposits of very dense sand, gravel or very stiff clay, at least several tens of m in thickness, characterised by a gradual increase of mechanics properties with depth shear wave velocity between 360 - 800 m/s, NSPT >50 blows and cu >250 kPa.

Subsoil class C – deep deposits of dense or medium dense sand, gravel or stiff clays with thickness from several tens to many hundreds of meters characterised by a shear wave velocity from 160 m/s to 360 m/s, NSPT from 15-50 blows and cu from 70 to 250 kPa.

Ground Conditions and Soil Investigations

Subsoil class D – deposits to loose to medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft to firm cohesive soil characterised by a shear wave velocity less than 180 m/s, NSPT less than 15 and cu less than 70 kPa.

Subsoil class E – a soil profile consisting of a surface alluvium layer with Vs,30 values of type C or D and thickness varying between about 5m and 20m, underlain by stiffer material with Vs,30>800m/s

Subsoil S1 – deposits consisting- or containing a layer at least 10 m thick-of soft clays/silts with high plasticity index (PI>40) and high water content characterised by a shear wave velocity less than 100 m/s and cu between 10-20 kPa.

Subsoil S2 – deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A-E or S1.

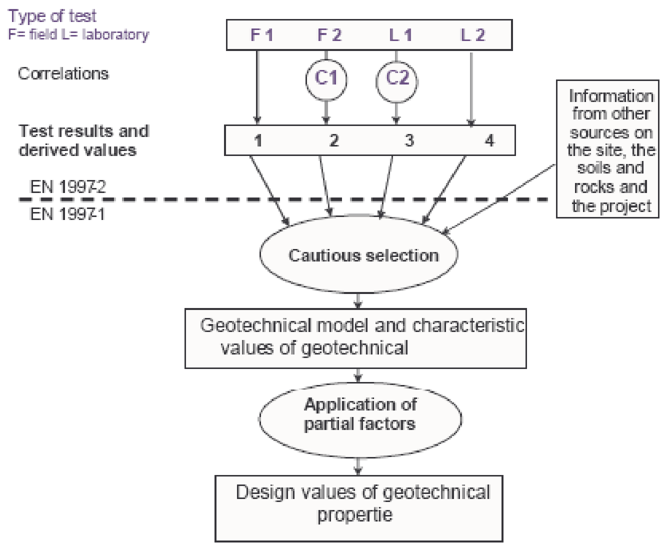
Presentation of Geotechnical Information

- A factual account of all field and laboratory work documentation based on the test reports of the methods used to carry out the field investigations and the laboratory testing
- names of all consultants and subcontractors
- purpose and scope of the geotechnical investigation
- dates between which field and laboratory work was performed
- field reconnaissance of the general area of the project noting particularly
- evidence of ground-water
- behaviour of neighbouring structures
- exposures in quarries and borrow areas
- areas of instability
- difficulties during excavation
- history of the site
- geology of the site, including faulting
- survey data
- information from available aerial photographs
- local experience in the area
- information about the seismicity of the area.

Evaluation of Geotechnical Information

- a review of the field and laboratory work
- a review of the derived values of geotechnical parameters
- any proposals for necessary further field and laboratory work
- tabulation and graphical presentation of the results of the field and laboratory work
- histograms illustrating the range of values of the most relevant data and their distribution
- depth of the ground-water table and its seasonal fluctuations
- subsurface profile(s) showing the differentiation of the various formations
- detailed descriptions of all formations including their physical properties and their deformation and strength characteristics
- comments on irregularities such as pockets and cavities
- the range and any grouping of derived values of the geotechnical data for each stratum.

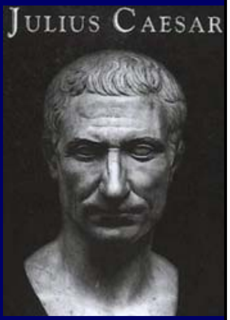
Derived Values



SELECTION OF CHARACTERISTICS VALUES

The selection of characteristic values for geotechnical parameters shall take account of the following:

- Geological and other background information, such as data from previous projects;
- The variability of the measured property values and other relevant information, e.g. from existing knowledge;
- The extent of the field and laboratory investigation;
- The type and number of samples;
- The extent of the zone of ground governing the behaviour of the geotechnical structure at the limit state being considered;
- The ability of the geotechnical structure to transfer loads from weak to strong zones in the ground. Characteristic values can be lower values, which are less than the most probable values, or upper values, which are greater



Julius Caesar made a crucial decision crossing the Rubican with the army

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SELECTION OF CHARACTERISTICS VALUES

- If statistical methods are used, the characteristic value should be derived such that the calculated probability of a worse value governing the occurrence of the limit state under consideration is not greater than 5%.

