Finnish design guidelines: Design of road structures

- New guideline published 28th of Nov 2018

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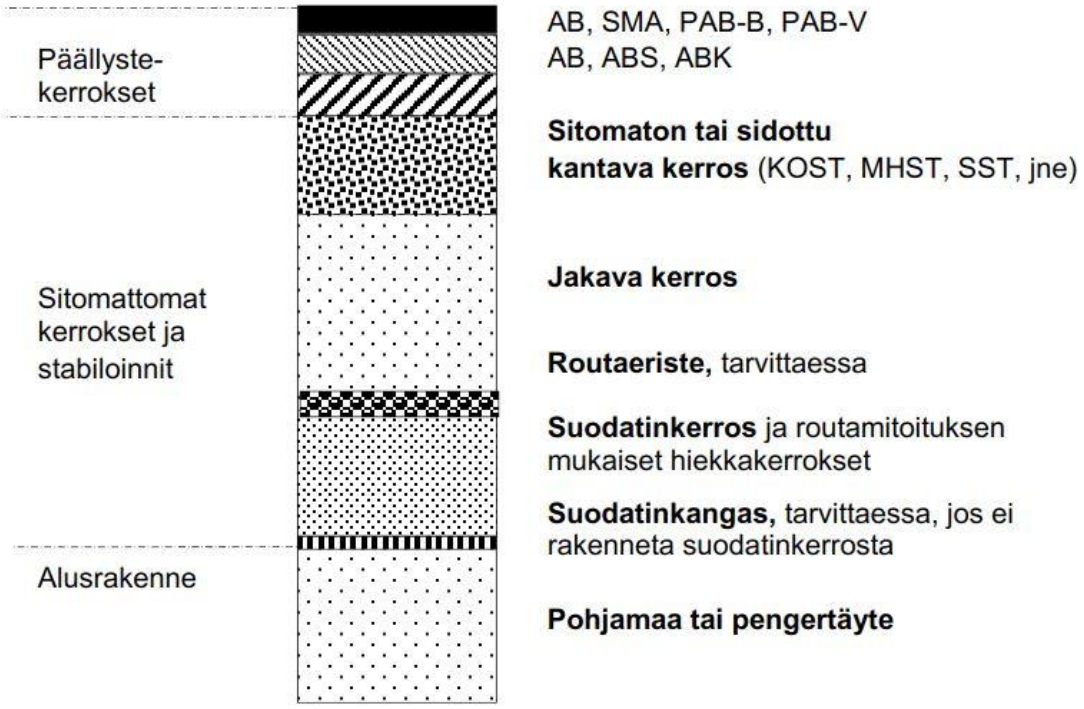
Design of road structures



- New guideline of design of road structures was published 28th of Nov 2018, biggest changes were:
  - General requirements about planning of asphalt pavements were added
  - The calculation of the number of equivalent standard axles was updated because of the changes in the biggest allowed measures and masses of trucks
  - A new bearing capacity category for most severely loaded roads was added
  - A demand for a memo of design of road structures was added
  - Some other guidelines were appended to the guideline
  - Also plenty of other smaller changes
- The guideline is written so that the demands are written in black text and the informatic texts are in green text
- The guideline is used when
  - Planning road structures
  - Setting demands for pavements of new roads
  - Evaluating the possibility to use old road structures when having a bigger renovation for the road

Frost protection of road structures

- **Calculated frost heave RN_{lask}** is determined based on thickness of freezing subgrade **P** and frost heave capacity **t** (%) of the subgrade
- **Frost heave capacity t** (%) is determined based on subgrade classification and on local conditions (wet/dry)
- **Thickness of freezing subgrade P** is determined based on **design frost depth S** and thickness of road structure layers
- **Maximum allowed frost heave RN_{sall}** is based on category of the road, subgrade homogeneity and the road structure sensitivity for permanent deteriorations

