



**Statens vegvesen**  
Norwegian Public Roads  
Administration

# New frost design specifications in Norway





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## Background

- The winters of 2009/10 and 2010/11 were cold and gave frost heave problems at some newly constructed roads, especially in the south-eastern part of Norway.
- Several reports in the newspapers and in media. Negative for the national road authorities.
- The Public Roads Adm. established an expert group to find the causes of the problems and to propose changes in the specifications to avoid future problems.



## Causes of problems on newly built roads

The investigations included excavation and analysis of the base, subbase and subgrade materials.

The investigations showed that the frost heave problems were mainly caused by one, or a combination of the following mistakes:

- Blasted rock in the subbase layer had too much fines and too large stones
- The pavement structure was too thin for the subgrade conditions and freezing index
- Deficient drainage system



## Problems with blasted rock in subbase

- Inhomogeneity
- Unclear requirement specification for the maximum fines content (requirements valid only when stones are «floating» in fines). In cases of doubt, this has shown to be a cause of dispute between the contractor and the road owner
- In practice, difficult to control the size of the largest stones,  $D_{\max}$



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# Blasted rock





## New regulations implemented in 2012

- Blasted rock prohibited for use in subbase layer
- Rock materials for use in subbase layer shall be crushed, and fines shall be removed
- Most used fractions (mm):
  - 22/90
  - 22/120
  - 22/180
- General requirements for over- and undersized materials are set according to NS-EN 13242 (d/D)
- Maximum aggregate size shall not exceed  $\frac{1}{2}$  or  $\frac{2}{3}$  of the layer thickness (depending on the subgrade conditions)



## Stone materials in frost protection layer

- Requirements regarding blasted rock in frost protection layer:
  - Stone size; max. 0.5 m (longest edge) or  $\frac{1}{2}$  layer thickness
  - Fines content; max. 15 %  $< 63 \mu\text{m}$  of materials  $\leq 22.4$  mm
- New regulations are under discussion
- New requirements for stone materials in the frost protection layer shall provide:
  - Homogeneity
  - Correct and safe control of fines content and  $D_{\text{max}}$
  - Easy control and documentation procedures



