RAILWAYS

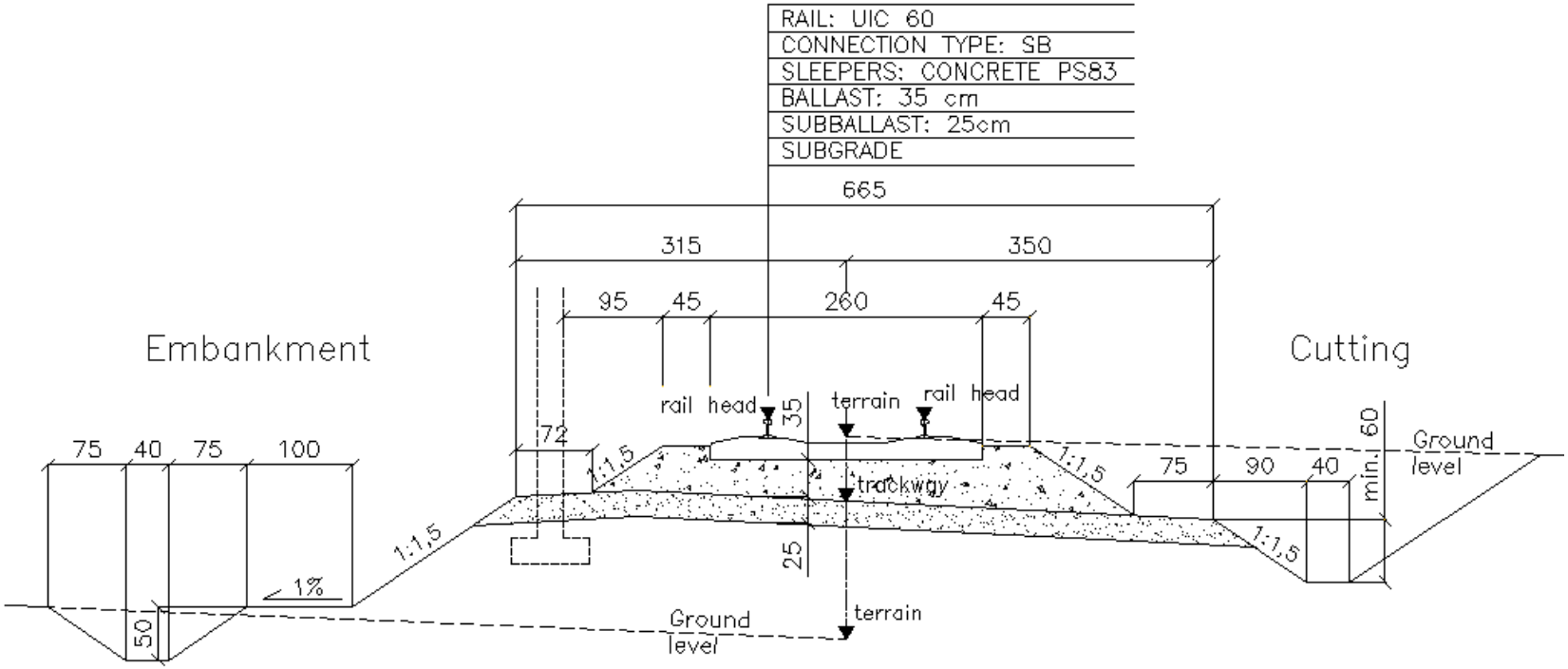
Formation & dewatering

Jarosław Zwolski, PhD CE

HUMAN CAPITAL
HUMAN – BEST INVESTMENT!
Wrocław University of Technology
EUROPEAN SOCIAL FUND
Project co-financed from the EU European Social Fund

Formation

Embankment or cutting formed in the in-situ ground to fit the requirements of the design of the track geometry in the terrain. In both cases it can be additional material (subbalast) provided between the ballast and the in-situ ground.



Embankment vs cutting





Role of formation

- Transfer of load from sleepers to the ground.
- Damping of vibrations excited by vehicles.
- Fast dewatering of the ballast by appropriate layers of subballast and transverse slopes.
- Preventing mixing the ground from lower layers with the ballast.

Requirements for the formation

- Strength and durability of the ground used as a material to build in.
- Good compactible characteristic (easy to compact), easy to soak through for water and freeze resistant.
- Stable and uniform properties of the ground on the section of the track (to avoid the threshold effect).
- Aprioppriate shape and slopes.

The strength and durability of the formation is achieved by the selection of appropriate material to build in and the use of proper technology of its compaction and dewatering.
The most preferred should be local ground, taking into account also the possibility of the correction of its parameters by supplements.

Minimum values for deformation module E_o [MPa] of the ground in formation measured on the trackway (the upper surface of the formation)

Velocity, V_{max}	Intensity of traffic [Tg/year]			
[km/h]	T > 25	10 < T < 25	3 < T < 10	T < 3
$200 < V_{max} < 250$	120 (80)	120 (80)	120 (80)	110 (70)
$160 < V_{max} < 200$	120 (80)	120 (70)	110 (60)	100 (55)
$120 < V_{max} < 160$	120 (70)	110 (60)	100 (50)	90 (45)
$80 < V_{max} < 120$	110 (60)	100 (55)	90 (45)	80 (40)
$V_{max} < 80$	100 (50)	90 (45)	80 (40)	80 (40)

Values in brackets – requirements for modernized lines

Requirement for diversity of grain:

Diversity of the grain is proper if:

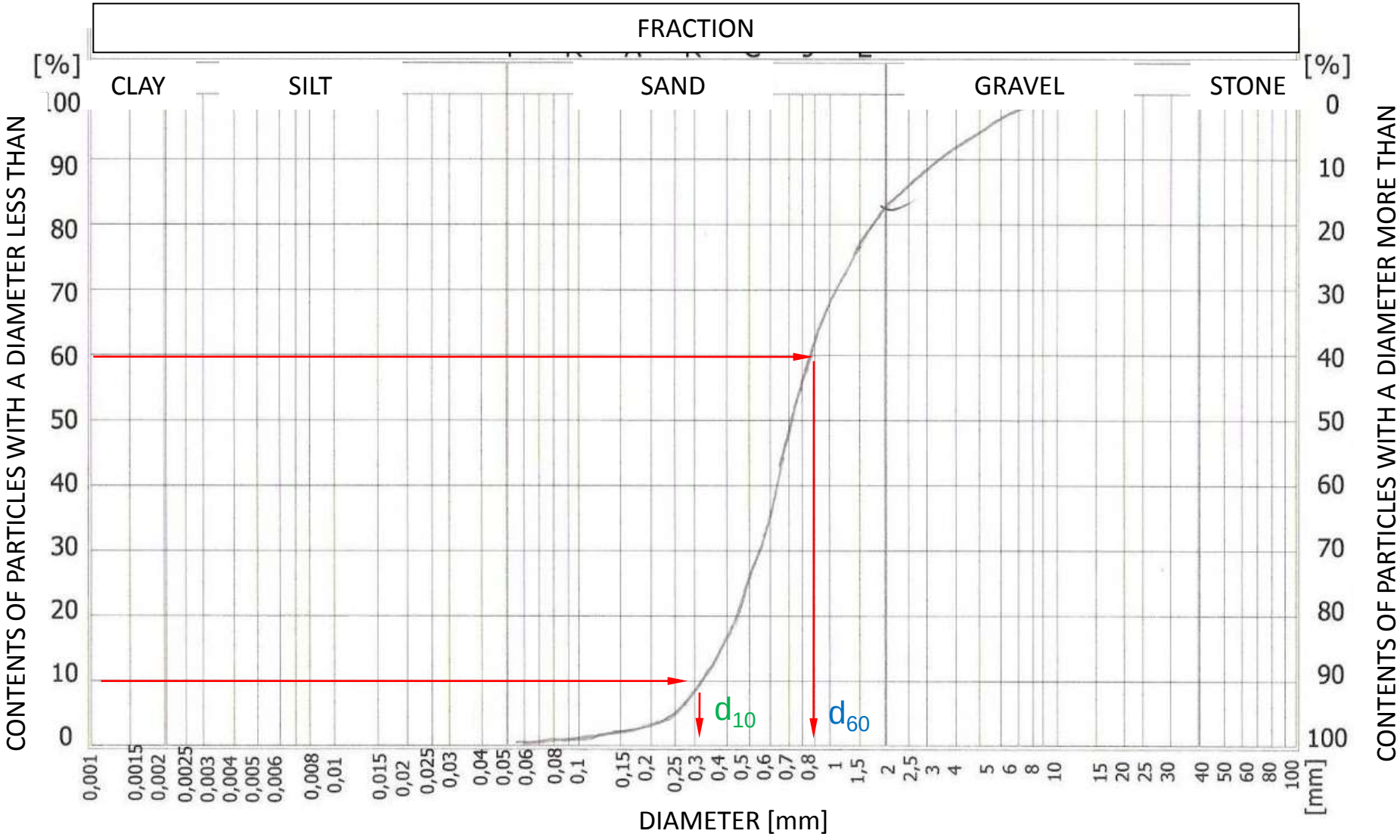
$U \geq 5 + V_{max}/160$ where $U = d_{60}/d_{10}$

d_{60} – diameter of particles, which with the smaller particles make 60% of the ground mass,
d_{10} – diameter of particles, which with the smaller particles make 10% of the ground mass.
The diameters d_{60} and d_{10} are identified from the soil grading curve.