- **Calculated frost heave < Maximum allowed frost heave**

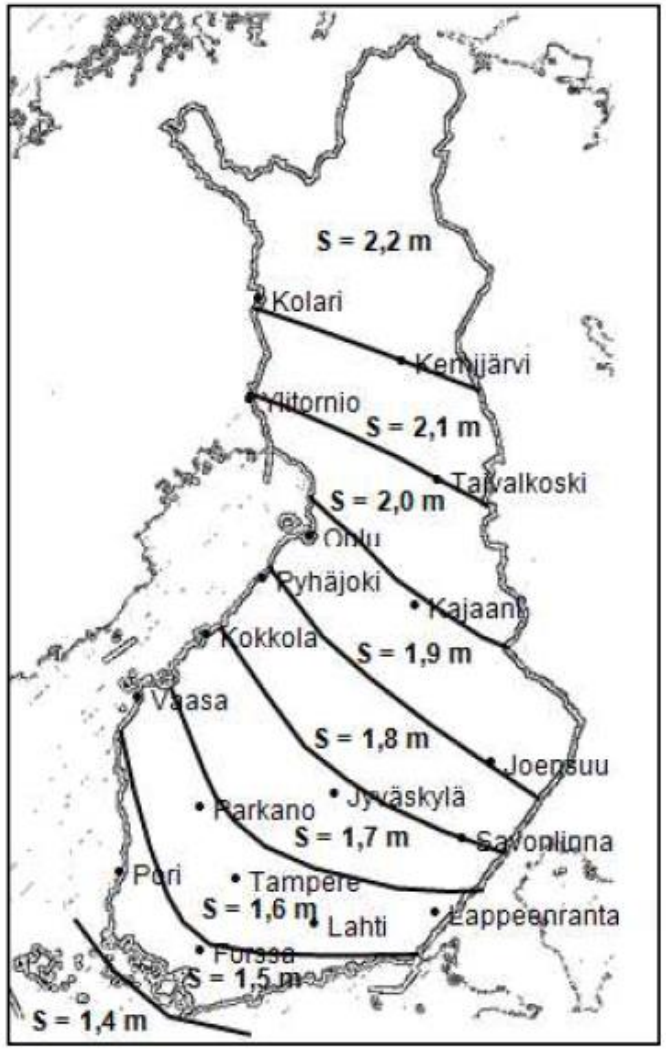


Table of subgrade class, frost heave capacity t(%) and E-modulus Type of soil S1…S4, subgrade class A…H

Sieve size (mm)		Type of soil	E-modulus, subgrade class, frost heave capacity %		Used in	Typical material
0,063	2		Dry	Wet		
			280 MPa, A, 0 %			Blasted rock
			200 MPa, B, 0 %		Base course	gravel
< 7 %	> 70	S1	100 MPa, C, 0 %		Sub-base	gravelly till
7-15	> 70	S2	70 MPa, D, 0 %	50 MPa, E, 3 %	Embankment	gravelly till
16-30	> 70	S3	50 MPa, E, 3 %	35 MPa, F, 6 %	Embankment	gravelly till
31-50	> 70	S4	35 MPa, F, 6 %	20 MPa, H, 12 %	Embankment (dry)	silty till

Type of soil (S1-S4, H1-H4, U1-U4) gives information about soil suitability for road structures or road embankment in diffrent conditions (wet/dry). Subgrade class A-J is defined based on gradation and condition (wet/dry). The design values for frost and bearing capasity design are chosen based on subgrade class.

Type of soil H1…H4 and U1…U3

Sieve size (mm) shearing strength (kPa)			Type of soil	E-modulus, subgrade class, frost heave capacity %		Typical material
0,002	0,063	2		Dry	Wet	
	< 7 %	< 70	H1	70 MPa, D, 0 %		sand
	7-15	< 70	H2	50 MPa, E, 3 %		sand, sandy till
	16-30	< 70	H3	35 MPa, F, 6 %	20 MPa, H, 12 %	sand, sandy till
	31-50	< 70	H4	35 MPa, F, 6 %	20 MPa, H, 12 %	Silty sandy till
< 30	≥ 50		U1	20 MPa, H, 0 %	20 MPa, J, 16 %	silt, silty till
≥ 30	≥ 50	≥ 40 kPa	U2		35 MPa, F, 12 %	Clay (stiff)
≥ 30	≥ 50	< 40 kPa	U3		20 MPa, G, 6 %	Clay (soft)

Type of soil (S1-S4, H1-H4, U1-U4) gives information about soil suitability for road structures or road embankment in diffrent conditions (wet/dry). Subgrade class A-J is defined based on gradation and condition (wet/dry). The design values for frost and bearing capasity design are chosen based on subgrade class.

Maximum frost heave

	Maximum frost heave RN (mm)					Gradient of transition section R/L
	Homogenous subgrade			Non-homogenous		
Category Of evenness	Non-steel mesh		Steel mesh	Non-steel mesh	Steel mesh	
	Standard	Special				
V1 Motorway	30	30	30	0	0	1:40
V2 Main road 80…100 km/h	70	70	100	10	10	1:30
V3 Other roads	100	70	130	10	10	1:20
V4 ADT < 1000 f/d	160	100	160	30	100	1:15
K1 pedestrian and bicycles	100	70	160	30	130	1:10

Bearing capacity design of road structures

- **E Modulus of subgrade** / embankment is defined based on soil classification (wet or dry / from the tables presented before)
- **Minimum allowed bearing capacity and thickness of asphalt** pavement is defined based on number of equivalent standard axles, type of pavement and base course
- **Calculated bearing capacity** is defined based on E Modulus of pavement materials, thickness of layers
- **Calculated bearing capacity > Minimum allowed value of bearing capasity**

