Road and Transportation Research Association

Working Group Concrete Pavements

FGSV

R 1

Additional technical conditions of contract and directives for the construction of base courses with hydraulic binders and concrete pavements

ZTV Beton-StB 07

Edition 2007
Translation 2012

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Working Group Concrete Pavements
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Task Group: ZTV/TL/TP Beton

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Preliminary remark

The “Additional technical conditions of contract and directives for the construction of base courses with hydraulic binders and concrete pavements”, issue 2007 (ZTV Beton-StB 07) were compiled by the task group “ZTV/TL/TP Beton” in the committee “Technical conditions of contract” (chairman: Prof. Dr.-Ing. E g e r).

In combination with the “Technical delivery terms for materials and material mixtures for base courses with hydraulic binders and concrete pavements” (TL Beton-StB 07) and the “Technical testing regulations for base courses with hydraulic binders and concrete pavements” (TP Beton-StB 07) this issue replaces the “Additional technical conditions of contract and directives for the construction of concrete pavements” (ZTV Beton-StB 01) as well as the parts of the “Additional technical conditions of contract and directives for base courses in road construction” (ZTV T-StB 95/02) which contain regulations for base courses with hydraulic binders (Section 3 of ZTV T-StB).

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1 General

1.1 Scope

The “Additional technical conditions of contract and directives for the construction of base courses with hydraulic binders and concrete pavements”, issue 2007 (ZTV Beton-StB 07) contain requirements for the construction of base courses with hydraulic binders and concrete pavement which are to be observed for the production of pavement layers in road construction and other trafficked areas.

The ZTV Beton-StB 07 shall be applied in conjunction with the “Technical delivery terms for materials and material mixtures for base courses with hydraulic binders and concrete pavements”, issue 2007 (TL Beton-StB 07).

The ZTV Beton-StB 07 take into account that the “German construction contract procedures – Part C: General technical specifications in construction contracts” (ATV), in particular the

– ATV DIN 18299 – “General rules applying to all types of construction work” and
– ATV DIN 18316 – “Road construction – surfacings with hydraulic binders”

are part of the construction contract.

ATV DIN 18299 and DIN 18316 are reproduced in Annex H and I.

Further relevant technical regulations are to be observed for special areas of application.

The paragraphs marked with a line at the right margin are “Supplementary Contract Provisions” in conditions of Section 1, No. 2d of the German Construction Contract Procedures VOB Part B – DIN 1961 – whenever the ZTV Beton-StB are part of the construction contract.

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

Paragraphs in small print refer to sections of the German Construction Contract Procedures, Part B or to sections in the ATV DIN 18299 and ATV DIN 18316, respectively.

Building materials and building material mixtures for base courses with hydraulic binders and concrete pavement from other member states of the European Community and goods originating from the member states of the European Economic Area or Turkey that do

not comply with these technical contract provisions but comply with the requirements of the standards specified in the TL Beton-StB, including the tests and inspections carried out in the country of manufacture, shall be regarded as equivalent provided that the required level of protection in regard to health, safety and usability is achieved in an equal and permanent manner.

The abbreviations used and the technical regulations indicated in the text are explained in Annex J.

1.2 Definitions

The pavement is structured as follows: s u p e r s t r u c t u r e
s u b s t r u c t u r e
e a r t h f o u n d a t i o n

Position, boundaries and designations of the individual layers are shown in Figures 1 and 2.

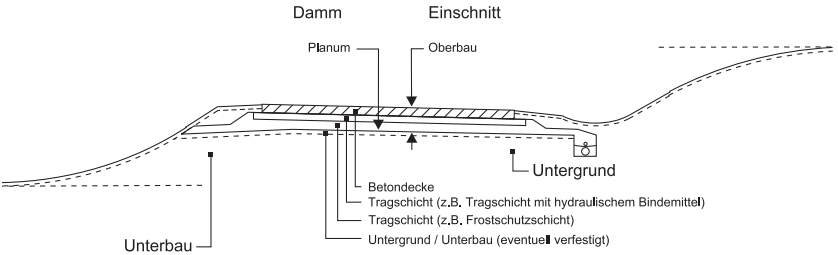


Figure 1: Example of concrete pavement structure outside built-up areas in classified road construction – embankment/cut

Key to figure:
Damm = embankment
Einschnitt = cut
Planum = planum (road bed)
Oberbau = superstructure
Untergrund = earth foundation
Betondecke = concrete pavement
Tragschicht (z.B. Tragschicht mit hydraulischem Bindemittel) = base course (e.g. base course with hydraulic binder)
Tragschicht (z.B. Frostschutzschicht) = subbase (e.g. frost-resistant subbase)
Unterbau = substructure
Untergrund/Unterbau (eventuell verfestigt) = subgrade (possibly stabilized)

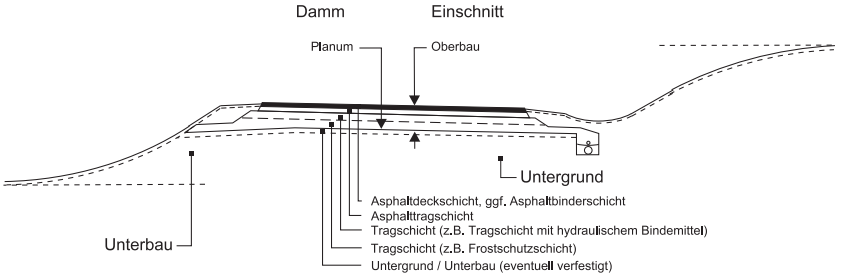


Figure 2: Example of asphalt pavement structure outside built-up areas in classified road construction – embankment/cut

Key to figure:
Damm = embankment
Einschnitt = cut
Planum = planum (road bed)
Oberbau = superstructure
Untergrund = earth foundation
Decke = surfacing/surface course
Asphalttragschicht = asphalt base course
Tragschicht (z.B. Tragschicht mit hydraulischem Bindemittel) = base course (e.g. base course with hydraulic binder)
Tragschicht (z.B. Frostschutzschicht) = subbase (e.g. frost-resistant subbase)
Unterbau = substructure
Untergrund/Unterbau (eventuell verfestigt) = subgrade (possibly stabilized)

The pavement structure can consist of the following:

- asphalt surface course, if applicable with asphalt binder course, concrete pavement, block or slab pavement
- asphalt base course, base course with hydraulic binder (stabilized layer, hydraulically bound base course, concrete base course)
- unbound granular layers

Base courses with hydraulic binders are the following:

- **Stabilized layers**
  Construction method for increasing the resistance of unbound granular base courses to the action of traffic and weather. Hydraulic binders and water are mixed with soil and/or aggregate mixtures using the mix-in-place or mix-in-plant processes. The building material mixture is compacted afterwards. The location of the stabilized layer in the superstructure is shown in Figures 1 and 2.
  - **Mix-in-place process**
    The mixing device operates on the layer prepared for stabilization, scarifying the layer and mixing in the intended binder and necessary water.

- **Mix-in-plant process**
  The soil or the mineral aggregates are mixed with the intended binder and water (mixing water) in stationary mixing plants, transported to the construction site and placed there.

– **Hydraulically bound base courses**
  Hydraulically bound base courses consist of uncrushed and/or crushed aggregate mixtures and hydraulic binders. The grading of the aggregate mixture must be within the specified grading curve region.

– **Concrete base courses**
  Concrete base courses are layers consisting of concrete according to DIN EN 206-1 and DIN 1045-2.

Pavement made of concrete is termed surfacing or concrete pavement below. It is produced from concrete according to DIN EN 206-1 and DIN 1045-2.

– **Concrete pavement**
  Concrete pavement is the upper part of the superstructure. It is supported by the base course or another suitable subgrade.

  The surfacing may be of single or double layer design.

  Double layer design means that the concrete pavement comprises two layers of different composition.

  The upper layer is designated as the upper portion of the concrete slab, the lower layer is designated as the lower portion of the concrete slab.

  Each layer may be placed in single or in multiple course form.

  Multiple course means that concrete of the same composition is placed in several layers.

– **Exposed aggregate concrete**
  Concrete with surface mortar removed in a wet or dry process.

– **Concrete pavement made with superplasticizer**
  Concrete made with superplasticizer is concrete of good workability. Depending on the type of composition, a distinction is made between the following.

  - High early strength pavement concrete with superplasticizer (consistency F2 or C2) and
  - Soft pavement concrete with superplasticizer (consistency F3 or C3).

  Initial concrete is the ready-mixed concrete delivered to the site and to which the superplasticizer has not yet been added.

Concrete with superplasticizer may be placed in single or multiple course form.

1.3 General regulations

See DIN 18316, Section 1.3

1.3.1 Limiting values and tolerances

The limits and tolerances specified in ZTV Beton-StB cover both the scatter during sampling and the confidence interval of the test methods (reproducibility), as well as the variations associated with the production process, unless other provision is made in a particular case.

1.3.2 Tests

1.3.2.1 General

The contractor shall provide the client with the test results obtained in the initial type test according to TL Beton-StB. On the basis of the test results, the contractor shall specify the intended building materials as well as the intended composition and inform the client in good time before construction work starts.

In special cases further initial type tests may be required. If additional requirements are made, these are to be indicated in the service specification.

Tests conducted within the scope of the execution of construction work are distinguished as follows:

- Self-monitoring tests
- Control tests,
- Additional control tests,
- Arbitration tests.

The tests include, if necessary the following:

- Sampling
- Packaging the sample ready for dispatch
- Transporting the sample from the sampling site to the laboratory
- Analysis, including test report.

1.3.2.2 Self-monitoring tests

See DIN 18316, Section 2.2.2

Self-monitoring tests are tests carried out by the contractor or his authorized representative to determine whether the quality char-

acteristics of the building materials, building material mixtures and the end product satisfy contractual requirements.

The contractor shall carry out the self-monitoring tests during execution of the construction work with adequate care and to the required extent. The results are to be logged. If deviations from the contractual requirements are determined, their causes are to be corrected immediately.

The results of the self-monitoring tests are to be presented to the client on request.

The type and scope of the self-monitoring tests are specified in Sections 2.2.5.1, 2.3.3.1, 2.4.3.1 and 3.5.1.

1.3.2.3 Control tests

See DIN 18316, Section 2.2.3

Control tests are tests carried out by the client to ascertain whether the quality of the building materials, building material mixtures and the finished product meet the contractual requirements; acceptance will be based on the results of the control tests. Sampling and on-site testing is carried out by the client in the presence of the contractor. Sampling and testing shall also take place in absence of the contractor if he fails to appear at the notified time.

If, alternatively, sampling and packaging the samples ready for dispatch is carried out by the contractor, these services are to be indicated in the service specification under a special ordinal number. Dispatch of the samples and testing must be carried out by the client or a testing laboratory authorized by the client; the testing laboratory is appointed by the client.

The type and scope of the control tests to be carried out are specified in Sections 2.2.5.2, 2.3.3.2, 2.4.3.2 and 3.5.2. The number of tests may be increased if required (e.g. in municipal road construction).

The results of the joint assessment for invoicing and the results of the self-monitoring tests determined in the presence of the client may be taken into account for the control test if possible and practicable.

1.3.2.4 Additional control tests

If it is to be assumed that the result of a control test is not characteristic of the entire assigned area, the contractor is entitled to demand that additional control tests are carried out. The client and contractor determine together the locations for taking samples and the partial areas to be assigned. If the partial area to be assigned to

the original test cannot be demarcated clearly or demarcated with mutual consent, e.g. following a visual inspection or on the basis of results of radiometric measurement methods, it is not permitted to be smaller than 20 % of the original area.

The right of the client to conduct additional control tests at his own discretion remains unaffected.

Acceptance depends on the results of the original and additional control tests for the partial areas now assigned to these.

The contractor shall bear the cost of any additional control tests he asks to be carried out.

1.3.2.5 Arbitration tests

An arbitration test is the repetition of a control test where the client or contractor has justified doubts that the control test was performed correctly (e.g. on the basis of their own investigations). It shall be undertaken on request of a contracting party by an authorized testing laboratory which did not perform the control test. The result of the arbitration test replaces the original test result.

The cost of the arbitration test plus all additional costs shall be borne by the party disadvantaged by the result.

1.3.2.6 Test methods

See DIN 18316, Section 2.24

1.3.2.6.1 General

For sampling and testing of mineral aggregates, binders, other building materials and admixtures, the methods specified in the appropriate technical specifications for material and standards (see Sections 2.1.1 and 3.2) apply.

By way of exception to the test methods specified in DIN 18316, Section 2.2.4, the “Technical testing regulations for base courses with hydraulic binders and concrete pavements” (TP Beton-StB) apply to sampling and testing of building material mixtures and concrete.

The test methods specified in the “Technical delivery terms for joint fillers in trafficked surfaces” (TL Fug-StB) apply to testing the properties of joint sealing materials.

1.3.2.6.2 Thickness of installed layers

The “Technical testing regulations to determine the thicknesses of superstructure layers in road construction” (TP D-StB) apply.

1.3.2.6.3 True-to-profile position

The true-to-profile position is checked by levelling. The transverse inclination may be checked with an inclinometer.

1.3.2.6.4 Evenness

The “Technical testing regulations for evenness measurements on road surfaces in longitudinal and transverse directions, Part: Measurements with contact” (TP Eben – measurements with contact) apply.

The evenness of base courses with hydraulic binders and concrete pavement is tested with a 4 m straightedge or an adequate device for measuring evenness. The longitudinal measurement is to be performed in the centre of the traffic lanes and the shoulders. The largest deviation from the limiting value is considered as the measure of exceedance of the maximum permissible unevenness, irrespective of its length.

1.3.2.6.5 Skid resistance

The “Technical testing regulations for skid resistance measurements in road construction, Part: Sideways force measurement (SKM)” (TP Griff-StB (SKM)) apply to the control testing of skid resistance.

Testing of concrete pavement for acceptance is to be conducted no sooner than 4 weeks after opening for traffic.

The “Technical testing regulations for skid resistance measurements in road construction, Part: Skid resistance measurement (SRT)” (TP Griff-StB (SRT)) apply to tests using the combined test method – SRT-skid resistance tester / outflow measurement.

1.3.3 Construction principles

1.3.3.1 Superstructure for trafficked areas

See DIN 18316, Sections 3.3.1.4, 3.3.2.4, 3.3.3.4 or 3.3.4.8

Base courses and surfacings are components of the frost-resistant superstructure. The required thicknesses of the individual layers and the entire structure are based on the “Directives for the standardization of the superstructures of trafficked surfaces” (RStO). The construction class is to be specified in the service specification.

If other layer thicknesses are required for technical and functional reasons, these are to be specified. The minimum thicknesses required for certain construction methods as specified in Sections 2.2.1, 2.3.1 and 2.4.1 are to be observed.

When producing layers, the true-to-profile position, the intended transverse slope and the geometric dimensions are to be observed.

The building materials and building material mixtures must comply with the “Technical delivery terms for materials and material mixtures for base courses with hydraulic binders and concrete pavements” (TL Beton-StB).

Each layer or course is to be produced in such a way that its quality characteristics are uniform and fulfil all requirements.

During construction of the layers, the order of the individual procedures must be carried out rapidly. The work and the number of devices required are to be coordinated appropriately.

1.3.3.2 Subgrade

See DIN 18316, Section 3.2

The subgrade is the structure beneath the layer to be laid.

The construction of layers in accordance with the “Supplementary technical contract provisions and guidelines for the construction of base courses with hydraulic binders and concrete pavements” (ZTV Beton-StB) presumes a suitable subgrade. In particular, it must be stable, capable of bearing loads, true-to-profile and even. These conditions are regarded as satisfied if the subgrade of the layer to be constructed fulfils the requirements of the appropriate technical conditions of contract.

If the subgrade does not fulfil the requirements of the appropriate technical contract conditions, provision is to be made for special measures.

Effective drainage systems must be available and adapted as construction work progresses. It is to be ensured by suitable measures that no water accumulates on the subgrade.

Further drainage systems may be necessary in the region of troughs for construction methods with fully bound superstructures as well as for restoration and widening measures.

In the case of fully bound superstructure, both sides of the base course or the stabilized subgrade (substructure or earth foundation) are to be provided with drainage systems. This includes the central reservation for carriageways in one particular direction.