- Guidelines on the probable range of geomaterial property coefficient of variation (COV) are useful as first order approximations. COV histrograms for field measurements are comparatively higher than those of laboratory measurements (Sêco e Pinto, 2005) for normal or lognormal distributions. Geotechnical uncertainties can be treated in reliability-based design (RBD) methodologies (index of reability).

- A simple approach to select the characteristics value Xk is to apply the equation Schneider (1999):

$$X_k = X_{mean} (1 - k_n V_x)$$

Where X mean is the arithmetical mean value of the parameter values; Vx is the coefficient of variation; and kn is a statistical coefficient which depends on the number n of the tests results, on the type of characteristic value (mean or fractile) and a prior knowledge about coefficient of variation (case unknown Vx or Vx known).

Table 6 - Values of coefficient of variation

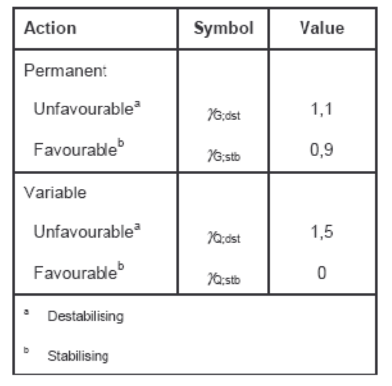
Soil property	Coef. of variation (%)	References
Unit weight	**0-10**	**Harr (1984), Eurocode 7 (2004)**
LL	6-11	Singh (1971)
PL	8-18	Singh (1971)
PI	5-40	Singh (1971)
Water content	6-29	Singh (1971)
ϕ`	5-15	Harr (1984), Eurocode 7 (2004)
C`	30-50	Eurocode 7 (2004)
Compressibility modulus	20-70	Eurocode 7 (2004)
Undrained shear strength	13-40	Harr (1984), Duncan (2000)
SPT(N blows)	15-45	Harr (1984),
CPT(electric)	5-15	Kulhawy (1992)
CPT(mechanical)	15-37	Harr (1984)
Dilatometer	5-15	Kulhawy (1992)
Vane shear	10-20	Kulhawy (1992)

DESIGN VALUES OF ACTIONS

The design value of an action (Fd) shall either be assessed directly or shall be derived from representative values using the following equation:

Fd =γF Frep (2) with Frep = ψ Fk (3)

The partial factor γF for persistent and transient situations are defined in Table 2



Action	Symbol	Value
Permanent		
Unfavourable[a]	$\gamma_{G;dst}$	1,1
Favourable[b]	$\gamma_{G;stb}$	0,9
Variable		
Unfavourable[a]	$\gamma_{Q;dst}$	1,5
Favourable[b]	$\gamma_{Q;stb}$	0

[a] Destabilising

[b] Stabilising

Table 2 - Partial factors on actions γF

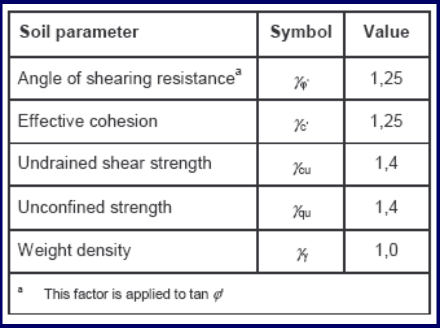
DESIGN VALUES OF GEOTECHNICAL PARAMETERS

Design values of geotechnical parameters (Xd) shall either be derived from characteristic values using the following equation:

$$Xd = Xk / \gamma\ m \quad (4)$$

or shall be assessed directly.

