Road and Transportation Research Association

Working Group Earthworks and Foundations

FGSV

Additional technical conditions of contract and directives for earthworks in road construction

R 1

ZTV E-StB 09

Edition 2009
Translation 2012

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Preliminary note

The "Additional technical conditions of contract and directives for earthworks in road construction", edition 2009 (ZTV E-StB 09) have been compiled by the "Earth and rock works" committee supported by the other working bodies within the "Earthworks and Foundations" working group. They replace ZTV E-StB, editon 1994.

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1 General

1.1 Scope of application

The “Additional technical conditions of contract and directives for earthworks in road construction”, edition 2009 (ZTV E-StB 09) are written so that the Tendering and Contract Regulations for Construction Services Part C: General Technical and Contract Provisions for Construction Services, in particular

ATV DIN 18299 “General Regulations for All Types of Construction Work”,

ATV DIN 18300 “Earthworks”

are part of the construction contract.

The paragraphs in the text that are marked with a margin line are “Supplemental technical contract provisions” pursuant to Section 1 No. 2d VOB Part B — DIN 1961 — if ZTV E-StB is a part of the construction contract.

The paragraphs in the text that are printed in italics and are not marked with a margin line are “directives”. They must be observed by the client when preparing the service specification and when monitoring and accepting the construction services.

Paragraphs in small print refer to sections of the VOB/B or to sections of ATV DIN 18299 and DIN 18300.

Products and goods originating from other European Community member states or Turkey and goods originating from member states of the European economic region that do not conform to these technical contract provisions will be treated as equivalent, including the tests and monitoring performed within the manufacturing country, if the required protection level in regard to safety, health and usability is achieved with equal duration.

The abbreviations used for the regulations are summarized in Appendix 6.

ZTV E-StB contains regulations for loosening, loading, conveying, placing and compacting soil and rock as well as other materials suitable for earthworks. It also includes application, testing and installation of geosynthetics in earthworks. ZTV E-StB regulates execution and quality requirements for the base and substructure of trafficked surfaces and other earthworks.

The additional regulations necessary for individual construction projects must be specified in the service specification, insofar as they result from directives and information sheets.

1.2 Definitions

1.2.1 Road construction is divided into:

– superstructure (load-bearing and surface courses),

– substructure

– base (earth foundation).

The position and limits of the superstructure, substructure and base can be seen in Figure 1.

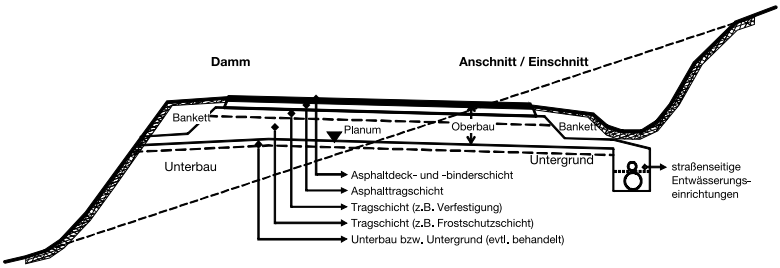

Figure 1: Embankment/cut slope (schematic diagram)

1.2.2 The **planum** is the surface of the substructure and base, processed according to plan, that lies directly below the superstructure.

1.2.3 The **substructure** is the embankment filling below the superstructure.

1.2.4 The **base** is the soil or rock directly under the superstructure or soil or rock under the substructure.

1.2.5 The **stabilized or improved planum** is the upper zone of the base or substructure that has been created using the measures in Sections 1.2.6 to 1.2.9.

1.2.6 **Soil treatment** is a process by which soil is altered to achieve the required properties. This includes soil stabilization and soil improvement.

1.2.7 **Soil stabilization** is a process by which the resistance of soil to traffic and climate action is increased through the addition of binders, so that the soil is permanently able to bear loads and is more frost resistant.

1.2.8 **Soil improvement** is a process for improving the suitability of soil for installation and compaction and easing construction.

1.2.9 **Qualified soil improvements** are soil improvements with binders that fulfil increased demands on certain properties.

1.2.10 **Construction classes:** For definitions and subdivisions, see RStO.

1.2.11 **Topsoil:** The principles of DIN 18915 are valid for the description of topsoil. Also see DIN 18300, Section 2.3.

1.2.12 **Shoulder** (unpaved side lane): The part of the road lying immediately beside the traffic lane or the hard shoulder (paved side lanes).

1.2.13 The **pipe zone** is the support and embedding area for trench conduits in the width of the pipe trench up to a height of 0.3 m above the crown of the pipe.

1.2.14 **Backfill zone** is the space within the pipe trench above the pipe zone to the planum.

1.2.15 **Protective barriers:** Dams made of soil, rock or other building materials that are erected as part of roads:

- for protection against road traffic noise emissions (noise barriers),
- for protection against vehicles leaving their lane (median barriers),
- for protection against glare,
- to protect the road against heavy rain flow or falling rocks.

1.3 Preparatory work and work during construction

Also see DIN 18300, Section 3.2.

1.3.1 Also see DIN 18300, Section 4.2.2.

The client must always assess the condition of the construction site. The bidders are expected to familiarize themselves with the location.

If condition assessment becomes necessary due to an alternative offer, this is the responsibility of the contractor.

1.3.2 The contractor must familiarize himself with the location.

1.3.3 Excavations inside and outside the construction site may be eliminated only with the consent of the client.

Excavations below the deposition surface and in the contract must be filled and compacted so as to meet the requirements in Section 4.3.2.

1.3.4 Areas designated for construction must be kept in proper condition during the construction work. It must be ensured that adjacent surfaces, structures and vegetation are not damaged.

1.4 Building materials

1.4.1 Depending on purpose and suitability, the building materials and mixtures thereof are:

- soil and rock,
- soils and building materials according to TL BuB E-StB,
- geosynthetics,
- lightweight construction materials,
- binders,
- materials for drainage and sealing and all other materials needed for subservices.

1.4.2 When using soils and building materials according to TL BuB E-StB, with regard to environmental requirements, the regulations at the site of application must be observed.

1.4.3 To prevent damage to buildings and building components, ZTV-ING, DIN 50929-1 and -3 “Corrosion of metals; probability of corrosion of metallic materials when subject to corrosion from the outside”, and DIN 4030 “Assessment of water, soil and gases for their aggressiveness to concrete”, must be observed.

1.5 Execution

1.5.1 Also see DIN 18300, Section 3.1.1.

Varying from DIN 18300, Section 3.1, specific construction procedures, devices or device types are to be prescribed in the service specification if it appears necessary for the safety and use of the structure to be built, or when required for reasons of environmental protection or protection of a neighbouring structure.

1.5.2 Also see DIN 18300, Section 3.1.2.

Water conservation and earthwork next to any type of traffic control device, as well as blasting operations, must also be performed with due care.

1.5.3 Also see DIN 18300, Section 3.1.3.

The necessary protection and safety measures must be observed for all construction systems and work, even for those that are not the subject of DIN 4123; see Section 1.5.2.

If special safety measures become necessary for protecting the construction areas and their surroundings, this is to be mentioned in the service specification.

1.5.4 Also see DIN 18300, Section 3.1.6.

The trees, plants and vegetation areas to be preserved are to be indicated in the service specification.

1.5.5 Also see DIN 18300, Section 3.1.7.

During earthworks in which endangered trees, plants and vegetation areas are to be preserved, RAS-LP must be followed.

1.5.6 *In the service specification, the type, location and number of traffic, supply and waste systems are to be indicated. The time period for performance of third-party work on the aforementioned systems should also be indicated.*

The provision of information on supply and waste lines does not absolve the contractor from the obligation to seek instruction from the line operator in individual cases and always to take special care.

1.5.7 *The distribution of amounts should be evident from the service specification according to size, production, installation and, if necessary, feed distance and feed height. The volume increase through loosening during extraction and the increased or decreased density to be achieved during installation compared to the state before extraction, as well as possible or probable settlement of the earthwork and the base, are to be separately inspected in advance and taken into account in the data on the amounts.*

1.5.8 *For earthworks in specially designated areas, such as in water protection areas or in excavation and monument protection areas, the regulations from the relevant technical regulatory documents are to be included in the service specification. For construction projects in water protection areas, the "Directives for road construction activities in water protection areas" (RiStWag) are to be observed.*

1.6 Testing

1.6.1 General

Tests are divided into

– suitability tests,
– self-monitoring tests,
– control tests.

If necessary, the tests include

– sampling,
– proper preparation, storage and dispatch-ready packaging of the sample,
– transport of the sample from the extraction location to the testing laboratory,
– the tests themselves, including the evaluation and test report.

The points for which testing is performed must be shown in the plans in terms of location and height (see Section 15).

Performance of the tests must be noted in the daily construction records.

1.6.2 Suitability tests

Suitability tests are tests to verify the suitability of the building materials and mixtures of building materials for the intended purpose in compliance with the requirements of the construction contract.

The contractor must verify the suitability of the building materials and mixtures of building materials intended for delivery.

Verification must be produced in the form of test certificates from a testing laboratory recognized by the client for the relevant building materials and mixtures of building materials (e.g. according to RAP Stra). The test certificate must contain data on for which application the intended building materials and mixtures of building materials are suitable.

The client can waive the submission of test certificates if he is aware of the suitability of the building materials or mixtures of building materials.

Available suitability tests can be used as long as the type and characteristics of the building materials and mixtures of building materials to be used have not changed and the test certificates are not older than two years.

The contractor must submit the investigation results obtained during suitability testing to the client. Based on these investigation results, the contractor must specify the intended building materials and the intended composition of the mixtures of building materials and provide them to the client in sufficiently good time before construction starts.

Suitability must be retested if the type and properties of the building materials and mixtures of building materials or the installation conditions change.

Sufficiently large samples of all building materials intended for construction must be provided to the client upon request. The client shall store these safely (as reference samples). The samples must be acknowledged by both contracting parties in a transcription. In the scope of control tests, they assist in judging contractually correct delivery.

If the client sets additional requirements or demands additional tests, they are to be indicated in the service specification.

The cost of the suitability tests and reference samples is not remunerated separately.

1.6.3 Self-monitoring tests

Self-monitoring tests, which also include building material acceptance tests, are tests performed by the contractor to determine whether the quality of the building materials, the mixtures of building materials and the finished performance meet contractual requirements.

The contractor must perform the self-monitoring tests during the execution with due care and in the necessary scope. If deviations from the contractual requirements are determined, the corresponding deficiencies and their causes must be resolved immediately.

The results of the self-monitoring tests must be submitted to the client in corresponding to the progress of construction.

The type and extent of the self-monitoring tests are governed by the relevant sections.

In individual cases — such as in urban road construction — more self-monitoring tests may be necessary. They should be indicated in the service specification or agreed upon.

1.6.4 Control tests

1.6.4.1 Control tests

Control tests are tests performed by the client to determine whether the quality of the building materials, the mixtures of building materials and the finished performance meet contractual requirements; acceptance will be based on the results of the control tests.

Sampling and tests that take place on the construction site are performed by the client in the presence of the contractor. They will take place in the absence of the contractor if he does not appear at the notified time.

If, alternatively, the sampling and packaging of the samples for dispatch is carried out by the contractor, these services are to be indicated under a special ordinal number in the service specification. Dispatch of samples and performance of tests are to be carried out only by the client or by a testing laboratory recognized according to RAP Stra. The client specifies the testing laboratory.

It may be practical to perform self-monitoring tests along with the control tests.

Control tests may be used only for assessing the entire construction lot or the entire surface to be tested if they are performed according to the agreed testing method.

For the control tests, as long as it is possible and practical, the results of the general findings may be used for invoicing (see Section 1.9).

Regardless of the method chosen for self-monitoring, the client reserves the right to perform control tests on visually selected or suspected flaws.

The result of such tests may lead to claims on an associated surface, which shall be consensually specified or isolated through additional tests.

The contractor must bear the cost of control tests that must be repeated due to non-compliance with requirements.

The sample material for the control tests will not be remunerated separately.

1.6.4.2 Arbitration tests

An arbitration test is the repetition of all or one of the control tests about which the contractor has well-founded doubts as to proper performance (e.g. based on his own investigations).

It is to be conducted by order of one of the contracting parties by a RAP Stra recognized testing laboratory that did not perform the control test. Its result replaces the original test result.

The cost of the arbitration test, including all ancillary costs, is born by the party whom the results prove wrong.

1.7 Acceptance of test lots

The acceptance of test lots is not an acceptance in the sense of Section 12 of VOB (B). Such construction-related status determinations serve only to prove that the contractor is working properly.

1.8 Deficiency claims

1.8.1 Handling deficiencies

See Sections 12 and 13 of VOB/B.

Handling of deficiencies is governed, for example, by the "Handbook for awarding and execution of construction services in road and bridge construction" (HVA B-StB), Section 3.10 deficiency claims.

In the event that the limiting values of layer thickness, amount of binder or degree of compaction are exceeded or fallen short of, and they represent a material deficiency according to § 13 No. 1 VOB/B, within an individual agreement, the client can offer the contractor temporarily deferment of assertion of deficiency claims (Section 13, No. 5 VOB/B) and a deduction as compensation. The amount of the deduction is calculated based on the deduction formulas in Appendix 1.

1.8.2 Limitation period for deficiency claims

The limitation period for all earthwork services is five years.

This also applies to passages and conduits that the contractor builds within the scope of the construction contract.

1.9 Accounting

See DIN 18299, Section 5 and DIN 18300, Section 5.

1.9.1 Topsoil layers are not included in the measurement of cut and application profiles.

1.9.2 Additional earthworks associated with conduits, slopes or troughs in application profiles are determined separately.

No deduction is made for application profiles.

If a different rule for financial calculation is to be applied, this is to be shown in the service specification.

1.9.3 See DIN 18300, Sections 5.4 and 5.5.

The increased quantities made necessary by settlement of the base will only be paid for separately if they have been proved.

Increased quantities needed due to embankments and walls settling on their own are included in the service.

The dimensions of seepage bodies, packed stones and suchlike with cross-sectional areas of more than 0.5 m^2 are subtracted from the dimensions of a compacted granular body determined in the contact.

1.9.4 When financially calculating a surface area, installations (storm drains, hydrants, manhole covers, etc.) or individual recesses up to 1.0 m^2 in area are not subtracted.

1.9.5 Increased quantities, widths and lengths are only remunerated if their execution has been ordered by the client in writing. The contractor must issue the order in sufficiently good time if increased widths or lengths become necessary for reasons for which he is not responsible.

1.9.6 If the construction contract for soil treatment requires that the binder be invoiced separately, the weight of the binder actually installed must be proved. The installation weight of the entire construction lot is used for determining the weight of the respective layer. However, the client has the right to demand weight verification for partial sections.

Additional binder weights are remunerated only up to 5 % of the specified weight determined from the suitability test; lower weights will be subtracted.

Additional weight will be remunerated if the client has issued a written order for it. The contractor must issue the order in sufficiently good time if more installation becomes necessary for reasons for which he is not responsible.

1.9.7 For geosynthetics, the surface covered by the product will be calculated financially according to measurement without regard to overlaps.

If a different calculation process (see M Geok E) is to be applied, this must be shown in the service specification.

2 Geotechnical investigations

2.1 General

See DIN 18299, Sections 0.1.9 to 0.1.13 and 0.1.20.

The soil, rock and groundwater conditions must be ascertained and investigated in such a way that the properties and suitability of the soil as a construction base or building material can be determined (see DIN 4020).

The geotechnical investigations also include determination of the type and extent of any backfilling, old landfills, former mining sites or contaminated soils.

If the investigation raises suspicion about contamination due to anthropogenic changes or geogenic material enrichment, the environmentally relevant parameters are to be determined. For excessive amounts, information on usability is required.

Ascertainment of the soil, rock and groundwater conditions should be performed with such timing that the knowledge obtained can be considered during planning, in constructive consequences, in design of the construction procedure, and in execution of the construction. If necessary, other construction-related investigations must be performed. The relevant data are to be indicated in the service specification.

See DIN 18300, Sections 0.1.2, 0.1.3, 0.2.7, 0.2.17, 0.2.22, 0.2.25 to 0.2.27.

The client is responsible for the geotechnical investigations for the tender. The type and scope of the investigations to be performed or supplemented are based on the state of planning and construction preparation. Other geotechnical investigations may become necessary while construction is in progress.

The geotechnical investigations and geotechnical reports upon which the tender is based are to be recorded in a summary description and assessment in the service specification.

The documents that are not recorded in the service specification must be made available to the bidders in suitable form. Otherwise, access to this document must be provided.

The results of the field and laboratory investigations apply only to the respective exploration site and the time of the investigations.

The contractor must immediately communicate and document deviations from the described construction ground conditions from which he derives claims.

If the execution is based on an alternative offer, the contractor must verify feasibility and usability through his own supplementary studies. In the process, the client's soil investigations and soil surveys may also be used.

Geotechnical measurements may be necessary (DIN 4020) for monitoring the stability, testing geotechnical calculation assumptions, observing the behaviour of structures and preservation of evidence on neighbouring construction systems.

2.2 Type and scope of explorations

The type, scope and timing of geotechnical investigations are determined by the state of planning, construction preparation and construction execution as well as by the geotechnical category (see DIN 4020). Exploration of soil and rock is to be performed comprehensively enough to enable adequate description of the construction ground (see M GUB).

In general, direct exploratory methods such as excavation and drilling as well as indirect probing will be carried out. The location and separation depend on prior knowledge and the structure, as well as on the layers and terrain conditions. As long as there are no other criteria, for the main investigation for roads, direct explorations may be about 100 m apart. The exploration depth must be chosen in such a way as to determine all layers and groundwater conditions that affect the construction project and its sphere of influence.

Special situations may require a narrower study grid, if necessary also vertically to the construction axis, as well as other investigation procedures.

The investigations for earthworks and other constructions are to be coordinated with regard to mutual interaction.

2.3 Investigation procedures

The following investigation procedures may be appropriate:

- *Site survey, visual inspection and evaluation of available documents, such as historical maps, aerial photos, etc.,*
- *soil exploration by excavation and drilling, exploration with pile driver probes, pressure probes and vane testers,*

– *mechanical experiments in the bore hole, optical methods in the bore hole, geophysical investigation in the terrain, e.g. with geoelectrics, refraction and reflection seismics, geosonar, magnetometry, ground radar and radiometric methods (see H GeoMess),*

– *physical soil investigations of samples in the laboratory to determine the soil properties (see Section 14),*

– *mineralogical investigations,*

– *chemical investigations of environmentally relevant parameters.*

Construction-related geotechnical measurements mainly include:

– *measurement of the ground water table,*

– *pore water pressure measurements,*

– *settlement, displacement and deformation measurements,*

– *vibration measurements.*

2.4 Description of construction ground conditions

The object of the construction ground description is a simple model of the construction ground which includes the main influencing values. The geotechnical report must be structured in consideration of M GUB and DIN 4020. Soil, rock, groundwater and building materials must be described with regard to any environmental influences.

The geotechnical report must include data on the effects of the geological situation and previous use of the investigation area on the construction project, and of the construction project on the surroundings. The documents and information used are to be declared in the report. The construction ground itself and the existing material as building material are to be described, so that soil from trenches, side-cuts and soil removed from the sides can be reused within the project.

These soils and their possible uses must be declared in the geotechnical report with their corresponding parameters.

Classification of soil and rock is performed for:

– soil types according to DIN EN ISO 14688-1,

– soil groups according to DIN 18196,

– Hard rock and rock groups through data from (see also DIN EN ISO 14689-1):
  - mineral components.
  - petrographic designation,
  - water absorption according to DIN EN 1097-6,
  - rock strength,
  - grain binding,
  - degree of weathering,
  - fracture joints,
  - weathering resistance,
– soil and rock classification according to VOB Part C,
– rocks of variable hardness (after the drum sieve test according to TP BF-StB, Part C 20).

Soil and rock that cannot be classified are to be described.

Construction-related assessment of the relevant base layers include:

– *frost susceptibility assessment*
– *representation of the special geotechnical features of the recorded soil layers,*
– *specification of geotechnical parameters with data on limiting values and spread,*
– *specification of characteristic values,*
– *data on the load capacity of the soil layers. Additionally, data must be provided on:*
– *the groundwater pressure levels, the highest and lowest ground water table,*
– *the designed water tables and their drainage,*
– *the effects of groundwater chemistry (degree of attack, hazard, discharge into the receiving water),*
– *the effects of various groundwater levels,*
– *the type of aquifer (pore aquifer, fissure aquifer),*
– *occurrence of temporary groundwater resources, water layers, floating aquifers and their harmless capture,*

– *the significance of groundwater resources of any kind for stability,*

– *permeability of the soil layers,*

– *any environmental pollution present.*

3 Soil and rock, geosynthetics and lightweight construction materials

3.1 Classification of soil and rock

See DIN 18300, Sections 0.2.2 and 0.2.7.

