



**Geo-Environmental**



# Preparing for Eurocode 7

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# Agenda



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- “ Introduction
- “ Overview of Eurocodes
- “ Brief overview of EN1990
- “ Overview of EC7 Part II
- “ Overview of EC7 Part I
- “ Potential Benefits
- “ Potential Implications



# Introduction – Eurocodes, opportunity or obstacle?



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Improved  
Workflow

More  
Robust  
Designs

Less  
Delays

But with closer working between  
Geotechnical and Structural Engineers  
we believe we can achieve

Fewer  
Cost  
Overruns

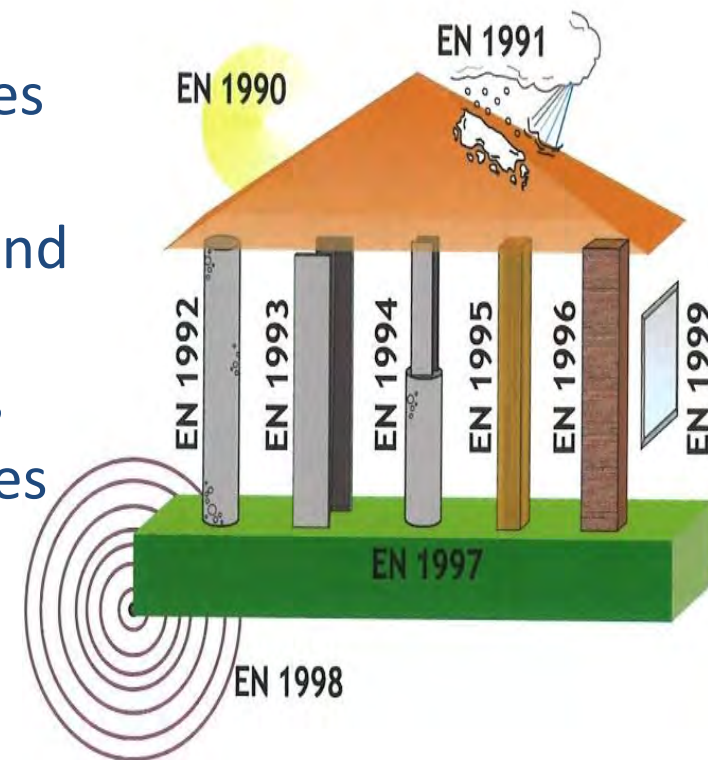
More  
Sustainable  
Designs

# An Overview of Eurocodes



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”	EN1990	Basis of structural design
”	EN1991	Actions on structures
”	EN1992	Design of concrete structures
”	EN1993	Design of steel structures
”	EN1994	Design of Composite steel and concrete structures
”	EN1995	Design of Timber structures
”	EN1996	Design of Masonry structures
”	EN1997	Geotechnical design
”	EN1998	Design of structures for earthquake resistance
”	EN1999	Design of aluminium structures

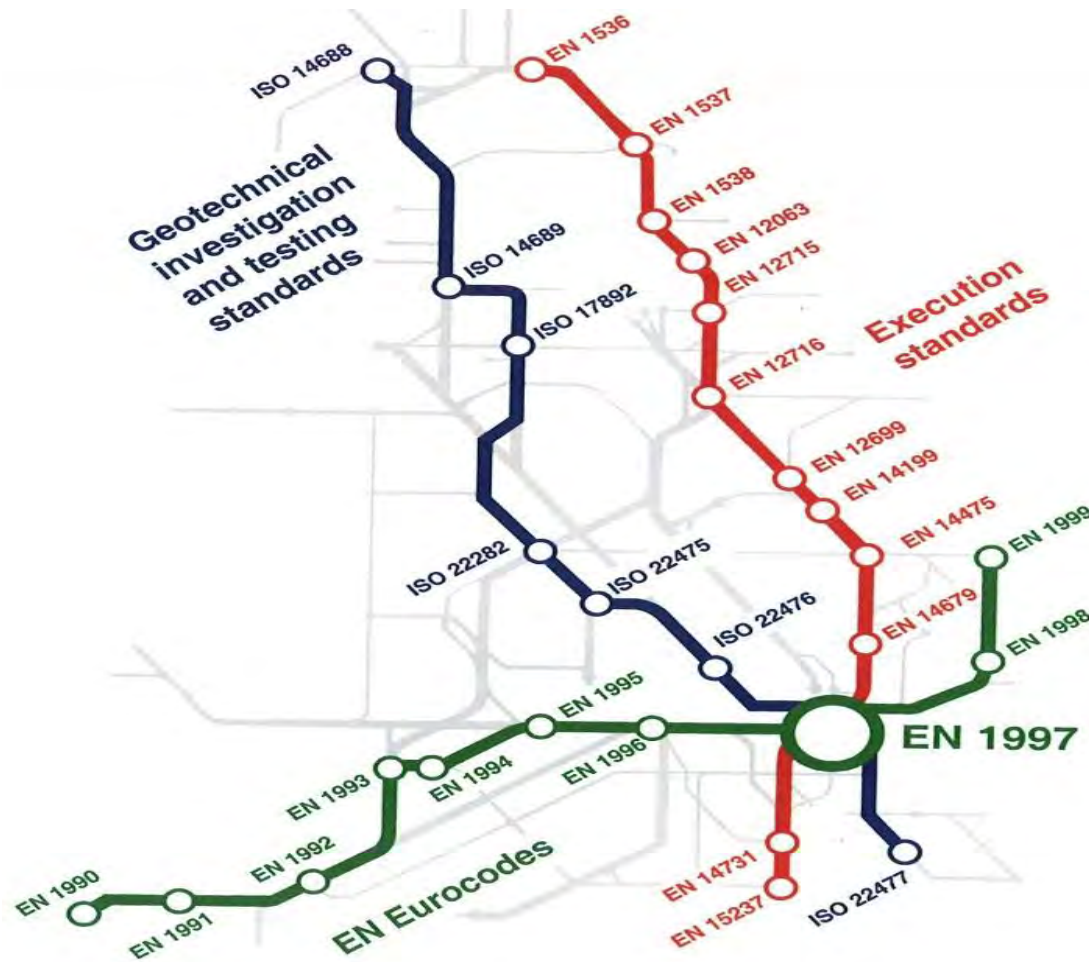


Source: Decoding Eurocode 7, Harris and Bond (2008), Plate 2

# Connections Between Eurocodes and Associated European and International Standards



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Source: Decoding Eurocode 7, Harris and Bond (2008), Plate 4

# EN1990 Basis of Structural Design



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EN1990 is the head document of the Eurocode suite and describes the principles and requirements for:

- ” Safety,
- ” Serviceability and ;
- ” Durability of structures



# EN1990 Basis of Structural Design



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A distinctive feature of the Structural Eurocodes is the separation of paragraphs into Principles and Application Rules

