



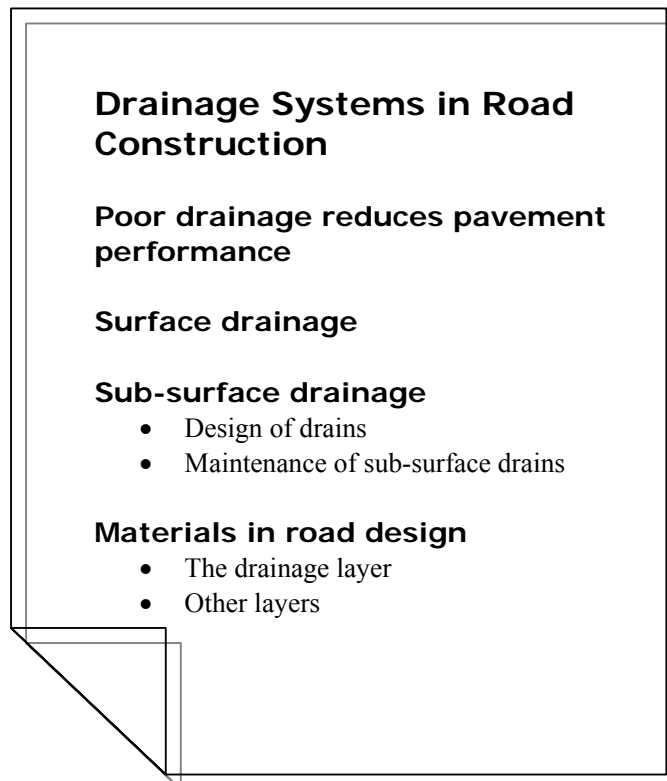
Drainage Systems in European Road Constructions

This report is the result of a questionnaire under the project “COST 351 - Water Movement in Road Pavements and Embankments”, with the acronym WATMOVE. WATMOVE is a European project with the main goal being to increase the knowledge required for improving highway performance and minimising the leaching of contaminants arising from roads and traffic.

The questionnaire was divided into two parts, one concerning “Pavement drainage” and the other concerning “Environmental aspects of water in road pavements and embankments”. This is the answers regarding pavement drainage.

Any country was invited to answer the questionnaire, and the WATMOVE members are thankful that as many as 18 countries answered – 16 European and two states in the USA. The countries answering were: Croatia, Czech Republic, Denmark, Finland, Germany, Greece, Iceland, Norway, Poland, Portugal, Romania, Serbia & Montenegro, Slovenia, Spain, Sweden, United Kingdom and the states of California and Virginia in the USA.

The answers are organised as follows:



Poor drainage reduces pavement performance

Water in the pavement layers reduces the bearing capacity of the road, and thereby its lifetime. In cold climates this problem is magnified by the risk of frost damage when water is present. Therefore well-performing drainage systems are important in road design.

Some examples of the reduction of the roads bearing capacity or pavement performance have been reported in the questionnaires.

Reduction in performance	Reference
E-modulus of unbound layers reduced 30 – 50 % if the layer has a lot of water	Finland. Finish Design Standard
E-moduli of unbound layers reduced in wet seasons to somewhere between 0.3 and 0.8 of summer value, dependent on layer and season.	Denmark. Danish Design Software, MMOPP
	Slovenia. Leben, B, “The influence of road cross-profile, subbase and subgrade and precipitation on the bearing capacity of flexible pavements”, 4 th International Conference

Drainage systems in Road Construction

Roads are constructed with two types of drainage systems, each taking care of their source of moisture:

- The surface drainage system taking care of runoff water (rainfall). A new pavement has a waterproof surface with a crossfall that leads the rainwater to the surface drains.
- The sub-surface drainage system, taking care of groundwater and water infiltrating through the pavement surface.

Figure 1 below shows the principles of a simple drainage system in smaller roads in rural areas.