Number of equivalent standard axles
KKL per traffic lane

- Calucation method 1:
  ADT greater than 1000 v/d
  KKL = L x (3,2 x truck and trailer + 0,9x other trucks) x 7300 d/20 yr

- Calucation method 2:
  ADT lower than 1000 v/d
  KKL = L x 0,22 x ADT/direction x 7300 d/20 yr Main roads
  KKL = L x 0,13 x ADT/direction x 7300 d/20 yr Regional roads
  KKL = L x 0,10 x ADT/direction x 7300 d/20 yr Local roads

- Calculation method 3:
  Local road with great number of raw material transport
  KKL = L x (5,5 x truck and trailer (full load) + 2,1 truck and trailer (no load)
  + 0,9 other trucks) x 7300 d/20 yr

- L = the coefficient of the road width (2,8 for narrow roads with steep slopes – 1,0 for wide roads)

Bearing capacity and thickness of pavement

Bearing capacity category (million standard axles / 20 yr)	**60,0**	**25,0**	**10,0**	**5,0**	**2,0**
Latest after 6 yr: bearing capacity Thickness of asphalt pavement (min)	525 MPa 240 mm	470 MPa 200 mm	415 MPa 170 mm	360 MPa 140 mm	285 Mpa 100 mm
Latest after 2 yr	200 mm	160 mm	130 mm	100 mm	
Opening of the road	160 mm	120 mm	90 mm	60 mm	60 mm
Bearing capacity, unbound base course	160 MPa	160 MPa	160 MPa	160 MPa	160 MPa

Bearing capacity and thickness of pavement

Bearing capacity and thickness of pavement (million standard axles / 20 yr)	**0,8**			**0,3**			
Type of asphalt pavement	**PAB-V**	**PAB-B**	**AB**	**SOP**	**PAB-V**	**PAB-B**	**AB**
Latest after 6 yr: Bearing capacity + minimum thickness of pavement			230 MPa 80 mm				
Opening of the road	145 MPa 40 mm	165 MPa 40 mm	185 MPa 50 mm	130 MPa	145 MPa 90 mm	165 MPa 60 mm	170Mpa 40 mm
Bearing capacity, unbound base course	145 MPa	145 MPa	145 MPa	130 MPa	130 MPa	145 MPa	145 MPa

PAB = Soft asphalt, AB = Asphalt concrete, SOP = Surface treatment of gravel road

Calculation of bearing capacity (Odemark method)

- Bearing capacity at the top of the layer **EY**
- Bearing capacity at the bottom of the layer **EA**
- Materialmodulus **E**
- Thickness of the layer **h**

$$E_Y = \frac{E_A}{\left(1 - \frac{1}{\sqrt{1 + 0{,}81 \cdot \left(\frac{h}{0{,}15}\right)^2}}\right)\frac{E_A}{E} + \frac{1}{\sqrt{1 + 0{,}81 \cdot \left(\frac{h}{0{,}15}\right)^2 \left(\frac{E}{E_A}\right)^{2/3}}}}$$

Materialmodulus E, aggregates, values that are used for calculation of bearing capasity

Grading category (EN 13285)	Material modulus E (MPa)			
	100	150	200	280
	Maximum grain size (0/D)			
G_O	0/8…11,2	0/16…22	0/31,5	0/40…80
G_P, G_C	0/8…11,2	0/16…22	0/31,5…63	0/80
G_A	0/8…11,2	0/16…22	0/31,5…56	0/63…80

