Second Generation of Eurocode 7

Slopes, cuttings, embankments, and traffic loads on geotechnical structures

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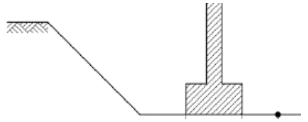
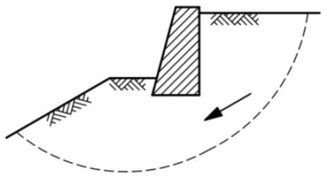
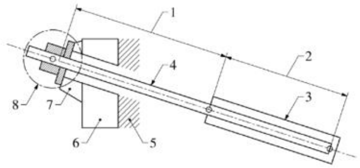
Scope and basic assumptions

Basic assumptions [4.1(1)-(2)]:

- **Overall stability, local stability, and displacement** of slopes, cuttings and embankments
- **Dams and levees are covered** but verification of water retention is excluded (additional provisions needed for CC3 and CC4 structures)
- EN 1997-3 to be used in conjunction with EN 16907 (all parts) on earthworks
- If the level of reliability required by EN 1990 is not obtained in the design verification, **stabilising measures** shall be considered. [4.5.1(4)]
- When verifying stability, all potential failure mechanisms shall be verified. [4.5.1(5)]

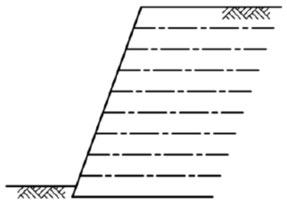


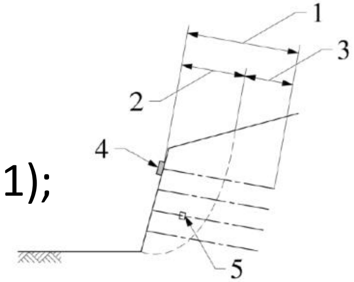


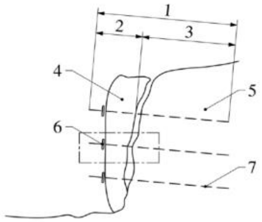


EN 1997-3, Clause 4 applies to overall stability of: [4.1.(3)]

- Slopes and cuttings supporting nearby structures, infrastructure or foundations;
- Existing slopes within the zone of influence of the construction works;
- Retaining structures (EN 1997-3, Clause 7);
- Slopes and cuttings supported by anchors (EN 1997-3, Clause 8);
- Reinforced fill structures (EN 1997-3, Clause 9);
- Soil nailed structures (EN 1997-3, Clause 10);
- Slopes and cuttings supported by rock bolts or rock surface support (EN 1997-3, Clause 11);
- Embankments on improved ground (EN 1997-3, Clause 12).







Extent of ground investigation

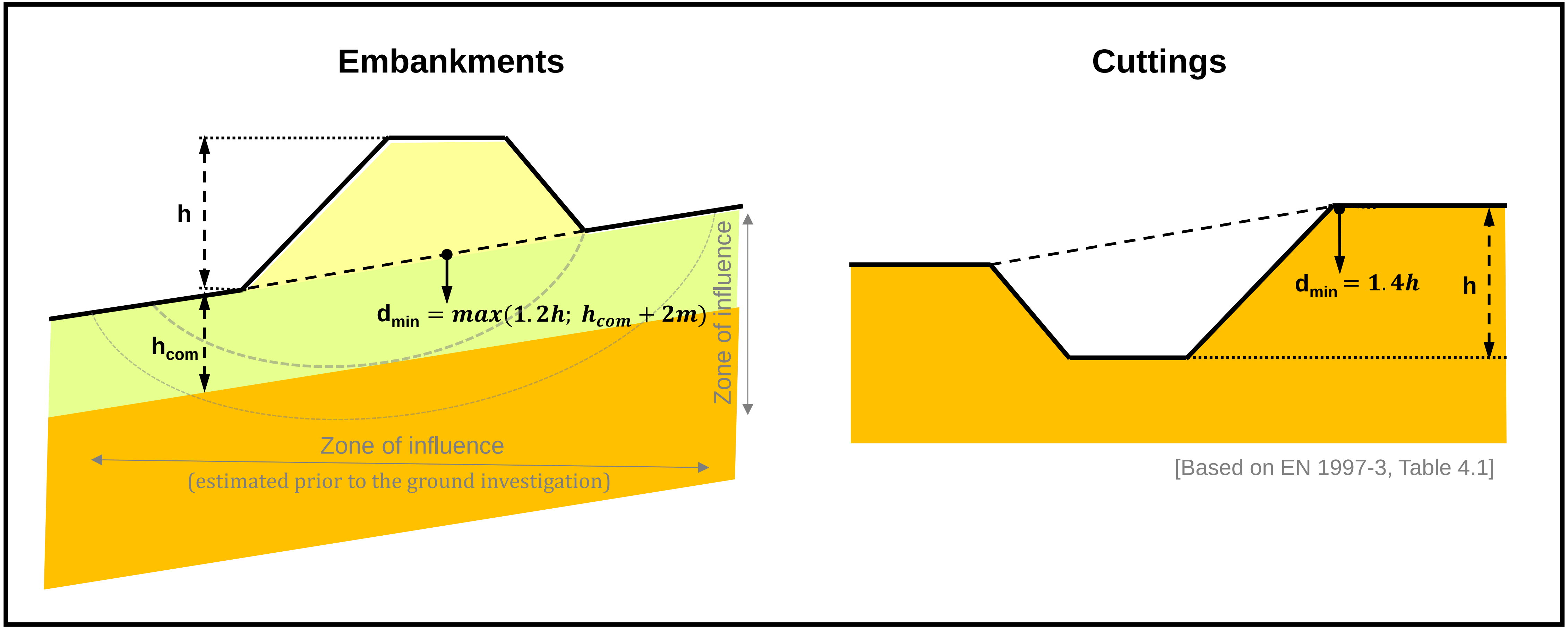
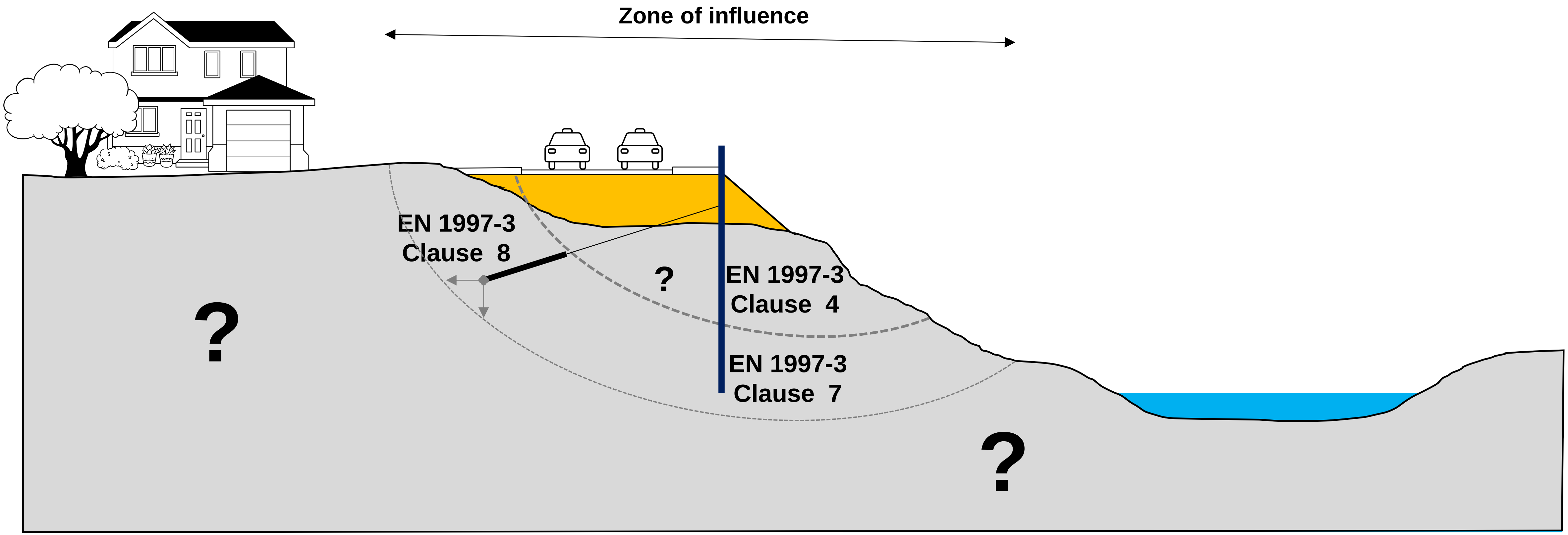