Requirement for freeze resistance:

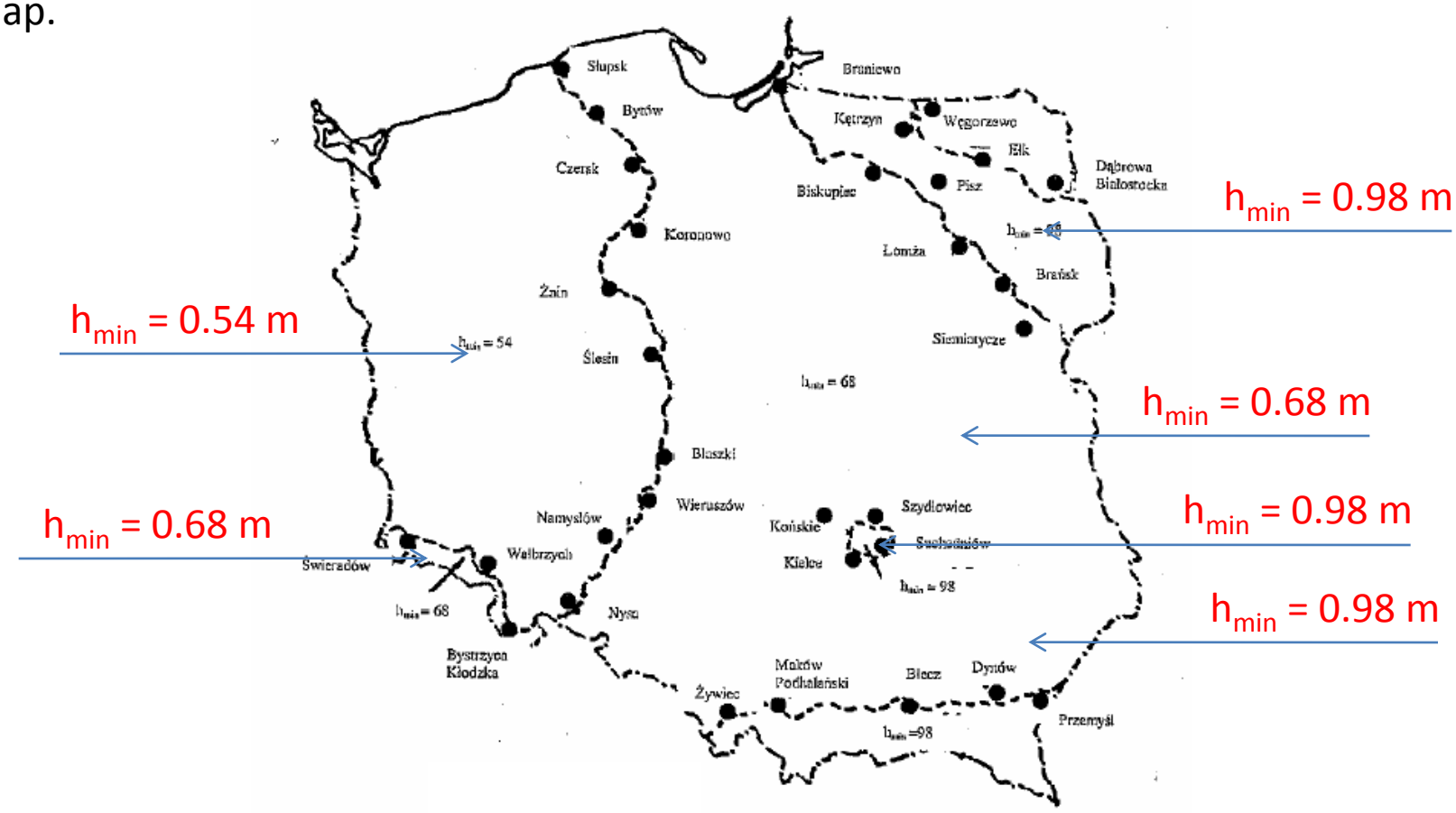
a) If $U > 15$ content of particles smaller than 0.02 mm (z) shouldn't be more than 3%,
b) If $U < 5$ content of particles smaller than 0.02 mm (z) shouldn't be more than 10%,
c) If $5 \leq U \leq 15$ content of particles smaller than 0.02 mm can be calculated from the formula: $z = 13.5 - 0.7U$
If the above criterion is not fulfilled an additional layer of sand is required of the minimum thickness: $h_o = h_{min} - h_p$

Soil grading curve



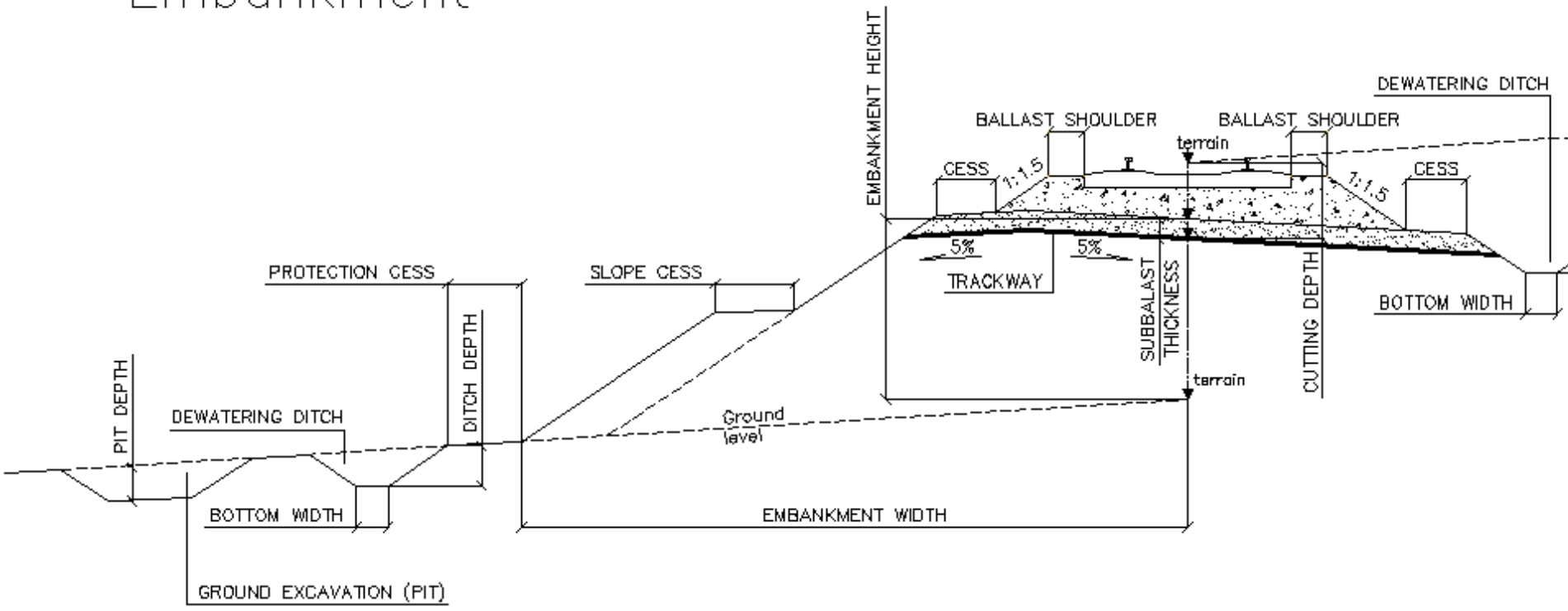
If the above criterion is not fulfilled an additional layer of sand is required of the minimum thickness: $h_o = h_{min} - h_p$

where h_p is the ballast thickness and h_{min} is the minimum thickness of the whole subbalast taking into account the freezing zone. The zones in Poland are defined on the map.



Shape of formation

Embankment



Embankments and cuttings should have slopes ensuring stability. Detailed analysis of stability is required at slopes higher than:

a) 12 m – made of rock, gravel, sand-gravel mixtures,
b) 8 m – made of sand or clayey sand,
c) 6 m – made of clay, silt, in the regions of mining exploitation and landslides.

Rules of formation dewatering

1. Dewatering should be used as one of the main ways of increasing ground capacity and stability of formation.
2. Formation should be dewatered by the proper shaping of slopes and using filtration and/or sealing materials if needed as well as using ditches and underground drainage. Ground water should be removed using deep drainage which doesn't freeze at low temperatures.
3. On lines surface water is removed from ballast using transversal inclination of trackway (3-5%) in the direction of the side ditches or underground drainage.
4. On stations surface water is removed by so called plate drainage: building a filtration layer with transversal inclination of 2-4% and removing water to side ditches and to internal shallow drainage located in every 2 or 4 space between tracks.
5. Other surfaces of the formation (cess, protection cess, surfaces of non-permeable grounds located under easy permeable grounds, except slopes) are shaped with an inclination of 5%.

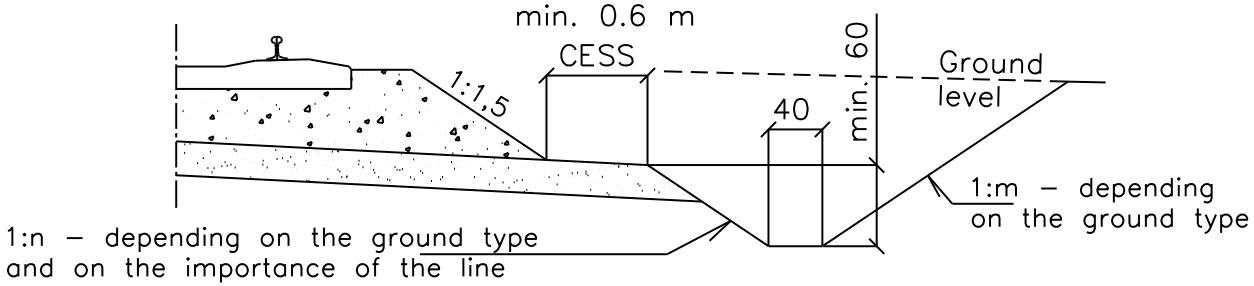
Elements of the dewatering system

1. Linear surface drainage (ditches, gutters, embankments).
2. Linear underground drainage with a dewatering system of pipes and auxiliary installations.
3. Plate drainage (e.g. drainage layers on the station plateau).
4. Slope drainage.
5. Vertical drainage.
6. Special and auxiliary devices.

Dewatering ditches

Ditches are required:

1. In all cuttings.
2. At the top of the cutting on the side of flowing water.
3. At all embankments lower than 0.6 m.
4. At embankments on the side of flowing water .
5. In order of surface water transporting through station plateau.
6. In order of removing water far from the track.
7. In places of lowered ground water level.