Drainage systems must be protected against damage and maintained in an operational state.

Base courses and pavements are not to be constructed on saturated or frozen subgrades.

Deviations from evenness, values below target thickness, target height or transverse inclination of the subgrade are to be compensated by the layer directly above.

1.3.3.3 Edge design

The edges of base courses must be scarped unless kerb stones are present. In this process, the individual layers shall be widened according to the overlying layers.

The minimum dimensions [cm] indicated in Figures 3 to 7 apply to the construction of edges using different construction methods.

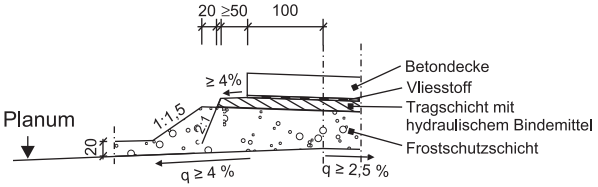


Figure 3: Edge design of concrete pavement on base course with hydraulic binder

Key to diagram:
Planum = planum
Betondecke = concrete pavement
Vliesstoff = non-woven fabric
Tragschicht mit hydraulischem Bindemittel = base course with hydraulic binder
Frostschutzschicht = frost-resistant subbase

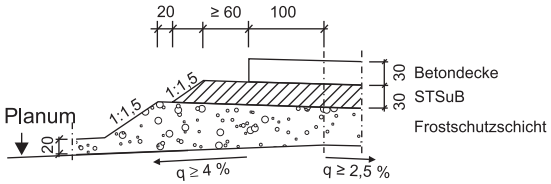


Figure 4: Edge design of concrete pavement on unbound crushed stone base course (STSuB)

Key to diagram:
Planum = planum
Betondecke = concrete pavement
STSuB = unbound crushed stone base course
Frostschutzschicht = frost-resistant subbase

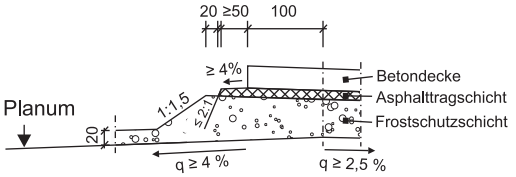


Figure 5: Edge design of concrete pavement on asphalt base course

Key to diagram:
Planum = planum
Betondecke = concrete pavement
Asphalttragschicht = asphalt base course
Frostschutzschicht = frost-resistant subbase

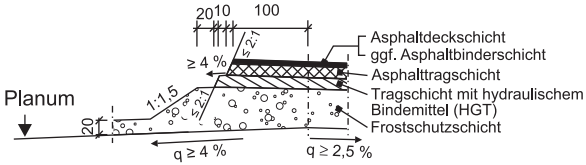


Figure 6: Edge design of asphalt pavement on base course with hydraulic binder

Key to diagram:
Planum = planum
Asphaltdeckschicht = asphalt surface course
Asphaltbinderschicht = asphalt binder course
Asphalttragschicht = asphalt base course
Tragschicht mit hydraulischem Bindemittel = base course with hydraulic binder
Frostschutzschicht = frost-resistant subbase

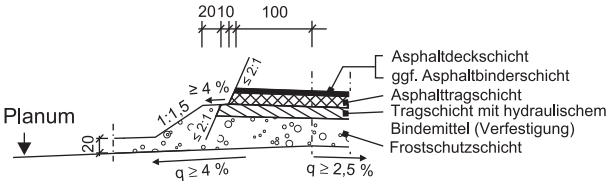


Figure 7: Edge design of asphalt pavement on stabilized base course with hydraulic binder

Key to diagram:
Planum = planum
Asphaltdeckschicht = asphalt surface course
Asphaltbinderschicht = asphalt binder course
Asphalttragschicht = asphalt base course
Tragschicht mit hydraulischem Bindemittel = base course with hydraulic binder (stabilization)
Frostschutzschicht = frost-resistant subbase

2 Base courses with hydraulic binders

2.1 General regulations for base courses

2.1.1 Building materials, building material mixtures and mixtures for placement

See DIN 18316, Section 2

The “Technical delivery terms for materials and material mixtures for base courses with hydraulic binders and concrete pavements” (TL Beton-StB) apply to the requirements. The results of the initial type tests must be presented to the client.

On request, samples of all building materials designated for the construction work shall be handed over to the client who effects tests in the scope of control testing or keeps these under lock and key (retained samples). The samples are to be approved by the contractual parties in a record.

2.1.2 Placement conditions

Building material mixtures with a temperature below +5 °C must not be worked with. If subzero temperatures are anticipated during the first 7 days following construction of the base course, the layer is to be suitably protected to avoid damage.

Before placement of the base course, the subgrade is to be moistened if it is feared that the water necessary for hardening will be removed from the building material mixture.

Before placement of connecting strips, loose components of a hydraulically bound base course which has already hardened are to be removed.

Further layers or courses may be placed upon the base course, provided no impermissible deformation of the base course results during placement and provided the water needed for hardening is not removed from the base course in a quantity which may cause damage.

In the exceptional case that road construction materials containing tar are stabilized in a mix-in-place procedure, the edging has to be carried out with particular care. Loose excess mixture at the edging is to be returned to the mixing cycle.

Additionally, it may be practicable to carry out the edging with a minimum width of 50 cm using reclaimed road construction materials which contain no tar or to carry out the edging as an asphalt base course.

Measures for protecting the edging against penetrating surface water are always to be taken.

2.1.3 Notches

See DIN 18316, Sections 3.3.1.3, 3.3.2.3 or 3.3.3.3

Base courses with hydraulic binders are produced with or without notches. If produced with notches, the base course is to be notched in a fresh state.

The depth of notches must be at least 35% of the intended placement thickness of the base course.

Notches in the transverse direction are to be formed by vibrating into place or sawing spaced at no more than 5 m. Joints to existing layers are to be carried out in a straight line and at right angles.

The arrangement of notches in longitudinal and transverse directions in the base course depends on the method of construction of the overlying layer.

If a base course is not notched in the fresh state, it is to be ascertained whether specific measures for cracking the base course are necessary before the next layer is laid. Proof of the effectiveness of the measures is to be provided.

Such measures may include, for example, the following:

- *Cutting notches at maximum spacing of 5 m*
- *Removing stress by using vibrating rollers*
- *Removing stress by using a drop blade at intervals of approximately 1.50 m, for thicknesses of the base course with hydraulic binder > 20 cm*

2.1.3.1 Notches beneath concrete pavement

If the concrete pavement is directly supported by the base course, notches are to be placed in accordance with the joint layout of the pavement.

Deviations up to 10 cm are not to be objected to.

Notches shall not be carried out if a non-woven fabric is placed between a base course with hydraulic binder and the concrete pavement.

2.1.3.2 Notches beneath asphalt layers

See DIN 18316, Sections 3.3.1.3, 3.3.2.3 or 3.3.3.3

Base courses under asphalt layers are to be notched. Proof of the effectiveness of the measure is to be provided.

In the transverse direction in cases where the total thickness of the asphalt is ≥ 14 cm, the spacing between the notches is not to exceed 5 m.

In following cases the spacing between the notches must not exceed 2.50 m:

– Total thickness of asphalt layers < 14 cm
– Stabilized layers with narrow-graded material according to DIN 18196

In the longitudinal direction, notches are to be placed in dependence of the spacing between the notches in the transverse direction, carriageway width and positions of the traffic lanes. A length-width ratio of 1.5 shall not be exceeded. Longitudinal paving joints are to be treated in principal like longitudinal notches.

2.1.4 Curing

See DIN 18316, Sections 3.3.1.1, 3.3.2.1 or 3.3.3.1

Base courses with hydraulic binders are to be cured. Curing is not required if, immediately following production, the course is covered with a further layer or course.

The type of curing is to be indicated in the service specification. Subsequent measures may be planned for curing.

In the case of asphalt coverings, options involving bitumen emulsion are preferential.

In the case of reclaimed materials containing tar, the layers must not be cured using water. Special measures are to be taken to prevent drying instead.

Early placement of the overlying layer is recommended. If this is not possible, a solvent-free bitumen emulsion covering is to be evenly sprayed on the entire surface and which is then gritted.

2.1.4.1 Wet curing

Base courses with hydraulic binders are to be kept continuously moist for at least three days.

2.1.4.2 Spraying with bitumen emulsion

A solvent-free bitumen emulsion C60B1-N according to the “Technical delivery terms for bitumen emulsions” (TL BE-StB) is to be sprayed evenly onto the compacted, slightly moist, glossy base course in such a way that a thin, sealed film results. The quantity to be applied is to be determined in preliminary tests depending on the surface structure of the base course.

As a rule, this quantity is 0.5 kg/m².

2.1.4.3 Spraying with bitumen emulsion and gritting with crushed aggregates

If the sprayed layer is subjected to the action of vehicles at an early stage, the surface cured in accordance with Section 2.1.4.2 has to be gritted with a coarse aggregate 2/5 mm before the bitumen emulsion breaks. The grit is to be embedded using rollers.

2.1.4.4 Application of water-retaining cover

The compacted base course is to be covered with a water-retaining covering e.g. burlap, sacking. The cover must be kept moist for at least three days.

2.1.5 Protecting base courses

If surface water is able to penetrate the bound base course at the elevated edge, countermeasures such as spraying the edge area with hot bitumen are to be taken.

If base courses are directly subjected to traffic for an extended period, or are to remain open over winter, provision is to be made for protective measures where necessary.

2.1.6 Requirements

The requirements apply irrespective of the construction class. This is regulated in detail in Annex A.

When using road building materials containing tar, the compressive strength of each individual specimen should not exceed 10 MPa after 28 days.

2.2 Stabilized layers

2.2.1 Building materials, building material mixtures and mixtures for placement

In the case of road building materials containing tar, the mass fraction < 2 mm of the original material mixture shall not exceed or be below the value in % by weight determined in the initial type test by more than 8.0 wt.%.

2.2.2 Construction principles

For structural reasons, the minimum thickness of each stabilized layer after compaction must be as follows:
– Mix-in-place process 15 cm
– Mix-in-plant process 12 cm

Depending on the maximum grain size, the minimum layer thickness must also be specified for the following.

– Building material mixture 0/32 at least 12 cm
– Building material mixture 0/45 at least 15 cm
– Building material mixture > 0/45 at least 20 cm

2.2.3 Execution

See DIN 18316, Section 3.3.1

2.2.3.1 Production of stabilized layers

Stabilization is not to be performed using frozen soil and/or frozen mixtures of aggregates. If ground frost is anticipated during the first 7 days after finishing construction work, work is to be stopped unless special measures are provided.

The terminal edge at the end of working phases or days is to be finished vertically.

2.2.3.1.1 Mix-in-place process

The course to be stabilized is to be levelled taking into account the effect of mixing in the binder and compacting regarding the height of the target profile. The course is to be compacted and profiled so that the required degree of compaction and evenness are achieved. The amount of water used for construction is to be determined on the basis of the results of the suitability test so that the optimum water content of the course to be stabilized is not exceeded and the required degree of compaction is achieved.

The binder is to be spread uniformly and mixed homogeneously using machines until the building material mixture is uniform in colour.

The equipment and processes for distributing water and binder, for mixing the binder with the course to be stabilized and for the compaction of the building material mixture are to be selected and coordinated so that stabilization is carried out continuously over the entire cross section within the period of workability of the mixture.

If single adjacent strips are stabilized, stabilization work is to be carried out fresh on fresh. The finished adjacent strip is to be milled to a minimum overlap of 20 cm and compacted together with the connecting strip.

2.2.3.1.2 Mix-in-plant process

The building material mixture is to be transported and placed uniformly so that segregation does not occur and the required evenness and layer thickness as well as the required degree of compaction is achieved.

Generally, the mixture is to be placed by paver.

In the case of smaller areas, at locations with complex profiling of trafficked areas or numerous construction units, the building material mixture may also be placed without using pavers.

2.2.4 Binder quantity

See DIN 18316, Section 3.3.1.2

The quantity of binder in a mixed-in-place stabilization beneath concrete and asphalt pavements shall not exceed the value specified in the suitability test by more than 8 %, or fall short of the value by more than 5 % (both relative quantities).

The binder content is considered to be the arithmetic mean of all individual test results of the binder content of the stabilized course over the entire contract area.

Regardless of the arithmetic mean, single test results must be below the desired value relating to the section assigned to the single test by more than 10 % or exceed the desired value by more than 15 % (relative amounts).

2.2.5 Type and scope of tests

2.2.5.1 Self-monitoring tests

Type and scope of the self-monitoring tests are specified in Annex C.

2.2.5.2 Control tests

Type and scope of the control tests are specified in Annex C.

2.3 Hydraulically bound base course

2.3.1 Construction principles

In the compacted state, the minimum installed layer thickness of each layer, depending on the maximum grain size of the building material mixtures, is as follows.

– Building material mixtures 0/32 12 cm
– Building material mixtures 0/45 15 cm

2.3.2 Execution

See DIN 18316, Section 3.3.2

The building material mixture shall be transported and placed uniformly so that segregation does not occur and the required evenness and layer thickness as well as the required degree of compaction is achieved.

Generally, the mixture shall be placed with pavers.

In the case of smaller areas, locations with complex profiled trafficked areas or areas with numerous installations, the building material mixture may also be placed without using pavers.

2.3.3 Type and scope of tests

2.3.3.1 Self-monitoring tests

Type and scope of the self-monitoring tests are specified in Annex D.

2.3.3.2 Control tests

Type and scope of the control tests to be carried out are specified in Annex D.

2.4 Concrete base courses

2.4.1 Construction principles

In the compacted state, the minimum placement thickness of each layer must be 12 cm. If immersion vibrators are used for compaction, the minimum placement thickness must be 15 cm.

Construction joints are to be produced as butt joints. Expansion joints are to be positioned at connections with structures and around installations.

In the case of asphalt pavement on concrete base courses, special measures are to be taken to avoid reflective cracking in the pavement, e.g. arranging joints in the pavement directly above the notches of the concrete base course.

2.4.2 Execution

See DIN 18316, Section 3.3.3

If air temperatures below +5 °C or above +25 °C are anticipated during concreting, measures according to Sections 3.3.1.7 or 3.3.1.8 are required. Fresh concrete with a temperature exceeding +30 °C must not be used.

The equipment for conveying, spreading and placing the concrete is be chosen suitably so that segregation of the concrete does not occur and the concrete is placed and finished before setting begins.

Generally, the concrete is to be placed with pavers.

In the case of smaller areas, at locations with complex profiled trafficked areas or areas with numerous installations, the building material mixture may also be placed without using pavers.

The concrete must be compacted uniformly and completely.

2.4.3 Type and scope of tests

2.4.3.1 Self-monitoring tests

Type and scope of the self-monitoring tests are specified in Annex E.

2.4.3.2 Control tests

Type and scope of the control tests to be carried out are specified in Annex E.

3 Concrete pavement

3.1 Construction principles

3.1.1 Subgrade

The edge of the subgrade beneath the concrete pavement is to be constructed according to Section 1.3.3.3.

Before placing the concrete, loose parts of the bound base course are to be removed and the subgrade cleaned and freed from any contamination. Loose constituents in unbound base courses are to be embedded using a light roller.

The subgrade is to be moistened if it is feared that water will be extracted from the fresh concrete.

During the production of the pavement, no water shall accumulate on the subgrade. Surface water should be removed or drained without negative effects. The “Additional technical conditions of contract and directives for the construction of drainage systems in road construction” (ZTV Ew-StB) regulate this in detail.

Section 2.1.3 applies for the position of notches in base courses.

Crushed stone road bases under concrete pavement and frost-resistant layers are to be produced in accordance with the “Addi-

tional technical conditions of contract and directives for the construction of layers without binder in road construction" (ZTV SoB-StB).

3.1.2 Intermediate layer of non-woven fabrics

Non-woven fabrics shall fulfil the requirements of the "Technical delivery terms for materials and material mixtures for base courses with hydraulic binders and concrete pavements" (TL Beton-StB).

Non-woven fabrics are to be laid along the carriageway axis shortly before placing the concrete according to the requirements in Annex B.

The sheets of non-woven fabrics shall be driven on by site traffic as little as possible.

