Road and Transportation Research Association

Working Group Infrastructure Management

FGSV

Guidelines for the standardisation of pavement structures of traffic areas

R 1

RStO 12

Edition 2012
Translation 2015

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Working Group Infrastructure Management
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Task group: Revision of RStO

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Preliminary remark

The "Guidelines for the standardisation of pavement structures of traffic areas", edition 2012 (RStO 12) have been drawn up by the task group "Revision of RStO" in the committee "Design" (Chairman: Univ.-Prof. Dr.-Ing. habil. Wellner). They replace the guidelines of the same name, edition 2001 (RStO 01). The revision of the RStO 01 was necessary due to new findings and, most importantly, to the increase in relevant design traffic load and changes in traffic composition. RStO 12 was drafted with the involvement of representatives from municipal building authorities, the German Ministry of Transport, Construction and Urban Development, and the senior state road authorities.

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1 General

These "Guidelines for the standardisation of pavement structures of traffic areas", edition 2012 (RStO 12) set out the standard situations for new construction and rehabilitation of standardized pavement structures in rural and urban areas. With the exception of the regulations in Section 3.4, they do not cover staged construction. Differing solutions can be designed in individual cases using the "Guidelines for the analytical (mechanistic-empirical) design of pavement structures" (RDO Asphalt, RDO Beton).

If the pavement structure is to be designed using the RDO, the preliminary design must include a pavement structure corresponding to the assigned load class. However, within the analytical design process, appropriate methods must be used to determine the layer thicknesses and/or to define the requirements for the pavement materials.

For carriageways with multiple lanes, all lanes must be designed with the same pavement structure as required for the main lane or the lane with the highest relevant design traffic load.

Separate technical regulations apply to rural roads, manoeuvring surfaces and road surfaces subject to exceptional loads.

The purpose of the RStO is to create and maintain a standard for carriageways and trafficked areas by using technically appropriate and economical structures. The guidelines are mainly based on the function of the traffic area, the relevant design traffic load, the position of the traffic area in the landscape, the subsoil conditions, the type of structure and the condition of the traffic area to be restored, along with the conditions that result from the location of the traffic area – in a rural or in an urban area.

The RStO guidelines are based on experience in the construction and use of pavements for traffic areas, and from research findings and calculations to estimate the performance of the different structures.

The design and construction are subject to the relevant additional technical conditions of contract and directives.

2 Basic principles

2.1 Terminology

2.1.1 Structure

The structure of a traffic area is divided into:

Pavement structure,

Subgrade (in some cases),

Subsoil.

The position and boundaries and the designations of the individual layers are shown in Figures 1 to 3. In addition, these schematic sketches provide an explanation of the local conditions defined in Table 7.

Pavement structure

All layers above the formation except for the shoulders.

Fully bound pavement structure

Pavement structure that consists only of layers with binders and, because of its total thickness, requires no additional frost protection measures.

Surface Course
Upper section of the pavement structure on which traffic moves, made of asphalt, concrete, blocks or slabs.

Asphalt surface course
Asphalt surface course and, if necessary, asphalt binder course.

Concrete surface course
One or two-layer concrete surface course.

Block pavement
Blocks, bedding and joint filler.

Slab pavement
Slabs, bedding and joint filler.

Asphalt intermediate course under concrete (AICuC)
Asphalt course as described in Section 4.4.4 of RDO Beton 09 on a base course with hydraulic binders for new construction or rehabilitation.

Asphalt base-surface course
Single asphalt layer that simultaneously has the function of a base and a surface course.

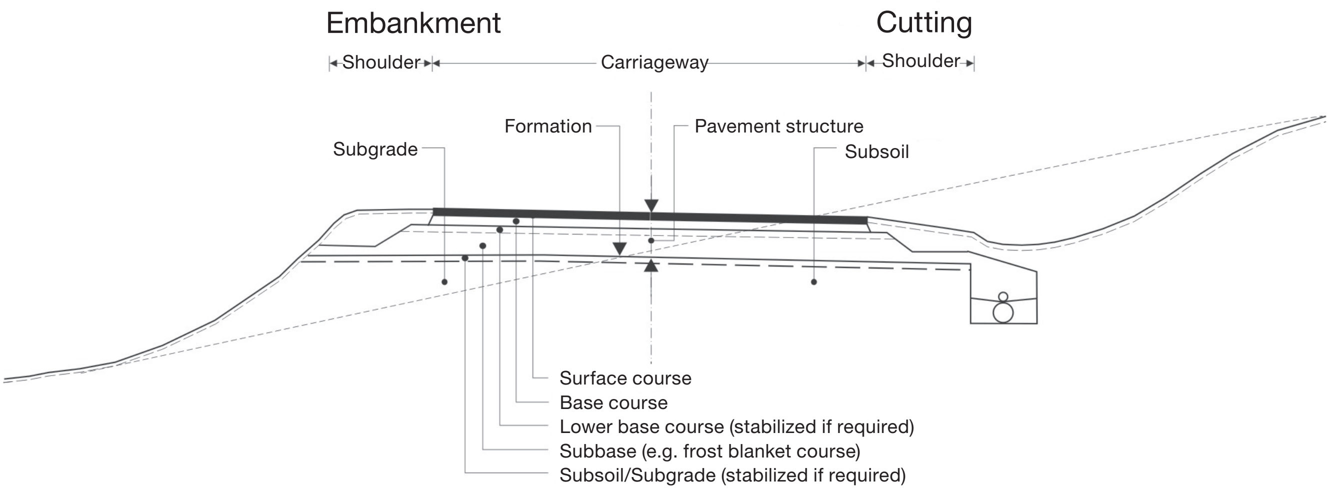


Figure 1: Example pavement in rural areas and in urban areas with water-permeable boundary areas – embankment/side-cut

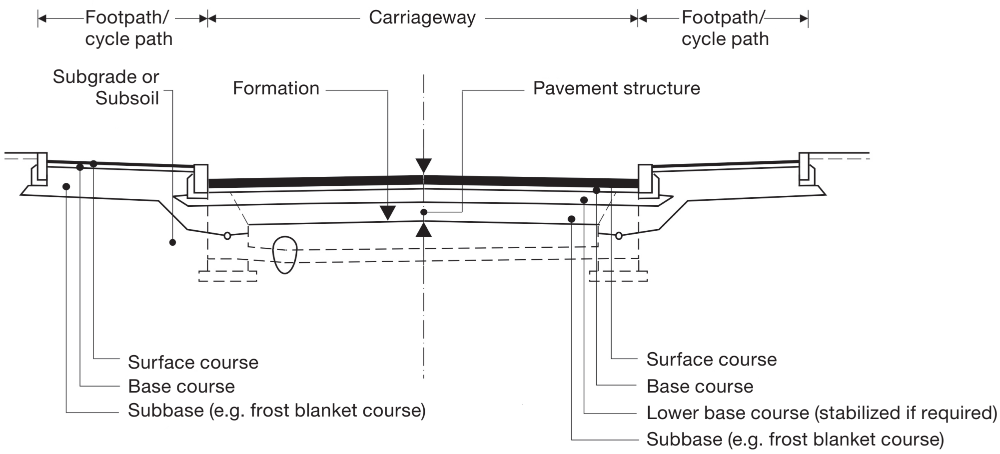


Figure 2: Example pavement in urban areas with partially water-impermeable boundary areas and with drainage facilities

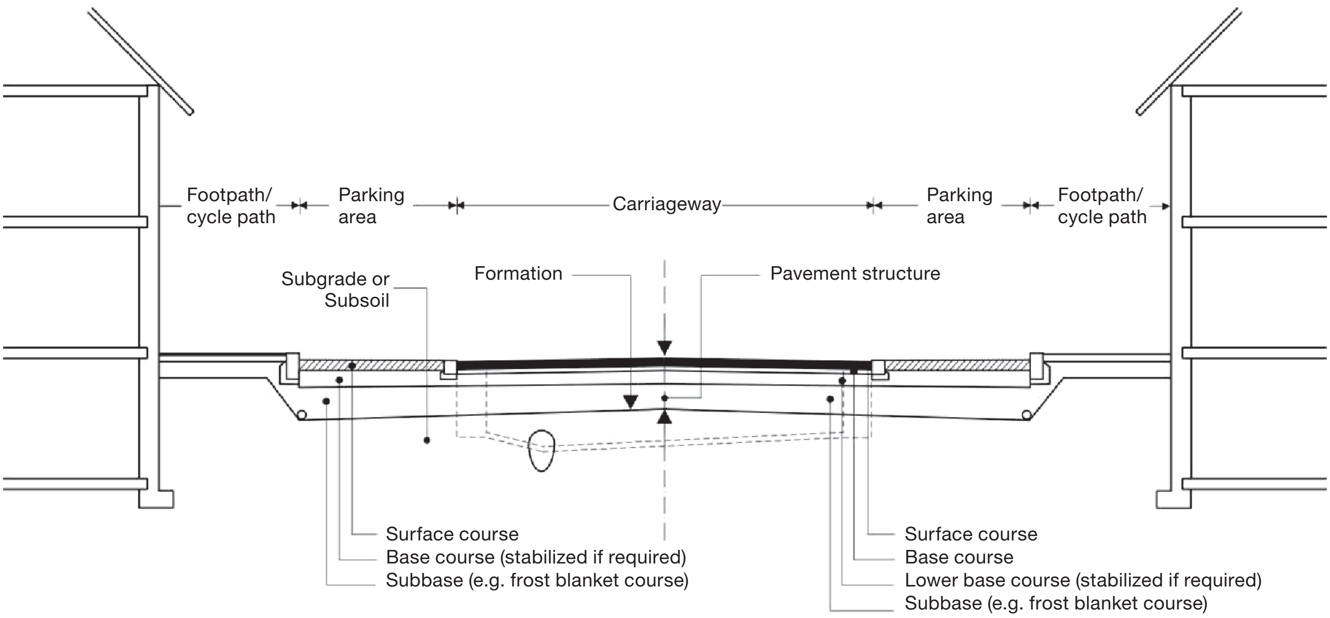


Figure 3: Example pavement in urban areas with water-impermeable boundary areas and closed side construction and with drainage facilities

Base course
Base courses are divided into:

- **Base courses with binders**
  - Asphalt base course / porous asphalt base course (WDA)
  - Base courses with hydraulic binders
    - Stabilized
    - Hydraulically bound base course (HBB)
    - Concrete base course
    - Porous concrete base course (PCB)
- **Unbound Granular Layer (UGL)**
  - Frost blanket course (FBC)
  - Crushed rock base course (RBC)
  - Gravel base course (GBC)

Layer of non-frost-susceptible material (SfM)
A layer of non-frost-susceptible material covering the subgrade or subsoil, which can be positioned as an additional layer below a base course to ensure that the frost-resistant pavement structure is sufficiently thick. It must be sufficiently water permeable even when compacted.

Subgrade
Embankment located below the pavement structure.

Subsoil
Soil or rock located immediately underneath the pavement structure or subgrade.

Formation
Subgrade or subsoil surface located immediately underneath the pavement structure and processed in line with the construction plans (final earthwork).

2.1.2 Rehabilitation

Rehabilitation is defined as any measures that improve the structure by completely or substantially restoring, or even extending, the serviceability of an existing pavement. Rehabilitation can involve complete or partial replacement of the existing pavement structure, in some cases with simultaneous modification for changed loading conditions, or incorporation of one or more layers onto the existing pavement after removal of unsuitable layers.

2.1.3 Relevant design traffic load

Heavy traffic (SV)
Heavy traffic vehicle types include trucks with a permitted total weight of more than 3.5 t with and without trailer, articulated trucks and buses with more than 9 seats including the driver.

$DTV^{(SV)}$ [vehicles/24h]
Average daily traffic for heavy vehicle types.

$DTA^{(SV)}$ [AP/24h]
Average daily number of axle passes (AP) from heavy traffic.

2.1.4 Loading from traffic

Equivalent 10-t-standard axles
Load from actual axle passes, standardised to 10-t-standard axles.

Relevant design traffic [B]
Total weighted equivalent 10-t-standard axles (ESALs[1)]) to be expected by the end of the intended life cycle in the lane with the highest relevant design traffic load. The weighting is carried out by taking account of lane factors, lane width factors and slope factors.

2.2 Criteria for the thickness design of the pavement structure

The thickness of the pavement structure should be specified to guarantee sufficient fatigue resistance and bearing capacity for relevant design traffic load and weathering over the planned life cycle, as well as adequate frost resistance. For cycle paths and footpaths, refer to Section 5.2.

2.3 Drainage

The pavement structure specified below require permanently effective drainage, particularly for the formation.

The facilities to be provided to drain the surface water and to drain slopes, the subgrade, subsoil, frost blanket course, and any course consisting of non-frost-susceptible material are described in the RAS-Ew. Further regulations for drainage can be found in the ZTV Ew-StB. The requirements from RiStWag must also be considered in water conservation areas.

At low points in the road's alignment (sags), for fully bound pavement structures and for rehabilitation and widening measures, additional drainage facilities may be necessary.

For pavement rehabilitation, the function and performance of any pre-existing drainage must be verified.

2.4 Selection of structures

2.4.1 New construction

The structures with asphalt surface course (Plate 1, Plate 4) or with concrete surface course (Plate 2, Plate 4) are specified on the principle that they are to a large extent technically equivalent; in other words the structures in a load class can withstand the predicted relevant design traffic load in such a way that suitability for use can be maintained with economically viable measures. For some structures, a greater thickness has been specified for structural reasons, or for reasons of fatigue resistance and bearing capacity.

The structures with block pavements (Plate 3) may not be equivalent to one another, nor may they be com-

1) In this document ESALs are based on a 10-t-standard whereas in some jurisdictions the standard axle weight is different.

pared to structures with asphalt or concrete surface courses rated in the same load class in terms of their bearing capacity and service life. These structures can be used particulary in urban areas, taking into account the special requirements for these roads.

The structures for cycle paths and footpaths (Plate 6) are not equivalent to one another.

When selecting structures and their specified variations, local conditions, regional experience, technical and economic considerations and environmental conditions must also be taken into account, for Example:
- Use of local materials,
- Staged construction (see Section 3.4),
- Use of industrially manufactured aggregates and recycled materials,
- Special features due to use,
- Maintenance strategies.

2.4.2 Rehabilitation

If an assessment of the structural substance of the existing traffic area has shown that:
- Rehabilitation will be required and/or
- The pavement thickness needs to be adapted for an increased relevant design traffic load,

then an appropriate and economically pavement rehabilitation should be selected for the specific purpose, local conditions and traffic during construction.

There are essentially three options for rehabilitation types:
- Rehabilitation with complete replacement of the existing pavement (see Section 4.4),
- Rehabilitation with partial replacement of the existing pavement (see Section 4.5),
- Rehabilitation on the existing pavement (see Section 4.6),

after removal of unsuitable layers/courses.

In addition to economic considerations, the selection criteria are:
- Improvement of the gradient and/or cross slope,
- Height constraints,
- Planned pavement widening,
- Concentrated series of transitional constructions with limited clearance,
- Traffic routeing (suitability of any diversion routes),
- Rehabilitation by lane (differentiation of measures across the pavement according to each lane's condition),
- Staged rehabilitation (for asphalt pavements),
- Constructability (loading capacity) of structures and pipelines,
- Non frost resistant traffic areas,
- Consideration of the type and construction of subsequent planned construction and extension stages,
- Suitability of existing layers/courses for future function,
- Usability of removed materials.

2.5 Load classes and relevant design traffic load

Carriageways, bus traffic areas, traffic areas in maintenance and service areas, parking areas, shoulders and merging/diverging lanes are assigned to the load classes Bk0.3 to Bk100 according to the loading from traffic.

2.5.1 Carriageways

For carriageways, the assignment to a load class is normally based on the relevant design traffic, as set out in Table 1.

Table 1: Relevant design traffic and assigned load class (see also annex 1**)**

Relevant design traffic Equivalent 10-t-standard axles (millions of ESALs)				Load class
Above	32[1)]			Bk100
From	10	to	32	Bk32
From	3.2	to	10	Bk10
From	1.8	to	3.2	Bk3.2
From	1.0	to	1.8	Bk1.8
From	0.3	to	1.0	Bk1.0
		to	0.3	Bk0.3

1) For a relevant design traffic greater than 100 million of ESALs, the pavement structure should be designed using RDO.