Formation	Ground type	Slope
Embankment	Sandy clay, sandy clay loam	1.5 - 1.8, 1.7 - 1.8 [1)]
	Pebbles, gravel, coarse sand and mixtures	1.5 - 1.8
	Boulders resistant to weathering	1.3 - 1.7 [2)]
	Very fine sand	2
Cutting	Sand, sandy clay, pebbles, gravel, coarse sand and mixtures	1.5 - 1.7 [3)]
	Cohesive soil	1.5 - 2.0 [4)]
	Loess in very dry conditions	0.1 - 0.5 [5)]
	Rocks resistant to weathering	0.2 - 1.0 [6)]
	Rocks non-resistant to weathering	0.5 - 1.5

[1)] in very wet regions

[2)] low values applicable for formation of layers; in case of boulders shelves or retention walls could be required

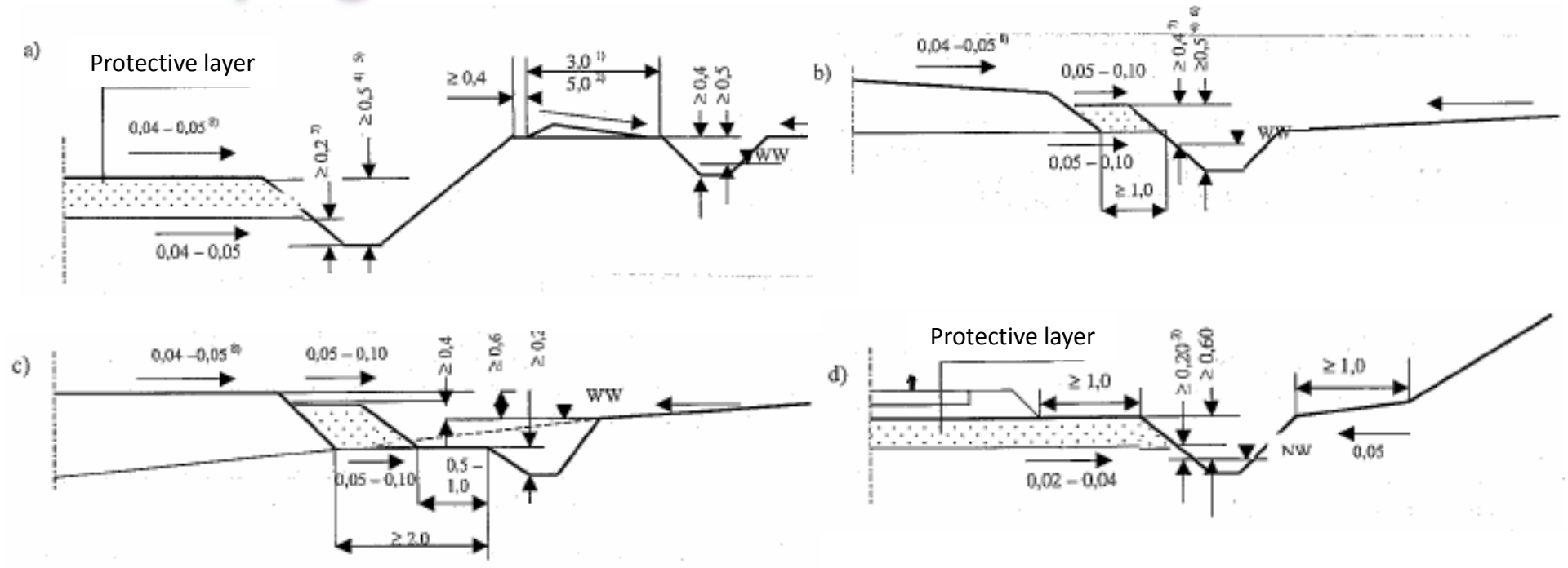
[3)] lower values applicable for dry clayey soils, cemented sands etc. and depending on the cutting depth (e.g. at the cutting to 8 m – 1.25; deeper – 1.5)

[4)] depending on the cuting depth and characteristic of soil

[5)] stability in various humidity conditions should be checked

[6)] at the slope base a protection against falling pebbles is required (e.g. a shelf with an embankment)

Shaping of a ditch



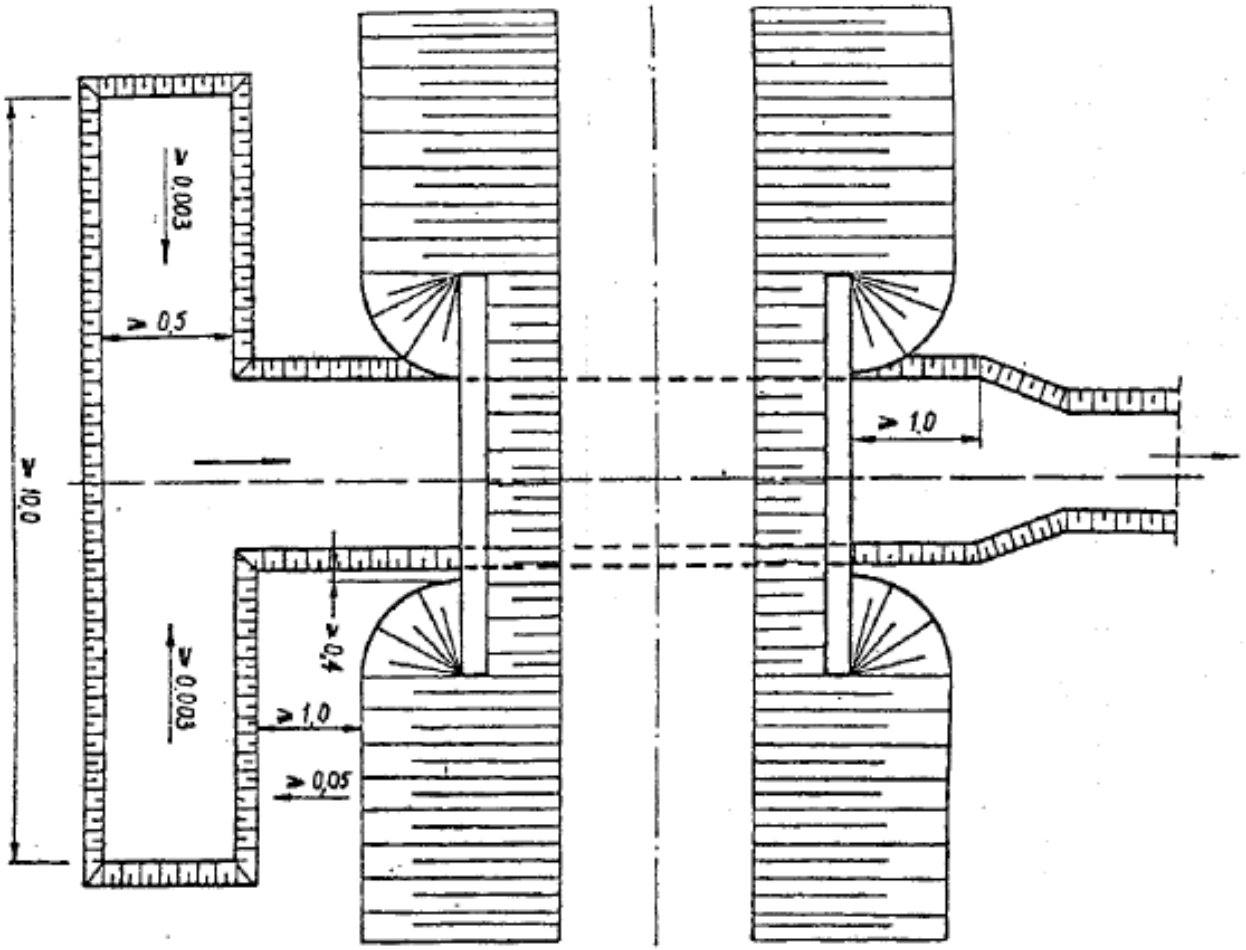
Cross-sections of formation in the zone of a ditch: a) cutting (railway line), b) embankment (railway line), c) embankment on flooding terrain, d) cutting (big railway station)

Longitudinal inclination of ditch

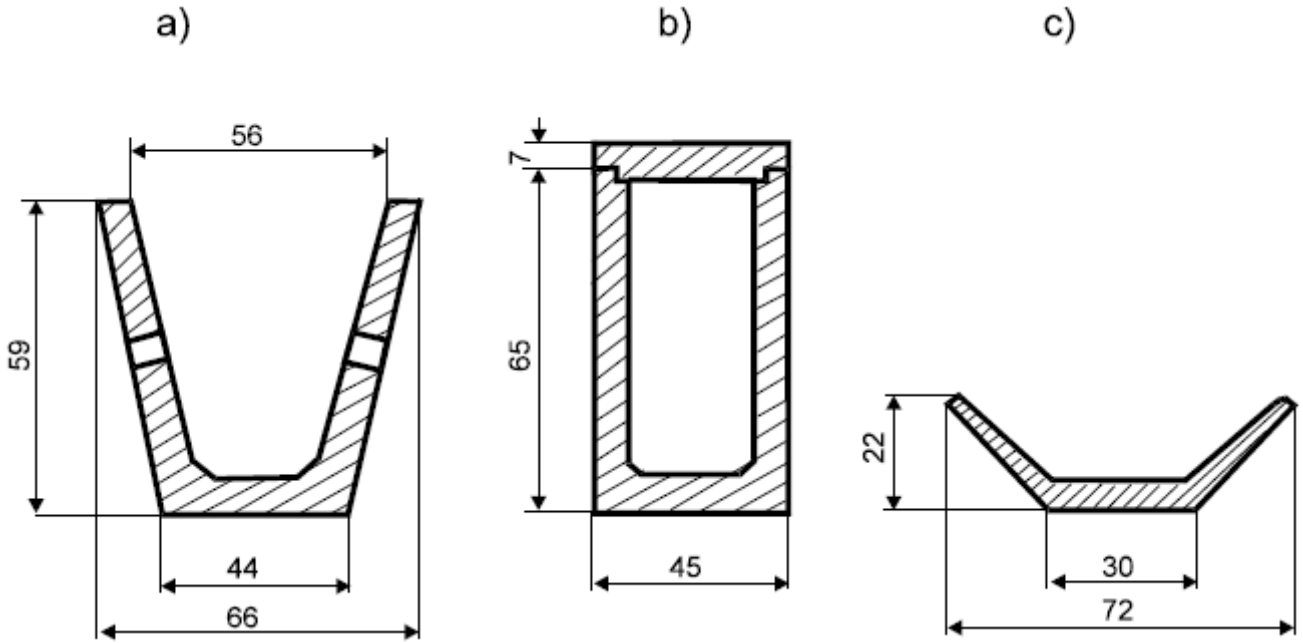
Rules for shaping of the ditch inclination:

1. The ditch bottom should be strengthen due to maintenance requirements and in case of a danger of:
   - erosion of the ground caused by too high speed of water (the speed of water in the ditch should be checked at inclinations steeper than 1,5% and in the case of too high speed a proper strengthening should be applied),
   - slime of the ditch caused by too low speed of water (the speed of water in the ditch should be checked at inclinations lower than 0,4% and in the case of the speed is less than 0.3 m/s a smooth strengthening should be applied which enables the incease of the speed and easier removing of the slime),
2. The ditch with the inclination steeper than 10% should be equipped with thresholds, cascades, waterfall wells or can be replaced by a gutter.
3. The speed of water in case of full ditch can be less than 0.3 m/s in the following cases:
   - a side ditch crossing a watershed – 0.1% is allowed,
   - a transverse dewatering of brakes – 0.5% is allowed,
   - local pipe drainage on existing lines – 0.5% is allowed.