3.1.1 General

The soil and rock classes are to be declared in the service specification. They relate to the loosening and loading construction processes.

The associated types of soil and rock are to be described and classified comprehensively with regard to their properties and construction suitability (see Section 2.4).

For types of soil and rock that belong to different classes and alternate within a construction lot in such a way that they cannot be separately measured, a summary of each class may be practical. However, this assumes that the soil and rock types are described precisely based on explorations and their proportions can be estimated with sufficient precision. A summary may also be useful if separate loosening of the soil or rock types is not possible or practical.

If the state of the soil or rock changes due to water entry after the loosening process, this is to be declared separately in the service specification.

Soil types, whose natural water content is too high for construction purposes, or that first must be stored, improved or discarded, are to be declared separately according to quantity and class. The same applies to other materials that are not usable for earthworks.

3.1.2 Soil and rock classification

See DIN 18300, Section 2.3.

Class 1: Topsoil

See Section 1.2.11.

Class 2: Flowing soils

This includes:

1) organic soils of groups HN, HZ and F,
2) fine-grained soils of groups UL, UM, UA, TL, TM, TA as well as organogenic soils and soils with organic admixtures of groups OU, OT, OH and OK, if they have a mushy or liquid consistency ($I_c < 0.5$),
3) mixed-grain soils of groups SU*, ST*, GU* and GT*, if they have a mushy or liquid consistency.

Classification of soils 2) and 3) into class 2 assumes as a further characteristic that they flow out during loosening.

In contrast, outflow of coarse and mixed-grain soils of groups SW, SE, SI, GW, GI and GE or SU, ST, GU and GT is not a distinguishing criterion.

Class 3: Easily loosened soil types

This includes:

1) coarse-grained soils of groups SW, SI, SE, GW, GI and GE,
2) mixed-grain soils of groups SU, ST, GU and GT,
3) peats of HN groups with low water content, as long as they remain stable during excavation.

Class 4: Moderately hard-to-loosen soil types

To these belong the following with soft to moderately firm consistency:

1) fine-grained soils of groups UL, UM, UA, TL and TM,
2) mixed-grain soils of groups SU*, ST*, GU* and GT*,
3) organogenic soils and soils with organic additions of groups OU, OH and OK.

Class 5: Hard-to-loosen soil types

Fine-grained soils of groups TA and OT with soft to moderately firm consistency:

Class 6: Easily loosened rocks and comparable soil types

This includes:

1) rock that does not meet the criteria of class 7,
2) soils of classes 4 and 5 with firm consistency,
3) post-solidified building materials according to TL BuB E-StB.

If drilling or blasting is performed to ease loosening, the classification does not change.

Class 7: Hard-to-loosen rock

These include weathered and unweathered rock with bodies of rock limited by separation planes whose volume is more than 0.1 m^3.

Slag heaps belong to this class only if the slag is solidified.

If drilling or blasting is performed to ease loosening, the classification does not change.

3.1.3 Assessment of frost susceptibility and frost resistance

3.1.3.1 Frost susceptibility of soils and rocks of variable hardness

The soil groups are distinguished according to the frost susceptibility classifications in Table 1. For rocks of variable hardness, the frost susceptibility of the product of weathering is decisive.

This classification according to particle size distribution and the plastic properties of the soil types indicates how susceptible to frost they behave if, at temperatures below 0 °C, water occurs in the freezing zone, flows into it or is sucked in from the ground. If regional experience is different, departure may be made from Table 1; the appropriate requirements are then to be indicated in the service specification.

Table 1: Classification of soil groups by frost susceptibility

	Frost susceptibility	Soil groups (DIN 18196)
F 1	Non-frost susceptible	GW, GI, GE SW, SI, SE
F 2	low to moderate frost susceptibility	TA OT, OH, OK ST[1)], GT[1)] SU[1)], GU[1)]
F 3	high frost susceptibility	TL, TM UL, UM, UA OU ST*, GT*, SU*, GU*

[1)] Belongs to F 1 with particle content below 0.063 mm of 5.0 wt.% at $C_U \geq 15.0$ or 15.0 wt.% at $C_U \leq 6.0$.
Within the range of $6.0 < C_U < 15.0$ the permissible particle proportion for F 1 classification can belinearly interpolated below 0.063 mm (see Figure 2).

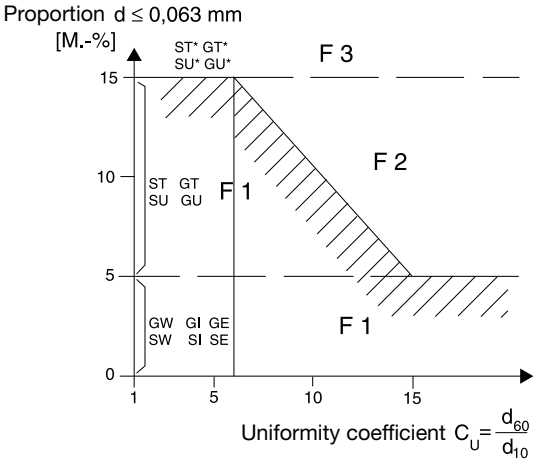

Figure 2: Frost susceptibility classification

If there are doubts about the frost susceptibility classification they may be clarified by frost heave tests or mineralogical investigations.

3.1.3.2 Frost susceptibility after soil improvement with binder

Soils of groups TL, TM, UL, UM, UA, ST*, GT*, SU*, GU* are classified after a soil improvement with binder into frost susceptibility class F 2 if the requirements for a qualified soil improvement have been complied with.

3.1.3.3 Frost resistance of rock

The frost resistance of rock is judged according to TL Gestein-StB.

The resistance of solid rock to frost action can be tested with the following procedures:

– Testing the water absorption according to DIN EN 1097-6,

– Testing the resistance against the freeze-thaw cycles according to DIN EN 1367-1.

For in situ rock, the frost behaviour of the rock mass is also to be assessed. It depends, among other things, on the composition and origin of the rock and the system of separation planes.

3.1.3.4 Frost susceptibility and frost resistance of building materials according to TL BuB E-StB

Various components in building materials according to TL BuB E-StB may disintegrate into finer grain fractions due to freeze-thaw cycles.

The frost resistance of building materials according to TL BuB E-StB is judged according to TL Gestein-StB. With the exception of hard coal fly ash, frost susceptibility is judged in keeping with Section 3.1.3.1.

Owing to its particle size distribution, hard coal fly ash is included in frost susceptibility class F 3.

Because the properties of fine material in hard coal fly ash do not correspond to those of natural soil, classification in another frost susceptibility class is possible if suitable proof is furnished by frost heave tests.

3.2 Soils and building materials according to TL BuB E-StB

3.2.1 General

The soils and building materials regulated by TL BuB E-StB are shown below: Further data are available in TL BuB E-StB.

Soils (BO) in the sense of TL BuB E-StB are soils of the same or different origin that are collected and prepared by a processing plant and are delivered for construction of earthworks. Soils with impurity content ≤ 10 vol.% are also considered soils.

Soils with impurity content (BmF) are soils with impurity content > 10 vol.% and up to 50 wt.%. Soils with impurity content ≥ 50 wt.% are recycled building materials.

Building materials in the sense of TL BuB E-StB are recycled and industrially manufactured aggregate and aggregate mixtures, as well as mineral building materials from mining activity.

Recycled building materials (RC) in the sense of TL BuB E-StB are recycled aggregate and aggregate mixtures, as well as soils with impurity content ≥ 50 wt.%.

Ferrous slag is blast furnace slag and steelworks slag from production of iron and steel (see DIN 4301). Blast furnace slags are granulated blast furnace slag (GBFS) and slag sand (SS), steelworks/steelmaking slags (SWS), electric furnace slag (EFS), basic oxygen steel slag (BOSS), secondary metallurgy slag (SMS) and stainless steel slag (SSS). In TL BuB E-StB, metalworks mineral mixtures (MWMM) are also included among ferrous slags.

Metallurgical slag (NFMS) are all slags from production of non-ferrous metals (see DIN 4301). These include slags from copper production (CUS/CUG).

Municipal solid waste incineration ash (MSWIA) is processed raw ash produced during incineration of municipal waste, household waste and domestic-like commercial waste in grate incinerators.

Power plant by-products are smelting chamber granulate (SCG), boiler ash (CBA), hard coal fly ash (HCFA) and lignite fly ash (LFA).

Foundry residues are recycled foundry sand (RFS) and foundry-cupola furnace slags (FCFS).

Mineral building materials from mining activity are wash waste from hard coal extraction (WW) and slag heaps from copper slate mining (CSMS).

Earthworks that are made using CSMS with total activity of ≥ 0.2 Bq/g must be recorded.

The installation site are to be recorded in a road register (road database).

3.2.2 Requirements

TL BuB E-StB applies to delivery of processed soils and building materials. Quality surveillance according to TL BuB E-StB must be performed for soils and building materials.

They must be compatible with other building materials or building components.

3.2.3 Testing

As part of the contractor's self-monitoring test, the building materials must be organoleptically inspected upon delivery.

The data on the delivery note must be documented along with the installation location of the particular delivery.

The client may demand that the contractor submits the results of the self-monitoring and external monitoring of the soils and building materials of the producer.

3.3 Geosynthetics

3.3.1 General

Geosynthetics are geotextiles, geogrids, geosynthetic membranes for sealing and composite materials that are made completely or mainly from polymer materials and are used in earthwork and road construction drainage systems.

Geosynthetics must comply with the “Technical delivery terms for geosynthetics in earthwork and road construction” (TL Geok E-StB).

The required values for geosynthetics in the construction contract refer to the 5 % minimum or 5 % maximum quantile. Deviating from this, the requirement for the characteristic O_{90} opening width of filters is related to the mean value of the test according to DIN EN ISO 12956.

Further information on choice, application and testing of geosynthetics is in M Geok E.

The intended application of geosynthetics and the functions they are to fulfil are to be recorded in the service specification. Additionally, the application-related requirements on the geosynthetics must be listed. Separation is always associated with filtering and/or reinforcement and is never to be considered separately in specifying requirements.

3.3.2 Application

Application areas for geosynthetics may be:

- *separating two adjacent soil bodies,*
- *securing slopes against erosion,*
- *protecting seals against damage,*
- *reinforcing embankments,*
- *filtering soil to be drained,*
- *draining water-bearing soil,*
- *sealing against water or pollutant-laden liquids.*

3.3.3 Requirements

3.3.3.1 Stability

Geosynthetics must be resistant to the materials and micro-organisms present in soil and water for the intended service life, unless, as protection for a landscaped slope, they are intended to decompose after plants have taken root.

The geosynthetics are to be protected against weather during storage at the construction site. After laying, they are to be protected with superstructures, coverings and/or greening. Materials with low weather resistance must be protected within one day, those with moderate weather resistance within two weeks, and those with high weather resistance no later than one month.

For determining chemical and microbiological resistance, the service specification is to contain the following information:

– *the intended service life (≤ 5 years, ≤ 25 years, ≤ 100 years),*

– *the ambient environment: pH value of the soil and covering material or ground water (pH ≤ 4.4 < pH < 9 or pH ≥ 9),*

– *special fill material, e.g.:*
  - *use in contact with soils that have been improved or stabilized with building lime or cement,*
  - *use in contact with concrete or crushed concrete,*
  - *use in contact with industrially manufactured aggregate and aggregate mixtures, e.g. slags.*

For long-term applications, in which the product is decisive for the safety of the reinforced construction, samples of geosynthetic material should be placed in the construction in such a way that they can be removed during inspections after long time intervals. The samples must be exposed to the same conditions as the product. As a reference value for determining changes, not only a freshly delivered sample is to be taken, but also one that has been subjected to installation stress. The number of samples and the location of their installation are to be documented in the service specification.

3.3.3.2 Resistance to mechanical action

The requirements for robustness of geosynthetics against the action of fill material and construction operation is specified by a classification. In the case of reinforcing elements, reduction coefficients are taken into account that are based on stress tests.

For separation, filter and protection layers, the necessary geotextile robustness class (GRC) is determined from the stresses from the fill material taking into account the effect of the base as well as stress due to the installation and construction operation. This geotextile robustness class is to be indicated in the service specification. Instructions for determination are in M Geok E.

The requirements listed in the GRC are regulated by the TL Geok E-StB.

For reinforcing elements, the necessary tensile strength and the permissible extension must be determined by calculation and indicated in the specification (see M Geok E; EBGEO). Furthermore, data on the fill material and its compaction, along with the structure's service life must be established.

For reinforcing elements, installation stress tests are to be performed at the beginning of a construction project under construction site conditions (intended fill material, installation and compaction method), unless there is verifiable relevant experience with the corresponding installation conditions at the site. The state of a sample that has been dug up after stress application is to be described and the residual strength determined by tensile loading tests according to TL Geok E-StB, Section 4.9.2.

The resulting reduction determines the reinforcement's A_2 factor.

These installation stress tests are special services.

3.3.3.3 Filter characteristics

The requirements for a geotextile filter are to be determined from data supplied by the client on the opening width O_{90} and water permeability $k_{V,\,5\,\%}$ based on the properties of the soil to be drained by using a filter measurement and indicated in the service specification (see M Geok E).

If data on the filter properties are not given, the following requirements apply to the mean value of the characteristic opening width:

– fleece materials: $0.06\ \text{mm} \leq O_{90} \leq 0.20\ \text{mm}$,

– woven fabrics: $0.06\ \text{mm} \leq O_{90} \leq 0.40\ \text{mm}$.

In the installed state, the filter must at least permanently be as water permeable as the soil to be drained. The following requirements apply to the 5 % minimum quantile of the water permeability coefficient of the geotextile filter (new material):

– water permeability coefficient $k_{V,\,5\,\%} \geq$ kf,

– water permeability coefficient $k_{V,\,5\,\%} \geq 1 \cdot 10^{-4}$ m/s,

where k_f is the water permeability coefficient of the soil to be drained. The higher value is decisive.

3.3.4 Testing

3.3.4.1 Sampling

The minimum size of a sample is 1.0 m in the longitudinal direction times the track width and must contain the roller imprint. Depending on the extent of testing, larger sample sizes may be necessary. A log is to be kept of the sampling and be signed by the contractor and the sampler. The log must show the roll number from which the sample was taken. Furthermore, the appropri-

ate CE label (DIN EN 13249 or DIN EN 13361) and the packaging label (DIN EN ISO 10320) must accompany the log.

The contractor shall take reference samples for the control tests performed by the client.

3.3.4.2 Suitability test

The contractor clarifies the suitability of the products intended to be installed for the application based on the requirements of the construction contract by submitting the manufacturer's product description according to TL Geok E-StB.

The client can demand that the contractor submits the results of the factory internal production inspection by the geosynthetics manufacturer. The manufacturer must make them available to the contractor for submission to the client. This must be agreed upon in the supply contract between the contractor and manufacturer.

3.3.4.3 Self-monitoring tests

See DIN technical report CEN/TR 15019.

As part of his self-monitoring test, the contractor must inspect the delivered products and the completed service. The inspection and its documentation include:

1. verification that the packaging label of each roll is marked with the CE label according to DIN EN ISO 10320 labelling, and the product itself every 5 m with the product name and type and that the data conform to the contractually agreed-upon product,
2. verification, based on the CE label and product description according to TL Geok E-StB, that the product properties correspond to the contractually agreed-upon requirements,
3. verification by a building material receipt inspection that the product properties conform to the requirements of the construction contract (Appendix 2, Table 1 or Table 2),
4. verification of compliance with the requirements for handling the product on the construction site and in installation.

The building material receipt inspection can be dispensed with if there is proof of equivalent voluntary monitoring by the manufacturer or the supplier.

The samples for the building material receipt inspection must be taken on the day of delivery according to DIN EN ISO 9862. Test certificates on 1., 2. and 3. must be submitted to the client before installation of the products. Logs regarding 4. must be handed over as the work progresses.

The necessary number of samples depends on the importance of the product to the safety of the structure and the area of the product delivered.

Stringent safety requirements exist for reinforcement or other applications for which long-term strength is decisive and/or in which the product is decisive for the safety of the design and the structure. The number of samples is at least 2 samples per delivery up to 6,000 m^2, thereafter 1 sample for every additional 6,000 m^2.

Normal safety requirements apply to all other applications. The number of samples is at least 2 samples per delivery up to 10,000 m^2, thereafter 1 sample for every additional 10,000 m^2.

The tests that are part of the building material receipt inspection are to be performed by competent, independent testing laboratories. Proof of competency can be shown, for example, by accreditation according to DIN EN ISO 17025.

The test results are to be indicated according to the applicable testing standards.

If each of 4 test results meets the contractually defined requirement values, the delivery must be accepted. If one or more test results do not meet these requirements values, the delivery is to be rejected or further samples are to be taken from the delivered product, tested and evaluated. Evaluation is performed based on the statistical process described below. The results of the first tests are to be included in the evaluation.

In the case of 5 or more test results, the statistical test quantity z is to be calculated for the 5 % minimum quantile T_M from the mean value $\overline{x}$ and standard deviation s of the test results.

$$z = \overline{x} - k \cdot s$$

For the 5 % maximum quantile T_H, the statistical test quantity

$$z = \overline{x} + k \cdot s$$

is to be calculated. In both cases k is the acceptability constant 1.645.

The delivery is to be accepted in the case of a required minimum quantile of $z \geq T_M$ and in the case of a maximum quantile of $z \leq T_H$; otherwise the entire delivery is rejected and replaced with contract-compliant products.

The requirement values specified in the contract with respect to the minimum quantiles (T_M) or the maximum quantiles (T_H) are as follows.

– For geosynthetics and related products: mass per unit area, thickness, breaking force and elongation at break, puncturing behaviour, water permeability normal to the surface, water permeability in the plane, drainage capacity

– For sealing membranes and liners: thickness, surface-related mass, melt flow index, swelling behaviour, breaking force and elongation at break, tear strength, water absorption and montmorillonite content.

For the water permeability of sealing membranes and liners, the maximum quantile is decisive.

3.3.4.4 Control tests

The client should convince himself of the correct performance of the self-monitoring tests by on-site inspections and examination of the test results.

On termination of the contract, the client should arrange that all test samples of the agreed-upon delivered products are submitted to him. To determine the identity of the products, he shall compare the test samples with the delivered products or with the reference samples (see Section 3.3.4.1).

If the client performs tests, their scope must conform to Tables 1 or 2 in Appendix 3.

Sampling, product tests and evaluation of the results within control tests must be performed according to the regulations in Section 3.3.4.3.

If the delivery is to be rejected owing to the control test result, it is to be sent back and replaced with contract-compliant material.

3.4 Lightweight construction materials

Lightweight construction materials are natural or artificial building materials with low density. They occur naturally (pumice), are thermally produced from primary heavy mineral materials (expanded clay, expanded shale) or are chemically produced (rigid EPS foams).

Rigid EPS foams must conform to DIN EN 14933 (certificate of conformity according to System 3).

Expanded clays must be quality monitored according to DIN EN 13055-2.

Construction-related requirements may be found in the "Information sheet on using rigid EPS foams in construction and road embankments" and the "Information sheet on using expanded clay as a lightweight building material in road substructures and bases". If necessary, they are to be indicated in the service specification.

Instructions on using lightweight construction materials are in Section 13.3.6.

4 Trenches and dams

4.1 Loosening and loading

See DIN 18300, Section 3.5.

4.1.1 General

See DIN 18300, Section 3.1.

Soils and rocks are to be loosened, loaded, conveyed and deposited on the installation site or interim storage in such a way that they retain their installation capability (see also Section 4.3.1.7).

If soil, rock or other materials of various suitability accumulate during cutting, and if they are to be used differently, they should be loosened separately and processed further.

4.1.2 Cut sections

Also see DIN 18300, Section 3.5.2.

If there is a cut section that does not belong to the scope of application or the purpose according to DIN 4124, the standard sections are to be used that conform to the data in the design and the structural surveys and calculations. Otherwise, specifications must be made which are based on investigations.

If at the height of the cutting planum it is necessary to remove rock shelves or boulders that interfere with the planum, or if it is necessary to excavate locally to depths below the intended depth under the planum according to the service specification, soils or building materials are to be installed and compacted in these local depressions in such a way that the planum is uniformly stable and sufficiently even.

If necessary, an appropriate ordinal number is to be recorded in the service specification.

4.1.3 Loosening processes for rock

Also see DIN 18300, Section 3.5.6.

The loosening process must not cause break-up that threatens the stability or goes beyond the planned slope profile. Inselbergs must be preserved.

If creating rock slopes requires a special work process so as not to loosen the bedrock's fracture joints structure, these services are to be indicated in the service specification.

The rules from the relevant directives and recommendations are to be indicated in the service specification (see "Information sheet on bedrock-preserving execution of blasting and removal work on rock slopes").

4.1.4 Blasting plans and legal requirements

Blasting is to be performed in such a way that the explosive effect does not extend beyond the intended slope profile. Extraction blasting (loosening explosions) and basting for slope profiling (fissure explosions) should be coordinated.

The contractor must submit the approved blasting plan to the client.

The blasting plans must include at least the following information:

- the construction project shown in a ground plan and sections, if necessary separately for the various layers to be removed,
- arrangement, diameter, inclination, direction and depth of the bore holes,
- type of explosive and detonator,
- load quantity and arrangement of the explosive in the bore hole,
- the detonation sequence.

The blasting plans for extraction explosions and slope profiling may be combined.

If test blasting is performed or changes made during excavation blasting to obtain small-sized debris, the corresponding blasting plans are also be submitted.

It is up to the contractor or his subcontractor to observe the legal regulations for blasting work (permit, qualification, blasting indicator, accident prevention regulations, etc.). The explosives expert must be named in writing by the client.

4.1.5 Loosening rock

When loosening rock or rock-like soil, a particle size is to be aimed at that allows immediate use as installation material (see also Section 4.3.1.4). If this size is not directly achieved during loosening, additional measures are to be taken. These actions are ancillary services.

4.2 Conveying

See DIN 18300, Section 3.6.

4.2.1 Beyond DIN 18300, Section 3.6.1, conveyance within the building site is part of the service.

4.2.2 *On applying the rinsing process, the work procedures of loosening, conveying and installing are generally performed as a joint service. The directives arising from the relevant recommendations are to be indicated in the service specification.*

4.2.3 *Partial areas of the construction site that must not be used, temporarily or permanently, must be indicated.*

4.3 Installation and compacting

See DIN 18300, Section 3.7.

See "Information sheet for compaction of the base and substructure in road construction".

4.3.1 Execution

4.3.1.1 Any work process can be used if it meets the requirements of Section 4.3.2 and avoids damage to the surrounding area.

At the beginning of compaction work, the contractor must verify with a test field that the selected work procedures meet the prescribed requirements for compaction in the service specification or are according to Section 4.3.2 (see also Section 14.2.4). If this is not achieved, the contractor must alter the work process accordingly.

The work process, (installation machinery, compaction machinery, permissible fill height, number of crossings, work speed, etc.) depends on the building material to be compacted and the compaction required. Furthermore, the work process is to be adapted to the conveying and installation to be performed.

If it is necessary to perform special test fields that are not part of the earthwork, this is to be declared in the service specification.

4.3.1.2 Also see DIN 18300, Section 3.7.4.

If the load base inclines by more than 1:8, it must be ascertained whether a tiered base is necessary for the stability of the embankment.

If soil or rock is being deposited on an embankment, steps about 0.6 m to 1.0 m in height must be formed for interlocking.

Sufficient drainage of the interlocking area must be ensured.

4.3.1.3 Also see DIN 18300, Section 3.7.5.

If the groundwater table in the base is high, it may be necessary to construct a capillary breaking, stable-filtering surface drainage system on the base material.

If rising water must be dealt with, the lower fill layer must be filled using weather-resistant material. It must always be able to take on rising water and redirect it.

4.3.1.4 Soils and other building materials must be carefully installed and compacted according to the data in the service specification and in consideration of possible changes in condition.

The largest particle size of the building material to be installed must not be larger than 2/3 the permissible fill height (see Section 4.3.1.1).

If rock boulders in the lower part of embankments are to be installed up to 1.0 m below the planum, and if an intermediate layer is to be constructed as a filter in the transition to the building materials to be installed over it, this is to be indicated in the service specification.

4.3.1.5 The soil is to be installed in layers over the entire embankment width and uniformly compacted.

The slope area must be carefully constructed according to one of the following processes:

(1) Depending on the height, the embankment material is to be deposited on both sides at least 1 m over the target profile and compacted over its entire width. Soil installed above the target profile must be removed without damaging the slope and may be reused for rounding the foot of the embankment or for depositing on other embankments.

(2) The slope must be compacted to its target profile with an appropriate compaction device and work process.

(3) The fill height must be reduced in the outer, at least 2 m wide slope area, and the soil must be compacted with an appropriate compaction device for this edge area.

4.3.1.6 The installation and compaction work must be adapted to the weather conditions and temporarily postponed if the means of construction are not sufficient to fulfil the agreed-upon requirements.

It is not permitted to install or cover soils with excessive water content that cannot be compacted to meet the requirements. Their water content must be reduced through aeration, drying, milling or addition of appropriate water-binding materials, such that the required compacting according to Section 4.3.2 is achieved. Otherwise they must be replaced with suitable building materials or other measures must be agreed upon according to Sections 12 or 13.

Appropriate measures are to be indicated in the service specification.

If the reasons for the aforementioned measures are the responsibility of the contractor, these measures are not paid for separately.

Appropriate measures must be used to prevent sand from drifting.

If the plan calls for a long waiting time, appropriate measures to prevent drifting must be indicated in the service specification.

4.3.1.7 For installing weather susceptible building materials, the surfaces to be covered are to be constructed with at least a 6 % transverse slope. Each layer must be compacted immediately after being deposited. If the day's work is finished or precipitation is expected, the compacted surface is to be rolled until it is even.

Drainage of the surface water in the longitudinal direction requires consent of the client (see also Section 4.6).

4.3.1.8 *Especially the suitability of the soil types must be verified if using rinsing processes.*

The upper installation zone to at least 1.0 m below the planum must, in addition, be compacted with appropriate compaction devices.

4.3.1.9 *Backfilling or bases made of coarse-grained or mixed-grain soils with low fine-grain content that are not deposited in layers and compacted, or that are layered too loosely, may be compacted to*

the required depth with deep vibrating methods or heavy falling plates.

Use of these methods requires special soil and stability investigations in order to verify their suitability.

In the zone up to 1.0 m below the planum, the soils must in any case be installed in layers and compacted, or compacted later with an appropriate compaction device.

4.3.1.10 For depositing under water, resistant fill materials must be used. Above the water line, the fill is to be compacted in such a way that the compaction extends at least 1.0 m below the existing water line.

4.3.1.11 *Geotextiles can be laid below a fill as a separation layer. The requirements for geotextiles must be adapted to the base conditions as well as the action of the fill material and construction site traffic (see Section 3.3).*

In general, the geotextiles must be laid perpendicular to the longitudinal axis of the construction. They must overlap in the direction of deposit. In the case of narrow surfaces up to a width of two sheets, it is permissible to lay them lengthwise. The overlap of each sheet and the lateral excess at the foot of the slope must be at least 50 cm, even after covering. If geotextiles are to be laid under water, the sheets must be bound together.

Vehicles must never be driven directly on the geotextiles. The thickness of a protective cover or protection layer must be adapted to the loading.

The first protective layer must be deposited on geotextiles at the head, distributed carefully and compacted. Construction site traffic is not permitted to pass over it until after compaction.

If the time between laying and covering is longer than one day, the product's weather resistance must be taken into account.

4.3.2 Compacting requirements

The base and substructure of roads and paths is to be compacted in such a way that the requirements shown in Table 2 are fulfilled.

Table 2: Requirements for the 10 % minimum quantile[1] for degree of compaction D_{Pr} or for the 10 % maximum quantile[2] for air voids content n_a

	Area	Soil groups	D_{Pr} in %	n_a in vd. %
1	Planum to 1.0 m depth for embankments and to 0.5 m depth for trenches	GW, GI, GE SW, SI, SE GU, GT, SU, ST	100	–
2	1.0 m under planum to embankment base	GW, GI, GE SW, SI, SE GU, GT, SU, ST	98	–
3	Planum to embankments and to 0.5 m depth for trenches	GU*, GT*, SU*, ST* U, T, OU[3], OT[3]	97	12[4]

[1] The minimum quantile is the smallest permissible quantile, below which no more than the specified proportion of characteristic values (e.g. degree of compaction) of the distribution is permitted (see also Section 14.2.2 and TP BF-StB, Part E 1).

[2] The maximum quantile is the largest permissible quantile, above which no more than the specified proportion of characteristic values (e.g. air void content) of the distribution is permitted (see also Section 14.2.2 and TP BF-StB, Part E 1).

[3] For soils of groups OU and OT, the requirements only apply if their suitability and installation conditions have been specially investigated and specified in agreement with the client.

[4] *If the soils are not stabilized or do not undergo qualified improvement (see Section 12), a requirement on the 10 % maximum quantile for air void content of 8 % vol.% is recommended for the installation of water susceptible mixed and fine-grained soils. The corresponding requirement is 6 vol.% for installation of rocks of variable hardness. These requirements are to be declared in the service specification.*

The requirements for coarse-grained soils also apply to grain mixtures made of broken stone with the corresponding grain composition. The requirements in Table 2 also apply if the soils and building materials have particles up to 35 wt.% > 63 mm and < 200 mm.

When depositing rock with a grain content of more than 35 wt.% particles content > 63 mm or the largest particle size > 200 mm, the service specification shall declare the requirements for the compaction and its testing.

The requirements in Table 2 also apply to soils and building materials according to TL BuB E-StB with corresponding particle composition.

If, within a construction stage, there is a change to soils with different compaction requirements, such that separate processing is not possible, the lower value in the table is to be used.

For this type of case, the client can separately determine and specify the requirement appropriate to the usability of the construction.

For particularly stressed earthworks or partial areas, as well as for special building materials, based on special investigations it may be necessary to specify higher compaction requirements than those of Table 2 in the service specification.

The requirements given in Table 2 can be reduced if local experience proves this to be justified, for example, in the case of a rinsing process under water. If variations of this type are intended, they are to be declared in the service specification.

For backfilling of inner surfaces of connection areas and backfilling of residual spaces, the requirements are to be stated in the service specification.

For compaction requirements for filling excavations and pipe trenches, see Section 9; for backfilling and covering of constructions, see Section 10; for construction of protective barriers, see Section 11.

If the required degree of compaction and/or air void content cannot be achieved by compaction, the required measures are to be indicated in the service specification.

For wash waste (WB) a degree of compaction D_{Pr} of 100 % (minimum quantile) and a porosity n of 22 vol.% (maximum quantile) are to be observed.

When assessing the degree of compaction of MSWIA, the water absorption behaviour and the change in particle composition are to be taken into account (see Section 14.3.3).

4.4 Planum

4.4.1 The planum must be produced according to the profile, even and load-bearing according to the requirements in Sections 4.3.2 and 4.5 (see Section 4.1.2).

4.4.2 The planum is not permitted to vary by more than ± 3 cm or, if a bound base layer is planned immediately above it, by no more than ± 2 cm of the target height.

4.4.3 Vehicles may only be driven on the planum if this does not cause any damaging impressions or obstruction to water drainage.

If necessary, appropriate special measures according to Section 4.4.6 are to be indicated in the service specification.

If vehicles are driven on the planum at only the disposition of the contractor, the necessary measures taken on the planum according to Section 4.4.6 are not remunerated separately.

4.4.4 If, during cutting, soil accrues with which it is able to fulfil the load-bearing capacity requirements, it is preferentially used directly under the planum in the contracted stretches, as long as the service specification indicates no other use.

4.4.5 *In the case of water susceptible soils and building materials, the planum's transverse inclination should be at least 4 %. After soil treatment with binder (soil stabilization, qualified soil improvement), the transverse inclination of the planum should be at least 2.5 %. The torsion areas must be kept as short as possible.*

The gradient conditions are to be indicated in the service specification in consideration of any necessary counter-slope at the high road edge (see ZTV SoB-StB).

In accordance with the design of the superstructure, drainage of the road body at the gradient's low points is to be ensured, especially for the first load-bearing layer (frost protection layer). For example, this can be achieved with a thicker load-bearing layer, a special composition of road-bearing layer materials or a seepage device underneath the planum.

4.4.6 *The finished planum should not remain unprotected for a long time if the soil and rock types are susceptible to water, especially during periods of precipitation. In particular, the following come into consideration as protection measures:*

(1) soil stabilization and qualified spoil improvement,

(2) leaving or depositing a protective layer of nearby soil of low permeability over the planum about 0.5 m thick.

(3) Building a bound base layer

(see "Information sheet for compaction of the base and substructure in road construction").

If no protective measures are taken, immediately before installation of the load-bearing layer on the planum, compaction must be performed again. If at this time the soil is too wet for compaction, it must either be improved through addition of binders or the softened zone removed and replaced with another building material.

If necessary, appropriate special measures are to be indicated in the service specification.

If a priori long waiting times are expected between the earthwork and superstructure work, the service specification should indicate the necessary action.

If the contractor produces the planum and superstructure of a construction project, protection of the planum will not be remunerated separately.

4.5 Modulus of deformation

4.5.1 If both earthworks and work needed to construct the superstructure are in the construction contract, the requirements of Section 4.5.2 must be met immediately before installation of the superstructure layers.

If the construction work ends with the production of the planum, the moduli of deformation according to Section 4.5.2 must be verified for acceptance.

If the planum is built over as part of another construction contract, the corresponding measures must be arranged (see also Section 4.4.6).

4.5.2 Requirements regarding the modulus of deformation.

The requirements shown below are with respect to the 10 % minimum quantile.

In the case of a road superstructure of construction classes SV and I to IV on a frost-proof base or substructure, on the planum a modulus of deformation of

$$E_{v2} = 120 \text{ MN/m}^2 \text{ or } E_{vd} = 65 \text{ MN/m}^2,$$

is required. For construction classes V and VI a modulus of deformation of

$$E_{v2} = 100 \text{ MN/m}^2 \text{ or } E_{vd} = 50 \text{ MN/m}^2$$

is required.

The modulus of deformation E_{v2} is verified by the static plate load test according to DIN 18134 and the modulus of deformation E_{vd} by the dynamic plate load test according to TP BF-StB, Part B 8.3.

If these requirements cannot be met until the load-bearing layers to be built on the planum have been compacted, for construction classes SV and I through IV it will suffice on the planum to verify

or determine by special investigations a modulus of deformation of

$$E_{v2} = 100\ MN/m^2 \text{ or } E_{vd} = 50\ MN/m^2$$

and for construction classes V and VI a modulus of deformation of

$$E_{v2} = 80\ MN/m^2 \text{ or } E_{vd} = 40\ MN/m^2.$$

For a frost susceptible base or substructure, a modulus of deformation of on the planum is necessary.

$$E_{v2} = 45\ MN/m^2$$

For a frost susceptible base or substructure, a modulus of deformation of

$$E_{v2} = 70\ MN/m^2$$

on the planum is necessary after qualified soil improvement.

The service specification must indicate whether the static or dynamic modulus of deformation is to be verified.

If the service specification contains no information in this regard, the static modulus of deformation is to be verified.

If the required modulus of deformation on the planum cannot be achieved through compaction, either:

(1) the base or substructure is to be improved or stabilized, or

(2) the thickness of the unbound load-bearing layer is to be increased.

The measures or requirements based on data from other regional experience are to be indicated in the service specification.

4.6 Water run-off

See DIN 18300, Section 3.3.

See RAS-Ew; see ZTV Ew-StB.

4.6.1 See DIN 18299, Section 4.1.10.

The measures necessary for removal of surface water from precipitation with out causing damage and the safety measures that must therefore be taken are ancillary services for all construction states.

4.6.2 See DIN 18300, Section 3.3.3.

If the necessary drainage measures are omitted, or performed improperly or not in sufficiently good time, the building materials thereby made unusable must be improved by appropriate means or replaced.

4.6.3 Water must not flow from the cut slope onto the planum. It must be captured and diverted by longitudinal drainage devices.

Water flowing off the planum over the embankment slope should flow uncollected to the downstream riparian or the longitudinal drainage at the foot of the embankment. On erosion susceptible slopes, the water must be captured and diverted through erosion-proof longitudinal drainage devices at the edge of the planum.

4.6.4 For drainage structure backfill, see Section 10.

4.7 Shoulder

4.7.1 Building materials

For building stable shoulders, the following soils and building materials or mixtures of building materials with a maximum particle size of 32 mm are suitable:

(1) mixed-grain soils of soil groups GU, GT,

(2) mixtures of broken rock aggregates, as long as they correspond to the aforementioned soil groups,

(3) gravel with a topsoil portion of 15 wt.%.

For constructing shoulders without a stability requirement, soils and building materials of soil groups SU, ST, GU, GT*, SU*, ST*, U, T, OK, OU and OT may be used.*

4.7.2 Installation and compacting

The soils and building materials must be installed evenly in layers no thicker than 30 cm and compacted.

For stable shoulders made of building materials (1) to (3), the requirements apply for the 10 % minimum quantile of the degree of compaction D_{Pr} = 100 %. A topsoil layer 5 cm thick is to be placed on shoulders constructed in this way. This does not apply if the shoulder is made using gravel. The gravel is to be 20 m thick.

For shoulders without stability requirements, the requirement applies for the 10 % minimum quantile of the degree of compaction D_{Pr} = 97 %. A topsoil layer 20 cm thick must be placed on shoulders constructed in this way.

The surface of the shoulder must have the planned transverse inclination and a closed structure.

4.8 Working during and after freezing weather

See DIN 18300, Section 3.12.

4.8.1 During freezing and thawing periods, cutting and depositing work is only to be conducted with the required precautionary measures.

The client must notify the contractor about earthwork interruptions due to frost and their resumption.

4.8.2 In the embankment area from the planum to 2.0 m below the road surface, frozen soil must not be covered.

If frozen soil more than 2.0 m below the road surface is to be covered, the conditions and measures for proceeding with the earthwork must be specially investigated.

5 Topsoil work

See DIN 18300, Sections 3.4 and 3.8.1.

5.1 *Topsoil forms the covering layer of earthworks and is used for vegetation purposes (vegetation layer).*

5.2 Removal of topsoil must be planned and performed in the way required for the subsequent earthworks in consideration of the soil's weather susceptibility and the weather conditions.

The thickness of the removal is to be indicated in the service specification.

DIN 18915 and ZTV La-StB apply to topsoil work. The topsoil work must be performed soon after final profiling in consideration of the plant growth seasons.

5.3 *The quantity of topsoil must be specially indicated.*

If the existing or otherwise available topsoil does not suffice, or is not suitable for the planned vegetation, it is to be ascertained whether other soils can be made usable for this purpose through

appropriate measures according to DIN 18915. These measures are to be indicated in the service specification.

Soils that can be made usable for vegetation purposes through appropriate measures according DIN 18915 are to be treated as topsoil.

5.4 *If topsoil work shall be performed on other surfaces in addition to the cutting and filling surfaces, these are to be indicated in the service specification by size and location.*

Plants and plant cover within the construction site that shall be transplanted are to be indicated by the client.

Plant work must proceed according to DIN 18916.

5.5 Erosion susceptible topsoil surfaces are to be protected.

The contractor must take protective measures against precipitation water from surfaces outside the construction site.

Appropriate measures are to be indicated in the service specification.

5.6 Plant remains, such as clippings, forest residue and stumps from clearing the surfaces are not to be burnt or dumped. They must be utilized in an appropriate manner.

6 Slopes

See DIN 18300, Section 3.8.

6.1 *The inclination of slopes must be determined in consideration of the soil, rock, water and climatic conditions. Loads and vibrations occurring in the vicinity of the slope must be taken into account.*

Slopes must be constructed with the regulatory inclination according to RAS-Q if their stability is guaranteed and there is no erosion hazard. Under these prerequisites, rock slopes may be made steeper.

If the stability is insufficient, it is to be ascertained whether it can be permanently achieved by decreasing the slope or other safety measures. Safety measures are to be indicated in the service specification.

6.2 The work processes and devices for addition and removal and for clearing the slope surface must be chosen in such a way that the ground structure or the bedrock's fracture joints are not loosened. This principle also applies to work with explosives.

If water layers, springs, field drainage and such like are expected, the cut slopes must be planned in such a way that the water escape points are known and specific safety measures can be taken.