Materialmodulus E for crushed rock och gravel, max grain size 80 mm

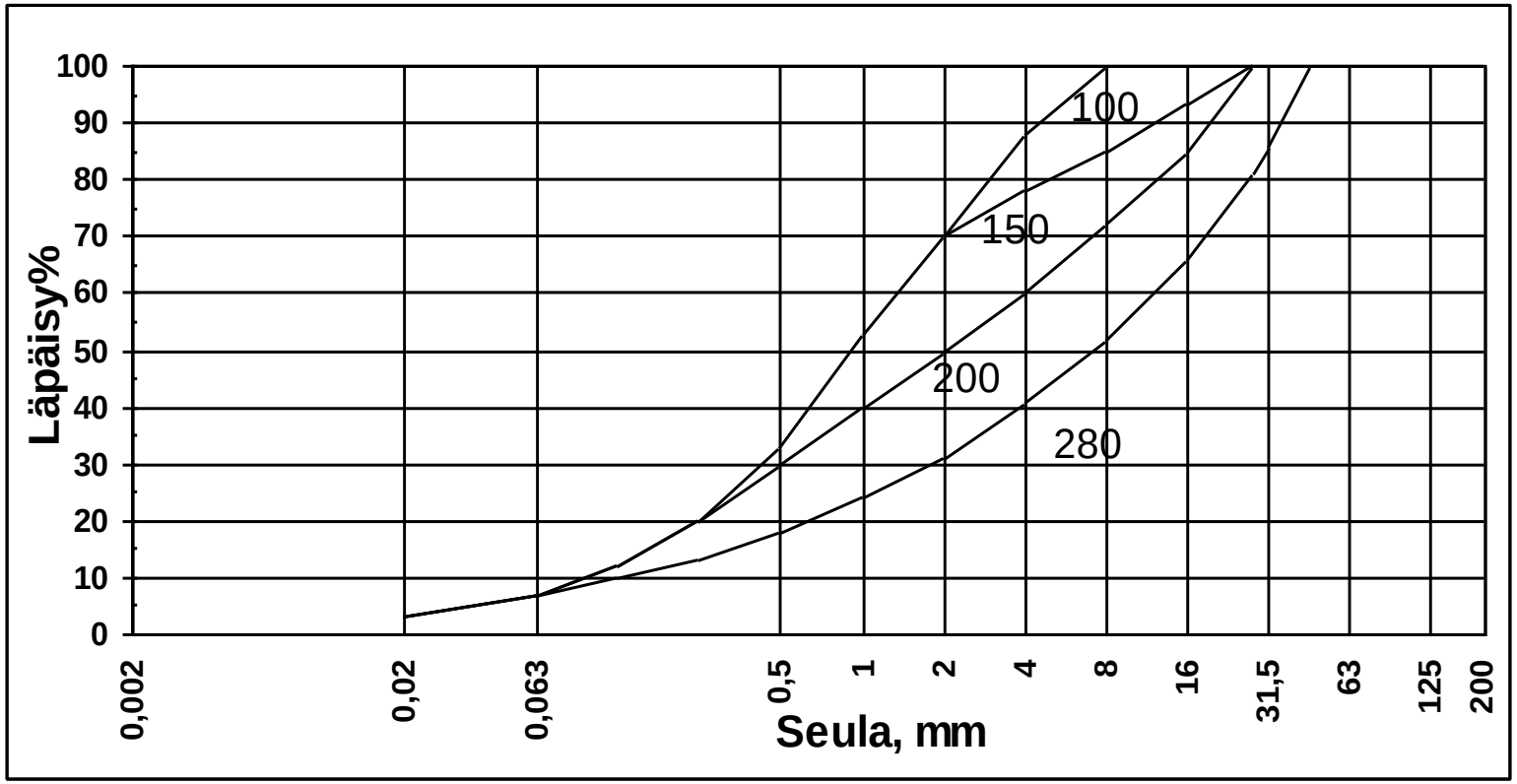
Materialmodulus E, values that are used for calculation of bearing capasity

	Materialmodulus (MPa)	
AB (Asphalt concrete), SMA	2500	
PAB-B Soft asphalt, 250/330 … 650/900	1650	
PAB-V Soft asphalt, V1500 / V3000	1400	
Bitumen bound mixtures, thick or thin standard	700 1050	Max. 10 x E_A Max. 15 x E_A
Cement bound mixtures, > 3 MPa after 7 d compressive strength > 5 MPa after 7 d	1500 3500	Max. 18 x E_A Max. 35 x E_A