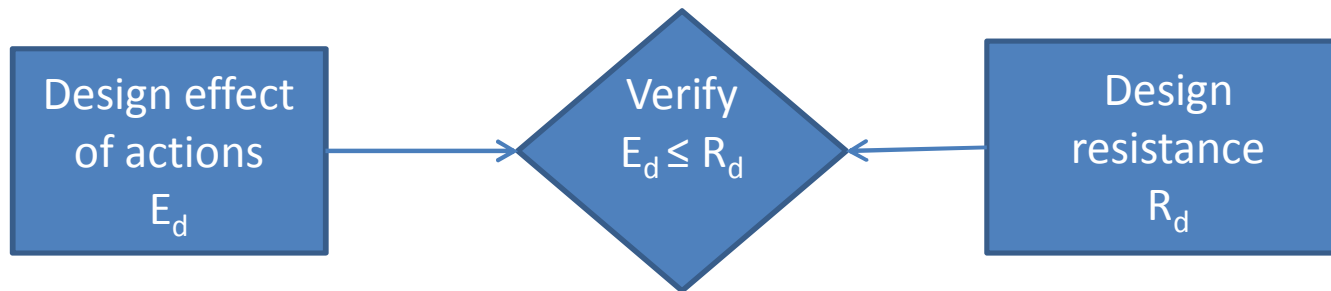
- “ **Principles** – identified by the letter (P) after their paragraph numbers – are general statements and definitions that must be followed, requirements that must be met, and analytical models that must be used. The English verb that appears in Principles is ‘shall’. (EN1990 s1.3(1))
- “ **Application Rules** – identified by the absence of a letter after their paragraph numbers – are recognised rules that comply with the Principles and satisfy their requirements. English verbs that appear in Application Rules include ‘may’, ‘should’, ‘can’, etc. (EN1990 s1.4.4(4))

# Limit States



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- “ **Ultimate Limit State** – concerned with the safety of people and the structure e.g.



- “ **Serviceability Limit State** – concerned with the functioning of the structure, comfort of users and visual appearance. Design effects of actions such as settlement or distortion must be less than or equal to the limiting value of that effect.



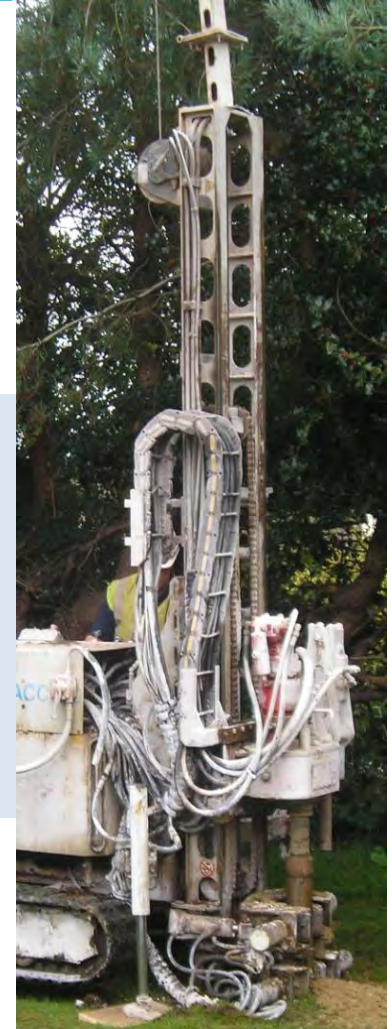
# Ultimate Limit States



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EN1990 – Three ULSs that must be verified where applicable:

- “ **EQU** (Equilibrium) – loss of equilibrium
- “ **STR** (Structure) – excessive deformation
- “ **FAT** (Fatigue) – failure by fatigue



# Design Situations



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Four design situations are considered in Eurocode 7:

- “ **Permanent** – Normal use
- “ **Transient** – temporary condition
- “ **Accidental** – exceptional condition
- “ **Seismic** – Seismic events



# Actions, combinations, and effects



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## Action = Load

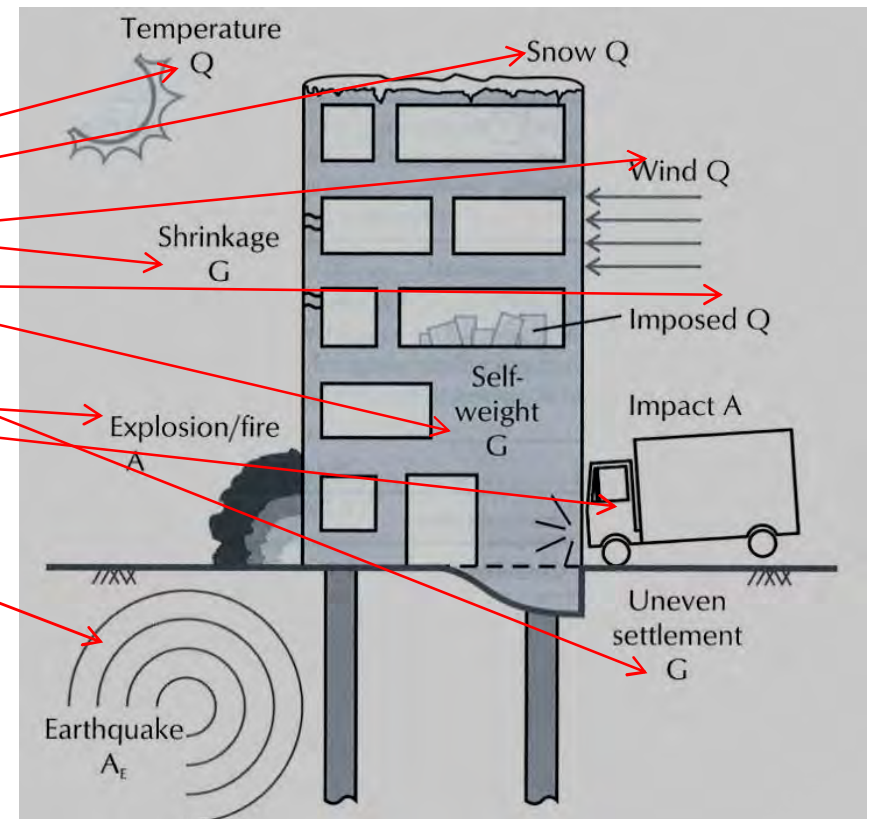
Different categories of actions:

- “ Permanent (G)
- “ Variable (Q)
- “ Accidental (A)

## Combinations:

Representative actions ( $F_{rep}$ ) obtained by calculating suitable combinations of characteristic values. This involves multiplying the variable actions by a combination factor  $\psi$ .