Sharp turning, hard braking and accelerating of vehicles is not permitted on non-woven fabrics.

The non-woven fabrics are to be moistened before placement of the concrete. This process may not be necessary if the installed non-woven fabrics are already moist as a result of the climatic conditions.

3.1.3 Thickness of concrete pavements

For structural reasons, the total thickness of the concrete pavement must be at least 10 cm in the compacted state. In the case of double or multi-layered concrete placement, the minimum thickness of each course or layer shall be at least three times the maximum aggregate particle diameter of the chosen grading. It is to be rounded up to the nearest full centimetre. However, the thickness of the compacted topmost layer must be at least 5 cm.

3.1.4 Joints

See DIN 18316, Section 3.3.4.4

The pavement is divided into slabs by joints in order to achieve controlled cracking and to compensate changes in length. A distinction is made between dummy, expansion or construction joints.

Dummy joints are predetermined breaking points in the concrete pavement produced by notches in the pavement surface.

A protective inlay may be pressed into cut transverse dummy joints to prevent foreign bodies penetrating the crack before installing the joint filling.

Expansion joints separate the slabs from each other over their entire thickness, a wide, preformed gap enables slab expansion.

In the case of expansion joints, inlays remaining in the pavement must not restrict the expansion of the slabs. They must be straight and sufficiently stiff so that they do not deform on compaction of the concrete. The thickness of the joint inlay shall be 18 mm.

Construction joints separate the slabs from each other over their entire thickness but, in contrast to expansion joints, do not provide any space for the slabs to expand.

The joints are to be made to fit closely.

Details regarding the design of joints are specified in the "Additional technical conditions of contract and directives for joints in trafficked areas" (ZTV Fug-StB).

3.1.4.1 Joint positions

For the specification of the joint positions by the contractor, a marking plan shall be enclosed in the tender documents.

A combined joint and marking plan which determines the arrangement of both tasks shall be drawn up for the work. Longitudinal joints must not be located in the region of wheel tracks. The plan is to be presented to the client.

Transverse joints generally run at right angle to the axis of the road. In the vicinity of buildings, they may also be inclined to the road axis (see Figures 18 and 19).

As a rule, the dimensions of slabs should not exceed 25 times the thickness of the slab (30 times the thickness in the case of square slabs). The edge length must not exceed 7.50 m.

In tunnel sections, the slab dimensions should generally not exceed 20 times the slab thickness.

In case of slabs with a width to length ratio less than 0.4 an upper layer of steel reinforcement according to Section 3.1.5. is to be installed.

Transverse joints along longitudinal joints are not to be positioned with an offset against each another in the longitudinal direction.

Concrete pavement is usually produced without expansion joints.

At connections with bridges or other structures which extend across the entire width of the carriageway and which should not be subjected to large forces in the longitudinal direction, provision is to be made for at least 2 consecutively dowelled expansion joints with pliable inlays. Expansion joints are not necessary if an asphalt pavement with a minimum length of 15 m between the concrete pavement and the structure is planned (see Section 3.1.6).

Permanent installations (e.g. drainage systems, road gullies, manholes) are to be avoided whenever possible. If they have to be installed, they are always to be separated from the pavement by expansion joints.

Due to the risk of fracture, gussets or pointed slab parts should be avoided. This also applies to slabs with strongly curved edges with regard to avoiding restraint of the free expansion of the pavement.

If gussets or acute-angled slabs parts cannot be avoided, these slabs are to be reinforced in the middle with at least 3 kg/m² of reinforcing steel to limit crack widths.

On parking areas, the slabs should match the parking spaces as far as possible.

3.1.4.2 Dowels and anchors

See DIN 18316, Sections 3.3.4.5 and 3.3.4.6

Generally, dowels are to be placed along transverse joints for load transmission and to ensure that slabs remain at the same level. Anchors are to be placed alongside longitudinal joints to prevent the slabs from moving apart.

Provision is always to be made for dowels and anchors in lanes and hard shoulders for pavement of construction classes SV, I to III.

The requirements for all types of dowels and anchors are specified in the "Technical delivery terms for materials and material mixtures for base courses with hydraulic binders and concrete pavements" (TL Beton-StB).

The spacing between dowels is usually 25 cm. The spacing between the outer dowels and the edge of the slab or the longitudinal joint is 25 cm.

The spacing between dowels may be doubled between wheel tracks and on less trafficked lanes (e.g. overtaking lanes and hard shoulders). If necessary, future use of the hard shoulder as a traffic lane is to be taken into consideration.

Examples of possible dowel distributions, joint positions and markings for different lane widths and traffic loads are shown in Figure 8. For concrete pavement with a joint in the centre between the lanes, the joint is shifted to the left away from the edge of the dividing line in the direction of travel by half a line's width according to Figure 9.

In the case of pavement structures of construction classes SV and I on crushed stone base courses, the dowels must be spaced according to Figure 8, detail B1.

The design is to be declared in the service specification. Expected future traffic loading due to long-term or alternative traffic routeing is to be taken into account.

Acceleration and exit lanes are to be doweled depending on the traffic loading according to design A or B1 respectively.

For trafficked areas with traffic flow in longitudinal and transverse directions, the joints are to be made in a way that enables movement of the slabs and transmission of loads in both directions.

Anchors are to be employed in longitudinal construction joints to connect adjacent traffic lanes or slabs.

This can be achieved by threaded tie bars or composite (chemical) anchors.

The letters in this figure indicate the following:
Design A: less trafficked lanes
Design B: heavily trafficked lanes (B2 not in the right-hand lane)
Design C: hard shoulders

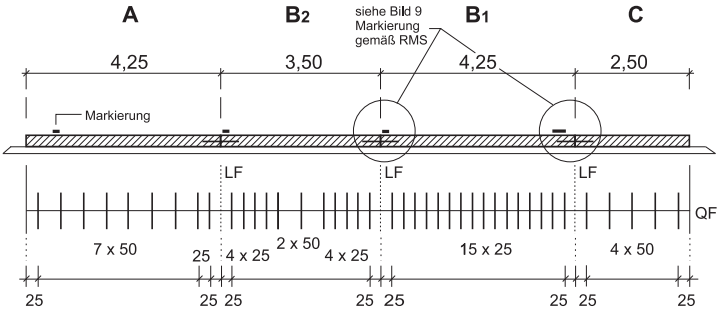


Figure 8: Joint and marking layout in cross section with example for distribution of dowels

Key to diagram:
siehe Bild 9 Markierung gemäß RMS = See Figure 9, marking according to RMS
Markierung = marking
LF = longitudinal joint
QF = transverse joint

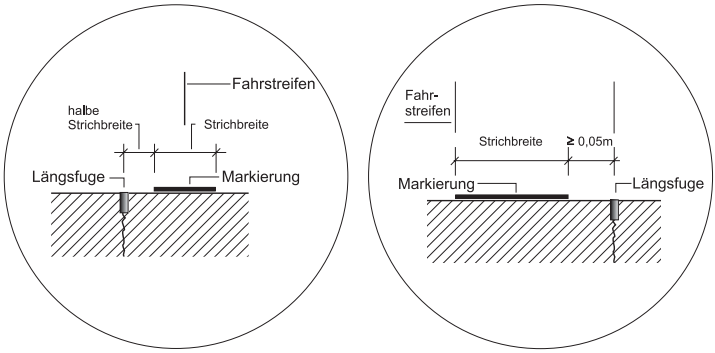


Figure 9: Details of marking along central longitudinal joint (left) and longitudinal joint to the hard shoulder (right) according to RMS 2

Key to diagram:
halbe Strichbreite = half a line's width
Strichbreite = line width
Längsfuge = longitudinal joint
Markierung = marking
Fahrstreifen = lane

Anchor bolts must be suitably designed with regard to the construction of the joint to ensure a firm and durable connection.

The drill hole diameter for positioning chemical anchors is 28 mm and the minimum depth 25 cm. An adhesive cartridge M 24 is to be used as the adhesion system. Proof of the pull out strength is to be provided by tensile tests with a minimum tensile force of 80 kN.

Other bonding systems may be used if proof is provided that they provide the same durable suitability.

In longitudinal joints on straight sections, 3 anchors per slab are to be placed at equal spacing a. The distance to transverse joints shall usually be a/2. In curves with radii up to 600 m, the same number of anchors are to be placed, but only in the central third of the slab's length.

In the case of pavement of construction classes SV, I to III, the number of anchors in longitudinal construction joints is to be increased to 5 per slab in order to transfer load.

In the case of pavement of construction classes SV, I to III on crushed stone base courses (STSuB), 5 anchors per slab shall be placed with equal spacing a in longitudinal joints. The distance to transverse joints shall, as a rule, be a/2.

3.1.5 Reinforcing steel

See DIN 18316, Sections 2.1.7 and 3.3.4.3

Reinforcing steel is only to be used in end regions and in special cases, e.g. slab length more than 25 times the pavement thickness (or 30 times in the case of square slabs), or if uneven settlement of the subgrade is expected.

Acute-angled slabs (< 80^{gon}) are to be reinforced with steel.

If upper layers of reinforcing steel are planned, the quantity of steel used in pavements of construction classes SV, I to III, must be at least 3 kg/m² (and at least 2 kg/m² in pavement of other construction classes).

In the case of reinforcement with steel mesh fabrics, the fabric must overlap by 2 mesh widths or overlap by at least 20 cm in the longitudinal direction. In the transverse direction, overlapping by one mesh width is sufficient.

In case of exceptional loads, e.g. parking areas for lorries, additional lower layers of reinforcing steel may be placed.

3.1.6 End regions

Provision is to be made for suitable measures to fix the end slab of the pavement, e.g. at the transition to asphalt pavement.

For concrete pavement on bound base courses, such measures may be the following.

- *Increasing the thickness of the end slab by at least the thickness of the bound base course*
- *An end spur*

The thickness of end concrete pavement slabs on non-woven fabrics is to be increased by at least the thickness of the bound base course. The intermediate layer of non-woven fabric ends before the strengthened slab.

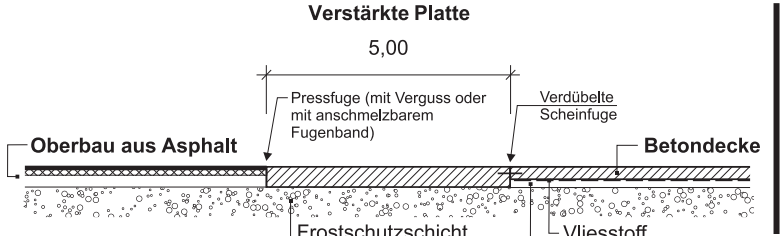


Figure 10: Example of end slab with increased thickness

Key to diagram:
Verstärkte Platte = strengthened slab
Oberbau aus Asphalt = asphalt superstructure
Pressfuge (mit Verguss oder mit anschmelzbarem Fugenband) = construction joint (with sealing or a water stop fixed by fusing)
verdübelte Scheinfuge = dowelled dummy joint
Betondecke = concrete pavement
Frostschutzschicht = frost-resistant subbase
Vliesstoff = non-woven fabric
Tragschicht mit hydraulischem Bindemittel = base course with hydraulic binder

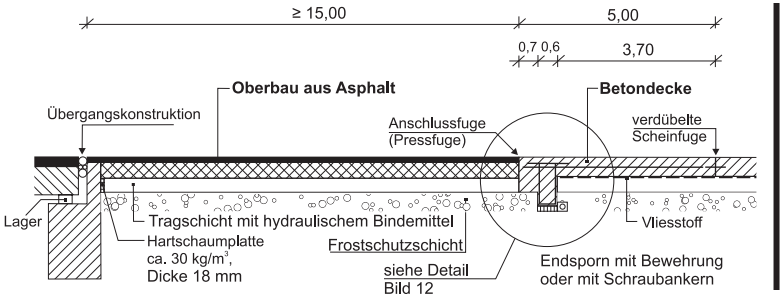


Figure 11: Example of end slab with end spur

Key to diagram:
Oberbau aus Asphalt = asphalt superstructure
Betondecke = concrete pavement
Übergangskonstruktion = transition structure
Anschlussfuge (Pressfuge) = connection joint (construction joint)
verdübelte Scheinfuge = dowelled dummy joint
Lager = bearing
Tragschicht mit hydraulischem Bindemittel = base course with hydraulic binder
Vliesstoff = non-woven fabric
Hartschaumplatte ca. 30 kg/m^3, Dicke 18 mm = rigid foam slab approx. 30 kg/m^3, thickness 18 mm
Frostschutzschicht = frost-resistant subbase
Siehe Detail Bild 12 = see Figure 12 for details
Endsporn mit Bewehrung oder mit Schraubankern = end spur with reinforcement or anchor bolts

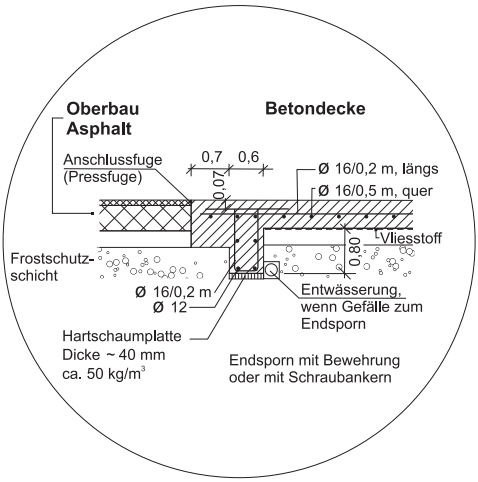


Figure 12: End spur in detail

Key to diagram:
Oberbau aus Asphalt = asphalt superstructure
Betondecke = concrete pavement
Anschlussfuge (Pressfuge) = connection joint (construction joint)
längs = longitudinal
quer = transverse
Vliesstoff = non-woven fabric
Frostschutzschicht = frost-resistant subbase
Entwässerung, wenn Gefälle zum Endsporn = drainage in case of inclination towards the end spur
Hartschaumplatte, Dicke ~ 40 mm, ca. 50 kg/m^3 = rigid foam slab, thickness ~ 40 mm, approx. 50 kg/m^3
Endsporn mit Bewehrung oder mit Schraubankern = end spur with reinforcement or anchor bolts

It is necessary to increase the thickness of end slabs of concrete pavement on crushed stone base courses to at least 40 cm. The transition is to occur over the length of the last but one slab.

If the concrete pavement has to be secured on inclinations or in front of bridges on inclines (with a longitudinal gradient > 3.5 % over a length > 300 m) at least 2 end spurs are to be planned. The last but one end spur should be installed at a distance of 300 m above the bridge.

End sections with end slab of increased thickness may be designed according to Figure 10 or Figures 11 and 12 in the case of an end spur.

3.1.7 Acceleration and exit lanes

Acceleration and exit lanes should be constructed with concrete up to the full cross section of the ramp in order to avoid end sections in the hard shoulder.

3.1.8 Concrete pavements on bridges

In the case of bridges without transition structures or bearings, concrete pavement is to be produced over the structure with the thickness of the construction class of the connecting pavement section (Figures 14 and 16).

Gullies must be avoided on bridges.

If the pavement cannot be produced across the structure with the same thickness as the connecting section, the thickness of the pavement on the bridge may be reduced by at most 15 %. If the pavement thickness no longer corresponds to the construction class according to Table 2, line 1.1, of the "Directives for the standardization of the superstructures of trafficked surfaces" (RStO), the pavement must be reinforced with steel.

At abutments, an expansion joint insert (rigid foam slab) is to be placed at least at the height resulting from the difference in thickness of the connecting pavement and additionally, where applicable, the thickness of the hydraulically bound base course (see Figures 15 and 17).

If in case of the construction type "concrete pavement on crushed stone base course (STSuB)" of construction class SV, the pavement thickness on the bridge is reduced to 27 cm (not reinforced) then the effect of longitudinal forces on the abutment is be avoided by placing an expansion joint insert (rigid foam slab) of at least 3 cm thickness at the thickness offset (see Figures 16 and 17). The same applies for pavement of other construction classes.

Transverse joints in the abutment region are to be produced in accordance with the location of the superstructure. In the case of concrete pavement on structures, the oblique course taken by the joints may be retained or adapted according to Figure 19. Acute-angled slabs (< 80^{gon}) are to be reinforced.