The partial factor γM for persistent and transient situations defined in Table 3 shall be used in equation (4)



Soil parameter	Symbol	Value
Angle of shearing resistance[a]	$\gamma_{\varphi'}$	1,25
Effective cohesion	$\gamma_{c'}$	1,25
Undrained shear strength	γ_{cu}	1,4
Unconfined strength	γ_{qu}	1,4
Weight density	γ_{γ}	1,0

[a] This factor is applied to tan φ'

Table 3 - Partial factors for soil parameters γm

General Principles for Statistical Evaluations of Materials

- **Reference for reliability theory and probability analyses in EC 0, but there is no compatibility and further application in EC7.**
- **Strong negative reaction of practitioners to the definition of characteristic value for materials, linked with probabilistic theory, stressing that this is not applicable for ground characterization. Even the definition of caution evaluation for characteristic value generates several discussions.**
- **There is a need for an increase and progressive introduction of probabilistic models in static geotechnical design that helps a lot to incorporate the uncertainties and to take the final decision related an optimal design based in a cost-benefit analysis.**
- **Uncertainties in design parameters and methods lead to errors, which may be random or systematic. Soil variability is the most source of random error and inaccuracies or simplifications in material and analytical models are the common sources of systematic errors**
- **There is a need for a different mental attitude and to train the universities students and the practitioners related the merits of the use of probabilistic models.**

Reliability Analysis

- For Reliability Based Design in general three levels are considered:
- i) level III-basic variables are treated as random variables with full distributions and the failure probability is evaluated based on a performance function
- (ii) level II a simplified version of level III and basic variables are parametrically described by mean, variance and covariance
- (iii) level I the necessary safety margin is preserved by applying partial factors to characteristic values

- In the Level II procedures, an alternative measure of reliability is conventionally defined by the reliability index ß which is related to *Pf* by :
- *Pf* ϕ (- ß)

where ϕ is the cumulative distribution function of the standardised Normal distribution.

Reliability Analysis

Table 7 Relation between ß and *P*f (after EN, 1990)

P_f	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
ß	1,28	2,32	3,09	3,72	4,27	4,75	5,20

Ulisses hero of Homero poem
has appointed the responsability
of Man in chosen his own Destiny

Reliability Analysis

Table 8. Target reliability index ß for Class RC2 structural members (after EN, 1990)

Limit state	Target reliability index	
	1 year	50 years
Ultimate	4.7	3.8
Fatigue		1.5 to 3.8
Serviceability (irreversible)	2.9	1.5
1) See Annex B 2) Depends on degree of inspectability, reparability and damage tolerance.		

Consequences Classes

Consequences Class	**Description**	**Examples of buildings and civil engineering works**
CC3	**High consequence for loss of human life,** *or* economic, social or environmental consequences **very great**	Grandstands, public buildings where consequences of failure are high (e.g. **a concert hall**)
CC2	**Medium consequence for loss of human life, economic, social or environmental** consequences **considerable**	Residential and office buildings, public buildings where consequences of failure are medium (e.g. **an office building**)
CC1	**Low consequence for loss of human life,** *and* economic, social or environmental consequences **small or negligible**	Agricultural buildings where people do not normally enter (e.g. storage **buildings), greenhouses**

Design Working Life

Design working life category	Indicative design working life (years)	Examples
1	10	Temporary structures (1)
2	10 to 25	Replaceable structural parts, e.g. gantry girders, bearings
3	15 to 30	Agricultural and similar structures
4	50	Building structures and other common structures
5	100	Monumental building structures, bridges, and other civil engineering structures
.		(1) Structures or parts of structures that can be dismantled with a view to being re-used should not be considered as temporary

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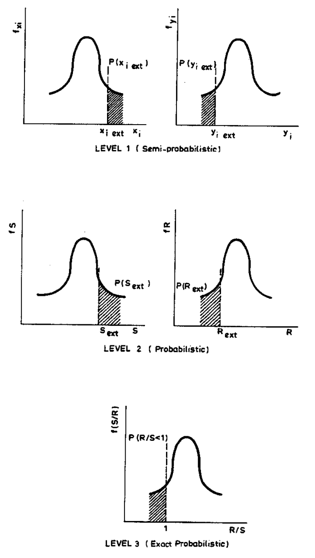
Quantitative Assessment of the Safety

- For level 1 the safety parameters are usually partial factors of safety and are related with characteristic values and design values.