## Effect = Reaction



Source: Decoding Eurocode 7, Harris and Bond (2008), Figure 2.11

# Overview of Eurocode 7

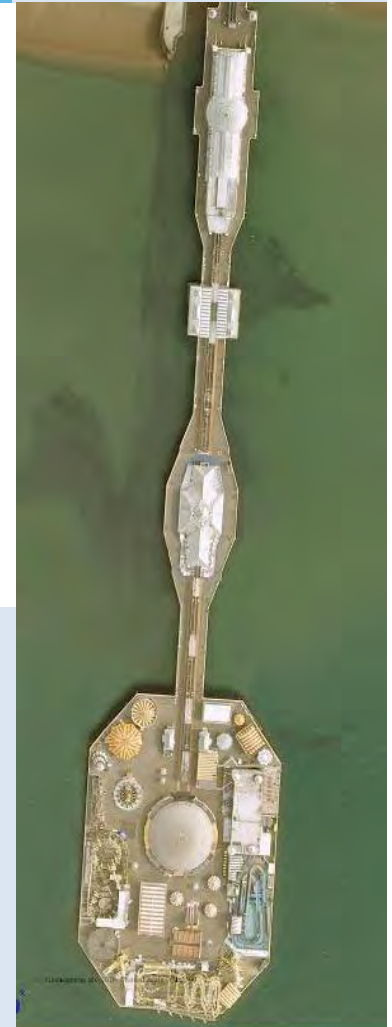


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- “ The standard has been adopted across most of Europe
- “ There are two parts to the new standard:

**Part I** – General basis for the geotechnical aspects of the design of buildings and civil engineering works

**Part II** – Requirements for the execution, interpretation and use of results of laboratory and field tests to assist in the geotechnical design of structures



# Part II



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1. **General**
2. **Planning ground investigations**
3. **Soil & rock sampling & groundwater measurement**
4. **Field tests on soil & rock**
5. **Laboratory tests on soil & rock**
6. **Ground investigation report**
7. **Annexes A-K**

Provides detailed rules for site investigations, general test specifications, derivation of ground properties and the geotechnical model of the site, and examples of calculation methods based on field and laboratory testing.



# Aim of Investigations



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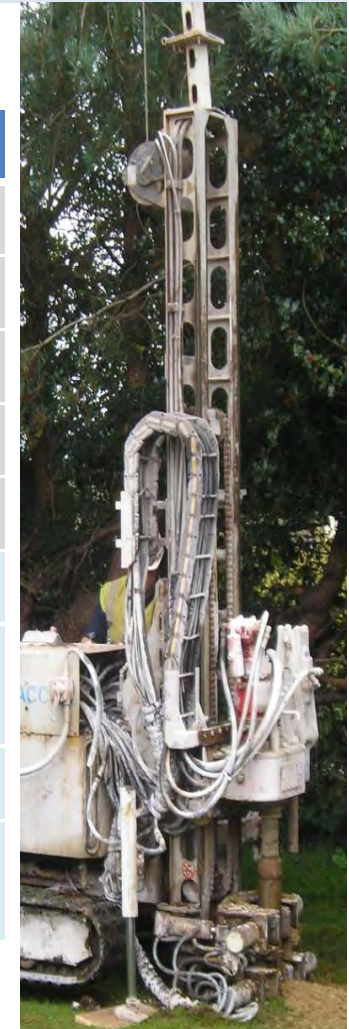
Geotechnical investigations ***shall*** provide sufficient data concerning the ground and groundwater conditions at and around the construction site for a proper description of the essential ground properties and ***a reliable assessment of the characteristic values of the ground parameters to be used in design calculations.*** (EN1997 s3.2.1(1)P)

# Geotechnical Investigations



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Type of Investigation	Objectives
" Preliminary	Assess general suitability of site
	Compare alternative sites
	Estimate changes caused by proposed works
	Plan design and control investigations
	Identify any borrow areas
" Design	Provide information for design
	Provide information for planning method of constructions
	Identify difficulties that may arise during construction
	Identify disposition and properties of all ground relevant to or affected by construction



# Spacing of Investigation Points



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Structure	Definition	Spacing	Arrangement
High-rise & industrial	-	15-40m	Grid
Large area	-	≤ 60m	Grid
Linear	Roads, railways, channels, pipelines, dikes, tunnels, retaining walls	20-200m	-
Dams & weirs	-	25-75m	Vertical sections
Special	Bridges, stacks, machinery foundations	2-6 per foundation	



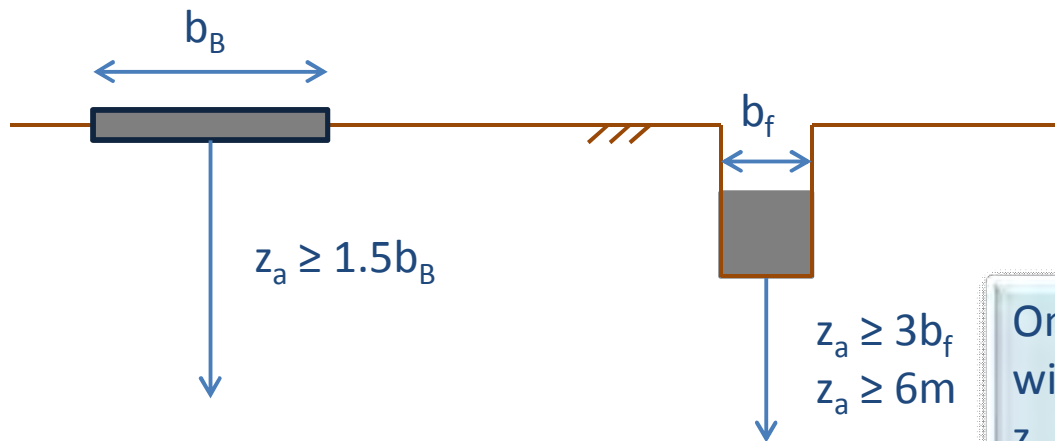
# Minimum Investigation Depths



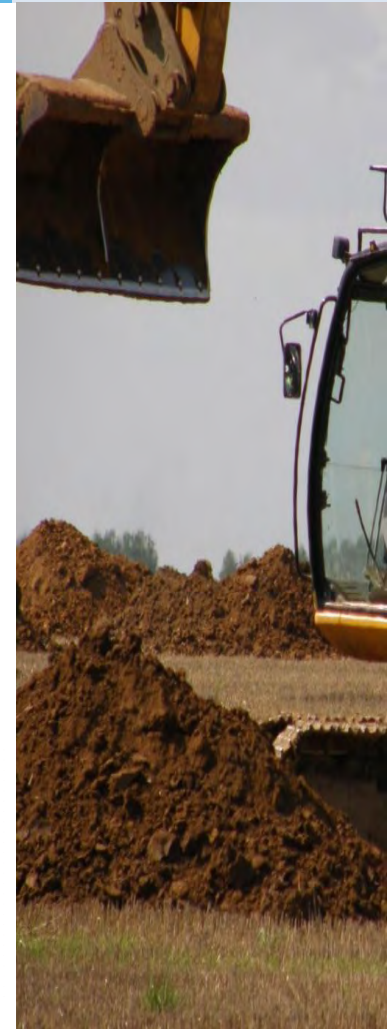
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Spread foundations  
supporting high rise  
structures or civil  
engineering Projects

