III. EARTHWORK

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Earthwork includes all construction work in which soil is the construction material or which involves excavation of the soil using the cut-and-cover method. Earthwork 'models' the surface of the terrain.

Typical earthwork:

> Roadbed/substrate of roads

> Noise protection walls

> Embankment construction

> Industrial sites

> Landfill construction

> Sealing courses

> Pipeline and culvert construction

1. CONSTRUCTION OF TRAFFIC ROUTES

The construction of a traffic route is divided into three areas:

> Pavement

> Roadbed (where applicable)

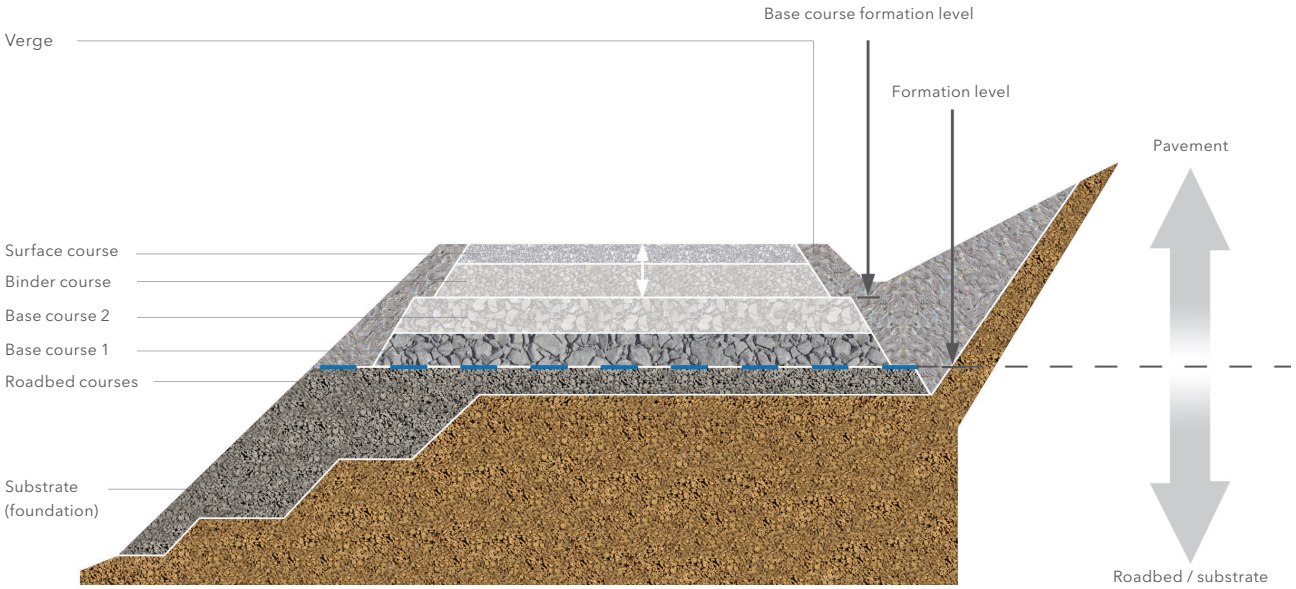
> Substrate

The areas and courses that are relevant to earthwork are described in this chapter.

1.1 SUBSTRATE

The substrate is the naturally occurring, undisturbed soil or rock. It is located directly under the pavement or roadbed. If the load-bearing capacity of the substrate is inadequate, the soil must be further compacted, consolidated, improved or replaced. It is also possible to improve the load-bearing capacity by laying geogrids and membranes.

> The world-famous H series compactors from HAMM are highly efficient and productive compaction machines for earthwork.



> *Schematic representation of the construction of traffic areas.Depending on the shape and properties of the substrate and on the load-bearing capacity requirements of the road, only some of the courses shown here are required.*

1.2 ROADBED

The roadbed is the artificially constructed earth body between the substrate and the pavement.
The main task of the roadbed is to even out the large irregularities in the terrain in order to attain the required height of the traffic areas. Furthermore, together with the substrate, it serves as the foundation for the subsequent structure (pavement).