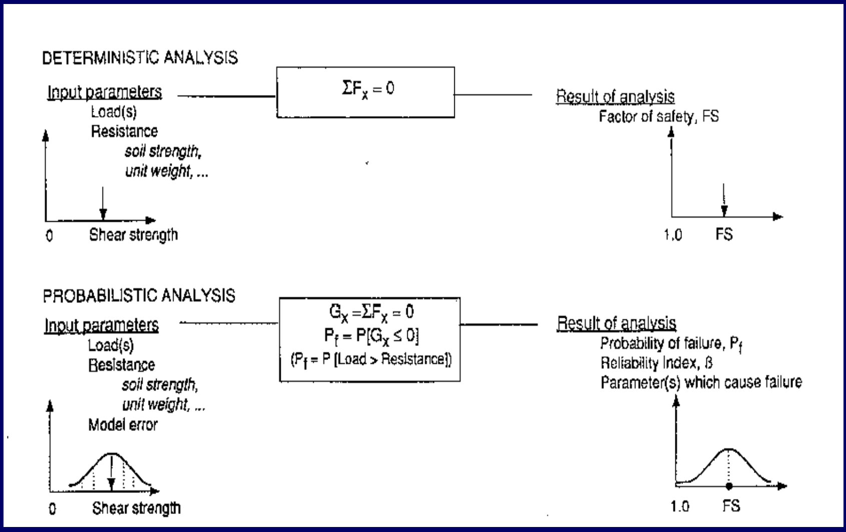
- Level 2 aims the approximate computation of the probabilities of failure and survival.

- Level 3 is related with the exact computation of the probabilities of failure and survival.

- In summary the probabilistic analysis raises great difficulties due the lack of information to define the distribution of functions R and S. In spite of this situation the definition of safety in probabilistic terms, besides the theoretic interest has some practical interest and contribute to the decisions involved in the design.



Comparison Between Deterministic and Probabilistic Methods



DETERMINISTIC ANALYSIS

Input parameters
Load(s)
Resistance
soil strength,
unit weight, ...

$\Sigma F_x = 0$

Result of analysis
Factor of safety, FS

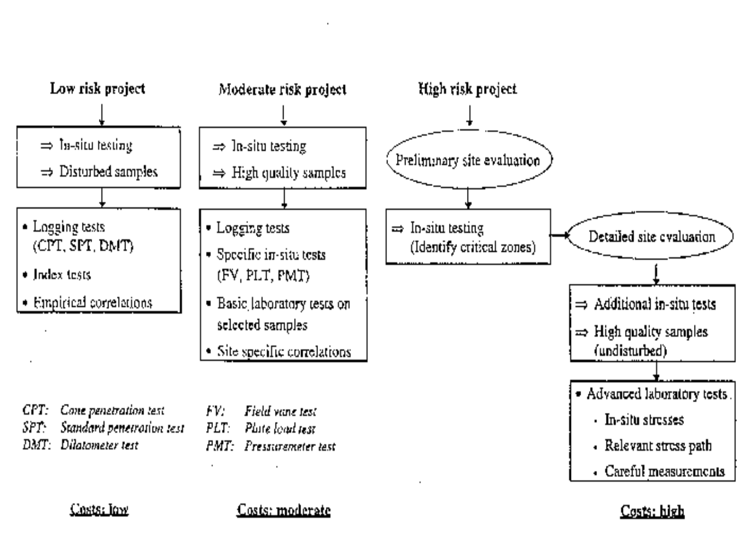
PROBABILISTIC ANALYSIS

Input parameters
Load(s)
Resistance
soil strength,
unit weight, ...
Model error

$G_x = \Sigma F_x = 0$
$P_f = P[G_x \le 0]$
(P_f = P [Load > Resistance])

Result of analysis
Probability of failure, P_f
Reliability Index, ß
Parameter(s) which cause failure