Raft



On competent strata  
with known geology  
 $z_a$  may be reduced to  
2m

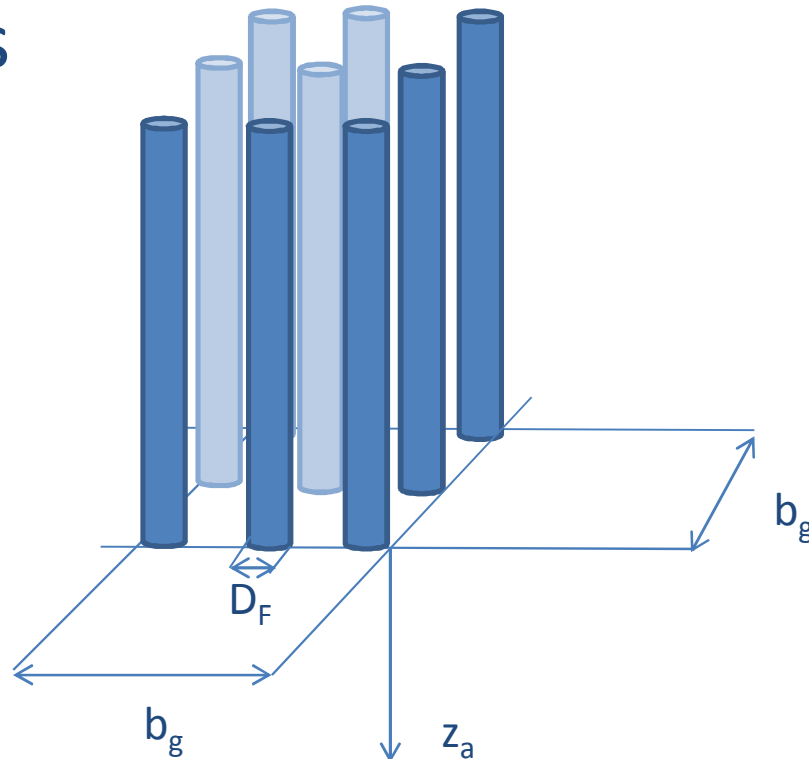


# Minimum Investigation Depths



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## Piles

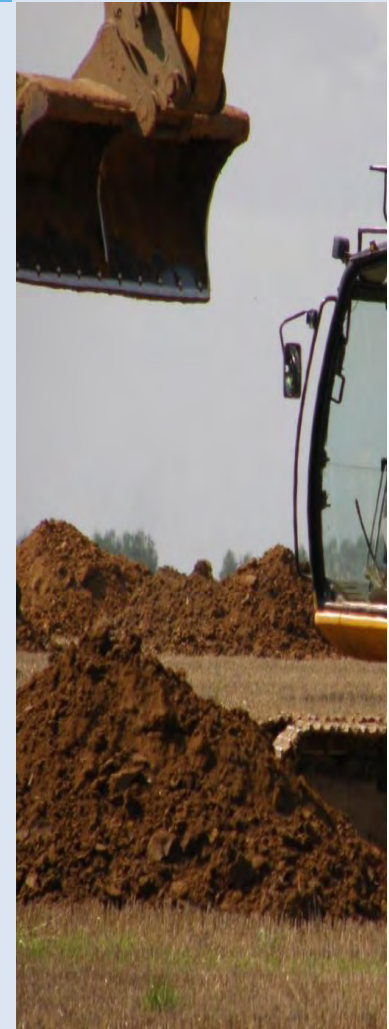


Recommended minimum depth of investigation beneath deepest pile is the max of:

$$z_a \geq b_g$$

$$z_a \geq 3D_F$$

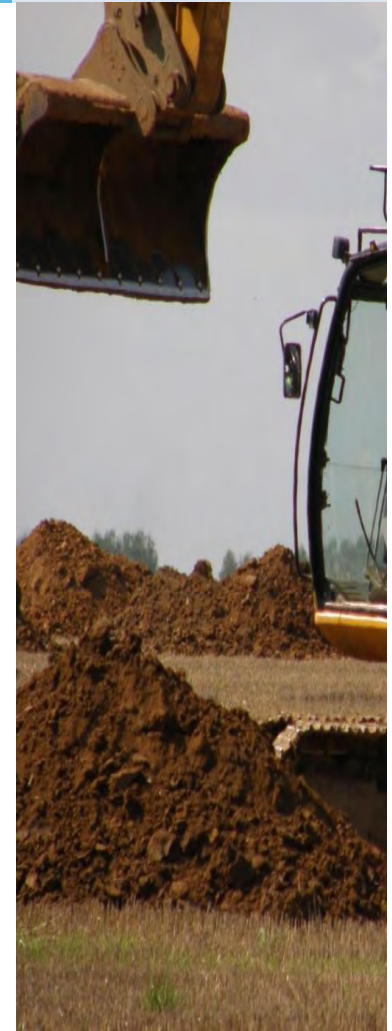
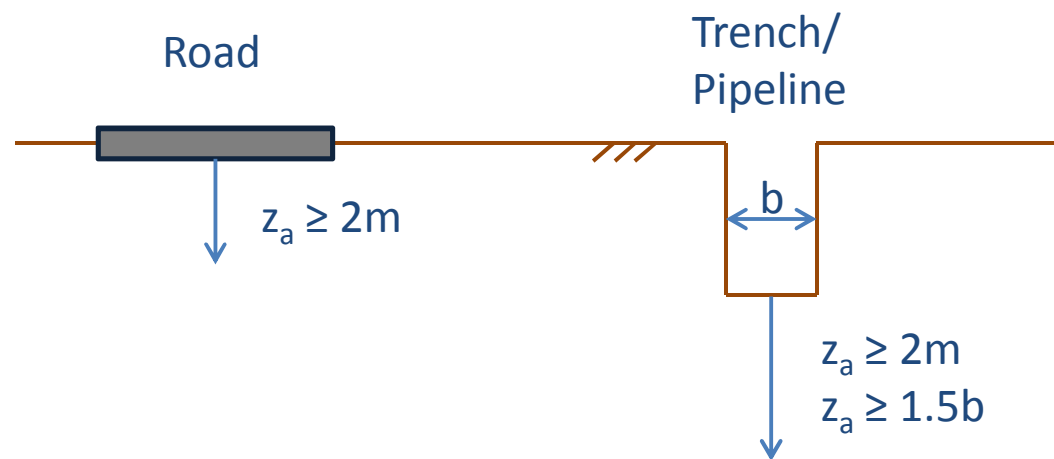
$$z_a \geq 5m$$



# Minimum Investigation Depths



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# Example



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Proposed new residential 6 storey apartment block with a footprint measuring 40m (B) x 80m (L)

Min grid spacing  $S_{\min} = 15\text{m}$  and  $S_{\max} = 40\text{m}$  Min No. of investigation points is:

$$n_{\min} = \left( \frac{B}{S_{\max}} + 1 \right) \times \left( \frac{L}{S_{\max}} + 1 \right) = 6$$

$$n_{\max} = \left( \frac{B}{S_{\min}} + 1 \right) \times \left( \frac{L}{S_{\min}} + 1 \right) = 23$$

As building is relatively low rise select a low number between these limits, say 9.