Table 4.1 is a National Determined Parameter (NDP) – Can be subjected to change at national level

Extent of ground investigation

The minimum extent of investigation [EN 1997-2, 5.4.3]:

- **shall be sufficient** to determine the ground conditions within the **zone of influence**;
- **should be increased** in the case of unfavourable ground conditions;
- **may be reduced** in competent ground, if sufficient comparable experience exists to allow its properties to be predicted throughout the zone of influence.



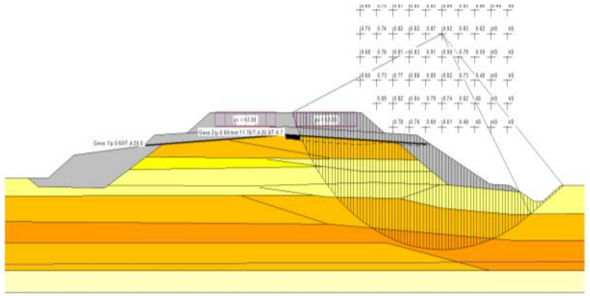
Calculation models

Calculation models for analysing the **stability of soil and fill** [A.3]

Models for geotechnical analysis - examples are given in Annex A, A.3:

- limit-equilibrium methods
- numerical models [EN 1997-1, 7.1.4]
- limit analysis.

Examples of models used for embankment stability assessment with geogrid reinforcement



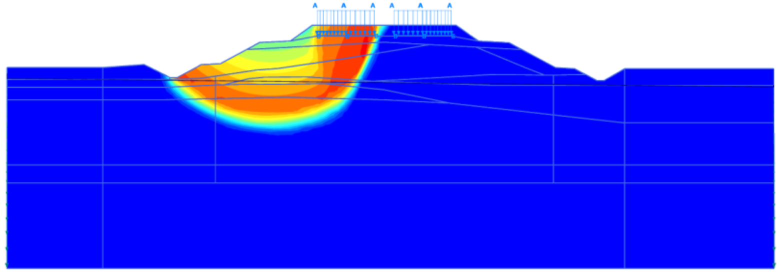


Table A.1 — Calculation models for analysing the stability of soil and fill

	Calculation model[c]	Type of method and assumed failure[a,b]	Special design conditions/limitations	Comments and assumptions
1	Bishop (simplified and rigorous)	Slices, circular arc	Not recommended with external horizontal loads	Simplified ignores interslice shear forces when interslice forces are horizontal
2	Generalized limit equilibrium	Slices, any shape of surface	Applicable with all slope geometries and soil profiles	---
3	Janbu generalized (modified)	Slices, circular arc, non-circular, polyline		Location of interslice normal force is assumed by a line of thrust
4	Morgenstern-Price			Direction of interslice forces by variable user function
5	Spencer			Constant interslice forces function
6	Sarma	Slices, polyline	Seismic loading, critical acceleration. Static conditions: horizontal load set to zero	Can include non-vertical slices and multi-wedge failure mechanisms
7	Kinematical approach of limit analysis	Multiple body, blocks, circular, planar or logarithmic spiral	---	Based on the compatibility of velocity fields
8	Block/wedge method	Multiple body, polyline	Pre-defined planar failure surface. Divided into three segments	Earth-pressure can be used as driving and resisting force. Rotational failure (assessed by moment equilibrium) not considered
9	Multiple wedge method	Multiple body, blocks, wedges, plane surfaces	---	Rotational failure (assessed by moment equilibrium) not considered
10	Infinite slope	Single body, plane surface	Long shallow slopes	
11	Culmann, finite slope		Steep slopes, drained analysis	
12	Logarithmic spiral	Single body; logarithmic spiral	Homogeneous soil, drained analysis	Rotational failure (assessed by moment equilibrium) only considered

[a] Where ground or embankment material is relatively homogeneous and isotropic, circular failure surfaces can normally be assumed, except when high external loads are present.

[b] Polyline includes interconnected plane surfaces.

Calculation models for analysing the **stability of rock mass** [A.4]

Table A.2 — Calculation models and considerations for analysing the stability of rock masses

No.	Type of method and assumed failure	Special design conditions/limitations	Comments and assumptions
1	Circular failure Large slope deformations[g]	Blocky or weathered rock mass[b] Tension crack with or without water	Method of slices, circular (see Table A4.1)
2	Plane failure	Tension crack with or without water	Plane surface, blocks
3	Wedge failure	Tension crack with or without water	Wedge
4	Block toppling	---	Blocks
5	Flexure toppling	---	Columns
6	Block-flexure toppling	---	Blocks and columns
7	Secondary toppling	---	---
8	Rock fall[c]	Block trajectories, bounce heights, velocities, energies, run out distances	Blocks