Risk Based on Soil Investigations



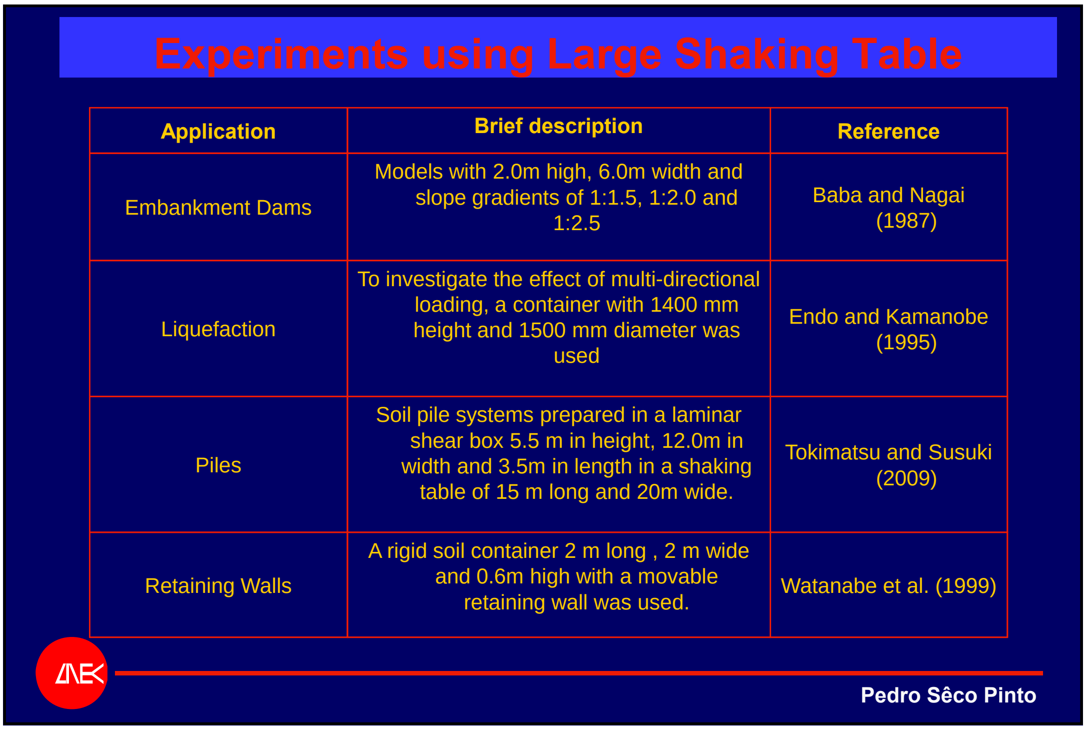
Low risk project
⇒ In-situ testing
⇒ Disturbed samples
- Logging tests (CPT, SPT, DMT)
- Index tests
- Empirical correlations

Moderate risk project
⇒ In-situ testing
⇒ High quality samples
- Logging tests
- Specific in-situ tests (FV, PLT, PMT)
- Basic laboratory tests on selected samples
- Site specific correlations

High risk project
Preliminary site evaluation
⇒ In-situ testing (Identify critical zones)
Detailed site evaluation
⇒ Additional in-situ tests
⇒ High quality samples (undisturbed)
- Advanced laboratory tests
  - In-situ stresses
  - Relevant stress path
  - Careful measurements