# Example (continued)



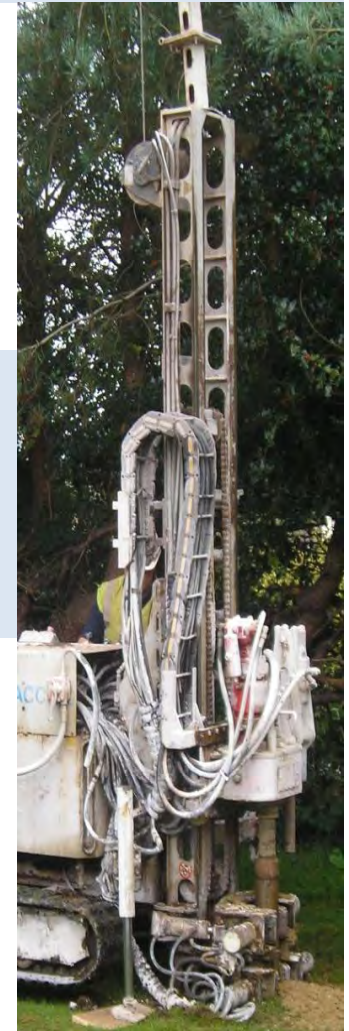
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Min depth of investigation for piles.

Assuming individual piles are 0.6m in diameter ( $D_f$ ) and the pile group width is 40m ( $b_g$ ).

- ”  $Z_a \geq 3 \times 0.6\text{m} = 1.8\text{m}$
- ”  $Z_a \geq 40\text{m}$
- ”  $Z_a \geq 5\text{m}$

However, assuming competent strata at 15m, maximum depth of investigation could be  $15\text{m} + 5\text{m} = 20\text{m}$ .



# Changes to Soil & Rock Descriptions



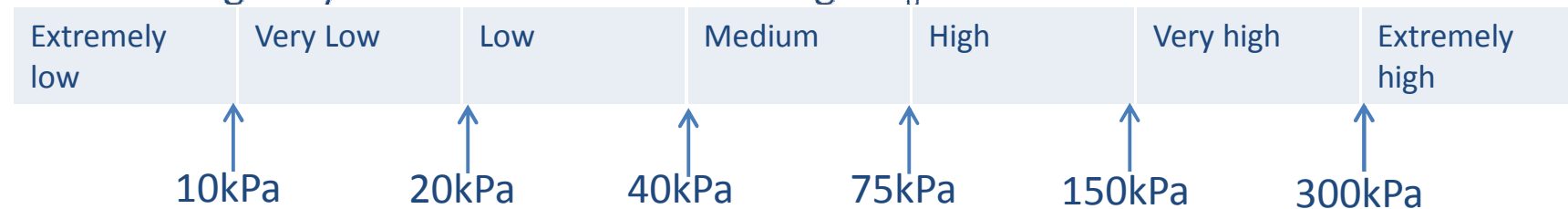
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Formerly the terms *very soft to hard* were used to describe both consistency and strength of soils. EC7 Part II defines the consistency according to the consistency index:

$$I_c = \frac{\text{Liquid Limit} - \text{Moisture Content}}{\text{Liquid Limit} - \text{Plastic Limit}}$$



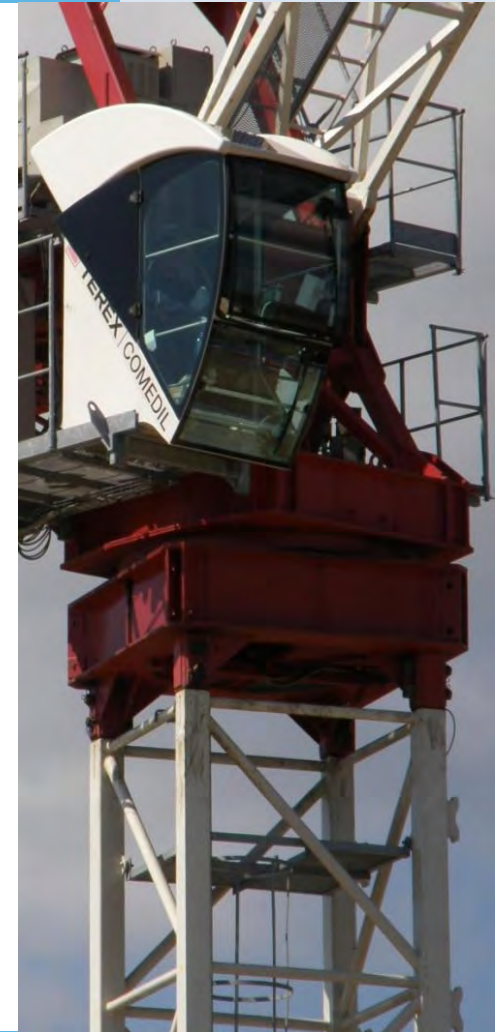
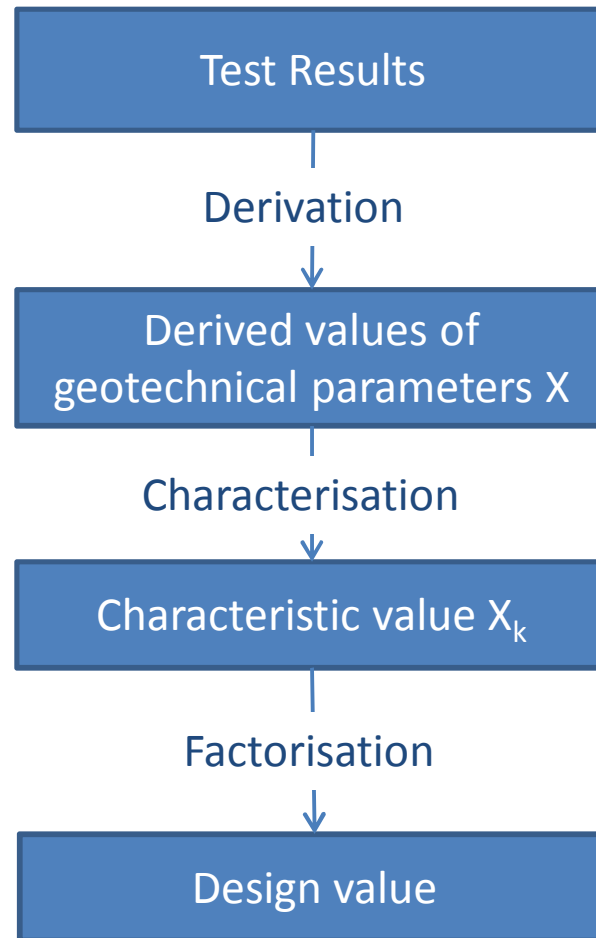
And strength by the soils undrained strength  $c_u$