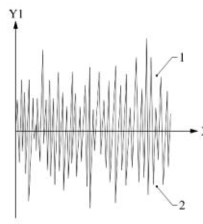
Limit state design

- *When verifying stability, **all potential failure mechanisms shall be verified**.* [4.5.1(5)]
- Clause specific **Ultimate Limit States** [4.2.5.1(1)]
  - *loss of overall and local stability of the ground and structures within the zone of influence;*
  - *failure due to gradual degradation of ground strength;*
  - *failure along discontinuities;*
  - *failure due to rock fall;*
  - *loss of bearing resistance of embankments;*
  - *structural failure of the face or surface of the slope, cutting or embankment and parts of it;*
  - *structural failure of stabilizing measures;*
  - *adverse hydraulic effects as a result of failure of drains, filters or seals;*
  - *rapid drawdown of surface water levels causing excess pore water pressure;*
  - *failure of the ground caused by surface or internal erosion, or scour; and*
  - *structural failure in structures, roads, railway lines, or utilities due to movements in the ground in the zone of influence.*
- Clause specific **Serviceability Limit States** [4.2.5.2(1)]
  - *settlement of embankments;*
  - *horizontal ground movements of slopes, cuttings, and embankments;*
  - *creep in soil and fill during the freezing and thawing period;*
  - *loss of serviceability in neighbouring structures, roads or services due to movements in the ground or due to changes in groundwater conditions;*
  - *deformation of the structure, which can cause serviceability limit states of existing nearby structures;*
  - *movements in the ground due to shear deformations, settlement, vibration or heave; and*
  - *accumulated ground movement or settlement due to creep.*

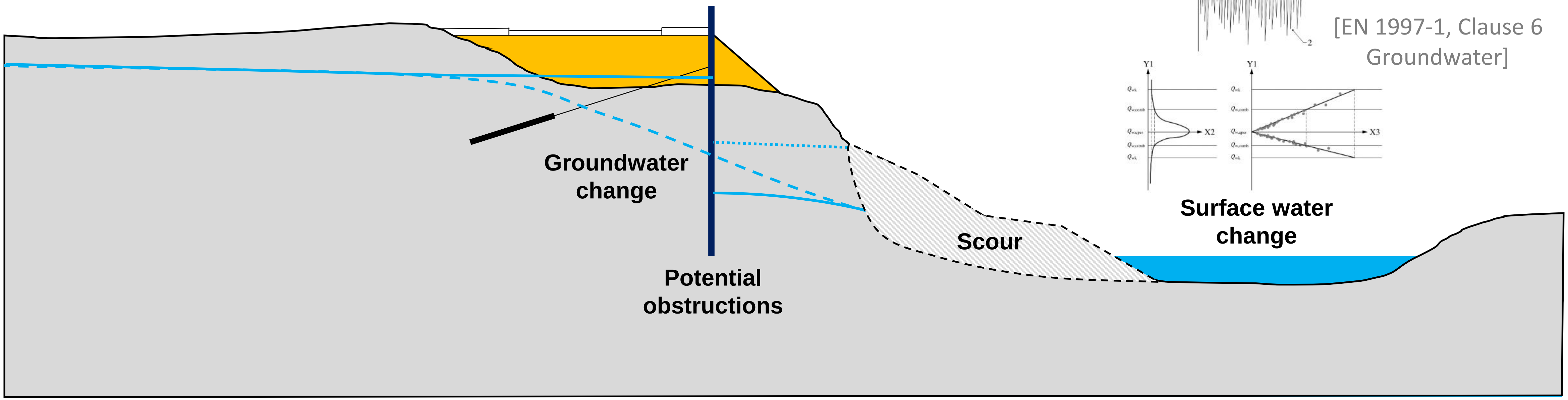
Groundwater

Examples of considerations:

- **Groundwater control measures** (EN 1997-3, Clause 13) may be provided to ensure that design groundwater and piezometric pressures are not exceeded due to unforeseen circumstances. [4.4.2(2)]
- If groundwater control measures are not provided, the design shall be verified to withstand **potential increase of groundwater pressures**. [4.4.2(3)]
- Potential **obstruction of natural groundwater flow** and change in the groundwater conditions induced by the retaining structure. [7.2.5.2(1), 7.4.1.(2)]
- *Measures shall be taken to prevent the **adverse effects of potential scour*** (…). [4.4.1(2)]



[EN 1997-1, Clause 6 Groundwater]



Overall stability - harmonisation

Table 4.2 (NDP) — Partial factors for the verification of ground resistance of slopes, cuttings, and embankments for fundamental (persistent and transient) design situations

Verification of	Partial factor on	Symbol	Material Factor Approach
Overall stability	Actions	γ_F	VC3[a]
	Ground properties[c]	γ_M	M2[b]
Bearing resistance	see Clause 5		

[a] Values of the partial factors for Verification Case 3 (VC3) are given in EN 1990:2023, Annex A.
[b] Values of the partial factors for Sets M2 are given in FprEN 1997-1:2024, 4.4.1.3.
[c] Also includes ground properties of Class AI ground improvement (see Clause 12).

One way of factoring for overall stability

Table 5.2 (NDP) — Partial factors for the verification of ground resistance of s… for fundamental (persistent and transient) design situations

Verification of	Partial factor on	Symbol	Material Factor Approach, either both combinations (a) and (b) or the single combination (c)			Resista… Appro… combi… or…
			(a)	(b)	(c)[d]	(d)
Overall stability	See Clause 4					

Table 7.2 (NDP) —Partial factors for the verification of ground resistance agains… structures for fundamental (persistent and transient) design situatio…

Verification of	Partial factor on	Symbol	Material Factor Approach – both combinations (a) and (b) or the single combination (c)			Resist… Ap…	
			(a)	(b)	(c)	(d)	(e)
Overall stability	See Clause 4						

Table 9.4 (NDP) — Partial factors for the verification of resistance of reinforced fill structures for fundamental (persistent and transient) design situations

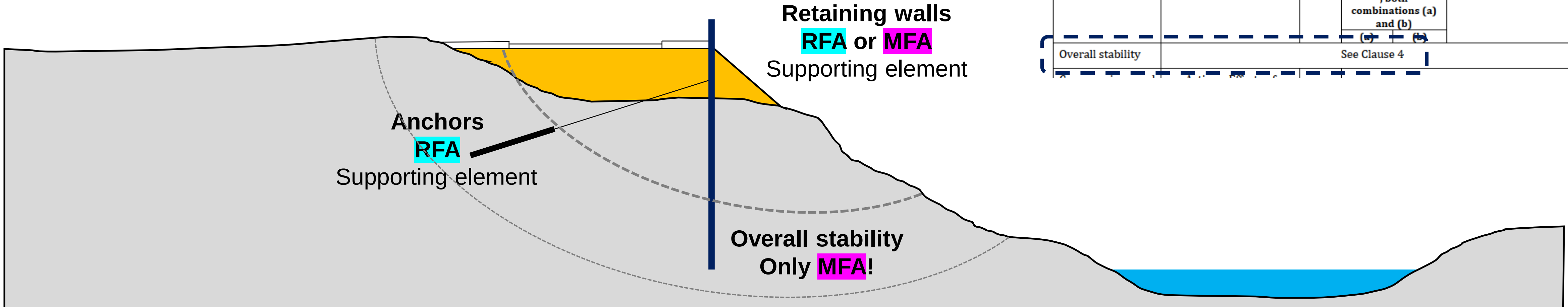
Verification of	Partial factor on	Symbol	Material Factor Approach	Resistance Factor Approach
Overall and compound failure mechanisms	See Clause 4			
Bearing	See Clause 5			