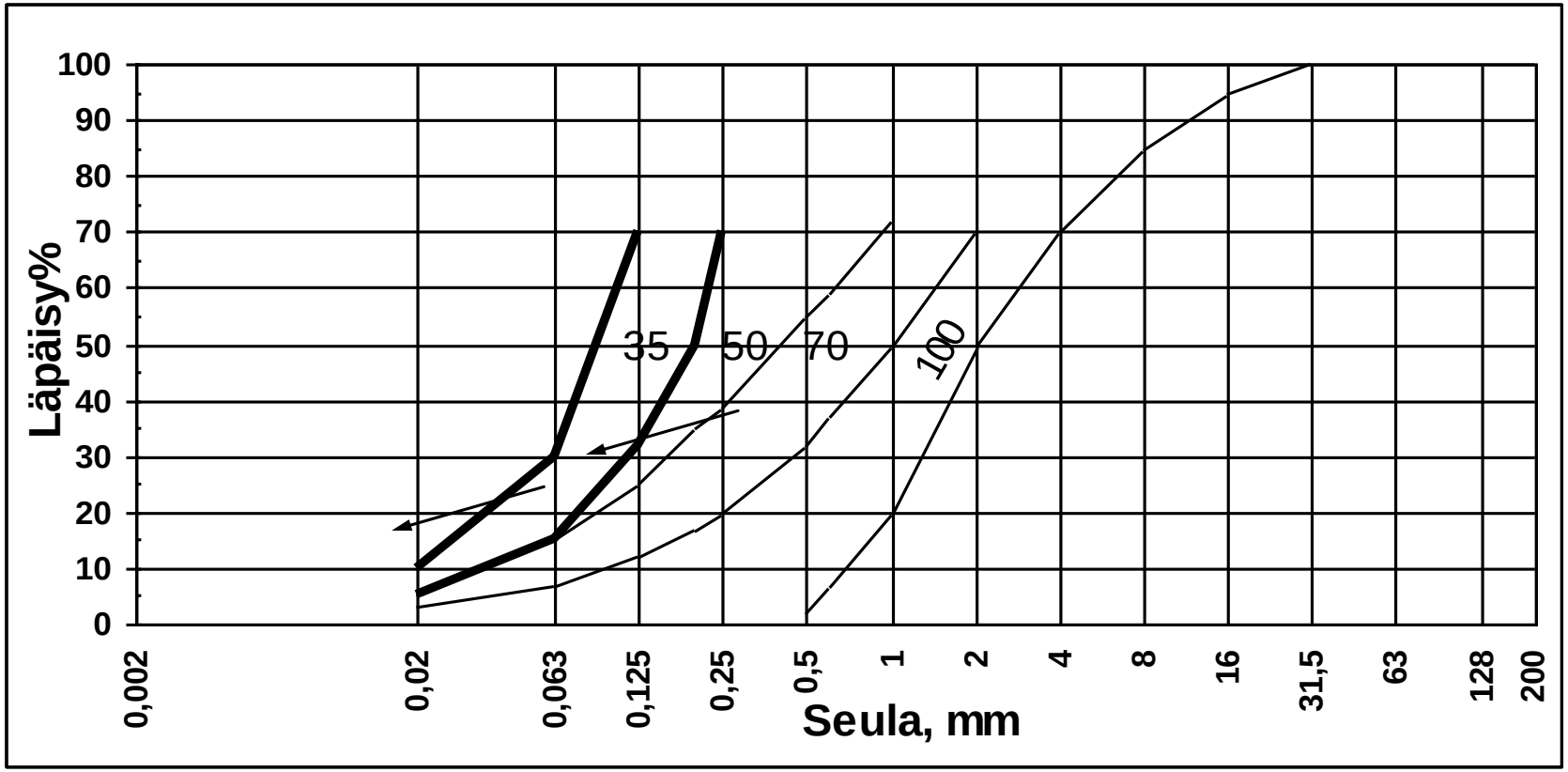
E_A = Bearing capacity (bottom of the layer)

Materialmodulus E, aggregates, values that are used for calculation of bearing capasity

- Materialmodulus E for crushed aggregates that are not classified by EN 13285



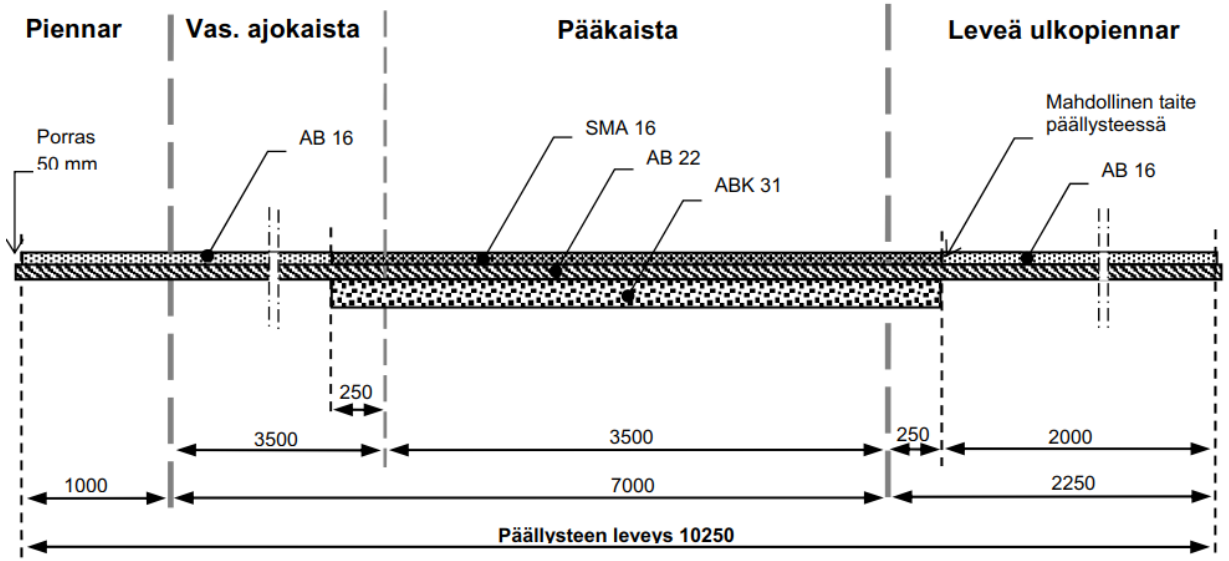
Materialmodulus E, sand used for filtering layer, values that are used for calculation of bearing capasity