# Ground Characterisation



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# Characteristic Value



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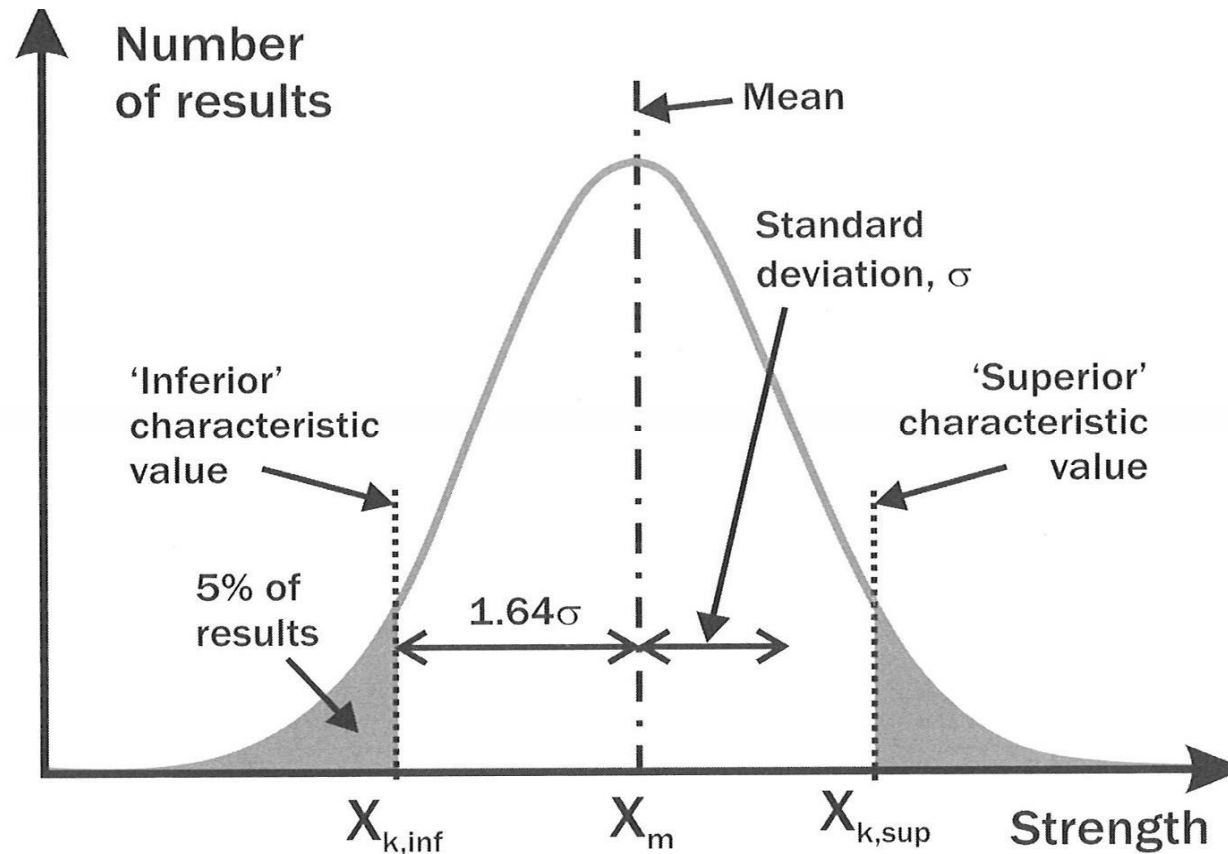
**EN1990 defines a characteristic material property as follows:**

Where a low value...is unfavourable, the characteristic value should be defined as the 5% fractile value; where a high value... is unfavourable,...(*the characteristic value should be defined*) as the 95% fractile value.

# Fractile Values



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Source: Decoding Eurocode 7, Harris and Bond (2008), Figure 2.15



# Cautious Estimate



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**EN1997 redefines the characteristic value as:**

*A cautious estimate of the value affecting the occurrence of limit state*

**Which by definition is:**

Approximate calculation/judgement that is careful to avoid problems or dangers

# Part I – General rules for geotechnical design



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## Part I Sections

- ” General
- ” Basis of geotechnical design
- ” Geotechnical data
- ” Supervision of construction, monitoring and maintenance
- ” Fill, dewatering, ground improvement and reinforcement
- ” Spread foundations
- ” Pile foundations
- ” Anchorages
- ” Retaining structures
- ” Hydraulic failure
- ” Overall stability
- ” Embankments
- ” Annexes



# Commitment to limit state



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For each geotechnical design situation it shall be verified that no relevant limit state... is exceeded (*EN 1997-1 s2.1(1)P*)

In the UK, this could be perceived as a significant change to the procedure where historically geotechnical engineers have used lumped factors of safety on the ultimate bearing pressure to derive an allowable bearing pressure.

# Commitment to limit state



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Two limit states considered are;

- **Ultimate Limit State**
- **Serviceability Limit State**

Standard states that the limit state may be verified by:

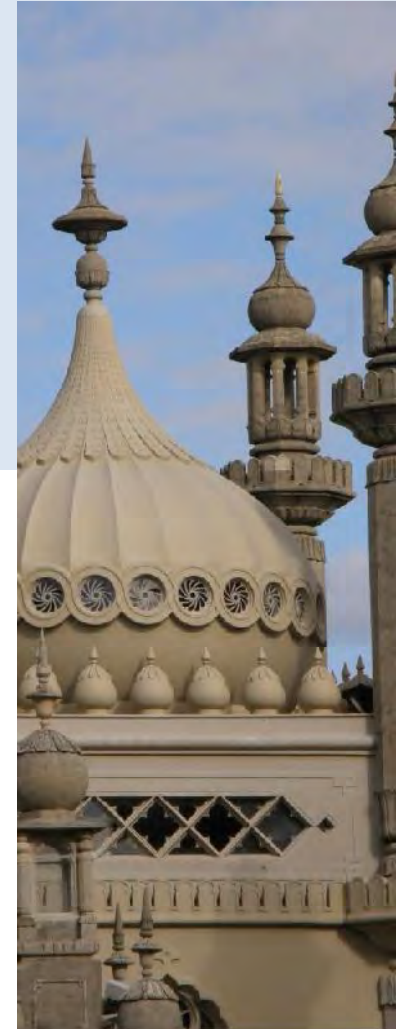
- ” calculation
- ” prescriptive measures
- ” experimental models or load tests
- ” an observational method
- ” combination of these.