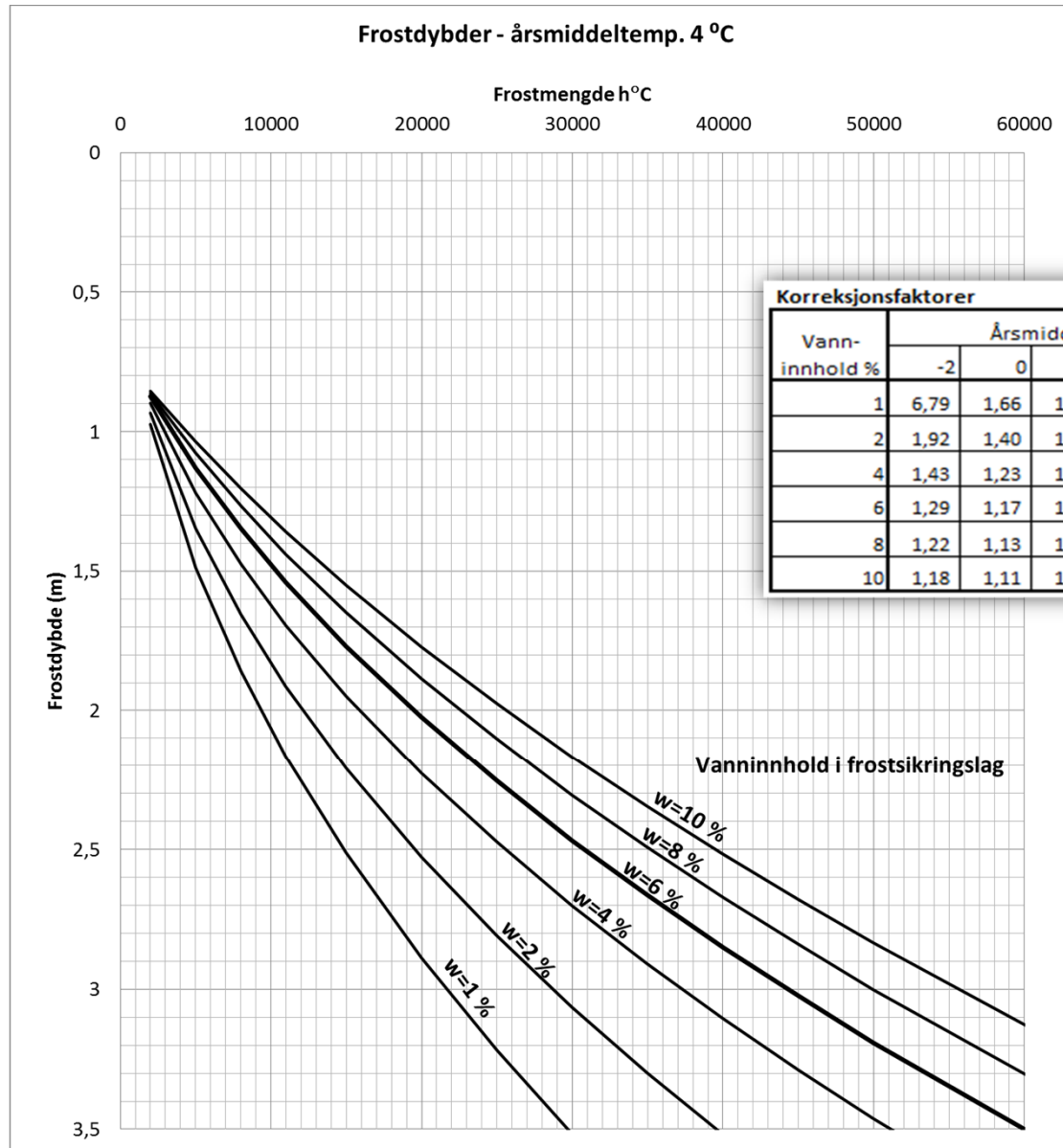
## Fines in the frost protection layer

- The resistance against frost penetration is highly dependent on the water content in the frost protection layer
- A gap graded crushed rock material will have very low water content and low resistance against frost penetration
- Preferable fines content;
  - high enough to ensure that the layer can keep some humidity
  - low enough to prevent frost-susceptibility



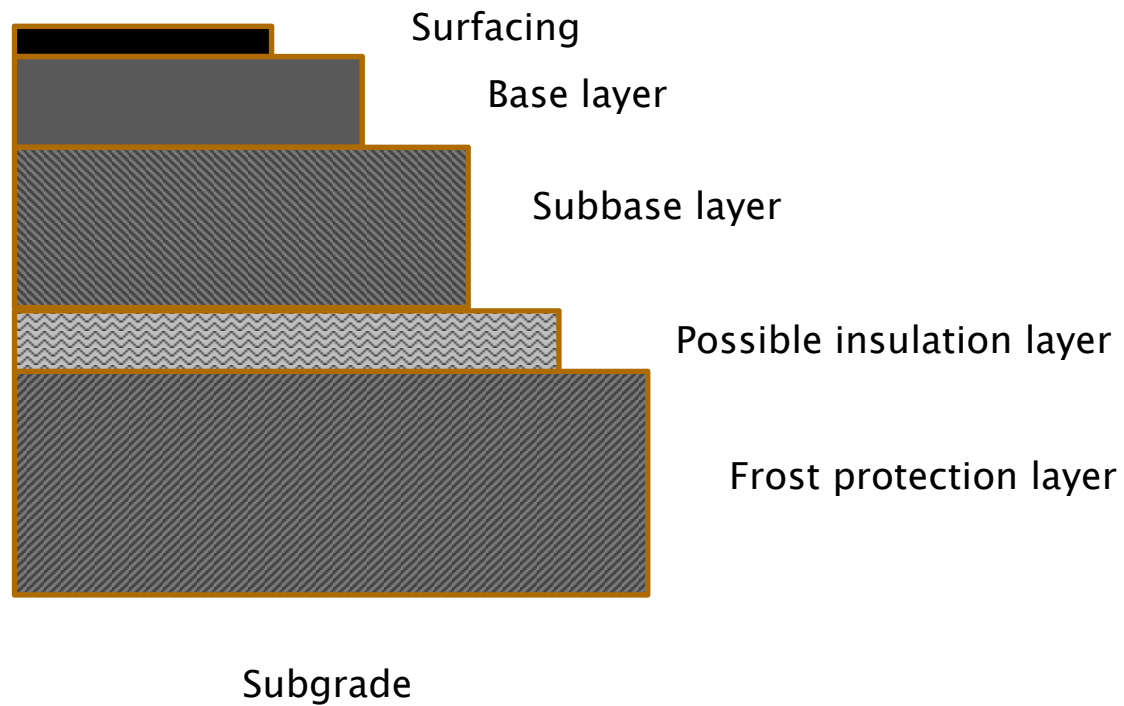


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# Frost protection design





## Frost design, old requirements

- Based on a classification of the subgrade conditions in three different classes:
  - 1 = homogeneous subgrade conditions, only minor uneven frost heave is expected.
  - 2 = somewhat varying conditions, some uneven frost heave is expected.
  - 3 = strongly varying conditions, major uneven frost heave is expected.
- The subgrade conditions shall be confirmed through site investigations.



## Frost design, old requirements

AADT	Ground conditions*)	Frost protection		
		Sand, gravel, stone	Lightweight aggregate and foam glass	Insulation boards (XPS)
1500 - 5 000	3	$h_5$ (max. 1.5 m)	$h_5$	$h_{10}$
$\geq 5\ 000$	1 2 3	$h_5$ (max. 1.2 m) $h_5$ (max. 1.5 m) $h_{10}$ (max. 1.8 m)	$h_{10}$ $h_{10}$ $h_{10}$	$h_{10}$ $h_{10}$ $h_{10}$

In frost protection with sand, gravel and stone,  $h_5$  and  $h_{10}$  are the *total thicknesses of the pavement* for a 5-year and 10-year winter (design frost quantity  $F_5$  and  $F_{10}$ )



## Experience with the old system

- Difficult to decide which variation class a specific road section should be placed in due to insufficient information about the subgrade conditions.
- Could lead to under-sizing of the frost protection layer if subgrade conditions were anticipated to be better than they really are.
- The Pavement Design Manual has mainly been focusing on providing adequate bearing capacity. The design of the frost protection has to some degree been subordinated and not clearly expressed in the manual.



## New frost design specifications

- AADT > 1500: Frost protection is required for roads on frost susceptible subgrade (category T3, T4)
  - 4 lane motorway: F100
  - AADT > 8000: F10, max. 2,4 m (not yet formally decided)
  - 1500 < AADT < 8000: F10, max 1,8 m
- AADT < 1500: Frost protection shall be considered for sections where special problems with uneven frost heave are expected.
- For roads on subgrade in category T1, T2: Frost protection is not required.
- Subgrade conditions shall be mapped by use of quaternary geological maps and site investigations.



# Subbase classification, frost susceptibility

Frost-susceptibility category	Of material < 22.4 mm		
	% by mass		
	< 2 μm	< 20 μm	< 200 μm
Not frost-susceptible T1		< 3	
Slightly frost-susceptible T2		3 - 12	
Moderately frost-susceptible T3	1)	> 12	< 50
Highly frost-susceptible T4	< 40	> 12	> 50
1) Soil types with more than 40% < 2 μm are also regarded as moderately frost-susceptible T3.			
Classification of the bearing capacity of the subsoil			
Subsoil	Bearing capacity class		
Rock cut, rockfill T1	1		
Gravel, Cu ≥ 15, T1	2		
Gravel, Cu ≤ 15, T1	3		
Rock cut, rockfill T2	3		
Sand, Cu ≥ 15, T1	3		
Sand, Cu < 15, T1	4		
Gravel, sand, moraine, T2	4		
Gravel, sand, moraine, T3	5		
Clay, silt, moraine T4	6		
Marsh <sup>1)</sup>	7		
For light fill materials, see Figure 234.3			

1) Bearing capacity class 7 'Marsh' is not included in the various design tables, and must be treated separately. Measures will often consist of subgrade improvement



## Topics for discussion

- Frost design specifications in other countries
- Requirements for rock materials in frost protection layer
  - Grading
  - Fines content
- Which materials are used in other countries?
- Requirements for documentation
- Control methods







Thank you!



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