Sand in the 35 Mpa -area might be susceptible for frost heave and must be used in dry conditions

General reguirements for asphalt pavements of new roads

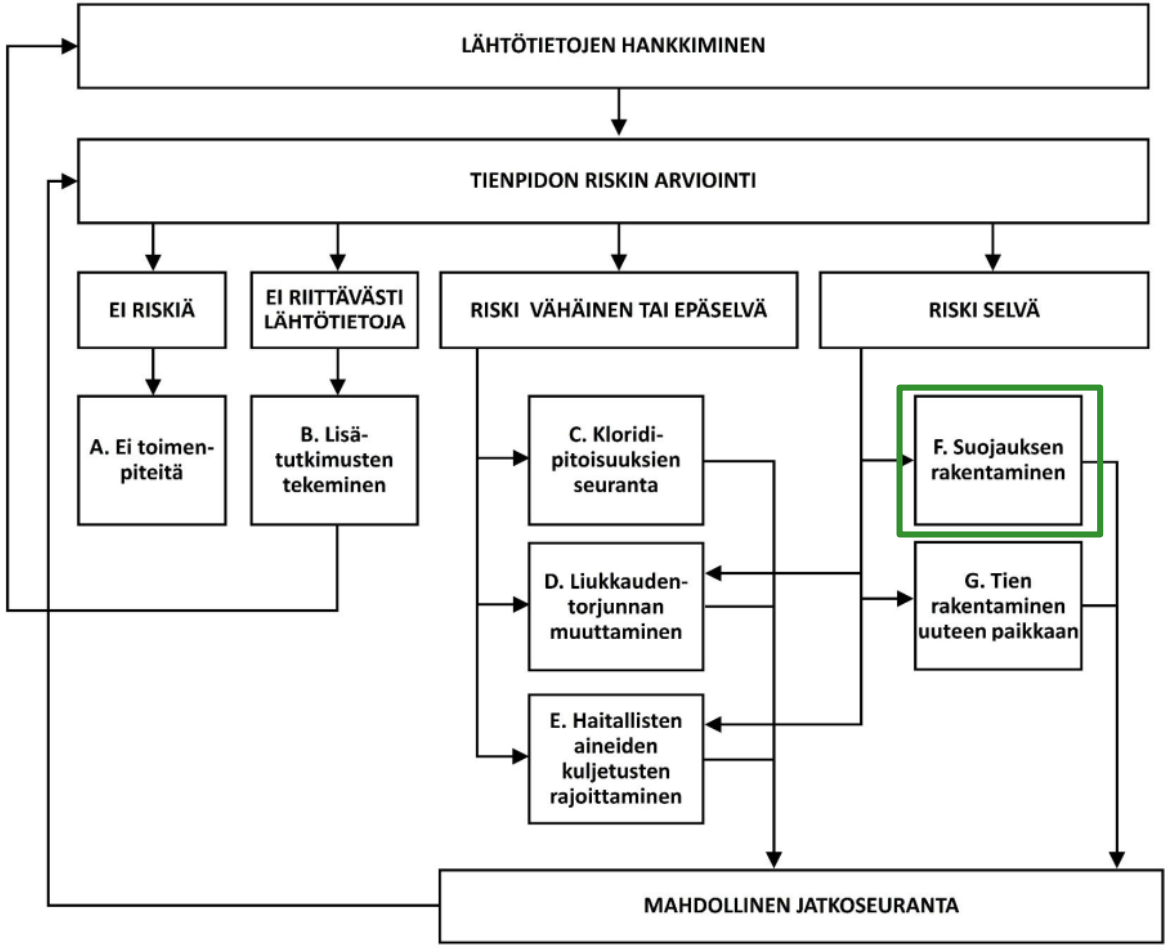
- The demands for raw materials of asphalt and the planning principles of the asphalt mass is in **Asfalttinormit**
- General requirements of building asphalt layers is in **InfraRYL**
- The width of the top pavement layer is according to the plan, the 2. asphalt layer is 100 mm wider
- The width of the maximum thickness layers (according to the bearing capacity design) might be smaller than the width of the paved road surface if there is a second lane that has a lower demand for bearing capacity
- Minimum thickness of a new asphalt layer is 2,5 x max nominal grain size of the aggregate that is used (2,2 x max for 22 mm and 31,5 mm)
- Minimum thickness of all pavement layers is according to the bearing capacity (tables in slides 9 and 10)
- If asphalt layers are built in stages
  - Total thickness of the asphalt layers must exeed 80 mm
  - Rut depth in the existing layer must not exceed 10 mm or if the existing layer is heated, the max value is 15 mm
  - REM treatment or recycled asphalt must not be used in the last asphalt layer of the contract when the ADT of the lane > 2500 f/d
  - A step is not allowed between lanes
  - Building in stages is not usually allowed on bridges short sections between bridges and on sections with side-curbes