The relevant design traffic can be calculated based on the $DTV^{(SV)}$ using the road class specific load spectrum quotients or using detailed axle load data (see annex 1). It is calculated for the lane with the highest relevant design traffic load from heavy traffic, taking account of the planned
- Number of lanes in the cross-section,
- Width of the lane, and
- Longitudinal slope.

Annex 2 contains examples of the calculation of the relevant design traffic.

The calculations are also suitable for determining number of axle load passes applied previously to a pavement.

A service life of 30 years is normally assumed when calculating the relevant design traffic.

If the relevant design traffic cannot be determined for traffic areas in an urban area, the load classes can be assigned to the typical design cases from RASt, as set out in Table 2. The selection of load class must be based on the expected heavy relevant design traffic load.

In crossing and intersection areas, the relevant design traffic of the link route lane with the heaviest load is determinative.

For roundabouts, the next higher load class should be used than that which applies to the most heavily trafficked road that enters the roundabout.

Pavements in pedestrian zones that also carry delivery traffic (heavy traffic vehicles) should be classified in the same way as main shopping streets or local shopping streets.

Table 2: Possible load classes for typical design situations according to RASt

Typical design situations	Road category	Load class
Open road	VS II, VS III	Bk10 to Bk100
Link road	HS III, HS IV	Bk3.2/Bk10
Industrial site access road	HS IV, ES IV, ES V	Bk3.2 to Bk100
Business access road	HS IV, ES IV, ES V	Bk1.8 to Bk100
Main shopping street	HS IV, ES IV	Bk1.8 to Bk10
Local shopping street	HS IV, ES IV	Bk1.8 to Bk10
Local access road	HS III, HS IV	Bk3.2/Bk10
Village main street	HS IV, ES IV	Bk1.0 to Bk3.2
Neighbourhood street	HS IV, ES IV	Bk1.0 to Bk3.2
Collector street	ES IV	Bk1.0 to Bk3.2
Residential street	ES V	Bk0.3/Bk1.0
Residential pathway	ES V	Bk0.3

2.5.2 Bus traffic areas

On the basis of their design traffic load, bus traffic areas can be classified according to Table 3. If the load class is determined according to Section 2.5.1, the variation of the lane width factor f_2 (lateral wander), the axles number factor f_A, and the load spectrum quotient q_{Bm}, must be considered.

It may be necessary to further consider the lateral wander of the vehicles, i.e. the width of the lane actually driven on, rather than the total width of the area.

Table 3: Design traffic load on bus traffic areas and load classes

Design traffic load	Load class
Over 1400 buses/day	Bk100
From 425 buses/day to 1400 buses/day	Bk32
From 130 buses/day to 425 buses/day	Bk10
From 65 buses/day to 130 buses/day	Bk3.2
Up to 65 buses/day[1)]	Bk1.8

1) If the design traffic load is lower than 15 buses/day, a lower load class can be chosen.

2.5.3 Maintenance and service areas

The traffic areas in maintenance and service areas can be classified according to Table 4, if the load class is not determined as set out in Section 2.5.1.

Maintenance and service areas immediately adjacent to highways must be designed using a load class no less than Bk10.

Table 4: Traffic areas in maintenance and service areas and load classes

Traffic type	Load class
Heavy traffic	Bk3.2 to Bk10
Cars including low volume of heavy traffic	Bk0.3 to Bk1.8

2.5.4 Parking areas

Parking areas can be classified according to Table 5. Parking areas immediately adjacent to highways must be designed using a load class no less than Bk10 if the use by heavy traffic is possible.

Table 5: Parking areas and load classes

Traffic type	Load class
Heavy traffic	Bk3.2 to Bk10
Areas not continuously used by heavy traffic	Bk1.0/ Bk1.8
Cars (Use by maintenance vehicles is possible)	Bk0.3

2.5.5 Other traffic areas

Merging lanes, diverging lanes and hard shoulders normally have the same structure and thickness as the main lanes of the continous carriageway.

The lanes at grade-separated intersections and junctions should be designed using load class Bk3.2, unless a higher relevant design traffic is established.

Median crossings (between the outer lanes of dual carriageways) should be designed using load class Bk3.2, unless designed for a specific relevant design traffic load.

Special areas such as container transhipment sites can be subject to loads that cannot be defined using the relevant design traffic. They should be designed using special guidelines or should be designed individually.

2.6 Special loading

Traffic areas can be subject to exceptional loading from heavy traffic, e.g.

– Canalized traffic,

– Tight cornering,

– Slow moving traffic,

– Frequent braking and acceleration processes,
– Crossing and intersection areas,
– Parking areas.

Traffic areas in load classes Bk3.2 to Bk100 are always subject to exceptional loading/stresses.

The influence of tracking traffic and traffic on slopes on the thickness of the pavement structure is considered by the factors f_2 and f_3 (see annex 1).

In addition, it is essential to verify whether any exceptional loading/stresses need to be taken into account when choosing the structure, the materials, their composition and when constructing individual layers of the pavement structure (see ZTV Asphalt-StB/ZTV Pflaster-StB).

3 Construction of new carriageways

3.1 Subsoil and subgrade

Requirements for the subsoil and subgrade, and criteria for assignment of soils according to their frost susceptibility, (F1-, F2- and F3-soils) can be found in ZTV E-StB.

3.1.1 F2- and F3- soils

The layer thicknesses set out in Plates 1 to 4 require the formation to have an E_{v2}-value of ≥ 45 MPa.

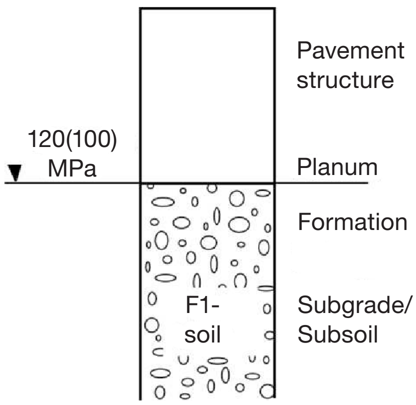
For pavements with fully bound structures with soils in frost susceptibility class F3, or with soils in frost susceptibility class F2 for critical moisture conditions, a capping layer (stabilization) with a minimum thickness of 15 cm is required. The capping layer cannot be counted towards the thickness of the pavement structure.

3.1.2 F1-soils

If the subsoil or subgrade immediately underneath the pavement structure is a soil of frost susceptibility class F1, there is no need for a frost blanket course provided the depth below the pavement surface is 1.2 m (1.3 m for frost action zone II; 1.5 m for frost action zone III). The soil must still meet the requirements of ZTV SoB-StB for a frost blanket course in terms of the degree of compaction.

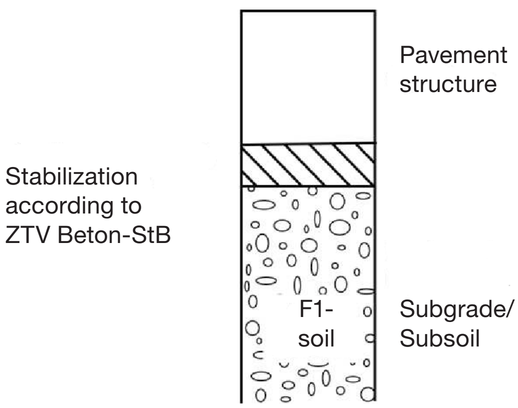
If an E_{v2}-value of ≥ 120 MPa (load classes Bk1.0 to Bk100) or an E_{v2}-value of ≥ 100 MPa (load class Bk0.3) is achieved on the F1-soil, the pavement structure can be positioned directly on top of the frost blanket course (Figure 4).

If the F1-soil does not meet these E_{v2}-values, either a layer of the F1-soil must be stabilized in line with ZTV Beton-StB (Figure 5) or a unbound granular layer of a thickness as set out in Table 8 must be laid down on the F1-soil. The crushed rock or gravel base course of the structures as set out in Plate 1, Line 5, Plate 2, Line 3.1 and Plate 3, Line 3 can be laid down immediately on the F1-soil.



Selection and thickness design of the remaining pavement structure as from upper level of the frost blanket course according to:
Plate 1, Lines 1, 2.1, 3 and 4
Plate 2, Lines 1.1, 2, 3.2 and 4
Plate 3, Lines 1, 2 and 4 to 7

Figure 4: Structures on F1-soil with E_{v2} ≥ 120 MPa (for load class Bk0.3 E_{v2} ≥ 100 MPa)



Selection and thickness design of the bound layers according to:
Plate 1, Lines 2.2 and 2.3
Plate 2, Lines 1.2 and 1.3

Figure 5: Structures on F1-soil with stabilization according to ZTV Beton-StB

3.2 Minimum thickness of frost resistant pavement structure

3.2.1 General

In addition to load distribution, the minimum thickness of frost resistant pavement structure should ensure that no harmful deformation occurs during frost and thawing periods.

If no local experience or special studies are available to determine the minimum thickness of frost resistant pavement structure, this thickness can be calculated using

– the frost susceptibility of the subsoil/subgrade as set out in Section 3.2.2 for the relevant load class, and
– the additional or reduced thicknesses determined according to Section 3.2.3.

Any soil stabilization in line with ZTV E-StB in the upper zone of a frost susceptible subsoil or subgrade can be counted towards the thickness of the frost resistant pavement structure up to a maximum thickness of 20 cm.

If a soil improvement in line with ZTV E-StB is carried out instead of soil stabilization at a thickness of ≥ 25 cm, this is taken into account by classifying the frost susceptible subsoil or subgrade into frost susceptibility class F2.

If there are changing local conditions, for technical construction reasons it is advisable to keep the thickness of the frost resistant pavement structure constant over large sections.

The procedure for determining the minimum thickness of the frost resistant pavement structure is not applicable for a fully bound pavement structure.

3.2.2 Initial values for determination of the minimum thickness

The frost susceptibility of the soil is determined by its classification in line with ZTV E-StB.

For frost susceptibility class F2- and F3- soils in line with ZTV E-StB, the initial values for determination of the minimum thickness of the frost resistant pavement structure set out in Table 6 are applicable, dependent on the load class.

Table 6: Initial values for determination of the minimum thickness of the frost resistant pavement structure

Frost susceptibility class	Thickness in cm for load class		
	Bk100 to Bk10	Bk3.2 to Bk1.0	Bk0.3
F2	55	50	40
F3	65	60	50

3.2.3 Additional or reduced thicknesses

Frost action, local climatic differences, moisture conditions in the subsoil, the vertical position of the carriageway relative to the surrounding ground and drainage of the carriageway/construction of the shoulders must also be taken into account when specifying the total thickness of the frost resistant pavement structure. The additional or reduced thickness to determine this total thickness from the individual values of the different criteria is established as follows, and as set out in Table 7:

Additional or reduced thickness = A + B + C + D + E.

Figure 6 shows the frost action zones I, II and III; the boundaries between the zones are a rough approximation. The geographical features plotted (rivers, mountains, towns) make it easier to assign a pavement to a region with its relevant frost action zone. Local features – e.g. deep valleys, narrow ranges of hills – cannot be seen from this map. Such topographical features must be taken into account in individual cases during the design process of the frost resistant pavement structure, according to the specific location of the road.

The depth of frost penetration into the soil depends not only on the altitude of the ground but also on the thermal conductivity in the subsoil/subgrade, the moisture conditions in the soil and in the pavement structure and on the heat radiation conditions, e.g. whether in urban areas. Because the measurements of these influencing variables are very complex and thus are only feasible in exceptional individual cases, experience from the past and knowledge of local conditions should be taken into account during the design process of a pavement structure.

Table 7: Additional or reduced thicknesses due to local conditions

Local conditions		A	B	C	D	E
Frost action	Zone I	± 0 cm				
	Zone II	+ 5 cm				
	Zone III	+15 cm				
Local climatic variations	Unfavourable climatic influences, e.g. northern slope or ridge locations in mountains		+ 5 cm			
	No special climatic influences		± 0 cm			
	Favourable climatic influences with closed side construction along the road		– 5 cm			
Water conditions in the subsoil	No groundwater or stratum water at a depth of ≤ 1.5 m below formation			± 0 cm		
	Permanent or occasional groundwater or stratum water higher than 1.5 m below formation			+ 5 cm		
Vertical position of the road surface	Cutting or side-cut				+ 5 cm	
	At-grade and up to embankment ≤ 2.0 m high				± 0 cm	
	Embankment > 2.0 m high				– 5 cm	
Carriageway drainage/ execution of boundary areas	Drainage of carriageway using troughs, ditches or slopes					± 0 cm
	Drainage of carriageway and boundary areas using channels or drains and pipelines					– 5 cm

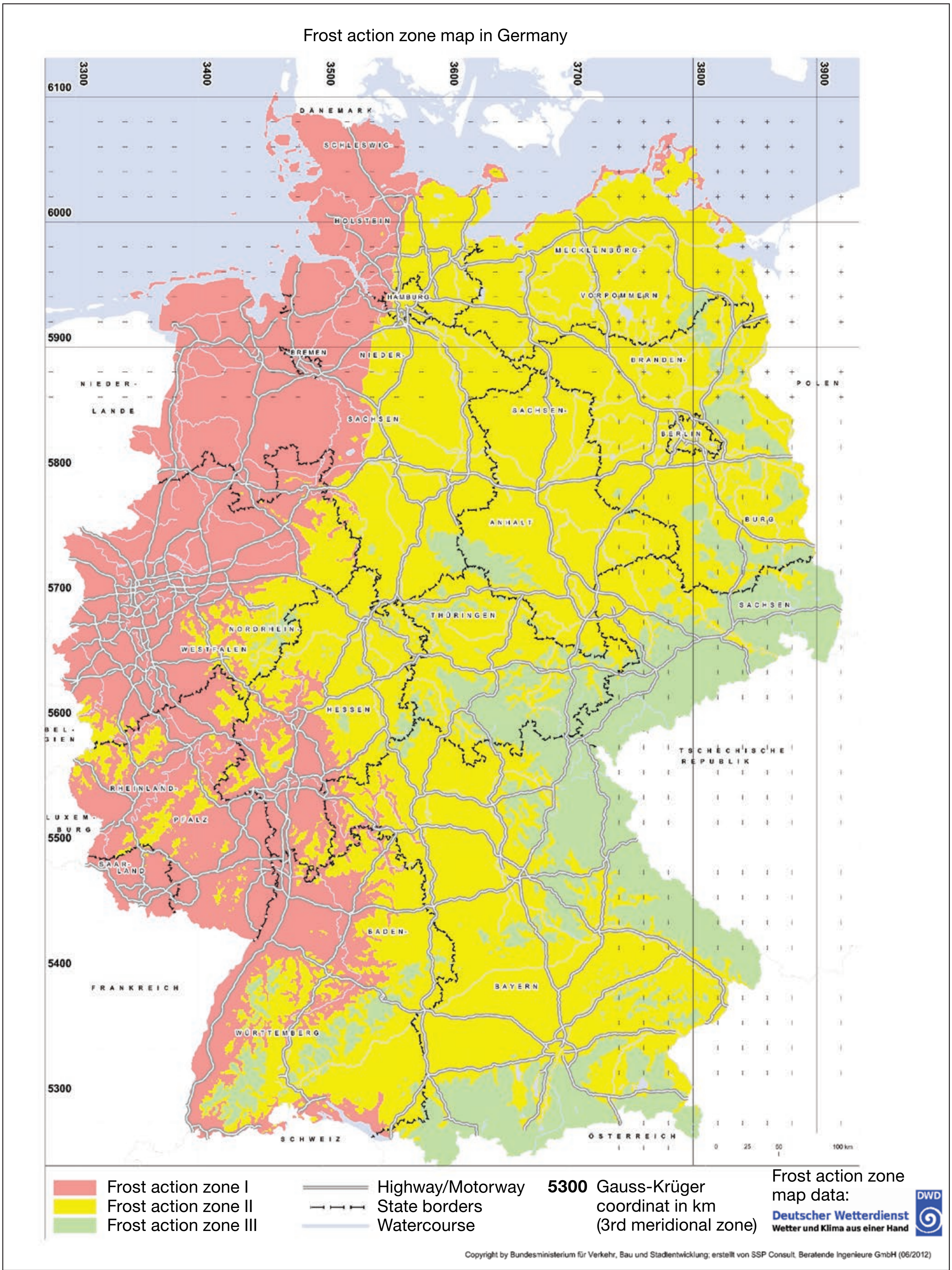


Figure 6: Frost action zones
A detailed version of this map can be downloaded from the website of the Federal Highway Research Institute (www.bast.de) and the FGSV Verlag (www.fgsv-verlag.de).