Transverse joints on the structure und in the region of abutments are to be sealed in accordance with the "Additional technical conditions of contract and directives for joints in trafficked areas" (ZTV Fug-StB).

Sealing of the bridge is to be performed in accordance with the "Additional technical conditions of contract and directives for civil

engineering works" (ZTV-ING). To reduce the amount of friction, a separating layer of non-woven fabric is to be installed between the different building materials of the protective layer and the concrete pavement. Damage to the protective and the sealing layer must be avoided when securing the non-woven fabric.

The dead weight of the concrete pavement must be accounted for in the structural design of the bridge. According to current standards, constructions thicknesses between 27 cm and 34 cm result, depending on the construction class (including 4 cm protective and sealing layer).

If, contrary to the original design, the connecting superstructure is an asphalt pavement, the remaining thickness for adjustment on the structure may also be constructed using asphalt. The asphalt base course then serves for height compensation.

An example of the structural design is shown in Figures 13 to 19.

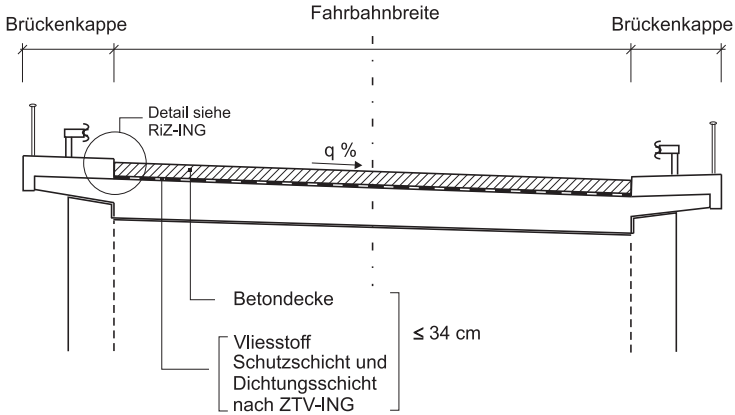


Figure 13: Concrete pavement on bridge deck – cross section

Key to diagram:
Brückenkappe = bridge deck edge beam
Fahrbahnbreite = carriageway width
Detail siehe RiZ-ING = Refer to the "Reference drawings for civil engineering works" RiZ-ING
Betondecke = concrete pavement
Vliesstoff = non-woven fabric
Schutzschicht und Dichtungsschicht nach ZTV-ING = protective and sealing layers according to the "Additional technical conditions of contract and directives for civil engineering works" ZTV-ING

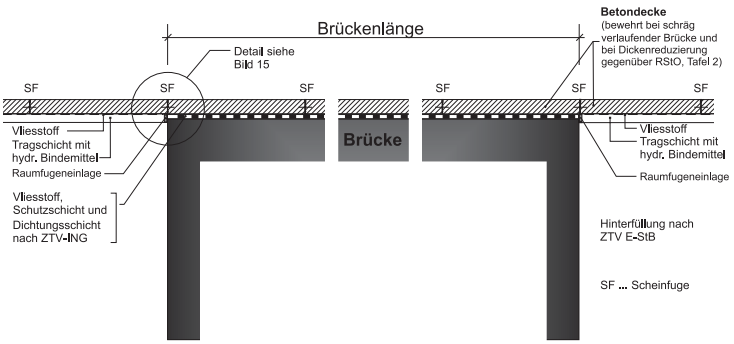


Figure 14: Concrete pavement on bridge without transition structure in the case of base course with hydraulic binder – longitudinal section

Key to diagram:
Brückenlänge = bridge length
Betondecke (bewehrt bei schräg verlaufender Brücke und bei Dickenreduzierung gegenüber RStO Tafel 2, Zeile 1.1) = concrete pavement (reinforced in the case of a bridge at an angle and reduced thickness compared to the “Directives for the standardization of the superstructures of trafficked surfaces” RStO Table 2, line 1.1)
Detail, siehe Bild 16 = refer to Figure 16 for details
Vliesstoff = non-woven fabric
Tragschicht mit hydraulischem Bindemittel = base course with hydraulic binder
Raumfugeneinlage = expansion joint insert
Vliesstoff und Schutzschicht = non-woven fabric and protective layer
Dichtungsschicht nach ZTV-ING = sealing layer according to the “Additional technical conditions of contract and directives for civil engineering works” ZTV-ING
Brücke = bridge
Hinterfüllung nach ZTV E-StB = backfilling in accordance with the “Additional technical conditions of contract and directives for earthworks in road construction” ZTV E-StB
SF ... Scheinfuge = dummy joint

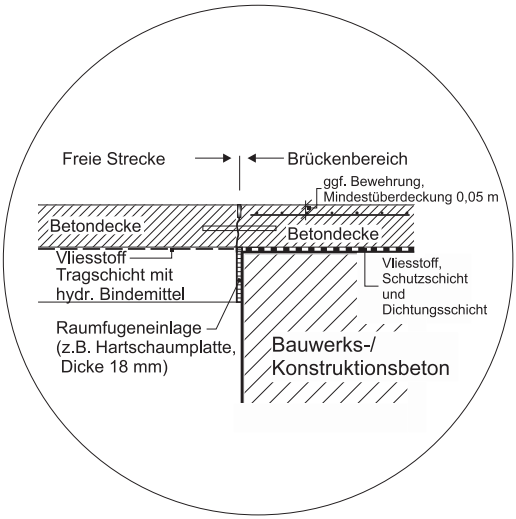


Figure 15: Design detail of base course with hydraulic binder – transition from the main section of the road to the bridge area

Key to diagram:
Freie Strecke = main section of road
Brückenbereich = bridge area
ggf. Bewehrung, Mindestüberdeckung 0,05 m = reinforcement if necessary, minimum cover 0.05 m
Betondecke = concrete pavement
Vliesstoff = non-woven fabric
Tragschicht mit hydr. Bindemittel = base course with hydraulic binder
Vliesstoff, Schutzschicht und Dichtungsschicht = non-woven fabric, protective layer and sealing layer
Raumfugeneinlage (z.B. Hartschaumplatte, Dicke 18 mm) = expansion joint insert (e.g. rigid foam slab, thickness 18 mm)
Bauwerks-/Konstruktionsbeton = (structural) concrete

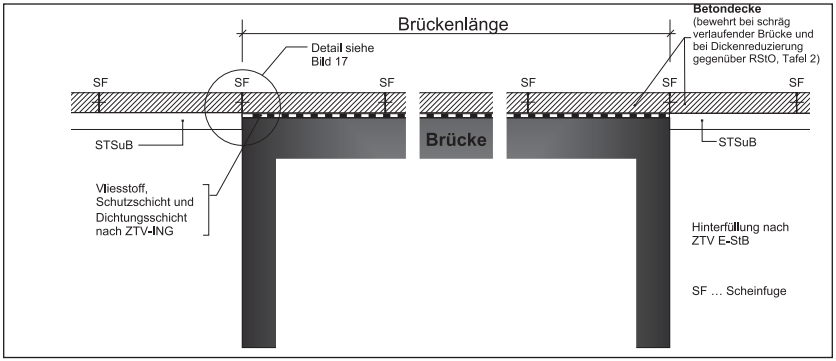


Figure 16: Concrete pavement on bridge without transition structure in the case of crushed stone base course – longitudinal section

Key to diagram:
Brückenlänge = bridge length
Betondecke (bewehrt bei schräg verlaufender Brücke und bei Dickenreduzierung gegenüber RStO Tafel 2, Zeile 1.1) = concrete pavement (reinforced in the case of a bridge at an angle and reduced thickness compared to the "Directives for the standardization of the superstructures of trafficked surfaces", RStO Table 2, line 1.1)
Detail, siehe Bild 18 = refer to Figure 18 for details
STSuB = crushed stone base course
Raumfugeneinlage = expansion joint insert
Vliesstoff und Schutzschicht = non-woven fabric and protective layer
Dichtungsschicht nach ZTV-ING = sealing layer according to the "Additional technical conditions of contract and directives for civil engineering works" ZTV-ING
Brücke = bridge
Hinterfüllung nach ZTV E-StB = backfilling in accordance with the "Additional technical conditions of contract and directives for earthworks in road construction" ZTV E-StB
SF ... Scheinfuge = dummy joint

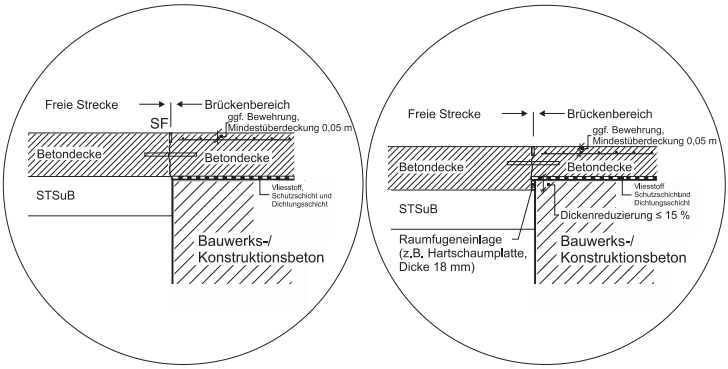


Figure 17: Design detail of pavement structures with crushed stone base – transition from main section of road to bridge area – left: standard case, right: exceptional case with reduced thickness

Key to diagram:
Freie Strecke = main section of road
Brückenbereich = bridge area
ggf. Bewehrung, Mindestüberdeckung 0,05 m = reinforcement if necessary, minimum cover 0.05 m
Betondecke = concrete pavement
Vliesstoff, Schutzschicht und Dichtungsschicht = non-woven fabric, protective and sealing layers
STSuB = crushed stone base course
Dickenreduzierung ≤ 15 % = reduced thickness ≤ 15 %
Raumfugeneinlage (z.B. Hartschaumplatte, Dicke 18 mm) = expansion joint insert (e.g. rigid foam slab, thickness 18 mm)
Bauwerks-/Konstruktionsbeton = (structural) concrete

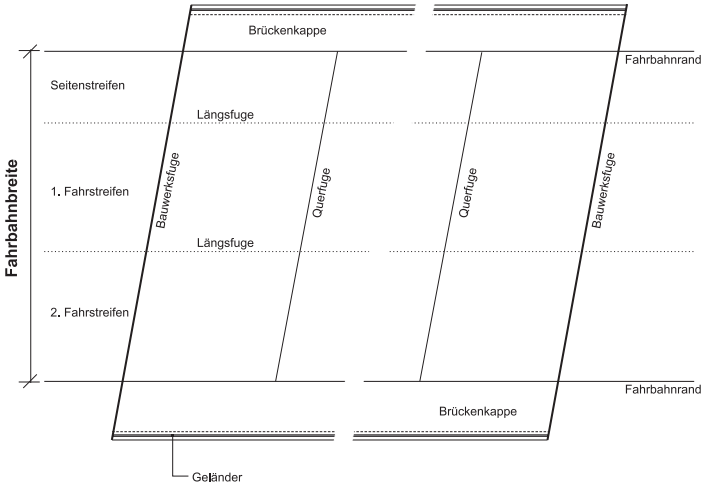


Figure 18: Joint layout for concrete pavement on bridges

Key to diagram:
Fahrbahnbreite = carriage way width
Brückenkappe = bridge deck edge beam
Fahrbahnrand = edge of carriageway
Standstreifen = hard shoulder
Längsfuge = longitudinal joint
Fahrstreifen = lane
Bauwerksfuge = structural joint
Querfuge = transverse joint
Geländer = railing

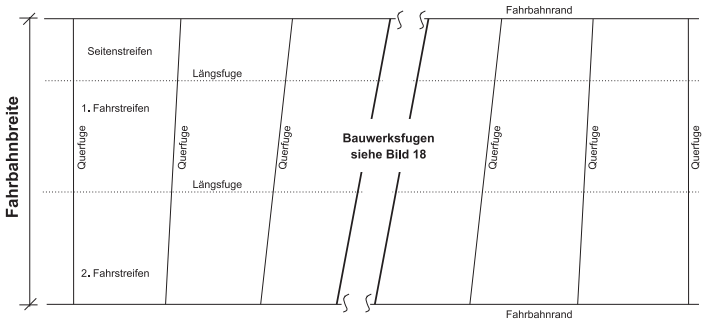


Figure 19: Possible joint layout in the transition region of concrete pavement from the connecting section of road to a bridge without transition structure for abutment at an angle – plan view

Key to diagram:
Fahrbahnbreite = carriageway width
Fahrbahnrand = edge of the carriageway
Standstreifen = hard shoulder
Längsfuge = longitudinal joint
Fahrstreifen = lane
Querfuge = transverse joint
Bauwerksfugen, siehe Bild 18 = structural joints, see Figure 18

3.1.9 Concrete pavements in tunnels and trough structures

According to the "Additional technical conditions of contract and directives for civil engineering works" (ZTV-ING), the road structure according to the "Directives for the standardization of the superstructures of trafficked surfaces"(RStO) is usually constructed with the same design and construction class in tunnel and trough structures as the adjacent section of the connecting road. According to the "Additional technical conditions of contract and directives for civil engineering works" (ZTV-ING), sealing is not necessary in this case. Sealing with a protective layer is required if, as an exceptional case, the pavement is laid directly on the tunnel or trough base.

A distinction between the following designs is made for tunnels and trough structures.

a) In the area of the tunnel/trough structure, the pavement is the same thickness as in the area of the connecting section of the road. The pavement is supported by structural concrete or the tunnel invert. The requirements for the unbound base course according to the "Additional technical conditions of contract and directives for civil engineering works" (ZTV-ING) are to be observed.

An example of pavement construction is shown in Figure 20.

b) If in the area of the tunnel/trough structure, the concrete pavement is, as an exception, placed directly on the blinding or structural concrete including a protective and sealing layer, the pavement construction is to be produced as, for example, in Figure 21.

The concrete slabs are to be dowelled and anchored according to Section 3.1.4.2.

The transverse joint at the transition between the connecting sections of the road with the tunnel or trough structure is to be suitably designed with regard to the position and slant of the transition.

In the case of a slanting joint at the transition, the direction of the joint perpendicular to the axis may be restored on concrete pavement over three pavement sections on both sides of the transition.

In the case of acute-angled slabs (< 80^{gon}), these are to be reinforced.

Transverse joints in tunnels and trough structures are to be sealed according to the "Additional technical conditions of contract and directives for joints in trafficked areas" (ZTV Fug-StB).

The transition regions between tunnels/trough structures and connecting road sections are to be formed corresponding to the transition regions between bridges and connecting road sections.