There are also several other reguirements presented in the guideline:

- Structural cross-section formation
- Draining the road structural layers
- Need for geotextile or filtering layer
- Setting requirements for the pavement resistance to abrasion caused by studded tires
- Setting requirements for the pavement deformation properties
- Requirements for the pavement recycleability
- Requirements for the non-permeable pavement used as part of ground water protection or on top of hydraulically bound layers to prevent infiltration of chlorides
- And other…

Ground water protection on highways, a new guideline will be published soon

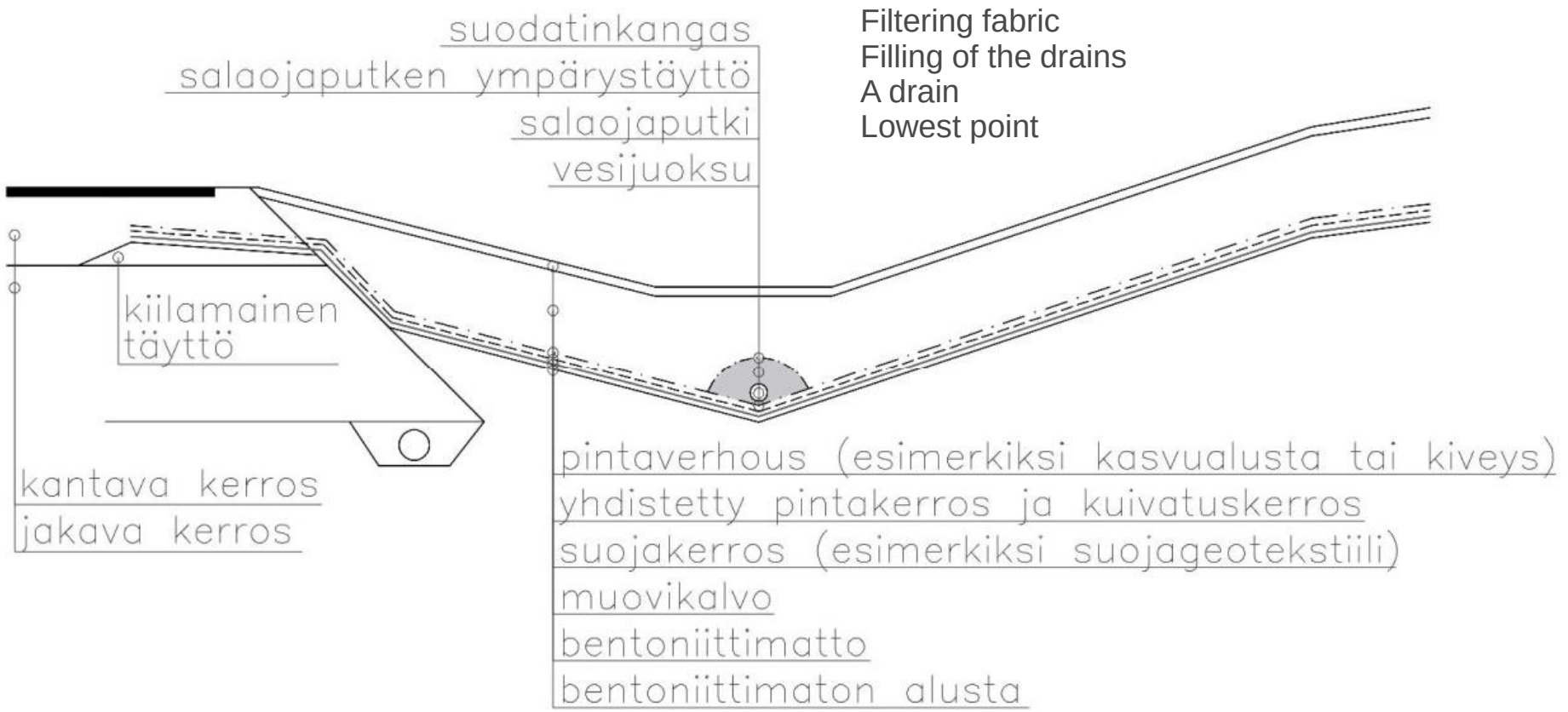


Selection of measures for groud water protection measures on highways:

A. No measures
B. More research and studies
C. Follow-up of chloride content
D. Chancing winter maintenance
E. Restricting transportation of dangerous liquids
F. Building a protection structure
G. Moving the road to a new location

Ground water protection on highways, a new guideline will be published soon

Names of the structural layers



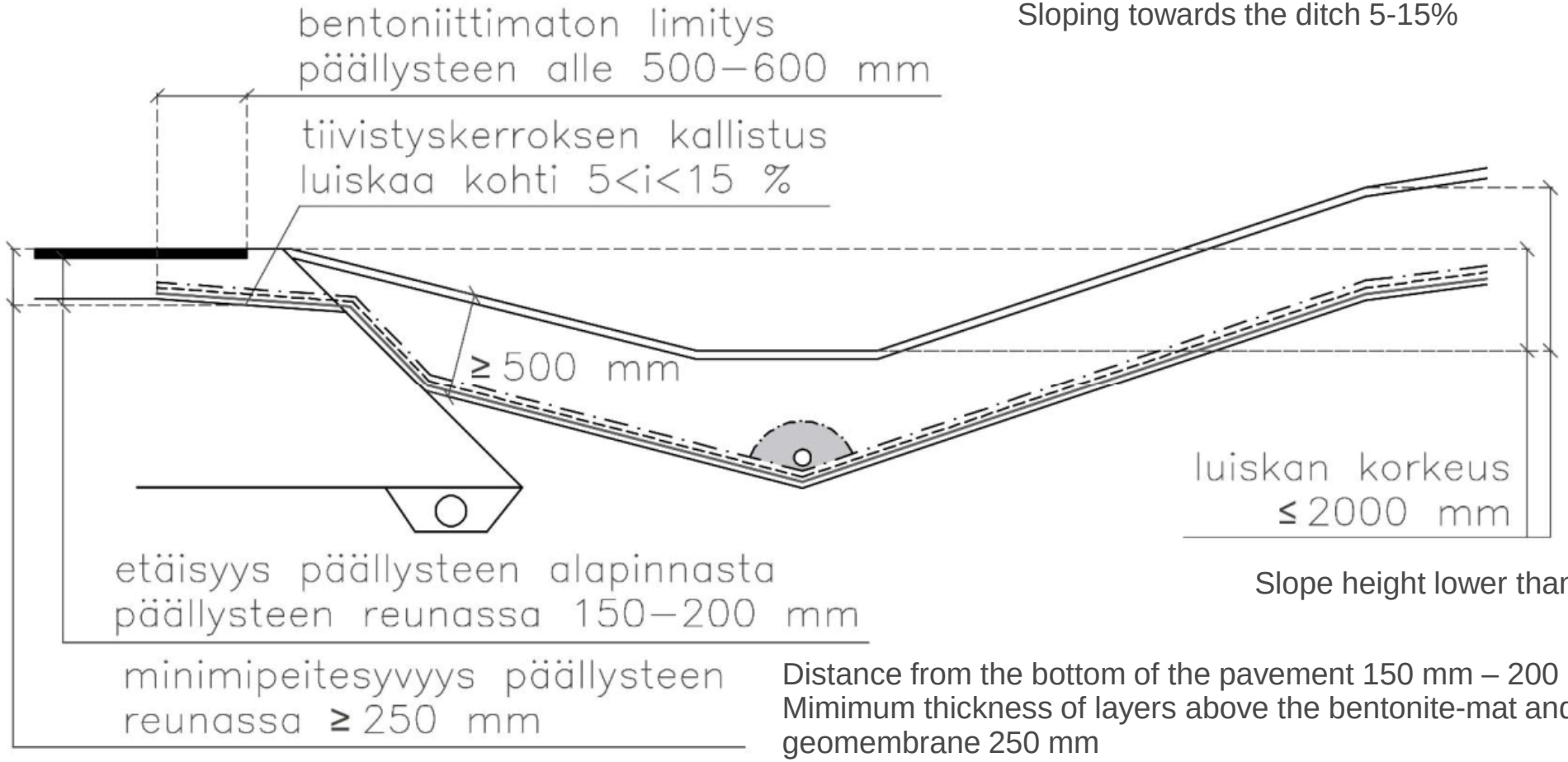
Filtering fabric
Filling of the drains
A drain
Lowest point

Top layer
Combined surface layer and drainage layer
Protection layer
Geomembrane
Bentonite-mat
Base course

Ground water protection on highways, a new guideline will be published soon

Measures of the structure

Bentonite-mat 500-600 mm under the pavement
Sloping towards the ditch 5-15%



Slope height lower than 2 m

Distance from the bottom of the pavement 150 mm – 200 mm
Mimimum thickness of layers above the bentonite-mat and geomembrane 250 mm