3.3 Pavement structure

3.3.1 Structures and layer thicknesses

Plates 1 to 3 show standardised structures with asphalt surface course, concrete surface course and block pavements on F2- and F3-soils for the relevant load classes. For F1-soils, refer to Section 3.1.2.

Plate 4 contains standardised structures for a fully bound asphalt and concrete pavement.

In Plates 1 to 3, the thicknesses of the frost resistant pavement structure on F2- and F3-soils are specified in 10 cm increments. If Section 3.2 results in a different thickness for the frost resistant pavement structure than that in the Plates, this thickness must be used.

Depending on the bearing capacity of the formation or frost blanket course, approximate values for the thicknesses of the unbound granular layer above them can be taken from Table 8.

3.3.2 Base courses

The requirements for base courses are set out in ZTV Asphalt-StB, ZTV Beton-StB and ZTV SoB-StB. For base courses under block pavements, the requirements of ZTV Pflaster-StB are also applicable.

Unbound granular layers
The frost blanket course must have at least the thickness specified in Plates 1 to 3 under “Thickness of frost blanket course” (see also Section 3.1.2). If no frost blanket course thickness is specified, this means that the required E_{v2}-value will probably not be achieved on the frost blanket course; in this case, either a thicker frost blanket course or a different structure should be selected. Alternatively, the frost blanket course can be completely replaced by the same material as used in the crushed rock or gravel base course above.

Base courses with hydraulic binders
Base courses with hydraulic binders can take the form of stabilized soil, hydraulically bound base course or concrete base course. They must satisfy different strength requirements, as stipulated in ZTV Beton-StB, depending on the type of pavement structure.

Base courses with hydraulic binders under block pavements must be water permeable (PCB).

To prevent reflection cracking, measures should be taken to achieve selective cracking as set out in ZTV Beton-StB in those base courses with hydraulic binders.

Asphalt base courses
Asphalt base courses under block pavements must be designed to be water permeable (WDA).

3.3.3 Asphalt surface courses

Requirements for asphalt surface layers and the asphalt binder layers required in load classes Bk100 to Bk3.2, along with specifications for the layer thicknesses, can be found in ZTV Asphalt-StB.

Where it is planned to deviate from the layer thicknesses in Plates 1 and 4, the corresponding specifications from ZTV Asphalt-StB must be considered. Any additional or reduced thickness normally has to be compensated by changes to the asphalt layer immediately below.

Table 8: Reference values for layer thicknesses required for bearing capacity reasons for unbound granular layers (UGL) according to ZTV SoB-StB depending on the E_{v2}-values of the base and the base course type
(thicknesses in cm)

E_{v2}-value [MPa] on the surface of the UGL		**≥ 80**	**≥ 100**	**≥ 120**	**≥ 150**	**≥ 100**	**≥ 120**	**≥ 150**	**≥ 120**	**≥ 150**	**≥ 180**	**≥ 150**	**≥ 180**
			↑				↑			↑		↑	
Type of UGL	Crushed rock base course [cm]	15*	15*	25	35**	–	20	25	15*	20	30	15*	20
	Gravel base course [cm]	15*	15*	30	50**	–	25	35	20	30	X	20	X
	Frost blanket course [cm] made of predominantly crushed material	15*	20	30	X	15*	25	X	X	X	X	X	X
	Frost blanket course [cm] made of predominantly uncrushed material	20	25	35	X	–	–	X	X	X	X	X	X
			↑				↑			↑		↑	
E_{V2}-value [MPa] for base		45				80			100			120	
Base		Formation							Frost blanket course				

X Combination not possible

– Combination not commonly used

15* Minimum practical thickness with 0/45

** Lower thickness also possible with local experience

In load class Bk 0.3, up to a relevant design traffic of 0.1 million of ESALs axles a 10 cm thick asphalt surface-base layer is sufficient on an unbound granular layer (frost blanket course, crushed rock base course, gravel base course). Instead of an asphalt surface base layer, an asphalt base course at least 8 cm thick with an asphalt surface layer according to ZTV Asphalt-StB or ZTV BEA-StB can be selected.

3.3.4 Concrete surface courses

The requirements for concrete surface courses and non-woven fabrics are set out in ZTV Beton-StB.

The structures in Plates 2 and 4 assume dowels in the transverse joints and anchors in the longitudinal joints.

As a variation from Plate 2, structures in line 1.1 can be used without non-woven fabrics if there is good local experience. In these cases, the concrete surface course thickness can be reduced by 1 cm.

Alternatively to Plates 2 and 4, in the structure using a concrete surface course with non-woven fabrics on a base course with hydraulic binders, an asphalt intermediate course (AICuC) can be used instead of the non-woven fabric. In that cases the concrete surface course thickness can be reduced by 1 cm.

The thickness of the AICuC can be counted towards the thickness of the frost blanket course or the layers made of non-frost-susceptible material.

The layer thicknesses in Plate 2 are based on the following concrete slab dimensions:

- Slab width in main lane 4.0 to 4.5 m
  - Load classes Bk3.2 to Bk100
    Typical slab length 5.0 m
  - Load classes Bk0.3 to Bk1.8
    Typical slab length 4.0 to 4.5 m
- Slab width in main lane 3.0 to 4.0 m
  - All load classes
    Typical slab length 4.0 m

The specifications in ZTV Beton-StB take precedence.

When using a structure from Plate 2, line 3, it is recommended to verify the requirement for the E_{V2}-value on the surface of the crushed rock base course under the concrete surface course (RBCuC) based on method M2 as set out in ZTV E-StB. Sufficient water permeability of the base course must be ensured.

3.3.5 Block pavements

The requirements for block pavements are set out in ZTV Plaster-StB.

Plate 3 shows the standard thicknesses for structures with block pavements. Blocks with a greater thickness can also be used. In these cases, the regulations for the thickness of the bedding and the thickness of block pavements formed of natural stone can be found in ZTV Pflaster-StB.

Sufficient water permeability of all base courses must be ensured. With good local experience, in load class Bk3.2 an E_{V2}-value of ≥ 150 MPa on the unbound granular layers is sufficient.

Lower block thicknesses, but not below 6.0 cm, can be used provided that there is sufficient local experience available using these proven regional block pavement structures. The additional or reduced thickness – including a variation in the thickness of the bedding layer – must be compensated by the complete pavement structure. Reduced thicknesses must be compensated by an increased thickness of the upper base course. Additional thicknesses must be compensated in the frost blanket course or in the layer of non-frost-susceptible material.

3.3.6 Special features

If there are any special conditions, e.g. around utility cables and pipes, or any technical and economic reasons, variations from the regulations in Sections 3.1 to 3.3.5 are possible.

3.4 Supplementary information for trafficked areas in urban areas

The regulations in Sections 3.1 to 3.3 and Section 4 also apply to pavements in urban areas, provided the special features of municipal pavement construction allow this and no other demands need to be taken into account. For Example, the construction can be hampered by

- Narrow carriageway width,
- Construction under traffic, particularly in crossing areas,
- Presence of utility pipes and cables with installations, e.g. covers, chambers, drains.
- Any other special loading conditions due to increased tracking, including visually constricted carriageways in traffic-calmed areas.

Depending on the local conditions, additional measures may be required in addition to selection of deformation resistant asphalt layers, e.g. increase in the thickness of a bound base course to count towards the thickness of the frost blanket course.

When constructing at development sites, staged construction of the pavements is the normal practice. The first construction stage should be able to withstand the expected construction site traffic. Here, structures that have bound base courses should normally be chosen. If the entire pavement structure is to be created after the adjacent construction has been largely completed, the condition of the remaining partial pavements as set out in Section 4 must be taken into account (see annex 2, Example 8). For both staged and non-staged construction of the pavements, the site traffic must be considered when determining the load class.

Plate 1: Structures with asphalt surface course for carriageways on F2- and F3-subsoil/subgrade

(Thicknesses in cm; ▼ E_{v2}-minimum values in MPa)

Line	Load class	BK100				BK32				BK10				BK3.2				BK1.8				BK1.0				BK0.3			
	B [million of ESALs]	> 32				> 10 – 32				> 3.2 – 10				> 1.8 – 3.2				> 1.0 – 1.8				> 0.3 – 1.0				≤ 0.3			
	Thickness of frost resistant pavement structure[1]	55	65	75	85	55	65	75	85	55	65	75	85	45	55	65	75	45	55	65	75	45	55	65	75	35	45	55	65
1	**Asphalt base course on frost blanket course**																												
	Asphalt surface course Asphalt base course Frost blanket course	12 / 22 / Σ34; ▼120; ▼45				12 / 18 / Σ30; ▼120; ▼45				12 / 14 / Σ26; ▼120; ▼45				10 / 12 / Σ22; ▼120; ▼45				4 / 16 / Σ20; ▼120; ▼45				4 / 14 / Σ18; ▼120; ▼45				4 / 10 }[6] / Σ14; ▼100; ▼45			
	Thickness of frost blanket course	–	31[2]	41	51	25[3]	35	45	55	29[3]	39	49	59	–	33[2]	43	53	25[3]	35	45	55	27	37	47	57	21	31	41	51
2.1	**Asphalt base course and <u>base course with hydraulic binders</u> on frost blanket course or layer of non-frost-susceptible material**																												
	Asphalt surface course Asphalt base course Cement stabilized base course (HBB) Frost blanket course	12 / 14 / 15 / Σ41; ▼120; ▼45				12 / 10 / 15 / Σ37; ▼120; ▼45				12 / 8 / 15 / Σ35; ▼120; ▼45																			
	Thickness of frost blanket course	–	–	34[2]	44	–	28[3]	38	48	–	30[2]	40	50																
2.2	Asphalt surface course Asphalt base course Stabilized granular material Layer of non-frost-susceptible material – widely or gap-graded in line with DIN 18196	12 / 18 / 15 / Σ45; ▼45				12 / 14 / 15 / Σ41; ▼45				12 / 10 / 15 / Σ37; ▼45				10 / 10 / 15 / Σ35; ▼45				4 / 12 / 15 / Σ31; ▼45				4 / 10 / 15 / Σ29; ▼45				4 / 10 / 15 / Σ29; ▼45			
	Thickness of layer of non-frost-susceptible material	10[4]	20[4]	30	40	14[4]	24	34	44	18[4]	28	38	48	10[4]	20	30	40	14[4]	24	34	44	16[4]	26	36	46	6[4]	16[4]	26	36
2.3	Asphalt surface course Asphalt base course Stabilized granular material Layer of non-frost-susceptible material – narrowly graded in line with DIN 18196	12 / 18 / 20 / Σ50; ▼45				12 / 14 / 20 / Σ46; ▼45				12 / 10 / 20 / Σ42; ▼45				10 / 10 / 20 / Σ40; ▼45				4 / 12 / 15 / Σ31; ▼45				4 / 10 / 15 / Σ29; ▼45				4 / 10 / 15 / Σ29; ▼45			
	Thickness of layer of non-frost-susceptible material	5[4]	15[4]	25	35	9[4]	19[4]	29	39	13[4]	23	33	43	5[4]	15[4]	25	35	14[4]	24	34	44	16[4]	26	36	46	6[4]	16[4]	26	36
3	**Asphalt base course and <u>crushed rock base course</u> on frost blanket course**																												
	Asphalt surface course Asphalt base course Crushed rock base course[7] E_{v2} ≥ 150(120) Frost blanket course	12 / 18 / 15 / Σ45; ▼150; ▼120; ▼45				12 / 14 / 15 / Σ41; ▼150; ▼120; ▼45				12 / 10 / 15 / Σ37; ▼150; ▼120; ▼45				10 / 10 / 15 / Σ35; ▼150; ▼120; ▼45				4 / 12 / 15 / Σ31; ▼150; ▼120; ▼45				4 / 10 / 15 / Σ29; ▼150; ▼120; ▼45				4 / 8 }[6] / 15 / Σ27; ▼120; ▼100; ▼45			
	Thickness of frost blanket course	–	–	30[2]	40	–	–	34[2]	44	–	28[3]	38	48	–	–	30[2]	40	–	24[3]	34	44	16[3]	26	36	46	–	18[3]	28	38
4	**Asphalt base course and <u>gravel base course</u> on frost blanket course**																												
	Asphalt surface course Asphalt base course Gravel base course E_{v2} ≥ 150(120) Frost blanket course	12 / 18 / 20 / Σ50; ▼150; ▼120; ▼45				12 / 14 / 20 / Σ46; ▼150; ▼120; ▼45				12 / 10 / 20 / Σ42; ▼150; ▼120; ▼45				10 / 10 / 20 / Σ40; ▼150; ▼120; ▼45				4 / 12 / 20 / Σ36; ▼150; ▼120; ▼45				4 / 10 / 20 / Σ34; ▼150; ▼120; ▼45				4 / 8 }[6] / 20 / Σ32; ▼120; ▼100; ▼45			
	Thickness of frost blanket course	–	–	25[3]	35	–	–	29[3]	39	–		33[2]	43	–	–	25[3]	35	–	–	29[2]	39	–	31[2]	41	51	–	–	23[2]	33
5	**Asphalt base course and <u>crushed rock or gravel base course</u> on layer of non-frost-susceptible material**																												
	Asphalt surface course Asphalt base course Crushed rock or gravel base course Layer of non-frost-susceptible material	12 / 18 / 30[5] / Σ60; ▼150; ▼45				12 / 14 / 30[5] / Σ56; ▼150; ▼45				12 / 10 / 30[5] / Σ52; ▼150; ▼45				10 / 10 / 30[5] / Σ50; ▼150; ▼45				4 / 12 / 30[5] / Σ46; ▼150; ▼45				4 / 10 / 30[5] / Σ44; ▼150; ▼45				4 / 8 }[6] / 25[5] / Σ37; ▼120; ▼45			
	Thickness of layer of non-frost-susceptible material	Above 12 cm made of non-frost-susceptible material, lower remaining thickness is to be compensated by the material above																											

[1] For other thicknesses of the frost resistant pavement structure, the thickness of the frost blanket course or of the layer of non-frost-susceptible material needs to be adjusted or recalculated as well, see also Table 8

[2] With gravel, only applicable with local experience

[3] Only applicable with crushed rock and local experience

[4] Only to be executed if the frost resistant material and the material to be stabilized is installed as one layer

[5] For gravel base course in load classes BK3.2 to BK100 with 40 cm thickness, and in load classes BK0.3 and BK1.0 with 30 cm thickness

[6] Alternative: Asphalt base and surface layer can be used as set out in Section 3.3.3

[7] Alternative: Reduction of asphalt base course by 2 cm with 20 cm thick crushed rock base course and E_{v2} ≥ 180 MPa (in load classes Bk1.8 to BK100) or E_{v2} ≥ 150 MPa (in other classes)

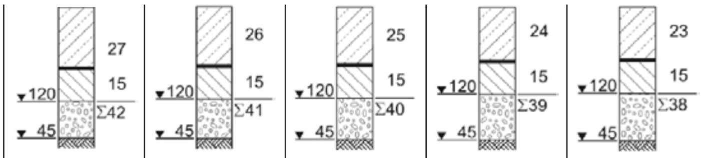
Plate 2: Structures with concrete surface course for carriageways on F2- and F3-subsoil/subgrade

(Thicknesses in cm; ▼ E_{v2} minimum values in MPa)

Line	Load class	BK100				BK32				BK10				BK3.2				BK1.8				BK1.0				BK0.3			
	B [million of ESALs]	> 32				> 10 – 32				> 3.2 – 10				> 1.8 – 3.2				> 1.0 – 1.8				> 0.3 – 1.0				≤ 0.3			
	Thickness of frost resistant pavement structure [1]	55	65	75	85	55	65	75	85	55	65	75	85	45	55	65	75	45	55	65	75	45	55	65	75	35	45	55	65

Line 1.1 – Base course with hydraulic binders on frost blanket course or layer of non-frost-susceptible material

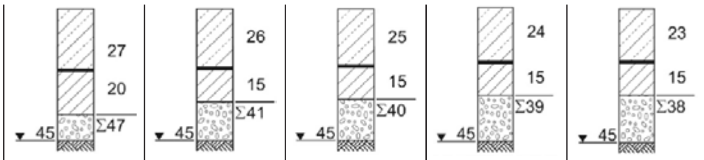
- Concrete surface course
- Non-woven fabric[8]
- Hydraulically bound base course (HBB)
- Frost blanket course