# Ultimate Limit States



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- “ Eurocode 7 has five categories for an Ultimate Limit State.
- “ Each category has a particular set of partial factor values associated, which should be applied in corresponding design calculations:



# Ultimate Limit States



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- . **EQU:** “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 providing resistance”
- . **STR:** “internal failure or excessive deformation of the structure or structural elements, including footings, piles, basement walls, etc, in which the structural material is significant in providing resistance”
- . **GEO:** “failure or excessive deformation of the ground, in which the strength of soil or rock is significant in providing resistance”
- . **UPL:** “loss of equilibrium of the structure or the ground due to uplift by water pressure (buoyancy) or other vertical actions”
- . **HYD:** “hydraulic heave, internal erosion and piping in the ground caused by hydraulic gradients

# Serviceability Limit State



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Those limit states that result in unacceptable levels of :

- “ **Deformation**
- “ **Vibration**
- “ **Noise**

*“partial factors...should normally be taken equal to 1.0”* EN1990 S2.3.8(2).

Verification of serviceability is expressed in EC7 by:

$$E_d \leq C_d$$

$E_d$  = design effect of actions (e.g. displacement, distortion)

$C_d$  = limiting design value of the effect of the action



# Supervision, monitoring & maintenance



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*...the construction process and workmanship shall be supervised; the performance of the structure shall be monitored during and after construction; the structure shall be adequately maintained. (EN1997-1 s4.1(1)P)*

# Geotechnical Categories



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GC	Includes	Design requirements	Examples
1	Small and relatively simple structures with negligible risk	Negligible risk of instability or ground movements; ground conditions are 'straightforward'; no excavation below water table or if so straightforward	No examples EC7
2	Conventional types of structure with no exceptional risk or difficult soil or loading conditions	Quantitative geotechnical data and analysis to ensure fundamental requirements are satisfied	Spread, raft, pile foundations; retaining walls, bridge piers and embankments etc
3	Structures not covered above		Very large or unusual structures, structures with abnormal actions, difficult ground conditions etc.

# Design Approaches



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Three different design approaches as consensus within Europe could not be reached for the verification of strength.

“ **Action and material partial factors**

Or

“ **Action and resistance partial factors**

UK has adopted Design Approach 1, which involves applying partial factors to two variables in two separate calculations. Combination 1 and Combination 2.

# Eurocode 7 design approach 1 for calculating ultimate limit states



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In order to calculate the ultimate limit state two combinations of calculations are done to produce a worst case scenario.

- Combination 1 – Partial Factors are applied to the actions on a structure
- Combination 2 – Partial Factors are applied to the materials (except in the case of piles where combination 2 is for resistance)



# Design Approach 1 - Partial Factors for GEO & STRL ULS



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Design Approach 1			Combination 1			Combination 2		
			A1	M1	R1	A2	M2	R1
Permanent actions (G)	Unfavourable	$\gamma_G$	1.35			1.0		
	Favourable	$\gamma_{G,fav}$	1.0			1.0		
Variable actions (Q)	Unfavourable	$\gamma_Q$	1.5			1.3		
	Favourable	$\gamma_{Q,fav}$	0			0		
Coeff. of shearing resistance ( $\tan \varphi$ )		$\gamma_\varphi$		1.0			1.25	
Effective cohesion ( $c'$ )		$\gamma_{c'}$		1.0			1.25	
Undrained strength ( $c_u$ )		$\gamma_{c_u}$		1.0			1.4	
Unconfined compressive strength ( $q_u$ )		$\gamma_{q_u}$		1.0			1.4	
Weight density ( $\gamma$ )		$\gamma_\gamma$		1.0			1.0	
Resistance (R)		$\gamma_R$			1.0		1.0	

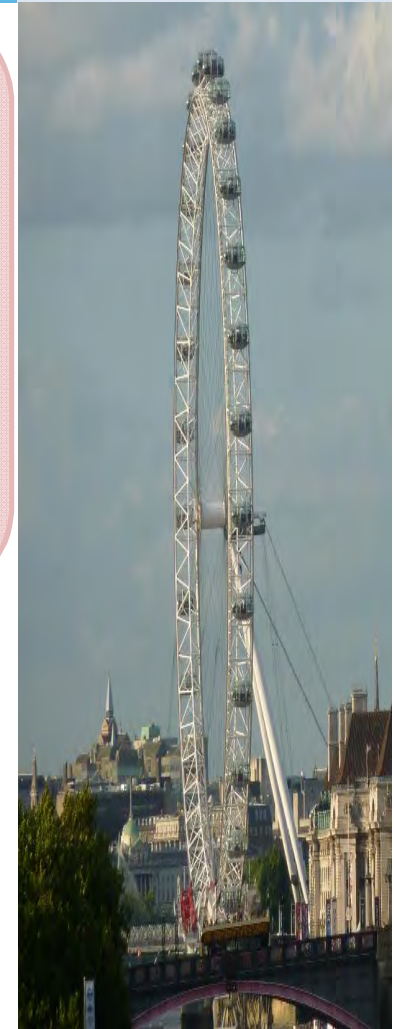
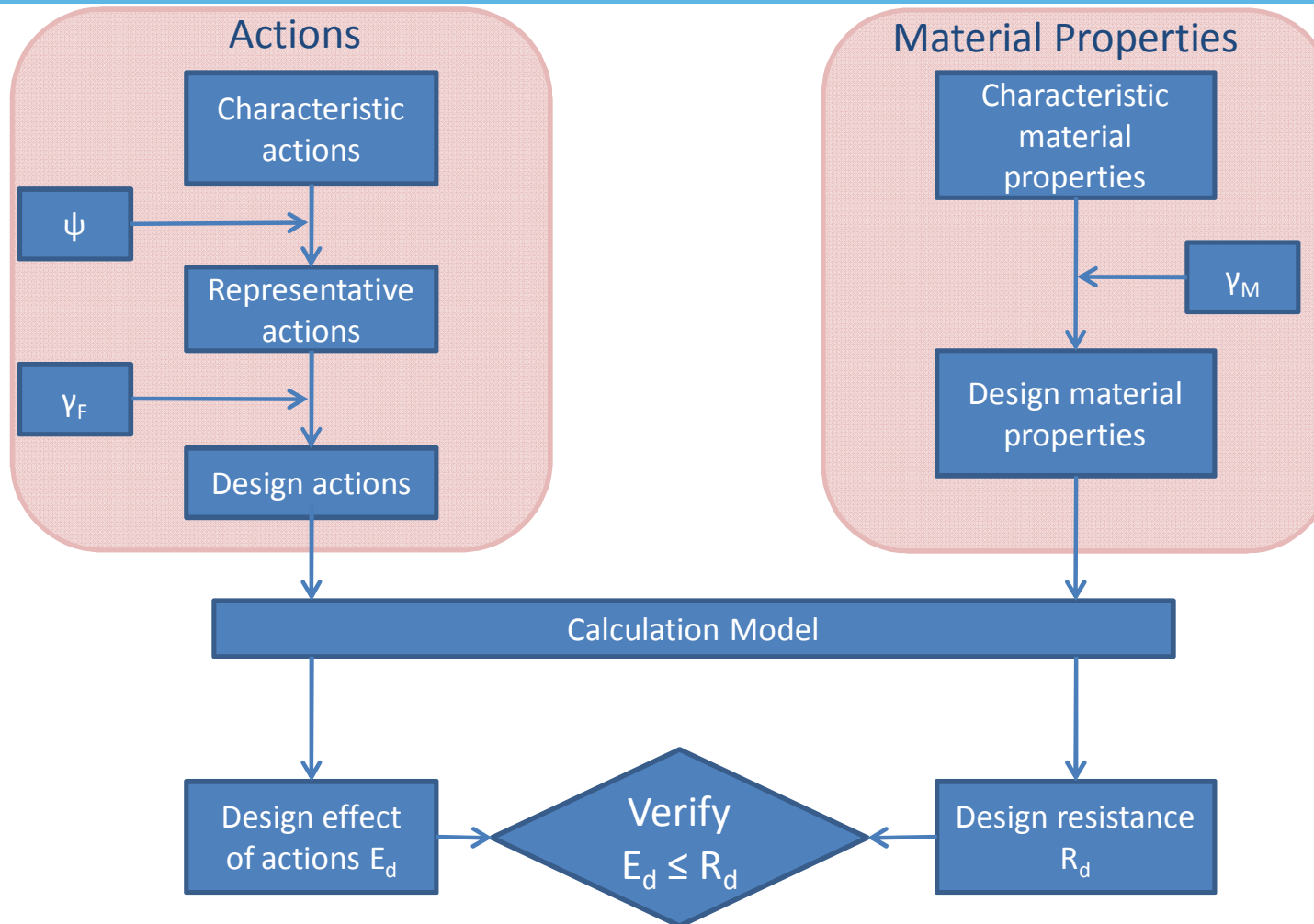
Partial factors for GEO/STR in persistent and transient design situation applicable to slopes, footings and walls).