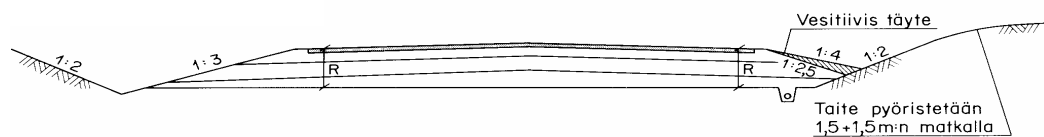
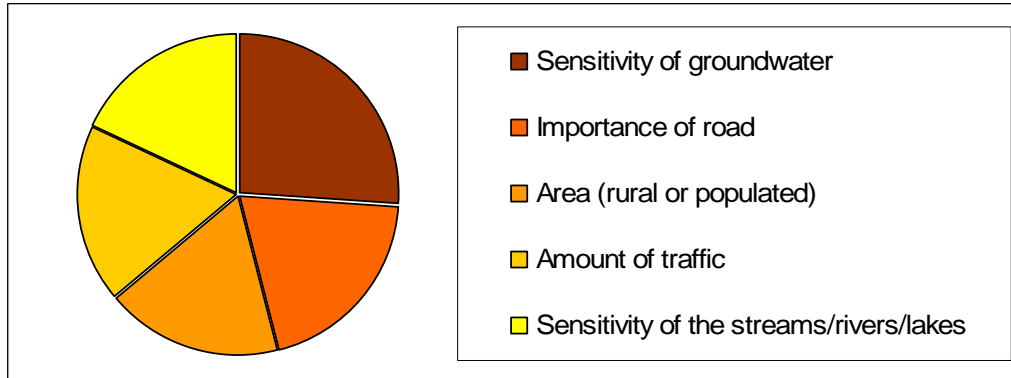


Figure 1: Cross profile of a road having a ditch in the left side and a conventional drain in the right side (from the Finnish standards).

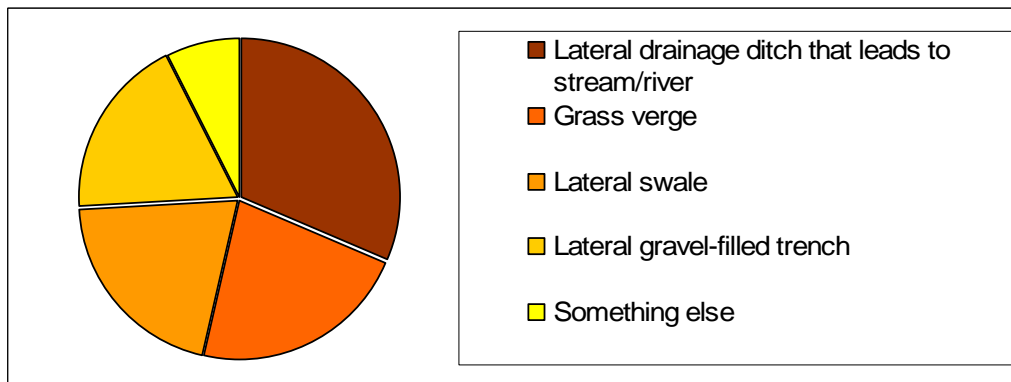
Surface drainage

The surface drainage system is not necessarily a piped system. The choice of using a piped system depends on factors as:



Also it is mentioned that a piped system can be used to save space.

When it is chosen not to have a piped system, the runoff water goes to:

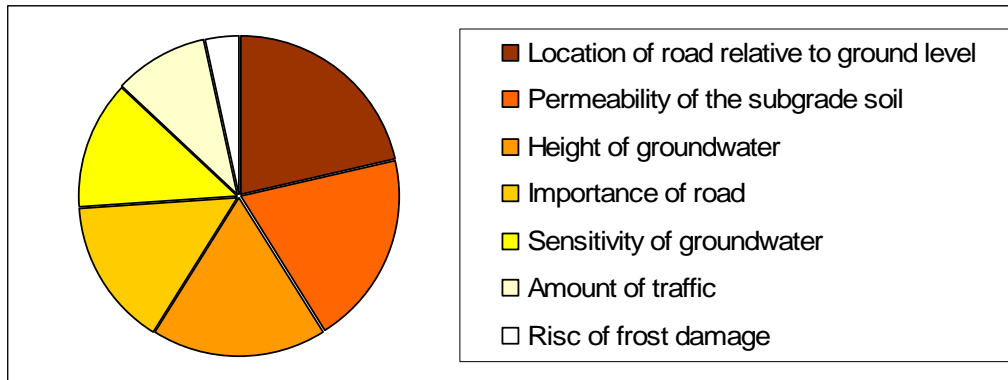


The experts answering the questionnaire estimate that somewhere between 80 – 100 percent of the rainfall arrives in the surface drainage system. This is not necessarily water that runs in pipes, as most of the surface water that runs into ditches soaks into the ground instead. The remaining part penetrates into the construction. For older pavements with increased cracking, the percentage that penetrates through the cracks might be as high as 20-50 percent.

