**GEOTECHNICAL DESIGN** with worked examples

13-14 June 2013, Dublin

Worked example – combination of actions

European Commission

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# Worked example – combination of actions **DESIGN SITUATION**



#### **Design situation for combination of actions**



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#### **Design situation for combination of actions**



Roof loading 0.6 kPa Office floor loading 2.5 kPa Partition loading 0.8 kPa Wind loading 1.15 kPa (ignore notional loads)



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## EN 1997-1 §2.4.6.1(2)P

Eurocode 7 defines the representative action  $F_{rep}$  as:

$$F_{rep} = \psi F_k \Longrightarrow \sum_{j \ge 1} G_{k,j} + Q_{k,1} + \sum_{i > 1} \psi_i Q_{k,i}$$

 $F_k$  = characteristic value

 $\psi$  = combination factor (taken from EN 1990) = 1.0,  $\psi_0$ ,  $\psi_1$ , or  $\psi_2$ G<sub>k,j</sub> = characteristic permanent action; Q<sub>k,i</sub> = characteristic variable action Q<sub>k,1</sub> = leading variable action; Q<sub>k,i>1</sub> = accompanying variable action





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## **Combination of actions**

Combin- ation	Rep. var'ble actions	Limit state	Design situation (DWL = design working life)	Example
Character- istic	$\psi_0 \; Q_k$	ULS	Persistent (period ~ DWL)	Normal use
		ULS	Transient (period << DWL)	During construction or repair
		SLS	Irreversible limit states	Stress checks for reinforcement
Frequent	$\psi_1 \; Q_k$	ULS	Accidental	Exceptional conditions, e.g. fire, explosion, impact, etc.
		ULS	Seismic	Earthquake
		SLS	Reversible limit states	Crack width/decompression checks in pre-stressed concrete or survival condition in accidental ULS combination waiting for repair
Quasi- permanent	$\psi_2 \; Q_k$	ULS	Accidental	Fire, explosion, impact, etc.
		ULS	Seismic	Earthquake
		SLS	Long-term effects and	Crack width checks in reinforced
			appearance	concrete
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#### **Combination of actions – for buildings**

Action	Ψο	Ψ1	Ψ2			
Imposed loads in buildings (EN 1991-1-1)						
A: domestic, residential areas	0.7	0.5	0.3			
B: office areas	0.7	0.5	0.3			
C: congregation areas	0.7	0.7	0.6			
D: shopping areas	0.7	0.7	0.6			
E: storage areas	1.0	0.9	0.8			
F: traffic area, vehicle weight $\leq$ 30kN	0.7	0.7	0.6			
G: traffic area, $30$ kN $\leq$ vehicle weight $\leq$ 160kN	0.7	0.5	0.3			
H: roofs	0 [0.7]	0	0			
Wind loads (EN 1991-1-4)						
Wind loads on buildings	0.6 [0.5]	0.2	0			
Values in [brackets], given in BS EN 1990, replace values in EN 1990						

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### Partial factors for buildings

Action		Symbol	Set B	Set C
Permanent	Unfavourable ('superior')	$\gamma_{G,sup}$	1.35	1.0
	Favourable ('inferior')	$\gamma_{ m G,inf}$	1.0	
Variable	Unfavourable	$\gamma_{\mathbf{Q}}$	1.5	1.3
Accidental	Unfavourable	ŶΑ	1	.0
Seismic	Unfavourable	$\gamma_{AE}$	1	.0



#### **Worksheet – combination of actions**



Calculate these combinations:

- 1. Wind as leading variable action with Set B factors
- 2. As 1, but removable permanent actions missing
- 3. Imposed loads as leading variable action/Set B factors
- 4. As 1, with Set C factors
- 5. As 2, with Set C factors
- 6. As 3, with Set C factors
- 7. As 1, for SLS
- 8. As 2, for SLS
- 9. As 3, for SLS

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Worked example – combination of actions **SOLUTION** 



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# **Solution – combination of actions**

#	Limit state	Leading variable action	Removed permanent actions?	N <sub>Ed</sub> (kN)	M <sub>Ed</sub> (kNm)
1	ULS	Wind	No	2400	2405
2	ULS	Wind	Yes	1631	2405
3	ULS	Imposed	No	2510	1443
4	ULS	Wind	No	1802	2084
5	ULS	Wind	Yes	1631	2084
6	ULS	Imposed	No	1898	1250
7	SLS	Wind	No	1688	0
8	SLS	Wind	Yes	1631	0
9	SLS	Imposed	No	1688	0

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# Summary of key points

Geotechnical engineers need to understand combinations of actions to ensure effective communication with structural engineers

ULS verifications are normally checked with Persistent/Transient (the 'fundamental') combination
SLS verifications are normally checked with Quasi-Permanent (i.e. 'average loading') combination

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