1.2.1 FORMATION LEVEL

The formation level (the finished surface of the substrate or roadbed) separates the substrate and/or roadbed from the pavement. The formation level is merely a boundary layer and has no height.

1.3 PAVEMENT

In Germany, the different types of pavement construction are governed by the 'Richtlinien für die Standardisierung des Oberbaus von Verkehrsflächen – Ausgabe 2012' (RStO 12) [Guidelines for standardisation of pavement of traffic areas – 2012 edition].
The pavement consists of the surface course, the binder course and one or several bound or unbound base courses. Surface, binder and base courses and their functions are described in detail in the chapter 'Asphalt construction'.

1.3.1 BASE COURSE (E. G. FROST-PROTECTION COURSE)

The task of the base course is to minimise traffic-induced vertical and horizontal loads that are not sufficiently reduced by the surface course, so that the formation level is not unduly subjected to stress with subsequent deformation. Base courses are constructed using unbound, bound or hydraulically bound mixes.
The frost-protection course is a special type of base course. Such unbound courses consisting of crushed rock or gravel have the added role of protecting the overlying pavement from damage caused by freeze/thaw cycles.
When freezing, the water in the frost-protection course can expand into the space between the individual aggregate particles without damaging the road body.

2. THE BASICS OF EARTHWORK

The most common terms, parameters and laboratory tests used in earthwork are described briefly below. Some of these descriptions are also relevant for asphalt construction.

2.1 SOIL TYPES

Soil is an amalgamation of non-cohesive (gravel, sand, stone) and/or cohesive (mud, clay, silt) components.

Because soil rarely consists of a single material but is almost always a mixture of several materials, there are many different types of soil.
With regard to the compactibility of soil types, the following simplified subdivision can be used, for example:

> Rock

> Non-cohesive, coarse-grained soils (sand, gravel, etc.)

> Mixed-grained soils (sandy silt, gravelly clay, etc.)

> Cohesive, fine-grained soils (clay, mud, silt, etc.)

2.1.1 ROCK

In contrast to loose rock (e.g. gravel and sand), rock is solid rock. It has high internal, mineral-bound cohesion and high structural strength.

For earthwork, rock must be broken before processing. Suitable methods are blasting, chiselling, milling and splitting. The materials obtained in this way can then be sifted and divided into individual particle-size classes. From these, it is possible to produce a well-graded filler, for example using a particle-size distribution curve.

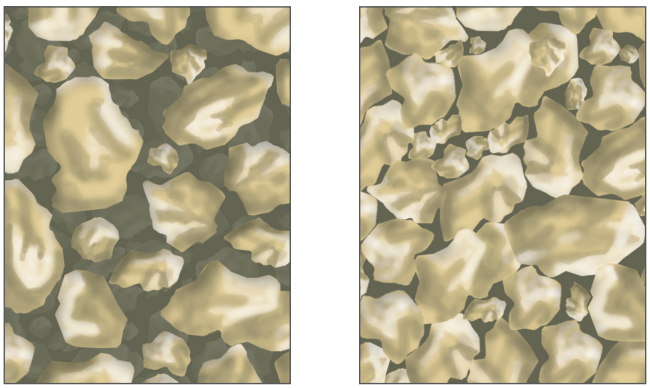
A soil or fill layer consisting of pure rock is best compacted at high amplitudes and with high weight. Moreover, padfoot compactors, as well as special rollers with vibration crusher drums, do an excellent job of crushing coarse rock.

For paving using pure rock material, it is important that levelling courses with coarse-grained material are alternately. This ensures that the fill layers are well compacted and passable. If rock material with very large boulders (diameter in excess of 50 cm / 19.7 in) is used for paving, then they must either be crushed or separated out. Otherwise, there is a risk of voids that may lead to subsidence at a later date.

2.1.2 NON-COHESIVE SOILS

Non-cohesive soils (coarse-grained soils) consist predominantly of individual particles. The material particles are larger than in cohesive soils and do not adhere to one another. The properties of such soils are determined mainly by the shape, size and distribution of the individual particles. In addition, the soil structure is influenced by the water content.