Line		BK100				BK32				BK10				BK3.2				BK1.8				BK1.0				BK0.3			
1.1	Thickness of frost blanket course	–	–	33[2]	43	–	24[3]	34	44	–	25[3]	35	45	–	–	26[3]	36	–	–	27[3]	37								

Line 1.2

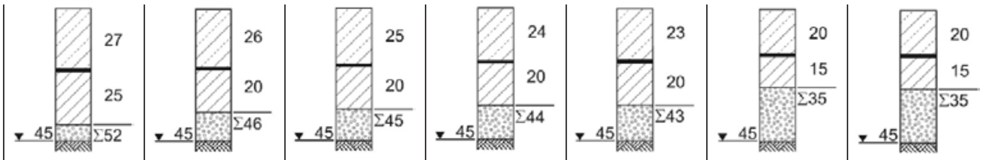
- Concrete surface course
- Non-woven fabric[8]
- Stabilized granular material layer of non-frost-susceptible material – widely or gap-graded in line with DIN 18196-



Line		BK100				BK32				BK10				BK3.2				BK1.8				BK1.0				BK0.3			
1.2	Thickness of layer of non-frost-susceptible material	8[4]	18[4]	28	38	14[4]	24	34	44	15[4]	25	35	45	6[4]	16	26	36	–	–	27[3]	37								

Line 1.3

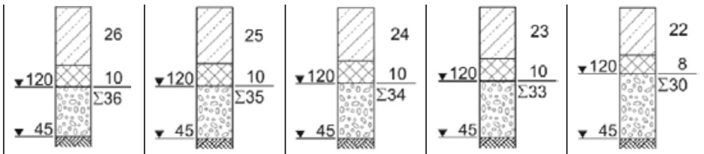
- Concrete surface course
- Non-woven fabric[8]
- Stabilized granular material
- Layer of non-frost-susceptible material – narrowly graded in line with DIN 18196-



Line		BK100				BK32				BK10				BK3.2				BK1.8				BK1.0				BK0.3			
1.3	Thickness of layer of non-frost-susceptible material	3[4]	13[4]	23	33	9[4]	19	29	39	10[4]	20	30	40	1[4]	11[4]	21	31	2[4]	12[4]	22	32	10[4]	20	30	40	–	10[4]	20	30

Line 2 – Asphalt base course on frost blanket course

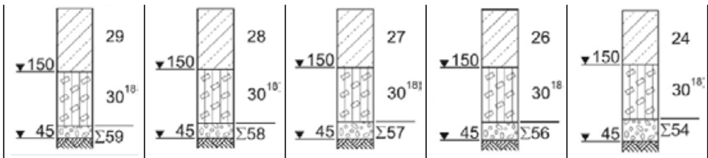
- Concrete surface course
- Asphalt base course
- Frost blanket course



Line		BK100				BK32				BK10				BK3.2				BK1.8				BK1.0				BK0.3			
2	Thickness of frost blanket course	–	29[3]	39	49	–	30[2]	40	50	–	31[2]	41	51	–	–	32[2]	42	–	25[3]	35	45								

Line 3.1 – Crushed rock base course on layer of non-frost-susceptible material

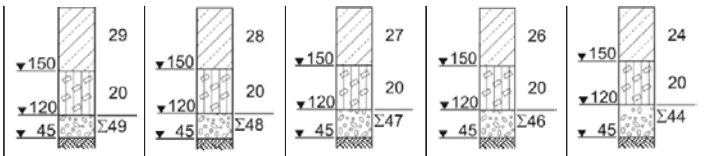
- Concrete surface course
- Crushed rock base course
- Layer of non-frost-susceptible material



Line		
3.1	Thickness of layer of non-frost-susceptible material	Above 12 cm made of non-frost-susceptible material, lower remaining thickness is to be compensated by the material above

Line 3.2 – Crushed rock base course on frost blanket course

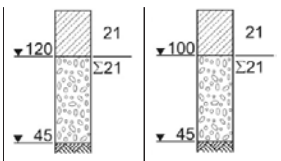
- Concrete surface course
- Crushed rock base course
- Frost blanket course



Line		BK100				BK32				BK10				BK3.2				BK1.8				BK1.0				BK0.3			
3.2	Thickness of frost blanket course	–	–	26[1]	36	–	–	27[1]	37	–	–	28[1]	38	–	–	19[1]	29	–	–	21[1]	31								

Line 4 – Frost blanket course

- Concrete surface course
- Frost blanket course



Line		BK100				BK32				BK10				BK3.2				BK1.8				BK1.0				BK0.3			
4	Thickness of frost blanket course																					24[3]	34	44	54	14[3]	24	34	44

[1] For other thicknesses of the frost-resistant pavement structure, the thickness of the frost blanket course or of the layer of non-frost-susceptible material needs to be adjusted or recalculated as well, see also Table 8

[2] With gravel, only applicable with local experience

[3] Only applicable with crushed and local experience

[4] Only to be executed if the non-frost-susceptible material and the material to be stabilized are installed as one layer

[8] Instead of the non-woven fabric, an asphalt intermediate course can be selected, see Section 3.3.4

[18] With local experience 25 cm

Plate 3: Structures with block pavements for carriageways on F2- and F3-subsoil/subgrade

(Thicknesses in cm; ▼ E_{v2} minimum values in MPa)

Line	Load class	BK100				BK32				BK10				BK3.2				BK1.8				BK1.0				BK0.3			
	B [million of ESALs]	> 32				> 10 – 32				> 3.2 – 10				> 1.8 – 3.2				> 1.0 – 1.8				> 0.3 – 1.0				≤ 0.3			
	Thickness of frost resistant pavement structure[1)]	55	65	75	85	55	65	75	85	55	65	75	85	45	55	65	75	45	55	65	75	45	55	65	75	35	45	55	65
1	**Crushed rock base course** on frost blanket course[13)]																												
	Block pavements[9)] Crushed rock base course Frost blanket course													▼180[15)] 10 4 25 ▼120 Σ39 ▼45				▼150 10 4 25 ▼120 Σ39 ▼45				▼150 8 4 20 ▼120 Σ32 ▼45				▼120 8 4 ▼100 15 Σ27 ▼45			
	Thickness of frost blanket course													–	–	26[3)]	36	–	–	26[3)]	36	–	–	33[2)]	43	–	18[3)]	28	38
2	**Gravel base course** on frost blanket course																												
	Block pavements[9)] Gravel base course Frost blanket course																	▼150 10 4 30 ▼120 Σ44 ▼45				▼150 8 4 25 ▼120 Σ37 ▼45				▼120 8 4 20 ▼100 Σ32 ▼45			
	Thickness of frost blanket course																	–	–	–	31[2)]	–	–	28[3)]	38	–	–	23[2)]	33
3	**Crushed rock** or **gravel base course** on layer of non-frost-susceptible material[13)]																												
	Block pavements Crushed rock or gravel base course Layer of non-frost-susceptible material													▼180[15)] 10 4 30[19)] Σ44 ▼45				▼150 10 4 30[11)] Σ44 ▼45				▼150 8 4 30[11)] Σ42 ▼45				▼120 8 4 25[11)] Σ37 ▼45			
	Thickness of layer of non-frost-susceptible material	Above 12 cm made of non-frost-susceptible material, lower remaining thickness is to be compensated by the material above																											
4	**Asphalt base course** on frost blanket course																												
	Block pavements[9)] Water permeable asphalt base course – porous asphalt[10)] Frost blanket course													10 4 ▼120 14 Σ28 ▼45				10 4 ▼120 14 Σ28 ▼45				8 4 ▼120 12 Σ24 ▼45				8 4 ▼100 10 Σ22 ▼45			
	Thickness of frost blanket course													–	27[3)]	37	47	–	27[2)]	37	47	–	31[2)]	41	51	–	23[2)]	33	43
5	**Asphalt base course** and **crushed rock base course** on frost blanket course																												
	Block pavements[9)] Water permeable asphalt base course – porous asphalt[10)] Gravel base course Frost blanket course													10 4 ▼150 10 ▼120 15 Σ39 ▼45				10 4 ▼150 10 ▼120 15 Σ39 ▼45				8 4 ▼150 8 ▼120 15 Σ35 ▼45				8 4 ▼120 8 ▼100 15 Σ35 ▼45			
	Thickness of frost blanket course													–	–	26[3)]	36	–	–	26[2)]	36	–	20[2)]	30	40	–	–	20[2)]	30
6	**Asphalt base course** and **gravel base course** on frost blanket course																												
	Block pavements[9)] Water permeable asphalt base course – porous asphalt[10)] Gravel base course Frost blanket course													10 4 ▼150 10 20 ▼120 Σ44 ▼45				10 4 ▼150 10 20 ▼120 Σ44 ▼45				8 4 ▼150 8 20 ▼120 Σ40 ▼45				8 4 ▼120 8 20 ▼100 Σ40 ▼45			
	Thickness of frost blanket course													–	–	–	31[2)]	–	–	–	31[2)]	–	25[3)]	35	45	–	–	15[3)]	25
7	**Drainage concrete base course** on frost blanket course																												
	Block pavements[9)] Porous concrete base course (PCB)[10)] Frost blanket course													10 4 ▼120 20 Σ34 ▼45				10 4 ▼120 20 Σ34 ▼45				8 4 ▼120 15 Σ27 ▼45				8 4 ▼100 15 Σ27 ▼45			
	Thickness of frost blanket course													–	–	31[2)]	41	–	–	31[2)]	41	18[3)]	28	38	8	–	18[3)]	28	38

1) For other thicknesses of the frost-resistant pavement structure, the thickness of the frost blanket course or of the non-frost-susceptible material needs to be adjusted or recalculated as well, see also Table 8
2) With gravel, only applicable with local experience
3) Only applicable with crushed rock and local experience
9) For different block thickness, see Section 3.3.5
10) See ZTV Pflaster-StB
11) For gravel base course in load classes BK1.8 and Bk3.2 with 40 cm thickness, and in load classes BK0.3 and BK1.0 with 30 cm thickness
13) Only to be used in Bk3.2 with local experience
15) Can be used with E_{v2} ≥ 150 MPa for pavements with local experience only
19) Crushed rock base course only

Plate 4: Structures with fully bound pavement structure for carriageways on F2- and F3-subsoil/subgrade

(Thicknesses in cm; ▼ E_{v2} minimum values in MPa)

Line	Load class	BK100	BK32	BK10	BK3.2	BK1.8	BK1.0	BK0.3
	B [million of ESALs]	> 32	> 10 – 32	> 3.2 – 10	> 1.8 – 3.2	> 1.0 – 1.8	> 0.3 – 1.0	≤ 0.3
	Asphalt surface course and <u>asphalt base course</u> on formation[12]							
1	Asphalt surface layer Asphalt base course	12 34 ▼45 Σ46	12 30 ▼45 Σ42	12 26 ▼45 Σ38	10 26 ▼45 Σ36	10 24 ▼45 Σ34	4 26 ▼45 Σ30	4 22 ▼45 Σ26
	Concrete surface course and <u>base course with hydraulic binders</u> on formation							
2	Concrete surface layer Non-woven fabric[8] Base course with hydraulic binders	27 25 ▼45 Σ52	26 25 ▼45 Σ51	25 23 ▼45 Σ48				

[8] Instead of the non-woven fabric, an asphalt intermediate course can be selected, see Section 3.3.4

[12] Soil stabilization if necessary, see Section 3.1.1

4 Rehabilitation of carriageways

4.1 Evaluation of the structural health of existing pavements substance

The following should be used to evaluate the structural health of existing pavements and to specify a technically and economically viable structure following rehabilitation:

- Determination of past relevant design traffic load and the age of the pavements,
- Surface condition,
- Bearing capacity,
- Type and condition of existing pavement, including the subgrade/subsoil, and its suitability for the intended function,
- Condition of drainage facilities.

Compliance with RPE-Stra is essential.

4.1.1 Relevant design traffic load and pavement age

To estimate the relevant design traffic load carried, the past relevant design traffic must be determined (see annex 2, Example 2). In addition, the age of the pavement structure layers should be determined.

4.1.2 Determination of surface condition and identification of pavement damage

To evaluate the surface condition and damage, the following features are used:

- Longitudinal unevenness,
- For asphalt structures,
  - accumulation of individual cracks,
  - alligator cracks,
  - deformations due to insufficient bearing capacity,
  - pot holes,
- For concrete structures,
  - individual cracks (longitudinal, transverse and diagonal),
  - alligator cracks (due to chemical reactions),
  - slab misalignment, vertical slab movement.

In addition, other relevant features identified during the condition examination and evaluation, and any damage and its causes must be taken into account when specifying an appropriate rehabilitation method (see Section 4.3).

4.1.3 Bearing capacity

The bearing capacity of existing pavements can be determined to supplement the evaluation of the pavement's condition, e.g.:

- to determine weaknesses that cannot be identified visually,
- to specify the rehabilitation requirements of sections having the same bearing capacity,
- combined with geo-radar measurements, to determine homogeneous sections so as to specify the location for core sampling.

With appropriate experience, bearing capacity measurements can also be used directly to determine the required thickness of the layers needed for the rehabilitation.

4.1.4 Type and condition of existing pavements

To assign the key condition features on the basis of which an appropriate type and method of rehabilitation will be specified, it is essential to determine the causes of surface damage and the suitability of the existing pavement, of its individual layers and, if necessary, of its subsoil/subgrade. Specifically, it is essential to establish:

– the type, thickness and properties of the individual layers,
– the type of subsoil/subgrade (particularly frost susceptibility class and moisture condition),
– the layer adhesion.

The layer structure is inspected and evaluated using cores, taken from the homogeneous pavement sections. If there is no layer adhesion, it is necessary to check whether a rehabilitation up to this layer boundary should be carried out.

For pavements subjected to load classes Bk10 to Bk100, it is recommended that the material properties of the asphalt and concrete layers remaining in the pavement structure, as well as those to be laid down in the pavement structure, are determined based on AL Sp-Asphalt or AL Sp-Beton. The calculation of the residual structural life for the remaining layers and the service life of the pavement after rehabilitation should then be based on RDO Asphalt for asphalt pavements and on RDO Beton for concrete pavements.

4.1.5 Drainage facilities

To determine the functional capability of the existing drainage, appropriate investigations should be carried out, e.g. inspection of pipes using cameras. The ability of the receiving water body to absorb the peak water discharge should be verified. The results should form the basis for deciding to which the drainage facilities are to be renovated.

4.2 Thickness of the frost resistant pavement structure

The required thickness of the frost resistant pavement structure for rehabilitation is to be determined based on the corresponding specifications in Section 3.2.

If a greater thickness of frost resistant pavement structure is required than would be provided by the pavement after the proposed rehabilitation, the thickness of the layers to be applied should be increased taking into account the thickness of the frost resistant layers of the existing pavement.

There is no need for frost protection measures if, after rehabilitation, the total thickness of the bound layers meets the thickness of the fully bound pavement structure as specified in Plate 4. Frost protection measures are also not required if existing damage has not been caused by a lack of frost protection and the future relevant design traffic load is rated, at a maximum, of one load class higher than previously.

4.3 Rehabilitation methods

The decision on whether a particular structure is technically and economical suitable for rehabilitation so as to provide the intended future service life should be based not only on the objective of reusing the existing construction materials but also on the local conditions, e.g. the options for routing traffic during construction, the defined pavement construction time and the length of the renewed pavement section.

The causes of any structural damage must be analysed and remedial measures defined. Prior to reconstruction, any unsuitable layers should be removed.

If local conditions fluctuate frequently, it makes sense from a technical construction perspective to renew pavement sections that are as long as possible at the same thickness.

4.4 Rehabilitation with complete replacement of existing pavements

For complete replacement of the pavement, the same regulations apply as for new pavements (Section 3).

4.5 Rehabilitation with partial replacement of existing pavements

If severe pavement damage has to be repaired, requiring partial removal of the existing pavements, the thickness of the layers to be installed should be specified according to the type and condition of the layer on which the new pavement will be placed, based on Plates 1 to 4 (see annex 2, Example 8).

Rehabilitation with partial replacement of the existing pavement is only possible if the layers remaining from the old pavement structure are suitable, in particular if they have sufficient bearing capacity and evenness (see Section 4.1.4).

For an existing block pavement, sufficient water permeability of the layers remaining from the old pavement structure must also be guaranteed. If any unbound granular layers remain in the pavement structure, the filter stability in between the existing and new unbound granular layers must be proved. The specifications in ZTV Pflaster-StB must be followed.

4.6 Rehabilitation on existing pavements

4.6.1 General

The guidelines for new construction (Section 3) also apply to the rehabilitation of existing pavements.

4.6.2 Rehabilitation using asphalt layers

Rehabilitation on existing pavements must always be based on a sound investigation and evaluation of the structural health. This should be combined with calculations for the rehabilitated pavement to determine the service life of the pavement and layer thicknesses according to RDO Asphalt.

Alternatively, for pavements subjected to load classes Bk0.3 to Bk3.2 having the condition features specified below – which indicate structural damage of the existing pavements whether occurring individually or in combination – rehabilitation of the asphalt pavement is possible with layer thicknesses as set out in Plate 5:

– For asphalt pavements:
  - coalescing of individual cracks (including longitudinal cracks beside the wheeltrack),
  - alligator cracks,
  - deformation due to insufficient bearing capacity,
  - longitudinal unevenness.

– For concrete pavements:
  - individual cracks (longitudinal, transverse and diagonal),
  - alligator cracks (due to chemical reactions),
  - slab misalignment, vertical slab movement,
  - longitudinal unevenness.

In addition ZTV BEA-StB must be considered, along with ZTV BEB-StB for existing concrete surface courses.

Overlaying reusable natural stone block pavements should be avoided.

Bearing capacity measurements are not appropriate for rehabilitation by paving asphalt placed on a rubblized concrete surface course in line with ZTV BEB-StB.

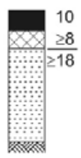
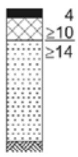
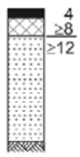
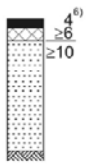
4.6.3 Rehabilitation using concrete layers

For rehabilitation using concrete layers, the requirements for bearing capacity, frost resistance and drainage must be met, see Sections 2.2 and 2.3. If the design is not based on RDO Beton, the thicknesses of the concrete surface course must not fall below those set out in Plates 2 and 4.

Requirements for compensation layers can be defined as set out in Section 4.4.4 of RDO Beton 09. The specifications in ZTV BEB-StB must also be considered.

Plate 5: Rehabilitation using asphalt layers on existing pavements
Existing pavements: Construction with asphalt surface course or rubblized concrete surface course in line with ZTV BEB-StB

(Thicknesses in cm)

Load class	BK100	BK32	BK10	BK3.2	BK1.8	BK1.0	BK0.3
B [million of ESALs]	> 32	> 10 – 32	> 3.2 – 10	> 1.8 – beside the track 3.2	> 1.0 – 1.8	> 0.3 – 1.0	≤ 0.3
Asphalt surface course Asphalt base course as compensating layer Existing pavement	Case by case analysis						

[6] Asphalt surface-base layer also possible, see Section 3.3.3

5 New construction and rehabilitation of other traffic areas

5.1 Bus traffic areas

A bus traffic area is classified according to Section 2.5.2. Structures and layer thicknesses are based on Plates 1 to 5 and Section 3.1 as appropriate.

The required minimum thickness of the frost resistant pavement structure should be determined as set out in Section 3.2.

5.2 Cycle paths and footpaths

Plate 6 shows the standardised structures for cycle paths and footpaths. The structures and layer thicknesses are selected to allow maintenance service vehicles to drive on these surfaces. Occasional use by other motor vehicles is not considered. Particular attention must be paid to the evenness and drainage of the surface when choosing the structure.

Soils in frost susceptibility class F1 do not require frost protection measures (see Section 3.1.2). The unbound granular layer can be positioned directly on the F1-soil, as specified in Plate 6, line 1. The thickness design of the unbound granular layer is based on Table 8.

For soils in frost susceptibility classes F2 and F3, the minimum thickness of the frost resistant pavement structure is 30 cm. Unfavourable climatic influences and moisture conditions in the subsoil must be taken into account.

Where motor vehicles cross the pavement, a pavement thickness appropriate to the relevant design traffic load should be selected. If there is a series of crossings in very close proximity, the structure and thickness chosen for the crossings should also be investigated for the sections between them. Structures with slabs should not be used here.

If cycle paths and footpaths are located at the edge of the road, for drainage reasons it is particularly beneficial to continue the formation and frost blanket course from the carriageway under the cycle path and footpath structure.

5.3 Maintenance and service areas

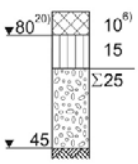
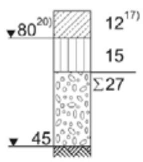
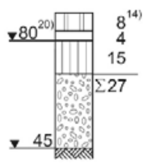
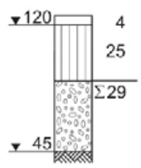
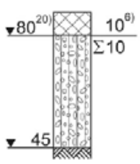
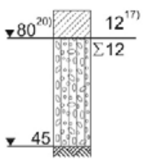
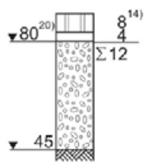
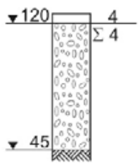
A traffic area in maintenance and service areas is classified according to Section 2.5.3. Structures and layer thicknesses are based on Plates 1 to 5 and Section 3.1 as appropriate.

The required minimum thickness of the frost resistant pavement structure should be determined as set out in Section 3.2.

Around filling points for fuels, pavements that are resistant to fuels should be chosen.

Plate 6: Structures for cycle paths and footpaths on F2- and F3-subsoil/subgrade

(Thicknesses in cm; ▼ E_{v2} minimum values in MPa)

Line	Structures	Asphalt		Concrete		Blocks (Slabs)		Unbound	
	Thickness of frost resistant pavement structure	30	40	30	40	30	40	30	40
1	**<u>Crushed rock or gravel base course</u> on layer of non-frost-susceptible material**								
	Surface layer Crushed rock or gravel base course Layer of non-frost-susceptible material								
	Thickness of layer of non-frost-susceptible material[16]	–	15	–	13	–	13	–	11
2	**UGL on formation**								
	Coating Crushed rock/gravel base course or frost blanket course								
	Thickness of crushed rock/gravel base course or frost blanket course	20	30	18	28	18	28	26	36

6) Asphalt surface base layer or asphalt base course and asphalt surface layer, see also Section 3.3.3
14) A lower thickness is also possible
16) If greater than 12 cm thickness is made of non-frost-susceptible material, a compensatory reduction in thickness may be applied to the material beneath
17) With a 12 cm thick concrete surface course, no dowels are possible
20) Where loaded by vehicles (maintenance and servicing), $E_{v2} \geq 100$ MPa

5.4 Parking areas

Parking areas are classified on the basis of Table 5. Structures and layer thicknesses are based on Plates 1 to 5 and Section 3.1 as appropriate.

The required minimum thickness of the frost resistant pavement structure should be determined as set out in Section 3.2.

For occasionally used parking areas, depending on the type of use, simple structures (e.g. “gritty lawn” in line with the “Guidelines for design, execution and maintenance of plantable pavements” from the Forschungsgesellschaft Landschaftsentwicklung, Landschaftsbau (FLL) or a unbound surface layer can be used. In addition, aesthetic and design considerations can also be incorporated into the decision process of an appropriate pavements type.

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Annex 1: Determination of the relevant design traffic [B]

There are two different methods of determining the relevant design traffic (equivalent 10-t-standard axles):

– **Method 1** is used if only $DTV^{(SV)}$ information is available

– **Method 2** requires knowledge of detailed axle load data.[1)]

Both methods can be simplified if constant factors are available (methods 1.2 and 2.2).

As both methods must result in the same figures for B for long periods and different general conditions, the examples have been calculated precisely.

Method 1 – Determination of B from $DTV^{(SV)}$ values

Method 1.1 – Determination of B with variable factors

If the geometric road and traffic data relevant for design are available for each year of use, the relevant design traffic is determined as follows:

$$B = 365 \cdot q_{Bm} \cdot f_3 \cdot \sum_{i=1}^{N} [DTA^{(SV)}_{i-1} \cdot f_{1i} \cdot f_{2i} \cdot (1 + p_i)]$$

Where:

B	Total of weighted equivalent 10-t-standard axles to be carried during the basic (unrehabitated) service life
N	Service life (in years); normally 30
q_{Bm}	Average load spectrum quotient assigned to a particular road class (see Table A 1.2), which expresses the road's class-specific average loading derived from the actual axle passes (quotient from the total equivalent 10t-standard axels and the total actual axle passes from heavy traffic (SV) for a defined period in one lane).
f_3	Slope factor (see Table A 1.5)
$DTA^{(SV)}_{i-1}$	Average number of daily axle passes (AP) from heavy traffic in the year of use i-1 [AP/24h] where $DTA^{(SV)}_{i-1} = DTV^{(SV)}_{i-1} \cdot f_{A-1}$
$DTV^{(SV)}_{i-1}$	Average daily traffic frequency for heavy traffic in year of use i-1 [vehicles/24h]
f_{Ai-1}	Average number of axles per vehicle for heavy traffic (axle number factor) in year of use i-1 [A/vehicle] (see Table A 1.1)
f_{1i}	Lane factor in year of use i (see Table A 1.3)
f_{2i}	Lane width factor in year of use i (see Table A 1.4)
p_i	Average annual fractional increase in heavy traffic in year of use i (see Table A 1.6).

The axle number factors f_{Ai} and the average load spectrum quotient q_{Bm} were determined using silhouette recording methods combined with axle load weights. Specially recorded axle number factors can also be used.

Method 1.2 – Determination of B with constant factors

The total period can be split into partial analysis periods, each with constant values for f_1, f_2, f_3, f_A, q_{Bm} and f_z. The calculation can be simplified for each partial analysis period (N > 1) to:

$$B = N \cdot DTA^{(SV)} \cdot q_{Bm} \cdot f_1 \cdot f_2 \cdot f_3 \cdot f_z \cdot 365$$

where $DTA^{(SV)} = DTV^{(SV)} \cdot f_A$

The increase in heavy traffic in subsequent years is given by:

$$f_z = \frac{(1 + p)^N - 1}{p \cdot N}$$

Where:

p	Average annual fractional increase in heavy traffic (see Table A 1.6).
f_z	Average annual growth factor for heavy traffic (see Table A 1.7).

Method 2 – Determination of B using axle load data

Method 2.1 – Determination of B with variable factors

If axle load data from axle load weight measurements are available, the relevant design traffic load can be determined as follows:

$$B = 365 \cdot f_3 \cdot \sum_{i=1}^{N}[EDTA_{i-1}^{(SV)} \cdot f_{1i} \cdot f_{2i} \cdot (1 + p_i)]$$

where:

B	Total of weighted equivalent 10t-standard axles to be carried during the service life
N	Service life (in years); normally 30
f_3	Slope factor (see Table A 1.5)
$EDTA_{i-1}^{(SV)}$	Average number of actual equivalent standard axles (equiv. AP/24h) from heavy traffic in year of use i–1 where $EDTA_{i=1}^{(SV)} = \sum_k \left[DTA_{(i=1)k}^{(SV)} \cdot \left(\frac{L_k}{L_0}\right)^4\right]$
$DTA_{i-1}^{(SV)}$	Average number of daily standard axle passages (A) from heavy traffic in year of use i–1 [AP/24h]
k	Load class, defined as a group of individual axle loads
L_k	Average axle load in load class k
L_0	Reference axle load: 10 t
f_{1i}	Lane factor in year of use i (see Table A 1.3)
f_{2i}	Lane width factor in year of use i (see Table A 1.4)
p_i	Average annual fractional increase in heavy traffic in year of use i (see Table A 1.6). For the first year $p_1 = 0$ is assumed.

Method 2.2 – Determination of B with constant factors

The total period can be split into partial analysis periods, each with constant values for f_1, f_2, f_3 and f_z. The calculation can be simplified for each partial analysis period (N > 1) to:

$$B = N \cdot EDTA^{(SV)} \cdot f_1 \cdot f_2 \cdot f_3 \cdot f_z \cdot 365$$

The increase in heavy traffic in subsequent years is given by:

$$f_z = \frac{(1 + p)^N - 1}{p \cdot N}$$

Where:

p	Average annual fractional increase in heavy traffic (see Table A 1.6)
f_z	Average annual growth factor for heavy traffic (see Table A 1.7).

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1) Axle load data are recorded and maintained by the Federal Highway Research Institute, BASt.

Table A 1.1: Axle number factor f_A

Road class	Factor f_A
National highways	4.5
Main national roads	4.0
State and district roads	3.3

Table A 1.2: Load spectrum quotient q_{Bm}

Road class	Quotient q_{Bm}
National highways	0.33
Main national roads	0.25
State and district roads	0.23

Table A 1.3: Lane factor f_1 for determination of $DTV^{(SV)}$

Number of lanes in the cross-section or driving direction	Factor f_1 recorded by DTV	
	In both directions	Separately for each direction
1	–	1.00
2	0.50	0.90
3	0.50	0.80
4	0.45	0.80
5	0.45	0.80
6 or more	0.40	–

Table A 1.4: Lane width factor f_2

Lane width [m]		Factor f_2
Below 2.50		2.00
Between 2.50	and 2.75	1.80
Between 2.75	and 3.25	1.40
Between 3.25	and 3.75	1.10
	More than 3.75	1.00

Table A 1.5: Slope factor f_3

Maximum longitudinal slope [%]		Factor f_3
< 2		1.00
≥ 2	< 4	1,02
≥ 4	< 5	1.05
≥ 5	< 6	1.09
≥ 6	< 7	1.14
≥ 7	< 8	1.20
≥ 8	< 9	1.27
≥ 9	< 10	1.35
	≥ 10	1.45

Table A 1.6: Average annual increase in heavy traffic p*)

Road class	p
National highways	0.03
Main national roads	0.02
State and district roads	0.01

*) When determining the relevant design traffic load for the lane to be designed, its limiting capacity must be taken into account.

Table A 1.7: Average annual growth factor for heavy traffic f_z

N [years]	Average annual increase in heavy traffic p		
	0.01	**0.02**	**0.03**
5	1.020	1.041	1.062
10	1.046	1.095	1.146
15	1.073	1.153	1.240
20	1.101	1.215	1.344
25	1.130	1.281	1.458
30	1.159	1.352	1.586

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Annex 2: Examples

The calculation examples normally cover long analysis periods, which means that rounding up or down when using the different methods can lead to significant differences. Therefore the calculations are carried out to several decimal places. For comparison, the calculations using both methods are shown.

Example 1: Determination of the relevant design traffic and load class to be assigned for a new highway

1. Initial data

1.1 General design data

– Service life:	N = 30 years		
– Number of lanes (constant):	4	$\Rightarrow f_1 = 0.45$	(Table A 1.3)
– Width of lanes with the highest relevant design traffic load (constant):	3.75 m	$\Rightarrow f_2 = 1.0$	(Table A 1.4)
– Maximum longitudinal slope:	4 %	$\Rightarrow f_3 = 1.05$	(Table A 1.5)

1.2 Traffic data

– $DTV^{(SV)}$ in 1st year of use:	3,900 vehicles/24h	$\Rightarrow p_1 = 0$	
– Average annual fractional increase in heavy traffic from 2nd to 4th year of use:	$\Rightarrow p_{2...4} = 0.02$		
– The new section will not achieve the anticipated traffic significance until the 5th year after construction	$\Rightarrow p_{5...30} = 0.03$		(Table A 1.6)

– The average number of axles per vehicle for heavy traffic, f_A, and the average load spectrum quotient, q_{Bm}, are known from the vehicle silhouette and axle load recorded at the time of design:
$\Rightarrow f_A = 4.5$ A/vehicle and $q_{Bm} = 0.33$.

2. Calculation

Method 1.1

$$B = 365 \cdot q_{Bm} \cdot f_3 \cdot \sum_{i=1}^{N} [DTA_{i-1}^{(SV)} \cdot f_{1i} \cdot f_{2i} \cdot (1 + p_i)]$$

The calculation is shown in Table A 2.1.

Method 1.2

The service life of 30 years is split into two analysis periods (years 1 to 4, years 5 to 30), each with constant factors.

$$B = N \cdot DTA^{(SV)} \cdot q_{Bm} \cdot f_1 \cdot f_2 \cdot f_3 \cdot f_z \cdot 365$$

To determine the growth factor:

$$f_z = \frac{(1 + p)^N - 1}{p \cdot N}$$

This results in

for years 1 to 4: $f_{z\ 1...4} = 1.030$
for years 5 to 30: $f_{z\ 5...30} = 1.483$

$DTV^{(SV)}$ = 3,900 vehicles/24h $\Rightarrow DTA^{(SV)}_1 = 17{,}550$ AP/24h

$\Rightarrow$ $B_{1...4} = 4.12$ million of ESALs

$DTA^{(SV)}$ in 4th year of use $\Rightarrow DTA^{(SV)}_4 = 17{,}550$ AP/24h $\cdot (1.02)^3 = 18{,}624.20$ AP/24h
(traffic increase in years 2 to 4)

$DTA^{(SV)}$ in 5th year of use $\Rightarrow DTA^{(SV)}_5 = DTA^{(SV)}_4 \cdot 1.03 = 19{,}182.93$ AP/24h

$\Rightarrow$ $B_{5...30} = 42.09$ million of ESALs

$B_{tot.} = B_{1...4} + B_{5...30} = 46.21$ million of ESALs

3. Result

The relevant design traffic using both methods is B = 46.21 million of ESALs. This pavement should therefore be assigned to load class Bk100 (see Table 1).

Table A 2.1: Calculation of relevant design traffic for Example 1 using Method 1.1

Year	p_i	$DTV^{(SV)}_{i-1}$	f_A	$DTA^{(SV)}_{i-1}$	q_{Bm}	f_1	f_2	f_3	Days/Year	$1+p_i$	B_i
1	–	3,900.00	4.5	17,550.00	0.33	0.45	1	1.05	365	–	998,816.57
2	0.02	3,900.00		17,550.00						1.02	1,018,792.90
3	0.02	3,978.00		17,901.00						1.02	1,039,168.76
4	0.02	4,057.56		18,259.02						1.02	1,059,952.13
5	0.03	4,138.71		18,624.20						1.03	1,091,750.70
6	0.03	4,262.87		19,182.93						1.03	1,124,503.22
7	0.03	4,390.76		19,758.41						1.03	1,158,238.31
8	0.03	4,522.48		20,351.17						1.03	1,192,985.46
9	0.03	4,658.16		20,961.70						1.03	1,228,775.03
10	0.03	4,797.90		21,590.55						1.03	1,265,638.28
11	0.03	4,941.84		22,238.27						1.03	1,303,607.43
12	0.03	5,090.09		22,905.42						1.03	1,342,715.65
13	0.03	5,242.80		23,592.58						1.03	1,382,997.12
14	0.03	5,400.08		24,300.36						1.03	1,424,487.03
15	0.03	5,562.08		25,029.37						1.03	1,467,221.64
16	0.03	5,728.94		25,780.25						1.03	1,511,238.29
17	0.03	5,900.81		26,553.66						1.03	1,556,575.44
18	0.03	6,077.84		27,350.27						1.03	1,603,272.71
19	0.03	6,260.17		28,170.77						1.03	1,651,370.89
20	0.03	6,447.98		29,015.90						1.03	1,700,912.01
21	0.03	6,641.42		29,886.37						1.03	1,751,939.37
22	0.03	6,840.66		30,782.97						1.03	1,804.497.56
23	0.03	7,045.88		31,706.45						1.03	1.858.632.48
24	0.03	7,257.26		32,657.65						1.03	1.914,391.46
25	0.03	7,474.97		33,637.38						1.03	1,971,823.20
26	0.03	7,699.22		34,646.50						1.03	2,030,977.90
27	0.03	7,930.20		35,685.89						1.03	2,091,907.23
28	0.03	8,168.10		36,756.47						1.03	2,154,664.45
29	0.03	8,413.15		37,859.16						1.03	2,219,304.38
30	0.03	8,665.54		38,994.94						1.03	2,285,883.51
$B_{1\ to\ 30}$ = 46,207,041.12											
$B_{1\ to\ 30}$ [million of ESALs] = 46.21											

Example 2: Verification of whether a highway constructed 20 years before the analysis date, based on load class Bk10, is sufficient to withstand the relevant design traffic load during the next 10 years (reconstruction is planned)

1. Initial data

1.1 General design data

– Number of lanes (constant):	4	$\Rightarrow f_1 = 0.45$	(Table A 1.3)
– Width of lanes with the highest relevant design traffic load (constant):	3.50 m	$\Rightarrow f_2 = 1.1$	(Table A 1.4)
– Maximum longitudinal slope:	Below 2 %	$\Rightarrow f_3 = 1.0$	(Table A 1.5)

1.2 Traffic data

- Traffic count results from the last 20 years are available for the highway section, including $DTV^{(SV)}$ values, as listed in Table A 2.2.
- Because heavy traffic on the highway at the time of analysis is made up predominantly of 2- and 3-axle individual vehicles and 2+2 trailers, the average number of axles per vehicle for heavy traffic – i.e. the factor f_A = 3.1 A/vehicles is set and assumed to be constant for the past 20 years. In the next 10 years, the factor f_A will increase to an average of 4.5 A/vehicle (Table A 1.1).
- The average load spectrum quotient for the past 20 years is assumed to be $q_{Bm} = 0.26$ and for the next 10 years $q_{Bm} = 0.33$.
- The average annual growth in heavy traffic for the past can be derived from the measured $DTV^{(SV)}$ values. For heavy traffic in the next 10 years, an average annual increase of $p = 0.03$ is assumed.

1. Calculation

Method 1.1 is selected to calculate the relevant design traffic for the last 20 years, as the load is specified by the average daily traffic for heavy traffic for each year.

For the next 10 years, the relevant design traffic is calculated using Method 1.1 and Method 1.2.

Method 1.1

$$B = 365 \cdot q_{Bm} \cdot f_3 \cdot \sum_{i=1}^{N}[DTA_{i-1}^{(SV)} \cdot f_{1i} \cdot f_{2i} \cdot (1 + p_i)]$$

The calculation for the past 20 years is shown in Table A 2.2. $B_{1...20}$ = 9.48 million of ESALs

The calculation for the next 10 years is shown in Table A 2.3. Here, the $DTV^{(SV)}$ for the 20th year is used as the initial value for the calculations in the 21st year.

$B_{21...30}$ = 20.28 million of ESALs

The total relevant design traffic is:

$B_{1...30} = B_{1...20} + B_{21...30}$ = 9.48 million of ESALs + 20.28 million of ESALs = 29.76 million of ESALs

Method 1.2

The $DTV^{(SV)}$ values for the 20 years before the time of analysis are available.

$$B = N \cdot DTA^{(SV)} \cdot q_{Bm} \cdot f_1 \cdot f_2 \cdot f_3 \cdot f_z \cdot 365$$

where

$$DTA^{(SV)} = DTV^{(SV)} \cdot f_A$$

Growth in 21st year of use, therefore:

$DTA^{(SV)}_{21} = DTA^{(SV)}_{20} \cdot 1.03$ = 29664.0 AP/24h

For the years 21 to 30:

$$f_z = \frac{(1+p)^N - 1}{p \cdot N}$$

$f_{z\,21...30} = 1.146$ $\Rightarrow B_{21...30}$ = 20.28 million of ESALs

2. Result

The total relevant design traffic is 29.76 million of ESALs. This relevant design traffic requires a pavement structure complying with load class Bk32 (see Table 1). The existing pavement, load class Bk10, must be strengthened accordingly.

Table A 2.2: Calculation of relevant design traffic for the past 20 years for Example 2 using Method 1.1

Year	p_i	$DTV^{(SV)}_{i-1}$	f_A	$DTA^{(SV)}_{i-1}$	q_{Bm}	f_1	f_2	f_3	Days/Year	B_i
1	–	1,100.00	3.1	3,410	0.26	0.45	1.1	1	365	160,186.46
2		1,400.00		4,340						203,873.67
3		1,700.00		5,270						247,560.89
4		1,900.00		5,890						276,685.70
5		2,100.00		6,510						305,810.51
6		2,300.00		7,130						334,935.32
7		2,400.00		7,440						349,497.72
8		2,500.00		7,750						364,060.13
9		2,700.00		8,370						393,184.94
10		2,900.00		8,990						422,309.75
11		3,100.00		9,610						451,434.56
12		3,400.00		10,540						495,121.77
13		3,600.00		11,160						524,246.58
14		3,800.00		11,780						553,371.39
15		4,100.00		12,710						597,058.61
16		4,300.00		13,330						626,183.42
17		4,600.00		14,260						669,870.63
18		5,100.00		15,810						742,682.66
19		5,700.00		17,670						830,057.09
20		6,400.00		19,840						931,993.92

$B_{1\ to\ 20}$ = 9,480,125.66

$B_{1\ to\ 20}$ [million of ESALs] = 9.48

Table A 2.3: Calculation of relevant design traffic for the next 10 years for Example 2 using Method 1.1

Year	p_i	$DTV^{(SV)}_{i-1}$	f_A	$DTA^{(SV)}_{i-1}$	q_{Bm}	f_1	f_2	f_3	Days/Year	$1+p_i$	B_i
21	0.03	6,400.00	4.5	28,800.00	0.33	0.45	1.1	1	365	1.03	1,768,649.26
22	0.03	6,592.00		29,664.00						1.03	1,821,708.73
23	0.03	6,789.76		30,553.92						1.03	1,876,360.00
24	0.03	6,993.45		31,470.54						1.03	1,932,650.80
25	0.03	7,203.26		32,414.65						1.03	1,990,630.32
26	0.03	7,419.35		33,387.09						1.03	2,050,349.23
27	0.03	7,641.93		34,388.71						1.03	2,111,859.71
28	0.03	7,871.19		35,420.37						1.03	2,175,215.50
29	0.03	8,107.33		36,482.98						1.03	2,240,471.96
30	0.03	8,350.55		37,577.47						1.03	2,307,686.12

$B_{21\ to\ 30}$ = 20,275,581.62

$B_{21\ to\ 30}$ [million of ESALs] = 20.28

Example 3: Verification of the suitability of an existing pavement structure of a rural road of load class Bk1.0 as a diversion route

1. Initial data

1.1 General design data

– Service life

- Designed at opening for traffic: 20 years
- Between opening for traffic and start of diversion: 12 years
- Duration of diversion: 4 years

– Number of lanes (constant): 2 ⇒ $f_1 = 0.5$ (Table A 1.3)

– Width of lanes with the highest relevant design traffic load (constant): 3.50 m ⇒ $f_2 = 1.1$ (Table A 1.4)

– Maximum longitudinal slope: Below 2 % ⇒ $f_3 = 1.0$ (Table A 1.5)

1.2 Traffic data

– $DTV^{(SV)}$ in year of opening for traffic: 200 vehicles/24h ⇒ $p_1 = 0$

– $DTV^{(SV)}$ in first year of diversion: 240 vehicles/24h ⇒ $p_{13} = 0$

– For the times with and without diverted traffic, $f_A = 3.3$ A/vehicle and $q_{Bm} = 0.23$ are assumed to be constant. The average annual increase in heavy traffic is p = 0.01 (see Table A 1.6).

2. Calculation

The relevant design traffic can be calculated using Methods 1.1 and 1.2, splitting into analysis periods each with constant factors.

– Before diversion

Method 1.1

$$B = 365 \cdot q_{Bm} \cdot f_3 \cdot \sum_{i=1}^{N} [DTA_{i-1}^{(SV)} \cdot f_{1i} \cdot f_{2i} \cdot (1 + p_i)]$$

$B_{1...12} = 0.39$ million of ESALs

The calculation is shown in Table A 2.4.

Method 1.2

$$B = N \cdot DTA^{(SV)} \cdot q_{Bm} \cdot f_1 \cdot f_2 \cdot f_3 \cdot f_z \cdot 365$$

For years 1 to 12 (without growth in 1st year):

$$f_z = \frac{(1+p)^N - 1}{p \cdot N}$$

$f_{z\,1...12} = 1.057$ ⇒ $B_{1...12} = 0.39$ million of ESALs

– During diversion

Method 1.1

$$B = 365 \cdot q_{Bm} \cdot f_3 \cdot \sum_{i=1}^{N} [DTA_{i-1}^{(SV)} \cdot f_{1i} \cdot f_{2i} \cdot (1 + p_i)]$$

$DTV^{(SV)}_{13} = 240$ ($DTV^{(SV)}$ immediately before diversion)

$B_{13...16} = 0.15$ million of ESALs

The calculation is shown in Table A 2.5.

Method 1.2

$B = N \cdot DTA^{(SV)} \cdot q_{Bm} \cdot f_1 \cdot f_2 \cdot f_3 \cdot f_z \cdot 365$

For years 13 to 16 (without growth in 13th year):

$$f_z = \frac{(1+p)^N - 1}{p \cdot N}$$

$f_{z\ 13...16} = 1.015$ $\Rightarrow B_{13...16} = 0.15$ million of ESALs

– After diversion

Method 1.1

$$B = 365 \cdot q_{Bm} \cdot f_3 \cdot \sum_{i=1}^{N} [DTA_{i-1}^{(SV)} \cdot f_{1i} \cdot f_{2i} \cdot (1 + p_i)]$$

$B_{17...20} = 0.15$ million of ESALs

The calculation is shown in Table A 2.6.

Method 1.2

$B = N \cdot DTA^{(SV)} \cdot q_{Bm} \cdot f_1 \cdot f_2 \cdot f_3 \cdot f_z \cdot 365$

For years 17 to 20:

Growth in 17th year of use $\Rightarrow DTA^{(SV)}_{17} = DTA^{(SV)}_{16} \cdot 1.01 = 773.90$ AP/24h

$$f_z = \frac{(1+p)^N - 1}{p \cdot N}$$

$f_{z\ 17...20} = 1.015$ $\Rightarrow B_{7...20} = 0.15$ million of ESALs

– Total relevant design traffic B

$B_{tot} = B_{1...12} + B_{13...16} + B_{17...20} = 0.39 + 0.15 + 0.15 = 0.69$ million of ESALs

3. Result

For the design of the pavement, a structure should be selected that meets at least the requirements of load class Bk1.0. Therefore, the existing pavement will be able to withstand the diverted heavy traffic.

Table A 2.4: Calculation of relevant design traffic for Example 3 before the diversion, using Method 1.1

Year	p_i	$DTV_{i-1}^{(SV)}$	f_A	$DTA_{i-1}^{(SV)}$	q_{Bm}	f_1	f_2	f_3	Days/Year	$1+p_i$	B_i
1	–	200.00	3.3	660.00	0.23	0.5	1.1	1	365	–	30,473.85
2	0.01	200.00		660.00						1.01	30,778.59
3	0.01	202.00		666.60						1.01	31,086.37
4	0.01	204.02		673.27						1.01	31,397.24
5	0.01	206.06		680.00						1.01	31,711.21
6	0.01	208.12		686.80						1.01	32,028.32
7	0.01	210.20		693.67						1.01	32,348.61
8	0.01	212.30		700.60						1.01	32,672.09
9	0.01	214.43		707.61						1.01	32,998.81
10	0.01	216.57		714.69						1.01	33,328.80
11	0.01	218.74		721.83						1.01	33,662.09
12	0.01	220.92		729.05						1.01	33,998.71
										$B_{1\ to\ 12}$ =	**386,484.69**
										$B_{1\ to\ 12}$ [million of ESALs] =	**0.39**

Table A 2.5: Calculation of relevant design traffic for Example 3 during the diversion, using Method 1.1

Year	p_i	$DTV^{(SV)}_{i-1}$	f_A	$DTA^{(SV)}_{i-1}$	q_{Bm}	f_1	f_2	f_3	Days/Year	$1+p_i$	B_i
13	–	240.00	3.3	792.00	0.23	0.5	1.1	1	365	–	36,568.62
14	0.01	240.00		792.00						1.01	36,934.31
15	0.01	242.40		799.92						1.01	37,303.65
16	0.01	244.82		807.92						1.01	37,676.69
											$B_{13\ to\ 16}$ = 148,483.26
											$B_{13\ to\ 16}$ [million of ESALs] = 0.15

Table A 2.6: Calculation of relevant design traffic for Example 3 after the diversion, using Method 1.1

Year	p_i	$DTV^{(SV)}_{i-1}$	f_A	$DTA^{(SV)}_{i-1}$	q_{Bm}	f_1	f_2	f_3	Days/Year	$1+p_i$	B_i
17	0.01	232.19	3.3	766.24	0.23	0.5	1.1	1	365	1.01	35,732.99
18	0.01	234.52		773.90						1.01	36,090.32
19	0.01	236.86		781.64						1.01	36,451.22
20	0.01	239.23		789.46						1.01	36,815.73
											$B_{17\ to\ 20}$ = 145,090.25
											$B_{17\ to\ 20}$ [million of ESALs] = 0.15

Example 4: Staged construction of a pavement

As part of the development of a construction zone in an urban area, a pavement is to be stage constructed, so that it will perform the function of a residential road after completion of the construction work. The first stage of construction must have sufficient bearing capacity to withstand the expected site traffic over the construction period of three years.

1. Initial data

1.1 General design data

- The entire pavement structure of the residential road will be assigned to load class Bk0.3.
- A pavement structure from Plate 1, Line 5 is selected, with an 8 cm thick asphalt base course on a 25 cm thick crushed rock base course (1st construction stage).
- The subgrade is to be assigned to frost susceptibility class F2.
- The minimum thickness of the frost resistant pavement structure is thus 40 cm, as set out in Table 6.
- The factors taking into account local conditions when determining the additional or reduced thicknesses as set out in Table 7 are as follows:
  - A = + 15 cm (frost action zone III)
  - B = ± 0 cm (no special climatic influences)
  - C = ± 0 cm (no groundwater / stratum water to a depth of 1.5 m below formation)
  - D = ± 0 cm (ground height to embankment ≤ 2.0 m)
  - E = – 5 cm (drainage of carriageway and boundary areas using channels or drains and pipelines).
- This results in a thickness of the frost resistant pavement structure of 40 + 10 = 50 cm.
- Number of lanes (constant): 2 ⇒ $f_1 = 0.5$ (Table A 1.3)
- Width of lanes with the highest relevant design traffic load (constant): 2.60 m ⇒ $f_2 = 1.8$ (Table A 1.4)
- Maximum longitudinal slope: 1 % ⇒ $f_3 = 1.0$ (Table A 1.5)

1.2 Traffic data during construction site traffic

– The $DTV^{(SV)}$ value is assumed to be constant at 30 vehicles/24h for the entire construction time of three years $\Rightarrow p_i = 0, f_z = 1$.
– The average number of axles per construction site vehicle is assumed to be $f_A = 3.5$ A/vehicle (determined for specific project), and the average load spectrum quotient is $q_{Bm} = 0.33$.

2. Calculation

Method 1.1

$$B = 365 \cdot q_{Bm} \cdot f_3 \cdot \sum_{i=1}^{N} [DTA_{i-1}^{(SV)} \cdot f_{1i} \cdot f_{2i} \cdot (1 + p_i)]$$

$B_{1...3} = 0.03$ million of ESALs

The calculation is shown in Table A 2.7.

Method 1.2

$$B = N \cdot DTA^{(SV)} \cdot q_{Bm} \cdot f_1 \cdot f_2 \cdot f_3 \cdot f_z \cdot 365$$

$f_z = 1$ $\Rightarrow B_{1...3} = 0.03$ million of ESALs

3. Verification of design appropriate load in the 1st construction stage

– The pavement structure in the first construction stage is made up of an 8 cm thick asphalt base course and a 25 cm thick crushed rock base course. It should therefore be assigned to load class Bk0.3 as set out in Section 3.3.3 (e.g. Plate 1, line 5).
– As an asphalt base course of only 8 cm is used, up to around 100,000 equivalent 10-t-standard axles, as specified in Section 3.3.3, can be withstood over a service life of 30 years. Thus, as part of the complete pavement structure could carry 65,852 more equivalent 10-t-standard axles than it is expected to carry during the first construction stage.

4. Assessment of the design appropriate for traffic of complete pavement structure

Apart from damage close to the surface, which could be repaired before installation of the 2nd construction stage (2 cm asphalt surface layer on the asphalt base course), no restriction of the duration of use of the complete pavement is likely.

Table A 2.7: Calculation of relevant design traffic for Example 4 using Method 1.1

Year	p_i	$DTV_{i-1}^{(SV)}$	f_A	$DTA_{i-1}^{(SV)}$	q_{Bm}	f_1	f_2	f_3	Days/Year	$1+p_i$	B_i
1	0	30.00	3.5	105.00	0.33	0.5	1.8	1	365	1.00	11,382.53
2	0	30.00		105.00						1.00	11,382.53
3	0	30.00		105.00						1.00	11,382.53
											$B_{1 \text{ to } 3}$ = 34,147.58
											$B_{1 \text{ to } 3}$ [million of ESALs] = 0.03

Example 5: Determination of the relevant design traffic and loading class to be assigned to a municipal bus traffic area

1. Initial data

1.1 General design data

– Service life:	30 years		
– Number of lanes (constant):	1	$\Rightarrow f_1 = 1.0$	(Table A 1.3)
– Width of lanes with the highest relevant design traffic load (constant):	3.0 m	$\Rightarrow f_2 = 1.4$	(Table A 1.4)
– Maximum longitudinal slope:	3 %	$\Rightarrow f_3 = 1.02$	(Table A 1.5)

1.2 Traffic data

- Number of bus passes (corresponds to $DTV^{(SV)}$) 150 vehicles/24h $\Rightarrow p_{1...6} = 0$
- Division of heavy traffic into 2 different vehicle types:

– 100 × 3-axle vehicles, axle load	Front axle:		6.6 t
	Rear double axle	1st axle:	10.0 t
		2nd axle:	11.0 t
– 50 × 2-axle vehicles, axle load	Front axle:		6.6 t
	Rear axle:		11.0 t

- After 6 years, a bus route using 2-axle vehicles with the same axle load is added, which increases the $DTV^{(SV)}$ by 20 vehicles/24h ($\Rightarrow p_{7...30} = 0$).

2. Calculation

Method 2.1

In the partial analysis periods (years 1 to 6 and 7 to 30), the relevant relevant design traffic load (bus passages) remains constant.

$$B = 365 \cdot f_3 \cdot \sum_{i=1}^{N} [EDTA^{(SV)} \cdot f_{1i} \cdot f_{2i}]$$

where $EDTA^{(SV)} = \sum_k \left[DTA_{ik}^{(SV)} \cdot \left(\frac{L_k}{L_0}\right)^4 \right]$

The calculation of equivalent average daily axle passes for heavy traffic and the relevant design traffic are shown in Tables A 2.8 to A 2.11.

$$EDTA_{1...6}^{(SV)} = \left[\left(\frac{6,6}{10}\right)^4 + \left(\frac{10}{10}\right)^4 + \left(\frac{11}{10}\right)^4\right] \cdot 100 + \left[\left(\frac{6,6}{10}\right)^4 + \left(\frac{11}{10}\right)^4\right] \; 50 = 348.08 \text{ equiv. AP/24h}$$

$B_{1...6}$ = 1.09 million of ESALs

$$EDTA_{7...30}^{(SV)} = \left[\left(\frac{6,6}{10}\right)^4 + \left(\frac{10}{10}\right)^4 + \left(\frac{11}{10}\right)^4\right] \cdot 100 + \left[\left(\frac{6,6}{10}\right)^4 + \left(\frac{11}{10}\right)^4\right] \; 70 = 381.07 \text{ equiv. AP/24h}$$

$B_{7...30}$ = 4.77 million of ESALs

$B_{tot} = B_{1...6} + B_{7...30} = 1.09 + 4.77 = 5.86$ million of ESALs

Method 2.2

The calculations of equivalent average daily axle passes for heavy traffic are shown in Tables A 2.8 and A 2.10.

$B = N \cdot EDTA^{(SV)} \cdot f_1 \cdot f_2 \cdot f_3 \cdot f_z \cdot 365$

$B_{tot} = B_{1...6} + B_{7...30} = 1.09 + 4.77 = 5.86$ million of ESALs

3. Result

The relevant design traffic is B = 5.86 million of ESALs. This relevant design traffic should be assigned to load class Bk10.

Table A 2.8: Calculation of the equivalent average daily axle passes from heavy traffic for Example 5 for years 1 to 6

HT	L_K	L_0	L_K/L_0	$(L_K/L_0)^4$	$DTA^{(SV)}$	$(L_K/L_0)^4 \cdot DTA^{(SV)}$	$EDTA^{(SV)}$
3-axle	6.60	10	0.66	0.19	100	18.97	
	10.00		1.00	1.00	100	100.00	
	11.00		1.10	1.46	100	146.41	265.38
2-axle	6.60	10	0.66	0.19	50	9.49	
	11.00		1.10	1.46	50	73.21	82.69
							$EDTA^{(SV)}_{1\ to\ 6}$ = 348.08

Table A 2.9: Calculation of the relevant design traffic for Example 5 using Method 2.1 for years 1 to 6

Year	$EDTA_{i-1}^{(SV)}$	f_1	f_2	f_3	Days/Year	f_z	B_i
1	348.08	1.0	1.4	1.02	365	1.0	181,426.26
2	348.08						181,426.26
3	348.08						181,426.26
4	348.08						181,426.26
5	348.08						181,426.26
6	348.08						181,426.26
							$B_{1\ to\ 6}$ = 1,088,557.55 **$B_{1\ to\ 6}$ [million of ESALs] = 1.09**

Table A 2.10: Calculation of the equivalent average daily axle passes from heavy traffic for Example 5 for years 7 to 30

HT	L_K	L_0	L_K/L_0	$(L_K/L_0)^4$	$DTA^{(SV)}$	$(L_K/L_0)^4 \cdot DTA^{(SV)}$	$EDTA^{(SV)}$
3-axle	6.60	10	0.66	0.19	100	18.97	
	10.00		1.00	1.00	100	100.00	
	11.00		1.10	1.46	100	146.41	265.38
2-axle	6.60	10	0.66	0.19	70	13.28	
	11.00		1.10	1.46	70	102.49	115.77
							$EDTA^{(SV)}_{7\ to\ 30}$ = 381.15

Table A 2.11: Calculation of the relevant design traffic for Example 5 using Method 2.1 for years 7 to 30

Year	$EDTA_{i-1}^{(SV)}$	f_1	f_2	f_3	Days/Year	B_i
7	381.15	1	1,4	1,02	365	198,663.00
8	381.15					198,663.00
9	381.15					198,663.00
10	381.15					198,663.00
11	381.15					198,663.00
12	381.15					198,663.00
13	381.15					198,663.00
14	381.15					198,663.00
15	381.15					198,663.00
16	381.15					198,663.00
17	381.15					198,663.00
18	381.15					198,663.00
19	381.15					198,663.00
20	381.15					198,663.00
21	381.15					198,663.00
22	381.15					198,663.00
23	381.15					198,663.00
24	381.15					198,663.00
25	381.15					198,663.00
26	381.15					198,663.00
27	381.15					198,663.00
28	381.15					198,663.00
29	381.15					198,663.00
30	381.15					198,663.00
						B7 to 30 = 4,767,912.07
						B7 to 30 [million of ESALs] = 4.77

Example 6: Rehabilitation of a highway section with known axle load data with complete replacement of the existing pavement

1. Initial data

1.1 General design data

– Service life N:	30 years		
– Number of lanes (constant):	6	⇒ $f_1 = 0.4$	(Table A 1.3)
– Width of lanes with the highest relevant design traffic load (constant):	3.75 m	⇒ $f_2 = 1.0$	(Table A 1.4)
– Maximum longitudinal slope:	4 %	⇒ $f_3 = 1.05$	(Table A 1.5)

1.2 Traffic data

$EDTA^{(SV)}$ in year of rehabilitation: 13,260 equiv. AP/24h ⇒ p1 = 0

The average annual increase in heavy traffic is p = 0.03 (see Table A 1.6).

2. Calculation

Method 2.1

A detailed calculation is shown in Table A 2.12.

$B_{1...30}$ = 96.71 million of ESALs

Method 2.2

$B = N \cdot EDTA^{(SV)} \cdot f_1 \cdot f_2 \cdot f_3 \cdot f_z \cdot 365$

For years 1 to 30 (without growth in 1st year):

$$f_z = \frac{(1+p)^N - 1}{p \cdot N}$$

$f_{z\ 1...30} = 1.58585$ $\Rightarrow B_{1...30} = 96.71$ million of ESALs

3. Result

The relevant design traffic is B = 96.71 million of ESALs. This relevant design traffic should be assigned to load class Bk100.

Table A 2.12: Calculation of the relevant design traffic for Example 6 using Method 2.1

Year	p_i	$EDTA_{i-1}^{(SV)}$	f_1	f_2	f_3	Days/Year	$1+p_i$	B_i
1	–	13,260.00	0.4	1.0	1.05	365	–	2,032,758.00
2	0.03	13,260.00					1.03	2,093,740.74
3	0.03	13,657.80					1.03	2,156,552.96
4	0.03	14,067.53					1.03	2,221,249.55
5	0.03	14,489.56					1.03	2,287,887.04
6	0.03	14,924.25					1.03	2,356,523.65
7	0.03	15,371.97					1.03	2,427,219.36
8	0.03	15,833.13					1.03	2,500,035.94
9	0.03	16,308.13					1.03	2,575,037.02
10	0.03	16,797.37					1.03	2,652,288.13
11	0.03	17,301.29					1.03	2,731,856.77
12	0.03	17,820.33					1.03	2,813,812.47
13	0.03	18,354.94					1.03	2,898,226.85
14	0.03	18,905.59					1.03	2,985,173.65
15	0.03	19,472.76					1.03	3,074,728.86
16	0.03	20,056.94					1.03	3,166,970.73
17	0.03	20,658.65					1.03	3,261,979.85
18	0.03	21,278.41					1.03	3,359,839.25
19	0.03	21,916.76					1.03	3,460,634.42
20	0.03	22,574.26					1.03	3,564,453.46
21	0.03	23,251.49					1.03	3,671,387.06
22	0.03	23,949.03					1.03	3,781,528.67
23	0.03	24,667.51					1.03	3,894,974.53
24	0.03	25,407.53					1.03	4,011,823.77
25	0.03	26,169.76					1.03	4,132,178.48
26	0.03	26,954.85					1.03	4,256,143.84
27	0.03	27,763.50					1.03	4,383,828.15
28	0.03	28,596.40					1.03	4,515,343.00
29	0.03	29,454.29					1.03	4,650,803.29
30	0.03	30,337.92					1.03	4,790,327.38
							$B_{1\ to\ 30}$ =	**96,709,306.88**
							$B_{1\ to\ 30}$ [million of ESALs] =	**96.71**

Example 7: Verification of the pavement structure as part of an extension plan

Because of increased traffic volume to $DTV^{(SV)}$ 1,910 vehicles/24h, the cross-section of a main national road, load class Bk10, is to be increased by one lane in each direction. Verify whether the existing pavement structure can survive, without damage, the period until reconstruction commences having already withstood 3.80 million of ESALs weighted equivalent 10-t-standard axles. Assuming an average annual growth rate of p = 0.02 % for the service life of a further 20 years, the load class to be assigned for the reconstructed pavement is to be determined.

1. Initial data

1.1 General design data

Before reconstruction

– Period between determination of $DTV^{(SV)}$ and start of construction: 5 years			
– Number of lanes:	2	$\Rightarrow f_1 = 0.50$	(Table A 1.3)
– Width of lane with highest load:	3.00 m	$\Rightarrow f_2 = 1.40$	(Table A 1.4)
– Maximum longitudinal slope:	4 %	$\Rightarrow f_3 = 1.05$	(Table A 1.5)

After reconstruction

– Duration of use after reconstruction:	20 years		
– Number of lanes:	4	$\Rightarrow f_1 = 0.45$	(Table A 1.3)
– As the lane with the highest load will become an overtaking lane after reconstruction of the 2-lane cross-section, it is assumed that:		$\Rightarrow f_1 = 0.05$	(0.50 – 0.45)
– Width of lane with highest load:	3.50 m	$\Rightarrow f_2 = 1.10$	(Table A 1.4)
– Maximum longitudinal slope:	4 %	$\Rightarrow f_3 = 1.05$	(Table A 1.5)

1.2 Traffic data

Before reconstruction

– Weighted equivalent 10-t-standard axles in both directions already carried:	3.80 million of ESALs		
– $DTV^{(SV)}$ after increase:	1,910 vehicles/24h	$\Rightarrow p_1 = 0$	
– Average annual growth rate:	2 %	$\Rightarrow p = 0.02$	(Table A 1.6)
– Average load spectrum quotient, q_{Bm}:	0,25		(Table A 1.2)
– Average number of axles per vehicle:	4,0	$\Rightarrow f_A = 4.0$ A/vehicle	(Table A 1.1)

After reconstruction

– Average annual growth rate:	2 %	$\Rightarrow p = 0.02$	(Table A 1.6)
– Average load spectrum quotient, qBm:	0,25		(Table A 1.2)
– Average number of axles per vehicle:	4,0	$\Rightarrow f_A = 4.0$ A/vehicle	(Table A 1.1)

2. **Calculation**

The relevant design traffic must be calculated for the “existing lane” and “new lane”.

Method 1.1

$$B = 365 \cdot q_{Bm} \cdot f_3 \cdot \sum_{i=1}^{N}[DTA_{i-1}^{(SV)} \cdot f_{1i} \cdot f_{2i} \cdot (1 + p_i)]$$

The calculation of the relevant design traffic is shown in Table A 2.13.

Existing lane

$B_{already\ carried} = 3.80 \cdot 0.5 = 1.9$ million of ESALs

$B_{1...5} = 2.67$ million of ESALs

$B_{before\ reconstruction} = B_{already\ carried} + B_{1...5} = 4.57$ million of ESALs

$B_{after\ reconstruction} = B_{6...25} = 1.08$ million of ESALs

$B_{total} = B_{before\ reconstruction} + B_{after\ reconstruction} = 4.57$ million of ESALs + 1.08 million of ESALs = 5.65 million of ESALs

New lane

$B_{after\ reconstruction} = B_{6...25} = 9.72$ million of ESALs

Method 1.2

$$B = N \cdot DTA^{(SV)} \cdot q_{Bm} \cdot f_1 \cdot f_2 \cdot f_3 \cdot f_z \cdot 365$$

Existing lane

$B_{already\ carried} = 3.80 \cdot 0.5 = 1.9$ million of ESALs

$f_{z\ 1...5} = 1.041 \Rightarrow B_{1...5} = 2.67$ million of ESALs

$B_{before\ reconstruction} = B_{already\ carried} + B_{1...5} = 4.57$ million of ESALs

$B_{after\ reconstruction} = B_{6...25} = 1.08$ million of ESALs

$B_{total} = B_{before\ reconstruction} + B_{after\ reconstruction} = 4.57$ million of ESALs + 1.08 million of ESALs = 5.65 million of ESALs

New lane

$B_{after\ reconstruction} = B_{6...25}$

Growth in 6th year of use $\Rightarrow DTA^{(SV)} = DTA^{(SV)}\ 5 \cdot 1.02 = 8{,}435.18$ AP/24h

$f_{z\ 6...25} = 1.215 \Rightarrow B_{after\ reconstruction} = 9.72$ million of ESALs

3. **Result**

Existing lane

Up to the time of the reconstruction, the relevant design traffic = 4.57 million of ESALs. This can be withstood by the existing pavement structure in load class Bk10 without any structural damage (see Table 1). The relevant design traffic for the entire period is B = 5.65 million of ESALs. This relevant design traffic should be assigned to load class Bk10 (see Table 1).

New lane

The relevant design traffic is B = 9.72 million of ESALs. This corresponds to load class Bk10 (see Table 1).

Conclusion

The pavement structure of the two new lanes should correspond to that of the existing lane.

Table A 2.13: Calculation of the relevant design traffic for Example 7 using Method 1.1

Year	p_i	$DTV^{(SV)}_{i-1}$	f_{Ai}	$DTA^{(SV)}_{i-1}$	q_{Bm}	f_{1i}	f_{2i}	f_{3i}	Days/Year	$1+p_i$	B_i
Before reconstruction											
1	–	1,910.00	4.0	7,640.00	0.25	0.5	1.4	1.05	365	1.00	512,405.25
2	0.02	1,910.00		7,640.00						1.02	522,653.36
3	0.02	1,948.20		7,792.80						1.02	533,106.42
4	0.02	1,987.16		7,948.66						1.02	543,768.55
5	0.02	2,026.91		8,107.63						1.02	554,643.92
											$B_{1\ to\ 5}$ = 2,666,577.50 **$B_{1\ to\ 5}$ [million of ESALs] = 2.67**
After reconstruction – existing lane											
6	0.02	2,067.45	4.0	8,269.78	0.25	0.05	1.1	1.05	365	1.02	44,450.75
7	0.02	2,108.79		8,435,18						1.02	45,339.76
8	0.02	2,150.97		8,603.88						1.02	46,246.56
9	0.02	2,193.99		8,775.96						1.02	47,171.49
10	0.02	2,237.87		8,951.48						1.02	48,114.92
11	0.02	2,282.63		9,130.51						1.02	49,077.22
12	0.02	2,328.28		9,313.12						1.02	50,058.76
13	0.02	2,374.84		9,499.38						1.02	51,059.94
14	0.02	2,422.34		9,689.37						1.02	52,081.14
15	0.02	2,470.79		9,883.15						1.02	53,122.76
16	0.02	2,520.20		10,080.82						1.02	54,185.21
17	0.02	2,570.61		10,282.43						1.02	55,268.92
18	0.02	2,622.02		10,488.08						1.02	56,374.30
19	0.02	2,674.46		10,697.84						1.02	57,501.78
20	0.02	2,727.95		10,911.80						1.02	58,651.82
21	0.02	2,782.51		11,130.04						1.02	59,824.86
22	0.02	2,838.16		11,352.64						1.02	61.021.35
23	0.02	2,894.92		11,579.69						1.02	62,241.78
24	0.02	2,952.82		11,811.28						1.02	63,486.61
25	0.02	3,011.88		12,047.51						1.02	64,756.35
											$B_{6\ to\ 25}$ = 1,080,036.28 **$B_{6\ to\ 25}$ [million of ESALs] = 1.08**

(Continued on p. 48)

Table A 2.13 (continued)

Year	p_i	$DTV^{(SV)}_{i-1}$	f_{Ai}	$DTA^{(SV)}_{i-1}$	q_{Bm}	f_{1i}	f_{2i}	f_{3i}	Days/Year	$1+p_i$	B_i
After reconstruction – new lane											
6	0.02	2,067.45	4.0	8,269.78	0.25	0.45	1.1	1.05	365	1.02	400,056.74
7	0.02	2,108.79		8,435.18						1.02	408,057.87
8	0.02	2,150.97		8,603.88						1.02	416,219.03
9	0.02	2,193.99		8,775.96						1.02	424,543.41
10	0.02	2,237.87		8,951.48						1.02	433,034.28
11	0.02	2,282.63		9,130.51						1.02	441,694.96
12	0.02	2,328.28		9,313.12						1.02	450,528.86
13	0.02	2,374.84		9,499.38						1.02	459,539.44
14	0.02	2,422.34		9,689,37						1.02	468,730.23
15	0.02	2,470.79		9,883.15						1.02	478,104.83
16	0.02	2,520.20		10,080.82						1.02	487,666.93
17	0.02	2,570.61		10,282.43						1.02	497,420.27
18	0.02	2,622.02		10,488.08						1.02	507,368.67
19	0.02	2,674.46		10,697.84						1.02	517,516.05
20	0.02	2,727.95		10,911.80						1.02	527,866.37
21	0.02	2,782.51		11,130.04						1.02	538,423.70
22	0.02	2,838.16		11,352.64						1.02	549,192.17
23	0.02	2,894.92		11,579.69						1.02	560,176.01
24	0.02	2,952.82		11,811.28						1.02	571,379.53
25	0.02	3,011.88		12,047.51						1.02	582,807.12
$B_{6\ to\ 25}$ = 9,720,326.48 **$B_{6\ to\ 25}$ [million of ESALs] = 9.72**											

Example 8: Rehabilitation of a main national road in a non-urban area by overlaying the existing pavements

1. Initial data

1.1 General design data

- Period since opening for traffic: 25 years
- Intended service life after rehabilitation: 20 years
- Intended pavement structure: Load class Bk1.8
- Exceptional loading due to heavy traffic

1.2 Evaluation of the structural condition of the existing pavements

- Surface condition
  The condition measure AUN (longitudinal unevenness) has a value of 4.7, and is thus above the warning value of 4.5. In addition, there are some areas with alligator cracks, some of them treated (patches).
- Bearing capacity
  In the areas with alligator cracks and partially treated areas (patches), deformation measurements were carried out using a Benkelman beam, which confirmed the suspected weak areas.

– Type and condition of existing pavements

- Existing pavements

Asphalt surface layer	3.0 cm
Asphalt binder course	5.0 cm
Asphalt base course	6.0 cm
Crushed rock base course	10.0 cm
Frost blanket course	25.0 cm
Total thickness	49.0 cm

- Subsoil

  Primarily soils in frost susceptibility class F3; permanent or occasional groundwater or stratum water higher than 1.5 m below formation.

- Layer adhesion

  Apart from the areas with patches, the layer adhesion appears to be adequate.

- Drainage facilities

  The facilities for longitudinal drainage (gullies and ditches) are to be repaired as part of the rehabilitation work.

2. Selection of an appropriate rehabilitation type and method

2.1 Rehabilitation type
As no height constraints have to be met, and as there is no dense series of overpass structures with a limited clearance, execution of asphalt overlays is selected for rehabilitation of the existing. This will be carried out on both lanes in turn.

2.2 Rehabilitation methods
The existing pavement will be restored using an asphalt structure, with removal of the surface layer in the areas with patches, to be replaced with a suitable asphalt layer.

3. Specification of rehabilitation method

There are areas with alligator cracks with and without patches. The rehabilitation is to be carried out using asphalt mixes.

4. Required thickness of rehabilitation layers for bearing capacity reasons

4.1 Areas with alligator cracks without patches

Asphalt surface layer	4 cm
Asphalt base course	10 cm
	14 cm

4.2 Areas with alligator cracks and patches
Replacement of existing surface layer using asphalt base course mix; further structure as described in Section 4.1.

5. Required thickness of rehabilitation layers based on frost resistance

5.1 Target thickness of frost resistant soil

For frost susceptibility class F3 and load class Bk1.8, the minimum required thickness of the frost resistant pavement structure is 60 cm.

The local conditions require the following additional thicknesses:

– Frost action zone II: + 5 cm

– Groundwater or stratum water permanently or occasionally higher than 1.5 m below formation: + 5 cm

This results in a target thickness of 70 cm.

5.2 Actual thickness of frost resistant pavement structure after completion of rehabilitation:

– Areas with alligator cracks (with/without patches) 14 + 49 = 63 cm

This means that the thickness of the layers must be increased by 7 cm because of the required frost resistance of the pavement structure.

6. **Selected thicknesses of rehabilitation layers**

As the patches were largely placed in order to repair frost damage, while on the other hand no frost damage has been observed in the areas without patches for more than 10 years, hence the thickness of the asphalt base course layer was increased by 4 cm (higher thickness of asphalt base course than required).

6.1 Areas with alligator cracks (with/without patches)

Asphalt surface course	4 cm
Asphalt base course	14 cm
	18 cm

The extent to which it is economical to place the overlay with a higher, uniform, thickness over the entire area to be rehabilitated needs to be inversigated.

Example 9: Rehabilitation of asphalt pavements with replacement of the existing asphalt layers

1. **Initial data**

– Existing pavement

Asphalt surface course	4.0 cm
Asphalt binder course	8.0 cm
Asphalt base course	10.0 cm
Stabilized layer	15.0 cm
Non frost susceptible material	43.0 cm
Total thickness	80.0 cm

This pavement structure should be assigned to the structure set out in Plate 1, line 2.2 for load class Bk10.

– Future load class: Bk100

– Evaluation of the structural substance of the existing pavement
The surface condition (structural deformation in transverse and longitudinal direction, occasional alligator cracks in the deformation bowl) indicated more severe damage. Excavations and sounding confirmed the suspicion that both the asphalt binder course and the asphalt base course are damaged. By contrast, the stabilized layer showed no damage.

2. **Selection of an appropriate rehabilitation type and m|ethod**

The rehabilitation can be carried out as set out in Plate 1, line 2.2, load class Bk100, with removal and replacement of the asphalt layers including the asphalt base course (no height constraints and no dense series of overpass structures with a limited clearance).

3. **Selected pavement structure**

– Rehabilitation layers

Asphalt surface course	4 cm
Asphalt binder course	8 cm
Asphalt base course	18 cm
Thickness of rehabilitation layers	30 cm

– Layers remaining in the pavement structure

Stabilized layer	15 cm
Non frost susceptible material	43 cm
Thickness of remaining layers	58 cm

– Total thickness 88 cm

The pavement therefore meets not only the requirements for sufficient fatigue resistance of the asphalt layers and for sufficient bearing capacity, but also those for adequate frost resistance.

Annex 3: Technical regulations

DIN[1]	VOB/C	Vergabe- und Vertragsordnung für Bauleistungen (German Construction Contract Procedures) Part C: General technical specifications in construction contracts (ATV), particularly: – DIN 18299 General rules applying to all types of construction work – DIN 18300 Earthworks – DIN 18315 Road construction; unbound granular layers for pavements – DIN 18316 Road construction; pavement layers with hydraulic binders – DIN 18317 Road construction; asphalt pavements – DIN 18318 Road construction; block pavements, slabs, edgings
FGSV[2]	AL Sp-Asphalt	Work instruction for determination of the stiffness and fatigue behaviour of asphalt mixes using the indirect tensile test to provide input values for pavement design (FGSV 430)
	AL Sp-Beton	Work instruction for determination of the characteristic tensile strength of cylindrical specimen as an input value for the design of concrete surface courses for traffic areas (FGSV 410)
	DBT	Information sheet for drainage concrete base courses (FGSV 827)
		Information sheet for water permeable pavements for traffic areas (FGSV 947)
	RAS-Ew	Guidelines for road construction (RAS). Part: Drainage using the RAS-Ew design tools on CD-ROM (FGSV 539)
	RASt	Guidelines for the design of Urban Roads (FGSV 200)
	RDO Asphalt	Guidelines for the analytical (mechanistic-empirical) design of pavements structures – asphalt pavements (FGSV 498)
	RDO Beton	Guidelines for the analytical (mechanistic-empirical) design of pavements structures – concrete pavements (FGSV 497)
	RIN	Guidelines for integrated network design (FGSV 121)
	RiStWag	Guidelines for construction measures on roads in water conservation areas (FGSV 514)
	RPE-Stra	Guidelines for planning maintenance measures for pavements (FGSV 488)
	ZTV Asphalt-StB	Additional technical conditions of contract and directives for the construction of asphalt pavements (FGSV 799)
	ZTV BEA-StB	Additional technical conditions of contract and directives for the maintenance of asphalt pavements (FGSV 798)
	ZTV BEB-StB	Additional technical conditions of contract and directives for the maintenance of concrete pavements (FGSV 898/1)
	ZTV Beton-StB	Additional technical conditions of contract and directives for the construction of base courses with hydraulic binders and concrete pavements (FGSV 899)
	ZTV 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 Pflaster-StB	Additional technical conditions of contract and directives for the construction of block pavements, slab pavements and edgings (FGSV 699)
	ZTV SoB-StB	Additional technical conditions of contract and directives for the construction of layers without binder in road construction (FGSV 698)
FLL[3]		Guidelines for design, execution and maintenance of plantable pavements Waterbound tracks Technical report on design, construction and maintenance of waterbound tracks

Reference sources

[1] **Beuth Verlag GmbH**
Address: Burggrafenstraße 6, 10787 Berlin
Phone: +49 (0) 30/26 01-22 60, Fax: +49 (0) 30 / 26 01-12 60
E-mail: info@beuth.de, Internet: www.beuth.de

[2] **FGSV Verlag GmbH**
Address: Wesselinger Straße 17, 50999 Cologne
Phone: +49 (0) 22 36/38 46 30, Fax: +49 (0) 22 36 / 38 46 40
E-mail: info@fgsv-verlag.de, Internet: www.fgsv-verlag.de

[3] **Forschungsgesellschaft Landschaftsentwicklung, Landschaftsbau e.V. (FLL)**
Address: Colmantstraße 32, 53115 Bonn
Phone: +49 (0) 228 / 96 50 10-0, Fax: +49 (0) 228 / 96 50 10-20
E-mail: info@fll.de, Internet: www.fll.de

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