Table 10.3 (NDP) — Partial factors for the verification of resistance of soil nailed structures for fundamental (persistent and transient) design situations

Verification of	Partial factor on	Symbol	Material Factor Approach	Resistance Factor Approach
Overall and compound failure mechanisms	See Clause 4			
Bearing				

Table 12.4 (NDP) — Partial factors for the verification of ultimate resistance of ground improvement for fundamental (persistent and transient) design situations

Verification of	Partial factor on	Symbol	Material Factor Approach, both combinations (a) and (b)		Resistance Factor Approach
			(a)	(b)	
Overall stability	See Clause 4				



[EN 1990-1, eq. 8.20]

$$R_d = \frac{R\{X_{rep}; a_d; \Sigma F_{Ed}\}}{\gamma_R} = \frac{R\{\eta X_k; a_d; \Sigma F_{Ed}\}}{\gamma_R}$$

$$R_d = R\{X_d; a_d; \Sigma F_{Ed}\} = R\left\{\frac{\eta X_k}{\gamma_M}; a_d; \Sigma F_{Ed}\right\}$$

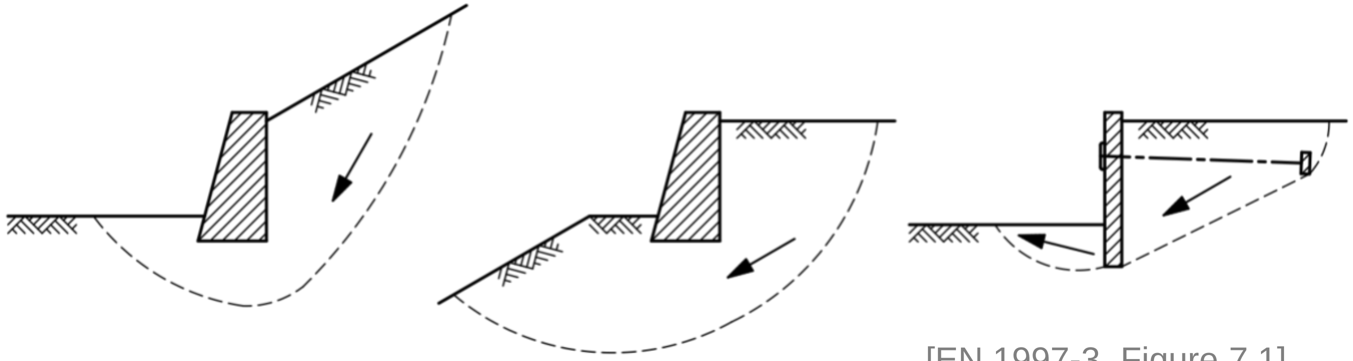
[EN 1990-1, eq. 8.19]

Overall stability – other geotechnical structures

[5.6.2(1)] *In accordance with Clause 4, it shall be verified that a **spread foundation** does not exceed an ultimate limit state of overall stability.*
NOTE This is particularly relevant when the spread foundation is within the zone of influence of sloping ground (…)

[7.6.2(1)] The overall stability of a **retaining structure** shall be verified in accordance with Clause 4.

[7.6.2(6)] For retaining structures in sloped ground, where **slope deformation induces additional thrust** on the wall, one of the following analyses should be used:
− the effects of actions on the retaining wall are checked using a continuum numerical model;
− failure surfaces intercepting the retaining structure are checked using a limit equilibrium method; or
− failure surfaces not intercepting the retaining structure are checked using a limit equilibrium method and by applying an additional model factor.



[EN 1997-3, Figure 7.1]

Supporting elements

- In cases where a **combined failure of supporting elements and the ground** could occur, ground-structure interaction shall be considered allowing for the difference in strength and stiffness of the ground and that of the supporting element. [4.6.2(1)]
- It shall be verified that the supporting element can resist design value of the effect of actions: [4.6.2(4)]

Verification Cases 1 and 3

$$E_{\mathrm{d}} = \max\{F_{\mathrm{d,ULS}};\ \gamma_{\mathrm{F}} F_{\mathrm{rep,SLS}}\} \qquad (4.1)$$

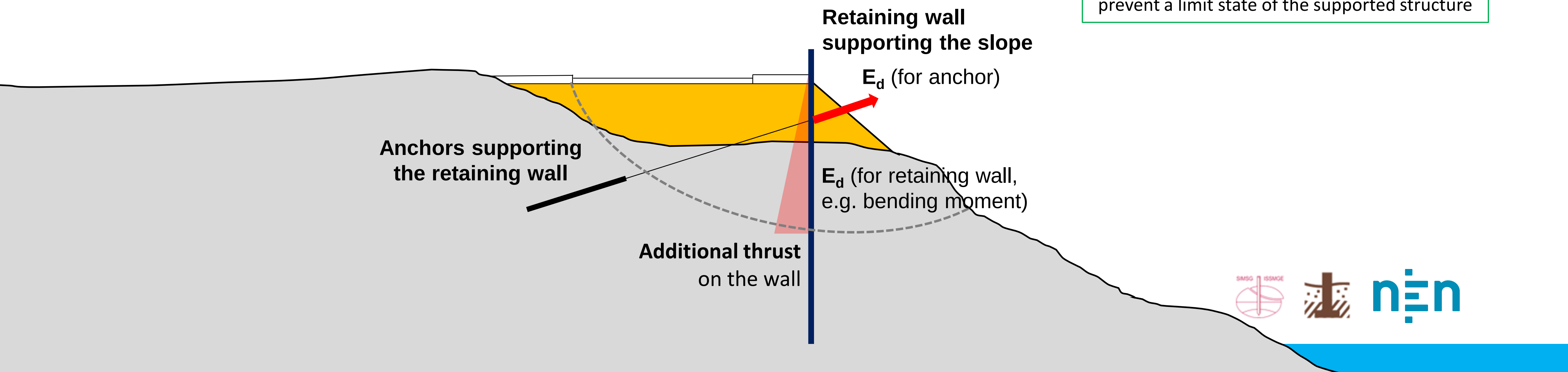
Verification Case 4

$$E_{\mathrm{d}} = \max\{\gamma_{\mathrm{E}} F_{\mathrm{rep,ULS}};\ \gamma_{\mathrm{E}} F_{\mathrm{rep,SLS}}\} \qquad (4.2)$$

Design value of the action that the supporting element shall provide to prevent a limit state of the supported structure

Partial factors used for conversion to design values

Representative value of the action that the supporting element shall provide to prevent a limit state of the supported structure