Such soils are best compacted with light rollers at low fill heights, at small amplitudes from 0.5 to 1.1 mm.



> Non-cohesive soils before and after compaction.

2.1.3 MIXED-GRAINED SOILS

These soils consist of a mixture of cohesive and non-cohesive soils. Their properties are highly dependent on the mix ratio of the individual soil types of which they are composed. According to DIN 18196, the proportion of fine particles (diameter <0.063 mm) can be from 5 to 40%. A soil with a high proportion of fine particles has properties that are similar to those of cohesive soil. However, if the proportion of fine particles is low, then the coarse-grained components form a load-bearing and stable granular structure. Nevertheless, it should be noted that the soil, on account of its fine-grained portion, can still exhibit reactions to weather conditions, i.e. sensitivity to water.

A definitive statement on the appropriate selection of amplitude cannot be made here due to the many different material combinations.

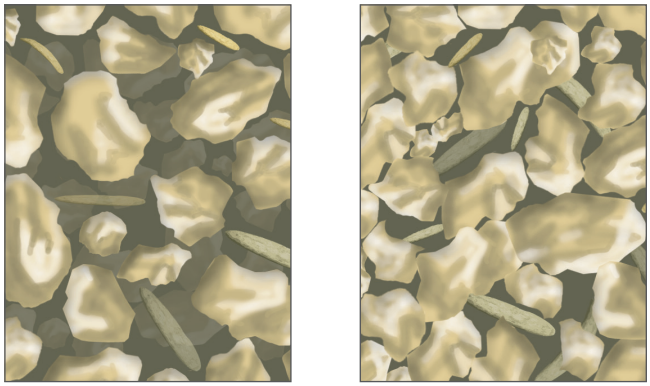
2.1.4 COHESIVE SOILS

Cohesive soils consist mainly of very small particles or solid particles with a correspondingly large surface area. The cohesion and therefore the properties of these soils are predominantly influenced by electrochemical forces acting on the surface of the particles. These forces are known as cohesion forces. Mass forces only play a subordinate role.

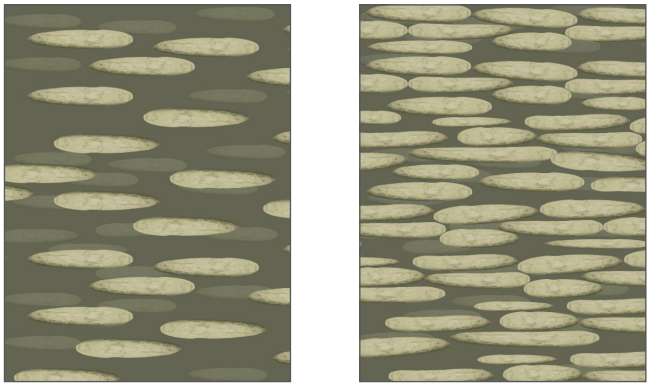
In cohesive soils, cohesion forces cause the particles to stick and adhere to one another. The structure and consistency of these soils also depends greatly on the water content. If the water content is low, the soil will be crumbly; if the water content is high, it will be pulpy or runny. Cohesive soils are thus highly sensitive to water. For this reason, it is important to make sure during paving that cohesive soils have close to the optimum water content (Proctor), that the weather is dry and that the soil does not subsequently soften again.

Cohesive soils are best compacted using vibration or oscillation at high amplitudes of up to 1.8 mm. Heavy padfoot rollers are especially suitable for this task because they knead the soil and increase the surface area. The water contained in the soil can thus evaporate more easily. The soil becomes more rigid in consistency, which increases its load-bearing capacity.

Cohesive soils can be considerably improved or stabilised before the actual compaction work by means of soil stabilisation (e.g. using lime to remove the water) or improvement (e.g. using cement to increase the load-bearing capacity).



> Mixed-grained soils before and after compaction.



> Cohesive soils before and after compaction.

2.2 GRADING CURVE

The grading curve describes the particle-size or piece-size distribution of a soil sample or an asphalt granulate. It is determined using a sieve analysis.

The sample to be tested is placed on the topmost sieve of a set of analysis sieves. The mesh sizes of these sieves correspond to standardised grading and decrease from top to bottom. To collect the smallest particles, a bowl is placed under the bottommost sieve. An engine gets the entire set of sieves to vibrate for a specified period. The duration and vibration intensity of the sifting depend on the sample to be tested (sample quantity, evident particle distribution and behaviour of the sample during sifting). After sifting, the individual sieves hold residues of the original sample. These residues are weighed and converted to a percentage by mass. For better assessment of the sieve analysis, the percentages obtained are entered in a chart with logarithmic x-axis against the respective sieve sizes. The resulting grading curve can now be compared to the given standard grading curves.

Differentiation according to particle size ranges:

> **Fine proportion** ≤ 0.063 mm
> **Sand** > 0.063 mm ≤ 2.0 mm
> **Gravel / crushed** > 2.0 mm ≤ 63.0 mm
> **Stone** > 63.0 mm

In addition, there is differentiation between particle sizes within the particle size ranges:

Fine proportion:
> Clay ≤ 0.002 mm
> Silt > 0.002 mm ≤ 0.063 mm

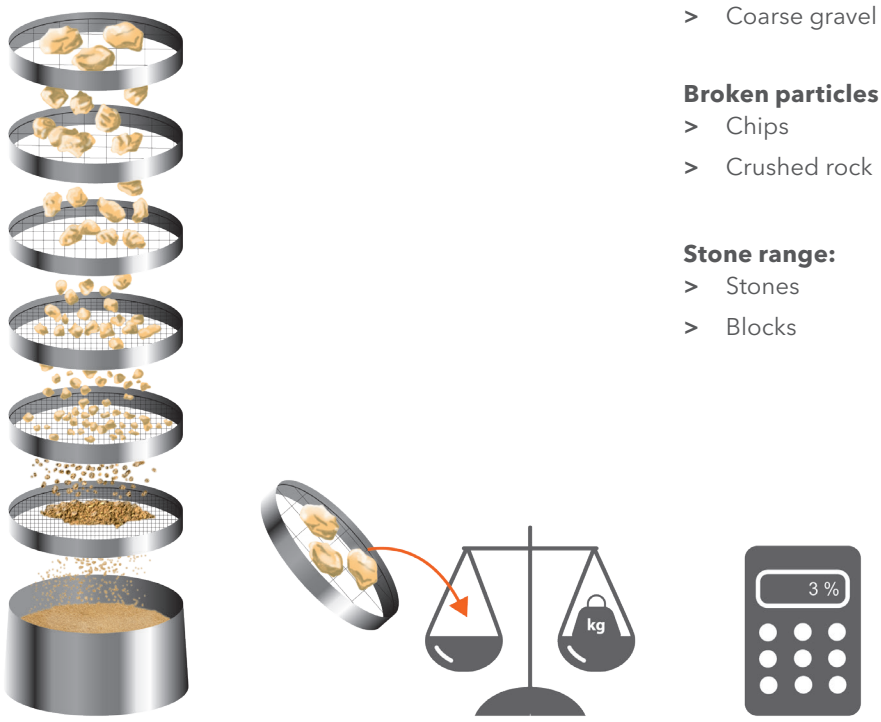
Sand range:
> Fine sand > 0.063 mm ≤ 0.2 mm
> Medium sand > 0.2 mm ≤ 0.63 mm
> Coarse sand > 0.63 mm ≤ 2.0 mm

Gravel / crushed rock range:

Gravel
> Fine gravel > 2.0 mm ≤ 6.3 mm
> Medium gravel > 6.3 mm ≤ 20.0 mm
> Coarse gravel > 20.0 mm ≤ 63.0 mm

Broken particles
> Chips > 2.0 mm ≤ 32.0 mm
> Crushed rock > 32.0 mm ≤ bis 63.0 mm

Stone range:
> Stones > 63.0 mm ≤ 200.0 mm
> Blocks > 200.0 mm



> *Typical set-up of a sieve analysis. The dried minerals pass through sieves with standardised mesh sizes. The contents of each sieve are separately weighed and the percentage proportion is calculated.*