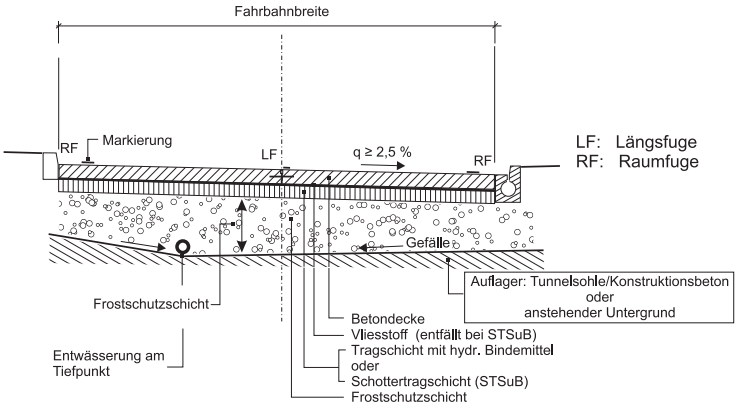


Figure 20: Standard design – concrete pavement in tunnel/trough structure with the same pavement as the connecting section of road – cross section

Key to diagram:
Fahrbahnbreite = carriageway width
Markierung = marking
Längsfuge = longitudinal joint
Raumfuge = expansion joint
Gefälle = gradient
Auflager: Tunnelsohle/Konstruktionsbeton oder anstehender Untergrund = support: tunnel invert/structural concrete or subgrade
Frostschutzschicht = frost-resistant subbase
Betondecke = concrete pavement
Vliesstoff (entfällt bei STSuB) = non-woven fabric (not required in case of a crushed stone base course)
Tragschicht mit hydr. Bindemittel oder Schottertragschicht (STSuB) = base course with hydraulic binder or crushed stone base course
Entwässerung am Tiefpunkt = drainage at low point

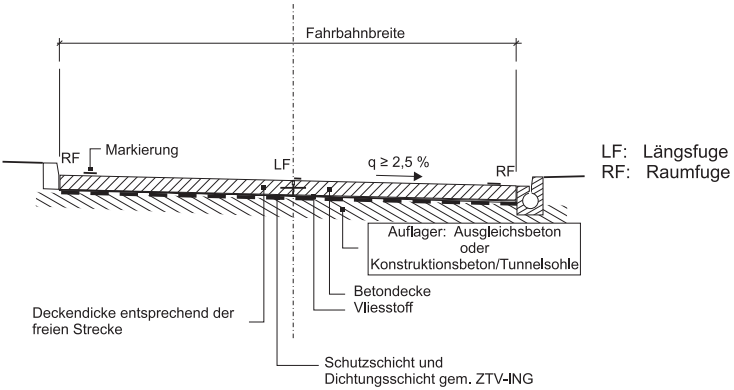


Figure 21: Special design – concrete pavement in tunnel/ trough structure supported directly by the blinding or structural concrete/tunnel invert – cross section

Key to diagram:
Fahrbahnbreite = carriageway width
Markierung = marking
Längsfuge = longitudinal joint
Raumfuge = expansion joint
Auflager: Ausgleichsbeton oder Konstruktionsbeton/Tunnelsohle = support: blinding concrete or structural concrete / tunnel invert
Betondecke = concrete pavement
Vliesstoff = non-woven fabric
Deckendicke entsprechend der freien Strecke = pavement thickness in accordance with the connecting section of road
Schutzschicht und Dichtungsschicht gem. ZTV-ING = protective and sealing layers according to the "Additional technical conditions of contract and directives for civil engineering works" (ZTV-ING)
Anmerkung: Höchster Grundwasserstand muss unterhalb OK-Fahrbahn liegen = Note: the maximum groundwater level must be below the upper edge of the carriageway

3.2 Building materials, concrete

See DIN 18316, Section 2.1

The regulations specified in the "Technical delivery terms for materials and material mixtures for base courses with hydraulic binders and concrete pavements" (TL Beton StB) apply.

If requested, samples of all building materials envisaged for the construction work are to be handed over to the client who shall keep these under lock and key (retained samples). The samples are to be approved by the contracting parties in a record.

The use of cement of strength class 42.5 R may be advantageous if the concrete is to achieve high strength at a young age, e.g. in

order to reduce the duration of traffic diversion measures. Even if the concrete shall harden more rapidly at low temperatures, the use of cement 42.5 R may be practicable.

Concrete used for the top of concrete pavement where surface mortar is removed is to be produced using a mineral aggregate mixture 0/8 mm. Coarse aggregate must comply with category $C_{100/0}$.

Mineral aggregate of category $C_{90/1}$ may be used if, in that particular region, positive experience is available regarding the required surface properties for the construction of concrete pavement. This is to be declared in the service specification.

3.3 Execution

The requirements specified in Annex B apply.

For reasons of uniformity of the concrete, only one construction machine is to be supplied from each mixing plant for each layer to be placed.

Section 3.4 also applies to pavement concrete made with superplasticizer.

3.3.1 Production of concrete pavement

The pavement is to be suitably produced to ensure a uniform structure and fulfil the specified requirements on a long-term basis.

The equipment and processes for the production, transportation and placement of the concrete must be suitably selected and co-ordinated so that the concrete can be placed quickly within the workable period. It must be ensured that the construction machines are continually supplied with concrete. Fine adjustment of the concrete composition must be ensured by permanent contact between the mixing plant and the construction site.

3.3.1.1 Transporting concrete

See DIN 18316, Section 3.3.4.2

The fresh concrete must be protected against harmful drying out, heavy rainfall and significant temperature increases.

When laying pavement of construction classes SV, I to III, permanent coordination between mixing plant and construction site must be ensured regarding the quantity of concrete to be supplied and the time of delivery.

Fresh concrete may not be transported on heated surfaces or in aluminium truck bodies. The fresh concrete may only be trans-

ported in aluminium bodies if special precautions are taken to exclude contact with aluminium surfaces.

During the transport of fresh concrete in mixer trucks, the drum must revolve slowly.

3.3.1.2 Formwork and guidance of construction equipment

The formwork and guidance of construction equipment is to be designed adequately to ensure the required lateral true-to-profile position and the pavement surface level, as well as the evenness of the concrete surface.

The concrete is to be placed between standing or towed formwork.

The formwork must be made of steel or concrete (e.g. prefabricated paving elements) or kerb stones. The use of timber formwork is only permitted for pavements of construction classes IV to VI or for narrow curves.

To prevent concrete from adhering to the standing formwork, the formwork shall be treated with a release agent.

Standing formwork shall only be removed if the concrete remains stable after the formwork is removed.

In the case of slipform paving, the concrete must be of suitable consistency so that the fresh, compacted concrete remains stable after the formwork has been removed.

The supports for the construction equipment are to provide adequate load-bearing capacity, be level and at the appropriate height. The control systems for the lateral position and height of construction equipment that is not rail-mounted are to be inspected continuously.

If hardened concrete sections are used for laying slide rails or used as supports for construction equipment when paving in adjoined strips, these sections must provide sufficient bearing capacity with being damaged.

3.3.1.3 Placing of dowels and anchors

Dowels are to be positioned in the centre of the slab thickness and in the longitudinal direction, following the slope of the carriageway so that the movement of the slabs in the longitudinal direction is not restricted.

If dowels are placed before the concrete is laid, they are to be secured in position to prevent them from moving or twisting during paving.

Supporting cages of reinforcing steel mesh may be used to fix the dowels at their intended position.

If dowels and anchors are vibrated into place, the pavement is to be placed in two layers or courses. Dowels and anchors must be vibrated into place before placement of the upper layer or course. For this purpose, the lower layer of the concrete slab must already be compacted.

Single-layer production is permitted if the contractor can provide proof of his capability to place dowels and anchors in the concrete according to plan without adversely affecting the concrete microstructure.

In longitudinal dummy joints, anchors are to be placed in the lower third of the slab thickness. In longitudinal construction joints, they are to be placed in the centre of the slab thickness.

3.3.1.4 Placing concrete and steel inserts

The concrete for each layer or course is to be spread over the entire placement area with uniform thickness and without segregation. Non-uniform pre-compaction is to be avoided when unloading the concrete.

Concrete for pavement of construction classes SV, I to III is to be spread using machines.

With two-layer design, the true-to-profile height of the lower concrete layer is to be observed in order that the top concrete layer obtains the specified thickness. Placement of the lower concrete is only to be extended so far that it does not dry out before placement of the upper concrete layer or has already begun to harden before compaction.

During warm and dry weather, the upper concrete layer must be processed no later than roughly half an hour after the lower course of concrete has been laid. During cool and damp weather, it must be processed no later than about one hour after the lower course of concrete has been laid.

Interruptions of construction work, e.g. at the end of a section, are to be located at a transverse joint which is to be formed as a construction joint.

In the case of reinforced pavement, yield of the reinforcing steel must be avoided during compaction. Reinforcing fabric is to be secured against displacement. Reinforcing steel inserts are to be interrupted all joints to provide a gap of 10 cm.

Upper reinforcing steel inserts are to be placed with a concrete cover of at least 5 cm, but not more than 7 cm.

The concrete cover of lower reinforcing steel is to be at least 4 cm towards the bottom.

3.3.1.5 Compacting concrete

Concrete must be compacted uniformly and completely over the entire cross section without segregation.

For pavement of construction classes SV, I to III, compaction equipment which processes the entire paving width is to be used. The forward feed is to be continuous and automatic.

In the case of dual-layer placement, it is to be ensured that the lower concrete is not pushed upwards to the surface when the upper concrete is compacted.

For concrete pavement of construction classes IV to VI as well as for edge and single slab sections, suitable small devices without direction guidance (e.g. immersion vibrators, vibrating screeds) may also be used besides mechanically directed compaction equipment.

3.3.1.6 Surface finishing

The pavement surface is to be finished with devices operating over the entire placement width. For pavement of construction classes IV to VI, vibrating screeds may also be used.

For pavement of construction classes SV, I to III, finishers operating in the longitudinal direction may additionally be used for final smoothing.

If pavement slabs are to be numbered, this is to be indicated in the service specification.

Finally, the surface must be treated to produce a texture suitable for the intended use.

Fresh concrete should not undergo any further surface treatment after rainfall.

The processes below may be chosen for surface treatment. Other processes may be chosen if proof of their suitability can be furnished. The "Fact sheet on the production of surface texture on concrete pavements" (M O B) is to be observed.

The final surface treatment procedure is to be indicated in the service specification. The particular requirements for the pavement

surface (noise reduction, skid resistance, etc.) are to be described and observed.

3.3.1.6.1 Removing surface mortar

For the production of exposed aggregate concrete surfaces, a thin film of retarder or a combination product (retarder with curing agent) are to be sprayed evenly on the placed, compacted and smoothed upper concrete layer.

The surface retarder delays the hardening of the near-surface concrete up to a certain depth for a limited period of time so that surface mortar can be removed mechanically. If a combined product is used as surface retarder, the concrete surface is also cured.

If a combination product is not used, the concrete surface is to be cured.

In this case two curing procedures are available.

– *Subsequent application of curing agent.*

– *Covering the surface with a polyethylene sheet up to the time of brushing.*

If a curing agent is applied it must be compatible with the surface retarder.

As soon as the concrete is sufficiently hard and can be subjected to traffic, the coarse aggregate at the surface is to be exposed over the entire cross section by brushing so that the surface consists of visible coarse aggregate particles at equal spacing. The texture depth should be between 0.6 and 1.1 mm.

The sequence of brushing and joint cutting will depend on local conditions.

Concrete is to be cured once more according to Section 3.3.3.2 immediately after brushing

3.3.1.6.2 Finishing in transverse direction using a steel broom

After smoothing and before application of a curing agent, the concrete surface is to be textured at right angles to the laying direction with a steel broom at least 45 cm wide. The broom is to be drawn over the fresh concrete paving inclined at an angle of approximately 30° with a slight downward pressure. Accumulation of mortar in front of the broom is to be avoided. The broom must consist of two sets of offset spring steel tufts.

3.3.1.6.3 Screeding using artificial grass

After smoothing and before application of curing agent, the concrete surface is to be textured in the longitudinal direction using artificial grass.

The following requirements apply to artificial grass.

- Minimum mass of 2000 g/m^2
- Pile height of 25 to 30 mm
- Minimum contact length of 2 m

The artificial grass is to be changed each working day or cleaned so that no loss of texture formation occurs.

It is to be cleaned during placement of the concrete in the following cases.

- Mortar accumulates beneath the artificial grass, causing imprints or pronounced indentations in the surface due to the increased mass
- Mortar begins to dry on or underneath the artificial grass
- Texture formation decreases

3.3.1.7 Concreting at low temperatures

If the air temperature is below +5 °C when placing the concrete, appropriate measures are to be taken (see "Technical delivery terms for materials and material mixtures for base courses with hydraulic binders and concrete pavements" (TL Beton-StB)).

Preparation is always to be made for protective measures if low temperatures are to be expected during concreting. All measures must ensure that for as long as possible the temperature of the concrete does not fall below +5 °C – at least during the first 3 days of hardening.

The dependencies on air temperature T_L and the temperature of the concrete T_B that are to be observed when placing the concrete are specified in Table 1.

3.3.1.8 Concreting at high temperatures

Appropriate measures are to be taken against high fresh concrete temperatures (see "Technical delivery terms for materials and material mixtures for base courses with hydraulic binders and concrete pavements" (TL Beton-StB)).

In the case of working at air temperatures above +25 °C, the temperature of the fresh concrete must be checked at the location where it is placed. The temperature must not exceed +30 °C.

The dependencies on air temperature T_L and the temperature of the concrete T_B to be observed when placing the concrete are be specified in Table 1.

Table 1: Temperature limits for concreting

Concrete placement	Air temperature	Temperature of concrete
permitted	$5\,°C \le T_L \le 25\,°C$	$5\,°C \le T_B \le 30\,°C$
only permitted when special measures are taken	$-3\,°C < T_L < 5\,°C$ $T_L > 25\,°C$	
not permitted	Always subzero $T_L \le -3\,°C$	–
	–	$T_B < 5\,°C$ $T_B > 30\,°C$

3.3.2 Notching of joints

See DIN 18316, Section 3.3.4.4

Concrete in the area of joints must be of the same state and strength as in the rest of the pavement. The procedures for notching joints must ensure that the joint notches maintain their specified dimensions over their entire depth and the entire width of the paving. The notches must be operative in sufficient time to prevent the slabs from cracking when contracting.

3.3.2.1 Dummy joints

See DIN 18316, Section 3.3.4.4.1

Dummy joints are produced as cut joint notches.

A notch is cut in the hardened concrete to the required depth. Early cutting of the notch is necessary to avoid cracking.

Devices which enable straight and sharp-edged cutting are to be used for notching.

To ensure that notches are cut in time, a sufficient number of cutting devices must be made available on site.

Sludge produced by notching is to be removed during cutting or immediately afterwards.

The notches on top of the pavement for cracking the transverse dummy joints must be at least 25 %, but no more than 30 % of the pavement thickness.

The notches on top of the pavement for cracking the longitudinal dummy joints must be at least 40 %, but no more than 45 %, of the pavement thickness.

To accommodate the joint filler, the joint notch is to be opened to a groove. The width and depth of the groove must comply with the dimensions of the provided joint filler. Details are specified in the "Additional technical conditions of contract and directives for joints in trafficked areas" (ZTV Fug-StB).

3.3.2.2 Expansion joints

See DIN 18316, Section 3.3.4.4.2

Expansion joints are to be filled with inserts just under the concrete surface prior to placement of concrete. These inserts must stand firmly at all positions on the base, be flush with the lateral formwork and properly fixed to prevent tilting and displacement.

The concrete cover of the inserts must not exceed 5 mm. It is to be cut open after the concrete has hardened. Details regarding the joint filler are specified in the "Additional technical conditions of contract and directives for joints in trafficked areas" (ZTV Fug-StB).

In pavement of construction classes IV to VI, the joint filler remaining in expansion joints without dowels may be vibrated into the fresh concrete if it is ensured that the joint insert reaches the base and the evenness of the pavement is not affected.

In the case of pavement of construction classes IV to VI, the height of the joint filler may be the same as the pavement thickness. In this case, joint cutting and joint filler do not have to be specified.

3.3.2.3 Construction joints

See DIN 18316, Section 3.3.4.4.3

Construction joints as a result of the production of consecutive paving strips after different times (including paving strips bordering lateral kerb stones) are to be produced with a groove in the upper part. The width and depth of the groove must comply with the dimensions of the provided joint filler.

Details are in the "Additional technical conditions of contract and directives for joints in trafficked areas" (ZTV Fug-StB).

3.3.3 Protective measures and curing

Concrete requires special protection and careful curing during and after production of the pavement.

Protective measures after production of the pavement may also simultaneously serve as curing measures.

3.3.3.1 Protective measures

Concrete is to be protected against precipitation during placement and for the first 2 hours after completion of the pavement. This may be achieved by erecting tents or other suitable measures. If such measures are not taken, the placement of concrete must be stopped during precipitation.

At air temperatures above 25 °C, the pavement must be wetted over its entire area at least three times at intervals of 2 to 3 hours immediately after notching. The pavement must not dry out during this period.

Cracks may occur if, following pronounced heating by high ambient temperatures and the hydration heat of cement during hardening, the concrete is sharply cooled owing to heat radiation, cool air and evaporation cooling at the surface. This may occur especially during the first night and on the next morning.

The danger of concrete heating may be reduced by application of a curing agent with increased brightness value.

If rapid cooling of placed fresh concrete is anticipated, the concrete must be protected by a heat-insulating cover until the notches are cut.

3.3.3.2 Curing

See DIN 18316, Section 3.3.4.7

The concrete must be cured.

The regulations of DIN 1045-3 are to be observed.

The type of concrete curing and, where applicable, the type of curing agent are to be indicated in the service specification.