Some other issues

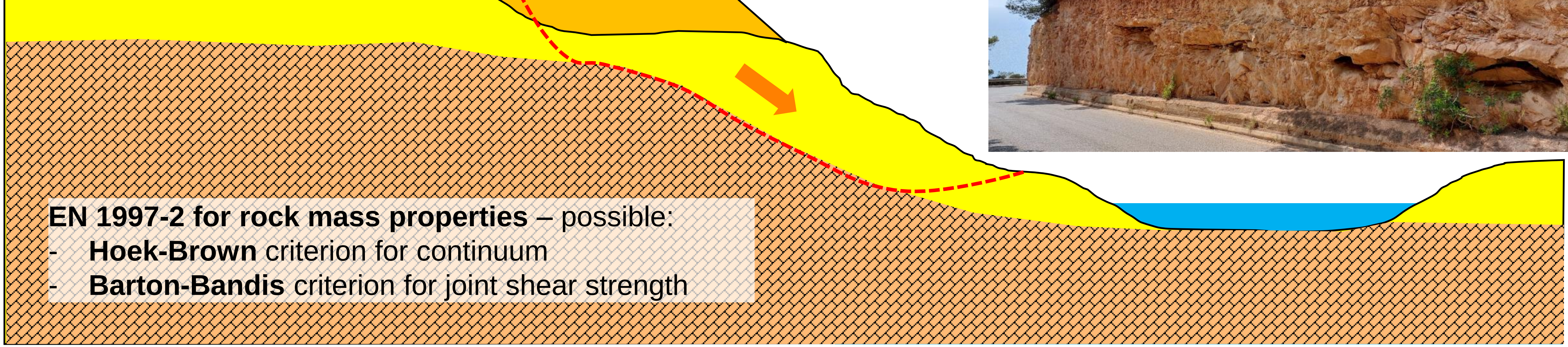
- **Pre-existing landslides**
  - Back-analysis can be used for deriving ground properties for unstable, slow-moving slopes. [4.3.1(6)]
  - *The resistance of **pre-existing sliding surfaces** should be determined using residual strength properties.* [4.5.1(3)]
- **Weather related issues**
  - Potential reduction in ground strength properties caused by **exposure to weather conditions** during or after execution should be considered. [4.3.1(3)]
  - Potential development of **tension cracks** in cohesive soils or cracks due to drying of high plasticity clays shall be considered when verifying limit states. [4.5.2(5)]
- **Cyclic and dynamic loading** – it should consider, among other factors [4.5.1(2)]:
  - *degradation of ground strength and stiffness;*
  - *accumulated ground movement or settlement;*
  - *build-up of excess groundwater pressures;*
  - *amplification of loads or displacements owing to resonance;*
  - *potential liquefaction of the ground.*

Rock slopes

- The verification of **rock mass stability** shall consider, but is not limited to: [4.5.3(1)]
  - *– the rock excavation technique and sequence;*
  - *– damaging effects of excavation by blasting;*
  - *– influence of rock discontinuities and weathered zones within slopes and cuttings on the local stability;*
  - *– the influence of strength anisotropy of the rock material;*
  - *– the effect of strength reduction with time through weathering, swelling, degradation, and climate effects;*
  - *– groundwater;*
  - *– geometry/curvature;*
  - *– rock stress (particularly horizontal); and*
  - *– effect of possible local instability on the overall stability.*

- The verification of limit states shall be based on **geotechnical mapping** and documentation of the rock conditions obtained from **site inspection and testing**. [4.5.3(2)]

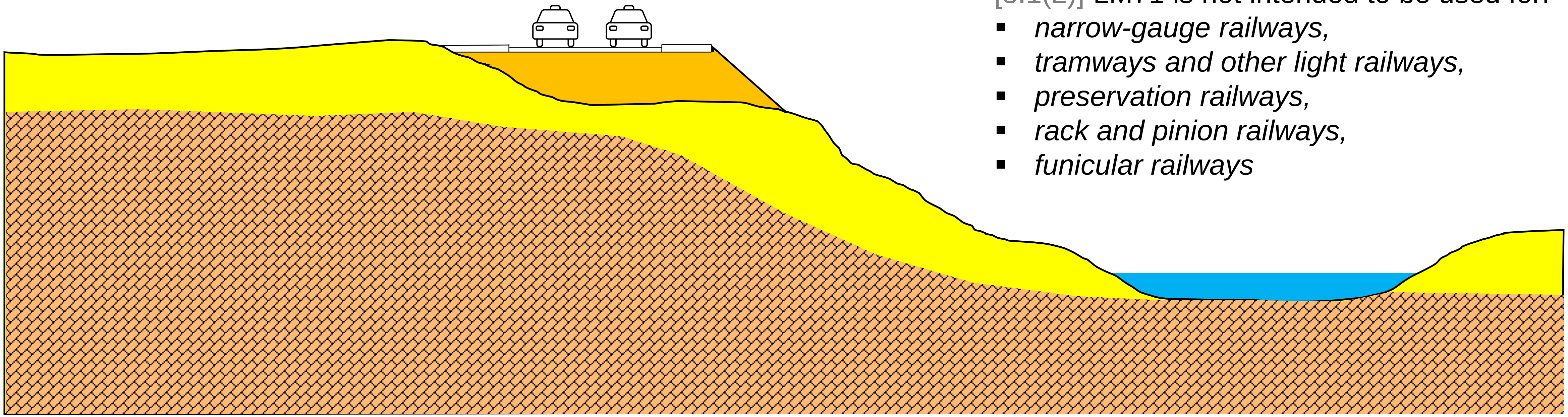
- Potential **instability along soil-rock interfaces** shall be considered when verifying limit states. [4.5.2(6)]



Traffic loads on geotechnical structures

- [EN 1997-3, 4.2.4.2(2)] ***Traffic load on slopes, cuttings and embankments*** *shall comply with EN 1991-2:2023, 6.9 and 8.10, as appropriate.*
- [EN 1991-2, 1(3)] ***The load models and values*** *given in this document are also applicable for the design of retaining walls adjacent to roads and railway lines and* ***the design of earthworks subject to road or rail traffic actions****. (...)*
- The rail traffic load models (e.g. LM71) do not describe actual loads, but represent the effects of service traffic. [8.1(1), Note]
- Load models for geotechnical structures are considered as alternatives. [EN 1991-2, 6.9.1(1)]
- **The loading is a part of geotechnical calculation model**, which has to be validated in line with EN 1997-1. [EN 1991-2, 6.9.1(2)]

Traffic loads
[EN 1991-2]



[8.1(2)] LM71 is not intended to be used for:

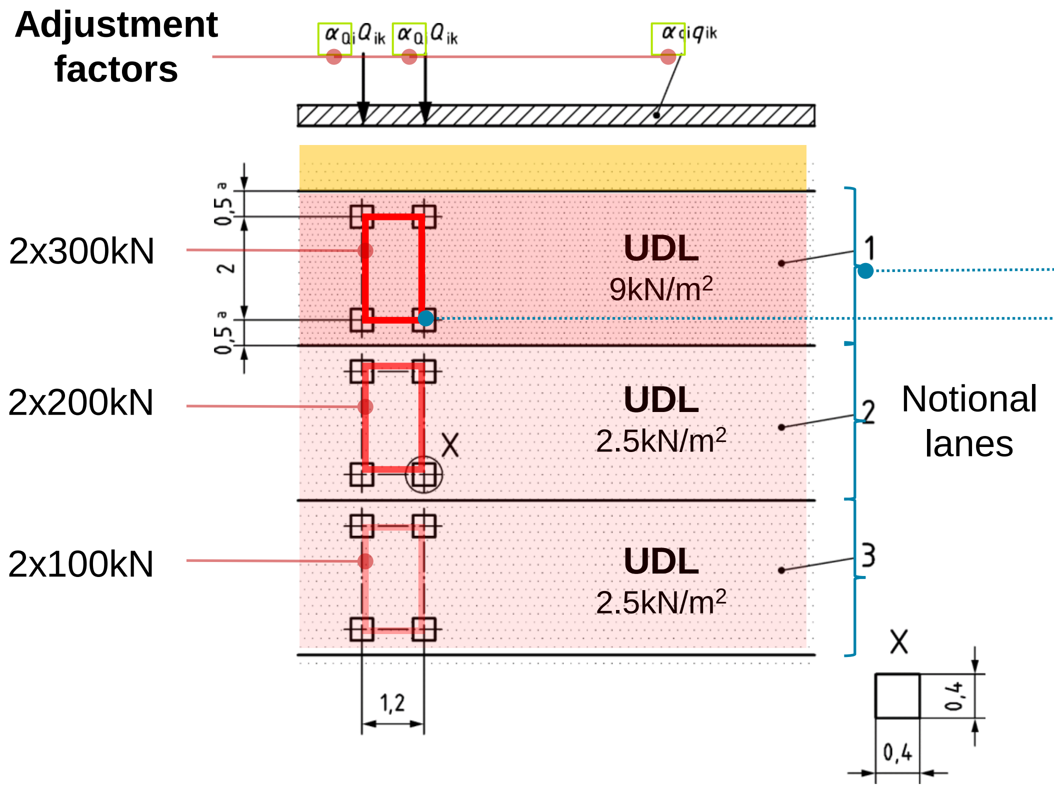
- *narrow-gauge railways,*
- *tramways and other light railways,*
- *preservation railways,*
- *rack and pinion railways,*
- *funicular railways*

Road traffic (EN 1991-2, Clause 6)

Load Model 1 (LM1)

[EN 1991-2, Figure 6.2]

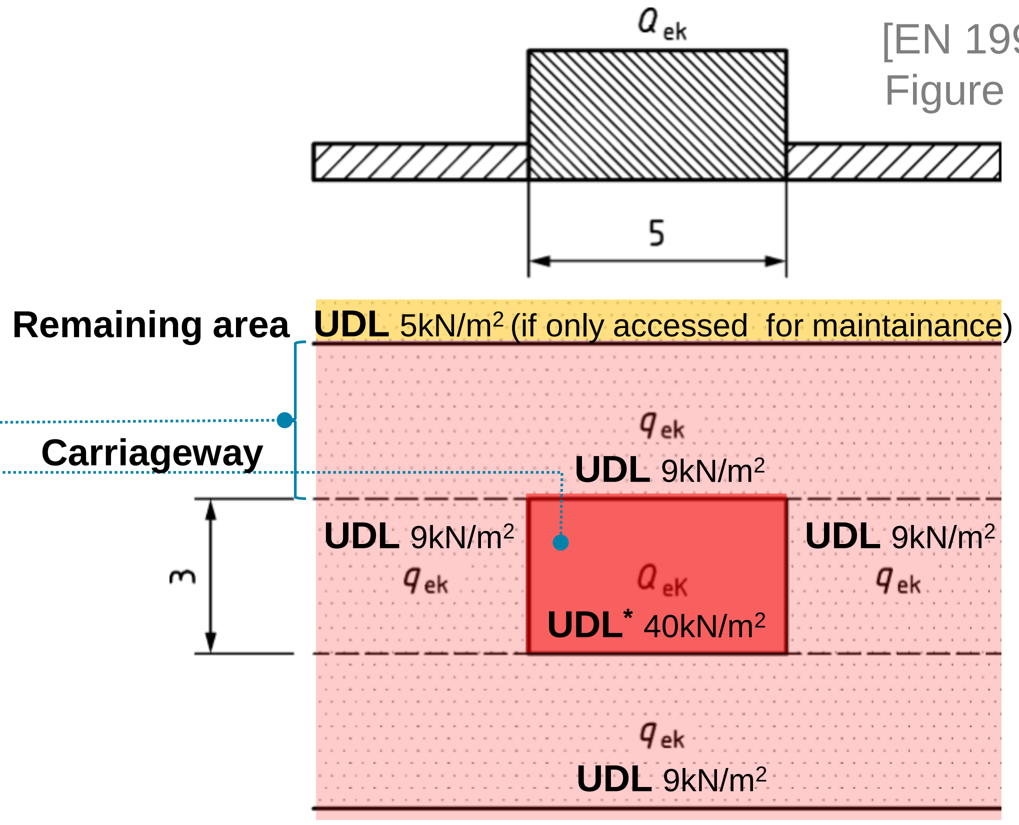
Characteristic loads



For geotechnical structures

Model considered as an alternative

[EN 1991-2, Figure 6.11]



- [6.9.2(2)] Q_{eK} **placed for the most adverse effect.**

- [6.3.2(3)] Dynamic amplification included.
- [6.3.2(4) Note] *Adjustment factors equal to 1 correspond to heavy industrial international traffic.*
- [6.3.2(6)] UDL q_k should be **applied only when acting as a destabilising action**!