The safety measures are to be indicated in the service specification.

Water leaving the slope seepage layers must be diverted without causing damage.

Such measures are to be indicated in the service specification.

6.3 Slopes are to be landscaped by extending their transitions into the terrain. These transitions are to be filled as part of the earthwork and not with topsoil.

6.4 See DIN 18300, Section 3.8.5.

The construction of slopes with rock is to be planned according to the "Information sheet on the bedrock-preserving execution of blasting and removal work on rock slopes" and correspondingly indicated in the service specification.

Rock slopes are to be cleared.

The degree of clearing is to be indicated in the service specification.

6.5 See DIN 18300, Section 3.8.4.

The regulations also apply to damage from erosion for the time after completion of the slope up to acceptance.

6.6 See DIN 18300, Section 3.8.3.

Bioengineering construction measures according to RAS-LP are to be indicated in the service specification.

Special measures for applying topsoil to slopes, e.g. production of steps or grooves and roughening of existing slopes, are to be indicated in the service specification.

Work for securing slopes through bioengineering construction measures must be performed with participation of landscape professionals.

Close to the surface, slopes can also be secured with mats for erosion protection or planting, and construction using planting methods (see M Geok E and "Information sheet for simple landscape-adapted safety construction methods").

In dry periods during the plant growth period of landscaping, the surfaces must be sprinkled with water.

6.7 *Steep slopes of embankments and protective barriers may be constructed by reinforcing the earth body with geosynthetics or support structures reinforced with steel bands (see Section 10.6).*

The necessary tensile strength of the reinforcement layers for stability of the reinforced earth body is to be determined (see EBGEO). The geosynthetics must be highly weather resistant.

The reinforcing sheets must be laid in the direction of the tensile load. No overlapping joint is allowed in this direction. A bonding connection is allowed only if it has been verified by testing or computationally. A lateral overlap must be planned if the reinforcing sheet also has a separating function. Then the overlap is at least 50 cm, but it may be reduced if the sheets are mechanically or adhesively connected.

In reinforced slopes, the support for the reinforcement must also be built and compacted. The reinforcing element must be installed evenly, fold-free and tightly. The visible surfaces must be protected soon after installation (such as with plants or attachments).

For reinforced slopes, it is to be ensured that the reinforcement layers are not punctured by installations (such traffic barrier posts, pipelines, foundations for sound protection walls or sign gantries) without special proof.

The slope surfaces must be protected from escape of soil.

6.8 *Qualified soil improvement is suitable for improving the stability and erosion resistance of slopes.*

The requirements of the soil binder mixture must be determined by geotechnical calculations.

7 Sealing

See DIN 18300, Section 3.9.

7.1 General

Sealing bodies of mineral soils and soil mixtures, as well as thin-layered geosynthetic sealing elements are suitable for sealing purposes. They form part of a sealing system that may additionally consist of protection, support and seepage layers.

The decisive requirements (thickness, permeability coefficient, etc.) for sealing must be taken from the application-specific regulations, e.g. RiStWag and RAS-Ew, and are to be indicated in the service specification. Sealing is also used as a technical safety measure (M TS E).

When selecting a sealing system, mechanical, biological and chemical exposure are to be considered.

Sealing are to be connected in a permanently water-tight manner to constructions and penetrations.

Sealing systems are to be made stable and secure against uplift.

If seepage or layer water is expected in sealing road slopes, the accumulation of water pressure under the seal is to be prevented by an efficient seepage layer with appropriate receiving water.

7.2 Seals made of mineral soils, soil mixtures and building materials

The use of mineral soils, soil mixtures and building materials to seal areas with gradients of more than 1 : 3 requires in all cases proof of the stability of the sealing system.

Construction techniques must be used to protect the sealing body against external influences (e.g. overlapping or bonding into the base) in such a way that it will be permanently functional.

The soil groups shown in Table 3 are appropriate for seals made of mineral soils and soil mixtures. The compaction requirements in Table 3 apply.

Table 3: Requirements for the 10 % minimum quantile of compaction D_{Pr} and the 10 % maximum quantile for the air voids content n_a of seals

	Soil groups	Degree of compaction D D_{Pr}	Air void content n_a
1	GU*, GT*, SU*, ST*, TL, TM, TA, OT	95 %	5 vol.%

Other soil groups or lower degrees of compaction or higher air void contents n_a as well as other building materials are permissible if it is verified that water-tightness, stability and functionality are assured.

Seals must be compacted uniformly and with special care.

Usually soils with water content above the optimum are to be compacted in order to achieve the lowest possible permeability.

7.3 Seals made of geosynthetic membranes and geosynthetic clay liners

Damaging mechanical loading on the geosynthetic barriers must be prevented by use of appropriate mineral or geotextile support or protection layers.

The substrate for the barriers is to be produced with sufficient evenness to achieve reliable performance of the sealing system.

The geosynthetic barriers are to be laid according to the manufacturers' laying instructions and according to a laying plan. The plan shall indicate the position of each barrier and the overlap necessary for the joining technique used. The work progress is to be recorded into the plan. After the work is completed, the plan is to be submitted to the client (see Section 15).

The joining and overlapping techniques are to be specified. The water-tightness of the joints and overlaps are to be verified.

The requirement for the 5 % minimum quantile of the thickness of geosynthetic membranes is $d_{5\,\%} = 2$ mm.

Construction of geosynthetic membranes is governed by directives DVS 2225, Parts 1 to 4.

See also M Geok E. The EAG-GTD contains more details on the materials, characteristic properties, design and execution of geosynthetic clay liners (bentonite mats).

For stability, the sealing system's friction behaviour must be taken into account (support layer – sealing liner – protection layer). To achieve stability, an additional reinforcing element, such as a geogrid, may be necessary. The EBGEO contains instructions on selection and measurement.

7.4 Other sealing systems

If sealing systems other than those described in Sections 7.2 and 7.3 are to be used, their suitability for their respective applications is to be determined. The requirements and execution conditions are to be indicated in the service specification.

8 Seepage systems and filter layers

See DIN 18300, Section 3.3.

See RAS-Ew; see ZTV Ew-StB.

8.1 General

Free-flowing water must be captured by seepage systems and diverted without damage.

Relevant ordinal numbers are to be recorded in the service specification.

The seepage systems must be made of filter-stable material (e.g. mineral building materials). The hydraulic filter stability of layers that water can flow through or into which fine-grained soil can penetrate is to be verified. The mechanical filter stability is also to be determined.

The building materials and techniques are to be selected in consideration of hazards from silting, sintering and formation of mineral deposits.

Soils and building materials according to TL BuB E-StB can only be used after appropriate suitability testing. Use of SWS/SMS, MWMM, MSWIA, RFS with bentonite content, FCFS and WW is excluded.

8.2 Seepage channels

Seepage channels are to be used to collect and transfer soil water. Generally they consist of a seepage pipe encased in a permeable, weather-proof, filter-stable material. Seepage pipes can be made of plastic, concrete or earthenware.

If seepage channels are encased in a geotextile filter, the overlap must be at least 50 cm. During installation and covering or filling, an intimate contact without cavities must be created between the filter and the soil.

The dimensions of the seepage channels depend on the work and filtration requirements.

The seepage channels are to be covered in the upper region with a layer of weakly permeable soil if no surface water is to flow into them.

The seepage pipes, including the adjoining and connected constructions, are to be selected in consideration of the depth and the determining load case.

Concrete seepage pipes may be used only if the water does not attack concrete.

8.3 Seepage and filter layers

Seepage and filter layers are made of mineral building materials, if necessary also in combination with geotextiles (see RAS-Ew and M Geok E). They must be dimensioned and designed according to the hydraulic and geotechnical requirements and be shown in the plan.

During installation, any damage that may affect soil retention properties must be prevented. The surface on which the geosynthetic seepage layer is to be placed must be even. During installation on appropriate surfaces, the sheets must be secured against sliding.

For the intended duration of use and the expected loading, the drainage mats must be capable of removing the accruing quantity of water.

The service specification must include data on the height of the covering, the fill material and the expected amount water occurring.

The 5 % minimum quantile requirement applies to the drainage capacity of the drainage mat q_d of 0.1 l/s·m.

9 Building pits and pipe trenches

9.1 Production

See DIN 18300, Sections 3.1.3 and 3.10.

9.1.1 *If adverse deformations are to be expected from the execution of pipe trenches or building pits, the resulting special measures are to be indicated in the service specification.*

9.1.2 Measures, for which the contractor is responsible, for underpinning or others to secure endangered structures will not be remunerated separately.

Blasting of ditches or building pits in rock must be performed so as to preserve the bedrock structure (see Sections 4.1.3 and 4.1.4).

9.1.3 As needed and appropriate, excavated soil is to be used for replacement, backfilling, covering or other filling work (see Section 4.1.1).

9.1.4 Appropriate measures are to be taken to protect building pits and pipe trenches from inflow of surface water. With frost and water susceptible soil and rock types, the base must be appropriately protected during periods of frost and precipitation.

If long waiting times are anticipated between the earthworks and subsequent works, the necessary measures are to be indicated in the service specification.

Measures for keeping building pits and pipe trenches dry and free of inflowing ground water are to be indicated in the service specification.

9.2 Filling

See DIN 18300, Section 3.11.

9.2.1 *For pipes requiring verification of load-bearing capacity and deformation, the required soil characteristics are to be indicated in the service specification.*

9.2.2 For particularly high loads on pipes during construction, e.g. when driven over by heavy construction machinery or vehicles, or such as thick filling coverings, the pipes must be appropriately dimensioned and protected as necessary.

9.2.3 Adequate measures are to be taken to prevent the pipe trench forming a longitudinal drainage channel for inflowing surface and ground water after filling.

Appropriate measures are to be indicated in the service specification.

9.3 Building materials

9.3.1 In the pipe zone, coarsely grained soils and building materials with a maximum particle size of 22 mm must be used.

If constraints or additions to the building materials to be used exist with regard to the pipe materials or dimensions, this is to be indicated in the service specification (see also Section 3.2).

Wash waste (WW), municipal solid waste incineration ash (MSWIA) and recycled foundry sands (RFS) must not be installed in the pipe zone.

9.3.2 Outside the pipe zone, excavated soil is to be used for filling pipe trenches or, in embankment zones, the fill material used in the embankment.

9.3.3 Appropriate measures are to be taken to ensure that stored soil suitable for filling the pipe trench is kept in a suitable condition for installation.

Where appropriate, wet excavated soil that is too wet may be reused after treatment with a binder.

If, due to changing soil stratification (such as alternating layers of coarse mixed or fine-grained soils), separate loosening of suitable individual soils is not possible, these must be homogenized before replacement.

9.3.4 *Especially in regions that are difficult to access or compact, temporarily flowable, self-compacting soil/binder mixtures may be used to fill pipe trenches.*

The suitability of the soil/binder mixture is to be verified by a suitability test.

9.4 Installation and compacting

See DIN 18300, Section 3.11.

9.4.1 Inside and outside the pipe zone, and in the fill spaces of pipe shafts, the building material is to be installed in uniform layers and carefully compacted. In so doing, it is to be ensured that the pipe stays in place. The building materials and installation techniques used must not cause damaging deformations or unfavourable loading of the pipe or the road surface.

Other building materials and installation techniques are to be indicated in the service specification.

Pipe trenches are to be filled immediately after the pipes have been laid, where appropriate in sections.

9.4.2 In the pipe zone and in the region up to 1 m above the pipe crown, compaction must be carried out only with a light compactor; up to 3 m above, it may be performed using a medium-weight compactor; and over 3 m above, with a heavy compactor.

9.4.3 Slippage from slopes of building pits or trenches is to be excavated.

The resulting space is to be treated as a part of the pipe zone or trench/building pit filling.

9.5 Compaction requirements

9.5.1 For pipe trenches within the body of the road, soils and building materials in the backfill zone is to be compacted so as to meet the requirements in Section 4.3.2. In the case of pipe trenches inside and outside the body of the road, the pipe zone require-

ment for the 10 % minimum quantile of degree of compaction D_{Pr} is 97 %. This requirement also applies to the backfill zone of pipe trenches outside of the body of the road.

For compaction requirements in building pits see Section 10.3.

9.5.2 Areas in the pipe zone in which soils or building materials cannot be perfectly compacted are to be filled with other appropriate building materials (e.g. temporarily flowable, self-compacting soil/binder mixture or concrete of appropriate quality), as long as this does not adversely affect the pipe bedding (see Section 9.4.1), the pipes themselves or the superstructure.

Appropriate measures are to be indicated in the service specification.

If the pipe is expected to affect the road superstructure adversely, suitable protective casings or half-calottes are to be used.

Special fill materials and installation techniques are to be indicated in the service specification.

10 Backfilling and covering structures

10.1 General

See DIN 18300, Section 3.11.

10.1.1 The area directly adjoining the structure below the upper edge of construction, or in the case of arched structures below the crown, is designated as the backfill zone.

The area immediately above the upper edge of construction or zone adjoining the crown up to 1.0 m thickness is classified as the covering zone of a structure. At the same time, the covering zone is the upper limit of the backfill zone.

10.1.2 The boundary of the backfill zone and the adjoining body of soil shall begin 1.0 m behind the rear edge of the foundation or from the rear wing edge projecting vertically from the plane (building pit base, ground level). The larger of the dimensions is decisive. The slopes should not be steeper than:

1 : 2 with subsequent backfill in the dam location, or

1 : 1 in the case of trench cutting and backfilling executed at the same time as dam filling.

If deviations from this are justified, the service specification may specify another volumetric form of the backfill zone.

10.1.3 The drainage zone is part of the backfill zone (see Section 10.7.2). If coarsely grained soils are being used for backfill according to Section 10.2.4, the entire backfill zone is the drainage zone.

The backfill, covering and drainage zones are to be shown in the plan, taking account of the earthworking conditions and the special design features of the structure.

10.1.4 If the client so demands, the contractor must communicate in writing, in sufficiently good time before work begins, the building materials, work procedures and machinery to be used and the measures to be taken for areas to be specially filled according to Section 10.2.7.

10.1.5 *Addition of binders may increase the load-bearing capacity and reduce the self-settling of the backfill. Relevant requirements are to be indicated in the service specification as appropriate.*

10.2 Building materials

10.2.1 *The type of material for the backfill, covering and drainage zones are to be indicated in the service specification, taking into consideration the structural design (see Section 10.3.1) and the importance of the transferred traffic route.*

10.2.2 Below the level under which the backfill can no longer be drained due to lack of receiving water, and in the case of a low-permeability base an appropriate low-permeability soil, or where appropriate concrete or a suitable soil/binder mixture, is to be placed so that water is not able to collect in this zone.

10.2.3 The drainage zone must be made of coarse-grained soils in accordance with DIN 18196.

10.2.4 The following fill materials are suitable for the backfill and covering zones:

(1) coarse-grained soils of groups SW, SI, SE, GW, GI, GE;

(2) mixed-grained soils of groups SU, ST, GU, GT;

(3) mixed-grained soils of groups SU*, ST*, GU*, GT* and fine-grained soils of groups TL, TM, UM, UL in conjunction with a qualified soil improvement;

(4) soils and building materials according to TL BuB E-StB, as long as they correspond to the soil groups indicated in (1) and (2).

Foundry mineral mixtures are not suitable for backfilling and covering structures.

For roads of RStO construction classes SV, I and II, use of coarse-grained soils of groups SW, SI, GW, GI is preferred.

10.2.5 The materials indicated in Sections 10.2.3 and 10.2.4 must be weather-resistant. They are not permitted to contain any components which are swellable, susceptible to disintegration or are aggressive to the structure.

10.2.6 When using broken or crushed material, the structure's seal must be protected. The function of the protective system must not be affected adversely during installation.

10.2.7 *In backfill zones which are difficult to access, other suitable building materials (such as soil/binder mixture, concrete of appropriate quality, etc.) are to be used for filling. These must not adversely affect the structure, pipes or the superstructure. Such measures are to be indicated in the service specification.*

10.3 Installation and compacting

10.3.1 The structural conditions and constructive development of the structure are to be considered when carrying out backfilling.

10.3.2 The building material in the backfill and covering zones is to be placed and compacted in uniform layers. The abutment cones at the structure's wings is to be produced at the same time as the backfilling or covering. In the backfill and covering zones the soil is to be installed in layers no thicker than 30 cm.

10.3.3 Rigid arches and frames, as well as flexible structures, must be backfilled from all sides evenly. The height difference during backfilling must not exceed 0.5 m if structural analysis is not performed. The backfill is to be compacted evenly.

10.3.4 Flushing or grouting in the backfill, covering or drainage zones is not allowed.

10.3.5 A 10 % minimum quantile requirement for the degree of compaction D_{Pr} of 100 % applies:

(1) in the backfill zones;

(2) in the covering zone according to Section 10.1.1 to a thickness of 1.0 m;

(3) in the slopes on the structure's wings.

10.3.6 The join of the backfill zone to a dam or trench embankment must be interlocked in the form of steps.

10.4 Covered, flexible arches

10.4.1 Structures of reinforced concrete or steel with load-bearing capabilities dependent on the assistance of the earth backfill are designated as flexible arches. They require even, low-yielding bedding.

10.4.2 For design, installation and covering, the relevant technical construction rules and the specifications of the system manufacturers are to be observed.

10.5 Grid constructions

See "*Information sheet for the design and production of grid walls and barriers".*

10.5.1 Grid constructions are composite systems made of layered pre-cast concrete components forming a spatially enclosed grid. They enclose a compacted embankment of fill soil that accounts for most of the total cross-section within the pre-cast concrete components. The stability of these constructions must be verified.

10.5.2 Grid walls are grid constructions that are backfilled in layers, with embankments which can assist in bearing loads due to horizontal earth pressure.

Grid walls can be suitable where construction measures cause undulations of terrain or excessively steep slopes that must be secured against slippage or caving-in by constructing structures. The slope side can be greened.

Grid walls are freestanding, mostly symmetrical grid constructions with excessively steep "slopes" that can be greened from both sides. They are mainly used for noise and immission control.

10.5.3 For the filling soil coarse and mixed-grain soils are to be used according to DIN 18196. The maximum particle size must be limited to prevent damage to the construction during filling and compacting. For soil types with a fine-grain portion of more than 15 wt.%, special soil mechanical investigations are necessary in regard to soil permeability and shear strength.

10.5.4 *Requirements for backfill soils for grid constructions depend on the type of adjoining soil and the use of the ground above the backfill. Requirements and drainage measures are to be indicated in the service specification.*

10.5.5 The filling and backfill soil must be continuously placed in layers as the grid wall is constructed. The thickness of each layer must not exceed 30 to 50 cm, depending on the type of soil. Filling and compacting must be adapted to the particular construction, so as not to cause damage.

If landscaping is planned, topsoil at least 30 cm wide is to be provided on the external chamber wall. The topsoil must be installed at the same time as the filling soil.

10.6 Reinforced support structures

Reinforced support structures consist of deposited, compacted soils with layers of geosynthetics, reinforcement sheets or elements laid to take up tensile loads.

The soil must be installed and compacted in layers so as to meet the requirements set out in Section 4.3.2. The area at least 1 m wide immediately behind the external wall is to be compacted separately using a light machine.

The soil's suitability for use in reinforced support structures is to be verified.

Construction design is carried out according to EBGEO. Further execution instructions are contained in M Geok E and DIN EN 14475.

10.7 Drainage

10.7.1 The backfill and covering zone must be drained in such a way that surface and groundwater can be collected and drained without damage.

Separate drainage zones are to be indicated in the service specification (see Section 10.1.3) and shown in the plan.

10.7.2 If coarse-grained soils according to Section 10.2.4 (1) are not used for the backfill zone, a filter-stable drainage zone at least 1 m wide must be installed at the rear walls of the adjoining parts of the structure at the same time as backfilling and compacted. This drainage zone must be provided both for structures in the trench as well as for structures in the dam zone.

If intense water inflow is expected at the trench of a structure, filter-stable surface drainage must be provided on the trench slope, which should be no steeper than 1 : 1.

Stones should be used only for drainage if it has been ascertained that they will not be destroyed during backfilling or by dynamic influences, e.g. traffic load, and will not cause settlement of the backfill zones. When using stones or layers of shingle concrete, a drainage layer is still needed.

10.7.3 During earthworks, surface water flowing towards the backfill zone must be captured in front of the structure's drainage zone and diverted to the side.

10.7.4 *Geotextiles can be used to protect structure seals and to separate building materials that are not mutually filter-stable. Their use is to be indicated in the service specification.*

When protecting the seal with geotextiles, the 5 % minimum quantile requirement for the thickness of the geotextile d is 2.5 mm.