Source: Decoding Eurocode 7, Harris and Bond (2008), Section 13.7.2

# Verification of strength



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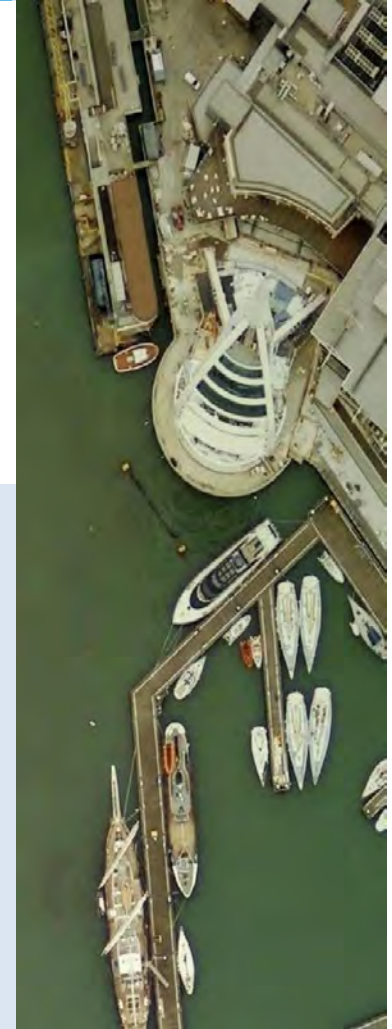
Applicable to verification of strength for spread foundations

# Current practices for calculating allowable bearing pressure



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- “ Currently an allowable bearing pressure (serviceability limit state) is often calculated by applying a factor of safety of 3 to ultimate bearing capacity.
- “ Going forward the new Eurocode 7 standard requires detailed knowledge of both building actions and ground resistance to calculate ultimate limit states and serviceability limit states.



# Reports



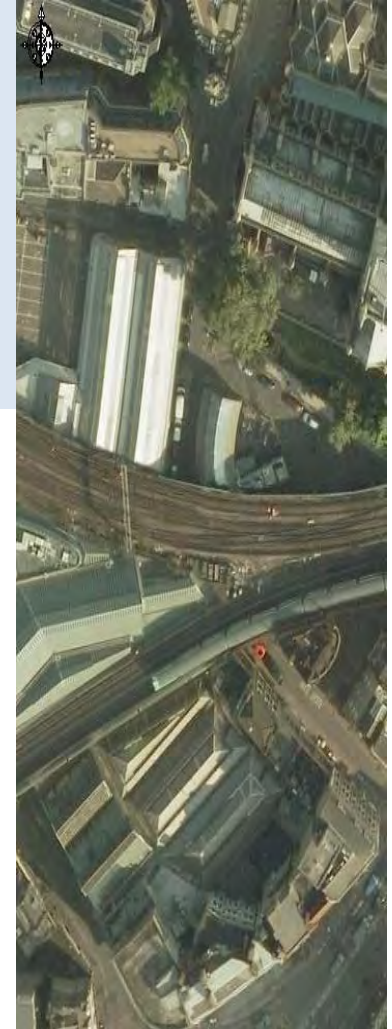
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## **Ground Investigation Report (GIR):**

- “ Equivalent to a factual report
- “ Presentation and evaluation of geotechnical information (derived values)

## **Geotechnical Design Report (GDR)**

- “ Assumptions (design values)
- “ Data (description of site, conditions, proposed construction)
- “ Methods of calculation
- “ Verification of limit states



# Benefits of Eurocode 7



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- “ Consistent approach between materials. Should in the long term improve workflow.
- “ The greater detail required for site investigations ensures that designs can be more reliable resulting in less cost and delays downstream in the development process
- “ It may be easier to collect the quality of information required to plan for sustainable energy solutions for developments.



# Potential implications for Geotechnical Design of Spread Foundations



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- “ Site investigation contractors may not be able to provide an allowable bearing pressure in the future.
- “ Structural engineers and geotechnical engineers will have to work more closely in order to design foundations.



# Overview of implications for Geotechnical Design



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“ If structural engineers and geotechnical engineers do not work together and understand each others terminology, there is a danger that both parties could apply partial factors that have already been applied, or not apply partial factors making a design structurally unsound.

“ Large cost burden in training and standards required. Disproportionately large on SMEs.



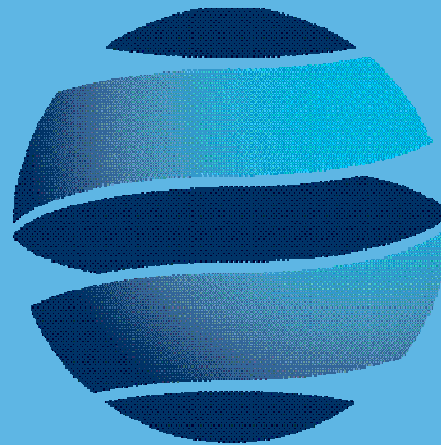
# Thoughts on combining approaches for Eurocode 7 and BS10175



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- “ One of the implications of Eurocode 7 is it’s ambiguities with regard borderline large and small developments, where it lacks detail on the number of exploratory holes.
- “ Many reports are written as joint geotechnical and geo-environmental reports and one of the ways of resolving this may be to incorporate the techniques within the forthcoming BS10175, which is more prescriptive about numbers and depths of boreholes required for sites.





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## Thank You Any Questions?

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