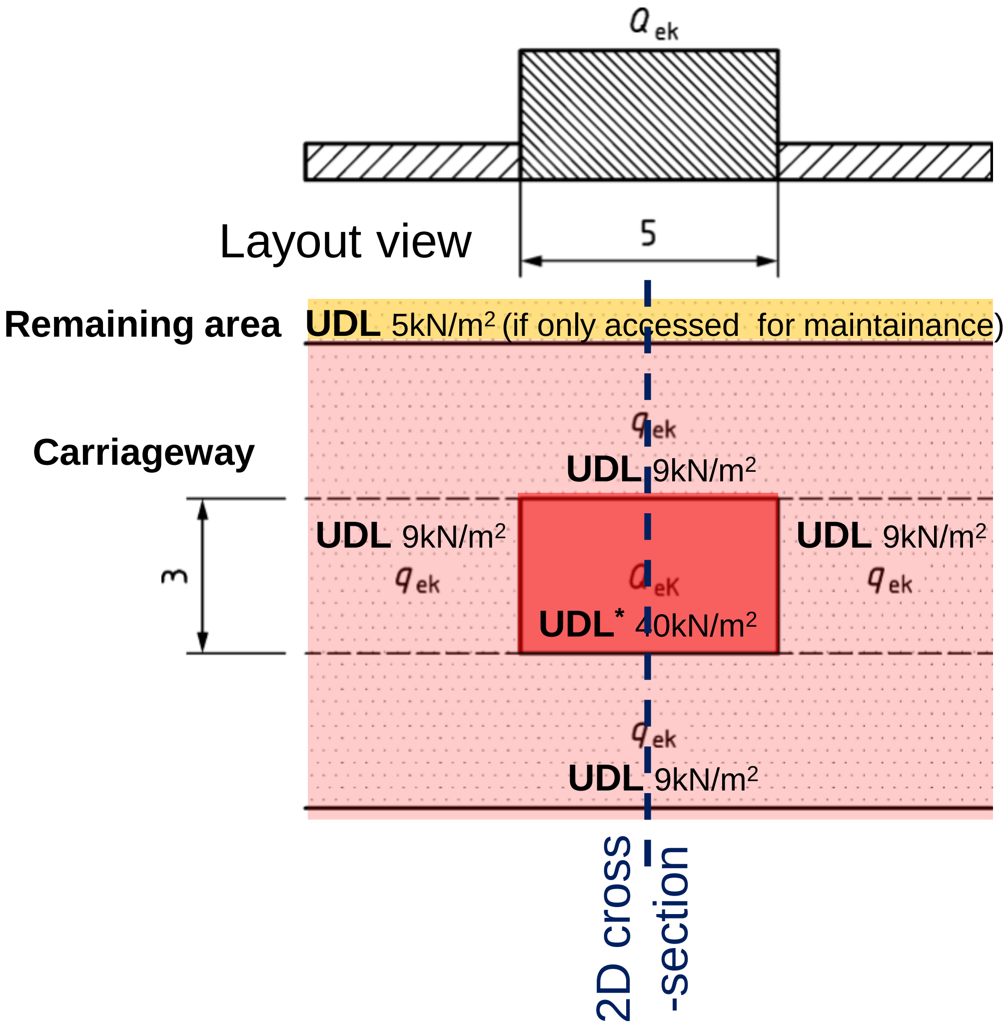
Road traffic (EN 1991-2, Clause 6)

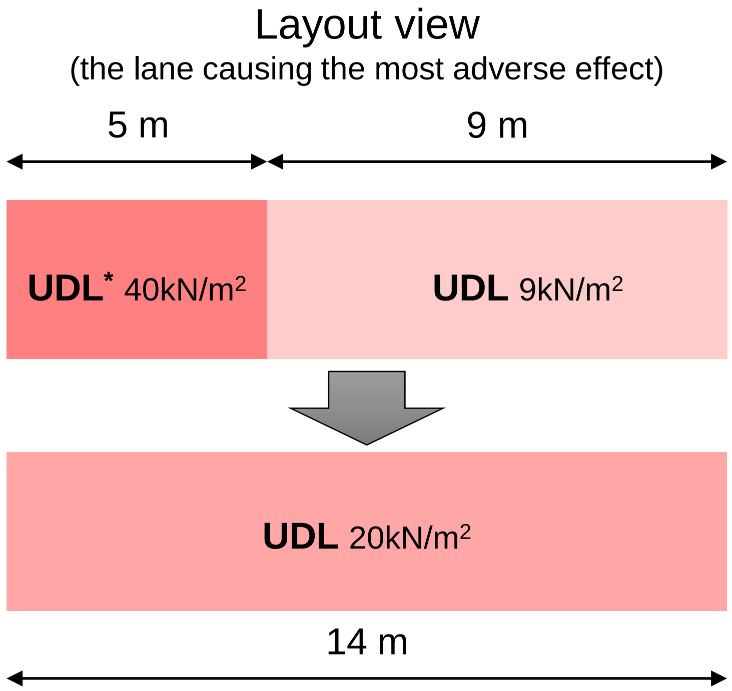
Simplified equivalent UDL

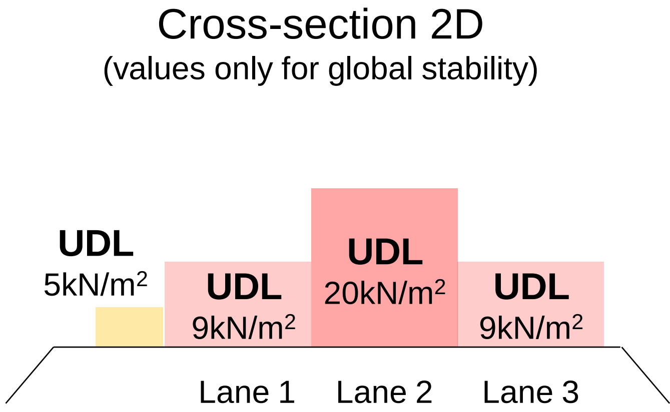
[6.9.3(1)&(2)] Simplified equivalent UDL $q_{ek,l}$ may be used when redistribution through the ground is allowed or local effects are not significant. Therefore:

- **2D & global problem – 20 kN/m² over 3m width** (infinite length) is allowed
- **3D or local problem – 40 kN/m² over the area 3m x 5m** should be used.

Note: Assumed uniform redistribution of the weight of a typical vehicle over a typical length of 14m; the load min. 1m from the structure.