Special composite materials are suitable for surface drainage at the rear of the structure. They do not replace the drainage zone according to Section 10.7.2.

Only highly weather-proof products are permitted to be used for structures. The sheets on the surface of structures shall be secured at individual points by suitable adhesives or be weighted down. The sheets must be joined in such a way that water transfer is unimpeded and soil particles cannot penetrate. A drainage pipe must be connected so as to allow the water to transfer safely.

11 Protective barriers

11.1 Principles

For protective barriers any soils or building materials may be used that guarantee the stability of the barriers for the intended slope.

If protective barriers are made from building materials or by techniques that are not covered by the regulations mentioned below, they require special investigation and verification.

Sections 6.1 and 6.5 to 6.7 apply.

If walls are to be placed on protective barriers, this is to be taken into account by the design of the barriers.

The planned crown height must be maintained with respect to the expected settlement. Planning must consider the expected settlement of the soil after the earthworks are finished.

The contractor must verify compliance with the target height at the time of acceptance (see Section 1.9.3).

When setting up protective barriers, the influence of existing structures (buildings, bridges, roads, pipes) is to be taken into account.

11.2 Installation and compacting

The soils and building materials are to be installed and compacted as specified in Section 4.3.1. The 10 % minimum quantile requirement for the degree of compaction D_{Pr} is 95 %. The 10 % maximum quantile requirement for the air void content n_a of 12 vol.% for the soils of the groups in Table 2, row 3 applies.

Deviations from this are to be indicated in the service specification on the basis of soil investigation results and stability testing.

If protective barriers are erected next to roads with embankments, the same requirements for installation and compaction apply to the widening of the road embankment for the protective barrier as to the road embankment.

11.3 Topsoil work

If there are no special plans and specifications for execution of landscaping, the service specification shall indicate the thickness of the covering for grass areas generally as 10 cm, and for trees and shrubbery 15 cm. In appropriate cases, surfaces may also be greened without topsoil.

12 Soil treatment with binders

For definitions see Sections 1.2.6 to 1.2.9.

12.1 Application

Soil stabilization is carried out in the upper zone of the base or substructure of roads, as well as on other trafficked surfaces and earthworks.

If the base or substructure immediately below the superstructure consists of soil of frost susceptibility class F 1, stabilization can be performed with a hydraulic binder. This stabilized soil is part of the superstructure of trafficked surfaces and is covered by the provisions of ZTV Beton-StB.

Qualified soil improvements may be applied to earthworks for roads and trafficked surfaces in the substructure or base, e.g. for

embankments, slopes, backfills and the planum area. Here the load bearing capacity, the shear strength and the erosion resistance are increased, and deformation and frost susceptibility are decreased. Thus, for example, suitable soils of frost susceptibility class F 3 can be classified as frost susceptibility class F 2.

Soil improvements are applied to earthworks of all types. In levelled areas, slopes and other surfaces, soil improvements with binders also serve as protection against erosion and weathering.

Soil treatment can be used as a technical protective measure. Refer to the "Information sheet on treating soils and building materials with binders to reduce leaching of environmentally relevant constituents".

For mechanical soil improvements, see Section 13.2.

12.2 Execution

12.2.1 Soil stabilization

12.2.1.1 Mixed-in-place technique

Topsoil, organic components and stones (diameter > 63 mm) and boulders (diameter > 200 mm) must be removed.

These measures are to be indicated in the service specification.

Mixed and fine-grained soils must be dug and broken up as necessary so that, apart from gravel, 80 % of the soil clumps appear smaller than 8 mm. The inside of soil clumps must be moist too.

The water content of the soil should correspond to the water content necessary for installation and compaction. If fine-grained soils need to be moistened before stabilization, this must be carried out in sufficiently good time so that the soil clumps are uniformly moistened before the binder is introduced. The soil must be homogenized or mixed until the entire layer achieves uniform colour and water content.

If coarse or mixed-grain soils (such as narrowly graded sands) are too dry, sufficient water must be added shortly after distributing the binder.

Water additionally required for compaction must be added during mixing or immediately beforehand.

In the case of excessively wet mixed and fine-grained soils (with water content significantly above the optimum), when stabilizing with hydraulic binders the water content must be reduced by

aeration by means of milling, tearing up or treatment with finely ground lime. If this is not possible, excessively wet soil must be replaced.

These measures are to be indicated in the service specification.

When using a combination binder, i.e. a combination of hydraulic binder and finely ground lime, pretreatment of the soil with finely ground lime can be dispensed with.

Fine and mixed-grain soils can be made workable for stabilization with hydraulic binders by mixing in, for example, 1 % to 3 % wt.% lime. The addition of lime must be taken in account during the suitability test. The treatment of fine and mixed-grain soils is to be indicated in the service specification.

If other building materials are added, e.g. to improve the particle size distribution, they are to be distributed and mixed-in mechanically in uniform layer thicknesses.

Before the binder is distributed, the soil must be levelled and compacted as according to Section 12.4.2.4. The height of the pre-compacted planum must be adjusted so that, in consideration of the compaction mass in the stabilized layer, it does not exceed or fall short of the target heights and layer thickness.

The binder must be mixed-in and distributed mechanically in order to achieve the required uniform layer thickness.

The layer must be compacted uniformly in order to achieve the specified degree of compaction (see Section 12.4.2.4).

For length and construction joints the milling tracks are to overlap.

12.2.1.2 Mixed-in-plant technique

The base must be levelled so as to achieve the intended thickness and height after installation of the soil stabilization.

Preparation of the base, e.g. post-compaction, production of the planned height and clearing of detrimental contamination, is to be indicated in the service specification.

If the base is produced by the contractor, or the necessity for the aforementioned work is due to other reasons for which the contractor is responsible, there is no separate remuneration.

The soil to be compacted, the binder and the required water are to be blended in a mixer. It must be mixed until the binder is uni-

formly blended with the soil and the soil/binder mixture has a uniform colour. The specifications relating to the mixed-in-place technique apply accordingly to water content. The prepared soil/binder mixture is to be transported to the installation site and uniformly placed in order to achieve the required layer thickness.

12.2.1.3 Installation and compaction applying the mixed-in-place and mixed-in-plant techniques

For soil stabilization, the base or substructure must meet the degree of compaction requirements as set out in Section 4.3.2.

The soil/binder mixture is to be compacted uniformly to achieve the specified degree of compaction (see Section 12.4.2.4) and the required evenness.

The stabilized layer shall only be used by vehicles if this will not cause impressions or damage.

Construction joints are to be executed as press joints. Before installation of connecting strips, loose components at the edges of the already installed and hardened layer are to be removed to create a slope which is as vertical as possible.

No notching or jointing is usually specified for soil stabilization. If, as an exception, additional measures are required, the notches are to be carried out according to ZTV Beton-StB.

The soil stabilization is to be performed rapidly over the entire cross-section, within the workability retention time of the soil/binder mixture.

The preparation of equipment and the operations for distributing the water and binder, for mixing the binder into the layer to be stabilized and for compaction of the soil/binder mixtures is to be adapted to this.

If soil stabilization is performed in individual adjacent strips, the work is to be carried out wet on wet. A 20 cm overlap of the strip which has already been produced is to be milled with the connecting strip and compacted again with the connecting strip.

If stabilization is planned in multiple layers, each layer is to be bound with the layer below before this layer has set. The layered installation is to be performed wet on wet.

Soil stabilization with frozen soil is not permissible.

Soil stabilization with finely ground lime and lime hydrate should be carried out at least 2 months before freezing weather sets in. Otherwise sufficient protection against frost is to be provided.

During construction, the surface water is to be drained without causing damage. This is to be performed in conformance to RAS-Ew.

12.2.2 Soil improvement

Before distribution of the binder, the soil is to be levelled so as to achieve uniform thickness in the layer to be improved. During soil improvement, the binder may also be distributed and mixed-in at the removal location.

It must be mixed until the soil/binder mixture is uniform.

The soil/binder mixture is to be compacted in such a way as to achieve the required compaction even in the lower part.

Reference is made to the "Information Sheet on soil improvement and soil stabilization with binders".

12.2.3 Thickness

The thickness of the layer when compacted is to be specified in accordance with the building purpose and soil conditions. For constructional engineering reasons, thicknesses of at least 15 cm are to be planned for soil stabilization, and 20 cm for soil improvement or qualified soil improvement.

12.2.4 Width and transverse inclination

For soil stabilization and soil improvement, the width of layers to be stabilized and improved is to be planned wider by at least the amount required for the subsequent layers due to the installation techniques.

The necessary widening of the edge of the road surface is to be chosen based on the soil properties in order to meet the profile and compaction requirements. In the planum area, soil treatment is carried out across the entire cross-section.

Soil improvement in partial areas can also be useful.

For the inclination in the embankment area, the specifications in Section 4.3.1.7 apply. In the case of stabilized or improved base/substructures, the transverse inclinations for the ground planum as specified in Section 4.4.5 apply. The edges must be designed so that water is drained outwards.

12.2.5 Processing time

If no experience or investigation results are available on permissible times for processing the soil/binder mixture in dependence of the soil and air temperature, the following permissible times apply:

(1) when using hydrophobic cement or hydrophobic base course binder:

maximum 2.0 hours at temperatures up to 20 °C;

maximum 1.5 hours at temperatures above 20 °C, beginning with mixing in of the binder until the end of compaction.

(2) when using cement and base course binder:

as in (1), but from the beginning of distribution or addition of the binder.

(3) when using combination binders (see Section 12.3.2):

maximum 4.0 hours at temperatures up to 20 °C;

maximum 3.0 hours at temperatures above 20 °C, beginning with distributing the binder until the end of compaction.

12.2.6 Curing

Soil treated with hydraulic binders must be kept continuously moist for at least 3 days, e.g. by finely spraying.

Curing is not required if a further layer is applied to the freshly compacted layer. The base must not be disturbed or impressed however.

12.2.7 Protective measures

If binder-stabilized layers are immediately used by vehicles over longer time periods or remain unprotected in winter for reasons for which the client is responsible, special protection measures are to be planned and indicated in the service specification.

If soil stabilization or improvement has to be carried out at temperatures below +5 °C, the required protective measures are to be indicated in the service specification.

If the work under the aforementioned conditions is the responsibility of the contractor, the protective measures will not be remunerated separately.

12.3 Building materials

12.3.1 Soils and other building materials

Suitable soil groups (according to DIN 18196) for soil treatment are:

- *coarse-grained soils (GE-GW-GI-SE-SW-SI) with maximum grain size 63 mm;*
- *fine and mixed-grain soils of groups SU-ST-GU-GT-SU*; -ST*-GU*-GT*-UL-UM-UA-TL-TM.*

Soil groups (according to DIN 18196) and building materials suitable for soil treatment subject to restrictions include:

- *pronounced plastic clays (TA), as long as they have a soft to stiff consistency and can be sufficiently reduced to small pieces;*
- *mixed-grain soils with stones over 63 mm, as long as they are able to be sorted out or, if weathered, crushed;*
- *soils with organic additions and organic soils;*
- *soils of highly variable composition or quality;*
- *building materials according to TL BuB E-StB;*
- *rocks of variable hardness, e.g. siltstone or mudstone, if they can be adequately crushed and have sufficient water content for compaction (to reduce air void content).*

Unsuitable soils and solid rocks for soil treatments include:

- *rocks of variable hardness, e.g. siltstone and mudstone, which cannot be adequately crushed;*
- *organic soils.*

In individual cases, soil improvement can be carried out with soils that are unsuitable for qualified soil improvement and soil stabilization. The suitability of soils and building materials containing sulphate is to be specially investigated where appropriate.

12.3.2 Binders

Binders must conform to:

DIN EN 197-1 Cement – Part 1: Composition, specifications and conformity criteria for common cements;

DIN EN 197-4 Cement – Part 4: Composition, specifications and conformity criteria for low early strength blastfurnace cements;

DIN 1164-10 Special cement – Part 10: Composition, requirements and conformity evaluation for special common cement;

DIN EN 459-1 Building lime – Part 1: Definitions, specifications and conformity criteria.

Supplementary requirements are imposed with regard to reactivity and particle size distribution. Depending on the type of lime, the reactivity shown in Table 4 and the fineness shown in Table 5 are to be observed.

Table 4: Lime reactivity requirements

Lime type	Reactivity
CL 90	t_{60} °C ≤ 25 min
CL 80	t_{50} °C ≤ 25 min
DL 85	t_{40} °C ≤ 25 min
DL 80	t_{35} °C ≤ 25 min
Note: The reactivity of lime is determined according to DIN EN 459-2. Before the reactivity is determined, limes of fineness class 2 (Table 5) are ground to a particle size distribution with residue ≤ 5 % wt.% on the 0.2 mm sieve.	

The fineness of the individual lime types must correspond to one of the two classes in Table 5:

Table 5: Lime fineness requirements

Sieve sizes	Fineness Residue as percentage of mass	
	Class 1 (fine)	Class 2 (grainy)
10 mm	0	0
5 mm	0	≤ 5
2 mm	0	–
0.2 mm	≤ 5	–
0.09 mm	≤ 15	–
Note: Particle size distribution ≥ 2 mm is determined by dry sieving, and < 2 mm by air-jet sifting.		

At low outdoor air temperatures, limes with high reactivity are especially suitable for rapid compaction of excessively moist soils according to requirements, in order to ensure sufficient construction progress.

Usually limes (finely ground limes) of fineness class 1 are used for soil treatment. Selecting class 2 allows the use of coarser limes.

DIN 18506 Hydraulic road binders – Composition, specifications and conformity criteria

Combination binders Combination of standardized hydraulic binders or their main hydraulic components and building lime.

The proportions of binders are to be indicated in the service specification.

Use of other binders can be agreed between the client and contractor provided their suitability has been fundamentally verified.

Hydraulic binders are suitable for all coarse and mixed-grain soils according to DIN 18196, and for fine-grained soils as long as they can be reduced in size and homogenized by standard processes. Finely ground lime and lime hydrate are suitable for all fine-grained and mixed-grain soils that have a high enough proportion of pozzolanic components. Combination binders are suitable for fine and mixed-grain soil in dependence of the proportions of the main components (cement and lime).

See also "Information sheet on soil improvement and soil stabilization with binders".

12.4 Requirements

12.4.1 General

The requirements key for execution is to be indicated in the service specification.

The building material mixture must be composed so as to comply with the requirements set out in Sections 12.4.2 to 12.4.4. The composition is to be determined by a suitability test (see TP BF-StB, part B 11).

The water must not contain any components or admixtures that damage the solidification or improvement of the soil.

12.4.2 Soil stabilization

12.4.2.1 Hydraulic binder quantities

The stabilization of coarsely grained soils is governed by ZTV Beton-StB (see Section 12.1).

The results of the suitability test are decisive in determining the binder quantity. The binder quantity must be selected so as to meet the requirements set out in Table 6.

Table 6: Criteria for determining the binder quantity in suitability testing for stabilization of fine and mixed-grain soils

Line	Soil group	Sample uplift[1)]	Compressive strength[2)]
1	SU-ST-GU-GT[3)]	$\frac{\Delta l}{l} \leq 1$ ‰	6.0 N/mm² at an age of 28 days
2	SU*-GU*-UL-UM ST*-GT*-TL-TM-TA	$\frac{\Delta l}{l} \leq 1$ ‰	–
3	Soils and building materials according to TL BuB E-StB	$\frac{\Delta l}{l} \leq 1$ ‰	6.0 N/mm² at an age of 28 days

[1)] Test according to TP BF-StB, Part B 11.1.

[2)] The compressive strength is only used to determine the binder quantity and is for a sample diameter of 10 cm. In special cases, the 7-day strength can be used for assessment. This shall take the strength development of the binder into account.

[3)] Sample uplift requirement only if belonging to F 2 as according to Section 3.1.3.1; otherwise only compressive strength test.

In the case of hydraulic binders which result in a slow strength development of a soil/binder mixture, in suitability testing it may be necessary to plan more than 28 days until the aforementioned compressive strength is verified.

12.4.2.2 Binder quantity for building limes

For soil stabilization with finely ground lime and lime hydrate, the binder quantity is to be specified according to TP BF-StB, Part B 11.5. The cylinder compressive strength must be at least 0.2 N/mm² after frost action. The binder quantity must not exceed 4 wt.%.

12.4.2.3 Binder quantity for combination binders and other agreed binders

For combination binders and other agreed binders, the binder quantity is to be determined according to Section 12.4.2.1.

12.4.2.4 Characteristic compaction values

(1) Requirements for the layer to be stabilized (only with the mixed-in-place technique):

The compaction requirements in Table 2 of Section 4.3.2 apply.

(2) Requirements for the layer stabilized with a binder:

Immediately after compaction, the requirement for the degree of compaction is at least 98 % of the Proctor density of the soil/binder mixture.

12.4.2.5 Verifying binder quantity

Based on the results of the suitability test, the contractor specifies the binder quantity for the mixed-in-place technique in kg/m² and for the mixed-in-plant technique in wt.%.

For the total construction lot, the delivered binder quantity must not be below the value determined in the suitability test by more than 5 % in relative terms, and must not exceed it by more than 8 % in relative terms. Values for individual binder amounts, determined according to TP BF-StB, Part B 11.2, must not exceed the specified value of the suitability test by more than 15 % in relative terms, or be below it by more than 10 % in relative terms.

12.4.2.6 Surface

The surface of the stabilized layer must not vary from the target height by more than ± 2 cm.

12.4.2.7 Evenness

The surface unevenness of stabilized soil directly underlying the superstructure must not be greater than 2.0 cm within section, 4 m in length.

12.4.2.8 Installation thickness

Individual values for layer and tier installation thickness must not exceed or be below the target value by more than 10 %.

12.4.3 Qualified soil improvement

12.4.3.1 Binder quantity

The binder quantity must not exceed 3 wt.%.

For qualified soil improvement of the planum (reduction in frost susceptibility class from F 3 to F 2), the binder quantity is to designed so that the uniaxial compressive strength, after 28 days in storage and testing according to TP BF-StB, Part B 11.5 is ≥ 0.5 N/mm². Alternatively, the CBR value according to TP BF-StB, Part B 7.1, may be tested. This must be ≥ 40 % for 28-day-old samples. In either case, after 24 hours' immersion in water, the decrease in strength must not be greater than 50 %

with respect to the value before immersion. Depending on the time specifications, the test may also be performed after 7 days and/or at other testing times.

In other applications of qualified soil improvement, the criteria for determining the binder quantity are dictated by geotechnical calculations.

12.4.3.2 Characteristic compaction values

The degree of compaction requirements in Sections 4.3.2, 9.5, 10.3.5, 10.5.4 and 11.2 apply.

12.4.3.3 Verifying binder quantity

Section 12.4.2.5 applies.

12.4.3.4 Surface, evenness, installation thickness

The requirements arising from the arrangement of the structure are to be met.

12.4.4 Soil improvement

12.4.4.1 Characteristic compaction values

The compaction requirements in Sections 4.3.2, 9.5, 10.3.5, 10.5.4 and 11.2 apply.

12.4.4.2 Surface, evenness, installation thickness

The requirements arising from the arrangement of the structure are to be met.

13 Measures to improve base and substructure with low load-bearing capacity

13.1 Principles

If the base or substructure is not stable, or the expected settling for the condition of the superstructure or the required evenness of the road surface is not within justifiable limits, improvement measures must be investigated and implemented with regard to technical features, timing, ecological and economic factors.

All measures are to be selected based on geotechnical investigations and on stability and settling calculations in consideration of the construction techniques and the timing of the construction process, the traffic, the type and composition of soils, the weather conditions and the available building materials, and indicated in the service specification.

For stability verification, the decisive construction conditions and the limiting states of load-bearing capacity and usability are to be investigated.

The measures specified in Sections 13.2 and 13.3 are based, among factors, on:

- *the time dependence of settling behaviour under load and the shear strength of the embankment soil and the embankment base;*
- *the embankment loading and geometry;*
- *the dynamic load, e.g. from traffic;*
- *the construction time available.*

If these measures cannot yet be foreseen at the time of the tender, or only become necessary once construction is in progress, they must be agreed upon separately at the appropriate time.

In the case of a vibration susceptible base, the gradients should be chosen so that for construction classes SV, I and II a distance of at least 2.0 m between the road surface and the susceptible base, based on the thickness of the superstructure and substructure, is observed.

When building on soil with low load-bearing capacity, intensive compaction in the immediate contact layer should be avoided if there is danger of the soil softening.