3.3.3.2.1 Wet curing

The entire pavement surface including edges is to be kept permanently moist for at least three days. The concrete is to be sprayed over its entire area. Very rapid cooling of the concrete surface is to be avoided.

3.3.3.2.2 Application of curing agents

A liquid curing agent (in most cases a combined product comprising retarding and curing agents) is to be applied to exposed aggregate concrete surfaces immediately after concrete placement. A curing agent according to the “Technical delivery terms for liquid concrete curing agents” (TL NBM-StB) is to be applied uniformly to all other surfaces after the finished surface has become slightly

moist and matt. The quantity to be applied is to be determined depending on the curing agent and the surface texture such that a sealed film with a blocking coefficient S according to the "Technical delivery terms for liquid concrete curing agents" (TL NBM-StB) is achieved by the application.

The application of too much curing agent may delay removal of the curing film by weathering and reduce the initial skid resistance of the concrete pavement.

In the case of intense direct sunlight and high summer temperatures, the use of curing agents with an increased brightness value VH-W or VM-W is practicable.

Areas treated with curing agents may only be exposed to traffic if premature drying of the concrete due to possible damage of the curing film can be excluded.

In the case of air temperatures above 30 °C, strong direct sunlight, strong winds or relative humidities below 50 %, the pavement surface must always be additionally wet cured after the curing agent has dried.

If the final texturing process involves removal of surface mortar with the sealed film of retarding agent and, where applicable, curing agent, a single application of type VM curing agent is to be performed immediately.

3.3.3.2.3 Sheeting as cover

The application of sheeting is only practicable during the cold season because sheeting during warm weather may cause unfavourable temperature gradients.

The surface structure shall not be damaged by the application of protective sheeting.

Sheeting is to be secured against displacement and lifting by wind.

If surface mortar is removed during the final texturing measure, a surface retarding agent and, up to the time of brushing, a sheet may be applied for curing as alternative to Section 3.3.3.2.2.

3.3.3.2.4 Applying water-retaining covers

After completion of the final surface, the pavement is to be covered with a water-retaining cover e.g. burlap/sacking or sheet of nonwoven fabric. The cover is to be kept moist for at least three days.

3.3.4 Requirements for concrete pavement

3.3.4.1 Concrete strength

The control test is carried out on cores of 150 mm diameter and 150 mm height after 60 days at the earliest. The strength of each single core and the mean strength must achieve at least the required values specified in Annex B.

3.3.4.2 Air void content of fresh concrete

The values specified in Table 2 are to be observed. Proof of the required air content is to be furnished directly at the site.

The "Fact sheet for production and processing air-entrained concrete" contains notes on the addition of air-entraining agents.

Table 2: Minimum air void content of fresh concrete

Maximum grain size (mm)	**Mean minimum air content for concrete** (vol.%)
8	5.5
16	4.5
32 or 22	4.0

Air-entraining agents are to be added to concrete in at least such a quantity that the air content specified in Table 2 is obtained immediately before placement. Individual test results may not fall below the required values by more than 0.5 vol.%.

If concrete of consistency class C2, ≥ F2 or C1 with superplasticizer or water reducing agent is used, the air void contents in Table 2 increased by 1.0 vol.% apply.

If it is necessary to determine the air void parameters of hardened concrete, the values according to Table 3 are to be observed.

Table 3: Requirements for air void parameters in hardened concrete

Type of test	**Micro voids ratio A300** (vol.%)	**Spacing factor** (mm)
Self-monitoring test	≥ 1.5	≤ 0.24

3.3.4.3 Pavement thickness

The values stipulated in the service specification are considered as the specified pavement thickness. Deviations for each individual test specimen shall not fall below the specified thickness by more than 5 mm (according to DIN EN 13877-2: Category T5).

3.3.4.4 Position of dowels

The inclination of the dowels shall not exceed 20 mm with respect to the dowel length of 50 cm. The deviation from the planned height measured at the centre of the dowel shall not exceed 20 mm. The displacement perpendicular to the joint shall not exceed 50 mm.

3.3.4.5 True-to-profile position

See DIN 18316, Section 3.3.4.9

The drainage of surface water shall not be impeded by concrete sections produced separately.

In twisting sections with longitudinal gradients less than 0.5 %, the transverse inclination of the pavement shall not deviate from the target value by more than 0.2 % at locations with a transverse inclination less than 1.5 %.

The pavement surface shall not deviate from the target height by more than ± 20 mm. Such deviations are only permitted if they are distributed in the same direction over a longer distance and no visual discontinuities or discontinuities causing unfavourable dynamic vehicle movement are ascertained.

The plan view position of the pavement shall not deviate by more than 30 mm from the target value. No sharp curves shall be visible in the carriageway even where such variations are permitted.

3.3.4.6 Evenness

See DIN 18316, Section 3.3.4.10

The pavement is to be produced with an even surface.

Unevenness of pavement of construction classes SV, I to III shall not exceed 4 mm in longitudinal and transverse directions within a measured 4 m section. Unevenness of pavement of construction classes IV to VI and sections not laid by pavers shall not exceed 6 mm.

Permissible deviations shall only occur gradually, not in short and regular intervals. Adequate water drainage must be ensured.

3.3.4.7 Skid resistance

In the acceptance test, the skid resistance measured with the sideways force coefficient routine investigation machine (SKM) of finished pavement of construction classes SV and I to IV shall not fall below the following limits for an individual value of a 100 m section by more than 0.03:

– at 80 km/h: $\mu_{SKM} = 0.46$

– at 60 km/h: $\mu_{SKM} = 0.51$

– at 40 km/h: $\mu_{SKM} = 0.56$.

Until expiry of the limitation period for warranty claims the following values apply:

– at 80 km/h: $\mu_{SKM} = 0.40$

– at 60 km/h: $\mu_{SKM} = 0.45$

– at 40 km/h: $\mu_{SKM} = 0.49$.

If skid resistance falls below the values during the limitation period for warranty claims, this does not necessarily prove a deficiency. In this case the client has to determine whether a deficiency exists and the contractor is obliged to eliminate the deficiency.

Until expiry of the limitation period for warranty claims for the sideways force measurement (SKM), the above limits and values do not apply to local residential distributor roads, residential roads, pedestrian precincts, bicycle paths, walkways and parking areas in municipal road construction.

Depending on local conditions, speeds of 40, 60 or 80 km/h may be chosen for the sideways force measurement (SKM). The measurement speed is to be indicated in the service specification.

3.3.5 Opening for traffic

The pavement may only be opened for traffic after the concrete has hardened sufficiently and achieved sufficient freeze-thaw deicing salt resistance. If a more precise specification does not occur, a minimum compressive strength of 26 MPa may be taken for sufficient hardening.

A minimum compressive strength of 26 MPa on opening for traffic is required for pavement made during the cold season or pavement with exposed aggregate concrete surface.

Hardening tests are tests designed to determine the earliest possible time at which the road can be opened for traffic.

The first hardening test is part of the control test.

If additional hardening tests are needed to determine the time at which the road can be opened for traffic, the party in whose interest the early opening occurs shall bear the costs for these tests.

3.4 Special rules for concrete pavement with superplasticizer

3.4.1 Application

A distinction is made between two fields of application for concrete pavements with superplasticizer.

- *Trafficked areas which may already be exposed to high loads at an early stage.*
- *Trafficked areas where the use of pavers is neither possible nor practicable.*

3.4.2 Construction principles

If an unbound granular subgrade or a non-woven fabric is beneath the pavement, it is to be ensured that no water is removed from the fresh concrete to an extent which causes damage.

It may be practicable to install sheets underneath.

3.4.3 Execution

3.4.3.1 Production of concrete pavement

3.4.3.1.1 Concrete consistency and mixing in superplasticizer

The necessary consistency of concrete depends on the construction equipment, the fresh concrete temperature at the time of placement and the gradient of the pavement.

If the plasticizing effect of the superplasticizer is of limited duration, the superplasticizer shall be mixed with the initial concrete just before delivery of concrete at the site or before placement. In this case, the mixing time in the transport mixing drum shall be at least 1 minute per m^3 of concrete, but no less than 5 minutes.

On adding the superplasticizer, the flow spread measured with the flow table test, of soft pavement concrete with superplasticizer must be increased by at least 100 mm compared to that of the initial concrete.

3.4.3.1.2 Placing of concrete

Concrete containing superplasticizer must be placed within 30 minutes. This is to be coordinated with the loading capacity of the ready-mix concrete trucks.

Special measures are to be taken for pavement with an overall slanting inclination more than 3 % when placing the concrete.

Such measures may include the following.

– *Placement in two courses or*

– *Screeding the surface after a certain waiting period.*

3.4.3.1.3 Compaction of concrete

Concrete containing superplasticizer requires compaction appropriate to its consistency.

Automatically guided and machine driven compaction devices are to be used for compacting connected sections of more than 3 m paving width. Hand-operated vibrating screeds may be used for compacting connected sections up to 3 m paving width and individual sections.

The compacting equipment must be suitably designed and operated so that the requirements for surface evenness are reliably observed.

3.4.3.1.4 Surface finishing

Final surface finishing is only to be performed when the plasticizing effect of the superplasticizer has sufficiently abated so that the structure applied to the surface of the concrete remains.

3.4.3.2 Production of joints

Due to its rapid hardening, pavement made with early high strength pavement concrete with superplasticizer requires earlier cutting of joint notches than pavement made with standard pavement concrete.

3.4.4 Requirements for early strength

When using early high strength concrete, proof of sufficient early strength must be furnished in addition to fulfilling the 28 day compressive strength and the flexural strength. If a more precise specification is not given, proof of a minimum compressive strength of 30 MPa (mean over 3 test specimens) after 2 days must be furnished by the initial type test. No individual value shall fall below 26 MPa. Compressive strength tests shall be performed on 150 mm cubes (storage under water at 20 °C).

3.4.5 Opening for traffic

Before opening pavement made with early high strength concrete with superplasticizer for traffic, a compressive strength test shall be carried out on specially produced test specimens stored at the construction site.

See also Section 3.3.5.

3.5 Type and scope of tests

3.5.1 Self-monitoring tests

The type and scope of the self-monitoring tests to be carried out are specified in Annex F.

For tests using the combined measuring method involving SRT pendulum and outflow meter, the values specified in Section 3.5.2 may serve as a reference.

3.5.2 Control tests

The type and scope of the control tests to be carried out in general are specified in Annex F.

The sideways force measurement (SKM) is optional for control testing skid resistance if the reference values below are fulfilled using the combined measuring method SRT pendulum / outflow meter.

– SR*T-value* ≥ *60*

– *Time* of outflow (sec) ≤ 30.

If the SRT value is smaller than or the time of outflow greater than the corresponding reference value, a sideways force measurement (SKM) is required.

The SRT measurement method is not suitable for the specification of requirements for skid resistance up to expiry of the limitation period for warranty claims

The joint determinations for invoicing (see Section 4) may also be considered in control tests if possible and practicable.

4 Warranty claims

See § 13 of the German Construction Contract Procedures – Part B (VOB/B)

4.1 Handling deficiencies

A deficiency exists if individual test results for 100 m sections fall below the respective skid resistance limit μ_{SKM} by more than 0.03 in the acceptance test. In this case the contractor may demand a repeated control test using the sideways force measurement (SKM). The original test result is replaced by the result of the repeated control test. The specifications in Section 1.3.2.4 and Section 1.3.2.5 are not affected by this. The contractor bears the costs of the repeated control test.

If the results of the control test fall below the limiting value by more than 0.06 or the requirements for the skid resistance are not ful-

filled in the repeated control test, the contractor shall determine the cause of the deficiency and shall carry out measures to improve skid resistance durably.

The treatment of deficiencies is regulated by, for example, the "Manual of contract award and construction in road and bridge construction" (HVA B-StB), Section 3.10, warranty claims.

If, at the time of acceptance, the requirements for layer thickness, amount of placed material, binder content, degree of compaction or evenness, which constitute a deficiency in quality according to § 13 No. 1 of the German Construction Contract Procedures – Part B (VOB/B) are not observed, the client may offer the contractor to defer a warranty claim (§ 13 No. 5 VOB/B) in an individual contractual agreement for the time being and to carry out a deduction as compensation instead. The amount of deduction is to be determined using the formulas for deduction in Annex G.

4.2 Limitation periods for warranty claims

The period of limitation for warranty claims shall be as follows.

– 5 years for pavement constructions of construction classes SV and I and
– 4 years for pavement constructions of construction classes II to VI

They apply if the pavement constructions with regard to the superstructure are produced completely (not in steps); the complete construction is designed according to the technical contract provisions and guidelines for the respective construction class.

5 Measurement and invoicing

5.1 General

The service specification shall indicate whether the base course is to be invoiced according to installed weight or installed layer thickness. In the case of installed areas less than 6000 m², the invoice is, in general, to be based on the weight of installed material.

Concrete pavement is always to be invoiced according to installed layer thickness.

If invoicing is prescribed according to installed layer thickness, the type of measuring method is to be declared.

The measuring profile is considered as a linear sequence of continuous single test points arranged perpendicular to the axis of the carriageway.

5.2 Measurements

See DIN 18316, Section 5

5.2.1 Installed width

In case of scarped edges, the width of the base course up to the centre of the prescribed line of slope is taken into account.

5.2.2 Installed layer thickness

Measurements of the installed layer thickness of pavement are performed at single points distributed evenly across the paved area. If the layer thickness is measured with a depth gauge or on cores, the locations of the measurement or sampling points are to be chosen alternately to the right, in the centre, and to the left of the carriageway axis.

On smaller contract sections or in municipal road construction, the number of measurement points may be reduced.

5.2.2.1 Base courses

As a rule, the distance between measuring profiles in the longitudinal direction is to be a uniform interval of 50 m. If cores are extracted, the distance may be increased up to 200 m. At least 20 measurement positions are required.

When paving thickness is measured using a cord or by levelling, at least three measurements for every measuring profile are to be recorded; on the carriageway axis and at both outer third positions of half the width of the carriageway (in the case of a 7.50 m wide carriageway, at a distance of 2.50 m from the carriageway axis).

If thickness is measured with a depth gauge or on cores, only one measuring position is necessary for each measuring profile; alternating right, centre and left of the carriageway axis.

5.2.2.2 Concrete pavement

Concrete cores taken for the determination of compressive strength are to be used for the determination of installed layer thickness. For every 1000 m^2 of pavement area only one core is to be taken. Measurements must comprise at least 3 measurement positions.

For invoicing purposes, samples taken jointly are to be handed over to the client on request.

5.2.3 Installed weight of base courses

If the installed weight per unit area (kg/m^2) is specified in the construction contract, proof is to be furnished for every layer/course

of to what extent the installed weight corresponds to that specified in the contract.

As a rule, the installed weight of the entire contract section for the respective layer/course is to be taken as a basis for determining the installed weight for the mix-in-plant process. The client is also entitled to determine the installation weight on the basis of partial sections. The partial sections should at least correspond to one daily output. The same requirement applies for this purpose.

5.3 Invoicing

See § 14 of the German Construction Contract Procedures – Part B (VOB/B)

5.3.1 Invoicing based on installed thickness

If invoicing of base courses or concrete pavement according to installed thickness is specified in the construction contract, proof must be furnished for every layer of to what extent the layer thickness corresponds to the contractually agreed thickness. An excess of the contractually agreed thickness is only remunerated if the client has awarded a written contract for this purpose.

5.3.1.1 Base courses

The installed thickness is considered as the arithmetical mean of all single values of layer thickness of a road base course with hydraulic binder over the entire contract section. Only individual values up to 20 % above the target pavement thickness are to be considered for the determination of the mean value.

5.3.1.2 Concrete pavement

The installed thickness is considered as the arithmetical mean of all single values of pavement sections of the same paving width over the entire contract section. Only individual values up to 15 % above the target pavement thickness are to be considered for the determination of the mean value.

5.3.1.3 Compensating thickness

5.3.1.3.1 Excess installed thickness

Excess installed thicknesses for a layer are considered for the compensation of shortfall of installed thicknesses of lower pavement layers according to the superstructure layers required by the construction contract, up to the limits stated in Sections 5.3.1.1 and 5.3.1.2.