Sub-surface drainage

Sub-surface drainage ensures that water that has found its way into the pavement –either from the surface or from ground water – is lead out of the pavement again. The system can be as simple as pourous layer materials (drainage layers) or it can be drainage pipes, or both.

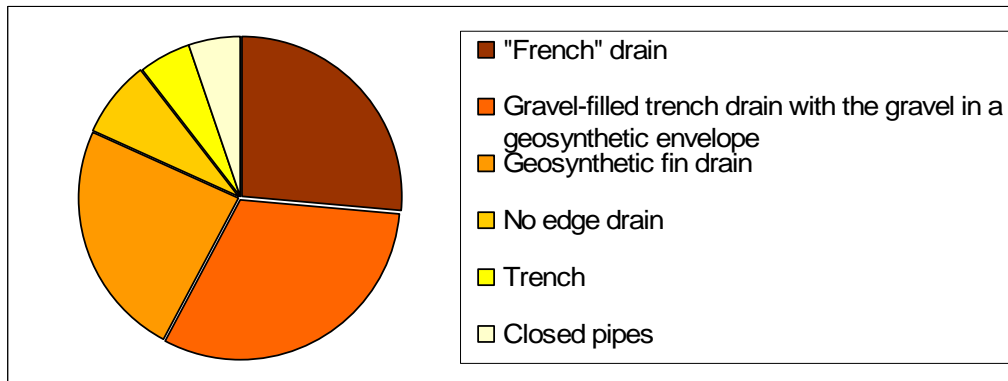
Sub-surface drains are chosen based on factors as:



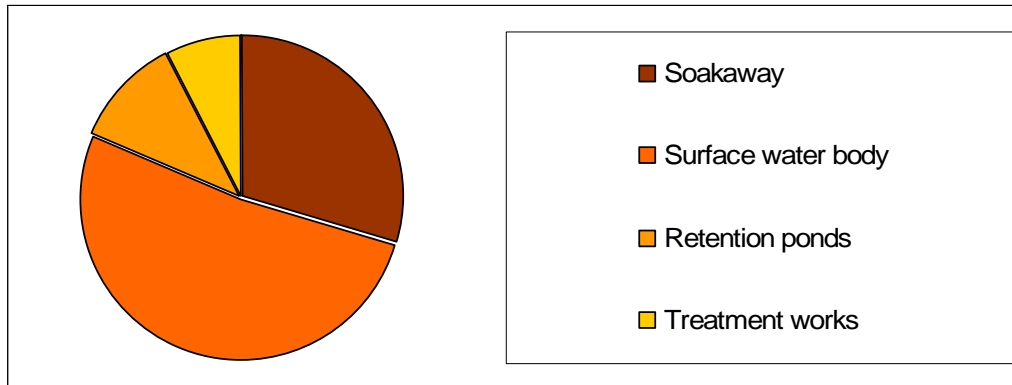
The above figure shows that the ground water is an important issue and also far the most of the countries that have answered the questionnaire have requirements for the distance between the pavement construction and the ground water table. The required distance is somewhere between 30 cm and 3.2 m.

Approximately half of the European countries use different drainage systems depending on the depth to the water table. Where the ground water is at shallow depth, the drainage layer is often thicker or an extra drainage layer is constructed, or drain types able to transport more water are chosen.