Instructions, recommendations and application constraints relating to the building techniques for new road construction, expansion and renovation that must be considered during planning, execution, monitoring and acceptance are contained in the "Information sheet on road construction on ground with low load-bearing capacity" and in M Geok E.

13.2 Mechanical soil improvement

Mechanical soil improvement may be applied in the embankment contact area and in the substructure to improve installability and compactability of soils and to aid execution of construction work.

The following processes may be considered:

(1) Improving soft soils by vibro-compaction or driving in suitable building materials.

Suitable building materials may be, for example, sand, gravel, stones, industrially manufactured aggregates and recycled building materials.

(2) Improving fine-grained soils by mixing in suitable soils and building materials, where necessary after previous loosening with appropriate equipment.

(3) Improving sand or gravel with a narrow particle size distribution (SE, GE) by mixing in suitable particle sizes.

13.3 Building techniques on bases with low load-bearing capacity

13.3.1 General

According to DIN 4020, construction work on ground with low load-bearing capacity is to be assigned to geotechnical category GK3. The following construction techniques may be considered:

(1) stabilization;

(2) soil replacement;

(3) ground improvement;

(4) techniques involving elevated foundation pads;

(5) use of lightweight building materials.

The various techniques may be combined. They may be supplemented by supporting measures, such as accelerating settling, improving drainage conditions, increasing stability and/or reducing the load on the base.

Generally when applying these construction techniques, at least deformation and pore water pressure measurements are required during construction. The measuring program is to be designed by a geotechnical expert and indicated in the service specification as appropriate.

Turf maintenance may be useful in assisting earthworks and with regard to trafficability.

13.3.2 Stabilization procedures

For consolidation, at least the service loads from the road embankment, including traffic load during the construction time, are anticipated in order to achieve a stabilized or over-stabilized state of the ground with low load-bearing capacity. This can be achieved by covering, lowering the groundwater table, vacuum dewatering or electro-osmosis. The most common method is covering.

13.3.3 Soil replacement

Soil replacement involves the partial or complete removal of unsuitable soils and replacement by suitable building materials. Replacement of soil layers with low load-bearing capacity is carried out in a dry pit, where appropriate with groundwater control, protected by temporary shoring elements, by underwater dredging, wet dredging or soil displacement.

If the soil excavation is effected by wet dredging, compliance with DIN 18311 must be assured.

The service specification shall indicate the type and scope of specially required self-monitoring.

During underwater dredging, the contractor shall ensure execution in compliance with the contract based on continuous self-monitoring.

If the base material has low shear strength, soil replacement may also be achieved at least partially by displacement using a filling applied in a concentrated manner as a load.

It should be noted that after filling, the replaced area can act as longitudinal drainage for inflowing surface and groundwater. If this must be prevented, appropriate measures are to be indicated in the service specification.

13.3.4 Base improvement

In improving a base with low load-bearing capacity, suitable coarse-grained building materials, binders or mixtures of them are introduced into the base at points on a narrow grid. The base material is displaced and improved by the binder at the grid points.

Common methods are ballast or ballast-packed columns, geosynthetic-encased ballast, gravel or sand columns, mortar or ready-mixed mortar columns, stabilizing columns and also driving in stones. With suitable soils, the improvement can also be effected by point-specific compaction with heavy falling plates and filling of the craters with permeable soils.

The improvement is effected by adding material and by displacement and drainage of the base. It can be incorporated into geotechnical calculations by increasing the rigidity and shear strength of the improved base material.

13.3.5 Techniques using elevated foundation pads

Elevated foundation pads consist of horizontally load-distributing layers – where appropriate geosynthetic-reinforced – mounted on vertical supports which run through the region of the ground with low load-bearing capacity. In service, the support elements must bear all loads, including traffic loads. Application of the vaulting effect in the load-distributing layer is only permitted if the height difference between the top edge of the vertical supports and the bottom face of the road superstructure is greater than twice the axial spacing of the vertical supports.

Depending on the base conditions, geosynthetic-enclosed sand, gravel or ballast columns are mainly considered for use as flexible vertical supports (see EBGEO). Ready-made piles (ductile cast iron, steel, concrete), columns packed with ready-mixed mortar or vibrated concrete columns, as well as columns of soil stabilized with binder may potentially be used as rigid vertical supports. Compliance with the relevant standards and approval conditions is to be assured.

13.3.6 Use of lightweight building materials

The use of lightweight building materials is particularly beneficial where adequate stabilization of the low load-bearing ground cannot be achieved when using natural embankment materials due to their insufficient stability, or where, in the course of renovation and/or widening measures, an over-consolidated state is to be reached.

Instructions and recommendations for the use of lightweight building materials can be found in the "Information sheet on using rigid EPS foams in construction of road embankments" and the "Information sheet on using expanded clay as a lightweight building material in road substructures and bases".

13.3.7 Use of geosynthetics

Geosynthetics are used in various building techniques:

(1) Stabilization: as a separating layer, a strip drain for vertical drainage, or as reinforcement

(2) Soil replacement: as a separating layer or as reinforcement

(3) Ground improvement: as a separating layer, a strip drain for vertical drainage, or as reinforcement

(4) Techniques using elevated foundation pads: as reinforcement

(5) Use of lightweight building materials: as a separating layer or as reinforcement

If the reinforcement layer in the embankment is laid directly on the ground, major unevenness must be smoothed out beforehand. The reinforcement must be laid without creases, and must be secured against shifting when the covering soil is distributed.

The reinforcement layer in the case of an embankment on a base of lesser load-bearing capacity should be folded back to enclose the first fill layer. A minimum fold length of 2.0 m is to be maintained.

When positioning vertical drains, after making the drains the reinforcement must be laid at the work level for them to be installed.

If the reinforcement is to perform a separating function at the same time, a woven fabric or geogrid may be laid in combination with a separating fleece.

Sections 4.3.1.11 and 6.7 apply accordingly to the laying and covering processes.

14 Testing the attained quality

14.1 General

With regard to testing, a distinction is made between test methods and test procedures. The term 'method' designates the systematic approach by which the planned quality is checked according to the compaction requirements in Sections 4, 7 and 9 to 12. 'Test procedures' define and determine the test characteristics (compaction parameters, e.g. degree of compaction according to DIN 18127 or modulus of deformation according to DIN 18134). Test procedures contain the actual working instructions to determine the compaction characteristics.

14.2 Methods for testing compaction parameters

14.2.1 General

A distinction is made between the following methods:

Method M 1: performed according to test plan (Section 14.2.2)

Method M 2: performed applying full-area dynamic measuring procedure (Section 14.2.3);

Method M 3: performed to monitor the work process (Section 14.2.4).

Each method is based on a decision-making rule to ensure unambiguously, objective assessment of the test results. Application of the decision-making rule results in acceptance or rejection of the test lot.

Key factors in choosing the applicable method are the type, size and importance of the earthwork structure, the type and composition of the earthworking materials, the machinery required and the necessary earthworking performance (see Sections 14.2.2 to 14.2.4).

The information provided by the various methods differs however. Each method offers specific advantages depending on the application case, so users can select the most suitable method for the given conditions. Self-monitoring tests and control tests can only be compared if the same method is used by both.

The test method is to be indicated in the service specification. If secondary bids relating to methods other than the tendered one are required, this is to be indicated in the service specification.

One test lot is assessed for each of the three methods. A test lot is a layer of compacted soil processed under uniform conditions to which a uniform requirement applies. The area of the test lot is to be defined precisely. If one of the aforementioned conditions is not met, the test lot is to be divided in several partial areas in each of which the conditions are met. Each of these partial areas requires separate assessment as a test lot.

Test lots or partial areas of them are to be defined in consultation between the client and contractor.

14.2.2 Method M 1: procedure according to test plan

The procedure is based on part E 1 of TP BF-StB.

In method M 1 the statistical distribution of the assessed test characteristic within a test lot is determined by random sampling. Based on the sampling result, a decision is made as to whether the test lot is accepted or rejected (see "Information sheet for compaction of the base and the substructure in road construction").

Method M 1 is applicable to all soil types.

Application of method M 1 is advisable especially in the following cases:

– in the case of large test lots;

– *in the case of test lots for which the uniformity of the compaction is to be assessed;*

– *in the case of test lots for which test procedures needing little time commitment are applied, the results of which are available immediately.*

Method M 1 is also applicable to trial compacting (see Section 4.3.1.1).

The testing is carried out on a random sampling basis. The location of the test points on the test area is determined at random, e.g. by random selection methods according to TP BF-StB, part E 1. The sample size n depends on the test lot size and the test plan used. A simple test plan is derived as shown in Table 7, for example.

The test results are determined at the n randomly selected test points x_1, ….., x_n. The arithmetic mean $\bar{x}$ and the standard deviation s are calculated from the sample results x_i.

Arithmetic mean x of sample of size n:

$$x = \frac{1}{n} \sum_{i=1}^{i=n} x_i \tag{1}$$

Standard deviation s of sample:

$$s = \sqrt{\left[\sum_{i=1}^{i=n} (x_i - \bar{x})^2 \right] / (n - 1)} \tag{2}$$

In the case of a 10 % minimum quantile T_M (degree of compaction, modulus of deformation, see Section 4), the statistical test quantity z

$$z = \bar{x} - k \cdot s \tag{3}$$

is calculated from $\bar{x}$ and s.

In the case of the 10 % maximum quantile, T_H for the air void content the test quantity z is

$$z = \bar{x} + k \cdot s \tag{4}$$

where k is the acceptance factor according to Table 7.

The test lot is accepted if in the case of a specified minimum quantile $z \geq T_M$ and a maximum quantile $z \leq T_H$; otherwise the test lot is rejected. It is then to be brought by the contractor to a state in accordance with requirements.

In the event of a rejection, the full area of the test lot is to be rejected.

Part E 1 of TP BF-StB contains further random sampling-based test plans which may result in a smaller test sample size than shown in Table 7.

Table 7: Sample size and acceptance factor for a simple plan for variables testing depending on the size of the test lot

Test lot size Area in m^2	Pipe trench length in m per 1 m trench depth	Sample size n	Acceptance factor k
up to 1,000	up to 100	4	0.88
over 1,000 to 2,000	over 100 to 200	5	0.88
over 2,000 to 3,000	over 200 to 300	6	0.88
over 3,000 to 4,000	over 300 to 400	7	0.88
over 4,000 to 5,000	over 400 to 500	8	0.88
over 5,000 to 6,000	over 500 to 600	9	0.88

When applying the dynamic plate load test to measure the dynamic modulus of deformation, the sample size stated in Table 7 is to be doubled.

14.2.3 Method M 2: application of full-area dynamic measuring procedure

The method is based on part E 2 of TP BF-StB.

In method M 2, using a roller-mounted measuring instrument a dynamic measurement value is determined from the interaction between the roller and the soil over the full area which correlates with the rigidity and compaction of the soil. Thus, by this method a 'full test' of a compacted layer (= test area) with an indirect test procedure (= dynamic measurement value) is used to decide whether the test area (= test lot) is accepted or rejected.

More information is provided in the "Information sheet on full-area dynamic procedure to test compaction in earthworks" and in the "Information sheet for compaction of the base and the sub-structure in road construction".

The application of full-area dynamic measuring procedures within the framework of method M 2 requires calibration of dynamic measurement values against the compaction parameters specified in Section 4, with a correlation coefficient of $|r| > 0.7$.

A correlation coefficient $|r| > 0.7$ is to be expected with the following soils:

1. Coarse-grained soils of soil groups GE, GW, GI, SE, SW, SI

2. Mixed-grain soils of soil groups GU, SU, GT, ST with a water content below the optimum water content in the Proctor test.

Application of method M 2 is advisable especially in the following cases:

– *construction projects with high daily output and mostly uniform soil type composition;*

– *in the case of test areas for which the uniformity of the compaction is to be assessed;*

– *where the compaction assessment is integrated in the working process.*

Method M 2 is divided into the following steps:

1. Calibration for the particular soil and construction site conditions according to TP BF-StB, part E 4.

2. Definition of the 10 % minimum quantile T_M for the dynamic measurement values.

3. Testing of the compacted layer by the full-area dynamic measuring procedure (full test, number of measurement values N).

4. Calculation of the mean value μ and the standard deviation σ of all dynamic measurement values of the test area and calculation of the test quantity z:

$$z = \mu - 1.28\,\sigma \qquad (5).$$

   The z value is usually calculated by the roller manufacturer's program.

5. Presentation of all measured values in an area plot.

6. A test lot is accepted provided the test quantity z is greater than the minimum quantile T_M ($z \geq T_M$).

   In addition, the area plot is to be used to check whether the locations in the tested area where the minimum quantile is not reached are distributed evenly across the area. If the tested area includes large connected regions in which the dynamic measurement values are below the specified minimum quantile T_M, the regions in question must be assessed jointly by the client and contractor.

If the test quantity z falls below the minimum quantile T_M, the test lot is rejected and must be brought to a condition in accordance with requirements.

If some other acceptance rule in accordance with the "Information sheet on full-area dynamic procedure to test compaction in earthworks" is valid, this is to be indicated in the service specification.

The track on the compacted layer must not be longer than 150 m and there must not be more than 20 adjacent tracks.

The test can be performed directly integrated into the work process with the roller used for compaction, or using a special measuring roller.

Application of method M 2 is advisable particularly for the contractor's self-monitoring, since at the same time the dynamic measurement values provide additional indications for optimization of the working processes. The results of the self-monitoring may, expediently, be recognised as control tests. This requires that the client should supervise the calibration process and the self-monitoring tests.

Other applications of the full-area dynamic measuring procedure are in the "Information sheet for compaction of the base and substructure in road construction".

14.2.4 Method M 3: monitoring of the work process

The method is based on Part E 3 of TP BF-StB.

In method M 3, a trial compaction is usually undertaken to verify the suitability of the chosen compaction process. Based on the results of the trial compaction, work instructions for the compaction process are drawn up. The compaction work on the earthwork structure is carried out according to the work instructions. Compliance with the work instructions must be documented.

Further information is set out in the "Information sheet for compaction of the base and substructure in road construction".

The application requires that the trial compaction (see Section 4.3.1.1) or verified in-house experience should define a specific work process for the installation and compaction of the ground concerned (in work instructions) and that conformance to the procedure is documented by the contractor in the course of self-monitoring. The work instructions shall specify:

1. the suitable compactor;
2. the installation procedure;
3. the number of compaction passes required;
4. the soil type and group;
5. the maximum thickness of the uncompacted fill layer;
6. the installation water content permissible for compaction.

The contractor shall provide the client with proof of compliance with the work instructions by keeping a daily log. This shall, at least, record the following parameters:

1. Deployment (e.g. kilometres of construction) by location and altitude
2. Fill layer number/width; thickness of the uncompacted layer
3. Number of passes per layer
4. Compactor unit used, with working parameters (frequency, amplitude, speed) per layer
5. The associated trial compaction
6. The weather conditions during installation
7. The installed soil type and its water content

If tachographs, the Global Positioning System (GPS), automatic self-levelling equipment or wireless communication are to be used to provide more detailed documentation, the required means of documentation are to be indicated in the service specification.

The daily log also serves the documentation according to Section 15.

It is expedient that the client should participate in the trial compaction.

In addition to the records of the daily log, the contractor shall conduct testing to the extent set out in Table 8.

Table 8: Minimum number of self-monitoring tests

Line	Area	Minimum number
1	Planum, substructure, base	1 per 1,000 m^2 or part thereof, but at least 2 tests
2	Structure backfill	see Section 14.6
3	Structure covering	3 in the first metre of the covering
4	Pipe trenches	3 per 150 m length per m trench depth
5	On local roads and in sectional working	1 per 1,000 m^2 or part thereof, but at least 100 m each and at least 2 tests

From the n test results x_i the mean value $\bar{x}$ (see Equation 1) and the standard deviation s (see Equation 2) are to be calculated. The test results are to be evaluated as follows (decision-making rule):

1. With 2 test results (n = 2)

   Accept test lot if $\bar{x} - 1.28\ s \geq T_M$ otherwise reject

2. With 3 test results (n = 3):

   Accept test lot if $\bar{x} - 1.15\ s \geq T_M$ otherwise reject

3. With 4 tests or more (n = 4):

   Accept test lot if $\bar{x} - 0.88\ s \geq T_M$ otherwise reject.

If a test lot is rejected, contractor shall bring it into a condition in accordance with requirements.

The results of the trial compaction, the monitoring of the work procedure to be documented by the contractor (daily log) and the results of the self-monitoring tests must be submitted to the client.

If compliance with the work instructions is not verified both by the daily log and by means of the individual tests in Table 8 as described, the compaction is to be tested in accordance with method M 1 (see Section 14.2.2).

14.3 Test procedures to determine characteristic values for compaction

14.3.1 Sampling and test procedures

The sampling and test procedures are subject to the “Technical test rules for soil and rock in road construction” (TP BFStB). Measurement uncertainties are to be ignored since the requirements (see Sections 4, 7 and 9 to 12) refer to measured values.

Application of all the indirect test procedures named requires prior agreement between the client and contractor.

Intended indirect test procedures are to be indicated in the service specification.

14.3.2 Degree of compaction D_{Pr}

To calculate the degree of compaction, the ratio of the dry density of the tested sample to the Proctor density of the sample is calculated and given as a percentage (see DIN 18127). For soils and building materials, the Proctor density of the sample taken in the respective density measurement is to be determined as a reference value and used as the basis of the assessment.

In the case of soils and building materials of homogeneous composition, the Proctor density determined in the suitability test or the trial compaction may also be used as a reference value for the degree of compaction.

14.3.3 Dry density ρ_d and porosity n

If the Proctor density cannot be reliably measured as a reference value for the degree of compaction (e.g. in the case of variable solid rock, stony and lumpy soils, and some industrially manufactured and recycled aggregates), it may be replaced by the dry density ρ_d or the pore content n may be specified as characteristic value for the compaction.

The values to be specified as requirements for the dry density and the pore content are to be defined based on existing local experience or previous investigations for the specific application case by mutual consent between the client and the contractor.

14.3.4 Air void content n_a

The air void content n_a is calculated from the results of the density measurement according to DIN 18125 and the results of the water content measurement according to DIN 18121.

The air void content may also be specified as an additional parameter for the compaction as set out in Section 14.3.3.

14.3.5 Indirect test procedures for degree of compaction

In the case of coarse-grained soils and mixed-grain soils with a fine grain content of less than 15 wt.%, the following test procedures can be used as a replacement for the determination of the degree of compaction:

(1) Static plate load test to DIN 18134

(2) Dynamic plate load test according to TP BF-StB, part B 8.3. The test procedures to be applied in the specific case are to be indicated in the service specification.

When producing the test area (see Section 4.3.1.1), calibration tests are to be employed to determine the relationship between the selected indirect test procedure and the degree of compaction (see TP BF-StB, part E 4). The relationship may also be provided by in-house verification or based on recognised third-party experience.

When applying the dynamic plate load test as an indirect test procedure to determine the degree of compaction, the scope of testing with respect to that required in the case of direct test procedures according to Sections 14.2.2 and 14.2.4 is to be doubled.

In the case of coarse-grained soils, the allocation values set out in Tables 9 and 10 may be applied.

Table 9: Guide values for allocation of the static modulus of deformation EV2 to the degree of compaction D_{Pr} for coarse-grained soils

Soil group	Static modulus of deformation E_{v2} in MN/m²	Degree of compaction D_{Pr} in % in %
GW, GI	≥ 100 ≥ 80	≥ 100 ≥ 98
GE, SE, SW, SI	≥ 80 ≥ 70	≥ 100 ≥ 98

The ratio of the modulus of deformation E_{V2}/E_{V1} shall additionally be applied to assess the compaction status. Herewith apply $E_{V2}/E_{V1} \leq 2.3$ for $D_{Pr} \leq 100$ % and $E_{V2}/E_{V1} \leq 2.5$ for $D_{Pr} \leq 98$ %. If the value of E_{V1} already reaches 60 % of the value of E_{V2} given in Table 9, higher ratios E_{V2}/E_{V1} are also permissible.

Table 10: Guide values for allocation of the dynamic modulus of deformation E_{vd} to the degree of compaction D_{Pr} for coarse-grained soils

Soil group	Dynamic modulus of deformation E_{vd} in MN/m²	Degree of compaction D_{Pr} in % in %
GW, GI, GE, SW, SI, SE	≥ 50 ≥ 40	≥ 100 ≥ 98

For the soil groups GE and SE the allocations in Tables 9 and 10 are to be checked in the course of trial compaction.

Recommendations for testing in pipe trenches and in confined work spaces:

(1) Measurement of the probing resistance by means of special pipe trench probes in the case of layer-by-layer installation or in the case of shallow pipe trenches (depth ≤ 0.7 m), with preferentially coarse-grained soils and mixed-grain soils with a fine grain content < 15 wt.%

(2) Measurement of the probing resistance by means of pile driver probes in deep pipe trenches and with fill material comprising coarse-grained soils and mixed-grain soils with a fine grain content < 15 wt.%.

14.4 Testing modulus of deformation, profile layer trueness and evenness on the planum

To test the load-bearing and deformation behaviour on the planum as the base for the road superstructure, the requirements for the modulus of deformation E_{V2} and for the dynamic modulus of deformation E_{vd} must be verified according to Section 4.5.2. Method M 1 or M 3 according to Section 14.2.2 or 14.2.4, respectively, is to be applied for this.

Testing is performed by means of the static plate load test according to DIN 18134 or the dynamic plate load test according to TP BF-StB, Part B 8.3. When applying the dynamic plate load test, the scope of testing according to Sections 14.2.2 and 14.2.4 is to be doubled.

Method M 2 according to Section 14.2.3 may also be applied, provided it is applicable in terms of soil mechanics.

The test results obtained with the measuring roller must be calibrated with the modulus of deformation E_{V2} (see TP BF-StB, Part E 4). The correlation may also be provided by in-house verification or based on recognised third-party experience.

The profile-oriented positioning is tested by standard surveying techniques. Evenness testing according to Section 12.4.2.7 is performed with the 4 m level (TP Level – contact measurements).

14.5 Tests during soil treatment

14.5.1 Tests during soil stabilization

The type and scope of testing during soil stabilization is shown in Table 11.

The self-monitoring and control tests on the stabilized layer are to be performed jointly by the contractor and the client immediately after compaction.

Testing of the modulus of deformation on the planum may be omitted if the base or substructure is stabilized with binders.

Table 11: Type and scope of testing during soil stabilization

	Parameter	Self-monitoring test	Control test
1.	**Binders**		
	Conformance between delivery and agreed binder type and grade	Every delivery (delivery note)	random sampling
2.	**Soil**		
2.1	Particle size distribution	Each 250 m or each 3,000 m^2	random sampling
2.2	Condition constraints	As required	
2.3	Org. components	Each 250 m or each 3,000 m^2	
2.4	Water content	As required	
2.5	Proctor density and associated water content	–	
3.	**Soils intended to be stabilized**		
3.1	Degree of compaction	[1)]	random sampling
3.2	Profile-oriented positioning	Three times each 20 m	
4.	**Stabilized layer**		
4.1	Degree of compaction	Each 250 m or 3,000 m^2	Each 250 m or 3,000 m^2 at least once a day
4.2	Binder amount	As required	Each 1 000 m^2
4.3	Profile-oriented positioning	Three times each 20 m	50 m each
4.4	Evenness	As required	As required
4.5	Layer thickness	As required	Each 1 000 m^2

[1)] For testing the degree of compaction of the layer intended to be stabilized, method M 1, M 2 or M 3 is applied as for soil compaction. The scope of testing is determined as according to Section 14.2.2, 14.2.3 or 14.2.4.

14.5.2 Tests during qualified soil improvement

The type and scope of testing, and choice of the suitable methods, is determined according to the details in Sections 14.1 to 14.3. The details in Sections 4.5.2, 12.4.3 and 14.5.1 apply to the tests relating to the binder, the building material mixture and the improved layer.

14.5.3 Tests during soil improvement

The type and scope of testing, and choice of the suitable methods, is determined as according to the details in Sections 14.1 to 14.3. The details in Section 14.5.1 apply to tests relating to the binder.

14.6 Tests during structure backfill

In the case of structure backfill, at least one measurement of the degree of compaction is to be performed in every third fill layer (for an assumed layer thickness of at most 30 cm) each 200 m^2 layer area.

It may be useful to increase the scope of testing for backfilling. After completion of the backfill, at least two pile driver probes driven through the complete backfill height are recommended as completion tests. This is to be indicated in the service specification.

In the area of the backfill on the planum, at least one test by the static plate load test (alternatively: two tests by the dynamic plate load test) is to be performed every 100 m^2. At least one test per abutment must be performed by the static plate load test (alternatively: two tests by the dynamic plate load test).

All test results must attain or surpass the minimum quantiles specified in Sections 10.3.5 and 4.5.

14.7 Other test procedures

In the course of the control tests the trueness of the profile layer is to be tested at intervals of at most 50 m.

The layer thickness is tested at excavation points distributed regularly across the test area. The thickness is measured with a rule.

15 Documentation of quality assurance

If documentation of quality assurance is to be provided according to Section 15, the client shall specify this in the service specification.

All quality assurance measures on an earthwork structure are to be comprehensively documented and submitted to the client in tabular and graphical form – if requested by the client also in digital form. The listings of self-monitoring tests according to Section 1.6.3 and tests according to Section 3.2.3 are to be maintained continuously and kept ready for inspection by the client.

A site plan is to be drawn up for each earthwork structure. This two-dimensional and/or three-dimensional plan contains the following information:

1. *Geometry of the filled embankment by location (e.g. coordinates according to Gauß-Krüger, positioning etc.) and altitude.*

2. *Soils and rock as well as other building materials according to type and origin. The filled materials are to be kept apart.*

3. *The areas in which soil improvement/soil stabilization has been carried out. The binder used is to be specified according to type and quantity (e.g. in kg/m^3 or in wt.% etc.).*

4. *The method of compaction of the slope areas in the embankment zone (e.g. slope covering with subsequent cutting, slope compaction by cable-guided rollers, etc.).*

5. *All sampling points for laboratory soil mechanics testing and the test points of all soil mechanics field tests (e.g. plate load tests, density measurements, degree of compaction, etc.). The results of all tests are to be summarized and submitted in concise tabular form.*

6. *The measuring points and the results of settlement measurements (and possibly additional displacement measurements).*

7. *The results of evenness measurements on the planum.*

8. *All sampling points for chemical analyses. The results of all chemical analyses are to be summarized additionally and submitted in concise tabular form.*

9. *Results of probes (pile drive and pressure probes), such as on bridge abutments and pipe trenches, are to be entered to*

scale in the transverse and longitudinal sections of the earthwork structure.

10. *All earthwork and design measures to assure the stability of cut slopes.*
11. *Seals, where appropriate with layout plan.*
12. *The area and thickness of topsoil application on the slope.*
13. *Special events (e.g. slope or ground break-ups, exchange zones of already filled, unsuitable and material which has been removed again) during production.*
14. *All suitability tests.*
15. *Other works.*
16. *Other measurements and tests.*

Results of self-monitoring and control tests are to be entered in the site plan.

The plans of the superstructure, the drainage systems and the documentation of quality assurance of the earthwork structure should be synchronized with each other.

Appendix 1

Deductions for non-conformance to requirements on soil stabilization

A 1 Preliminary notes

A 1.1 If the client makes deductions according to Section 1.8.1 due to identified deficiencies regarding installation thickness, binder quantity or degree of compaction, the amount of any such deduction shall be based on the formulas set out in Section A 2.

A 1.2 If deficiencies are identified regarding installation thickness, binder quantity or degree of compaction, the relevant deductions are added together.

A 2 Deductions

A 2.1 Shortfall of agreed installation thickness for soil stabilization using hydraulic binders

If the agreed installation thickness is not attained, regardless of the amendment to the unit price applicable in the event of reduced installation, a deduction will be applied according to the following formula:

$$A = \frac{p}{100} \cdot 3.75 \cdot EP \cdot F.$$

Where:
A = deduction in Euro
p = percentage shortfall below the agreed installation thickness above the limit value of 10 %
EP = the invoiced unit price in Euro/m^2
F = the area to which the verification relates in m^2

The deduction is determined on the basis of the partial deductions from the individual values.

A 2.2 Shortfall of and excess binder quantity for soil stabilization using hydraulic binders

In the event of a shortfall or excess relative to the limit value in Section 12.4.2.5, a price deduction will be applied according to the following formula:

$$A = \frac{p^2}{100} \cdot 0.5 \cdot EP \cdot F.$$

Where:
A = deduction in Euro
p = percentage relative shortfall below the agreed binder quantity installation thickness over the limiting value of 5 %, or 8 % excess above the agreed binder quantity. Individual values are subject to the limiting value of 10 % on a shortfall and 15 % for excess.
EP = the invoiced unit price in Euro/m^2 for the finished layer
F = the area to which the sample relates in m^2

The deduction is determined either based on the mean value of all single values for the complete construction lot or based on the individual values. The higher value is decisive.

A 2.3 Shortfall of degree of compaction for soil stabilization using hydraulic binders

If the requirement according to Section 12.4.2.4 is not met, a deduction will be applied according the following formula:

$$A = \frac{1}{100} (11p - 4.5)\ EP \cdot F.$$

Where:
A = deduction in Euro
p = percentage shortfall of specified minimum degree of compaction
EP = the invoiced unit price in Euro/m^2 for the finished layer
F = the area to which the sample relates in m^2.

Appendix 2

Building material receipt inspection for geosynthetics

Table A 1: Geotextiles and geotextile-related products – Scope of testing and verification for inspection of incoming building materials

Characteristic	Test procedure	Function				
		Separation	Filtering	Drainage	Reinforcement	Protection
Mass per area unit	DIN EN ISO 9864	+	+	+	+	+
Thickness	DIN EN ISO 9863-1 and -2	–	+	+	–	+
Maximum tensile force[1)] and maximum elongation due to tensile force	DIN EN ISO 10319	+	+	+	+	+
Tensile strength of seams and joints	DIN EN ISO 10321	–	–	–	x	–
Puncture resistance[1), 2)]	DIN EN ISO 12236	+	+	–	–	+
Shear behaviour	DIN EN ISO 12957-1, -2	–	–	–	N	–
Tensile creep behaviour	DIN EN ISO 13431	–	–	–	N	–
Compressive creep behaviour	DIN EN 1897	–	–	N	–	–
Damage on installation	DIN EN ISO 10722	–	–	–	N	–
Protective effect of geotextiles	DIN EN 13719	–	–	–	–	N
Characteristic opening width	DIN EN ISO 12956	+	+	–	–	–
Water permeability normal to plane	DIN 60500-4, DIN EN ISO 11058	+	+	–	N	N
Discharge capacity	DIN EN ISO 12958	–	–	+	–	–
Stability	DIN EN 13249 ff. appendix B	N	N	N	N	N
Chemical resistance	DIN EN 14030, DIN EN ISO 13438, DIN EN 12447	N	N	N	N	N
Weathering resistance	DIN EN 12224	N	N	N	N	N
Environmental safety	TL Geok E-StB, Section 3.1 M Geok E, Section 6.28	N	N	N	N	N

+: Testing required/ –: Testing not required

x: Required if connections to be made in direction of tensile load

N: Verification by test certificate possible

1) If the tensile strength and puncture resistance are specified with +, the decisive strength test for determining the class of geotextile robustness (tensile strength testing of woven fabrics, stamp puncture resistance testing of fleece materials) is sufficient specific to application

2) This test cannot be applied to all products

Note: The 'separation' function must always be viewed in conjunction with the 'filtering' or 'reinforcement' function. The scope of testing is based on the sum total of the required tests.

Table A 2: Geosynthetic barriers – scope of testing and verification for incoming inspection of building materials

Characteristic	Types		Testing standardstandards	
	KDB	GTD	KDB	GTD
Thickness	+	+	DIN EN 1849-2	DIN EN ISO 9863-1
Mass by area	–	+	–	DIN EN 14196
Melt flow index (MFI)	+	–	DIN EN ISO 1133	–
Thickness	+	–	DIN EN ISO 1183	–
Water permeability (leak-tightness against liquids)	N	+	DIN EN 14150	ASTM D 5887
Swelling behaviour	–	+	–	ASTM D 5890
Tensile strength and maximum elongation due to tensile force	+	+	DIN EN ISO 527-1, -3[1)]	DIN EN ISO 10319
Puncture resistance	+	+	DIN EN ISO 12236	DIN EN ISO 12236
Burst strength	N	–	DIN EN 61551	–
Tear resistance	+	–	DIN ISO 34-1, method B[2)]	–
Shear behaviour	N	N	DIN EN ISO 12957-1 DIN EN ISO 12957-2	DIN EN ISO 12957-1[3)] DIN EN ISO 12957-2
Cold bending behaviour	N	–	DIN EN 495-5	–
Thermal expansion	N	–	ASTM D 696	–
Weathering resistance	N	–	DIN EN 12224	[4)]
Microbiological resistance	N	N	DIN EN 12225	DIN EN 12225
Oxidation resistance	N	N	DIN EN 14575	DIN EN ISO 13438, Methods C 1 and C 2
Stress crack resistance	N	–	DIN EN 14576	DIN EN 14576[5)]
Resistance to leaching (water-soluble)	N	N	DIN EN 14415	DIN EN 14415
Water absorption (Enslin-Neff)	–	+	–	DIN 18132
Montmorillonite content – Methylene blue test	–	+	–	DIN EN 933-9
Resistance to wetting and drying	–	N	–	DIN EN 14417
Resistance to freeze-thaw cycles	–	N	–	DIN EN 14418
Resistance to root penetration	N	N	DIN EN 14416	DIN EN 14416
Environmental safety	N	N	TL Geok E-StB, Section 3.1, M Geok E, Section 6.28	TL Geok E-StB, Section 3.1, M Geok E, Section 6.28

KDB: Geosynthetic membrane; GTD: Geosynthetic clay liner

+: Testing required/ –: Testing not required

N: Verification by test certificate possible

1) Measurement sample type 5A

2) Angle measurement sample without notching

3) The internal bonding of geosynthetic clay liners can be determined by a shear or peel test

4) Since geosynthetic clay sealing liners always have to be covered immediately, this test can be omitted

5) Applies to a geosynthetic clay liner only if joined to a geosynthetic membrane

Control tests for geosynthetics

Table A 3: Geotextiles and geotextile-related products – Scope of control testing

Characteristic	Test procedure	Function				
		Separation	Filtering	Drainage	Reinforcement	Protection
Mass per surface unit	DIN EN ISO 9864	+	+	+	+	+
Thickness	DIN EN ISO 9863-1 and -2	–	+	+	–	+
Maximum tensile force[1] and maximum elongation due to tensile force	DIN EN ISO 10319	+	+	+	+	+
Tensile strength of seams and joints	DIN EN ISO 10321	–	–	–	x	–
Puncture resistance[1], [2]	DIN EN ISO 12236	+	+	–	–	+
Characteristic opening width	DIN EN ISO 12956	+	+	–	–	–
Water permeability normal to plane	DIN 60500-4, DIN EN ISO 11058	+	+	–	–	–
Discharge capacity	DIN EN ISO 12958	–	–	+	–	–

+: Testing required/ –: Testing not required

x: Required if connections to be made in direction of tensile load

[1] If the tensile strength and puncture resistance are specified with +, the decisive strength test for determining the class of geotextile robustness (tensile strength testing of woven fabrics, stamp puncture resistance testing of fleece materials) is sufficient specific to application

[2] This test cannot be applied to all products

Table A 4: Geosynthetic barriers – Scope of control testing

Characteristic	types		Testing standards	
	KDB	GTD	KDB	GTD
Thickness	+	+	DIN EN 1849-2	DIN EN ISO 9863-1
Mass by area	–	+	DIN EN 1849-2	DIN EN 14196
Melt flow index (MFI)	+	–	DIN EN ISO 1133	–
Thickness	+	–	DIN EN ISO 1183	–
Water permeability (leak-tightness against liquids)	–	+	–	ASTM D 5887
Swelling behaviour	–	+	–	ASTM D 5890
Tensile strength and maximum elongation due to tensile force	+	+	DIN EN ISO 527-1, -3[1]	DIN EN ISO 10319
Puncture resistance	+	+	DIN EN ISO 12236	DIN EN ISO 12236
Tear resistance	+	–	DIN ISO 34-1, method B[2]	–
Water absorption (Enslin-Neff)	–	+	–	DIN 18132
Montmorillonite content – Methylene blue test	–	+	–	DIN EN 933-9

KDB: Geosynthetic membrane; GTD: Geosynthetic clay liner

+: Testing required/ –: Testing not required

[1] Measurement sample type 5A

[2] Angle measurement sample without notching

Appendix 4

Excerpts from:

Soil and rock classification (according to VOB – Part C: General technical specifications in construction contracts (ATV) – earthworks, ATV DIN 18300, October 2006 issue*))

…

2.3 Soil and rock classification

Soils and rock are classified according to their condition when loosened. Regardless of its condition when loosened, topsoil is in a separate class in view of a special treatment.

Class 1: **Topsoil**

Top layer of soil which, in addition to inorganic substances such as gravel, sand, silt and clay mixtures, also contains humus and organisms.

Class 2: **Flowing soils**

Soil types of fluid to pulpy consistency which do not release water readily.

Class 3: **Easily loosened soil types**

Non-cohesive to weakly cohesive sands, gravels and sand/gravel mixtures with up to 15 % silt and clay (particle size less than 0.06 mm) and with a maximum of 30 % stones of over 63 mm particle size up to 0.01 m^3 volume[1)].

Organic soil types with low water content, e.g. solid turfs.

Class 4: **Moderately hard-to-loosen soil types**

Mixtures of sand, gravel, silt and clay with more than 15 % of their particle size less than 0.06 mm.

Cohesive soil types of light to moderate plasticity which are soft to semi-solid, depending on water content, and which contain a maximum of 30 % stones of over 63 mm particle size up to 0.01 m^3 volume[1)].

Class 5: **Hard-to-loosen soil types**

Soil types according to classes 3 and 4, but with more than 30 % stones of over 63 mm particle size up to 0.01 m^3 volume[1)].

Non-cohesive and cohesive soil types with a maximum of 30 % stones of over 0.01 m^3 to 0.1 m^3 volume[1)].

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Highly plastic clays which are soft to semi-solid, depending on water content.

Class 6: **Easily loosened rocks and comparable soil types**

Rock types which possess an inner mineral cohesion, but are heavily fissured, brittle, crumbly, slaty, soft or weathered, as well as comparable solid or solidified cohesive or non-cohesive soil types, e.g. due to drying out, freezing, chemical bonding.

Non-cohesive and cohesive soil types with more than 30 % stones of over 0.01 m^3 to 0.1 m^3 volume[1)].

Class 7: **Hard-to-loosen rock**

Rock types which possess an inner mineral cohesion and high structural strength and are only slightly fissured or weathered, as well as solid-deposited, unweathered shale, conglomerate layers, slag heaps from metallurgical plants and the like.

Stones of over 0.1 m^3 volume[2)].

2.4 Description and classification of other materials

Materials such as recycled materials, industrial by-products and waste are, as far as possible, described according to Section 2.2 and classified according to Section 2.3. Otherwise, materials are described specifically with regard to their characteristic properties in earthworking.

…

[1)] 0.01 m^3 volume corresponds to a sphere with a diameter of ≈ 0.3 m.

[2)] 0.1 m^3 volume corresponds to a sphere with a diameter of ≈ 0.6 m.