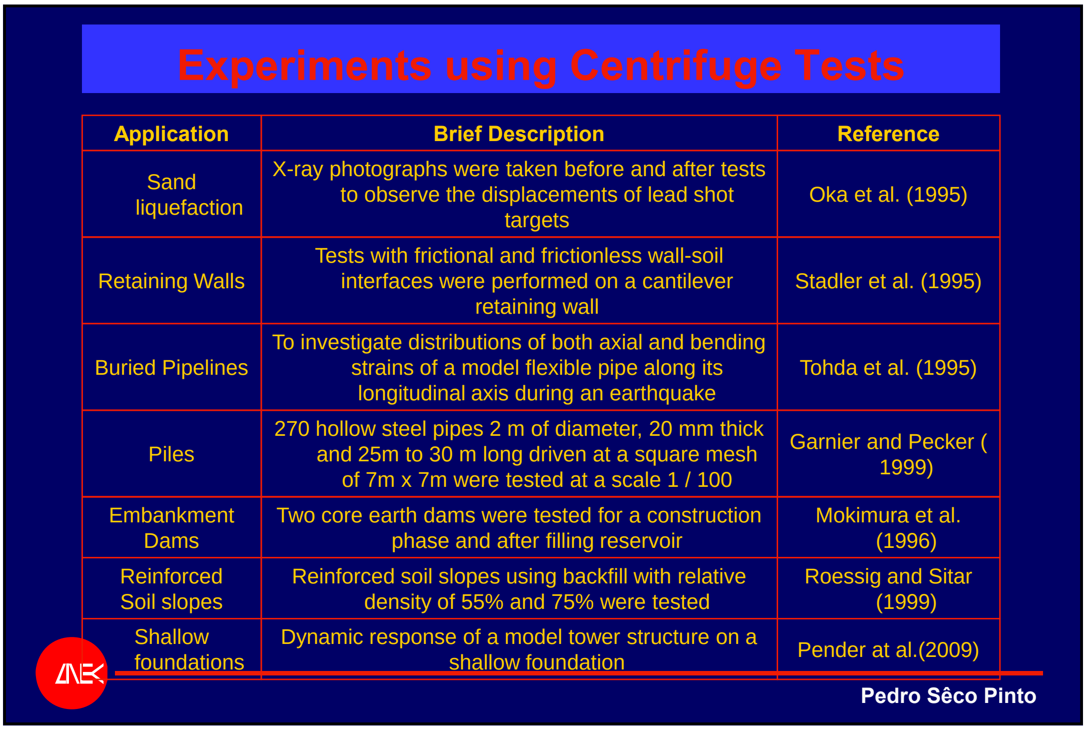
CPT: Cone penetration test
SPT: Standard penetration test
DMT: Dilatometer test
FV: Field vane test
PLT: Plate load test
PMT: Pressuremeter test

Costs: low
Costs: moderate
Costs: high



Experiments using Large Shaking Table

Application	Brief description	Reference
Embankment Dams	Models with 2.0m high, 6.0m width and slope gradients of 1:1.5, 1:2.0 and 1:2.5	Baba and Nagai (1987)
Liquefaction	To investigate the effect of multi-directional loading, a container with 1400 mm height and 1500 mm diameter was used	Endo and Kamanobe (1995)
Piles	Soil pile systems prepared in a laminar shear box 5.5 m in height, 12.0m in width and 3.5m in length in a shaking table of 15 m long and 20m wide.	Tokimatsu and Susuki (2009)
Retaining Walls	A rigid soil container 2 m long , 2 m wide and 0.6m high with a movable retaining wall was used.	Watanabe et al. (1999)



Experiments using Centrifuge Tests

Application	Brief Description	Reference
Sand liquefaction	X-ray photographs were taken before and after tests to observe the displacements of lead shot targets	Oka et al. (1995)
Retaining Walls	Tests with frictional and frictionless wall-soil interfaces were performed on a cantilever retaining wall	Stadler et al. (1995)
Buried Pipelines	To investigate distributions of both axial and bending strains of a model flexible pipe along its longitudinal axis during an earthquake	Tohda et al. (1995)
Piles	270 hollow steel pipes 2 m of diameter, 20 mm thick and 25m to 30 m long driven at a square mesh of 7m x 7m were tested at a scale 1 / 100	Garnier and Pecker (1999)
Embankment Dams	Two core earth dams were tested for a construction phase and after filling reservoir	Mokimura et al. (1996)
Reinforced Soil slopes	Reinforced soil slopes using backfill with relative density of 55% and 75% were tested	Roessig and Sitar (1999)
Shallow foundations	Dynamic response of a model tower structure on a shallow foundation	Pender at al.(2009)

Computer Codes

Code	Main Features	References
SHAKE	1D analysis considering an equivalent linear model	Schanabel et al. (1972)
QUAD 4	2D analysis considering an equivalent linear model	Idriss (1973)
CHARSOIL	1D nonlinear analysis using Ramberg-Osgood representation method of characteristics	Streeter et al. (1973)
FLUSH	3D analysis of a soil-structure system considering an equivalent linear model	Lysmer et al. (1975)
GADFLEA	Analyses the generation and dissipation of pore pressure in horizontal stratified soil deposits	Booker et al (1976)
PLUSH	Probabilistic model for seismic action considering an equivalent linear model	Romo et al. (1980)
MASH	1D dynamic response of horizontal soil layers assuming visco-elastic or non linear behavior for the soil	Martin and Seed (1978)
DESRA-2	1D nonlinear analysis using both total and effective analysis	Lee and Finn (1978)
DYNAFLOW	Elastic-plastic 2D model in effective stress analysis based on Biot`s equations	Prevost (1981)
TLUSH	3D analysis assuming an equivalent linear behavior for the model	Takaaki et al. (1981)
SASSI	3D analysis assuming an equivalent linear behavior for the material to analyze soil-structure interaction	Lysmer et al.(1981)
DIANA	2D nonlinear elastic-plastic model	Kawai (1985)
TARA-3	2D nonlinear hysteretic model	Finn et al. (1986)
FLAC	2D nonlinear elastic-plastic finite difference code	Cundall and Board (1988)
DINAPLANO	2D code with an equivalent linear model	Serra (1989)
DYSAC2	2D nonlinear elastic-plastic model	Mureleetharan et al (1991)
SHAKE 91	1D analysis considering an equivalent linear model	Idriss and Sun (1992)
QUIVER	1D seismic response of slopes	Kaynia (2009)

Interaction Between Codes

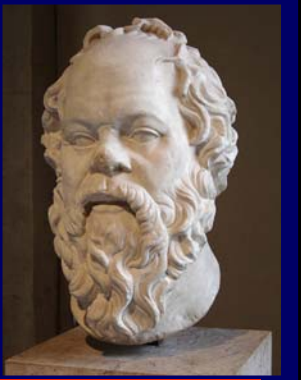
EN 1997-2 - Geotechnical investigations for design

- Detailed rules for site investigations
- General test specifications
- Derivation of ground properties and geotechnical model of the site
- Examples of calculation methods based on field and laboratory tests
- Execution standards
- Specific design rules (informative annexes)
- Specific test procedures.

- **CEN/TC288 - Execution of geotechnical works**
- Standards for
- Drilling and sampling methods and groundwater measurements
- Laboratory and field tests on soils and rocks
- Tests on structures or parts of structures
- Identification and classification of soils and rocks.

- **(CEN/TC341) - Test standards Design rules**
- General framework for geotechnical design
- Definition of ground parameters
- Characteristic and design values
- General rules for site investigation
- Rules for the design of main types of geotechnical structures
- Some assumptions on execution procedures.

Socrates has evoked
the swan song and
stressed that considering
our work a creation of
our last action
is very important



FINAL REMARKS(1)

- The work performed by the Commission of the European Communities (CEC) in preparing the "Structural Eurocodes" in order to establish a set of harmonised technical rules is impressive. Nevertheless, we feel that some topics deserve more consideration.
- One very important question to be discussed is: (i) how detailed a code must be, (ii) what is the time consuming to establish a set of harmonised technical rules for the design and construction works? (iii) how to improve the relations between the users: relevant authorities, clients and designers? (iv) how to implement in practice that codes may not cover in detail every possible design situation and it may require specialised engineering judgement and experience?

The good fortune which
the valiant Don Quixote
had in the terrible and
undreamt adventure

FINAL REMARKS(2)

- Due to the difficulties to quantify the uncertainties and the increasing of complexity of projects there is a great need for reliability analysis.
- The probabilistic analysis should be performed with great care analyzing in a critical way the conclusions of each step and should be used in addition to deterministic analysis.
- The probabilistic analysis increases our confidence on the results, allows an optimization of the project considering the risks of failure, can lead to a better cost-effective design and construction, satisfy our personal needs providing a better insight of the different factors of the design and give more confident to our decisions.
- The problematic of structural safety is huge and complex and need the co-operation of the Owners, Official Authorities, Research Institutes, Designers and Constructors

•Prometheus offers the fire to the Humanity that represents the knowled
Descartes in his book Methodology inspired in Prometeus and has
considered that the lessons are important to benefit human life
and knowledge

RAPHAEL

Advancement of Learning

- “If a man will begin with certainties, he shall end in doubts; but if he will be content to begin with doubts, he shall end in certainties.”

Francis Bacon