Shaping of ditches in plane



Reinforcement of ditches

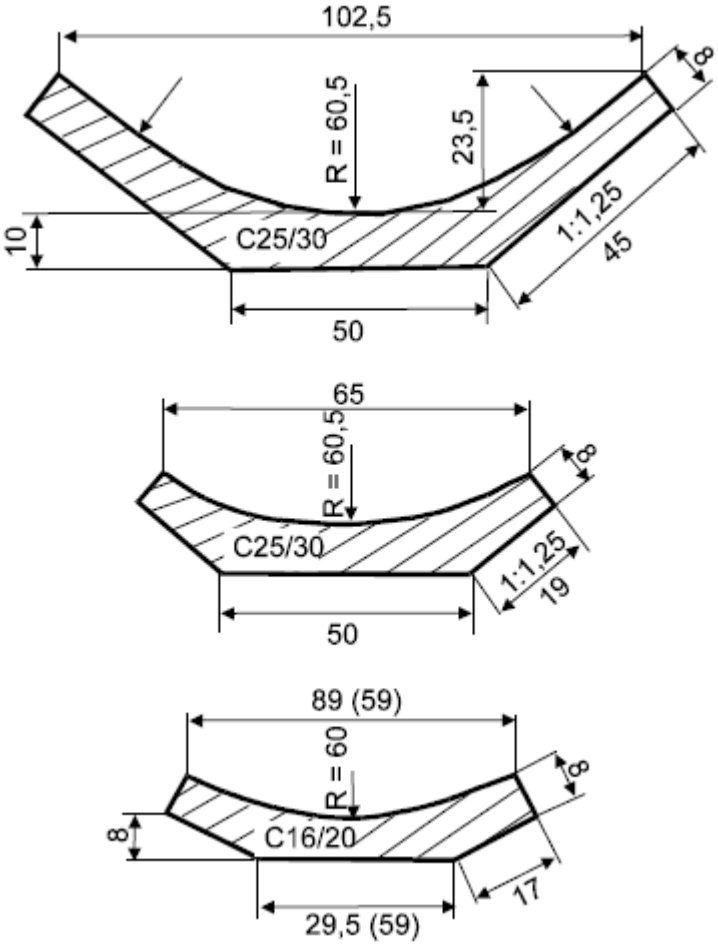


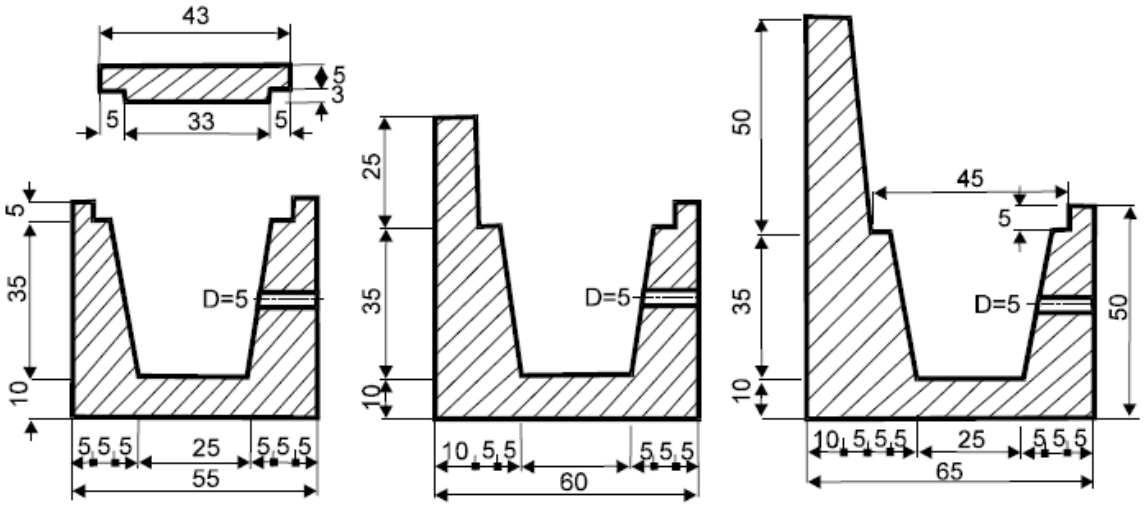
Cross-sections of concrete precast elements used for the reinforcement of a ditch:
a) deep trapezoid shape (PL), b) deep type with a cover (PL), c) shallow Gara type (PL)

source: E. Skrzyński, „Podtorze kolejowe”, Warszawa, 2010

Reinforcement of ditches

Other types of concrete precast elements



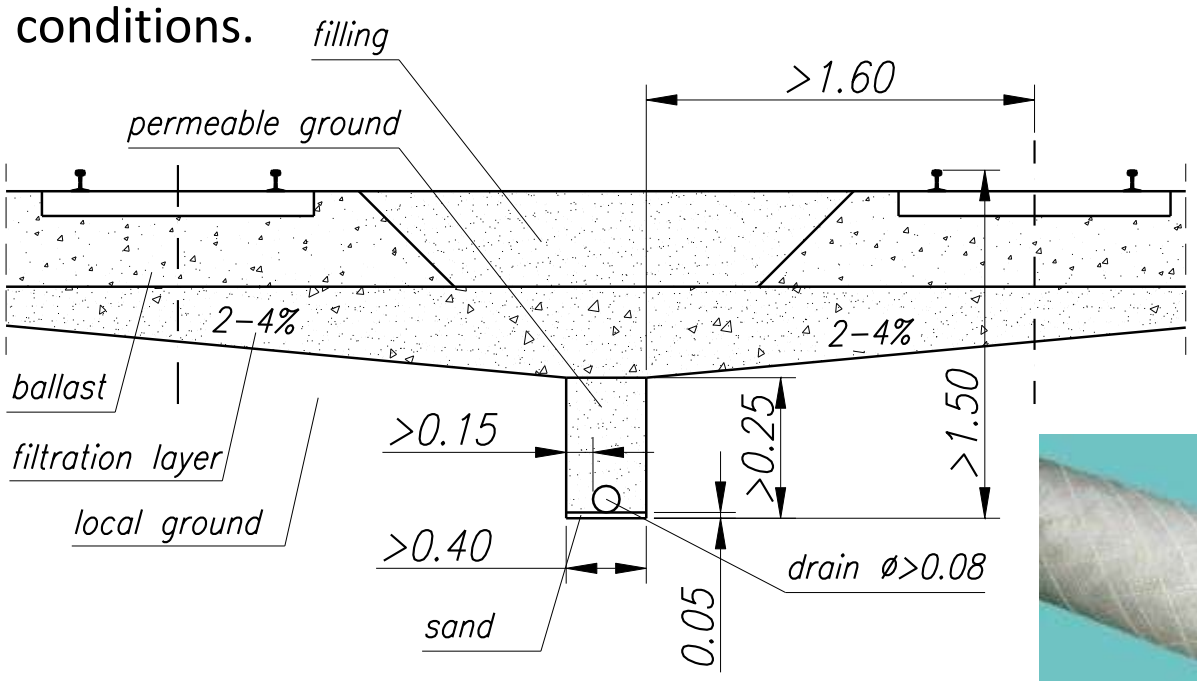




source: E. Skrzyński, „Podtorze kolejowe”, Warszawa, 2010

Shallow underground drainage

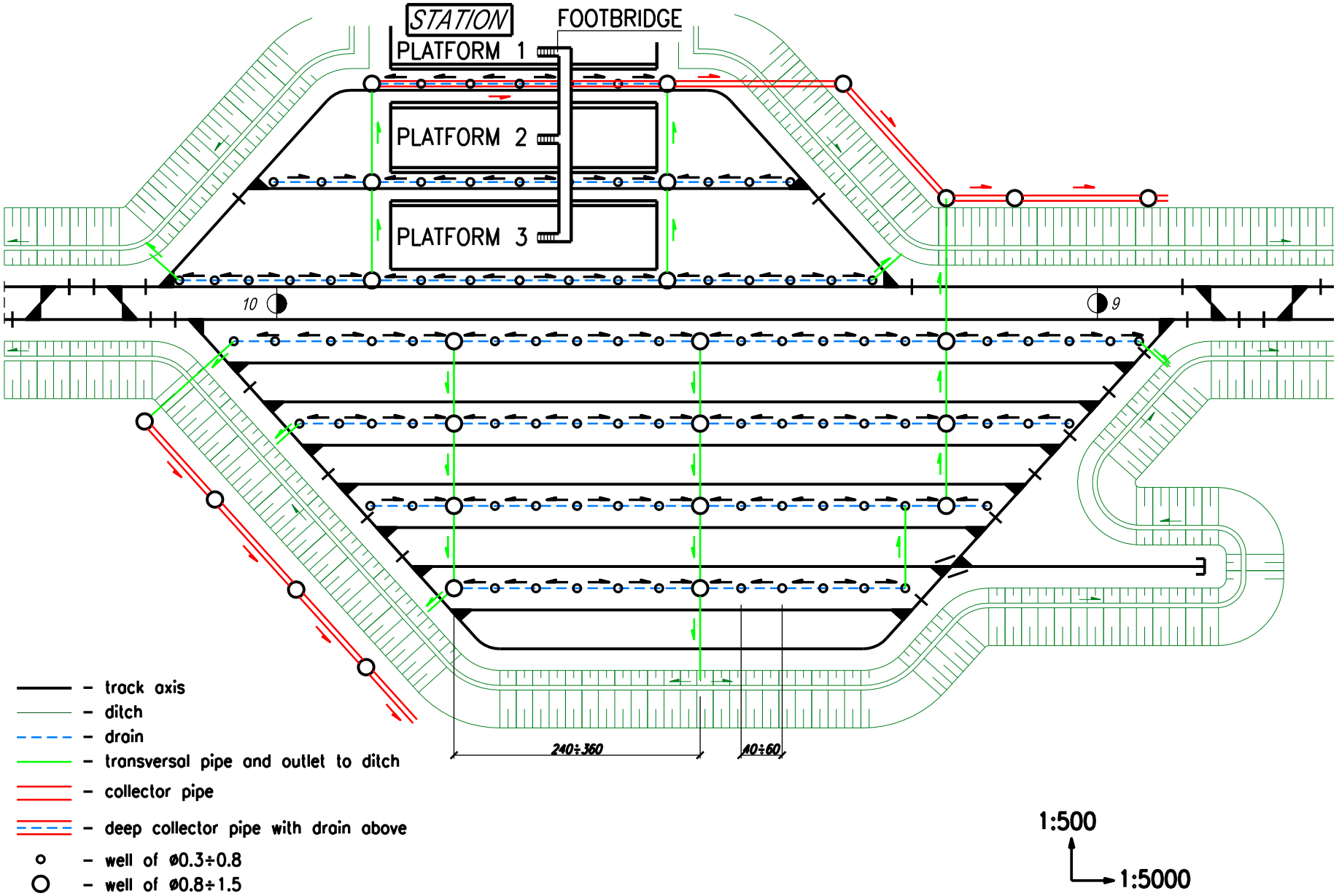
Shallow underground drainage is used when ditches aren't advisable (e. g. lack of space). This kind of drainage is used as a basic method of dewatering of wide station plateaus. The drainage is located in every 2 or 4 spaces between tracks, also in the case of permeable grounds in the formation.
The drainage can be avoided only in the case of very favourable ground conditions.



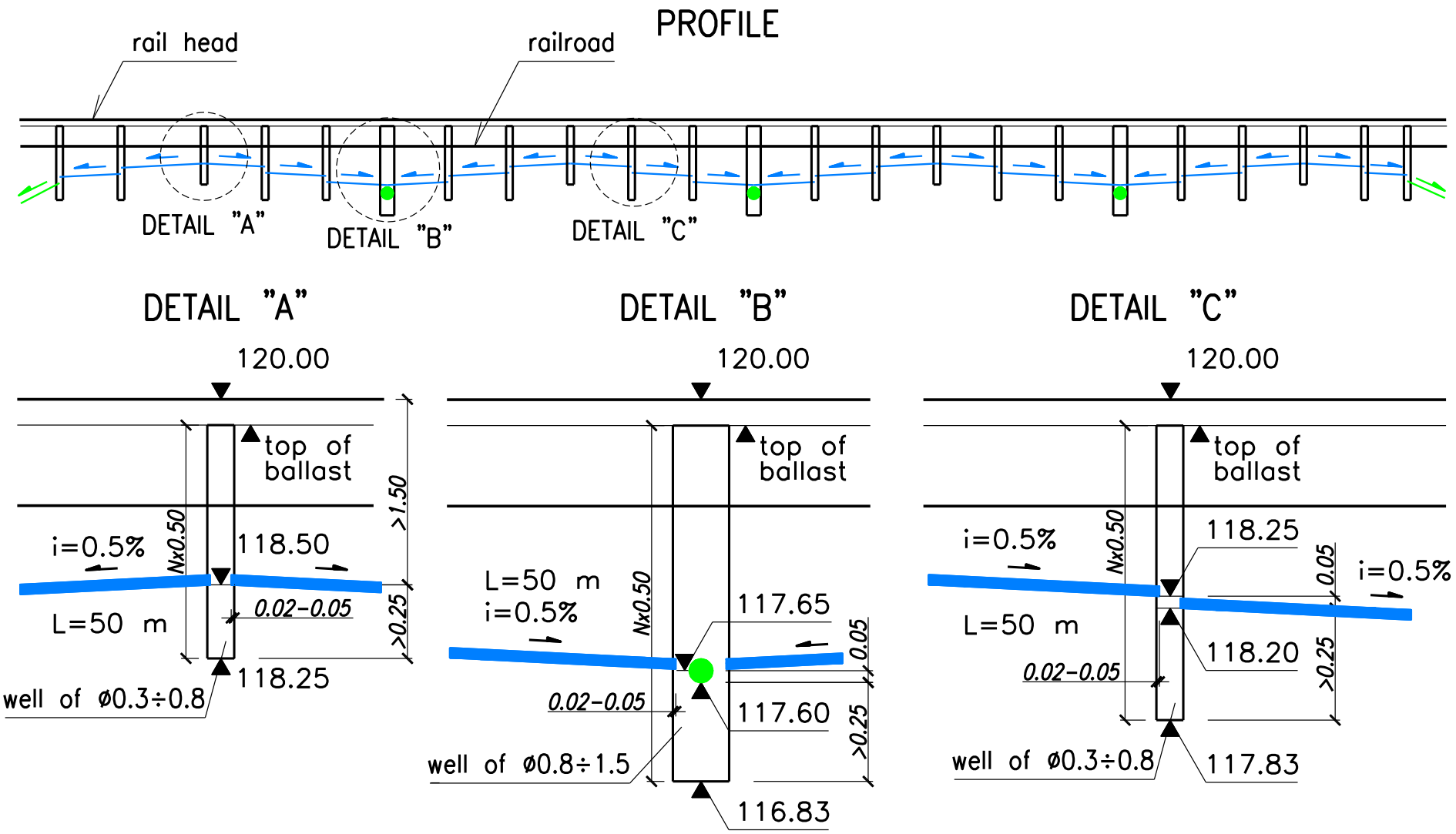




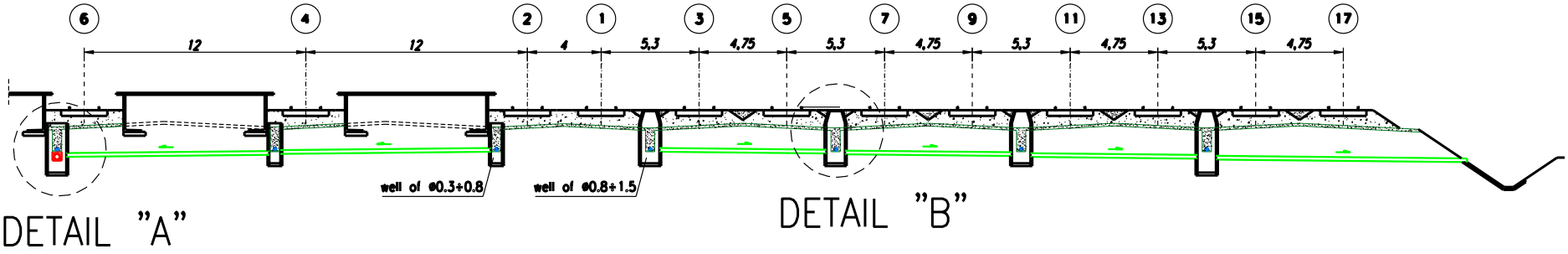
Example of station plateau dewatering

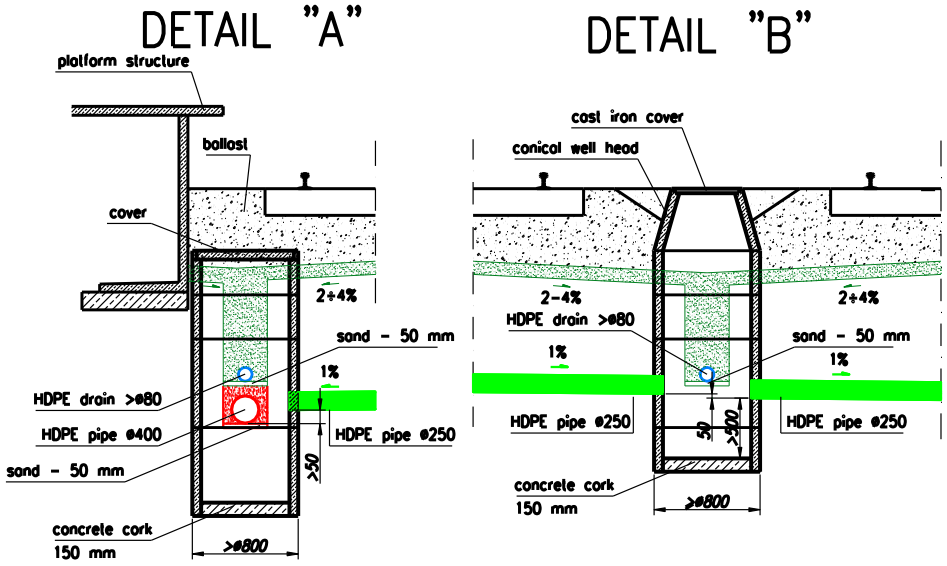


Example of station plateau dewatering

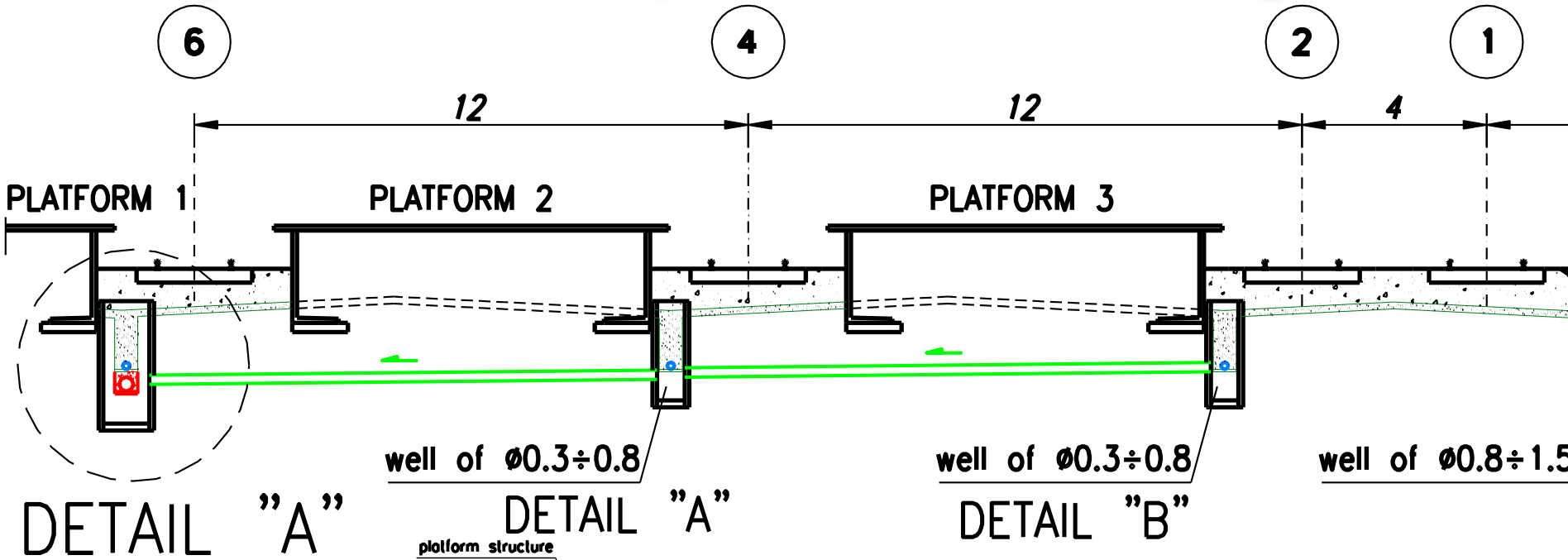


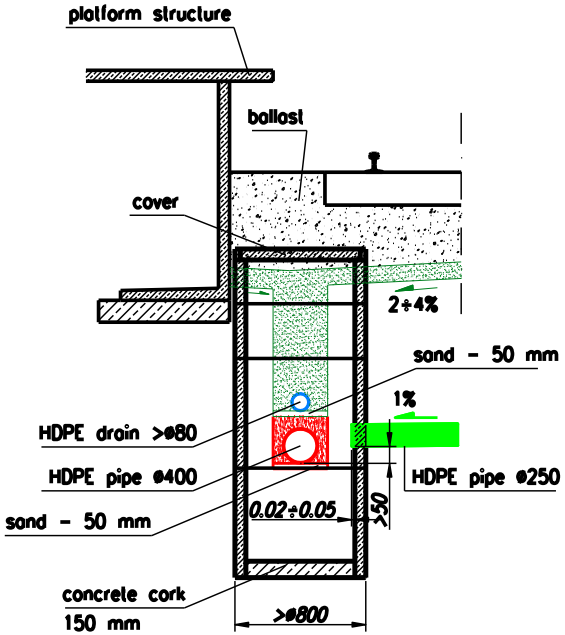
Example of station plateau dewatering

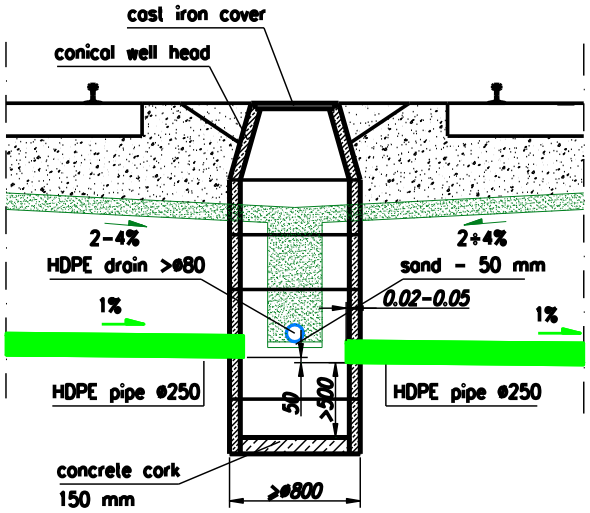




Example of station plateau dewatering



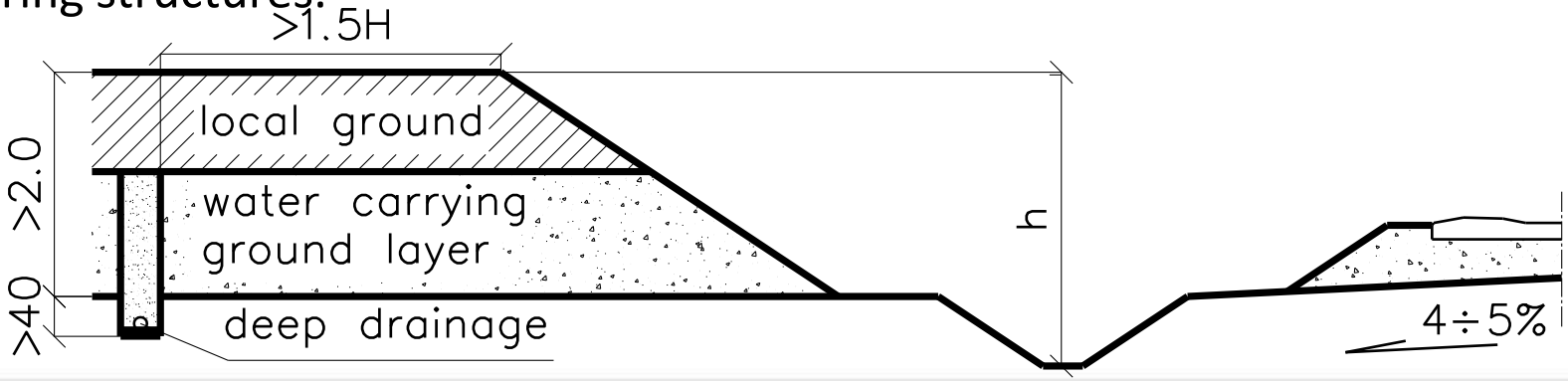




Deep underground drainage

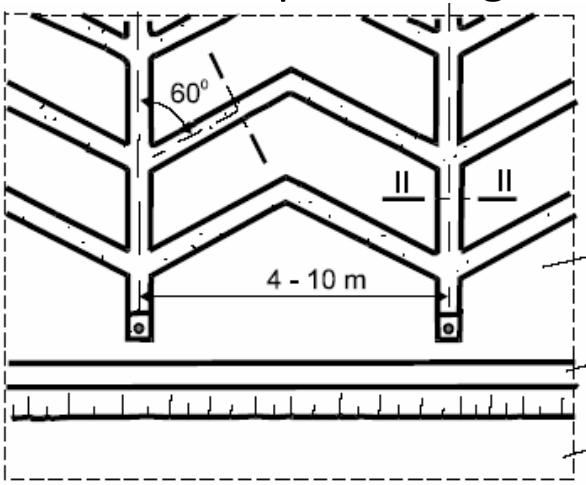
The drainage can be used in case ground water unfavourably influences the function of formation and can not be removed by surface dewatering facilities:

1. In case water carrying ground layers are tilted towards the cutting and are more shallow than 2 m under the terrain surface.
2. In case of water carrying ground layers drive water under the embankment.
3. In case of the drying of the higher zone of formation in order to avoid a heave (in that case the drainage should also be placed under the ditch or instead of the ditch).
4. In case of the drying of landslide terrain.
5. In case of the drying of foundation ground around buildings and civil engineering structures.



Shallow slope drainage

In the case of slope erosion and the oozing of water from the slope ground a shallow slope drainage is used.

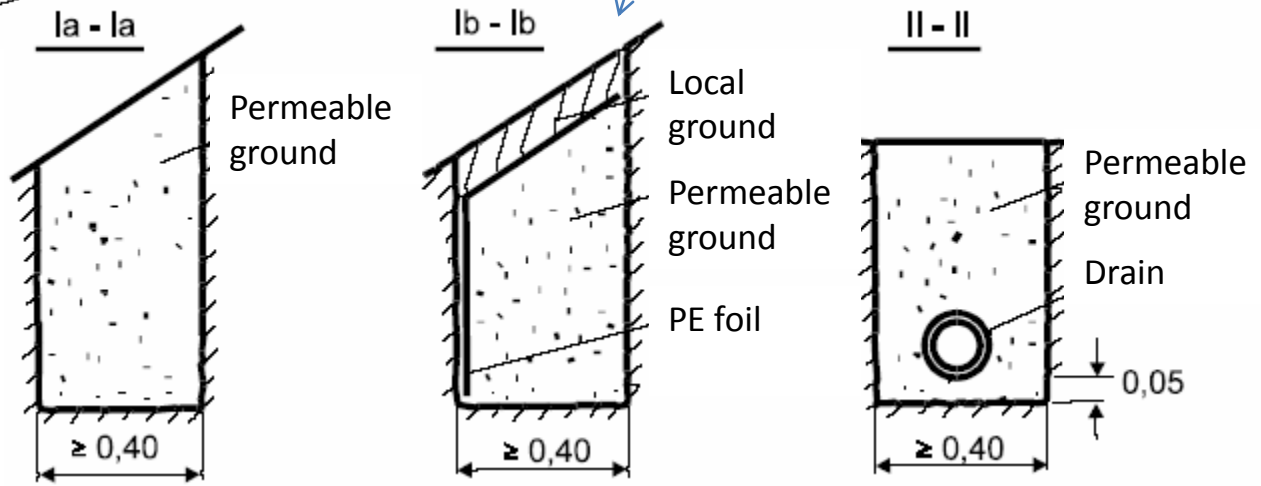


slope

the bottom of the ditch

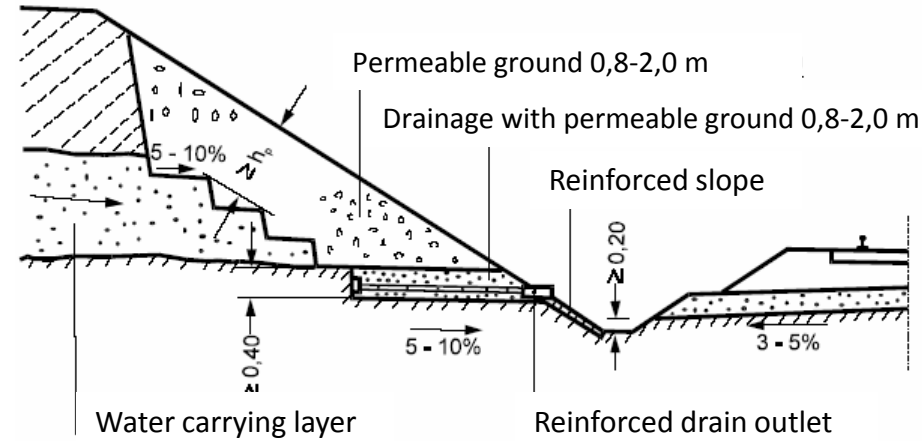
railrooad

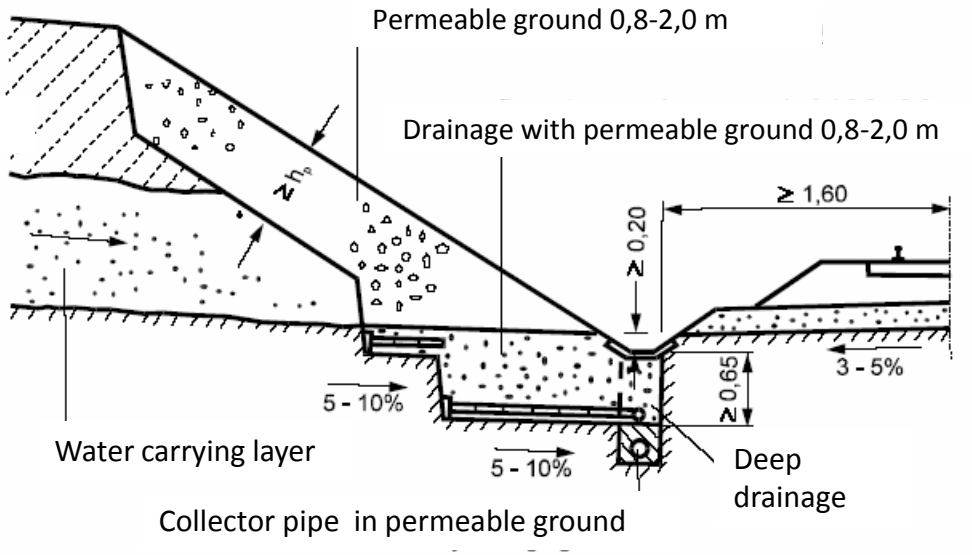
For steep slopes

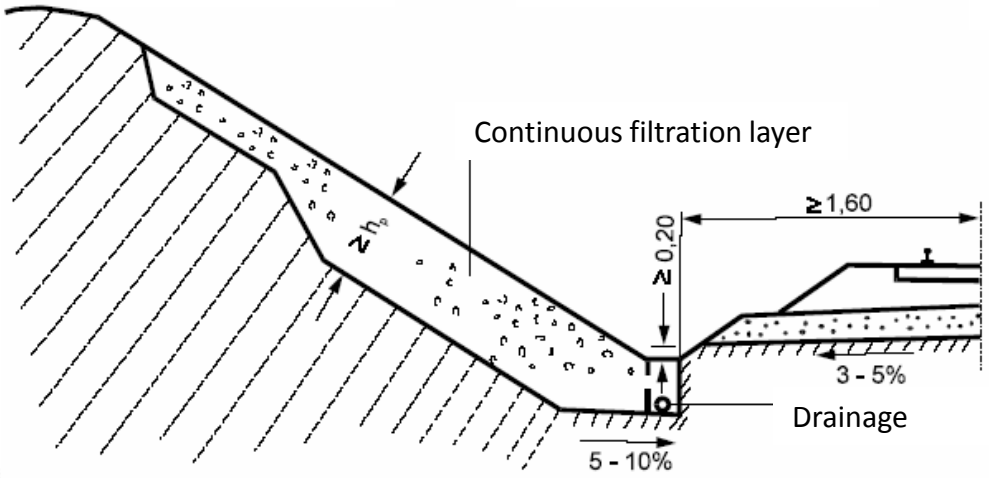


Buttress slope drainage

In the case of slope erosion, landslides and the oozing of water from the slope ground a shallow slope drainage can also be used.

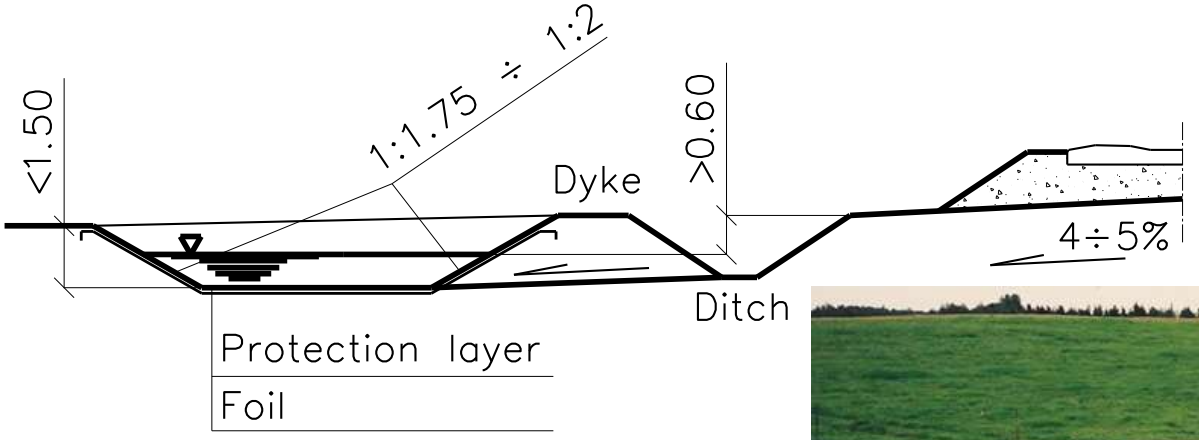






Retention/evaporation pool

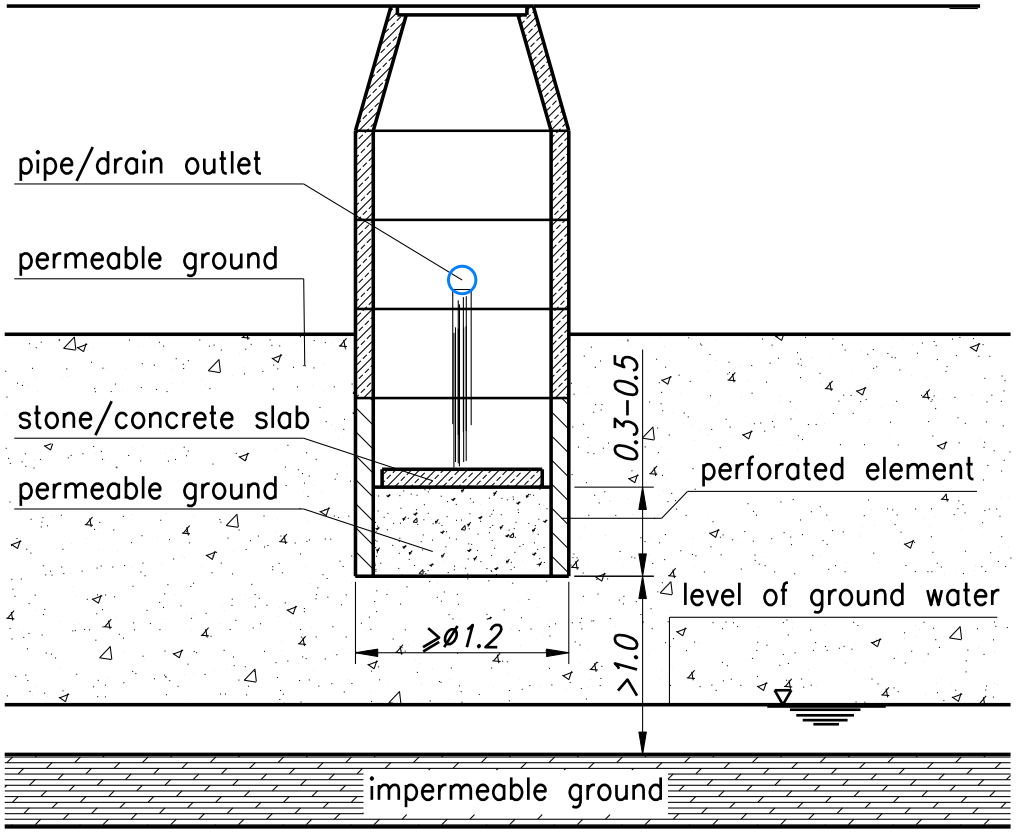
In the case of a lack of other receiver of water a retention pool can be used. The capacity depends on the average monthly water tributary and the assumption that in a temperate climate 0.47 m^3/year is able to evaporate. The pool area has to be less than 200 m^2 and the depth less than 1.5 m.





Absorbent well

In the case of a lack of other receiver of water an absorbent well can be used. The capacity of the well depends on the average monthly water tributary and the ability of the water carrying ground layer to dewater it.



Dewatering of grade crossing



Transverse dewatering trough between a road and a track for water and mud.

Geosynthetics

















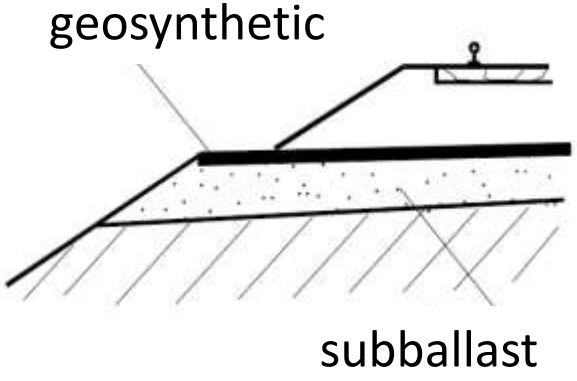
Geosynthetic functions

Function	Characteristic
Separation	Separation of grounds of different granulation. Avoiding migration of fine particles of silt, loam or sandy loam in between the coarse granulated ground (gravel). Uncontrolled mixing of such materials is unfavourable.
Filtration	Filtration of water flowing across the material. Filters enable water flow and stop the fine particles transported away from the surrounding ground.
Separation/filtration	Water filtration, dewatering, pressure evening, and stopping of the fine particles migrating to more porous layers.
Draining	Water carrying along the material in drainage systems and separating the elements driving of water from the ground. The material should be permeable along the fibre.
Strengthening	Even stress distribution and limitation of the formation deformation. In ground building it is a kind of ground reinforcement.
Protecting	Surface protection of a stable slope against erosion (for such protection biodegradable geosynthetics are sometimes applied.
Insulation	Insulation (sealing) of the formation against water and other liquids leaking.

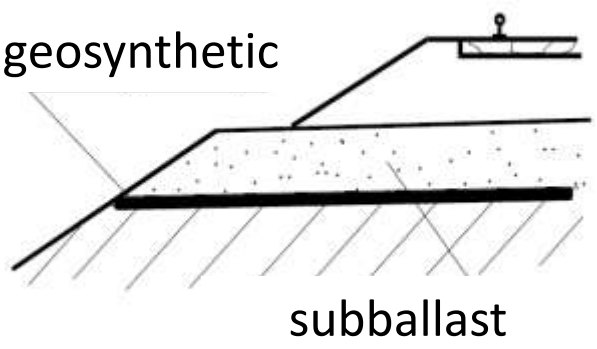
Geosynthetic application

1. Strenghtening of formation.

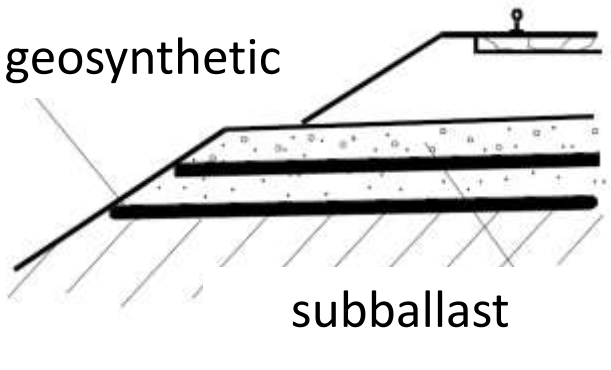
Exceptionally under the ballast



Under the subballast layer

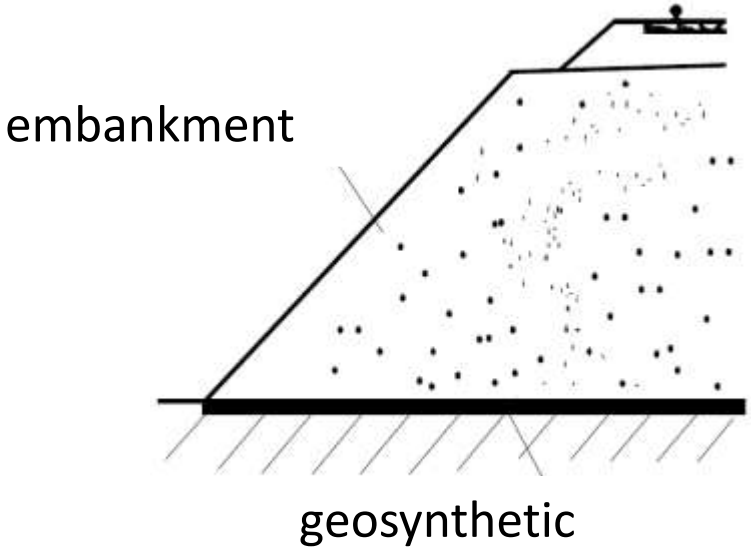


Reinforcement of the subballast layer



Geosynthetic application

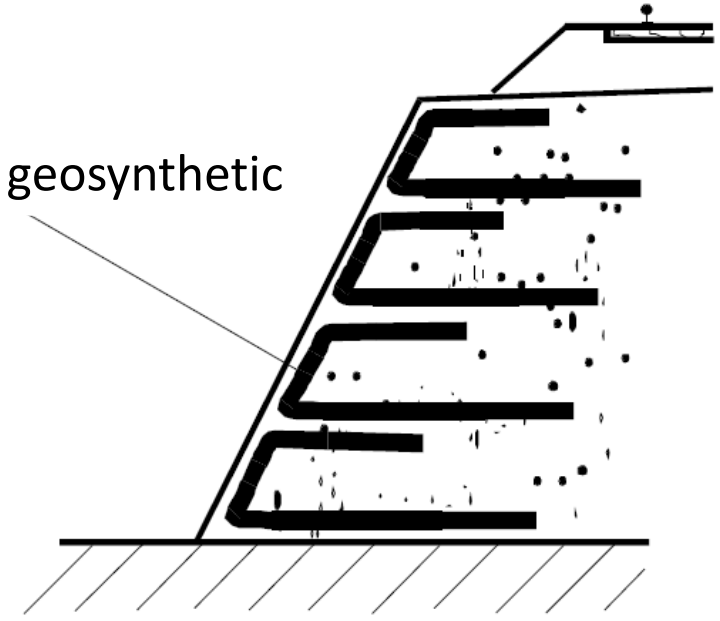
2. Strenghtening of the foundation of an embankment



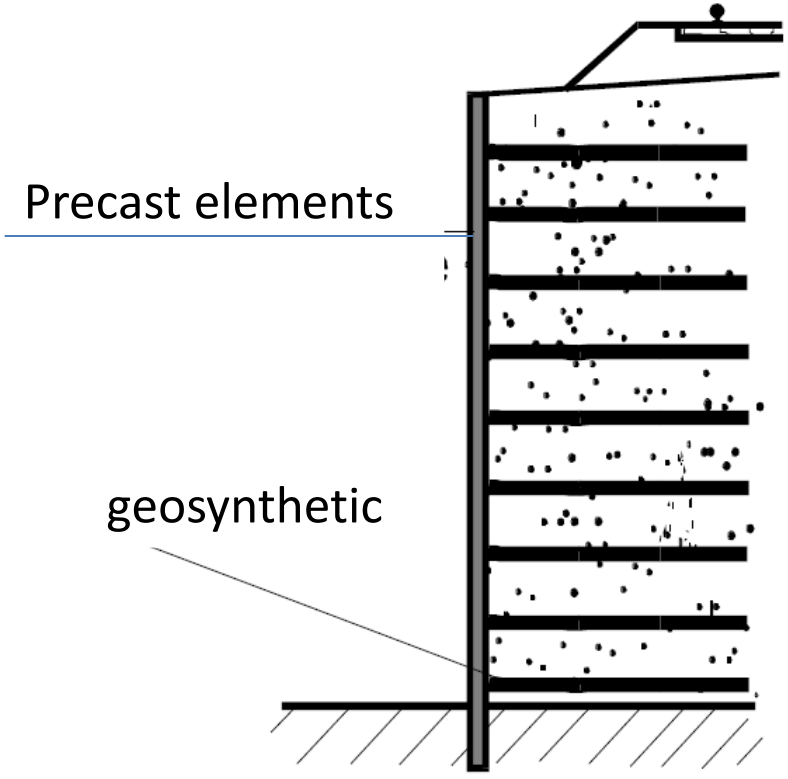
Geosynthetic application

3. Strenghtening of the slope

With inclination > 45˚



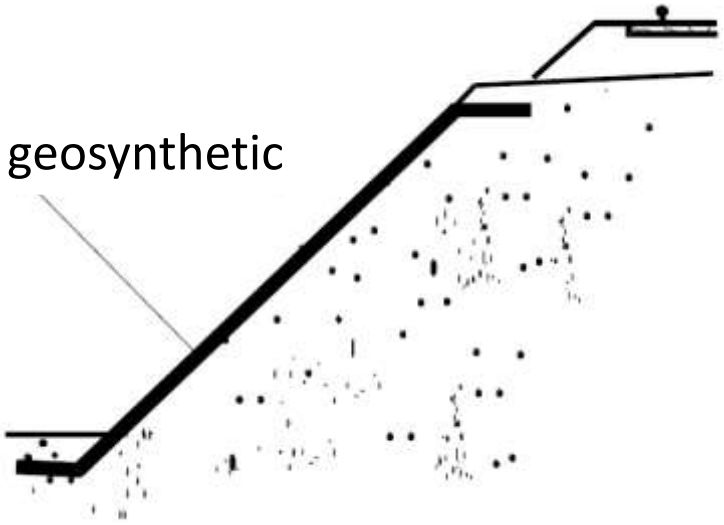
With inclination 80-90˚



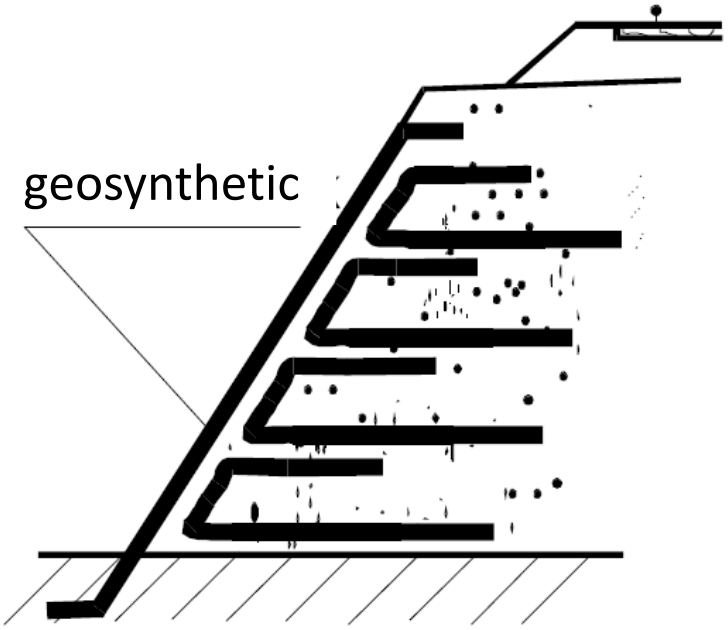
Geosynthetic application

4. Protection of the slope against surface erosion

Without reinforcement



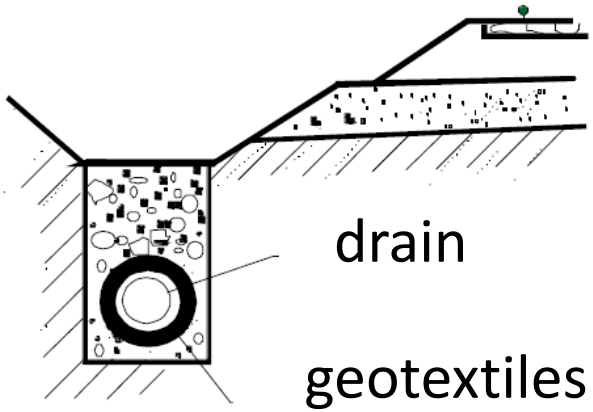
With reinforcement

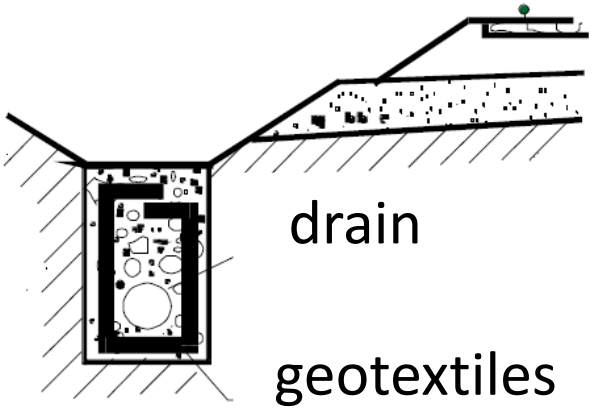


Geosynthetic application

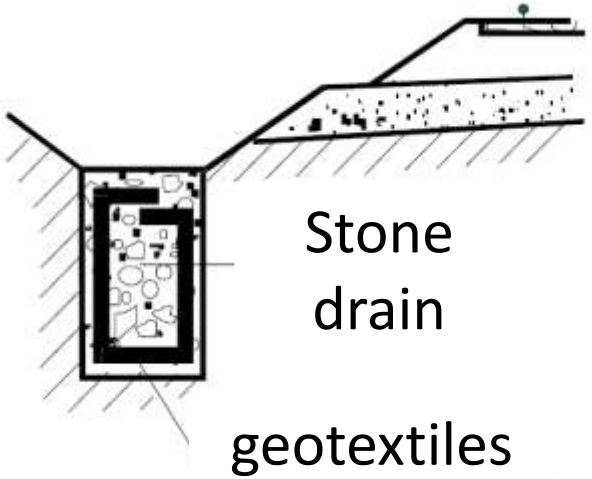
5. Filtration/drainage

Pipe drainage





Stone drainage
(French application)



Geosynthetic application

6. Formation protection against precipitation water