Appendix 5.1

Soil classification for construction purposes (according to DIN 18186, June 2006 issue); german version

Sp	1	2	3	4	5	6	7	8			9	10	11	12	13	14	15	16	17	18	19	20	21	Sp
Zeile	Definition und Benennung							Erkennungsmerkmale (u.a. für Zeilen 15 bis 22)			Anmerkungen[a]													Zeile
	Hauptgruppen	Korn-größen-Massen-anteil		Lage zur A-Linie (siehe Bild 1)	Gruppen		Kurzzeichen Gruppensymbol[b]				Beispiele	Bautechnische Eigenschaften						Bautechnische Eignung als						
		Korn-durch-messer																	Baustoff für					
		≤ 0,063 mm	≤ 2 mm					Trocken-festigkeit	Reaktion beim Schüttel-versuch	Plastizität beim Knet-versuch		Scherfestigkeit	Verdichtungsfähigkeit	Zusammendrückbarkeit	Durchlässigkeit	Erosionsempfindlichkeit	Frostempfindlichkeit	Baugrund für Gründungen	Erd- und Baustraßen	Straßen- und Bahndämme	Dichtungen	Stützkörper	Dränagen	
1	grobkörnige Böden	kleiner 5 %	bis 60 %	—	Kies (Grant)	eng gestufte Kiese	GE	steile Körnungslinie infolge Vorherrschens eines Korngrößenbereichs			Fluss- und Strandkies	+	+o	++	--	++	++	+	-	+	--	+	++	1
2						weit gestufte Kies-Sand-Gemische	GW	über mehrere Korngrößenbereiche kontinuierlich verlaufende Körnungslinie			Terrassen-schotter	++	++	++	-o	+	++	++	++	++	--	++	+o	2
3						intermittierend gestufte Kies-Sand-Gemische	GI	meist treppenartig verlaufende Körnungslinie infolge Fehlens eines oder mehrerer Korngrößenbereiche			vulkanische Schlacken	++	+	++	-	o	++	++	+	++	--	++	+o	3
4			über 60 %	—	Sand	eng gestufte Sande	SE	steile Körnungslinie infolge Vorherrschens eines Korngrößenbereichs			Dünen- und Flugsand Fließsand Berliner Sand Beckensand Tertiärsand	+	+o	++	-	-	++	+	--	+o	--	o	+	4
5						weit gestufte Sand-Kies-Gemische	SW	über mehrere Korngrößenbereiche kontinuierlich verlaufende Körnungslinie			Moränensand Terrassensand	++	++	++	-o	+o	++	++	+	+	--	+	+o	5
6						intermittierend gestufte Sand-Kies-Gemische	SI	meist treppenartig verlaufende Körnungslinie infolge Fehlens eines oder mehrerer Korngrößenbereiche			Granitgrus	+	+	++	-o	+o	++	++	o	+	--	+	+o	6
7	gemischtkörnige Böden	5 % bis 40 %	bis 60 %	—	Kies-Schluff-Gemische	5 % bis 15 % ≤ 0,063 mm	GU	weit oder intermittierend gestufte Körnungslinie Feinkornanteil ist schluffig			Moränenkies	++	+	++	o	+o	-o	++	++	+	-	+	-	7
8						über 15 % bis 40 % ≤ 0,063 mm	GU*				Verwitterungs-kies	+	+o	+	+	-o	–	+	+o	-o	+o	-	–	8
9					Kies-Ton-Gemsche	5 % bis 15 % ≤ 0,063 mm	GT	weit oder intermittierend gestufte Körnungslinie Feinkornanteil ist tonig			Hangschutt	+	+	+	+o	+o	-o	++	++	+	-o	+o	-	9
10						über 15 % bis 40 % ≤ 0,063 mm	GT*				Geschiebelehm	+o	o	+o	++	+o	-	+o	+o	+o	+	–	--	10
11			über 60 %	—	Sand-Schluff-Gemische	5 % bis 15 % ≤ 0,063 mm	SU	weit oder intermittierend gestufte Körnungslinie Feinkornanteil ist schluffig			Tertiärsand	++	+	+	o	o	o	++	o	+o	o	-o	-	11
12						über 15 % bis 40 % ≤ 0,063 mm	SU*				Auelehm Sandlöss	+	o	+o	+	-	–	o	-o	-o	+o	--	--	12
13					Sand-Ton-Gemische	5 % bis 15 % ≤ 0,063 mm	ST	weit oder intermittierend gestufte Körnungslinie Feinkornanteil ist tonig			Terrassensand Schleichsand	+	+o	+o	+o	o	-o	+	+	+o	o	-	–	13
14						über 15 % bis 40 % ≤ 0,063 mm	ST*				Geschiebelehm und -mergel	+o	-o	+o	++	-o	-	o	o	o	+	--	–	14
15	feinkörnige Böden	über 40 %	—	$I_P \leq 4$ % oder unterhalb der A-Linie	Schluff	leicht plastische Schluffe $w_L < 35$ %	UL	niedrige	schnelle	keine bis leichte	Löss Hochflutlehm	-o	-o	+o	+o	--	–	+o	--	-o	o	--	–	15
16						mittelplastische Schluffe 35 % $\leq w_L \leq$ 50 %	UM	niedrige bis mittlere	langsame	leichte bis mittlere	Seeton Beckenschluff	-o	-	-o	+	-	–	o	-	-o	+o	--	--	16
17						ausgeprägt plastische Schluffe $w_L > 50$ %	UA	hohe	keine bis langsame	mittlere bis ausge-prägte	vulkanische Böden Bimsboden	-	-	-	++	-o	-o	-o	-	-	-o	--	--	17

18	feinkörnige Böden	über 40 %	—	$I_P \geq 7$ % und oberhalb der A-Linie	Ton	**l**eicht plastische Tone	$w_L < 35$ %	TL	mittlere bis hohe	keine bis langsame	leichte	Geschiebemergel Bänderton	-o	-o	o	+	-	--	o	-	-o	++	–	--	18
19						**m**ittelplastische Tone	35 % ≤ w_L ≤ 50 %	TM	hohe	keine	mittlere	Lösslehm, Seeton, Beckenton Keuperton	-	-	-o	++	-o	-o	o	-	-o	+	–	–	19
20						**a**usgeprägt plastische Tone	$w_L > 50$ %	TA	sehr hohe	keine	ausgeprägte	Tarras, Lauenburger Ton, Beckenton	–	--	–	++	o	+o	-o	–	-	-	--	–	20
21	organogene[c] und Böden mit organischen Beimengungen	über 40 %	—	$I_P \geq 7$ % und unterhalb der A-Linie	nicht brenn- oder nicht schwelbar	Schl**u**ffe mit **o**rganischen Beimengungen und organogene[c] Schluffe	35 % ≤ w_L ≤ 50 %	OU	mittlere	langsame bis sehr schnelle	mittlere	Seekreide Kieselgur Miutterboden	-o	-	-o	+o	--	–	–	--	–	-	--	–	21
22						**T**one mit **o**rganischen Beimengungen und organogene[c] Tone	$w_L > 50$ %	OT	hohe	keine	ausgeprägte	Schlick, Klei tertiäre Kohletone	–	--	-	++	-o	-o	–	--	–	-	--	–	22
23		bis 40 %		—		grob- bis gemischtkörnige Böden mit Beimengungen **h**umoser Art		OH	Beimengungen pflanzlicher Art, meist dunkle Färbung, Modergeruch, Glühverlust bis etwa 20 % Massenanteil			Mutterboden Paläoboden	o	-o	-o	o	+o	-o	-	o	-	–	--	–	23
24						grob- bis gemischtkörnige Böden mit **k**alkigen, kieseligen Bildungen		OK	Beimengungen nicht pflanzlicher Art, meist helle Färbung, leichtes Gewicht, große Porosität			Kalk-Tuffsand Wiesenkalk	+	o	-o	-o	o	+o	-o	o	-o	–	--	–	24
25	organische Böden	—	—		brenn- oder schwelbar	**n**icht bis mäßig zersetzte Torfe (**H**umus)		HN	an Ort und Stelle aufgewachsene Humusbildungen	Zersetzungsgrad 1 bis 5 nach DIN 19682-12, faserig, holzreich, hellbraun bis braun		Niedermoor-, Hochmoor-, Bruchwaldtorf	-	--	–	o	+o	-	–	--	–	–	--	–	25
26						**z**ersetzte Torfe		HZ		Zersetzungsgrad 6 bis 10 nach DIN 19682-12, schwarzbraun bis schwarz			–	--	–	+o	-	–	–	--	–	–	--	–	26
27						Schlamme als Sammelbegriff für **F**aulschlamm, Mudde, Gyttja, Dy und Sapropel		F	unter Wasser abgesetzte (sedimentäre) Schlamme aus Pflanzenresten, Kot und Mikroorganismen, oft von Sand, Ton und Kalk durchsetzt, blauschwarz oder grünlich bis gelbbraun, gelegentlich dunkelgraubraun bis blauschwarz, federnd, weichschwammig			Mudde Faulschlamm	–	--	–	+o	-	–	–	--	–	–	--	–	27
28	Auffüllung	—	—			Auffüllung aus natürlichen Böden (jeweiliges Gruppensymbol in Klammern)		[ ]	—			—	—												28
29						**A**uffüllung aus Fremdstoffen [d]		A	—			Müll, Schlacke Bauschutt Industrieabfall													29

a Die Spalten 10 bis 21 enthalten als grobe Leitlinie Hinweise auf bautechnische Eigenschaften und auf die bautechnische Eignung nebst Beispielen in Spalte 9. Diese Angaben sind keine normativen Festlegungen.

b An den Kurzzeichen U und T darf anstelle des Sterns auch der Querbalken verwendet werden, siehe Tabelle 3.

c Unter Mitwirkung von Organismen gebildete Böden.

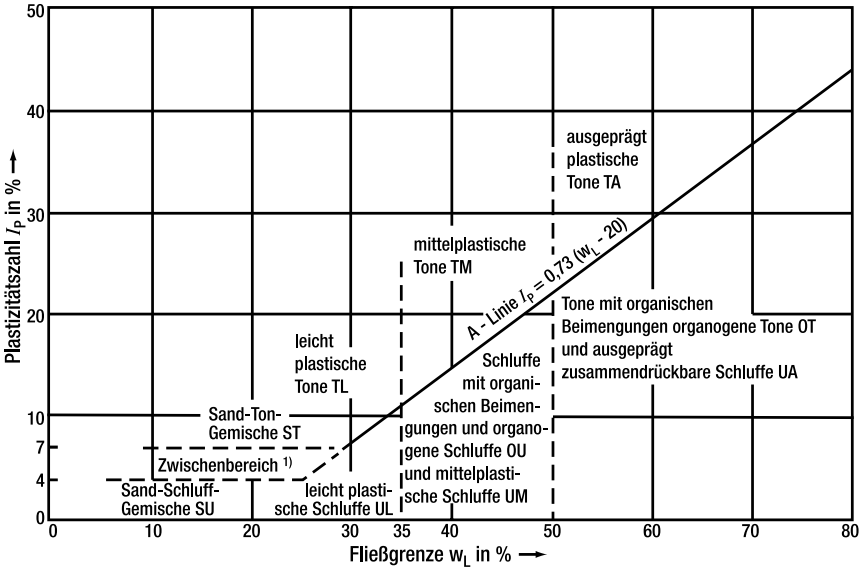
d Die Klassifizierung ist kein Ersatz für die abfalltechnische Bewertung.

Legende: Bedeutung der qualitativen und wertenden Angaben

Spalte 10		Spalte 11		Spalten 12 bis 15		Spalten 16 bis 21	
--	sehr gering	--	sehr schlecht	--	sehr groß	–	ungeeignet
-	gering	-	schlecht	-	groß	-	weniger geeignet
-o	mäßig	-o	mäßig	-o	groß bis mittel	-o	mäßig brauchbar
o	mittel	o	mittel	o	mittel	o	brauchbar
+o	groß bis mittel	+o	gut bis mittel	+o	gering bis mittel	+o	geeignet
+	groß	+	gut	+	sehr gering	+	gutgeeignet
++	sehr groß	++	sehr gut	++	vernachlässigbar klein	++	sehr gut geeignet

Appendix 5.2

Plasticity diagram with soil groups (according to DIN 18196*), June 2006 issue); german version



1) The plasticity index of soils with a low yield point can be determined only inaccurately by testing. Consequently, soils which fall into the intermediate range must be classified by other methods, such as according to DIN 4022, part 1, 09.87, Section 8.5 to Section 8.9, the clay and silt range.

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Appendix 6

Technical regulations

DIN[1)]	VOB/B	Construction contract procedures – Part B: General conditions of contract relating to the execution of construction work – DIN 1961
	VOB/C	Construction contract procedures – Part C: General technical specifications in construction contracts (ATV)
	DIN 1164-10	Special cement – Part 10: Composition, requirements and conformity evaluation for special common cement
	DIN 4020	Geotechnical investigations for civil engineering purposes
	DIN 4030	Assessment of water, soil and gases for their aggressiveness to concrete
	DIN 4123	Excavations, foundations and underpinnings in the area of existing buildings
	DIN 4124	Pits and trenches – slopes, planking and strutting, breadths of working spaces
	DIN 4301	Ferrous and non-ferrous metallurgical slag for civil engineering and building construction use
	DIN 18121	Soil, investigation and testing – water content
	DIN 18125	Soil, investigation and testing – determination of density of soil
	DIN 18127	Soil, investigation and testing – Proctor test
	DIN 18134	Soil – testing procedures and testing equipment – plate load test
	DIN 18196	Earthworks and foundations – soil classification for civil engineering purposes
	DIN 18299	VOB – Part C: General technical specifications in construction contracts (ATV) – General rules applying to all types of construction work
	DIN 18300	VOB – Part C: General technical specifications in construction contracts (ATV) – earthworks
	DIN 18311	VOB – Part C: General technical specifications in construction contracts (ATV) – dredging work
	DIN 18315	VOB – Part C: General technical specifications in construction contracts (ATV) – road construction – surfacings without binder
	DIN 18506	Hydraulic road binders – Composition, specifications and conformity criteria
	DIN 18915	Vegetation technology in landscaping – soil working

Technical regulations – continued

DIN[1)]	DIN 18916	Vegetation technology in landscaping – plants and plant care
	DIN 18920	Vegetation technology in landscaping – protection of trees, plantations and vegetation areas during construction work
	DIN 50929, Parts 1 and 3	Corrosion of metals, probability of corrosion of metallic materials when subjected to corrosion from the outside – Part 1: Corrosion of metals, probability of corrosion of metallic materials when subjected to corrosion from the outside; general – Part 3: Corrosion of metals, probability of corrosion of metallic materials when subjected to corrosion from the outside; buried and underwater pipes and structural components
	DIN EN 197-1	Cement – Part 1: Composition, specifications and conformity criteria for common cements
	DIN EN 197-4	Cement – Part 4: Composition, specifications and conformity criteria for low early strength blastfurnace cements
	DIN EN 459-1	Building lime – Part 1: Definitions, specifications and conformity criteria
DIN[1)2)]	DIN EN 1097-6	Tests for mechanical and physical properties of aggregates – Part 6: Determination of particle density and water absorption
	DIN EN 1367-1	Test for thermal and weathering properties of aggregates – Part 1: Determination of resistance to freezing and thawing
DIN[1)]	DIN EN 13055-2	Lightweight aggregates – Part 2: Lightweight aggregates for bituminous mixtures and surface treatments and for unbound and bound applications
	DIN EN 13249	Geotextiles and related products – required characteristics for use in the construction of roads and other traffic areas
	DIN EN 13251	Geotextiles and geotextile-related products – required characteristics for use in earthworks, foundations and retaining structures
	DIN EN 13252	Geotextiles and geotextile-related products – required characteristics for use in drainage systems
	DIN EN 13253	Geotextiles and geotextile-related products – required characteristics for use in external erosion control systems

DIN[1)]	DIN EN 13254	Geotextiles and geotextile-related products – required characteristics for use in the construction of reservoirs and dams
	DIN EN 13361	Geosynthetic barriers – characteristics required for use in the construction of reservoirs and dams
	DIN EN 14475	Execution of special geotechnical works – reinforced fill
	DIN EN 14933	Thermal insulation and light weight fill products for civil engineering – factory made products of expanded polystyrene (EPS) – specification
	DIN EN 15382	Geosynthetic barriers – characteristics required for use in transportation infrastructure
	DIN EN ISO 9862	Geosynthetics – sampling and preparation of test specimens
	DIN EN ISO 10320	Geotextiles and geotextile-related products – identification on site
	DIN EN ISO 12956	Geotextiles and geotextile-related products – Determination of the characteristic opening size
	DIN EN ISO 14688	Geotechnical investigation and testing – identification and classification of soil
	DIN EN ISO 14689	Geotechnical investigation and testing – identification and classification of rock
	DIN EN ISO 17025	General requirements for the competence of testing and calibration laboratories
	DIN EN ISO 22475	Geotechnical investigation and testing – sampling methods and groundwater measurements
	DIN EN ISO 22476	Geotechnical investigation and testing – field testing
	DIN technical report CEN/TR 15019	Geotextiles and geotextile-related products – on-site quality control
FGSV[2)]	H GeoMess	References on application of geotechnical and geophysical measuring methods in road construction (FGSV 558)
	M Geok E	Information sheet for application of geosynthetics in road construction earthworks (FGSV 535)
		Information sheet for the design and production of grid walls and barriers (FGSV 540)
		Information sheet for compaction of the base and substructure in road construction (FGSV 516)

Technical regulations – continued

FGSV[2)]		Information sheet on using rigid EPS foams in construction of road embankments (FGSV 550)
		Information sheet for simple landscape-adapted safety construction methods (FGSV 229)
	M GUB	Information sheet for geotechnical investigations and calculations in road construction (FGSV 511)
	M TS E	Information sheet on methods of construction for technical protection measures when using soils and building materials containing environmentally relevant constituents in earthworks (FGSV 559)
		Information sheet on soil improvement and soil stabilization with binders (FGSV 551)
		Information sheet on treating soils and building materials with binders to reduce leaching of environmentally relevant constituents (in preparation)
		Information sheet on the influence of the backfill on structures (FGSV 526)
		Information sheet on the bedrock-preserving execution of blasting and removal work on rock slopes (FGSV 537)
		Information sheet on using expanded clay as a lightweight building material in road substructures and bases (FGSV 556)
		Information sheet on descriptions of rock groups for construction engineering purposes in road construction (FGSV 532)
		Information sheet on full-area dynamic procedure to test compaction in earthworks (FGSV 547)
		Information sheet on road construction on ground with low load-bearing capacity (FGSV 542)
	TL BuB E-StB	Technical delivery terms for soils and building materials earthworks in road construction (FGSV 597)
	TL Gestein-StB	Technical delivery terms for aggregates in road construction (FGSV 613)
	TL Geok E-StB	Technical delivery terms for geosynthetics in earthworks road construction (FGSV 549)

FGSV[2)]	TP Beton-StB	Technical test regulations for load-bearing layers with hydraulic binders and concrete road surfaces (FGSV 892)
	TP BF-StB	Technical test regulations for soil and rock in road construction (FGSV 591)
	TP D-StB	Technical test regulations to determine the thicknesses of superstructure layers in road construction (FGSV 974)
	TP Eben – Contact measurements	Technical test regulations for evenness measurements on road surfaces in longitudinal and transverse direction, part: measurements with contact (FGSV 404/1)
	RAS-Ew	Directives for road construction (RAS), part: drainage (FGSV 539)
	RAS-LG	Directives for road construction (RAS), part: landscaping (RAS-LG), section: living material retaining structures (FGSV 293/3)
	RAS-LP	Directives for road construction – part: landscape care (RAS-LP), Section 4: protection of trees, vegetation and animals when carrying out construction works (FGSV 293/4)
	RAS-Q	Directives for road construction (RAS), part: cross-sections (FGSV 295)
	RAP Stra	Directives for accreditation of test centres for building materials and building material mixtures in road construction (FGSV 916)
	RiStWag	Directives for civil engineering measures on roads in water conservation areas (FGSV 514)
	RStO	Directives for standardization of the superstructures of trafficked surfaces (FGSV 499)
	RuA-StB	Directives for the environmentally compatible use of industrial by-products and recycled building materials in road construction (FGSV 642)
	ZTV Beton-StB	Additional technical conditions of contract and directives for the construction of base courses with hydraulic binders and concrete pavements (FGSV 899)
	ZTV Ew-StB	Additional technical conditions of contract and directives for the construction of drainage systems in road construction (FGSV 598)
	ZTV SoB-StB	Additional technical conditions of contract and directives for the construction of layers without binder in road construction (FGSV 698)

Technical regulations – continued

FGSV[2)]	ZTV Verm StB	Additional technical conditions of contract and directives for surveying in road and bridge construction (FGSV 247)
BMVBS[2)]	HVA B-StB	Handbook for awarding and execution of construction contracts in road and bridge construction
	ZTV-ING	Additional technical conditions of contract and directives for civil engineering works
	ZTV La-StB	Additional technical conditions of contract and directives for landscaping in road construction (FGSV 224)
DGGT[3)]	EAG-GTD	Recommendation for the application of geosynthetic clay liners
	EBGEO	Recommendations for geosynthetic reinforcements
DVS[4)]	DVS 2225-1	Joining polymer sealing liners Materials in earthworks and hydraulic engineering – Welding, bonding, vulcanizing
	DVS 2225-2	Joining polymer sealing liners in earthworks and hydraulic engineering – Site inspections
	DVS 2225-3	Joining polymer sealing liners in earthworks and hydraulic engineering – Requirements for welding machinery and equipment
	DVS 2225-4	Joining polyethylene (PE) sealing liners to seal landfill and polluted sites

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