5.3.1.3.2 Shortfall of installed thickness

Insufficient installed layer thicknesses of individual base courses are deducted if they have not been compensated by excess installed layer thicknesses of overlying base courses or pavement layers.

5.3.1.4 Invoicing unit price

If shortfall of installed layer thickness is to be considered for invoicing, the agreed unit price less any costs for joints and reinforcing steel inserts contained therein is to be changed according to the ratio of installed thickness to be remunerated to the prescribed installed thickness and taken as basis for invoicing (invoicing unit price).

If excess installed layer thickness above the, if applicable, required compensation thickness is to be considered for invoicing of concrete pavement, this will only be remunerated, in the invoicing unit price, up to 1.5 cm above the installed thickness prescribed in the construction contract.

5.3.2 Invoicing of base courses based on installation weight

Excess installation weight of a base course is first used for the compensation of shortfall of installation weight of lower pavement layers for the superstructure layers required by the construction contract. The remaining excess installed weight of the base course to be invoiced will only be remunerated if the client has awarded a written contract for this purpose.

For calculating the mean value, only excess installation weight up to 20 % is to be considered. Installed weight in excess thereof will only be remunerated if the client has awarded a written contract for this purpose.

Insufficient installation weights of individual base courses are to be deducted if not compensated by excess installation weights of overlying base courses or pavement layers.

If excess or insufficient installation thickness is to be considered for invoicing, the agreed unit price is changed according to the ratio of installation weight to be remunerated to prescribed installed weight and taken as basis for invoicing (invoicing unit price).

5.4 Building materials provided by the client

If building materials are provided by the client, Sections 5.3.1.3.1 and 5.3.1.3.2 apply to invoicing of excess and insufficient layer thicknesses and quantities, respectively. In the event of changes, the unit price for the work to be provided by the contractor is taken as basis.

Annex

Requirements for base courses with hydraulic binders

Line		Stabilization		Hydraulically bound base courses	Concrete base courses
		Mix-in-place process	Mix-in-plant process		
(1)	(2)	(3)	(4)	(5)	(6)
1	Degree of compaction of the layer to be stabilized	≥ 100 %[1)]	–		
2	Degree of compaction of the stabilized layer	≥ 98 %[1)]			–
3	Deviation of surface from target height (true-to-profile position)	Maximum ± 1.5 cm[2)] Maximum + 0.5 cm or – 1.5 cm[3)]			
4	Evenness	≤ 1.5 cm/4 m			
5	Permissible deviation in installed layer thickness[6)]/installation weight[7)]	Single values ≤ 3.0 cm on average ≤ 10 %			Single values ≤ 2.5 cm on average ≤ 10 %
6	Compressive strength determined in the initial type test (after 28 days)	7.0 MPa[4) 8) 9)] ≥ 15.0 MPa[3) 8) 9)]			f_{ck}
7	Compressive strength determined in the control test (after 28 days)	≥ 3.5 MPa[4) 10)] n = 1 ≥ 6.0 MPa[3) 8) 10)] n ≤ 8 ≥ 8.0 MPa[3) 8) 11)] n ≥ 9 ≥ 10.0 MPa[3) 8) 11)]			$f_{ci} \geq f_{ck} - 4$ MPa $f_{cm} \geq f_{ck} + 4$ MPa
8	Strength class	–			C12/15 up to C20/25
9	Frost resistance with particle size < 0.063 mm between 5 and 15 wt.%	Change in length ≤ 1 %			–
10	Minimum binder content	≥ 3.0 wt.%			–
11	Binder content determined in the control test[13)]	on average –5 to +8 % relative Single values –10 to +15 % rel.[4) 5)]	–		
12	Minimum thickness of each layer or course	15 cm (≤ 0/45) 20 cm (> 0/45)	12 cm (≤ 0/32) 15 cm (0/45) 20 cm (> 0/45)	12 cm (0/32) 15 cm (0/45)	12 cm[14)]

Line		Stabilization		Hydraulically bound base courses	Concrete base courses
		Mix-in-place process	Mix-in-plant process		
(1)	(2)	(3)	(4)	(5)	(6)
13	Requirements for particle size distribution	–		< 0.063 mm ≤ 15 wt.%, > 2 mm between 55 and 84 wt.%, coarsest particle size fraction ≥ 10 wt.%, oversized particles ≤ 10 wt.%	According to DIN 1045 or DIN EN 206
14	Permissible deviation from the particle size distribution specified in the initial type test	–		for 2 mm, 8 mm and 16 mm ± 8 wt.% < 0.063mm[15)]	–

Notes on the requirements for base courses with hydraulic binders

1) Proctor density
2) General requirements
3) Beneath concrete pavement
4) Beneath asphalt pavement
5) No requirements beneath concrete pavements
6) The arithmetical mean of all single values of installed layer thickness for the respective layer over the entire contract section is considered as the installed layer thickness.
7) Usually, as mean value over the entire contract section. Mean values may also be calculated for partial sections which must correspond to at least one daily output.
8) Tested with the Proctor specimen, height/diameter = 125/150 mm. If specimen with height/diameter = 120/100 mm are tested, the compressive strength values are to be multiplied by 1.25 to be comparable to the values given in the table
9) Mean of three related test specimens whose individual values do not deviate from the mean by more than ± 2.0 MPa
10) Individual value
11) Mean value
13) The arithmetical mean of all individual values of binder content in the stabilized layer over the entire contract section is considered as binder content; excess content values only up to 15 % rel. above the target value shall be considered for the calculation of the mean value
14) For compaction with immersion vibrators ≥ 15 cm
15) The fraction of fines < 0.063 mm shall not exceed the value specified in the initial type test and the value increased by the binder content by more than 2.0 wt.%.

Annex B
Requirements for concrete pavement

Line		
(1)	(2)	(3)
1	Exposure class	According to TL Beton-StB
2	Permissible shortfall in installed layer thickness	≤ 5 mm from the target thickness (category T5 according to DIN EN 13877-2)
3	Compressive strength determined in the control test on a core (H = D = 15 cm)	$f_i \geq 35$ MPa $f_m \geq 40$ MPa
4	Cement content	Construction classes SV and I to III ≥ 340 kg/m³
5	Air void parameters in hardened concrete (core)	$A_{300} \geq 1.5$ vol.% Spacing factor 0.24 mm
6	Minimum thickness of the concrete pavement	According to RStO, but no less than 10 cm
7	Thickness of each layer or course	At least 5 cm and at least three times the maximum grain size (rounded up to the nearest full cm)
8	Requirements for grading	According to DIN 1045 or DIN EN 206, respectively < 1 mm ≤ 27 wt.%, < 2 mm ≤ 30 wt.% (with maximum grain size of 8 mm ≤ 35 wt.%)
9	Position of dowels	Inclination ≤ 20 mm with respect to dowel length of 500 mm, height deviation in the centre of dowel ≤ 20 mm, displacement perpendicular to joint ≤ 50 mm
10	Skid resistance	at 80 km/h $\mu_{SKM} = 0.46$ at 60 km/h $\mu_{SKM} = 0.51$ at 40 km/h $\mu_{SKM} = 0.56$
11	True-to-profile position	Transverse inclination in twisting sections at locations with longitudinal inclination q ≤ 1.5 % deviation ≤ 0.2 % from the desired value, deviation from the target height ≤ 20 mm, position in ground plan ≤ 30 mm from the target value without sharp curves in the carriageway
12	Evenness	Construction class SV and I to III ≤ 4 mm/4 m Construction class IV to VI and on sections not laid with pavers ≤ 6 mm/4 m
13	Non-woven fabrics beneath concrete pavement	Taut, crease-free and fixed position, projecting length at the edge of the carriageway 10 cm +/– 5 cm, longitudinal and transverse overlap 20 cm +/– 5 cm No four-fold overlaps

Annex C

Tests on building materials and finished stabilization work

Line		Self-monitoring tests	Control tests
	(1)	(2)	(3)
1	**Installed mixture**		
	a) Compliance with initial type test	Comparison of delivery notes or visual inspection for each delivery	
	b) Compressive strength		At least for every 500 m started or 6000 m^2 base course, respectively
	c) Beneath asphalt layers, the binder content may be determined instead of the compressive strength if produced by the mix-in-place process		At least every 100 m started or 1000 m^2, respectively, but at least once daily
2	**For mix-in-place process, on the layer prepared for stabilization**		
	a) Degree of compaction	Every 250 m started or 3000 m^2 started, respectively	
	b) True-to-profile position	As required	
	c) Binder content	As required	
3	**Stabilized layer (immediately following compaction, irrespective of the production process and the type of overlying layer)**		
	a) Layer thickness	As required	At least every 100 m started or 1000 m^2, respectively
	b) True-to-profile position and evenness	As required	At intervals not exceeding 50 m
	c) Degree of compaction	At least every 250 m started or 3000 m^2, respectively	At least every 500 m started or 6000 m^2, respectively, but at least once daily

Annex D
Tests on building materials and finished work for hydraulically bound base courses

Line		Self-monitoring tests	Control tests
	(1)	(2)	(3)
1	**For the installed mixture**		
	a) Compliance with the initial type test	Comparison of delivery notes or visual inspection for each delivery	
	b) Grading		As required, at least every 6 000 m^2 of base course started
	c) Proctor density (one-point Proctor)	At least twice daily	
	d) Compressive strength on test specimen, diameter D = 150 mm, height H = 125 mm		As required, at least every 6 000 m^2 of base course started
	e) Condition of the placed mixture	Visual inspection	
	f) Water content	Every 3 000 m^2 started, but at least twice daily	
2	**For the finished work**		
	a) Installed layer thickness/installed weight	Proof required	At least every 100 m started or 1 000 m^2, respectively
	b) True-to-profile position and evenness	As required	At intervals not exceeding 50 m
	c) Degree of compaction (of the layer which has not already set)	At intervals of less than 500 m, but at least every 6 000 m^2 under construction	As required, at least every 6 000 m^2 of base course started

Annex E

Tests on building materials and finished work for concrete base courses

Line		Self-monitoring tests	Control tests
	(1)	(2)	(3)
1	**For fresh concrete**		
	a) Compliance with initial type test	Comparison of delivery notes or visual inspection for each delivery	
	b) Consistency and bulk density of fresh concrete	At least every 3000 m^2	As required
	c) Water/cement ratio of fresh concrete	At least every 3000 m^2	
2	**For finished work**		
	a) Compressive strength and bulk density of hardened concrete	At least every 3000 m^2	Every 3000 m^2
	b) Installed layer thickness	At least every 3000 m^2	Every 3000 m^2
	c) True-to-profile position and evenness	As required	At intervals not exceeding 50 m

Annex F
Tests on building materials, concrete and finished work for concrete pavement

Line		Self-monitoring tests	Control tests
	(1)	(2)	(3)
1	**Non-woven fabrics beneath concrete pavement**		
	a) Compliance with declaration of conformity	Comparison of delivery notes or visual inspection for each delivery	
	b) Taut, crease-free and fixed position	Continually and immediately before placement of concrete	As required
	c) Excess length at the edge of the carriageway 10 cm +/– 5 cm	Continually and immediately before placement of concrete	As required
	d) Longitudinal and transverse overlap 20 cm +/– 5 cm	Continually and immediately before placement of concrete	As required
	e) No four-fold overlaps	Continually	As required
	f) Alkali resistance		As required
2	**Fresh concrete**		
	a) Compliance with initial type test	Comparison of delivery notes or visual inspection for each delivery	
	b) Consistency	Once daily[1] and in case of doubt	
	c) Water/cement ratio	Once daily[1]	
	d) Composition	Once daily[1]	
	e) Bulk density	For every production of test specimen[1]	
	f) Air voids content and air temperature	Hourly for the upper concrete[1], daily for the lower concrete	Hourly for the upper concrete[1], daily for the lower concrete
	g) Temperature of concrete	Every 2 hours at air temperatures below +5 °C or above +25 °C	

[1] Only for construction classes SV and I to III

[2] Only for construction classes SV and I to III, at least once daily for construction classes IV to VI

[3] In the case of high early strength pavement concrete with superplasticizer, the specifications in this table apply also for the early strength at the time of opening for traffic or after 2 days, respectively, within the scope of the self-monitoring tests of hardened concrete.

[4] For construction classes IV to VI at a distance of 50 m

[5] Due to the hitherto unknown tolerances of non-destructive measurement systems, the results obtained with these methods are not suitable to express reservations within the framework of the acceptance.

Annex F continued

Line		Self-monitoring tests	Control tests
	(1)	(2)	(3)
3	**Hardened concrete**		
	a) Bulk density and compressive strength	At the beginning of construction work and every 1000 m²: 1 cube; Max imum: 6 cubes per type and day[1) 3)]	Every 1000 m², one core per paving strip
	b) Air voids content, micro voids content and spacing factor (only for the upper concrete in the case of dual-layer design)	On one core from the first day's production and in case of doubt	
	c) Pavement thickness	At least every 200 m by measuring using a cord or other suitable measurements	Every 1000 m², one core per paving strip (cores taken for a) are to be used for measuring thickness)
	d) Evenness	The first and the second day's production are to be inspected for evenness in longitudinal and transverse directions as soon as possible for each paving strip and after each shifting of paving equipment[1)]	In the longitudinal direction one continuous measurement for each lane, hard shoulder and separately produced hard shoulders, in the transverse direction one continuous measurement in suspect areas
	e) True-to-profile position	Measurement of the pavers' guiding equipment at intervals of 20 to 25 m[4)]	Determination of location of pavement edges at intervals of 100 m as a rule[4)], levelling at intervals of 20 to 25 m[1)]
	f) Extraction force of chemical anchors	In case of doubt	
	g) Skid resistance	Every day's production (not for exposed aggregate concrete)	One continuous measurement in the longitudinal direction for each lane
	h) Exposed aggregate concrete: Mean texture depth	– After first day's production: In 4 measuring areas uniformly distributed over the finished section length. For each measuring section the lane has to be alternated – Subsequent production days: One measuring area per 500 m, but at least once daily. The distance has to be reduced if the appearance of the surface changes.	*As required*

Annex F continued

Line		Self-monitoring tests	Control tests
	(1)	(2)	(3)
	i) Dowel location[5)]	First day's production: – At a minimum of 10 transverse dummy joints after cutting of joints. Subsequent production days: – 5 transverse dummy joints every 500 m. These measurements may be conducted together in one run.	

Annex G

Annex to the individual contractual agreement on deductions in the event of excess or shortfall of the limiting values according to ZTV Beton-StB

Deductions

Deductions for multiple deficiencies are added.

A reduced service life due to provisional arrangements is to be taken into account for the calculation of deductions.

Deductions for falling short of the required compressive strength exclude deductions for falling short of the required binder content.

Part A Base courses with hydraulic binders

A 1 Falling short of the limiting value for installed weight

If the actual installed weight falls below the installed weight specified in the construction contract by more than the respective limiting value, a deduction is calculated according to the below formula. The deduction is calculated irrespective of a change of the unit price for the settlement of accounts as result of an installed weight below the limiting value (see Section 5.3.2).

$$A = \frac{p}{100} \cdot 3.75 \cdot EP \cdot F$$

Here:

A = deduction in €
p = percentage amount of shortfall over the limiting value of 10 % of installed weight as specified in the construction contract
EP = the unit price in €/m² resulting from invoicing according to Section 5.3.2
F = the area in m² belonging to the verification.

If proof of weight is required for partial sections, the formula is only to be applied to the partial sections.

A 2 Falling short of the limiting value for installed layer thickness

The deduction is calculated on the basis of the mean of all individual values as well as on the basis of the sum of the partial deductions of the individual values. The resulting value which is higher is used for the deduction.

If the actual installed layer thickness (mean value) falls short of the installed layer thickness specified in the construction contract by more than the limiting value specified for the particular base

course, a deduction is calculated according to the below formula. The deduction is calculated irrespective of a change of the unit price in the scope of the settlement of accounts as result of insufficient installed layer thickness (see Sections 5.3.1.4 and 5.3.1).

$$A = \frac{p}{100} \cdot 3.75 \cdot EP \cdot F$$

Here:

A = deduction in €

p = percentage amount of shortfall over the limiting value of 10 % of installed layer thickness as specified in the construction contract

EP = the unit price in €/m2 resulting from invoicing according to Section 5.3.1.4 and Section 5.3.1

F = the area in m2 belonging to the verification.