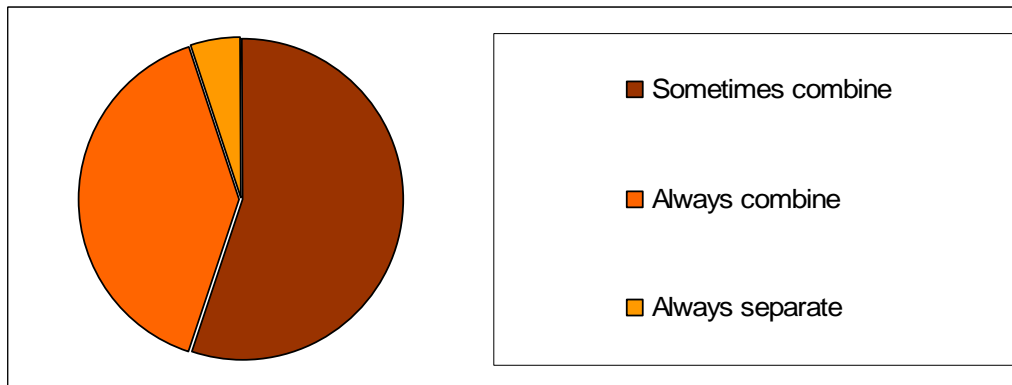
The most commonly used edge drains to collect sub-surface water are:



Most often there is a pipe at the bottom of the edge drain. The pipe leads the water to:



In the drains, the sub-surface water is often combined with the surface water. To this question the answers were:



Design of drains

Name of software or method to design drains	
Surface drains	Sub-surface drains
National guidelines	National guidelines
Method: Chezy-Manning-Stricker	CANALIS
Software: CANALIS, HYDRA, MOUSE	HYDRA
Rational method	MOUSE
Mannings equation for hydraulic design	
AASHTO surface drainage design	
KANVOD (software used in Czech Republic)	
Empirical method	

Maintenance of sub-surface drains

It is of great importance that the drainage systems are working properly, so regular checks and maintenance is required. Six out of 15 countries answering the questions about maintenance, monitor the performance of the sub-surface drains. The intervals of monitoring varies greatly. From checking once after construction or only when pavement show distress, to a specified interval in drain maintenance guidelines, i.e. every 2 years. Inspections can be both visual and video inspection, depending on pipe diameters and drain types.

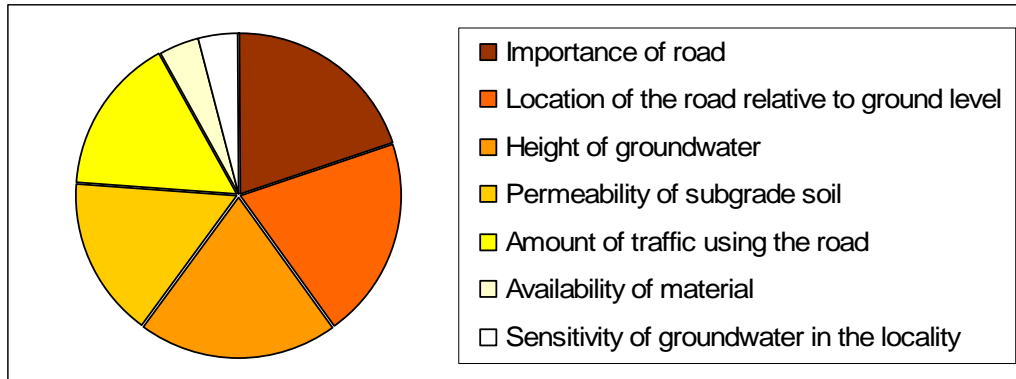
The problems encountered with sub-surface drains are:

- Filling with impermeable materials /clogging – especially after heavy rainfalls
- Collapse of asphalt treated drainage layers
- Normal deterioration
- Crushed pipes
- Poor outlet conditions
- Outlets have negative slope
- Poor compaction of the asphalt cap materials
- Difficulty in inspection for long mainline pipe (> 50 m)
- Root penetration
- Generation of ferrous oxid and calxium carbonate
- Insufficient capacity
- Inadequate water velocity
- The (plastic) cover of the inspection well at the slope may be damaged (sometimes due to snow clearance of the road)
- Acces for inspection and/or remediation is not possible
- Sub-surface drains, if used as combined (French) drain, are known to cause deterioration of foundation, due to large volumes of water being introduced into road foundation in the event of the system becoming blocked up.