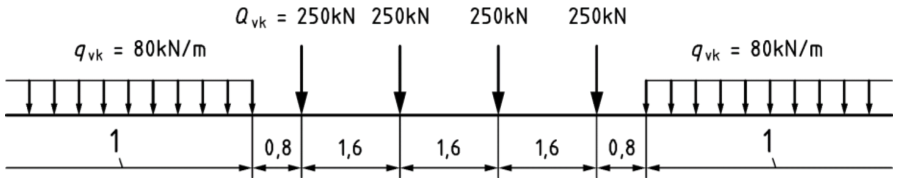


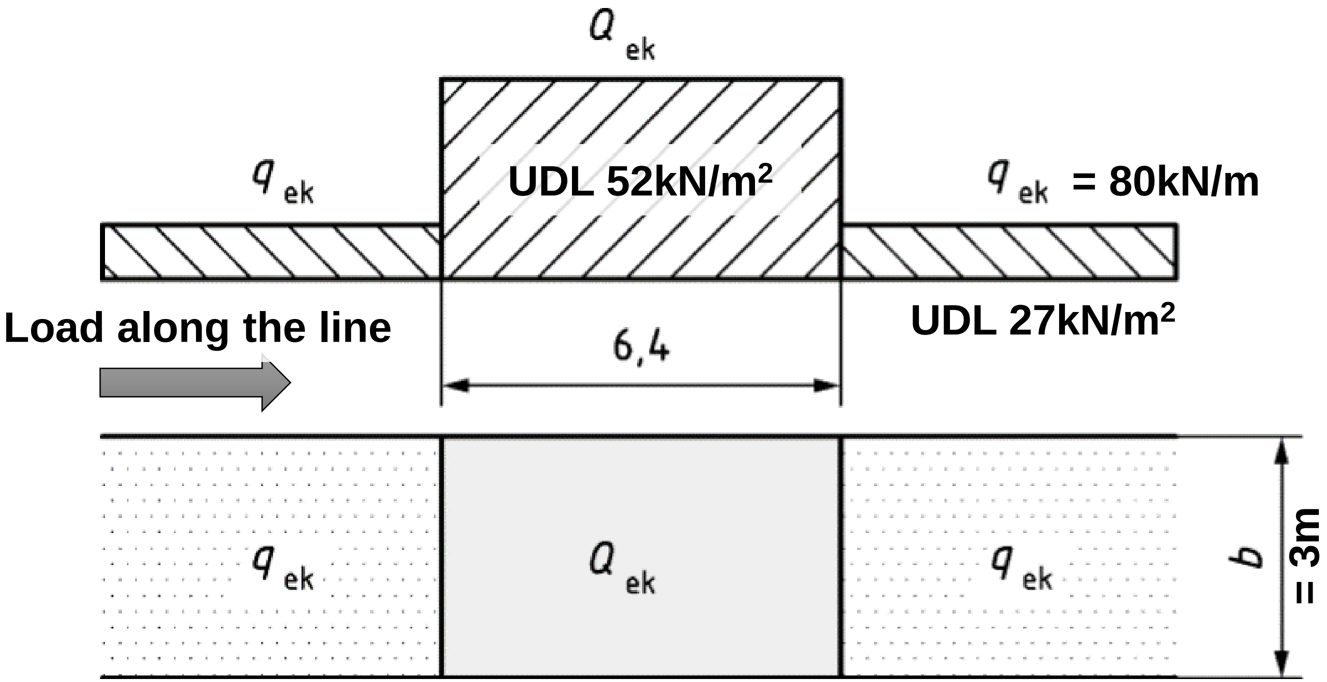




Rail traffic (EN 1991-2, Clause 8)

Load Model 71 (LM71)
representing normal rail traffic on mainline railways [8.3.1(1), Figure 8.1]





Equivalent load arrangement for LM71 for geotechnical structures
Model considered as an alternative

- Applied **at a level 0.70 m below** the running surface of the track [8.10.2(1)]
- **The width b is 3 m** (NDP) [8.10.2(1) Note]
- Load Model SW/2 can also be used [8.10.2(2)]

- *"Classified vertical loads" shall be obtained by multiplying the characteristic values given in Figure 8.1 by **a factor α**.* [8.3.2(3)]
- No **dynamic factor** or enhancement should be applied to the load [8.10.1(5)]

- *For structures carrying **two tracks**, Load Model 71 shall be applied to one track or both tracks* [8.3.2(10)]
- *For structures carrying **three or more tracks**, Load Model 71 shall be applied to one track or to two tracks or 0.75 times Load Model 71 to three or more of the tracks.* [8.3.2(10)]

Rail traffic (EN 1991-2, Clause 8)

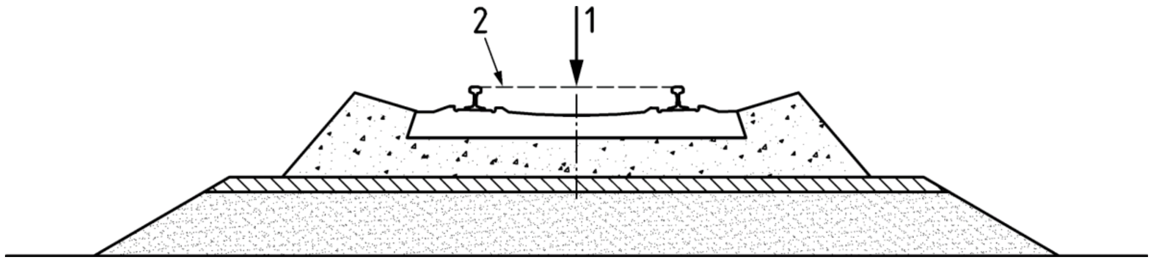
[8.10.3(1)] A characteristic load $q_{ek,l}$ may be used when redistribution through the ground is allowed or local effects are not significant. The value is:

- LM71: 100kN/m (33 kN/m^2)
- LM SW/2: 150kN/m (50kN/m^2)

Cannot be applied if distance between track sleeper and the structure is less than 1 m.

Simplified load model for geotechnical structures

[Figure 8.29]



Comparison of the load models for geotechnical structures

Source	Type of load	Type of analysis	
		2D (global)	3D (global and local)
Roads (LM1)	Uniformly distributed load or point load Q_{ek}	**20 kN/m^2** (one lane: 3 m)	**2 x 300 kN (40 kN/m^2)** (area 3 m x 5 m)
	Uniformly distributed load q_{ek}	**9 kN/m^2** (other lanes)	
	Areas used for maintainance only q_{ek} (e.g. unpaved area)	**5 kN/m^2**	
Trains (LM71)	Point load Q_{ek}	**100 kN/m** or **33 kN/m^2**	**4 x 250 kN (52 kN/m^2)** (6,4 m x b)
	Uniformly distributed load q_{ek} (width b)		**80 kN/m (27 kN/m^2)**
Trains (SW/2)	Uniformly distributed load q_{vk} (25.0 m x b)	**150 kN/m (50 kN/m^2)**	

Comments:
- Dynamic factor is not used for those values.
- Loads should be located, where they will result in the most onerous effects.
- Width (b) is 3.0 m, unless National Annex provides a different value.
- Train load is assumed at the level of 0.7 m below the top of the rail.

Some common design questions

How do I assess the stability of an exisiting slope?
[4.1(1), Note 2] The stability of existing slopes can be assessed using reliability levels for existing structures according to EN 1990.

Do I need to calculate displacements of a slope or a cutting?
[4.7.2(1)] No if there are no explicit serviceability criteria; the verification of serviceability limit states of slopes may be omitted provided ultimate limit states are verified.

What weight density should I use for slope stability?
[4.5.2(3)] *The permanent weight density of ground within a slope, embankment, or cutting should be determined in accordance with EN 1990:2023, 6.1.2.2.*
*NOTE: The **weight density is a mean value when the uncertainty is small**; otherwise it is either the superior (upper) or inferior (lower) characteristic value, whichever is more critical.*

Should I use drained or undrained analysis?
- Stability can be verified using **effective stress or total stress** ground properties and conditions. [4.3.1(4)]
- When it is not obvious which governs overall stability **a combination of drained or undrained** conditions should be used - the most unfavourable combination is chosen. [4.5.2(2)]

Summary

- Compared to the first generation Eurocode 7, the provisions for slopes, cuttings, and embankments were **not subjected to any revolutionaly changes**.

- Analysis of overall stability of slopes, cuttings, and embankments in **Clause 4 has been harmonised with the other geotechnical structures**, recognising that design often involves multiple problems.

- **Only one partial factoring approach** (MFA) is defined for overall stability.

- Overall stability of **rock slopes** is as important as stability of slopes in soils.

- Including **traffic loads on geotechnical structures in EN 1991-2** resolves the issue of converting the bridge loads to equivalent loads on a project-by-project basis.

- Most of the numerical values are **National Determined Parameters** (NDPs). They can be modified at the national level! Ask your National Standardisation Body for more details.

Thank you

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