If single values of installed layer thickness fall below the values specified in the construction contract by more than the limiting value specified for the respective base course, partial deductions are calculated for the respective areas according to the formula above.

In this formula, p then stands for the following:
Shortfall of the installed layer thickness specified in the construction contract beyond the limiting values of 2.5 cm, 3.0 cm or 3.5 cm, converted into percentage of this installed layer thickness.

For the determination of individual and mean values of installed layer thickness in the calculation of deductions at the measuring positions, the excess installed layer thicknesses of the overlying layers are considered to the full extent for the compensation of insufficient installed layer thicknesses of the layer underneath.

A 3 Falling short of or exceeding the quantity of binder or the binder content for mixed-in-place stabilization beneath asphalt layers

If the actual value is below or above the limiting value, a price deduction is calculated according to the below formula.

$$A = \frac{p^2}{100} \cdot 0.5 \cdot EP \cdot F$$

Here:

A = deduction in €

p = amount of shortfall below the limiting value of 5 % or exceedance above 8 % of the amount of binder agreed on in relative percentage. In the case of single values, a limiting value of 10 % for shortfall and 15 % for exceedance apply.

EP = the unit price of the finished layer in €/m2 resulting from invoicing

F = the area in m² related to the sample.

The deduction is determined either on the basis of the mean of all individual values of the entire contract section or on the basis of the individual values. The higher value is used.

A 4 Falling short of the limiting value for the degree of compaction of base courses with hydraulic binders

If the actual value falls below the required value, a deduction is calculated according to the below formula.

$$A = \frac{p}{100} \cdot (11p - 4.5)\ EP \cdot F$$

Here:

A = deduction in €
p = shortfall of the required minimum degree of compaction in %
EP = the unit price of the finished layer in €/m2 resulting from invoicing
F = the area in m² related to the sample.

The deduction is determined on the basis of the results for the assigned area.

A 5 Falling short of the limiting value for compressive strength of base courses with hydraulic binders

If the compressive strength is below the limiting value, a deduction is calculated according to the below formula.

$$A = \frac{p}{100} \cdot 2 \cdot EP \cdot F$$

Here:

A = deduction in €

$$p = \frac{\text{minimum compressive strength} - \text{actual compressive strength}}{\text{minimum compressive strength}} \cdot 100$$

(p in %, compressive strength in MPa)

EP = the unit price in €/m2 resulting from invoicing
F = the area related to the sample in m².

The deduction is determined on the basis of the mean actual compressive strength of all test specimens or on the basis of the sum of the partial deductions for each individual test specimen. The higher deduction value is used.

Part B Concrete pavement

B 1 Falling short of the compressive strength of concrete

If the compressive strength of concrete falls below the limiting value, a deduction is calculated according to the below formula.

$$A = \frac{p}{100} \cdot 3 \cdot EP \cdot F$$

Here:

A = deduction in €

p = $\frac{\text{minimum compressive strength} - \text{actual compressive strength}}{\text{minimum compressive strength}} \cdot 100$

actual compressive strength < minimum compressive strength (p in %, compressive strength in MPa)

EP = the unit price in €/m2 resulting from invoicing according to Section 5.3.1.4

F = the area to be verified in m2.

The deduction is determined on the basis of the sum of the partial deductions with each individual test specimen (f_i) or on the basis of the mean actual compressive strengths of all test specimens (f_m). The higher deduction value is used.

Example:

Number of test specimens: 4
EP = € 25.00/m²
F_N = 1000 m², F = 4000 m²

Minimum compressive strength f_i of the core = 34.0 MPa
Mean minimum compressive strength f_m = 42.0 MPa

Actual compressive strength of individual test specimen:
f_1 = 32.9 MPa
f_2 = 33.8 MPa
f_3 = 38.8 MPa
f_4 = 50.9 MPa

Mean value of actual compressive strength of all individual test specimens:

$$f_{im} = \frac{156.4}{4} = 39.1 \text{ MPa}$$

a) $p_1 = \frac{34.0 - 32.9}{34.0} \cdot 100 = 3.2\ \%$

$A_1 = \frac{3.2}{100} \cdot 3 \cdot 25.00 \cdot 1000 = € 2{,}400.00$

$p_2 = \frac{34.0 - 33.8}{34.0} \cdot 100 = 0.6\ \%$

$A_2 = \frac{0.6}{100} \cdot 3 \cdot 25.00 \cdot 1000 = € 450.00$

$p_3 = p_4 = 0$, *since actual compressive strength > minimum compressive strength*

$A_3 = A_4 = € 0.00$

$\sum A_N = 2{,}400.00 + 450.00 + 0.00 + 0.00 = € 2{,}850.00$

b) $p_M = \frac{42.0 - 39.1}{42.0} \cdot 100 = 6.9\ \%$

$A_M = \frac{6.9}{100} \cdot 3 \cdot 25.00 \cdot 4000 = € 20{,}700.00$

$\sum A_N < A_M$, *therefore A = € 20,700.00.*

B 2 Shortfall of installed layer thickness

If the installed layer thickness of an individual value (actual thickness) falls below the installed layer thickness agreed on in the construction contract (target thickness) by more than 0.5 cm, a deduction is calculated according to the formula below. The deduction is calculated irrespective of a change of the unit price in the scope of the settlement of accounts as result of insufficient installed layer thickness.

$$A = f \cdot EP \cdot F$$

Here:

A = deduction in €

f = deduction factor depending on p

$$p = \frac{\text{target thickness} - 0.5\ (\text{cm}) - \text{actual thickness}}{\text{target thickness}} \cdot 100\ (\%)$$

(p in %, thickness in cm)

actual thickness < target thickness – 0.5 cm

EP = the unit price in €/m2 resulting from invoicing according to Section 5.3.1.4

F = the area to be verified in m2

The deduction is determined solely on the basis of individual values of installed layer thickness.

Tabular representation of the deduction factor f
(corresponds to the deduction in %)

p %	0.5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
f	0.03	0.06	0.10	0.15	0.18	0.24	0.27	0.31	0.34	0.38	0.42	0.45	0.48	0.51	0.54	0.57	0.59	0.62	0.64
A' %	3	6	10	15	18	24	27	31	34	38	42	45	48	51	54	57	59	62	64

Example:

EP = € 25.00/m²

F = 1000 m²

Target thickness: 26.0 cm *Actual thickness: 24.5 cm*

$$p = \frac{26.0 - 0.5 - 24.5}{26.0} \cdot 100 = 3{,}8\ \%$$

f = 0.17 (from table)

A = 0.17 · 25.00 · 1000 = € 4,250.00.

B 3 Exceedance of the limiting value for longitudinal evenness of pavement surface

If the evenness exceeds the specified limiting value, a deduction is calculated according to the below formula.

$$A = 0.3 \cdot \sum p_i^2 \cdot EP \cdot B$$

Here:

A = deduction in €
pi = evenness measured in mm, above the specified limiting value
EP = unit price in €/m2 resulting from invoicing according to Section 5.3.1.4
B = lane width in m related to each measurement.

The lane width includes simultaneously produced adjacent hard shoulders.

Individual excess values (p_n) are firstly squared and then summed for the evaluation.

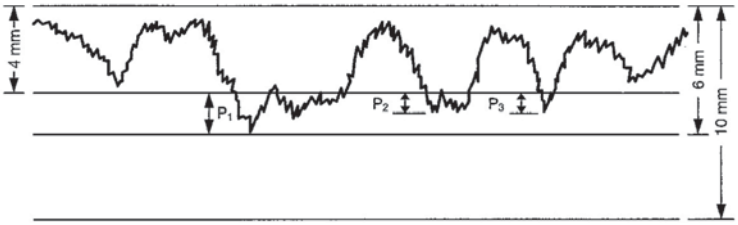
Example:

EP = € 25.00/m²

B = 4.25 m

Permissible deviation: 4 mm

Planograph record (enlarged)



$p_1 = 2$ mm $\quad p_1^2 = 4$
$p_2 = 1$ mm $\quad p_2^2 = 1$
$p_3 = 1$ mm $\quad p_3^2 = 1$
$\sum p_n^2 = 6$

$A = 0.3 \cdot 6 \cdot 25.00 \cdot 4.25 = € 191.25.$

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Annex H

German Construction Contract Procedures – Part C (VOB/C):
General Technical Specifications in Construction Contracts (ATV)
General Rules Applying to All Types of Construction Work – DIN 18299 – Edition 2006*)

Annex I

German Construction Contract Procedures – Part C (VOB/C):
General Technical Specifications in Construction Contracts (ATV)
Road Construction – Surfacings with Hydraulic Binders – DIN 18316 – Edition 2006*)

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The standard are published by and available at Beuth Verlag GmbH, Burggrafenstrasse 6, D-10787 Berlin, www.beuth.de.

Annex J

Abbreviations and technical regulations

Abbreviations

Abbreviation	Meaning
ATV	General technical specifications in construction contracts (VOB/C)
BASt	Federal Highway Research Institute
BMVBS	Federal Ministry of Transport, Building and Urban Development
DAfStb	German Committee for Reinforced Concrete
DIBt	German Institute for Building Technology
DIN	German Institute for Standardisation
EN	European standard
FGSV	German Road and Transportation Research Association
VOB	German Construction Contract Procedures

Technical regulations

DAfStb[1)]	Alkali Guideline	Preventative measures against detrimental alkali- reaction in concrete
DIN[2)]	VOB/B	German construction contract procedures – Part B: General conditions of contract relating to the execution of construction work – DIN 1961
	VOB/C	German construction contract procedures – Part C: General technical specifications in construction contracts (ATV) – general rules applying to all types of construction work– DIN 18299
		German construction contract procedures – Part C: General technical specifications in construction contracts (ATV) – road construction – surfacings with hydraulic binders – DIN 18316
	DIN 488	Reinforcing steels – Part 1: Grades, properties, marking

Technical regulations continued

DIN[2)]	DIN 1045-2	Concrete, reinforced and prestressed concrete structures – Part 2: Concrete – specification, properties, production and conformity – application rules for DIN EN 206-1
	DIN 1045-3	Concrete, reinforced and prestressed concrete structures – Part 3: Execution of structures
	DIN 1164-10	Special cement – Part 10: Composition, requirements and conformity evaluation for special common cement
	DIN 18196	Earthworks and foundations – soil classification for civil engineering purposes
	DIN 18506	Hydraulic road binders – composition, specifications and conformity criteria
	DIN V 20000-100	Application of building products in structures – Part 100: Concrete admixtures according to DIN EN 934-2:2002-02
	DIN EN 197-1	Cement – Part 1: Composition, specifications and conformity criteria for common cements
	DIN EN 10221	Surface quality classes for hot-rolled round bars and rods – technical delivery conditions
	DIN EN 13249	Geotextiles and geotextile-related products – required characteristics for use in the construction of roads and other trafficked areas
	ISO 1035-1	Hot-rolled steel bars; Part 1: Dimensions of round bars
DIN[2)3)]	DIN EN 206-1	Concrete – Part 1: Specification, performance, production and conformity
	DIN EN 934-1	Admixtures for concrete, mortar and grout – Part 1: Common requirements
	DIN EN 934-2	Admixtures for concrete, mortar and grout – Part 2: Concrete admixtures – definitions, requirements, conformity, marking and labelling
	DIN EN 13877-1	Concrete pavements – Part 1: Materials
	DIN EN 13877-2	Concrete pavements – Part 2: Functional requirements for concrete pavements
	DIN EN 13877-3	Concrete pavements – Part 3: Specifications for dowels to be used in concrete pavements

Technical regulations continued

FGSV[3)]	M Geok E-StB	Information sheet for the application of geosynthetics in road construction earthworks with check lists for the use of geogrids in road construction earthworks (C Geok E-StB) (FGSV 535)
	M OB	Information sheet for the production of surface textures on concrete pavements (FGSV 829)
		Information sheet for production and processing air-entrained concrete (FGSV 818)
		Information sheet for recycling of concrete from road pavements (FGSV 828)
	M VAG	Information sheet for recycling of reclaimed asphalt (FGSV 754)
	M VuB	Information sheet for use of non-woven fabrics and related products under concrete pavements (FGSV 830)
	RAP Stra	Directives for accreditation of test centres for building materials and building material mixtures in road construction (FGSV 916)
	RMS-2	Directives for road markings, Part 2: Application of carriageway markings (FGSV 330/2)
	RStO	Directives for the standardization of the superstructures of trafficked surfaces (FGSV 499)
	RuVA-StB	Directives for the environmentally compatible use of reclaimed materials with tar containing components and reclaimed asphalt in road construction with comments (FGSV 795)
	TL AG-StB	Technical delivery terms for reclaimed asphalt (FGSV 749)
	TL BE-StB	Technical delivery terms for bitumen emulsions (FGSV 793)
	TL Fug-StB	Technical delivery terms for joint fillers in trafficked surfaces (FGSV 897/2/3)
	TL Gestein-StB	Technical delivery terms for aggregates in road construction (FGSV 613)
	TL G SoB-StB	Technical delivery terms for material mixtures and soils for the production of unbound granular layers in road construction, Part: Quality monitoring (FGSV 696)

Technical regulations continued

FGSV[3)]	TL NBM-StB	Technical delivery terms for liquid concrete curing agents (FGSV 814)
	TL SoB-StB	Technical delivery terms for material mixtures and soils for the production of unbound granular layers in road construction (FGSV 697)
	TL Beton-StB	Technical delivery terms for materials and material mixtures for base courses with hydraulic binders and concrete pavements (FGSV 892)
	TP D-StB	Technical testing regulations to determine the thicknesses of superstructure layers in road construction (FGSV 974)
	TP Eben	Technical testing regulations for evenness measurements on road surfaces in longitudinal and transverse directions, Part: Measurements with contact (TP Eben – measurements with contact) (FGSV 404/1)
	TP Griff-StB (SCRIM)	Technical testing regulations for skid resistance measurements in road construction, Part: Sideways force measurement (SCRIM) (FGSV 408/1)
	TP Griff-StB (SRT)	Technical testing regulations for skid resistance measurements in road construction, Part: Skid resistance measurement (SRT) (FGSV 408/2)
	ZTV Asphalt-StB	Additional technical conditions of contract and directives for the construction of asphalt pavement (FGSV 799)
	ZTV E-StB	Additional technical conditions of contract and directives for earthworks in road construction (FGSV 599)
	ZTV Ew-StB	Additional technical conditions of contract and directives for the construction of drainage systems in road construction (FGSV 598)
	ZTV Fug-StB	Additional technical conditions of contract and directives for joints in trafficked areas (FGSV 897/1)
	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

BMVBS[4)]	RiZ ING	Reference drawings for civil engineering
BASt[5)]	ZTV-ING	Additional technical conditions of contract and directives for civil engineering works

Reference Source

[1)2)] **Beuth-Verlag GmbH**
Address: Burggrafenstrasse 6, 10787 Berlin
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[4)5)] **Verkehrsblatt Verlag**
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R stands for regulations:

These publications either specify the technical design or realization (R1) or give recommendations on the technical design or realization (R2).

W stands for information documents:

These publications represent the current state-of-the-art knowledge and define how a technical issue shall be practicably dealt with or has already been successfully dealt with.

Category R1 indicates 1st category regulations:

R1-publications contain the contractual basis (Additional Technical Conditions of Contract and Guidelines, Technical Conditions of Delivery and Technical Test Specifications) as well as guidelines. They are always coordinated within the FGSV. R1-publications – in particular if agreed on as integral part of the contract – have a high binding force.

Category R2 indicates 2nd category regulations:

R2-publications contain information sheets and recommendations. They are always coordinated within the FGSV. Their application as state-of-the-art technology is recommended by the FGSV.

Category W1 indicates 1st category documents of knowledge:

W1-publications contain references. They are always coordinated within the FGSV but not with external parties. They represent current state-of-the-art knowledge within the respective responsible boards of the FGSV.

Category W2 indicates 2nd category documents of knowledge:

W2-publications contain working papers. These may include preliminary results, supplementary information and guidance. They are not coordinated within the FGSV and represent the conception of an individual board of the FGSV.

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