Materials in road design

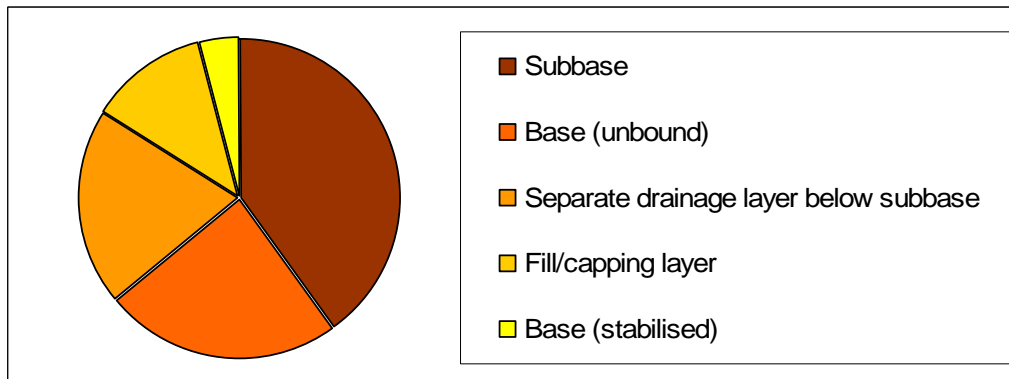
The drainage layer

The sub-surface drainage system often includes a (permeable) drainage layer in the pavement. Some countries always uses a drainage layer in standard designs, and on the contrary very few countries never have a drainage layer. Often the inclusion of a drainage layer depends on factors as:



There are different national traditions for which layer in the pavement works as the drainage layer. Some countries only mention that one layer works as drainage layer, i.e. the subbase, where other countries mentions i.e. three different layers. Dependent on the available material and the specific construction, any one or more of these works as drainage layer.

The layers working as drainage layers are:



To ensure the drainage effect, the drainage layer has to fulfill certain requirements. An overview is given in the table next page.

Requirements for drainage layer		
Requirement	No. of countries answering “YES” for requirement	Value/type of requirement*
Grading specification	13	Not shown here
Mechanical performance	11	Stiffness (i.e. plate bearing test or CBR) (6) Rate of compaction (2) Durability (1) Los Angeles value (2) Type of rock (1) Compression strength of rocks (1) Soundness test (1) Atterberg limits (1)
Change of design with increased width of pavement	8	Thickness (4) Permeability and thickness (2) Thickness and crossfall (1) Crossfall (1)
Design permeability	4	$k \geq 1 \times 10^{-5}$ m/s (Germany) $k \geq 9.26 \times 10^{-5}$ m/s (Poland) $k \geq 10 \times 10^{-5}$ m/s (Slovenia) 30 ft/day (10.58×10^{-5} m/s) for drainage blankets laid beneath or within the pavement structure (Romania)
Design drainage time Some answers that sufficient drainage is defined by level of crossfall and slope.	4	5 hours, defined as time to 15 % saturation (Spain) 2 hours, - 50 % saturation (Virginia, US) 48 hours, - 40 % saturation (Romania) 10-20 years, defined by experience (Greece)

*) Name or number in parenthesis is countries using the requirement.

The performance of the drainage layer does not necessarily stay unchanged through time. Some countries report that they have noted that the layer might become more or less clogged with time. The fines content might increase caused by degradation of aggregates and/or migration of fines from other layers. This causes decreased permeability and increased frost susceptibility.

Other layers

Generally, the different countries design standards, are concerned with suction and frost penetration, not only for the drainage layer, but also for some of the layers above the drainage layer.

Does suction and frost affect the choice of material of the pavement layers?														
Design parameter	No. of countries answering "YES"	Layers affected												
Suction	12	<table border="1"> <caption>Data for Suction Bar Chart</caption> <thead> <tr> <th>Layer</th> <th>No. of countries</th> </tr> </thead> <tbody> <tr> <td>Subbase</td> <td>10</td> </tr> <tr> <td>Base (unbound)</td> <td>8</td> </tr> <tr> <td>Fill/capping layer</td> <td>8</td> </tr> <tr> <td>Surface course</td> <td>2</td> </tr> <tr> <td>Base (stabilised)</td> <td>1</td> </tr> </tbody> </table>	Layer	No. of countries	Subbase	10	Base (unbound)	8	Fill/capping layer	8	Surface course	2	Base (stabilised)	1
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Not surprisingly it is generally the southern countries in Europe that are not so concerned with suction and in particular frost penetration (Spain, Portugal and Greece).

To obtain knowledge about the possible water movement in the pavement layers, a number of tests are used. The most common tests are:

