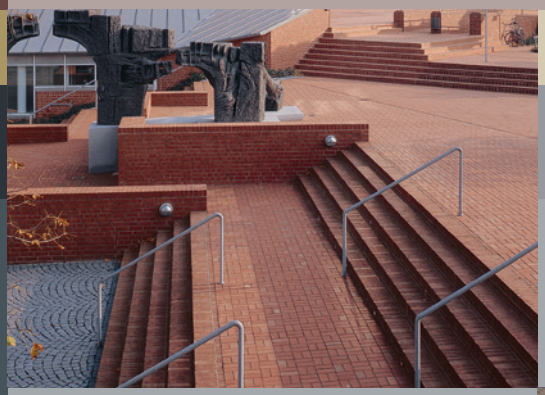
Original Clinker Pavers – Quality in Fired Clay

Technical Information

Planning, design and construction of surfaces with original clinker pavers

CLINKER PAVERS



ORIGINAL PFLASTER®
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KLINKER

Arbeitsgemeinschaft Pflasterklinker e. V.

Dantes, Copenhagen, Denmark

Technical Information

Planning, Design and Installation of Surfacing with Original Clinker Pavers

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Foreword

This brochure presents the design possibilities, the basic principles for planning and construction of surfacing with clinker paving. The content of the brochure is equally applicable to private pathway and surfacing projects as well as to public roads and other trafficked surfaces. With the application of the content of this brochure, premature damage should be avoided in order to obtain extremely durable clinker paving.

In the following, the most important specifications contained in the technical regulations are described. In addition, the findings of scientific studies are presented. No liability is accepted for errors or changes in the technical regulations as a result of updates. The recommendations for the planning, design and construction of clinker paving have been compiled on the basis of practical experience. The technical notes contained in this brochure describe the proper planning and construction methods for common applications. It is, however, not possible to cover all imaginable special applications which could require both further measures and restrictions. The use of this brochure does not exempt the user from responsibility for individual actions, compliance, however, does enable acceptable technical performance based on all previous findings. Readers are also advised to consult qualified experts with regard to the choice of construction methods, calculation of the course thickness, earthwork, construction materials and drainage.

We should appreciate any communication of your experience with the use of this brochure as well as criticism and suggestions with regard to the content with a view to updating the technical information it contains.

Arbeitsgemeinschaft Pflasterklinker e.V.
Berlin, January 2018

Water feature with clinker pavers, Odense, Denmark

Content

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»Road construction regulations are based on theoretical principles and experience with tried and tested regional construction methods. These insights, supplemented with concrete recommendations on the planning and installation of clinker paving, are the subject of this brochure.«

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»You only learn to appreciate what's special about clinker pavers after years. There's no question, every building material gets older, but, as people say, clinker pavers "grow old gracefully". The patina formed on clay pavers is characterized by high colour stability and resistance to signs of wear. That makes clinker pavers so unique.«

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1 | Clinker pavers – a traditional building material for paving

Along with precast concrete and natural stone paving, clinker pavers are traditional paving materials for the construction of public roads and paths.

Clinker pavers are particularly important whenever high-quality design is required for representative surfaces in administration, commercial and hotel building. Architects and landscape designers like to use clinker pavers to enhance the design of the surroundings for private, commercial and residential buildings.

Thanks to the high material strength of clinker pavers, it is possible to manufacture bar-shaped and long formats in lengths up to 490 mm. Laid on edge, the visibly slimmer width of the bar-shaped pavers of 40 mm, 52 mm or 71 mm creates an interesting joint pattern. Besides the proven herringbone and elbow bonds, stretcher bonds are now possible in which format lengths of 490 mm, 360 mm, 240 mm and 115 mm are combined. With embedding depths of 100 mm or 115 mm, clinker pavers laid on edge are one of the highest-quality road surfacings available.

The most important argument in favour of clinker pavers is and remains colour fastness and stability. Even after years, thanks to the high-strength ceramic bond, clinker paver surfaces provide optimum protection against abrasion, scratches, frost, salt or acid effects and the build-up of dirt. It is not for nothing that large areas of the seafront promenades on the German and Belgian coasts are surfaced with clinker pavers. If signs of wear or greening have to be removed, clinker pavers can be cleaned even after years without concern with suitable mechanical equipment or – if necessary – with chemical agents.

Ceramic building materials like clinker pavers have an above-average service lifetime. A long service lifetime conserves resources and is always a precondition for a positive sustainability rating. If a paved surface does have to be taken up again at some time, the hard-fired clinker paver after separate removal is in great demand as a starting material for processing to recycled building materials for road construction and vegetation engineering. It is not rare for historical clinker paving to be taken up, cleaned and reused in the spirit of genuine recycling. Naturally, signs of wear cannot be avoided on clinker pavers. But especially the patina typically formed on ceramic is chosen as a design element for building projects in the preservation of historical buildings: for such projects, paver manufacturers offer so-called rumbled clinker pavers that are artificially aged in a drum mill. Coal- and peat-fired clinker pavers are valued highly by architects because, with their play of ceramic colours, they pleasingly set themselves apart from the uniformity of industrial production.

Clinker pavers should be used primarily where requirements must be met for functionality, design, representativeness and durability. In the following, the wide-ranging possibilities for the use of clinker pavers are described.

Goudkantoor Groningen, Netherlands

Where architectural epochs meet, clinker pavers create a connection. The generous surface design is emphasized by the inserts of light-coloured natural stone bonds.

Antique clinker pavers

2 | Advantages and applications of clinker paving

2.1 Areas of use for clinker pavers

Clinker pavers are used for surfacing in built-up trafficked areas like main roads, residential streets, trafficked pedestrian precincts and public carparks. Especially with regard to urban design objectives, clinker pavers offer numerous advantages as they open up extensive design possibilities adapted to their environments. Another important application is the design of paved areas in garden design and landscaping. This includes all surfaces and paths around houses, like driveways, access and parking strips, patios, private parking spaces and covered carports.

Tram stop, Justinianstrasse, Cologne, Germany

2.2 Clinker pavers in the construction of public roads and paths (RSTO)

According to the Guidelines for the Standardization of Surfaces of Road Traffic Areas (RStO 12 StB), carriageway surfaces in dry jointed sett pavement construction are possible to Construction class BK3.2. This includes local entry and business roads, commercial or industrial roads. However, the main application for clinker pavers is probably in representative business roads, village main roads and in residential and lodging roads. The standard thickness of the clinker paver measures – depending on the construction class – 8 cm or 10 cm. RStO also permits smaller thicknesses, although not less than 6 cm, providing sufficient experience is available with proven regional construction methods. Clinker pavers can be laid flat or on edge. Care must be taken to ensure adequate traction of the usable surface.

2.3 Patios, stairs, paths around the house

Easy care, dirt repellent, colour-fast and colour-stable are the quality features in demand in the private sector. The brilliance of the colours produced in ceramic firing, i.e. black, anthracite, chrome grey, natural red and buff shades, are unique feature of clinker pavers. Especially sealed surfaces, even outdoors, are easy to care for. But here too, the quality and durability of the paving is crucially dependent on the correct dimensioning and installation of the functional courses in the superstructure. This includes frost resistance, load-bearing capacity and adequate water permeability of the structure. A special material also has special requirements for the quality of the workmanship in its installation.

Municipal park, La Rioja, Spain

2.4 Parking strips, drives – paved surfaces in garden design and landscaping

For paving trafficked by cars and occasionally by service and maintenance vehicles, clinker pavers are particularly suitable. The exceptionally high material strength of clinker pavers enables cost-effective flat laying of the pavers. Already clinker pavers with a paver thickness from 52 mm meet the requirements for Tranverse Breaking Load Class T4. The use of de-icing salts often necessary for traffic safety does not damage clinker pavers. Environmental influences have only a minor influence on the long-term performance of the clinker pavers thanks to their low water absorption and high resistance to freeze-thaw cycles.

Baroque garden, Münster, Germany

Seafront promenade, Wenduine, Belgium

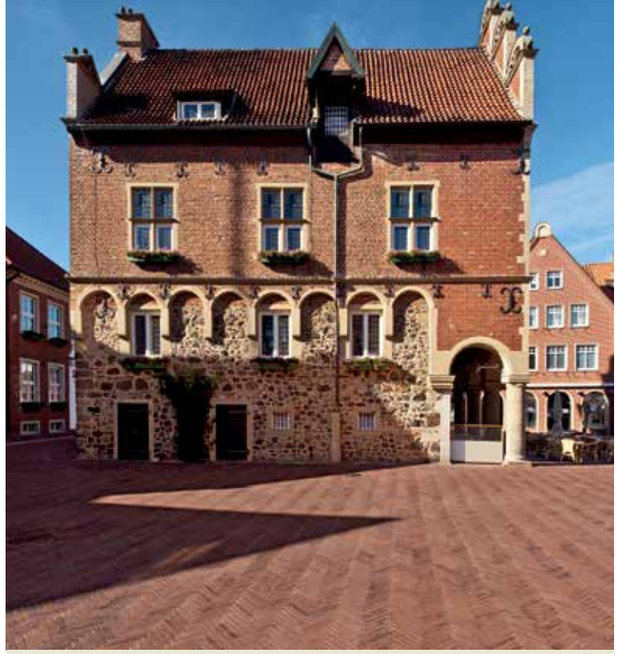
2.5 Agricultural construction

Clinker pavers exhibit high resistance to the effects of acid and are therefore ideally suited for use in the commercial areas of farms and floors that are constantly exposed to aggressive chemical conditions. This includes applications in the food industry, chemical plants and farms where silage and aggressive liquors may be found. For most of these applications the acid resistance exhibited by clinker pavers is completely adequate. The option is available to have the manufacturer expressly declare the acid resistance with a "C" marking in accordance with DIN EN 1344, Section 4.11.

2.6 Roof terraces – installation on top of building structures

There is a trend for the combination of walkable surfacing with greened roofs. In extensive or intensive roof greening systems, functional courses of brick chipping substrate ensure the required water retention. Partly paved surfaces, step stones up to the paving of entire roof terraces guarantee unlimited usage even on greened roofs. Clinker pavers is the only surfacing material with an application as roofing material that can be declared as roof construction materials in compliance with the standard EN 1344. Fire reaction and fire resistance are always specified in the manufacturer's declaration of performance. On account of the high material strength of clinker pavers, the paver thickness for unbound laying in chippings bed can be reduced to 40 mm. Clinker pavers must conform to the transverse breaking load Class T2 (DIN EN 1344) in compliance with the technical terms of delivery. For example, a clinker paver with width of 80 mm must withstand a breaking load of at least 2 400 N (240 kg).

2 | Advantages and applications of clinker paving



Market square and townhall, Meppen, Germany

Brick paving on the indoor and outdoor areas of the plaza, Elbphilharmonie, Hamburg, Germany

2.7 Conservation of historical monuments – refurbishment and extensions of historical surfacings

Clay pavers were already used by the Assyrians, the Egyptians and the Romans for flooring and surfacing traffic areas. Particularly in regions in which natural stone suitable for constructing paving was not available, clinker pavers have been used for centuries for surfacing roads and pathways. In the Netherlands and Northern Germany, clinker paving has therefore been a common sight in the towns and cities for centuries. The manufacturers of clinker pavers have adapted their products to this and can, on request, supply artificially aged clinker pavers. For this purpose, the clinker pavers are "rumbled". This involves the mechanical treatment of the clinker pavers to give them signs of wear like those that could be expected after 100 years of use. For refurbishment or extension of historical clinker surfaces, this enables the supply of additional matching pavers.

2.8 Clinker pavers in a mortar bed

There is always a demand for mortared paved surfaces whenever the paving is expected to withstand high loads, e.g. on slopes, ramps or roundabouts, and the joints therefore need to be very stable. Intensive care and maintenance of the paving by vacuum sweepers can be the reason for deciding against the advantages of unbound laying and instead executing the base courses, foundation and joints with a bound mortar method. But for private projects, too, mortared joints are often in demand. As a model, reference is often made to traditional brick paving in Southern Europe. But unlike at the Piazza del Campo in Siena, where brick paving has withstood a wide range of stresses for centuries, planning of installation in northern climes must take high precipitation levels and the action of frost into account.

Park path, Lithuania

2.9 Drainage paving (water-permeable paving)

Water-permeable clinker paving can be installed with the help of widened joints (5 to 15 mm) or with specially manufactured water-permeable or perforated clinker pavers. During installation, the gaps are filled with special aggregate so that rainwater can seep through the surfacing down into the subgrade (water-permeable paving). For plantable surfacing, the gaps can be filled with a mix of aggregate, substrate and grass seeds. Such an "desealing" of built-up areas results in rain- and surface water being able to seep into the ground so that the natural water cycle is not interrupted. Many town and city councils also offer tax incentives for certified rainwater infiltration of surfaced areas and roofs.

Paving joint – bound with jointing mortar and open to the environment as a greened joint

2.10 Trafficked areas on building structures

Unlike use on greened roofs, in the case of trafficked surface on or in building structures, like underground carparks, parking decks or courtyard throughways, a load from rubber-tyred vehicles must be expected. The absence of a connection to the ground necessitates special considerations with regard to statics, sealing and water management.

2.11 Flooring indoors

On account of the high-quality appearance and the in-service performance typical of ceramics, clinker pavers are often used indoors. The pavers are generally laid with a bound method with mortar joints.

Pedestrian precinct, Le Touquet, France

3 | Requirements for clay pavers / clinker pavers

3.1 Requirements for placing clinker pavers on the market in compliance with CPR

Clay pavers are manufactured in compliance with the requirements of the European harmonized standard EN 1344 Clay Pavers and placed on the market on the basis of the European Construction Products Regulation (CPR). In addition to the European product quality, for the production of clinker pavers typical in Germany, particularly dense-firing clays with high apparent density and low water absorption (i.e. clinker quality) are used.

Clay pavers / clinker pavers – what's the difference?

Clay pavers and shaped clay pavers are a construction product standardized and harmonized in compliance with the European product standard EN 1344. The term "clay paver" covers almost all grades produced in Europe. Clinker pavers are a German speciality. Only products with a low water absorption (≤ 6 mass %) and a high apparent density (≥ 1.9 kg/dm³) may be referred to as clinker pavers in accordance with DIN 18503. The clinker quality depends on the raw material. Especially suitable for this is shale clay. Only where material-related differences must be taken into consideration is a differentiation made between clinker pavers and clay pavers in this brochure.

Clinker pavers in a historical setting. Carolingian „Torhalle" gatehouse, Lorsch, Germany

3.2 Clay pavers in compliance with DIN EN 1344

The harmonized product standard DIN EN 1344: 2013+AC:2015 published in October 2015 contains a European-wide definition of the properties, requirements and testing methods for clay pavers and clinker pavers. To make provision for the wide range of conditions of use for clay pavers in Europe, the European harmonized DIN EN 1344 defines different requirement levels and classes. For the following properties, in DIN EN 1344 the described levels and classes as well as the associated required values are defined.

3.2.1 Dimensional deviations

3.2.1.1 Permissible dimensional deviations from the mean value

Clay pavers in accordance with DIN EN 1344 meet the requirement for dimensional deviation when the deviation of the mean value (±) for the length, width and height measured in a random sample is not higher than the 0.4 times the square root of the nominal dimension d (in mm) specified by the manufacturer. This requirement does not apply to shaped and ancillary pavers.

Permissible dimensional deviations from the mean value

$$\leq 0{,}4 \cdot \sqrt{d}$$

where:
d nominal dimension (in mm) for the length, width and height, the permissible dimensional deviation is rounded up to the next millimetre.

3.2.1.2 Permissible measurement range

As a sub-requirement it applies that within one consignment of the same product, the difference between the largest and the smallest measured value in Class R1 for every dimension may not be greater than the 0.6 times the square root of the nominal dimension d (in mm) specified by the manufacturer.

Class	Range mm
R0	No requirement
R1	≤ 0,6 √d

Table 3-1: **Permissible dimensional range in accordance with DIN EN 1344**

To test the dimensional accuracy and the range, on ten clay pavers or clinker pavers, the length, width and thickness are measured with a calliper gauge in accordance with DIN EN 1344. For every measured dimension, the mean value as well as the largest and the smallest measured value are specified. For each dimension, the deviation of the mean value may not be greater than 0.4 times the square root of the nominal dimension d specified by the manufacturer.

For the usual nominal dimensions, the permissible measurement deviations and measurement ranges for Class R1 are specified in Table 3-2.

	Nominal dimension mm	Permissible **deviation** from the mean value	Permissible **range** Class R1 mm
	d	**± 0.4 √d**	**0.6 √d**
Thickness/ width	45	± 3	4
	52	± 3	4
	62	± 3	5
	71	± 3	5
	80	± 4	5
	100	± 4	6
	118	± 4	6
Length	200	± 6	8
	240	± 6	9
	360	± 8	11

Table 3-2: **Permissible dimensional deviations and ranges**

3.2.2 Freeze-thaw resistance

For testing of the freeze-thaw resistance in accordance with DIN EN 1344, the clinker pavers are immersed in a water bath at 80 °C for 24 hours. For the subsequent freezing, the clay pavers are arranged in a test frame so that only one side is directly exposed to the frost. The clinker paver is frozen through until the entire absorbed water is frozen. The water near the surface of the clay pavers is thawed and re-frozen several times. The resistance is assessed based on the damage to the clay pavers and clinker pavers after 100 frost-thaw cycles.

Class FP0 is only suitable for indoor application in Germany. If the freeze-thaw cycling test in the class FP100 is passed without significant damage, this property is not influenced by conventional de-icing salts either.

Class	Freeze-thaw resistance mm
FP0	No requirement
FP100	Freeze-thaw resistant

Table 3-3: **Freeze-thaw resistance in accordance with DIN EN 1344**

3.2.3 Transverse breaking load (strength)

The transverse breaking load is tested on ten wetted clay pavers or clinker pavers that are supported at the ends and loaded in the middle to fracture. Depending on the expected loading direction, the wearing surface must face upwards. If the clinker pavers are manufactured with more than one wearing surface, both for laying flat and on edge, the transverse breaking load must be specified for the respective orientation. Four tranverse breaking load classes are defined.

	Transverse breaking load [a,d] **(N/mm)**	
Class	**Mean value**	**Smallest individual value**
T0[b]	No specification	No specification
T1	≥ 30	≥ 15
T2	≥ 30	≥ 24
T3	≥ 80	≥ 50
T4	≥ 80	≥ 64[c]

a This requirement for the transverse breaking load does not apply to accessories or clay pavers with an overall length < 80 mm.
b Class T0 is only suitable for pavers intended for use for rigid laying where the pavers are laid with cementitious mortar joints on a similar mortar bed itself placed on a rigid base.
c The manufacturer may declare a mean value and a minimum individual value higher than those corresponding to Class T4.
d The manufacturer may declare a mean value and a minimum individual value for the bending tensile strength calculated from the formula given in D.4.2 (DIN EN 1344).

Table 3-4:
Transverse breaking load in accordance with DIN EN 1344

Optionally, in addition to the tranverse breaking load, the manufacturer may specify the mean value and the smallest individual value for the bending tensile strength of the specimen (in N/mm²) as determined with the following equation:

$$\sigma_t = \frac{3}{2} \cdot \frac{F \cdot s}{w \cdot t^2}$$

where
σ_t bending tensile strength [N/mm²]
F breaking load [N]
s distance between the supports [mm]
w measured width of the clay paver [mm]
t measured thickness of the clay paver [mm]

The load-bearing behaviour of a clinker paver in the paving is essentially dependent on the load-bearing capacity of the bedding. If the clinker paver is not evenly supported or if the permissible axle loads for lorry traffic are substantially exceeded, which is not rarely observed, considerable bending stresses can occur. For trafficked clinker paver surfaces or those subject to significant static loads, the transverse breaking load T4 should therefore be used in every case.

3.2.4 Abrasion resistance

The abrasion resistance is tested in accordance with DIN EN 1344 with the Capon test on unpolished clay pavers and clinker pavers. The abrasion resistance is determined based on the measurement of the volume loss of an abraded groove, which is made in the surface of the clay paver with a grinding wheel under defined conditions and with the addition of an abrasive. The resistance to deep abrasion is calculated based on the chord length l of the abraded groove and specified as the volume V of the abraded material in mm³. Three classes are defined for the abrasion resistance.

Class	Mean abrasion volume mm³
A1	≤ 2100
A2	≤ 1100
A3	≤ 450

Table 3-5: **Abrasion resistance in accordance with DIN EN 1344**

3.2.5 Slip/skid resistance

The slip/skid resistance is measured in accordance with DIN EN 1344 with the Skid Resistance Tester on new unpolished clay pavers and clinker pavers straight from the factory. The test is conducted with the skid resistance tester in accordance with CEN/TS 16165:2012, Annex C. Based on the measured value (unpolished skid resistance value), the product is classified in four classes. The manufacturer declares the slip/skid resistance in accordance with the requirements classes U0 to U3 specified in Table 5 of EN 1344. This specification applies only to the declared wearing surface (e.g. for flat or on edge laying). Providing they are given the usual maintenance, clay pavers / clinker pavers exhibit acceptable slip/skid resistance during their lifetime.

Class	USRV mean value
U0	No requirement
U1	≥ 35
U2	≥ 45
U3	≥ 55

Table 3-6: **Slip/skid resistance in accordance with DIN EN 1344**

3.2.6 Acid resistance

Clinker pavers exhibit high resistance to the effects of acid and are therefore ideally suited for use in areas that are constantly exposed to aggressive chemical conditions. These include applications in the food industry, chemical plants and farms, where silage and aggressive liquors may be present.

Acid resistance is tested on dried fine particles that are boiled for approx. one hour in 10 % sulphuric acid and 10 % nitric acid in a round-bottom flask. The mass loss between the measurement may not be more than 7 mass%.

Class	Weight loss %
C	≤ 7

Table 3-7: **Resistance to chemicals in accordance with DIN EN 1344**

Clinker pavers – laid on edge in herringbone pattern

3.3 Clinker pavers in compliance with DIN EN 1344 and DIN 18503

In addition to "European" clay pavers in compliance with DIN EN 1344, in Germany there are also proven clinker pavers in compliance with DIN 18503, published in 12/2003. Clinker pavers are clay pavers in compliance with DIN EN 1344, however, with additional requirements for water absorption and body density. As the European standard cannot include all product features common nationally, DIN 18503 has been retained in part. For this reason, an additional standard was published in December 2003, DIN 18503:2003-12 Clinker bricks for paving – requirements and test methods. This contains the entire specifications from DIN EN 1344 and adds the key criteria of "water absorption" and "body density" for the clinker quality.

3.3.1 Water absorption

The water absorption of clinker pavers may not exceed 6 mass%. Water absorption is determined after 24-h immersion in water at 80 °C, in accordance with the specifications in DIN EN 1344, Section C.3.2. In this test, a maximum water absorption of 6 mass% may be determined.

3.3.2 Body density

The body density of clinker pavers must correspond to at least 2.0 kg/dm³ (mean value) or at least 1.9 kg/dm³ (individual value). If sampling is performed in compliance with DIN EN 1344:2002-07, Annex A, and the measurement complied with DIN EN 1344:2002-07, section C.3.2, a mean value of at least 2.0 kg/dm³ and an individual value of at least 1.9 kg/dm³ must be determined. In the marking of the body density by the manufacturer, only the minimum value for the mean value is specified.

3.4 Declaration of performance

Suitability of the construction products for the intended purpose, on the basis of the declaration of performance complied by the manufacturer, is certified in accordance with Article 4 and Annex III of regulation (EU) 305/2011 (Construction Products Regulation – CPR). The manufacturer's declaration of performance contains the full declaration of all property values necessary for the intended use. The specific property values concerned in each case are specified in Annex ZA of the specific product standard. With the signature of the officer responsible, responsibility for compliance with the declared performance values is guaranteed for the user of the construction products.

3.4.1 Declaration in printed form as a document accompanying delivery

The declaration of performance can be found either in printed form as a label, insert with the construction product, as an attachment to an order confirmation or as an enclosure with a delivery note. The signed original of the declaration of performance is retained by the manufacturer in his files for the event that a buyer/customer requires the declaration of performance in printed form. The manufacturer can make the declaration of performance available in electronic form (e-mail, e-mail with link to the DoP, CD, USB or fax). At the explicit request of the buyer, the manufacturer will issue a printed version. For the case that one lot of the same products is delivered to a single buyer, only one single copy of the declaration of performance must be provided. Responsibility for the provision of the declaration of performance is always with the direct contract partner. That means that if construction products are supplied from the construction products trade, the specific construction products trade outlet is responsible for provision of the declaration of performance. If construction products are sold abroad in non-German speaking countries, the importer of the construction products (manufacturer, trade outlet, etc.) is also responsible for provision of the declaration of performance in the language in common use where the construction products are to be used.

DECLARATION OF PERFORMANCE

0.		**DoP Nr.: AAX12-12345**
1. Unique identification code of the product type:		**Clay pavers - AAX12-12345**
2. Intended use:		**Clay pavers for floor coverings indoors and outdoors**
3. Manufacturer:		**Brick plant, road, town**
4. Authorized representative:		**N.S.**
5. System of assessment and verification of constancy of performance:		**System 4**
6. Harmonized standard:		**EN 1344:2013+ AC:2015**
7. Declared performance:		

Key characteristics		**Performance**	**hEN**
Fire behaviour:		Class $A1_{FL}$	**EN 1344:2013 +AC:2015**
Release of hazardous substances:		Not applicable	
Transverse breaking load:	Laid flat	Class T4	
	Laid on edge	Class T4	
Slip/skid resistance:	Laid flat	Class U3	
	Laid on edge	Class U3	
Thermal conductivity:		NPD	
Durability: Freeze-thaw cycling resistance		FP 100	
Durability: Slip/skid resistance		NPD	

The performance of the above-mentioned product complies with the declared performance/declared performances.
For the compilation of the declaration of performance in compliance with regulation (EU) Nr. 305/2011, the above-mentioned manufacturer is solely responsible.

Signed for the manufacturer by

.....

Company owner/CEO/authorized representative (name and function)

.....

Place and date of issue/signature

Declaration of performance in accordance with Annex III CPR for clay pavers in compliance with EN 1344

0) Reference number of the declaration of performance in accordance with Article 9, Paragraph 2 of Regulation (EU) No. 305/2011. The reference number can be freely allocated by the manufacturer.
1) Product type – with addition of the DoP reference number
2) Intended use – declared by the manufacturer in accordance with EN 1344
3) Manufacturer – address of the clinker paver manufacturer who is legally responsible for placing the product on the market.
4) Authorized representative (optional) – contact partner for the surveillance authorities, for keeping the declaration of performance
5) As a system for assessment and verification of constancy of performance for clinker pavers is required according to EN 1344 System 4 (manufacturer declaration without intervention of a notified body).
6) Harmonized standard: Name and date of issue of the European harmonized standard.

7) Declared performance in accordance with EN 1344 annex ZA Table ZA.1:

7.1) Fire behaviour – no certification necessary.
7.2) Release of hazardous substances: Not applicable – national environmental regulations in Germany do not require certification on the basis of harmonized test methods.
7.3) Transverse breaking load depending on the direction of load (flat/on edge) here: Class T4
7.4) Slip/skid resistance depending on the intended surface use - here: Class U3 (USRV mean value ≥ 55)
7.5) Thermal conductivity – here NPD (no performance determined). Specification only in the case of indoor use on the basis of EN 1745 as Lambda, 10, dry - value
7.6) Durability – specified in the form of freeze-thaw resistance – here: Class FP100
7.7) Durability – of the slip/skid resistance; here: NPD (no performance determined) until a standardized test method on European level becomes available

Fig. 3-1: **Example of a declaration of performance**

3.4.2 Declaration of performance on the website of the manufacturer

The construction product manufacturer also has the option of providing the declaration of performance on a website rather on paper with every delivery. However, he also has to ensure that the declaration of performance is always available and accessible over the minimum period of 10 years as specified in the CPR. The manufacturer must also ensure by appropriate means that the declaration cannot be subsequently changed or manipulated. The regulators expressly leave it open as to how these measures are met and their effectiveness is certified..

3.4.3 Declaration of performance in internet databases

Various manufacturers have already made their declarations of performance available on the European internet platform DoPCAP®. DoPCAP is an abbreviation of "Declaration of Performance/Common Access Point". DoPCAP is an initiative of construction product manufacturers who make their construction products available on the European market. Trade, planners and users can download, save or print the information on website www.dopcap.eu by entering the number of the declaration of performance specified in the CE marking. Use of DoPCAP by the user of construction products is free of charge and does not require any registration.

3.5 CE marking

Compliance with the requirements of DIN EN 1344 is declared by the manufacturer with the Europe-wide standard conformity mark (CE mark). The CE mark is therefore not a quality mark, but documents that the marked products comply with the requirements of DIN EN 1344 and accordingly may be traded and used in all EU countries. Central element of the Construction Product Regulation is the obligation of the manufacturer to mark the products with the CE mark and to provide / make available the so-called declaration of performance for the trade, planners and users of the product. The declaration of performance lists all product properties in the standard relevant to the specific intended use according to a formally defined scheme.

On the basis of the declaration of performance, the manufacturer creates the CE mark.

CE marking – consisting of the pictograph "CE", followed by supplementary details and performance values – should be affixed indelibly to the product itself, or if this is not possible, to the packaging or the accompanying documents such as the pack insert or delivery note, etc. The number of the declaration of performance is allocated by the manufacturer himself. On the basis of this DoP number on the CE marking, the trade, planners or users can clearly identify the detailed declaration of performance of the manufacturer. In accordance with Annex V of the CPR, depending on the systems for assessment and verification of the constancy of performance, external bodies notified for the product area should be called in. For clay pavers conforming to DIN EN 1344, the declaration of the manufacturer (declaration of performance) is sufficient without the intervention of an external notified body being necessary. The manufacturers of original clinker pavers additionally undergo voluntary independent monitoring including product testing.

3.6 Additional manufacturer's specifications

Unlike for the configuration of the CE marking, the form and content of the additional manufacturer's specifications are not regulated in detail in accordance with DIN EN 1344. Additional manufacturer's specifications such as the dimensions of the clinker paver, abrasion resistance, measurement range within one consignment and – if required – the acid resistance, can be declared, for example, in table form or in the so far customary form of a pack insert.

Following the withdrawal of the previously applicable DIN 18503:1989-08, the declaration of the clinker paver properties is not regulated in a standard. Nevertheless, it is certainly possible for the manufacturer to declare the properties of clinker pavers, like a limit to the water absorption or a minimum density, as voluntary manufacturer's specifications. Instead of individual specifications for the voluntary additional manufacturer's specifications, a quality mark e.g. "Original Pflasterklinker-Geprüfte Qualität" ("Original Clinker Pavers – Tested Quality") issued by the Arbeitsgemeinschaft Pflasterklinker e.V. (Clinker Paver Working Group) can be printed on the pack insert.

The common form for the design of product inserts does not need to be abandoned solely because of the CE marking obligation. For example, declarations concerning colour, units per pallet, joint width, (E = narrow or F = wide) can still be used unchanged. It is only important that the additional manufacturer's specifications are not mixed with the (statutory) declarations for CE marking.

CE		
Brick plant 1 Brick Street 12345 Bricktown		
04		
Clay pavers - AAX12-12345		
EN 1344:2013+ AC:2015		
DoP Nr.: AAX12-12345		
Clay pavers for floor coverings indoors and outdoors		
Transverse breaking load	Flat laying	Class T4
	On-edge	Class T4
Fire behaviour		Class $A1_{FL}$
Slip/skid resistance	Flat laying	Class U3
	On-edge	Class U3
Durability (Freeze-thaw cycling resistance)		Class FP 100

Additional manufacturer's specification in accordance with DIN EN 1344	
Dimensions (length/width/thickness):	240 x 118 x 52 mm
Range:	Class R1
Abrasion behaviour:	Class A3
Bending tensile strength (MV) Bending tensile strength (IV	≥ 10 N/mm² ≥ 8 N/mm²
Acid resistance	Class C

Manufacturer's specifications in accordance with DIN 18503	
Water absorption:	≤ 6 mass%
Body density (MV):	≥ 2.0 kg/dm³

CE marking in accordance with DIN EN 1344

0) CE-conformity mark
1) Manufacturer and/or supplier: Name, trademark and address of the clinker paver manufacturer
2) Year (last two numbers) in which the mark was attached (here: 2004)
3) Product type
4) Standard: Name of the European harmonized standard
5) Reference number of the declaration of performance in accordance with the CPR
6) Application range: Clay pavers are generally manufactured for unbound laying in a sand/chippings bed.
7) Transverse bending load depending on the direction of load (flat/on edge) here: Class T4 suitable for trafficking by lorries
8) Fire behaviour: No certification required. Specification only in the case of indoor use
9) Slip/skid resistance depending on the intended area of use – here: Class U3 (USRV mean value SRT ≥ 55)
10) Freeze-thaw resistance – here: Class FP100 (resistant to freeze-thaw cycling)

Additional manufacturer's specifications DIN EN 1344

11) Additional manufacturer's specifications in accordance with DIN EN 1344 are specified by the manufacturer, clearly separated from the declaration of the main properties according to Annex ZA Table ZA.1 (CE marking).
12) Shape and dimensions: Nominal dimensions are specified in the order length / width / thickness [in mm]. The dimensional deviation from the nominal dimension (mean value) should not be greater than ± 0.4·√d, "d" being the nominal dimension in mm.
13) Range – here: Class R1 (measurement range not larger than 0.6·√d, where the specific nominal dimension in mm should be inserted for "d")
14) Abrasion resistance – here: Class A3 (medium abrasion volume ≤ 450 mm³) corresponds to the clinker quality.
15) Bending tensile strength: Optionally, in addition to the transverse bending load (see 7), the mean value and smallest individual value for the bending tensile strength of the specimen (in N/mm²) can be specified. The bending tensile strength is estimated based on a conversion.
16) Acid resistance: Clay pavers/clinker pavers are acid-resistant here: Class C corresponding to certification of the acid resistance in accordance with DIN EN 1344 Annex F.

Additional manufacturer's specifications DIN 18503

17) If in addition to the „European" clay pavers in accordance with DIN EN 1344, the pavers comply with special requirements for the water absorption and body density, the clinker paver quality is marked with reference to DIN 18503.
18) Water absorption – here: ≤ 6 mass%.
19) Body density (mean value) – here: ≥ 2.0 g/cm³

Fig. 3-2: **Example of CE marking and additional manufacturer specifications**

CE		
Any Brick Plant Brick Street, 12345 Bricktown		
04		
EN 1344: 2013 + AC: 2015		
DOP Nr. AAF 12-12345		
Clay pavers for floor coverings indoors and outdoors		
Fire behaviour:		Class A1 FL
Traverse bending load:	Laid flat	Class T4
	On edge	Class T4
Slip/skid resistance:	Laid flat	Class U3
	On edge	Class U3
Durability: (freeze-thaw cycling resistance)		Class FP100

Additional manufacturer's specifications in compliance with DIN EN 1344	
Dimensions L/W/D	240 x 118 x 52 mm
Range	R1
Abrasion resistance	Class A3
Acid resistance	Class C
Bending tensile strength Mean value Individual value	 ≥ 10 N/mm² ≥ 8 N/mm²

Clinker paver properties in accordance with DIN 18503	
Water absorption	≤ 6 mass%
Body density	≥ 2000 kg/m³

BLUE-Multi-DF

432 units with chamfer

Clinker pavers DIN EN 1344 and DIN 18503
240 x 118 x 52 mm

DOP CAP

Clinker brickworks
Article number

ORIGINAL PFLASTER® GEPRÜFTE QUALITÄT KLINKER

Fig. 3-3: **Example of a pack insert**

Clinker pavers, blue-glazed, Charleroi, Belgium

3.7 Requirements for the use of clay pavers/ clinker pavers

With the CE marking or Declaration of Performance, the manufacturer does not necessarily certify compliance with the nationally applicable requirements for the use of construction products in a building structure. The regulatory competence for the definition of requirements for building structures – and therefore for the application of the construction products – remains with the EU member states. These are precisely defined for Germany in the Construction Products List and the specimen list of the Technical Building Regulations2 and implemented in the building codes of the Länder lists. As paving is not considered relevant to building code legislation, these products are neither named in the Construction Products List B Part 1, nor is reference made to codes of practice for construction products in the Specimen List in the Technical Building Regulations.

3.7.1 Requirements in accordance with VOB/C ATV DIN 18318

If for the paving work, a construction contract is concluded in accordance with the German Construction Contract Procedures (VOB), then in accordance with the General Technical Terms and Conditions for Construction Work ATV DIN 18318 Road Construction, the requirements of TL Pflaster-StB (Technical delivery terms for building products for the production of paving, tiled surfaces and edgings) also apply as part of the contract. Clay pavers must fulfil the requirements regarding the measurement range, freeze-thaw resistance, transverse bending load and abrasion resistance in accordance with Section 4.2 of TL Pflaster-StB. If a surface is to be paved with clinker quality, then, in addition to DIN EN 1344, the use of clinker pavers conforming to DIN 18503:2003-12 must be specified in the construction contract (performance specifications). Clinker pavers conforming to DIN 18503:2003-12 fulfil additional requirements for water absorption and body density.

3.7.2 Technical delivery terms TL Pflaster-StB

If a construction contract is concluded in accordance with General Construction Contract Procedures (VOB) or in the scope of paving work explicit reference is made to compliance with General Technical Specifications (ATV) DIN 18318 Road Construction, then the properties for clay pavers and clinker pavers defined in the technical delivery terms TL Pflaster-StB are subject of the contract. That means that if more than one class of requirements is offered for one characteristic in a European product standard, TL-Pflaster defines clearly which class (and therefore which requirements) clay pavers or clinker pavers must comply with when they are used in Germany. As TL Pflaster-StB are mentioned in ATV DIN 18318 as applicable for the definition of the construction material requirements, these classes automatically apply as binding in construction contracts for regular execution in accordance with ATV DIN 18318, providing other specifications are not given in the performance description.

3.7.2.1 Clay pavers and clinker pavers

In TL Pflaster-StB the national German requirements for clay pavers and clinker pavers are defined. The definition contains in each case the definition of the highest class in accordance with DIN EN 1344. Accordingly, the following requirements apply for each property:

Property	Class
Measurement range	R1
Freeze-thaw resistance	FP 100
Transverse bending load	T4
Abrasion resistance	A3

Table 3-8: **Requirements classes for clay pavers/clinker pavers in accordance with TL Pflaster-StB**

Requirements for the slip/skid resistance are not defined in TL Pflaster StB, a class is not included. For this reason – depending on the conditions for the clinker paving to be installed – a class must be chosen and specified in the performance description.

Manufacturers of "Original Clinker Pavers" assure with the quality mark compliance with the highest requirements class (U3) of DIN EN 1344 with an USRV value of 55, measured on unpolished clay pavers. This specification applies only for the declared wearing surface (e.g. for flat laying on the bearing surface). This value agrees with the slip/skid resistance of paving and slab paving for the highest SRT value pedestrian traffic in the Road and Transportation Research Association (FGSV) as a guide value for the production of clinker pavers. The required value in the class U3 for the fresh, unlaid clay paver/clinker paver is chosen so that acceptable slip/skid resistance of the clinker paver is achieved after this has been laid.

Clinker pavers have sufficient slip/skid resistance during their lifetime providing they are subject to usual maintenance and these are not ground and/or polished to obtain a smooth surface. There is no required value for the skid resistance on aged brick (as yet). As a recommendation for the assessment of existing surfacings in pedestrian areas, Table 3 of the FGSV datasheet – depending on outflow value – a SRT-value of 35 (starting negative) to SRT value of 55 (still positive). A reduction in the slip/skid resistance on account of the polishing effect caused by the traffic load is unavoidable. The initial roughness of the clay paver / clinker paver should, however, be so high that, for the intended purpose and with standard maintenance, an acceptable slip/skid resistance is retained over the duration of use.

For clinker pavers to be laid on edge, already during ordering, it is necessary to ensure that the declared SRT value for slip / skid resistance is also given for the wearing surface (in this case the stretcher surface). For this purpose, manufacturers supply clinker pavers specially for this with a "peeled wearing surface".

3.7.2.2 Clinker slabs

According to Section 5.2 of TL Pflaster-StB, clinker slabs must meet the same requirements as for clay pavers / clinker pavers. The transverse breaking load of clinker slabs have to fulfil the requirements of Class T4. Deviating from this, the transverse bending load for clinker slabs with a thickness ≤ 45 mm must meet the requirements of Class T2.

	Transverse breaking load (N/mm) not lower than	
Class	**Mean value**	**Lowest individual value**
T2	30	24
T4	80	64
NOTE For calculation of the breaking load [kN], the transverse breaking load [N/mm] is multiplied by the measured width of the clinker slab [mm], divided by 1000 and the result rounded to the nearest 0.1 kN (see DIN EN 1344, Annex D.4.1.)		

Table 3-9: **Requirement classes for clinker slabs in accordance with TL Pflaster-StB**

3.7.2.3 Kerb clinkers

In accordance with Section 6.2 of TL Pflaster-StB, kerb clinkers must fulfil the same requirements as for clay pavers/clinker pavers.

Fitting clinker pavers around manhole covers and drains (installations)

Park way with clinker pavers, laid in a stretcher bond in the walking direction, Lorsch Abbey

[2] See also the Construction Products List/Technical Construction Rules

4.1 Manufacturing of clinker pavers

Clay or clinker pavers are a building material that has been used in road construction in Northern Germany and the Netherlands for over 300 years. Today clinker pavers are formed from loam, clay or clayey bodies with or without additives and fired until sintered. The mechanized production of clinker pavers in modern plants can be divided into nine production steps.

4.1.1 Extraction of raw materials

The natural clay deposits used for the production of clinker pavers are worked mechanically and the materials extracted in open-cast mining operations. Excavators, usually bucket chain excavators or wheel loaders, are used for extraction of the raw materials. In this way the material is removed gently and loaded onto transfer cars, dumper trucks or lorries.

Raw material extraction

Most of the raw materials are extracted in the immediate vicinity of the brickworks, resulting in very short, energy-saving transport routes. The photo on page 24 shows clay extraction in a pit with red-firing clay. The colour scale shows the possible colour shades. Depending on the type of clay, the firing temperature and the firing atmosphere, different paver colours can be achieved, from buff through red to very dark shades.

The extraction of clay for the manufacture of clinker pavers leads to intervention in nature and the landscape. With the extraction, however, new habitats are formed with conditions that were not present originally. For a planned recultivation, subsequent uses, e.g. as lakes for water sports and leisure activities and recreational facilities as well as land usage as forest land, agricultural land or construction land, are possible.

4.1.2 Stages in raw material preparation

Loam, clay or clay schist are only rarely found with a composition and structure necessary for the production of clinker pavers. For this reason, the extracted raw material must first be prepared at the brickworks. The preparation of the raw materials for the production of clinker pavers is divided into several steps:

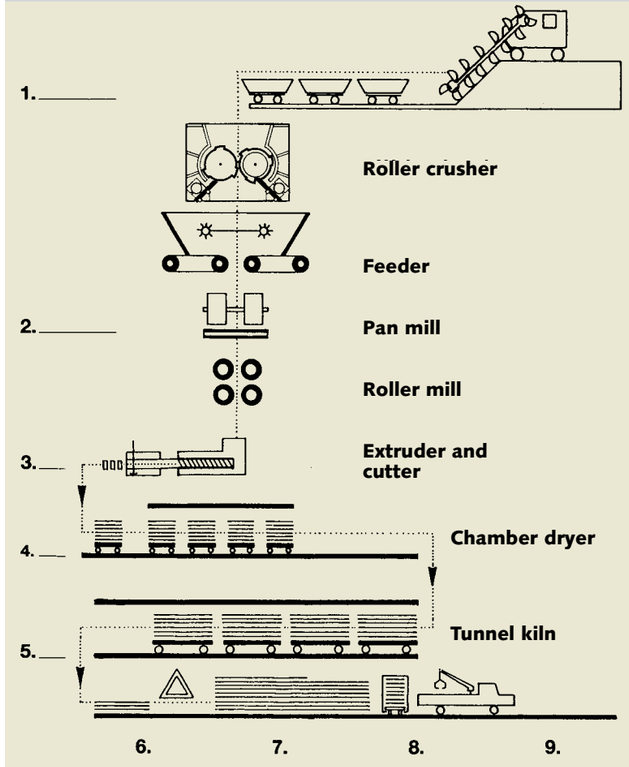
- Mixing of the clay and loam raw materials and addition of sand, clay meal or other suitable shorteners (grog)
- Removal of any unwanted constituents
- Comminution of any constituents that are too large and too hard
- Adjustment to the required plasticity with regulation of the moisture content

The raw materials pass a roller crusher, the box feeder, the pan mill and the roller mill.

Pan mill, two heavy rollers comminute the clay

Fig. 4-1: **Production process**

1. Raw material extraction
2. Preparation
3. Shaping
4. Drying
5. Firing
6. Quality control
7. Storage
8. Packaging
9. Loading



The pan mill is particularly important in the fine preparation of the raw materials. Here runners roll around the mill to further comminute the coarser particles of the prepared material before this is fed to the roller mill. It is ground to the required particle size (0 – 1 mm) so that a fine-grained batch of material is produced. To make the mixed and comminuted raw materials plastic for processing, moisture is then added.

The clay column is divided by a harp-wire cutter into the paver sizes

Tunnel kiln car setting with clinker pavers

4.1.3 Shaping

Via a roller mill, the prepared raw material arrives in a deairing chamber in which it is evacuated and heated with hot steam to make it smooth and plastic. It is then fed to the press. This is usually an extruder. A screw presses the raw material through the die of the extruder to form a column. This column of clay is cut with a wire cutter to the required lengths. The green pavers formed now have the shape of the finished pavers, but the dimensions are larger than that of the finished pavers. This is necessary as the pavers shrink during drying and firing. Shrinkage depends on the raw material used and ranges between 7 % and 12 %.

For pavers with an all-round chamfered edge on the fair face, the chamfer is already formed on the clay column.

4.1.4 Drying

The wet-shaped pavers are dried slowly in a chamber dryer at temperatures up to 100 °C. Water is extracted from the body.

The dried clinker pavers are stacked on special tunnel kiln cars in an automated process, leaving sufficient space between the pavers for the hot air to flow between them during the firing process (setting pattern). On the kiln car, the set pavers are transported into the tunnel kiln.

4.1.5 Firing

The dried pavers are fired as the cars travel through the tunnel kiln. At temperatures of over 1 100 °C, the raw material components are fired until sintered as a result of chemical conversion. In this way, the characteristic fired body of the paver is formed.

During the firing process, the pavers set on the tunnel kiln car first pass through the preheating zone, then the actual firing zone and finally the cooling zone. They are slowly heated, fired and then gradually cooled again. As a result, a product is guaranteed that is free of stress cracks. The entire firing cycle takes around 72 hours. During this time, the pavers travel through the length of the tunnel kiln, which, depending on the kiln model, can measure between 60 and 180 metres, to leave the kiln as finished clinker pavers.

The energy is usually supplied to the tunnel kiln from the top, but occasionally from the side. Natural gas is used predominantly for firing the pavers, as this fires with only low residue. Any thermal energy that is no longer needed is processed in heat recovery systems for reuse, for example in the dryer.

4.1.6 Packaging and Transport

At the kiln exit, the kiln car loaded with fired pavers is transferred to a program-controlled automatic transfer car, which pushes it, depending on requirements, to the unloading track or the storage track. An unloading gripper takes up complete fired packs and places them on ready-standing pallets. To secure the packs during transport, the stacks of pavers are strapped with horizontal and vertical plastic straps. A plastic film pulled over the pack of pavers is heated, contracts as it cools and gives a firm hold on the paver packs. These extremely stretchable films, with high tension, additionally contribute to the fixing and rainproofing of the paver packs. The finished packs are transported on a stacker truck to the stockyard and then loaded onto lorries.

Fired clinker pavers after they have exited the kiln

4.2 Quality control

For quality control, System 4 of the conformity certification procedure is defined. In System 4, the initial type testing and the factory production control (FPC) are performed by the manufacturer. The calling in of a notified body for the first type test and for the regular monitoring of the Factory Production Control and product testing is not prescribed. Before a clay paver is affixed with a CE mark, first a type test must be performed and a system for factory production control introduced by the manufacturer. With this process, it is ensured and documented that the products placed on the market comply with DIN EN 1344 and the values specified by the manufacturer.

The factory production control must consist of repeated control, tests and assessment of the results, to monitor raw materials, equipment, the production process and the finished product, the clinker pavers. Details on the factory production control are regulated in Section 5.3 of DIN EN 1344. The type tests for frost resistance, abrasion, resistance and slip / skid resistance must be repeated at least once a year.

According to 5.3.2.6 of DIN EN 1344, in the scope of the factory production control, tests on the finished product are conducted. The frequency of the sampling and tests is oriented to statistical rules that ensure that the finished product agrees with the acceptance criteria to be complied with in the standard and every specified value. For the unit tests, at least the mean values of the dimensions must be tested daily, values for the transverse bending load tested weekly and the results recorded. Sampling is performed according to a precise testing plan, which is set down in the documentation.

Quality mark

The quality mark of the Arbeitsgemeinschaft Pflasterklinker e.V. “Original Pflasterklinker – Geprüfte Qualität” (“Original Clinker Pavers – Tested Quality”) guarantees the highest quality standard and maximum product safety for building owners and planners, for quality and preservation of their investment.

The quality mark is used to ensure:

- Compliance with the highest requirement classes in accordance with DIN EN 1344 for clay pavers,
- Clinker paver quality in accordance with DIN 18503 and a
- Regular and independent quality control of the product properties

The quality mark **“Original Pflasterklinker – Geprüfte Qualität”** (“Original Clinker Pavers – Tested Quality”) guarantees the user compliance with the requirements of TL Plaster and can be used as proof of the suitability of the construction products for use in compliance with ZTV-Pflaster.

ORIGINAL PFLASTER® GEPRÜFTE QUALITÄT KLINKER

4.3 Formats

4.3.1 Joint width and grid spacing

The grid spacing to be taken into account in the planning of a paved area always consists of the nominal dimensions of the clinker pavers in addition to the joint width derived from the installation requirements. This also applies if different sizes of paver are used in one area. The thickness of the clinker pavers of 52, 62 and 71 mm was originally adopted from the common sizes for masonry bricks used in building construction (thin format, "Reich" format and standard format). Clinker pavers and masonry bricks were often produced on the same production line. In the further development towards higher material thicknesses, specialized production of road construction bricks has been systematically adjusted to thicknesses of 80 mm and 100 mm.

Flat laying	Material requirement in units* per m², approx.:
Length x width in mm	
200 x 100 mm	48
240 x 118 mm	34
220 x 108 mm	40
200 x 200 mm	24
240 x 240 mm	17
150 x 150 mm	43
300 x 150 mm	22
* In addition to cutting wastage	

Table 4-1: **Selected formats and derived material requirement for flat laying of pavers**

On-edge laying	Material requirement in units* per m² approx.:			
	Width in mm			
Length in mm	52 mm	62 mm	71 mm	80 mm
200 mm	88	75	66	59
240 mm	74	63	55	49
280 mm	65	54	47	42
360 mm	50	42	37	33
* plus cutting wastage				

Table 4-2: **Selected formats and derived material requirement for laying on edge**

4.3.2 Standard formats

Rectangular or square clinker pavers are produced for grid spacings of 100 to 300 mm. In addition, smaller sizes, i.e. mosaic clinker pavers are available (see Table 4-3).

Formats and dimensions are not regulated in the standard. The production dimensions are based on the paver laying system and must be agreed prior to delivery.

The required number of clinker pavers depends on the selected format and method of laying the pavers.

Clinker pavers can be supplied with or without chamfered edge. Other intermediate sizes and special formats as well as clinker pavers with shaped spacers are possible by arrangement. Clinker pavers with spacers enable machine laying. If for on-edge laying, the slip resistance must meet special requirements, peeled clinker pavers can be produced.

The thickness of the clinker paver must be defined depending on the load-bearing behaviour in the bond and expected traffic load.

Product	Laying method	Used surface mm	Thickness mm
Rectangular formats	Flat laying	200 x 100 220 x 108 240 x 118 300 x 150	45* / 52* / 62 / 71 / 80 / 100
Rectangular formats	On edge (bar shape)	200 x 52 200 x 62 200 x 71 200 x 80 240 x 52 240 x 62 240 x 71 240 x 80	52 / 62 / 71 / 80 / 100
Rectangular formats	Long shapes	280 x 52 280 x 62 280 x 71 280 x 80 360 x 52 360 x 62 360 x 71 360 x 80	71 / 80 /100
Square shapes	Flat laying	100 x 100 150 x 150 200 x 200	45* / 52* / 62 / 71 / 80 / 100
Mosaic	Flat laying	60 x 60	52 / 62 / (80)
Perforated lawn pavers	Flat laying	200 x 100 230 x 110 240 x 115 300 x 145	71 / 113

Table 4-3: **Selected sizes and laying patterns for clinker pavers**

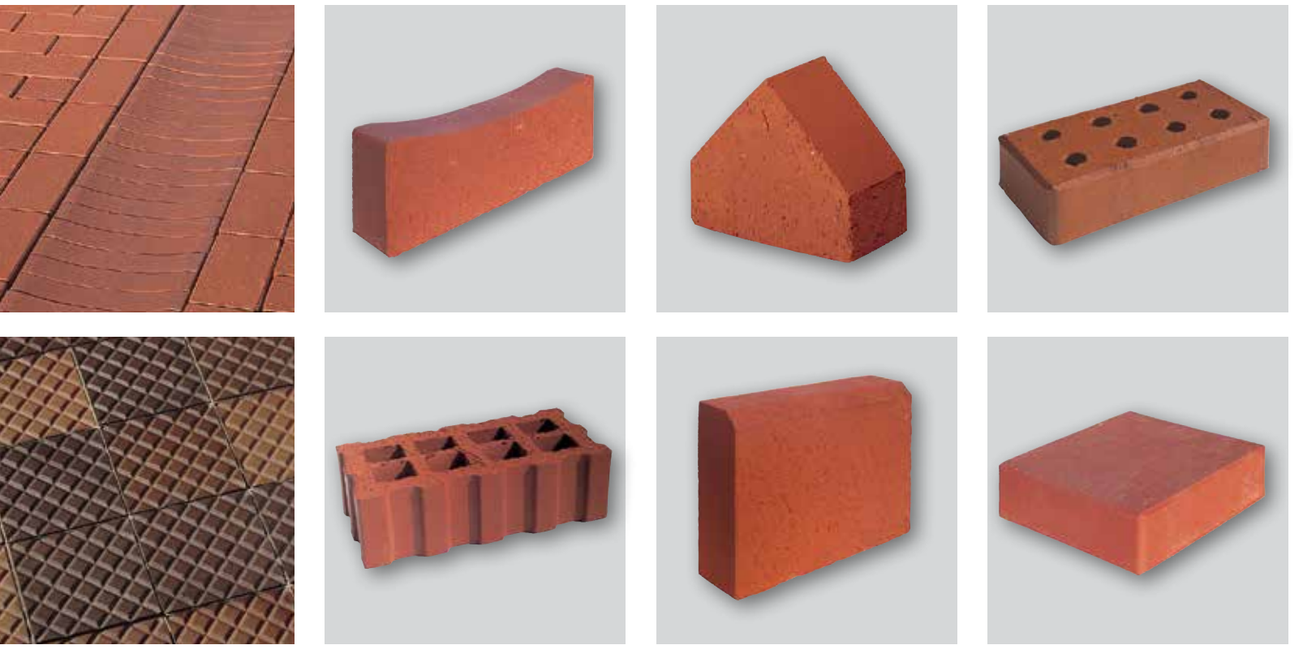
Promenade, Bilbao, Spain

Clinker pavers, elbow bond, promenade in Bilbao, Spain

4.3.3 Shaped clinker pavers

To complement the rectangular shapes predominantly used, clinker pavers are available in special shapes. For example, for the edging of diagonal or herringbone bonds, for instance, so-called bishop's hat pavers can be used. Clinker pavers are available in triangular, polygonal or circular shapes. In addition, interlocking clinker pavers and lawn pavers are available.

Fig. 4-2: **Shaped clinker pavers – trough gutter, gutter paver, bishop's hat, drainage paver, pavement slab, perforated lawn paver, step paver, square format**



4.4 Colours

The colours of the clinker pavers are influenced by the different geological composition of the clay, the percentages of the minerals it contains and the firing atmosphere. The colours produced in ceramic firing are colour- and light-fast. Fading or discolouring – even with intensive solar radiation – does not occur. For individual design preferences, original clinker pavers are available in a wide range of colour shades. The standard colours listed below are available in all product ranges.

4.5 Special manufacturing-related features

4.5.1 Colour and structural deviations

Clinker pavers come in a natural colour that is not determined by chemical additives but influenced by the minerals contained in the natural raw material and the firing process. On account of the raw-material- or production-related variations in colour and structure typical for ceramics, a desirable play of colour shades can be obtained. With mixing of the clinker pavers from different packs, disruptive effects in the surface appearance of the finished paving can be reduced.

4.5.2 Dimensional and shape deviations

Clinker pavers are natural heavy clay products. On account of the production process and unavoidable variations in the composition of the raw clays used, deviations from the nominal dimensions cannot be excluded.In accordance with DIN EN 1344 "Clay pavers", the range, that is the permissible difference between the smallest and largest dimension of the clinker paver, is limited for one consignment. The range applicable to Class R1 is specified in Table 3-1.

The measurement to determine the dimensional accuracy of clay pavers must be conducted before the pavers have been laid with a calliper gauge and sample number of ten pavers.

4.5.3 Hairline cracks

Fine hairline cracks are not completely avoidable in many commonly used construction products. Such cracks do not have any influence on the structural properties of the supplied clinker pavers, e.g. transverse breaking load and the freeze-thaw resistance. The observed hairline cracks are related to the production of the pavers and are not a material-related defect.

Fig. 4-3: **Clinker paver colours (standard)**

Red
The classical natural red colour of the clinker pavers with interesting variations that go from light red through reddish orange to dark shades like reddish brown. The red colour is determined by the iron content in the clay body.

Brown
For brown shades, clays with a high lime and low iron content are used. These are initially buff-coloured, the colour changing with increasing temperature up to sintering to brownish and brown shades.

Yellow/buff
The warm yellow shades range from a vibrant yellow shade through yellow-orange to a copper shimmer. The calcium compounds in the clay are responsible for the development of these yellow shades.

Black/anthracite
Dark to black fired colours are obtained by means of reduction firing. Here the supply of combustion air is controlled so that less oxygen is contained in the firing atmosphere.

Blue
Blue shades vary from muted blue to bluish-black. With reduction firing (e.g. blue reduction firing, silver reduction firing), a characteristic blue to silver-grey body surface can be obtained.

Red multi (flashed)
Flashed mixed shades like red-blue multi or red-black multi set individual accents. Flashed clinker pavers with iridescent-looking surfaces are produced with very high firing temperatures.

Yellow multi
In the case of yellow-firing pavers, the firing temperature influences the colour, the colour becoming more yellow, i.e. lighter, with increasing temperature. This natural play of colour can be used for multishades like yellow-multi.

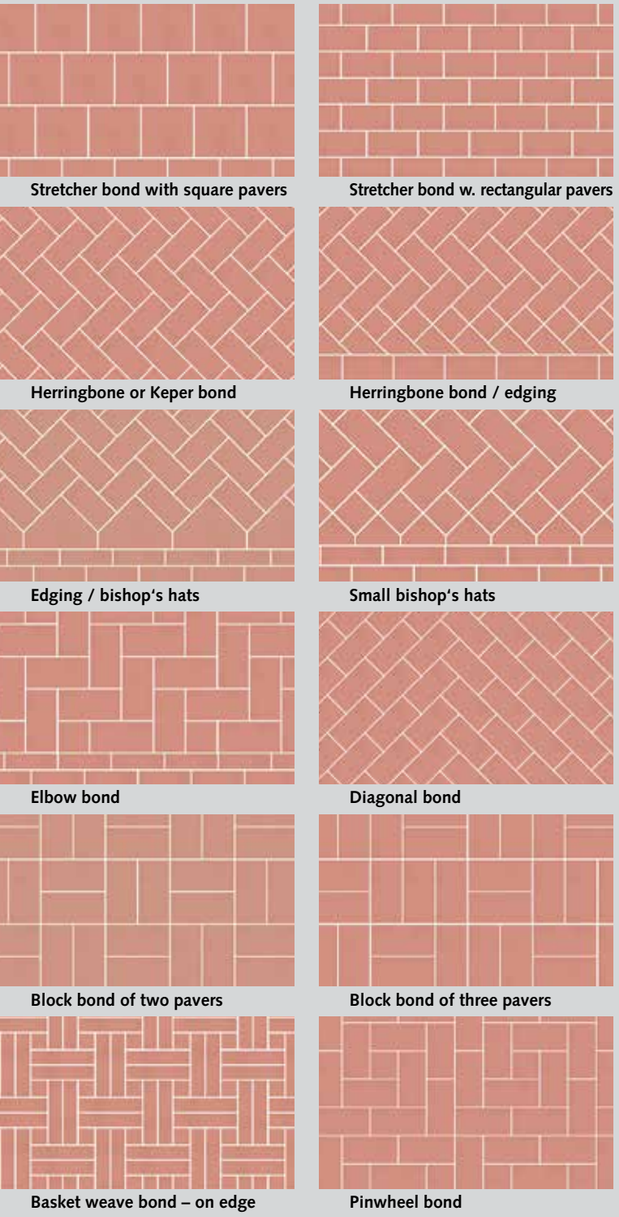
5 | Design and construction

5.1 Design of clinker paver surfaces

Urban streets are planned and constructed with the objective of balancing usage requirements and the usage of the surroundings to achieve compatibility. This compatibility must generally be striven for on given surfaces with consideration of the urban development, design and environmental interests. Especially, in respect of the urban design objectives, clinker pavers offer numerous advantages as traffic surfacing as they offer design possibilities adapted to the surroundings.

With clinker pavers, a large number of different bonds (laying patterns) can be constructed. Solely with the use of rectangular clinker pavers, several bonds can already be realized. With combination with bishop hats and square clinker pavers, a large number of other bonds are possible.

Fig. 5-1: **Bonds (laying patterns)**



5.1.1 Stretcher bond

For rectangular or square clinker pavers, the stretcher or straight course bond is the classic or most common laying pattern. Stretcher bonds are easy to lay and need no fitting pieces, and even laying the pavers around curves presents only minor difficulties.

5.1.2 Herringbone/Keper bond

This bond is very suitable for paths and slopes (e.g. also garage approaches). It is particularly stable, because it exhibits a better load-bearing effect, especially when exposed to horizontal forces, as the pavers are turned 45°. With this pattern, a good grip is achieved on account of the evenly distributed joint lengths with laying of the pavers at an angle of 45° to the path axis. At the edges, either special fitting pieces are necessary, for example bishop's hat pavers, or the clinker pavers laid at the edges must be cut to fit. When the herringbone bond is laid in the direction of the carriageway (elbow bond), half-pavers are sufficient for fitting.

5.1.3 Diagonal bond

The diagonal bond is a stretcher or vertical bond laid at an angle of 45° to the path axis. For the diagonal bond, the same remarks concerning the herringbone or "keper" bond apply by analogy.

5.1.4 Block or parquet bond

For the block or parquet bond, clinker pavers are grouped into small blocks of two or three pavers or around a centre paver. This results in patterns with a wide range of variations. As these bonds have cross-joints and/or end-to-end lengthways joints and the paving therefore only demonstrates low resistance to deformation, they should only be used for surfaces that are not trafficked by motor vehicles. They are therefore used primarily as ornamental bonds for garden areas or patios. If they are to be used in areas with heavier traffic, for example in pedestrian precincts, bound construction is necessary.

Clinker pavers in a long rectangular shape laid in herringbone bond

Seafront promenade, Wenduine, Belgium

5.1.5 Linear laying patterns

Linear laying patterns permit a strictly linear division of the area. When the pavers are laid, care must be taken that the pavers are laid exactly in the grid so that straight joint lines are achieved. Curves cannot be laid with this laying pattern. As these bonds have cross-joints and end-to-end longitudinal joints and the paved surface has no bonding effect, they should only be used for areas that are not trafficked by motor vehicles.

5.1.6 Design examples with the use of square clinker pavers

Besides the predominantly used rectangular formats, square shapes are often used for paving surfaces and sections. During laying, it is necessary that clinkers of different shapes should have the same thickness when possible.

Other design examples like

- Connections of clinker pavers at tree bases or installations,
- Paved curves and round shapes,
- Walls and parapets in combination with clinker paving,
- Paved stairs and ramps as well as
- Transitions of paved surfaces at building walls

can be found in the annex.

5.1.7 Suitable bonds for trafficked surfaces

Bonds that have crossed joints and/or continuous long joints (in the direction of trafficking) are unsuitable for surfaces that are regularly trafficked by motor vehicles. In accordance with ZTV Pflaster StB, bonds with cross joints need the express agreement of the client ordering the construction in advance.

In laboratory and field trials, JUNGFELD, KRASS and ROHLEDER [1] systematically tested the horizontal displacement resistance of clinker paver surfaces with an expander tool. The results of the tests show that construction methods with a cross-laid stretcher bond, as well as with herringbone and elbow bond exhibit high horizontal displacement resistance. The above-mentioned tests, like the studies of GLEITZ, ROSSBERG and WELLNER [2], show a somewhat higher deformation resistance for bonds laid at an angle of 45° (herringbone and diagonal bond), as with these bonds horizontal forces can be dissipated better.

Machine laying of clinker pavers,
Den Haag, the Netherlands

5.2 Urban development and installation aspects

In the planning and design of roadways in built-up areas, the following directives, recommendations and tips should be taken into consideration:

- Directives for the design of urban roads (RASt),
- Recommendations for road design within built-up areas (ESG),
- Recommendations for the design of parking areas (EAR),
- Recommendations for cycle traffic installations (ERA),
- Recommendations for pedestrian traffic installations (EFA),
- Recommendations for barrier-free traffic installations (H BVA).

In the planning and design of surfacing for public and private projects, the focus is frequently on design aspects. Especially for areas trafficked by motor vehicles, a series of construction-related principles and requirements must also be taken into account and harmonized with the design preferences to ensure maximized, damage-free service lifetime of the surfacing.

In the selection of clinker pavers, the specification of the laying pattern and the choice of the other building materials used in the superstructure of the surfacing, it is, however, necessary to take equal account of design and construction requirements. The construction-related requirements are derived from the number and the type of vehicle- and other traffic loads. It is imperative to note that the paving method is not generally suitable for traffic areas with heavy to very heavy traffic load, corresponding to Construction classes Bk100, Bk32 and Bk10 in RStO.

5.3 The technical regulations and their importance in the construction contract

Assuming that many readers of this brochure will not necessarily be familiar with the technical regulations, in the following the most important technical regulations for the installation of surfaces for trafficked areas with clinker pavers are described and explained. Public contracting authorities always agree these regulations as part of their contracts. However, in building projects for private clients, work should be executed according to the basic principles formulated here, which presupposes stipulation of the regulations in the contractual agreement.

Application and load categories		
1	**2**	**3**
High traffic loads	**Medium to low traffic loads**	**Minor loads**
High axle loads, Medium to high freight traffic loads (Construction classes Bk3.2, BK1.8 and BK1.0) High horizontal loads Frequent manoeuvring	Medium, low or only occasional freight traffic load (Construction classes Bk1.0 or Bk0.3) Predominantly passenger car traffic Other low loads	Surfaces without any vehicle loads
Examples: Main commercial roads, trunk roads Lorry parking spaces and traffic lanes Bus traffic areas Roundabouts Squares and pedestrian precincts with goods traffic Industrial traffic areas	**Examples:** Residential roads and streets Carparks and laybys for cars Agricultural and forestry roads Areas of squares and pedestrian precincts without goods and bus traffic Pedestrian and cycle paths Driveways and yards	**Examples:** Patios and garden areas Recreational areas in residential environments Outdoor recreational areas near schools, nurseries and swimming pools, etc.

Table 5-1: **Usage and load categories depending on the load situation based on the M FP code of practice**

In the design and construction of clinker paving for trafficked areas, the following technical and additional contractual terms, terms of delivery, standards and directives should be taken into account.

The DIN standards are available from the German publisher Beuth Verlag. All other technical rules are – unless indicated otherwise – issued by the Forschungsgesellschaft für Strassen- und Verkehrswesen (FGSV – German Road and Transportation Research Association) and can be obtained from the FGSV-Verlag publishing house.

5.3.1 General technical specifications in construction contracts

If the German Construction Contract Procedures (VOB), Part B, are agreed as part of a contract, that is if a building contract is concluded on the basis of the VOB, then in accordance with § 1 of VOB/B, the general technical terms and conditions for construction work (ATV) contained in VOB, part C also form part of the construction contract. The standards, regulations or technical terms of delivery described in this as applicable or relevant therefore form part of the contract. The following General Technical Terms and Conditions for Construction Work are relevant:

- ATV DIN 18318 Road construction – Dry jointed sett and slab pavements, and surrounds
- ATV DIN 18299 General rules applying to all types of construction work
- ATV DIN 18300 Earthworks
- ATV DIN 18315 Road construction – Surfacings without binder
- ATV DIN 18316 Road construction – Surfacings with hydraulic binders
- ATV DIN 18317 Road construction – Asphalt surfacings

In ATV DIN 18318, flat laying of clinker pavers in rows with offset joints is prescribed as the standard installation. This forms the basis for costing and as the agreed performance for acceptance, providing no other method of laying (e.g. laying on edge) is described in the performance specifications.

5.3.2 Technical terms of delivery (TL)

The relevant technical terms of delivery specifically include:

- TL Pflaster-StB – Technical delivery terms for building products for the production of paving, tiled surfaces and edgings
- TL SoB-StB - Technical delivery terms for building material mixtures and soils for production of courses without binders in road construction
- TL Gestein-StB - Technical delivery terms for rock aggregate in road construction

TL Pflaster and TL Gestein specified in this as also applicable are, on account of their specification in ATV DIN 18318, part of the contract in VOB contracts.

5.3.3 Standards

On account of their particular relevance with regard to the requirements for clinker pavers, only the following are listed here:

- DIN EN 1344 – Clay pavers – Requirements and test methods
- DIN 18503 – Clinker bricks for paving – Requirements and test methods

In addition, naturally numerous other standards not mentioned here must be taken into consideration as "codes of practice".

5.3.4 Additional technical contract terms

It is necessary to supplement the ATV with additional technical contract terms (ZTV) when the minimum requirements specified in the ATV for the specific surfacing are not sufficient. The contents of the ZTV are, however, only effective if the respective ZTV are expressly specified in the construction contract. For public authority contracts, agreement of ZTV is mandatory. For private contracting clients, at least for trafficked areas, agreement of ZTV is recommended. Relevant terms for paved surfaces include:

- ZTV Pflaster-StB – Additional technical contract terms and directives for production of stone and tile pavements, kerbs
- ZTV SoB-StB – Additional technical terms of contract and directives for the construction of courses without binder in road construction

- ZTV E-StB – Additional technical contract terms and directives for earthworks in road construction
- ZTV A-StB – Additional technical contract terms and directives for excavations in traffic areas
- ZTV LW – Additional technical contract terms and directives for paving agricultural tracks
- ZTV Ew-StB – Additional technical contract terms and directives for the construction of drainage installations in road construction

5.3.5 Directives

The directives contained in the ZTV and indicated as text printed in italics as well as the directives issued as independent texts include stipulations and recommendations that should be taken into account primarily in the design and planning phase. Agreement as part of the contract is not mandatory. These include:

- RStO – Directive for the standardization of surfaces of road traffic areas
- RAS-Ew – Directives for road construction, drainage
- RLW – Directives for rural road construction
- RuA-StB – Directive for the environmentally compatible use of industrial secondary products and recycled building materials in road construction.

5.3.6 Codes of practice, recommendations and working documents

The content of codes of practice and recommendations can already be regarded as state of the art, whereas in the working documents, usually interim research findings or further activities are formulated. If the texts contained in these are agreed in the contract, the relevant content must be included in the description of work and services.

General inclusion in contract agreements is not mandatory. The following are relevant for the design and installation of surfacings with clinker pavers

- Code of practice for surface paving with pavers and slabs in unbound construction and for surrounds – M FP
- Working paper on surfacing with pavers and slab pavements in bound construction – FGSV Working Paper (draft) (New edition under compilation as a code of practice)
- Bound construction – Historical paving – code of practice E 5-21-07/D (published by: WTA)
- Code for water-permeable paving of traffic areas – M VV
- Code of practice on the skid resistance of surface paving with pavers and slabs for pedestrian traffic
- Cement Code – Road construction, pervious concrete base courses – M DBT
- Code of practice for the production of base and wearing courses without binders
- Code of practice for the construction of bus traffic areas
- Merkblatt für den Bau von Busverkehrsflächen
- Code of practice for the construction of traffic areas in track installations of tramways
- Plantable paving – recommendations for the design, execution and maintenance of surfaces of plantable paved surfaces and paving (published by: FLL)
- Traffic areas on building structures – recommendations on the design and construction of traffic areas on building structures (published by: FLL)

Kastruplundgade, Copenhagen, Denmark

5.4 Construction principles

5.4.1 Course structure of surface paving

The surfacing of traffic areas generally consists of several courses in the superstructure. The purpose of these courses is to absorb the static and dynamic vehicle loads, distribute these over a wider area and transfer them to the subsoil. Fig. 5.2 shows a typical course structure. Clinker paver surfacing consists of the paver course itself and usually only one base course, although more than one base course may be installed if required. Below this is the surface of the subgrade, the subsoil. Only where filling is first necessary to obtain a level height of the subsoil is a substructure installed in the form of the filling.

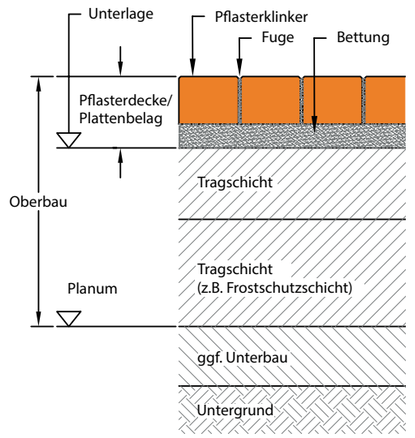


Fig. 5-2: **Structure of traffic area surfacing with clinker pavers in accordance with ZTV Pflaster-StB**

With proper design and construction, and providing the traffic load taken as the basis for the design does not change, clinker paving achieves a service lifetime on par with that obtained with other methods for traffic surface construction. Field experience and independent scientific investigations [1] confirm good deformation behaviour for the clinker paving overall. Studies on horizontal displacement resistance (shear force capacity) reveal equally good results for clinker paving as for other paving materials. With regard to vertical deformation loads, clinker paving even achieves the better values. Moreover, this positive property of clinker paving is even reinforced with increasing number of load cycles.

5.4.2 Terminology

The following terms are used to describe the elements in the course structure of paving:

Superstructure	Paving, Base course(s)
Substructure	Filling to obtain a level height of the subsoil (if required)
Subgrade	Naturally found foundation (soil, rock)
Paving / Clinker paving	Clinker paving, joint filling and bedding
Bedding	Lower section of the paving, also known as the paving bed
Base surface	Top base course as support for the paving
Base course(s)	Crushed stone, gravel and/or frost blanket
Subsoil	Surface of the subsoil or subgrade on which the superstructure Is installed
Interlocking clay pavers	Clinker pavers shaped to enable special interlocking of the pavers, designed to prevent the displacement of individual pavers when exposed to traffic loads
Joint filling	Aggregate without binder for filling the spaces (joints) between pavers or between pavers and edge restraints or installations
Bond	Geometrical pattern in which the clay pavers or slab are laid or offset
Paving	The clinker paving forms the top layer of the superstructure. According to ZTV Pflaster-StB, the surfacing elements for paving have a ratio of total length to thickness of ≤ 4; their total length may not exceed 400 mm.
Slabs	Surfacing elements for slab pavements have in accordance with ZTV Pflaster-StB a ratio of total length to thickness of > 4. The surfacing elements for slab pavements should not exceed the maximum total length of 600 mm – otherwise these are classed as large-format products.

Fig. 5-3: **Terms relating to the course structure of paving in accordance with ZTV Pflaster-StB**

5.5 Drainage

5.5.1 Surface drainage

Surface drainage of paving is of particular importance both in respect of traffic safety and the durability of the paving. It is therefore imperative to draw up a drainage plan in the traffic-related design of roads, paths and squares. Here, the transverse slope, q, and longitudinal slope, s, of the surface of the respective traffic area are defined depending on the selected method for construction of the wearing course. The resulting slope with an effective run-off or diagonal slope, p, is calculated from the transverse slope, q, and longitudinal slope, s.

$$p = \sqrt{q^2 + s^2}$$

In the determination of the slope of the surface, the notes of the relevant directives and recommendations (see Section 5.1) on the longitudinal, transverse and diagonal slope of the respective traffic surface should be taken into account. Basically, a minimum value of 2.5 % for the resulting slope with an effective run-off (resulting from the transverse and longitudinal slope) of the paving should be maintained. If necessary, the surface should be divided into subareas with different run-off efficiencies.

In order to avoid hazards and nuisances caused by the formation of puddles, it is essential to ensure that the above-mentioned minimum value of 2.5 % for the run-off efficient resulting slope is maintained. An accumulation of water on the surface also results in increased infiltration of precipitation water through the paving joints, which leads to a reduction in load-bearing capacity of the paving and the base courses and accordingly the service lifetime of the paving. If the above-mentioned disadvantages are consciously regarded as acceptable, any resulting slope should not, however, be defined lower than 2.0 %.

Surfacing designed to be drainable (see Section 7.2) should be designed with a lower slope to increase the drainage rate.

For construction-related reasons, the required slope (minimum transverse slope: 2.5 % for carriageways) must be installed in all courses of the traffic area surfacing. The subsoil and the surfaces of the base courses must already exhibit the longitudinal and transverse slopes of the paved surface.

Further information on surface drainage of traffic areas can be obtained from the " Directives for road construction, drainage" (RAS-Ew).

Difference between clinker pavers and clinker slabs

In accordance with DIN EN 1344, clinker pavers must have a minimum thickness of 40 mm (minimum thickness for laying in a mortar bed: 30 mm). The applicability of the harmonized product standard DIN EN 1344 covers clay pavers that do not exceed the ratio of total length to thickness (based on the nominal dimension) with a value of 6. ZTV Pflaster StB, on the other hand, specifies in Section 1.2 that for clinker pavers the ration of total length to thickness should not be greater than 4. If the ratio value or 4 is exceeded, then according to this definition, the product is a clinker slab.

The differentiation between paving blocks and slabs contained in ZTV Pflaster-StB applies uniformly for all paving blocks and slabs, irrespective of the construction materials. However, it goes back to the differentiation between paving blocks and slabs made of concrete and is based on the definition in accordance with DIN EN 1338. On account of the much higher material strength of clinker pavers compared to corresponding concrete products, in terms of strength, it would be certainly possible to use clinker pavers in accordance with DIN EN 1344, providing this has been agreed and positive experience is available with this regionally over a number of years:

Clinker paver	**Total length to thickness ≤ 6**
Clinker slab	**Total length to thickness > 6**

Another reason for the limitation of length for paving elements in ZTV Pflaster-StB is assuring sufficient stability of the paving elements in the paving surface. Therefore, for the use of bar-shaped and long-format pavers that have a thickness / length ratio > 4, a special agreement must be concluded if they are to be used in public traffic areas trafficked by motor vehicles.

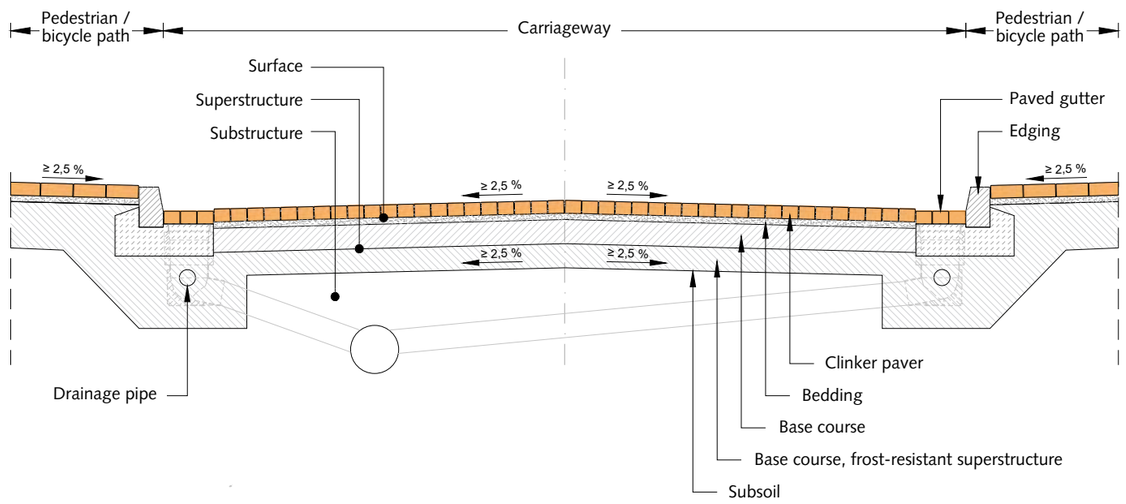
5.5.2 Subsoil drainage

Installations for the drainage of the subsoil are necessary if the surfacing of the traffic area is to be installed on water-sensitive soils. In general, F2 and F3 soils as specified in the ZTV E-StB can be regarded as "water sensitive". As paving absorbs part of the surface water through its joints and transfers this into the base course to the subsoil, drainage of the subsoil is particularly important for the durability of the surfacing. It is necessary for the discharge of the precipitation or stratum water penetrating into the paving.

The subsoil is drained by means of:

- Sufficient transverse slope of the subsoil and
- discharge of the water from the surfacing at the lowest point of the subsoil, if possible with seepage layers (in an elevated position), otherwise with seepage sections or drainage pipes. These should be designed according to the criterion of hydraulic efficiency (see RAS-Ew).

Fig. 5-4: **Transverse slopes of a road in a built-up area (RAS-Ew)**



5.6 Dimensioning and specification of the courses in the structure of the surfacing

5.6.1 Procedure for trafficked surfaces

The dimensioning of the traffic surfacing with clinker pavers is based on the "directives for the standardization of the surfacing of traffic areas" (RStO). The standard construction methods listed in this cover both the surfacing of carriageways and other traffic areas as well as cycle paths and pedestrian pathways. For private surfacing projects, the sequence and thickness of the courses should also be defined in accordance with RStO, although the procedure according to ZTV Wegebau is also possible (see Section 5.5.3).

In accordance with RStO, the substructure is dimensioned with consideration of the following input data:

- The traffic load in the form of the dimensioning-related action effect B, corresponding to number of equivalent 10-t axles in the dimensioning-related action period (generally 30 years),
- Details on the local conditions, especially in respect of determining the minimum thickness of the frost-resistant superstructure,
- Load-bearing capacity of the subgrade and substructure.

The thickness of the structure of traffic area surfacing should be determined so that sufficient and necessary frost resistance are guaranteed.

Traffic area surfacing is dimensioned in accordance with RStO in several, in some cases, consecutive stages.

Table 5-2: **Construction methods with paving for carriageways on F2 and F3 subgrade/substructure (RStO 12)**

(thickness in cm; ▼ E_{V2} minimum values in MN/m²)

Line	Construction class	Bk_{100}				Bk_{32}				Bk_{10}				$Bk_{3.2}$				$Bk_{1.8}$				$Bk_{1.0}$				$Bk_{0.3}$			
	B [million]	> 32				> 10-32				> 3.2 – 10				> 1.8 – 3.2				> 1.0 – 1.8				>0.3-1.0				≤ 0.3			
	Thickness of frost-resistant superstructure[1]	55	65	75	85	55	65	75	85	55	65	75	85	45	55	65	75	45	55	65	75	35	45	55	65	35	45	55	65
	Crushed rock base course on frost blanket course																												
1	Dry jointed sett pavement [9] Crushed rock base course Frost blanket course													▼180 [19] 10 / 4 / 25 / Σ39 / ▼120 / ▼45				▼150 10 / 4 / 25 / Σ39 / ▼120 / ▼45				▼150 8 / 4 / 20 / Σ32 / ▼120 / ▼45				▼120 8 / 4 / 15 / Σ27 / ▼100 / ▼45			
	Thickness of frost blanket course													-	-	26[3]	36		-	26[3]	36	-	-	33[2]	43	-	18[3]	28	38
	Gravel base course on frost blanket course																												
2	Dry jointed sett pavement [9] Gravel base course Frost blanket course																	▼150 10 / 4 / 30 / Σ44 / ▼120 / ▼45				▼150 8 / 4 / 25 / Σ37 / ▼120 / ▼45				▼120 8 / 4 / 20 / Σ32 / ▼100 / ▼45			
	Thickness of frost blanket course													-	-	-	31[2]	-	-	-	31[2]	-	-	28[3]	38	-	-	23[2]	33
	Crushed rock or gravel base course on course made of material not susceptible to frost																												
3	Dry jointed sett pavement [9] Crushed rock or gravel base course Course made of material not susceptible to frost													▼180 10 / 4 / 30[19] / Σ44 / ▼45				▼150 10 / 4 / 30[19] / Σ44 / ▼45				▼150 8 / 4 / 30[19] / Σ42 / ▼45				▼120 8 / 4 / 25[11,19] / Σ37 / ▼45			
	Thickness of course made of material not susceptible to frost	From 12 cm and up from material not susceptible to frost, lower residual thickness to be levelled with material of course above it																											
	Asphalt base course on frost blanket course																												
4	Dry jointed sett pavement [9] Water-permeable asphalt base course[10] Frost blanket course													▼120 10 / 4 / 14 / Σ28 / ▼45				▼120 10 / 4 / 14 / Σ28 / ▼45				▼120 8 / 4 / 12 / Σ24 / ▼45				▼100 8 / 4 / 10 / Σ22 / ▼45			
	Thickness of frost blanket course													-	27[3]	37	47		27[2]	37	47		31[2]	41	51	-	23[2]	33	43
	Asphalt base course and crushed rock base course on frost blanket course																												
5	Dry jointed sett pavement [9] Water-permeable asphalt base course[10] Crushed rock base course Frost blanket course													▼150 10 / 4 / 10 / 15 / Σ39 / ▼120 / ▼45				▼150 10 / 4 / 10 / 15 / Σ39 / ▼120 / ▼45				▼150 8 / 4 / 8 / 15 / Σ35 / ▼120 / ▼45				▼150 8 / 4 / 8 / 15 / Σ35 / ▼120 / ▼45			
	Thickness of frost blanket course													-	-	26[3]	36	-	-	26[2]	36	-	-	20[2]	30	-	-	20[2]	30
	Asphalt base course and gravel base course on frost blanket course																												
6	Dry jointed sett pavement[9] Water-permeable asphalt base course[10] Gravel base course Frost blanket course													▼150 10 / 4 / 10 / 20 / Σ44 / ▼120 / ▼45				▼150 10 / 4 / 10 / 20 / Σ44 / ▼120 / ▼45				▼150 8 / 4 / 8 / 20 / Σ40 / ▼120 / ▼45				▼150 8 / 4 / 8 / 20 / Σ40 / ▼120 / ▼45			
	Thickness of frost blanket course													-	-	-	31[2]	-	-	-	31[2]	-	-	25[3]	35	-	-	15[3]	25
	Pervious concrete base course on frost blanket course																												
7	Dry jointed sett pavement [9] Pervious concrete base course (DBT) [10] Frost blanket course													▼120 10 / 4 / 20 / Σ34 / ▼45				▼120 10 / 4 / 20 / Σ34 / ▼45				▼120 8 / 4 / 15 / Σ27 / ▼45				▼120 8 / 4 / 15 / Σ27 / ▼45			
	Thickness of frost blanket course													-	-	31[2]	41	-	-	31[2]	41	-	18[3]	28	38	-	18[3]	28	38

1) In the event of deviating values, the thicknesses of the frost blanket course or the material not susceptible to frost shall be determined by forming the difference, see also Table 8
2) With round-particle aggregate only if proven effective under local conditions
3) With broken aggregate and if proven effective under local conditions only
9) For deviating rock thickness see point 3.3.5
10) See ZTV Pflaster
11) For gravel base course in construction classes $Bk_{1.8}$ and $Bk_{3.2}$ in 40 cm thickness, in construction classes $BK_{0.3}$ and $Bk_{1.0}$ in 30 cm thickness
15) Applicable with $E_{v2} \geq 150$ MN/m² and proven regional construction methods
19) Only crushed rock base course

Table 5-3: **Construction methods with paving for cycle and pedestrian paths on F2 and F3 subgrade/substructure (RStO 12)**

(thickness in cm; ▼ E_{V2} minimum values in MN/m²)

Line	Construction methods using	Bitumen macadam		Concrete surface		Dry jointed sett pavement (slab cover)		Unbound surfacings	
	Thickness of the frost-resistant superstructure	30	40	30	40	30	40	30	40
	Crushed rock or gravel base course on course made of material not susceptible to frost								
1	Surface Crushed rock or gravel base course Course made of material not susceptible to frost	[20] 60 / ▼45 — 10[6] / 15 / Σ25		[20] 60 / ▼45 — 12[17] / 15 / Σ27		[20] 60 / ▼45 — 8[16] / 4 / 15 / Σ27		▼120 — 4 / 25 / Σ29 — ▼45	
	Thickness of course made of material not susceptible to frost[16]	-	**15**	-	13	-	13	-	11
	Base course without binders on plane								
2	Surface Crushed rock, gravel base course or frost blanket course	[20] 60 / ▼45 — 10[6] / Σ10		[20] 60 / ▼45 — 12[17] / Σ12		[20] 60 / ▼45 — 8[16] / 4 / Σ12		▼120 — 4 / Σ4 — ▼45	
	Thickness of the crushed rock or gravel base course	20	30	18	28	18	28	26	36

6) Base course surface, see also Point 3.3.3
14) Lower thickness possible
16) From 12 cm and up from material not susceptible to frost, lower residual thickness to be levelled with material of course above it
17) Dowelled joining or anchoring of a 12 cm thick concrete surface is not possible
20) On loading by vehicles(repair and maintenance) $E_{v2} \geq 100$ MPa

Stage 1: **Assignment of the Construction class**

In RStO, depending on the traffic volume of vehicle types of freight traffic, seven construction classes (Bk100 to Bk0.3) are defined. The construction class for a traffic surface can be basically assigned according to two procedures:

a) Based on calculation of the dimensioning-related action effect B according to Method 1 or Method 2 of RStO (see Annex 1). This procedure should be the rule. It is, however, necessary for this that details on the average daily traffic volume of freight traffic DTV(SV) or data from axle load weighing in the traffic are available.

b) If in an exceptional case, the traffic load is based on freight traffic vehicles, so according to the RStO the load case can be assigned based on the "typical draft situations" in accordance with RASt. For traffic surfaces with stationary traffic or for bus traffic surfaces, the construction class can be assigned directly. The necessary tables from the RStO are given in Annex 1.

Stage 2: **Determining the minimum thickness of the frost-resistant superstructure**

The thickness of the frost-resistant structure of courses of the traffic area surfacing must be defined such that no damaging deformation is suffered during freeze and thaw periods. The required minimum thickness of the frost-resistant superstructure is calculated depending on the

- the frost susceptibility of the soil in accordance with ZTV E-StB,
- the local climate and construction-related conditions, including the frost action zone and groundwater level as well as the
- previously determined construction class

The procedure is explained in Annex 1. With regard to their frost susceptibility, the soils in the standard DIN 18196 are classified in ZTV E StB in the frost susceptibility classes F1 (frost-resistant), F2 (frost-sensitive) and F3 (extremely frost-resistant) (see Annex 2).

Stage 3: **Selection of the construction method**

The construction methods with paving for carriageways are listed in Chart 3 of RStO (Table 5-2). Construction methods with clinker pavers for carriageways can be used for Construction classes Bk3.2, Bk1.8, Bk1.0 and Bk0.3. The construction methods with paving for cycle- and pedestrian paths are listed in Chart 7 of RStO (Table 5-3).

Selection of the most technically and economically expedient construction method for the respective construction project can be based on the following aspects:

- locally available construction materials,
- regional experience,
- capability and competence of the construction firms that may be contracted,
- expected load situation.

Stage 4: Determining the course thicknesses

For the selected construction method, the course thicknesses are specified in the corresponding fields of Tables 5-2 and 5-3. RStO takes 10 cm as the nominal thickness of the clinker pavers for Construction classes Bk3.2 and Bk1.8 and 8 cm as the nominal thickness for Construction classes Bk1.0 and Bk0.3 as well as for cycle and pedestrian paths. For carriageways of Construction classes Bk3.2 to Bk0.3, clinker pavers with greater thickness can be used (if required for on-edge laying). Smaller thicknesses, although not below 6 cm, can be used in conjunction with correspondingly proven regional construction methods providing sufficient positive experience is available in this respect. For cycle and pedestrian paths or corresponding private area surfacing, clinker pavers with a lower thickness than 6 cm, e.g. 45 to 52 mm, can be used, providing sufficiently positive experience is available with these.

The values for the thickness of the frost-resistant superstructure contained in Charts 3 and 6 of RStO (Tables 5-2 and 5-3) should be used for a frost-susceptible subgrade/substructure (F2 or F3 soil). The defined thickness of the frost-resistant superstructure must be complied with even with the use of clinker pavers that deviate from the regular thickness. It is necessary to compensate for the deviation by changing the thickness of the frost blanket or the course of frost-unsusceptible material. The thickness of the frost blanket results from the defined dimension for the frost-resistant superstructure less the course thicknesses of the paving, the bedding, and the specified thickness of the base course. For reasons concerning the load-bearing capacity, it is necessary to comply with the minimum thicknesses for the frost blanket specified in Table A 1-15.

If a frost-resistant soil (F1 soil) is available in a sufficient thickness as the subgrade/substructure, no frost blanket is necessary. Often, however, for reasons concerning the load-bearing capacity, a base course should be prescribed instead of the frost blanket. For determination of the thickness of the base course, Table 8 of RStO can be used as a guide (in this context, see Table A1-15).

Stage 5: Minimum values for the load-bearing capacity on the courses without binders

For the subsoil and the individual base courses without binders, the minimum values for the load-bearing capacity (static deformation modulus Ev2 in MPa) are specified in Tables 5-2 and 5-3. These are recommendations. For installation, the requirements specified in ZTV E-StB, ZTV SoB-StB and ZTV Pflaster-StB apply.

If ZTV SoB-StB are agreed in the construction contract, on crushed rock base courses with a thickness of at least 20 cm and gravel base courses from a thickness of at least 25 cm (providing a frost blanket course with $E_{v2} \geq 120$ MPa is installed below), a static deformation modulus E_{v2} of ≥ 180 MPa should be achieved (cf. ZTV SoB-StB, Section 2.3.4.2). This applies irrespective of the recommendations in RStO 12. It is, however, imperative to ensure that the necessary water permeability is not endangered by excessive compaction. For this reason, a test installation on construction-site scale is recommended. If the required E_{v2} values are not achieved, more suitable aggregate blends for the crushed rock or gravel base course should be used.

5.6.2 Supplementary notes for special types of surfacing

5.6.2.1 Trafficked surfaces in track areas

Traffic areas in track areas are areas trafficked jointly by track and road vehicles. For these paving areas, at least the same total thickness of superstructure as that of the adjoining road should be chosen. Details on this construction method are contained in the "Code for the construction of traffic areas in track installations of tramways".

5.6.2.2 Agricultural tracks and other agricultural areas

Basis for the construction of tracks for agricultural traffic are:

- RLW – Directives for rural track construction
- ZTV-LW – Additional technical contract terms and directives for paving of rural tracks
- ZTV Pflaster-StB – Additional technical contract terms and directives for production of paving, slab surfaces . and kerbs

Areas at junctions to higher-level roads should be dimensioned like these.

On account of the high acid resistance of clinker pavers, these are frequently used for surfacing agricultural stables/sheds and silo floors. The superstructure can be dimensioned with allowance for the load on these surfaces on the basis of RLW or RStO.

5.6.2.3 Construction methods with drainage clinker pavers

Permeable traffic area surfacing with drainage pavers are suitable for carriageways, parking areas and low-traffic residential or supply roads of Construction class Bk0.3 in accordance with RStO. These include low-load traffic areas in agriculture areas, lay-bys, and traffic-calmed zones. Further information is available in the "Code of practice for permeable traffic areas (M VV)".

Determination of the thickness of the frost-resistant superstructure can – derived from RStO – be performed according to a simplified procedure based on the following tables. Factors considered here are whether the subgrade consists of a frost-resistant (F1) soil, a low-to-medium frost-susceptible soil (F2) or a highly frost-susceptible soil (F3) in accordance with ZTV E-StB. Guide values for the required superstructure thickness for water-permeable traffic areas with drainage pavers or lawn clinker pavers in the case of frost-resistant and water-permeable subgrade (F1 subgrade/substructure) can be found in Table 5-4.

If the subgrade/substructure consists of a low/medium to highly frost-susceptible soil of the frost susceptibility classes F2 or F3, dimensioning and design should always be conducted as for an F3 soil. In addition, unfavourable water conditions and drainage by infiltration must be taken into account in the determination of the thickness of the frost-resistant superstructure. Moreover, an additional thickness may have to be included owing to the gradient (for traffic areas in the cutting or face) or other unfavourable microclimatic influences. Accordingly, for frost-susceptible soils of the frost susceptibility classes F2 and F3, the minimum thickness of the frost-resistant (water-permeable) superstructure results within the ranges listed in Table 5-5.

Subgrade with sufficient water permeability:		**Necessary superstructure thickness for**	
Frost susceptibility class	**Type of base course**	**Carriageways of Construction class Bk0.3** (RStO-Chart 3, Line 3)	**Cycle and pedestrian paths** (RStO-Chart 6, Line 2)
F1	Crushed rock base course	40 cm	30 cm
F1	Gravel base course	50 cm	30 cm

Table 5-4: **Guide values for the necessary superstructure thickness for water-permeable traffic area surfacing with drainage paving or lawn clinker pavers in the case of frost-resistant and water-permeable subgrade (F1 subgrade/substructure)**

Greenable surfacing with perforated lawn clinker pavers

Subgrade:		**Thickness range of the frost-resistant superstructure for**			
Frost susceptibility class	**Frost-**	**Carriageways of the Construction class Bk0.3** (RStO-Chart 3, Line 3)		**Cycle and pedestrian paths** (RStO-Chart 6, Line 2)	
		min.	max.	min.	max.
F2 or F3	I and II	60 cm	70 cm	40 cm	50 cm
F2 or F3	III	70 cm	80 cm	50 cm	60 cm

Table 5-5: **Thickness ranges of the frost-resistant superstructure for water-permeable traffic area surfacing with drainage or lawn clinker pavers for frost-sensitive soils (F2 and F3 soils)**

5.6.3 Dimensioning of the superstructure for private, irregularly trafficked surfaces

In August 2013, the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e. V. (FLL Research Society for Landscape Development and Landscaping) the "Additional Technical Specifications for the Construction of Paths and Squares outside Road Traffic Areas (ZTV Wegebau)". These have been specially developed for surfaces subject to low loads, and their construction-related requirements consciously compiled to be less stringent than the Technical Regulations for Road Construction. Their use is specifically designed for the landscaping of privately used surfaces. Here surfaces are basically classed in three usage categories.

Usage category N 1

This covers walk-on surfacing that cannot be trafficked by motor vehicles outside of road traffic areas (e.g. patios, garden paths, paths in the vicinity of houses/gardens, seating areas in parks).

Usage category N 2

This covers trafficked surfacing for vehicles up to 3.5 t permissible total weight outside of road traffic areas (e.g. garage approaches, car parking spaces).

Usage category N 3

This covers trafficable surfacing subject to a load like N 2, however, with occasional trafficking by vehicles with up to 20-t permissible total weight with wheel loads up to 5 t outside road traffic surfaces (e.g. care, maintenance and rescue routes as well as fire brigade, garage and building access roads).

Assignment to the usage categories requires an accurate estimation of the prevailing vehicle loads during the service lifetime of the surfacing. In this context, especially furniture, delivery and waste disposal vehicles and vehicles/equipment with supporting lugs must be taken into account as even if the assumed load is only exceeded once, this can cause damage to the surfacing.

Corresponding to the usage categories, ZTV Wegebau specifies the minimum thicknesses for the frost-resistant superstructure listed in Table 5-6.

No.	Subsoil frost susceptibility class in accordance with ZTV E-StB 1	Minimum thickness [1] cm 2	Increase thicknesses for frost action zones according to RStO cm 3
	Usage category N 1		
1	F1	27	Zone II: + 5 Zone III: +15
2	F2	30	
3	F3	30	
	Usage category N 2		
4	F1	30	Zone II: + 5 Zone III: +15
5	F2	40	
6	F3	50	
	Usage category N 3 [2]		
7	F1	32	Zone II: + 5 Zone III: +15
8	F2	40	
9	F3	50	

[1] With the use of gravel base courses or frost blankets as the top base course, the thickness of the top base course should be increased by 5 cm.
[2] In the case of Usage category N 3, the use of a frost blanket as the top base course is not permissible.

Table 5-6: **Minimum thicknesses of the frost-resistant superstructure for surfacing outside of road traffic areas in accordance with ZTV Wegebau**

Static plate load test to determine the deformability and load-bearing capacity of the soil

5.7 Planning and installation of the surfacing

In the specification of the standardized construction in the charts of RStO, three requirements are taken as a basis

- Frost protection,
- Sufficient load-bearing capacity,
- Resistance to deformation (stability) during the planned service lifetime for the assumed traffic load.

For paving, as surface water penetrates into the joints at least at some times during the lifetime, all courses must

- exhibit sufficient water permeability in combination with the necessary resistance to erosion.

5.7.1 Subgrade/substructure

To withstand traffic loads, especially, however, to install and compact the base course, the subgrade/substructure must exhibit sufficient load-bearing capacity and resistance to deformation. The subsoil may only be trafficked if no damaging displacement is caused that can impede water drainage.

5.7.1.1 Load-bearing capacity

For proof of sufficient load-bearing capacity of the subsoil, a static deformation modulus E_{v2} of at least 45 MPa must be proven with the help of the plate load test as specified in DIN 18134. If dynamic testing methods, like the dynamic plate load test, are to be used, then for each test field first calibration on the same soil is necessary relative to the plate load test as specified in DIN 18134. If the required load-bearing capacity is not achieved, then soil substitution or soil consolidation is necessary, which in turn requires suitable drainage of the subsoil.

5.7.1.2 Compaction

As a precondition for the required deformation resistance of the subgrade/substructure, the existing or installed soil must exhibit the compaction levels listed in Table 5-7.

Other information can be found in the "Code of practice for the compaction of the subgrade and substructure in road construction".

	Area	Soil group in accordance with DIN 18196	Compaction level D_{Pr} [%]
1	Subsoil to 1.0 m depth in embankments and 0.5 m depth in cuttings	GW, GI, GE SW, SI, SE GU, GT, SU, ST	100
2	1.0 m below subsoil to fill base	GW, GI, GE SW, SI, SE GU, GT, SU, ST	98
3	Subsoil to fill base and to 0.5 m depth in cuttings	GU*, GT*, SU*, ST* U, T, OU[1], OT[1]	97

[1] For soils in the groups OU and OT, the requirements only apply when their suitability and installation conditions are specifically tested and specified in consultation with the client.

Table 5-7: **Requirement for the 10% minimum quantile for the compaction level DPr in accordance with ZTV E-StB**

5.7.1.3 Planeness and required profile

The subsoil must be produced with the required profile, planeness and load-bearing capacity. In accordance with ZTV E StB, the deviation of the subsoil from the set height should not total more than ± 3 cm if a course without binders is installed above it. The transverse slope of the subsoil should correspond to the transverse slope of the paving, but amount to at least 2.5 %. Only if the subgrade/substructure consists of a water-susceptible soil, then deviating from the above, the subsoil should be prepared with a transverse slope of at least 4.0 %.

5.7.1.4 Water permeability

The subgrade/substructure must exhibit sufficient water permeability to allow the water penetrating through the joints and base courses to pass through to the soil. To date, no required values have been defined in the regulations. Subgrade/substructure can generally be regarded as sufficiently water-permeable if the subgrade/substructure installed in compliance with requirements has an infiltration coefficient of ki ≥1·10-5 m/s. For the water-permeable paving, the infiltration coefficient ki should be at least 3·10-5 m/s. This can be verified with the quick test according to the "Code of practice for traffic surfaces (M VV)". If the subgrade/substructure has an infiltration coefficient between 1·10-6 m/s and 1·10-5 m/s, the thickness of the frost blanket must be increased by at least 10 cm for reasons concerning load-bearing capacity. If the subgrade/substructure has an infiltration coefficient below 1·10-6 m/s or if rising water or the ingress of the water from the side can be expected, then drainage of the subsoil must be arranged.

5.7.2 Base courses without binders

The term base courses refer to all courses in the superstructure below the actual paving. The purpose of the base courses is to distribute the loads input from the paving over the relevant area and to dissipate these loads into the subgrade. Base courses therefore have to exhibit sufficient load-bearing capacity to meet requirements and sufficient resistance to frost and deformation. The base courses used under the paving must also be permanently water-permeable to drain off any surface water that has seeped into paving to the subgrade/substructure.

For paving, mainly base courses without binders are used. On areas where, on account of the traffic load, the base courses must meet high requirements with regard to deformation resistance, often drainage concrete or water-permeable asphalt base courses are installed. For surfacing with clinker paving, predominantly base courses without binders are used. The requirements to be met by these courses and notes on their installation are compiled below. Information on drainage concrete courses can be found in the "Code of practice for drainage concrete bases courses" (M-DBT). Water-permeable asphalt base courses are designed according to the "Code of practice for water-permeable surfacings of traffic areas" (M VV).

5.7.2.1 Requirements for base courses without binders

The requirements for soils or aggregates used for the construction of base courses without binders can be found in the "Technical terms of delivery for soils and aggregate mixes for the construction of courses without binders in road construction" (TL SoB-StB). For the aggregates used in these, the requirements of the "Technical terms of delivery for aggregates in road construction" (TL-Gestein StB) also apply in respect of the material composition, the grain size distribution, the grain shape, the fines content, resistance to fragmentation and frost resistance. The properties of the aggregates as well as the required categories (minimum values) are compiled in tabular form in Annex E of TL Gestein-StB.

Base courses without binders in accordance with TL SoB-StB and ZTV SoB-StB are on the one hand "courses consisting of frost-unsusceptible material" and "frost blanket courses" in accordance with Section 2.2 of these regulations and "crushed rock base courses" (CRBC) and "gravel base courses" ´(GBC) in accordance with Section 2.3 of ZTV SoB-StB and TL SoB-StB.

An acceptable water permeability of the base courses without binders is given providing the infiltration coefficient ki measured on these courses after installation is $\geq 10^{-5}$ m/s. It is recommended that the infiltration coefficient is checked *in situ* after installation of the respective course with the methods specified in TP Gestein, Part 8.3.2 (Modified Pipe Infiltrometer), Part 8.3.3 (Drop Infiltrometer) or Part 8.3.4 (Double-Ring Infiltrometer). For qualitative estimation of the infiltration rate, the quick test according to the "Code of practice for water-permeable traffic areas" (M VV) can be conducted on the base course prepared in line with requirements. It is recommended that a requirement and test method be agreed in the construction contract.

Instead of the use of natural aggregate, the use of aggregate prepared from recycled construction materials or other industrial by-products is often considered. Water rising up from the base courses to the surface of the clinker paving, where it evaporates, can cause efflorescence on the clinker pavers if recycled construction materials or industrial by-products are used. If recycled construction materials or industrial by-products are to be used under clinker paving, these should be subject to quality control in accordance with TL G SoB-StB. The requirements of TL SoB-StB and ZTV SoB-StB apply in full also for the use of recycled construction materials and industrial by-products. The "Directives for environmental-compatible use of the industrial by-produces and recycled construction materials in road construction" (RuA-StB)" must also be taken into account. In addition, the producer should declare that their use under clinker paving is acceptable and cannot lead to efflorescence.

5.7.2.2 Courses of frost-unsusceptible material (FUSM) and frost blankets (FB)

Courses of frost-insusceptible (FUSM) are used exclusively to increase the thickness of the superstructure in order to achieve the planned thickness of the frost-resistant superstructure. An increase in the load-bearing capacity, starting from the subsoil, is not the objective of these courses. For their construction, frost-resistant soils of the soil groups GE, GW, GI, SE, SW and SI as specified in DIN 18196 are used. In contrast to courses of frost-unsusceptible material, with frost blankets (FB) the objective is also an increase in the load-bearing capacity starting from subsoil. For this reason, the surface of a frost blanket must be proven to reach a minimum value for the static deformation modulus E_{v2} in a plate load test as specified in DIN 18134. Frost blankets are constructed with frost-unsusceptible aggregates and/or soils. Aggregates in the grain sizes 0/2, 0/4, 0/5, 0/8, 0/11, 0/16, 0/22, 0/32, 0/45, 0/56 and 0/63 are used, in the upper 20 cm of the frost blanket the nominal maximum size of the grains having to measure at least 8 mm. Requirements for the grain distribution curves are specified in TL SoB-StB and ZTV SoB-StB. In accordance with TL SoB StB, the fines content (grain sizes smaller than 0.063 mm) in the as-delivered material should not exceed a maximum of 5 mass%. In the installed state (with allowance for the grains becoming finer during installation), a maximum fines content of 7 mass% is permissible. The minimum installation thickness of each course or layer is specified in ZTV SoB-StB as a function of the nominal maximum grain size of the aggregate. After the installation of the course, it is necessary to verify that it has the required profile and planeness and meets the requirements for the compaction level and the static deformation modulus (only on the surface of FBs).

a) Load-bearing capacity

To prove the load-bearing capacity, the static deformation modulus E_{v2} must be determined with the plate load test as specified in DIN 18134. The values for the static deformation modulus E_{v2} listed in Table 5-8 must be met.

b) Compaction

The frost blanket or course of frost-unsusceptible material should be compacted so at least the compaction level D_{Pr} in Table 5-9 is achieved.

If instead of a compaction test, an alternative assessment of the compaction quality is to be performed based on the results of the plate load test, then according to ZTV SoB-StB, the following applies:

"The ratio value of the compaction moduli E_{v2}/E_{v1} should not be larger than 2.2 if a compaction level D_{Pr} > 103 % is prescribed. If a compaction level D_{Pr} under 103% is required, the ratio value E_{v2}/E_{v1} should not be larger than 2.5. Higher ratio values E_{v2}/E_{v1} than 2.2 or 2.5 are permissible if the E_{v1} value is at least 0.6 times the required E_{v2} value."

c) Planeness and required profile

The frost blanket should have sufficient planeness and the required profile to ensure that the material required for the overlying base course is sensibly limited. According to DIN 18315, deviation from planeness under a 4-m measuring bar (4-m measurement section) may not be higher than 3 cm on the surface of a frost blanket. The required profile is given in accordance with ZTV SoB-StB providing the deviation of the surface of the frost blanket from the set height is not more than ± 2.0 cm.

On the surface of the frost blanket, starting from a static deformation modulus on the subsoil of $E_{v2} \geq 45$ MPa

in Construction classes Bk3.2, Bk1.8 and Bk1.0: **$E_{v2} \geq 120$ MPa ($E_{v2} \geq 100$ MPa)[1]**
in Construction classes Bk0.3I: **$E_{v2} \geq 100$ MPa ($E_{v2} \geq 80$ MPa)[2]**

The requirements do not apply for courses consisting of frost-unsusceptible material.

[1] If as a result of the compaction of the overlying base course, an E_{v2} value of ≥ 120 MPa can be subsequently obtained, an E_{v2} value of ≥ 100 MPa can be included in the performance specifications for the frost blanket.
[2] If as a result of the compaction of the overlying base course, an E_{v2} value of ≥ 100 MPa can subsequently be obtained, an E_{v2} value of ≥ 80 MPa can be included in the performance specifications for the frost blanket.

Table 5-8: **Minimum values for the static deformation modulus on frost blankets in accordance with ZTV SoB-StB**

			Compaction level D_{Pr} in %	
No.	**Areas**	**Construction material mixes and soils [1] in accordance with ZTV SoB-StB, Section 2.2.2**	**Construction classes Bk3.2 to Bk0.3**	**At B < 100.000 [2], cycle and pedestrian paths, other traffic areas**
1	Surface of frost blanket to 0.2 m depth	0/8 to 0/63 and soils GW and GI	103	100
2	Frost blanket below Area No. 1 and course of frost-unsusceptible material	All construction material mixes and soils of Area No. 1 as well as SE, SW, SI, GE and aggregate grades 0/2 and 0/4	100	

[1] Soil groups in accordance with DIN 18196
[2] Dimensioning-related action effect B according to RStO 12

Table 5-9: **Minimum requirements for the compaction level D_{Pr} of construction material mixes and soils in the frost blanket or course of frost-unsusceptible material based on ZTV SoB-StB**

5.6.2.3 Gravel (GBC) and crushed rock (CRBC) base course

Construction material mixes for gravel and crushed stone base courses are extracted at gravel pits and quarries by means of mechanical mineral processing and selectively mixed from different grades to obtain a specific grain composition. The construction material mixes 0/32, 0/45 and 0/56 are produced. However, to avoid excess segregation and to ensure the necessary filter stability, only the mixes 0/32 and 0/45 should be used as bedding material for paving.

The grain distribution curves of the construction materials mixes have to be within the grading curve ranges specified in TL SoB-StB and ZTV SoB-StB. To ensure sufficient water permeability and frost resistance, contrary to ZTV SoB-StB, the fines content (grain diameter < 0.063 mm) after installation should not exceed 5 mass% (instead of 7 mass%). Recommended are mixes of natural aggregates with a grading curve near lower-limit grading curve of the grading curve ranges specified in TL SoB-StB and ZTV SoB-StB. The coefficient of uniformity of the mixture should be CU ≥ 13.

To avoid grain fragmentation and grain refinement during installation, the aggregates should exhibit high resistance to fragmentation. They should correspond to at least category SZ_{22}/LA_{25}.

Of particular importance for good installation and compaction of the aggregates as well as to avoid segregation is compliance with the specified installation water content (see "Code of practice for production of base and surface courses without binders"). The aggregates must therefore be uniformly wetted and mixed in the production plant. At the construction site, they may need to be protected against drying out and carefully installed and compacted to avoid segregation. Segregation occurs during transport and tipping processes, so the number of these processes should be minimized.

The material must be distributed in line with the required profile and then compacted quickly, without any long work interruptions. Type and number of required installation units should be planned and kept ready on hand. The gravel and crushed rock base courses should, if possible, always be installed with road finishers to achieve the required quality of the base courses. In public traffic areas, the preferred area of application for paving, road finishers cannot be used on account of numerous installations and

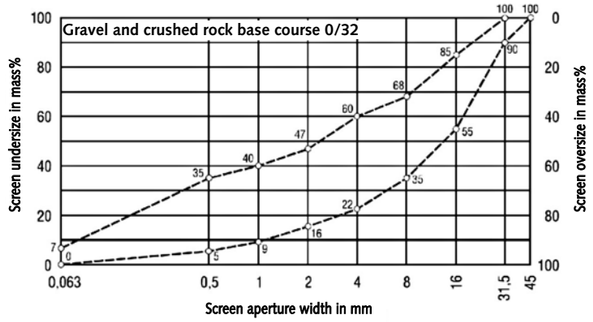


Fig. 5-5: **Screening curve range for gravel and crushed rock base courses 0/32 after installation in accordance with ZTV SoB-StB**

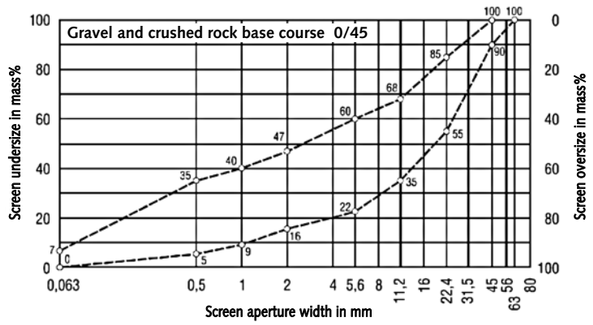


Fig. 5-6: **Screening curve range for gravel and crushed rock base course 0/45 after installation in accordance with ZTV SoB-StB**

frequently changing cross-sectional widths. Here installation with graders or dozers is one option. This, however, requires experience and particular care during installation.

When delivering the base course material, the vehicles used may not cause any deformation to the subsoil in the form of tracks or depressions. If the load-bearing capacity of the prepared subsoil is low, end-tipping of the base course material is necessary. Further information on installation can be found in the "Code of practice for the production of base and surface courses without binders".

Following installation of the course, the installation thickness, the planeness, the required profile, the degree of compaction and the static deformation must be assessed:

a) Load-bearing capacity

To provide proof of the load-bearing capacity, the static deformation modulus E_{v2} must be determined with the plate load test as specified in DIN 18134. The test results must comply with the values given in Table 5-10 for the static deformation modulus E_{v2}.

In accordance with ZTV Pflaster-StB, for traffic area surfacing in Construction classes Bk3.2 to Bk1.0, the upper base course without binders should exhibit a static deformation modulus of $E_{v2} \geq 180$ MPa. With regard to the necessary water permeability of the base course, with the help of a test installation, it is necessary to verify whether the requirements for the load-bearing capacity and for the water permeability can both be met equally. If necessary, a different construction material mix should be used. If there is positive regional experience with crushed rock base courses on which a static deformation modulus of just $E_{v2} \geq 150$ MPa has been proven in Construction class Bk3.2, then according to RStO, it is permissible to continue using this method of construction.

On the surface of the base course, starting from a static deformation modulus on the frost protection course of $E_{v2} \geq 120$ MPa	
Gravel base course in Construction classes Bk3.2 to Bk1.0 Thickness ≥ 20 cm: $E_{v2} \geq 150$ MPa Thickness ≥ 25 cm: $E_{v2} \geq 180$ MPa	**Crushed rock base course** in Construction classes Bk3.2 to Bk1.0 Thickness ≥ 15 cm: $E_{v2} \geq 150$ MPa Thickness ≥ 20 cm: $E_{v2} \geq 180$ MPa
On the surface of the base course, starting from a static deformation modulus on the frost protection course of $E_{v2} \geq 100$ MPa	
Gravel base course in Construction class Bk0,3 Thickness ≥ 20 cm: $E_{v2} \geq 120$ MPa Thickness ≥ 25 cm: $E_{v2} \geq 150$ MPa	**Crushed rock base course** in Construction class Bk0,3 Thickness > 15 cm: $E_{v2} \geq 120$ MPa Thickness > 20 cm: $E_{v2} \geq 150$ MPa
On gravel or crushed rock base courses installed directly on the subsoil with $E_{v2} \geq 45$ MPa: in Construction classes Bk3.2 to Bk1.0: $E_{v2} \geq 150$ MPa in Construction class Bk0.3: $E_{v2} \geq 120$ MPa for cycle and pedestrian paths: $E_{v2} \geq 80$ MPa	

Table 5-10: **Minimum values for the static deformation modulus on gravel and crushed rock base courses in accordance with ZTV SoB-StB**

b) Compaction

For gravel or crushed stone base courses, a degree of compaction D_{Pr} of at least 103 % is required. Exceptions are traffic areas with numerous installations (shafts, gates, etc.) that prevent compaction. Here only a degree of compaction of at least 100 % is required. If instead of the determination of the degree of compaction, the ratio E_{v2}/E_{v1} from the results of the plate loading test is used as indirect characterization of the compaction state, the citation from ZTV SoB-StB under "Frost protection courses" applies equally.

c) Planeness and required profile

According to ZTV SoB-StB, the planeness of the surface of gravel or crushed rock base courses may only deviate by a maximum of 2 cm within a 4-m-long measured section. To ensure uniform bed thickness, it is recommended that the upper base course should meet a higher planeness requirement and the permissible deviations be limited to ≤ 1.0 cm within a ≤ 4-m measuring section.

The required profile is given according to ZTV SoB-StB providing the deviations of the surface of the base courses total no more than ± 2.0 cm from the set height.

d) Installation thickness

Each compacted course or layer should exhibit the minimum thickness specified in ZTV SoB-StB as a function of the nominal maximum grain size of the base course material. According to ZTV SoB-StB, the mean values of the measured installation thicknesses calculated for the contract section may not be more than 10 % lower than the values specified in the construction contract. The individual values for the installation thickness should be no more than 3.5 cm lower than the agreed value.

5.7.3 Paving

The paving consists of the clinker pavers, bedding and joint filling. The requirements for clinker paving, bedding and jointing materials are specified in ATV DIN 18 318 and TL Pflaster-StB. Specifications in respect of the installation of the paving surfaces and slab surfacing and requirements for the quality of the installation work are contained in ZTV Pflaster-StB supplementary to DIN 18318.

Prior to starting construction of the paving, it is necessary to assess whether the underlying base meets the requirements of the Technical Regulations in respect of the

- load-bearing capacity,
- quality of compaction,
- water permeability,
- the planned height, slope and planeness.

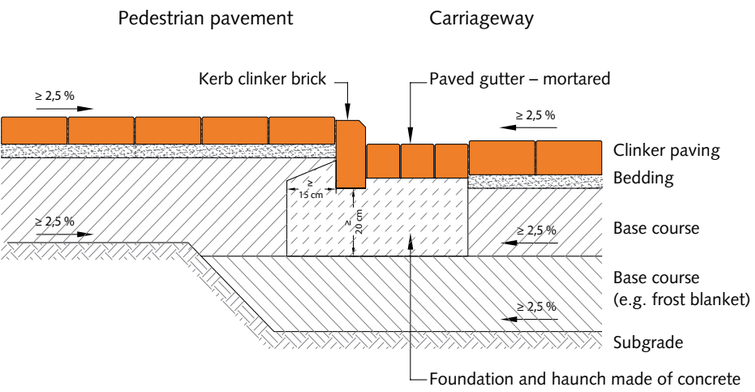


Fig. 5-7: **Edging with high kerb with a three-row drainage gutter**

5.7.3.1 Bedding

In the standard construction method as specified in DIN 18318 and ZTV Pflaster-StB, unbound aggregates in the grades 0/4, 0/5 or 0/8 are used as bedding material. Requirements for the bedding material are described in TL Pflaster-StB and ZTV Pflaster-StB [3]. In Fig. 5-7, by way of example, the specifications for a bedding material 0/5 for paving for a defined load are summarized. The product datasheet, which can be used as a basis for a description in the specifications, makes provision for the requirements and recommendations of TL Gestein-StB, TL Pflaster-StB and ZTV Pflaster-StB.

The purpose of the bedding is to compensate for dimensional tolerances in the thickness of the clinker pavers. During the service lifetime, the loads introduced into the surfacing must be dissipated into the substrate with sufficient resistance against deformation.

Aggregate grades that are to be used as bedding material must always have the following properties:

- Homogeneous mixing to avoid grain displacement
- Good compactibility to even out thickness tolerances of clinker pavers
- Sufficient water permeability, also in compacted condition, by means of coordinated grain size distribution
- Sufficient strength (e.g. hard rock, like diabase, basalt)

Aggregates with latent hydraulic properties should only be used if sufficiently positive experience with these is available, especially over a longer period with comparable load.

As a bedding material for traffic surfaces of Construction classes Bk3.2 to Bk1.0 aggregate mixes should be used with a flow coefficient corresponding to category $E_{CS}35$ (cf. TL Pflaster-StB). The content of broken surfaces results according to category $C_{90/3}$ (cf. TL Gestein-StB). The above requirements are generally fulfilled only by crushed aggregates. The rocks should exhibit an impact fragmentation resistance of the category SZ_{22} (impact fragmentation resistance value) or LA_{25} (Los Angeles value). Recommended are crushed hard rock (e.g. basalt chippings), which after vibration of the clinker paving demonstrate high position stability and are not pulverized by the traffic load. Limestone with its weaker grains cannot be recommended as bedding material with increased traffic load as the grains can be easily ground down.

For traffic surfaces subject to special loads as well as generally for Construction class Bk3.2, increased requirements should be specified for the impact fragmentation resistance of the bedding material, e.g. category SZ_{18} or LA_{20}.

For traffic surfaces of Construction class Bk0.3 as well as for paths and other surfaces, round-grained aggregates can be used as alternative bedding material.

The bedding materials used for traffic surfaces of Construction classes Bk3.2 to Bk0.3 must also meet the following requirements of TL Pflaster-StB for the grain size distribution curve:

- **Bedding material 0/4 and 0/5**
  (TL Pflaster-StB, Table 4, Line 1, Category $G_{U,B}$):
  Screen undersize 30 to 60 mass% at an aperture width of 2 mm,
- **Bedding material 0/8**
  (TL Pflaster-StB, Table 5, Line 1, Category G_U):
  Screen undersize 30 to 75 mass% at an aperture width of 2 mm and 50 to 90 mass% at an aperture width of 4 mm.

It is recommended that these requirements are also specified for bedding material used for traffic surfaces with lower loads.

PRODUKTDATENBLATT ***Bettungsmaterial B0/8G***	Sorten-Nr. .....
Baustoffgemisch aus gebrochenen Gesteinskörnungen für Pflasterdecken und Plattenbeläge in ungebundener Ausführung gemäß den TL Pflaster-StB und den ZTV Pflaster-StB **Gesteinsart** ..... (Hüttensand (HS) und Hochofenstückschlacke (HOS) dürfen gemäß den TL Pflaster-StB 06, Abschn. 2, nur in geeignetem Gemisch mit natürlichen Gesteinskörnungen eingesetzt werden)	

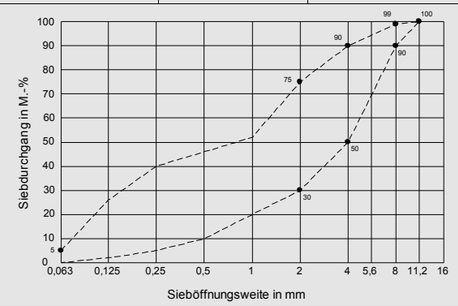
Anwendungsbereich
Pflasterdecken bis einschließlich Belastungsklasse Bk3,2 gemäß den „RStO 12“ und Plattenbeläge

Gesteinsspezifische Eigenschaften[1]			
Kornform grober Gesteinskörnungen	Kornformkennzahl ≤ 50 bzw. Plattigkeitskennzahl ≤ 50	Kategorie SI_{50} bzw. Kategorie FI_{50}	TL Gestein-StB 04, Fassung 2007, Anhang H
Schlagzertrümmerungswert bzw. Los Angeles Koeffizient	Soll: ≤ 26[2] Ist:	Soll-Kategorie SZ_{26}[2] Ist-Kategorie	TL Gestein-StB 04, Fassung 2007, Anhang H
	Soll: ≤ 30[2] Ist:	Soll-Kategorie LA_{30}[2] Ist-Kategorie	TL Gestein-StB 04, Fassung 2007, Anhang H

[1] Alle hier nicht aufgeführten gesteinsspezifischen Eigenschaften gemäß den TL Gestein-StB 04, Fassung 2007, Anhang H, werden ebenfalls eingehalten.
[2] Gesteine, die zur Herstellung von Bettungsmaterial für Pflasterdecken der Belastungsklasse Bk1,0 oder höher (RStO 12) verwendet werden, sollten mindestens der Kategorie SZ_{22} (LA_{25}) entsprechen. Bei Pflasterdecken mit besonderen Beanspruchungen gemäß den „RStO 12“ oder solchen mit einer Tragschicht mit Bindemittel mindestens SZ_{18} (LA_{20}) (ZTV Pflaster-StB 06, 1.5.1.1).

Gemischspezifische Eigenschaften			
Anteil gebrochener Oberflächen	Anteil vollständig gebrochener und teilweise gebrochener Körner 90-100 M.-%; Anteil vollständig gerundeter Körner 0-3 M.-%	Kategorie $C_{90/3}$	ZTV Pflaster-StB 06, 1.5.1.1
Fließkoeffizient	≥ 35	Kategorie $E_{CS}35$	ZTV Pflaster-StB 06, 1.5.1.1
max. Feinanteil	Durchgang 0,063 mm ≤ 5 M.-%	Kategorie UF_5	TL Pflaster-StB 06, 3.2.2
min. Feinanteil	keine Anforderung	Kategorie LF_{NR}	TL Pflaster-StB 06, 3.2.2
Überkornanteil	Durchgang bei 2 D 100 M.-% Durchgang bei 1,4 D 100 M.-% Durchgang bei D 90-99 M.-%	Kategorie OC_{90}	TL Pflaster-StB 06, 3.2.3

Die Kornzusammensetzung des Baustoffgemisches liegt innerhalb des nebenstehenden Sieblinienbereiches.
(Siebdurchgänge mit Wertangabe gemäß den TL Pflaster-StB 06, 3.2.2, 3.2.3 und 3.2.4, Tabelle 5, Zeile 1, Kategorie G_U.
Siebdurchgänge ohne Wertangabe in Anlehnung an die Empfehlungen der Herausgeber.)



Das Baustoffgemisch wird gleichmäßig durchfeuchtet und gleichmäßig gemischt ausgeliefert (TL Pflaster-StB 06, 3.1)

Fig. 5-8: **Example of a product datasheet for bedding material (here: bedding material B 0/8 G consisting of crushed rock)**

The requirements for bedding materials for paving surfaces have been compiled in clearly arranged product datasheets. These can be viewed on the internet at Arbeitsgemeinschaft Pflasterklinker e.V.: **www.pflasterklinker.de/datenblaetter**

Of considerable importance is sufficient water permeability of the bedding material in the compacted state and above all filter stability to the base course without binders under the bedding to avoid any erosion effects at the boundary between bedding and base course without binder. Filter stability can be proven based on the grain distribution curves of bedding and base course material. Filter stability is deemed as given providing the following conditions are met:

$D_{15}/d_{85} \leq 5$ Safety condition against erosion

$D_{50}/d_{50} \leq 25$ Safety condition against contact erosion (spacing of the grading curves)

where:

D_{15}, D_{50} Grain diameter [mm] of the base course material at 15 and 50 mass% screen undersize

d_{50}, d_{85} Grain diameter [mm] of the bedding material at 50 and 85 mass% screen undersize

The bedding material must be installed with the planned thickness plus a degree of compactibility (excess to offset the reduction in thickness as a result of subsequent compaction). The degree of compactibility depends on the type and size of the clinker pavers, the bedding material and its moisture content on installation. For machine-laid paving, pre-compaction of the bed prior to screeding is recommended.

The thickness of the bedding in the compacted state may measure 3 to max. 5 cm. The maximum thickness should not be exceeded in order to avoid any settling damage. According to ZTV Pflaster-StB, 1 cm below the minimum value is permissible (minimum thickness of the paving bed: 2 cm). Unevenness in the top base course should not be levelled out with bedding material.

Continuous areas should be laid with clinker pavers of the same thickness. Any differences in thickness (e.g. for rowlocks or crossing areas with higher paving thickness) must not be levelled out in the bedding, but in the base course.

Fig. 5-9: **Screeding of the bed surface using previously aligned metal rails**

Fig. 5-10: **Screeding of the bed surface using a screeding bar**

5.7.3.2 Paving course

Both the shape and the thickness of clinker pavers have a considerable influence on the stability and the service lifetime of the paving. The clinker pavers should therefore be selected depending on the expected traffic load and respective load category (see Section 5.2).

Clinker pavers for trafficked surfaces:

For traffic areas trafficked by freight vehicles, in Construction classes Bk1.0 und Bk0.3 specified in RStO 01, the standard thickness of the clinker pavers should measure 80 mm. Clinker pavers with a smaller thickness, although not smaller than 60 mm, can be used as an alternative according to RStO 01 providing sufficient experience is available with proven regional construction methods. Differences in thickness compared to the standard structure specified in RStO must be levelled out in the base courses.

In Construction classes Bk3.2 and Bk1.8, on account of the high traffic load, clinker pavers with a standard thickness of 100 mm are specified (see RStO). Alternatively, laying of the pavers in a rowlock (upright) course is possible to obtain a paver course thickness of 100 mm. In addition, paver bonds should be chosen that ensure a good load distribution. If high horizontal loads are expected (e.g. as a result of steering, braking or accelerating procedures at bus stops, in front of junctions or on areas with a high longitudinal slope or in turning areas), the pavers should, where possible, be laid in a diagonal or herringbone bond.

Clinker pavers for cycle and pedestrian paths:

As the standard thickness, in RStO 01, a paver thickness of 80 mm is also specified for cycle and pedestrian paths. Here, however, clinker pavers with a smaller thickness, e.g. thicknesses of 45 mm or 52 mm can be used providing sufficient positive experience is available with these. For crossing areas, like, for example, property access roads that are regularly trafficked by motor vehicles, the thickness of the clinker pavers or, in the case of on-edge laying, the thickness of the paver course must be matched to the traffic load.

Clinker pavers for private, non-trafficked areas:

Non-trafficked paved areas with low loads as found in private use can be surfaced with pavers with a smaller thickness. For paths around houses, patios and entrances, clinker pavers in thicknesses of for example 45 mm, 52 mm, 62 mm and 71 mm are suitable.

Already on delivery of the clinker pavers to the construction site, the customer/contractor should refer to the delivery note to check whether the consignment corresponds to the products ordered by inspecting the pavers and, if necessary, comparing them with sample pavers. If there are any reservations or doubts, then laying of the pavers should not be commenced. If pavers are delivered that deviate from the order, installation should only be commenced after the relevant issues have been resolved.

Clinker pavers are predominantly laid by hand, according to the planned pattern with uniform joints, on a bed screeded to the correct height. If no laying pattern has been planned or specified for a particular project, clinker pavers should be laid flat in rows or a stretcher bond (Fig. 4.6.1) with offset joints, the paver offset being at least ¼ of the paver length.

Fig. 5-11: **Laying of clinker pavers by hand**

Paving and slab coverings should be laid to the same height at the joints. The permissible offset from paver to paver at an even paver surface after vibration is 2 mm. Besides edging and installations, the joints must lie 3 to 5 mm above their surface, besides water-carrying gutters 3 to 10 mm above the gutter.

The pavers are laid from the already laid surface, pavers from several packs being mixed and then placed next to each other either flat or upright. Here it is necessary to ensure that the pavers are laid in the agreed bond. Straight joints lengthways or crossways must be checked regularly with line and angle. It is extremely important to maintain a minimum joint width of 3 mm in compliance with DIN 18318. If this minimum width is not maintained, the joints cannot be properly filled. If pavers touch each other, then already during vibration of the paving, the edges of the pavers can become chipped. The requirement for the maximum joint width of 5 mm specified in DIN 18318 should also be complied with. However, joint widths to 7 mm should be tolerated as, owing to the permissible dimensional tolerances of clinker pavers, otherwise regular, straight joints cannot always be obtained.

If the area to be paved is of sufficient size, machine laying of the pavers can be an economic alternative. The preconditions for machine laying, however, are that the clinker pavers have spacer nibs and the clinker pavers have been previously packed ready for machine laying. In the laying of pavers with a machine, one pallet layer

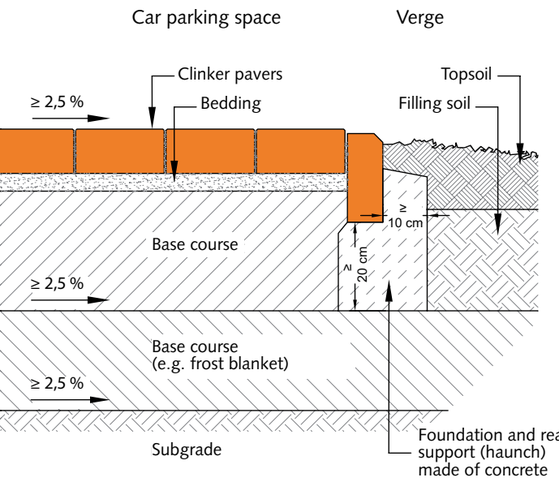


Fig. 5-13: **Edging with inverted kerb**

of pavers is gripped with the help of the laying clamp. Once clamped, the spacer nibs give a minimum distance of around 2 to 2.5 mm between the pavers. As a result of the release of the clamping force as the pavers are laid on the bed with the help of a special laying tool or release device, with which most modern laying machines are equipped, the pavers are placed down in an arc forming out of the clamp. This widens the joint width to the required size. The pavers should not, under any circumstances, be horizontally pushed closer together after laying, e.g. with the help of a mallet and a square timber. If necessary, the pavers should be aligned, often with the help of a straightening tool, to make the joint grid more uniform: This, however, should not result in the joints being made smaller than the minimum joint width.

During planning of clinker paver surfaces, where possible, the laying width should be coordinated with the grid dimension. The grid dimension is calculated from the nominal dimensions of the clinker paver plus the joint width. As for production reasons, the dimensions of clinker pavers can vary within the permissible tolerances, prior to installation the dimensions of the clinker pavers must be checked. After this, the grid dimension may need to be adjusted with allowance for the standard-compliant joint width.

In this way, unnecessary cutting at the edges can be avoided. If, however, it is necessary to cut adapter pavers, the shortest length of the adapter paver must measure

- at least one third of the largest edge length of the delivered clinker paver and
- at least half of the thickness of the delivered clinker paver

The pavers should be wet-cut.

Moreover, very sharp angled adapter pavers (with angles of less than 45°) should be avoided. Very small adapter pavers should also be avoided so as not to endanger the stability of the paving as these pavers often work loose after a short time. The number of adapter pavers should be minimized. To systematically pursue this aim, it may also be necessary to change the laying bond near junctions or connections although this may lead to unsatisfactory design solutions.

5.7.3.3 Compaction and joint filling
Jointing material

The standard method of construction in accordance with ZTV Pflaster-StB includes the use of unbound aggregate as jointing material, crushed, graded aggregate (formerly referred to as: crushed sand-chipping blends) being particularly suitable (cf. [3]). The maximum grain size must be coordinated to the joint width. The jointing material should sweep easily into the joints, but on the other hand exhibit high resistance to removal so that the joints remain as full as possible during later intensive cleaning.

ZTV Pflaster StB permits construction material mixes of the grades 0/4 mm, 0/5 mm. 0/8 mm and 0/11 mm as joint material. To ensure sweeping of all the jointing material into the joints and to avoid blocking of the joint openings with coarser grains, it is recommended to choose a maximum grain size that is not larger than the maximum joint width. So jointing materials of the grades 0/4 and 0/5 are generally used. In the case of interlocking clinker pavers, jointing materials 0/2 or 0/3 can be used.

Experience from construction practice shows that jointing materials 0/4 and 0/5 mm cannot generally be completely worked into the joints of regular width from 3 mm to 5 mm. Often, individual grains wedged at the top edge of the joints prevent a complete joint filling. In respect of a complete filling of the joints over the entire height of the joint, the use of a 0/3 jointing material should be considered as an alternative. This can be achieved, for example, with a mix of 0/2 and 1/3 aggregate.

The jointing material must have a minimum content of fines (grain diameter < 0.063 mm) of 2 mass% (category LF2). With regard to the frost resistance of the joint filling, the maximum fines content is defined in ZTV Pflaster-StB as 9 mass% (Category UF9).

For trafficked areas in accordance with Construction classes Bk0.3 to Bk3.2, jointing materials must be used that fulfil the requirements of TL Pflaster-StB in respect of their grain size distribution:

PRODUKTDATENBLATT ***Fugenmaterial F0/5G*** Sorten-Nr. .....

Baustoffgemisch aus gebrochenen Gesteinskörnungen für Pflasterdecken und Plattenbeläge in ungebundener Ausführung gemäß den TL Pflaster-StB und den ZTV Pflaster-StB

Gesteinsart .....
(Hüttensand (HS) und Hochofenstückschlacke (HOS) dürfen gemäß den TL Pflaster-StB 06, Abschn. 2, nur in geeignetem Gemisch mit natürlichen Gesteinskörnungen eingesetzt werden)

Anwendungsbereich

Pflasterdecken bis einschließlich Belastungsklasse Bk3,2 gemäß den „RStO 12" und Plattenbeläge

Gesteinsspezifische Eigenschaften[1)]

Kornform grober Gesteinskörnungen	Kornformkennzahl ≤ 50 bzw. Plattigkeitskennzahl ≤ 50	Kategorie SI_{50} bzw. Kategorie FI_{50}	TL Gestein-StB 04, Fassung 2007, Anhang H
Schlagzertrümmerungswert bzw. Los Angeles Koeffizient	Soll-Wert: ≤ 26 Ist-Wert:	Soll-Kategorie SZ_{26} Ist-Kategorie	TL Gestein-StB 04, Fassung 2007, Anhang H
	Soll-Wert: ≤ 30 Ist-Wert:	Soll-Kategorie LA_{30} Ist-Kategorie	TL Gestein-StB 04, Fassung 2007, Anhang H

[1)] Alle hier nicht aufgeführten gesteinsspezifischen Eigenschaften gemäß den TL Gestein-StB 04, Fassung 2007, Anhang H, werden ebenfalls eingehalten.

Gemischspezifische Eigenschaften

Anteil gebrochener Oberflächen	Anteil vollständig gebrochener und teilweise gebrochener Körner 90-100 M.-%; Anteil vollständig gerundeter Körner 0-3 M.-%	Kategorie $C_{90/3}$	ZTV Pflaster-StB 06, 1.5.1.2
Fließkoeffizient	≥ 35	Kategorie $E_{CS}35$	ZTV Pflaster-StB 06, 1.5.1.2
max. Feinanteil	Durchgang bei 0,063 mm ≤ 9 M.-%	Kategorie UF_9	TL Pflaster-StB 06, 3.3.2
min. Feinanteil	Durchgang bei 0,063 mm ≥ 2 M.-%	Kategorie LF_2	TL Pflaster-StB 06, 3.3.2
Überkornanteil	Durchgang bei 2 D 100 M.-% Durchgang bei 1,4 D 100 M.-% Durchgang bei D 90-99 M.-%	Kategorie OC_{90}	TL Pflaster-StB 06, 3.3.3

Die Kornzusammensetzung des Baustoffgemisches liegt innerhalb des nebenstehenden Sieblinienbereiches.

(Siebdurchgänge mit Wertangabe gemäß den TL Pflaster-StB 06, 3.3.2, 3.3.3 und 3.3.4, Tabelle 11, Zeile 1, Kategorie $G_{U,F}$.

Siebdurchgänge ohne Wertangabe in Anlehnung an die Empfehlungen des Merkblattes M FP 1.)

Das Baustoffgemisch wird gleichmäßig durchfeuchtet und gleichmäßig gemischt ausgeliefert (TL Pflaster-StB 06, 3.1)

Fig. 5-14: **Example of a product datasheet for jointing material (here: jointing material F 0/5 G consisting of crushed rock aggregate)**

- Jointing material 0/4 and 0/5 (TL Pflaster-StB, Table 11, Line 1): Screen undersize 30 to 75 mass% at an aperture width of 2 mm.
- For jointing materials 0/8 and 0/1, there are requirements for the screen undersize through the intermediate screens in accordance with Table 12 and 13 of TL Pflaster-StB.
- If a 0/2 jointing material is used, then in accordance with ZTV Pflaster-StB: Screen undersize 40 to 70 mass% at an aperture width of 1 mm.
- If a 0/3 jointing material is used, then in accordance with ZTV Pflaster-StB, screen undersize of 30 to 55 mass% must be complied with at an aperture width of 1 mm.

For traffic areas according to Construction classes Bk0.3 to Bk3.2, only construction material mixes should be used with a flow coefficient in the category ECS35 (cf. TL Pflaster-StB). The percentage of broken surfaces must correspond to category C90/3, that is the content of completely and partly broken grains must amount to between 90 and 100 mass%; the content of fully rounded grains may not exceed 3 mass% (cf. TL Gestein-StB). These requirements are generally only met by construction material mixes consisting of crushed aggregate.

Construction material mixes consisting of round-grained aggregate may not be used for traffic areas of Construction classes Bk0.3 to Bk3.2 according to ZTV Pflaster-StB. In some areas of the Federal Republic of Germany, however, only round-grained aggregates are regionally available. These can also be worked more easily into the joints than crushed aggregate, but they exhibit lower resistance to removal from the joints. If positive regional experience is available with the use of construction material mixes consisting of round-grained aggregate as jointing material, these can continue to be used. This, however, must be expressly included and agreed in the performance specifications. Even then, the jointing material should, however, have a maximum grain size of 4 mm and a uniformly graded grain size distribution.

The requirements for the bedding materials for paving surfaces are clearly compiled in the form of product specification sheets. These can be obtained from the Arbeitsgemeinschaft Pflasterklinker e.V. on the internet at **www.pflasterklinker.de/datenblaetter**

Of particular importance is the filter stability of the jointing material to the bedding material. If the filter stability is not sufficient, jointing material can ingress into the bedding. The joints then do not remain permanently filled. Stability of the position of the paving is then no longer guaranteed. The filter stability can be proven based on the grain distribution curves for jointing and bedding material. According to ZTV Pflaster –StB, filter stability is deemed given when the following conditions are met.:

$D_{15}/d_{15} \geq 1$ Permeability condition

$D_{15}/d_{85} \leq 4$ Safety condition against erosion

$D_{50}/d_{50} \leq 5$ Safety condition against erosion

with:

D_{15}, D_{50} Grain diameter [mm] of the bedding material at 15 and 50 mass% screen undersize respectively

d_{15}, d_{50}, d_{85} Grain diameter [mm] of the jointing material at 15, 50 and 85 mass% screen undersize respectively

For construction material mixes used as jointing material, according to TL Pflaster-StB, proof of agreement (quality control) is required.

Joint filling and vibration

To obtain a full and resistant joint filling, the following procedure is recommended according to Code of Practice M FP, in which several, sometimes repeated working steps are performed:

The joints are filled continuously as the laying of the paving advances. Prior to this – if possible with a straightening tool – the joint lines should be aligned so as to assure the uniform lines of the joint axes. The jointing material is then placed on the paving, evenly distributed and carefully swept into the joints. Grains that are too big to fit into the joints are swept off. Then the paving should be compacted with a light vibration plate. Paving without filled joints should not be vibrated.

Following this work step, more jointing material should be placed on the paving and washed in with a small amount of water. The jointing material can also be washed into the joints mechanically with the machines and equipment available for this. Then the surface of the paving should be swept clean. After washing-in of the jointing material, vibration should be delayed until the bedding and its foundation are sufficiently dry. During this period, the paving should not be trafficked by vehicles or equipment. After adequate drying, the paving surface is compacted with a compactor suitable for thickness of the clinker pavers and the load-bearing capacity of the bedding until the required planeness and stability are obtained.

The addition of joint material, sweeping and compaction by vibration should be repeated until no sagging of joint material after vibration can be observed or until the joints are only emptied to a depth of 10 mm maximum ready for subsequent sealing of the joints.

Joint Sealing

As the findings of scientific studies [4] and field experience have shown, new and recently laid paving – up to an age of around one to two years – exhibits a lower resistance to displacement than paving that has been laid longer. This is presumably directly related to the ingress of fines into the joints, which increases in the course of the service lifetime, further stabilizing the paving.

For this reason, to complete the paving work, the joints should then be “sealed”. For this purpose, a joint sealing material of the grade 0/2 or 0/3 with a fines content (grain diameter < 0.063 mm) of 15 to 30 mass% should be washed into the joints. This sealing of the joints pre-empts the expected flushing of fines into the joints over the service lifetime, increasing the stability of the paving. At the same time resistance to the removal of the jointing material is improved. Several washing-in processes may be necessary to improve the resistance of the joint filling. The joint sealing material should fill the maximum top 10 mm of the joint.

Fig. 5-15: **Vibration of the previously swept clinker paver surface with a light vibrating plate**

Suitable plate compactors

The plate compactors used to vibrate the paving surface must be suitable for the application according to the manufacturer's specifications. They must be equipped with a plate slide mechanism (e.g. plastic skirt) to prevent any damage to the surface of the pavers. Vibrating rollers should not be used. It is important to make sure that the surface has dried sufficiently after washing-in of the jointing material.

5.7.4 Gutters, edging and installations

5.7.4.1 Edging

For unbound clinker paved surfaces (standard construction method), stable edging is always required to prevent lateral (sideways) movement or sagging of the clinker pavers at the edge of the paving during installation and service lifetime of the paving. The edging has to be constructed before the clinker pavers or slabs are laid. Kerb or shaped clinker bricks, but also kerb elements or soldier pavers can be used. To avoid cutting the pavers, the exact distance of the edging should be determined in advance by setting out individual lines of clinker pavers or rows of slabs. Plans drawn up prior to the construction are usually based on nominal dimensions plus the planned joint widths. For production-related reasons, the dimensions of the clinker pavers or slabs delivered may deviate from the nominal dimensions, although within the permissible tolerances!

Kerb and edging pavers should be laid on an at least 20-cm-thick foundation of plain concrete C 20/25 in accordance with DIN EN 206. The edging must be laid in fresh, i.e. still workable concrete. If the kerbs or edging is regularly driven against, on or over by motorized vehicles, the installation of a bonding bridge underneath the kerb or edging is recommended. Behind kerbs or edging bricks, a rear support or haunch made of concrete in formwork should be installed. To obtain the necessary concrete strength, it is important to comply with the time permitted for working with the unset concrete.

The concrete rear support or haunch must measure at least 10 cm in width if the edging elements have a nominal width up to 80 mm. and at least 15 cm width if the edging elements have a nominal width of more than 80 mm. The height of the haunch depends on the thickness of the abutting surfacing. If there is no abutting surfacing, the haunch must have a height of 2/3 of the height of the edging. The surface of the haunch should be slightly slanted outwards. The concrete for the haunching should be placed “wet in wet” with the bed concrete. Steps and walls can also be used as edge restraints and constructed with clinker pavers.

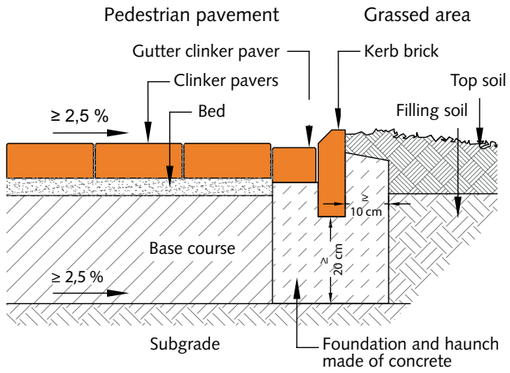


Fig. 5-16: **Gutter design with clinker pavers and clinker kerbs**

5.7.4.2 Gutters

Any precipitation falling on the clinker paver surface that does not seep through the joints should run-off over the slope of the paving. For drainage of the water, usually a longitudinal drainage system with gutters is installed. These are installed along or between traffic areas. They are used to receive the water flowing into them from the traffic areas and channel it to gullies or drains. Open and closed gutters are possible. Open gutters are kerb gutters and trough gutters. Closed gutters are box and slotted gutters.

Design principles for the drainage of traffic areas can be found in RAS-Ew.

Drainage gutters should be constructed prior to installation of the abutting surfacing. The gutter elements, e.g. gutter pavers, should be laid to ensure the prescribed longitudinal slope of the gutter, with joint widths of 8 to 12 mm on a 20-cm-thick bed foundation of C 20/25 plain concrete. The joints between the elements must be fully sealed with jointing mortar. Clinker or gutter pavers laid in bedding mortar should not be vibration-compacted.

The width of the gutter and the foundation depend, amongst other things, on the type and size of the drainage elements to be used. It is therefore recommended to make a true-to-scale cross-sectional drawing of the drainage gutter during planning.

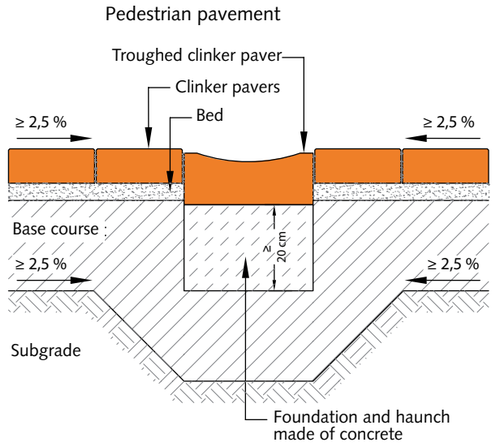
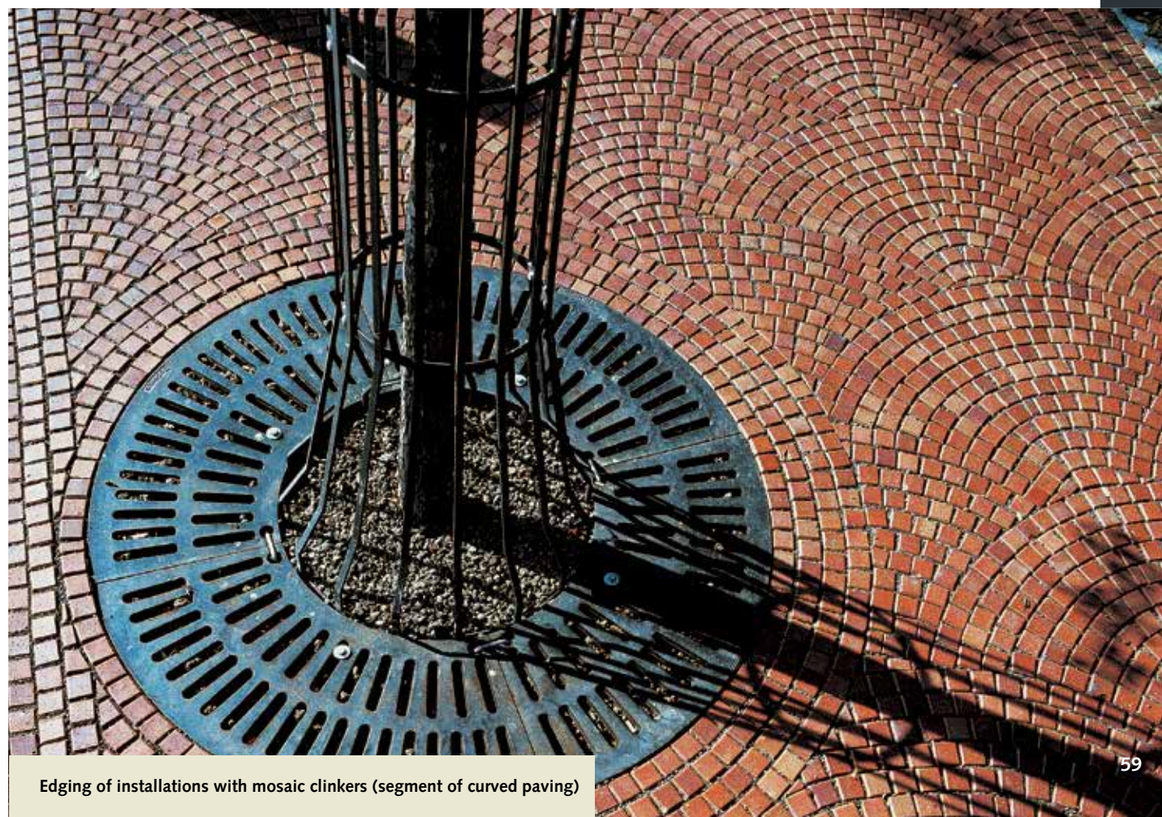


Fig. 5-17: **Gutter construction with clinker pavers and clinker kerbs**

Drainage gutters should be constructed with movement joints at a spacing of a maximum 12 m through the foundation and the haunch, if required. In the case of trafficked gutters, movement joints must be constructed at a spacing of 4 to 6 m. If the drainage gutter forms part of an edging, movement joints must be arranged right through the edging. The expansion joints should be sized between 8 and 15 mm wide and in the area of the drainage elements sealed with paving sealing compound and at least 30-mm-deep casting of elastic grouting in accordance with ZTV Fug-StB.

5.7.4.3 Installations and connections

Shafts, flower beds and other technical or design elements are installations within the paving surface. They should be designed either as fixed installations or enclosed in edging. With expedient selection of adapter or wedge bricks, connections to installations can be constructed satisfactorily with regard to both technical and design aspects.



Edging of installations with mosaic clinkers (segment of curved paving)

6 | Necessary work during the service lifetime of clinker paving

6.1 Visual assessment of the surfaces

A paved surface should always be assessed based on the overall visual impression. Important for this are a usual viewing distance and suitable light conditions. Design requirements should be defined in advance based on samples and the construction of sample surfaces. With the help of reference samples, the variation in colour and structure and the desired appearance can be assessed at any time in the construction phase.

6.1.1 Bond, joint width and joint pattern

The agreed bond (laying pattern) has to be uniformly constructed in the respective (part) areas in accordance with the design and plans. This also applies for machine laying. The joint axes must be in a uniform pattern. With regard to a uniform assessment, it is recommended that, based on a 4-m-long measurement section, deviations of no more than ± 5 mm from the joint axes should be permitted. From experience, such deviations are subjectively perceived as not disturbing the "still uniform joint pattern".

It may be necessary to abandon the uniform pattern of the clay pavers in connecting areas, curves, circles or angles to meet the requirements of ZTV Pflaster-StB.

The minimum joint width specified in the technical regulations should always be complied with. The maximum values for the joint width specified here can, if necessary, be slightly exceeded at individual joints on account of the permissible dimensional tolerances of the clinker pavers in order to obtain a regular joint pattern.

6.1.2 Unevenness, connections

Depending on the intended use of the clinker paver surfacing, the resulting slope of the surfaces and the measuring bar used, unevenness on the surface in the lengthways and crossways directions may not exceed the required values listed in Table 6-1.

Within the paved area, the clinker pavers should always join at the correct height at joints and connections. Between adjacent clinker pavers, the deviation should not be higher than 2 mm.

Next to edging and installations, the connections should lie 3 to 5 mm above their surface, next to drainage gutters 2 to 10 mm above the gutter.

Use of surface	Resulting slope	Planeness requirements [1] deviation [mm] under the:	
		2-m bar	4-m bar
Walkable, not accessible by motorized vehicles (usage category N1)	≥ 1.5 to < 2.0	≤ 5	≤ 8
	≥ 2.0 to < 2.5	≤ 6	≤ 10
	≥ 2.5	≤ 10	≤ 12
Trafficable by motorized vehicles (usage categories N2 and N3)	≥ 2.0 to < 2.5	≤ 5	≤ 8
	≥ 2.5	≤ 6	≤ 10

[1] Measurement in accordance with TP Eben – Contact Measurements with 2-m- or 4-m level and a 30-cm measurement wedge

Table 6-1: **Planeness requirements based on ZTV Wegebau**

6.1.3 Edge spalling

Spalling (chipping) at the edges is usually the result of improper installation, often with joints that are too narrow. The safety of use of the damaged area is generally not restricted. However, on account of the unattractive appearance, it should nevertheless be regarded as a laying fault.

6.1.4 Colour and structural deviations

Variations caused by the raw material or production can easily cause deviations in colour and structure. Clinker pavers possess a natural colour, without chemical additives, influenced by the minerals contained in the raw material and the firing process. With cross-mixing of clinker pavers from several packs, unwanted colour and structural variations can be reduced.

6.1.5 Efflorescence

Efflorescence is the term used to describe a whitish deposit on the surface of paving bricks and slabs in the dry state. It can be of varying intensity and/or patchy. Stains that are caused, for example, by improper storage of building materials, can have a similar appearance, but are not efflorescence. Efflorescence or the other stains mentioned can occur on clinker pavers or slabs as the result of improper jointing with hydraulically bound jointing material. Technically they do not pose any hazard and do not impair the mechanical properties of the clinker pavers and the paving surfaces constructed with these. Occasionally, after the pavers have been laid, a grey bloom can form on the surface, which disappears again naturally after a short time following rainfall. As this is pure salt efflorescence, these water-soluble compounds can be also washed away with water. It may also be the case that the bedding material used is not free of efflorescent substances. Before industrial by-products (slags, recycled material) are used, their suitability with regard to the efflorescence of chemical reactions and setting must be tested. Pure water-soluble salt deposits, which reach the surface as the result of capillary transport to the surface, can be swept or washed off. If a deposit cannot be removed in this way, there has been a reaction involving the efflorescent substance on the surface of the clinker paver. In this case, the deposit must be removed semi-mechanically or with special stone cleaners. Efflorescence is a temporary phenomenon; it disappears in the course of the service lifetime.

6.2 Hydrophobizing

Especially in the case of covered brick paving, owing to the absence of natural weathering, salts can become concentrated on the surface. This change in the appearance of the surface is often perceived as unattractive and visually disturbing, the clinker paver surfaces here should be regularly scrubbed with water. Cleaning of the clinker paver surface with a high-pressure cleaner is not advisable owing to the danger of material being flushed out of the joints. Experience has shown that the addition of washed sand as a scouring agent has a positive effect with regard to this cleaning process.

For covered clinker paver surfaces, subsequent hydrophobizing treatment is sometimes offered. This is supposed to effect a reduction in the capillary absorbing capacity. Here it is important to note that other properties, for example the slip/skid resistance, can be changed if a coating is applied to the paving. The suitability of the hydrophobizing agent therefore always has to be first tested on a sample area. The manufacturers' instructions for use must be followed very carefully.

6.3 Cleaning

Unbound clinker paving can be gently cleaned by sweeping with an ordinary broom or brush. Care must be taken so that no significant amount of jointing material is removed during cleaning. For this reason, no suction devices should be used under any circumstances. If the method of cleaning is already known in the planning phase, then the jointing material can be selected to counter the risk of jointing material being removed.

Clinker paving should only be machine-cleaned when the jointing material has been enriched with fines and consolidated such that it is sufficiently resistant to the removal of jointing material from the joints. Depending on the location and use of the surface, this can take different lengths of time. Scientific studies [5] in which the resistance of paved surfaces to horizontal displacement was measured with an expander show that new paving up to an age of around one to two years exhibits a lower resistance to displacement than older paving. It is recommended therefore that a surface should only be machine-cleaned one year after it has been laid at the earliest.

If cleaning results in the joints not being completely filled with jointing material, individual clinker pavers can be displaced and tilted, especially on trafficked areas, and the function of the paving can be severely impaired. The

Cleaning method	Location of the surfacing	Jointing material
By hand (dry)	Outdoor	Construction material mixes of the grades 0/4, 0/5, but also 0/2 consisting of crushed or unbroken aggregates
By hand (dry)	Covered	Construction material mixes of the grades 0/4, 0/5, but also 0/2 (flow coefficient category $E_{CS}35$) of crushed aggregates
By machine (sweeping, suction, washing)	Outdoor	Construction material mixes of the grades 0/4, 0/5 consisting of crushed aggregates (percentage of broken surfaces category $C_{90/3}$,flow coefficient category $E_{CS}35$)

Table 6-2: **Jointing material depending on the cleaning method and location of the surface** (Jointing material for traffic surfaces in Construction classes Bk0.3 to Bk3.2, see Section 5.6.3.3)

clinker paving should therefore be regularly inspected. Any missing jointing material must be replenished without delay.

If the clinker paving is stained by liquids, e.g. during barbecues or as a result of drops of engine oil, the cleaning agents available from the specialist trade can be used. Clinker pavers are not attacked by cleaning and their colour is not impaired by cleaning either. On surfaces exposed to natural weathering, most such stains disappear on their own over time.

For the removal of de-icing salt, the surface should be simply swept. With natural weathering, the de-icing salt is gradually removed. As an alternative to de-icing salt, chippings or granulate can be recommended as de-icing grit.

6.4 Maintenance work

As for all traffic area surfacings, regular inspection of the clinker paving is necessary to assess the condition of the surface, in order to schedule and prepare for any necessary maintenance work in good time. Special attention should be paid to the condition of the joints and the joint filling. If the joints are no longer filled completely, any missing jointing material must be replenished without delay. Otherwise there is a risk that the paving can no longer distribute the loads applied between the clinker pavers, leading to displacement and tilting of the clinker pavers. Research findings [4] [7] show that already from an emptying depth of around 20 % of the paver thickness, the stability of the paved surface is reduced.

If during the inspection of the paving condition, unevenness, e.g. troughed or undulating deformation, is detected and if this is so severe that it can cause water retention, this must be rectified without delay.

On account of their high resistance to mechanical, chemical and biological stresses, clinker pavers are very durable. The lifetime of the clinker paver surface is therefore essentially determined by the durability of the base courses, the bedding and joint filling. If during the course of the use of the paving, excavation or maintenance work is necessary, with the unbound method of paving, the clinker pavers can be taken up and most of the clinker pavers can be cleaned and reused.

Key information and recommendation on inspecting the condition of paving, the causes of damage in conjunction with typical damage patterns as well as on performing repair, maintenance and replacement work can be found in the "Code of Practice for the Structural Maintenance of Traffic Areas with Unbound Paving or Slab Surfacing and Edging" (M BEP).

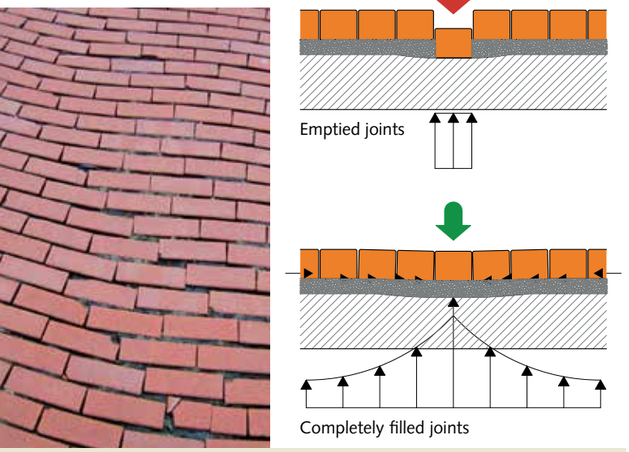


Fig. 6-1: **Insufficient bonding caused by emptied joints**

6.5 Excavations

Unbound clinker paving can be taken up either entirely or in parts at any time and re-laid on the same area later. Excavation, e.g. for laying or repair of supply or disposal pipes, can be easily done in clinker paving. Providing the excavation is properly refilled, the clinker pavers can be used to restore the traffic surfaces. For this purpose, the clinker pavers must be taken up and then carefully cleaned to remove any jointing and bedding material sticking to them. They are then intermediately stored. If single clinker pavers must be replaced, the new pavers must be matched in shape and colour to the existing surfacing. Replacement material should be installed in the joined areas. Colour deviations between the old and new brick pavers are often only caused by surface dirt on the old clinker pavers. With the later soiling on the new clinker pavers, hardly any difference in colour will be noticeable after a certain time.

If a utility trench or construction pit is dug, the paved surface should be taken up over a width to ensure that on further digging the remaining surface is no longer damaged or loosened. According to ZTV A-StB, the paving must be taken up over an area with a width exceeding the width of the trench so as to enable recompaction of the loosened edges of the unbound base course. Benches must be formed on either side of the trench in a width of at least 15 cm for trench depths to 2.00 m and of at least 20 cm for trenches deeper than 2.0 m (dimension "c" in Fig. 6-2). In the case of paved carriageways and lay-bys, remaining paving with a width of less than 40 cm to the edge of the paving (or half the width of an arc in the case of arc-shaped laying patterns) must also be taken up. For cycle and pedestrian paths, remaining pavers of one format width or a width < 20 cm including any existing bound base course must be removed.

Depending on the existing bedding material, there is a danger that during compaction of the trench filling or the unbound base course bedding material can flow out from under the clinker pavers at the edge of the trench, loosening the clinker pavers. If it can be seen from the widths of the joints that the paving bond has become loose over large edge areas, larger edge sections must be removed. The same problem arises when paving surfaces are laid with an unbound bed on a bound base course (e.g. asphalt base course). Here too, prior to the installation of the bound base course, a cut-back is necessary according to ZTV A-StB, to be able to compact the edge regions of the underlying unbound base course or frost blanket. After installation of the bound base course, it may be necessary to take up other pavers (one format width, cf. dimension "d" in Fig. 6-2) if these appear to have become loosened. If the pavers have been laid in a mortar bed on a bound base course, these generally do not become loose. However, benching according to ZTV A-StB is still necessary.

The paved surface should be restored in accordance with the specifications in ZTV A-StB, ZTV Pflaster-StB and DIN 18318. This applies particularly to the restoration of wedge areas or connections and the associated cutting of adapter pavers. Both in respect of the selection of the bedding and jointing material and with regard to the bed thickness and the joint width, ZTV A StB includes requirements similar to those for the construction of new paving (see Fig. 5.6.3)

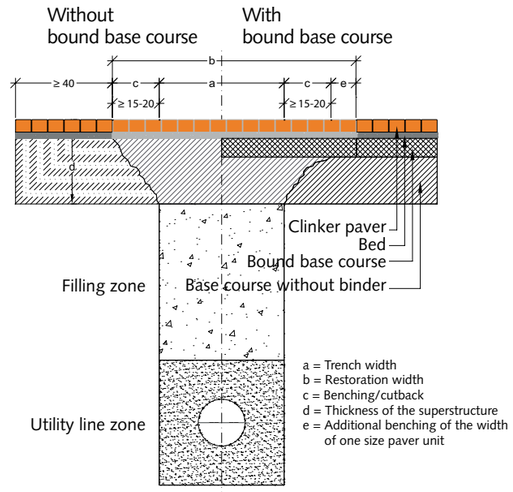


Fig. 6-2: **Benching at paved and slab surfacing in compliance with ZTV A-StB**

7 | Special construction methods

7.1 Bound construction

7.1.1 General

Bound construction is used in those cases where an especially high deformation resistance of the paving is necessary or where specifically for design or usage reasons a closed surface is required. Clinker paving laid with the bound construction method is produced by laying the clinker pavers in a mortar bed. The paving joints are filled with jointing mortar. This rigid construction method always requires the use of construction material mixes with binding agents both for the bedding and for the joints. Only limited experience is available with mixed construction methods in which only the bedding or the joint filling is bound with binders, so these methods are therefore not discussed here.

7.1.2 Usage

Use of the bound construction method described in the following is intended for privately used surfaces in landscaping. The following information and recommendations are taken from Additional Technical Specifications for the Construction of Paths and Squares outside Road Traffic Areas (ZTV Wegebau), published in 2013 by the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V. (FLL Research Society for Landscape Development and Landscaping). Here, three usage categories are defined (see Section 5.5.3):

Usage category N 1:

Walk-on surfacings (e.g. patios, garden paths, paths around houses, seating areas in parks) that cannot be trafficked with motor vehicles;

Usage category N 2:

Trafficable surfacing for motor vehicles to 3.5 t maximum permitted weight (driveways, car parking spaces);

Usage category N 3:

Trafficable surfacing with a load like N 2, however with occasional trafficking of vehicles up to 20 t maximum permissible weight with wheel loads to 5 t (e.g. paths around houses, rescue routes as well as fire brigade, garage and building access roads).

According to ZTV Wegebau, for the usage categories N 1 and N 2, mixed construction with bound bedding, i.e. bound paving on base course(s) without binder can be installed. For usage category N 3 on the other hand, bound paving on a bound base course as a base must be specified.

Not the subject of this brochure are information and recommendations for the use of bound construction for trafficked surfaces that can be assigned to the construction classes of RStO 12. Precondition for this is construction as bound paving with underlying bound base course. The bound base course is constructed as a water-permeable drainage concrete or asphalt base course. These recommendations can be obtained from the FGSV-working paper "Surfacing with paving and slabs in bound construction".

The Wissenschaftlich-Technischen Arbeitsgemeinschaft Bauwerkserhaltung und Denkmalpflege e.V. (WTA – Scientific-Technical Scientific & Technological study group for the restoration of buildings and preservation) compiled and published the E 5 21 07/D Code of Practice "Bound construction method – historical paving", from which information and recommendations on bound construction can obtained.

So long as the bound construction is not described sufficiently in the Technical Regulations, for tendering and drafting construction contracts for construction projects with bound paving, it is necessary to compile one's own specifications. All details concerning the construction materials to be used, the construction process and quality assurance must be formulated fully. A reference to the above-mentioned working paper or code of practice is not sufficient; if necessary, the texts contained in them must be copied.

7.1.3 Characteristics of the bound construction method

The standard method of construction without binders is a flexible method of construction, i.e. the clinker pavers, unbound bedding and jointing material have different mechanical properties. As a result of the friction within the structure of the granular aggregates and against the bottom and side surfaces of the clinker pavers, there is a bonding effect that enables mutual load transfer. Tensile stresses cannot be absorbed; they lead to opening of the joints.

The bound construction method, on the other hand, is a rigid construction method. Clinker pavers, bedding and jointing mortar enter into a largely permanent bond. The bearing behaviour therefore corresponds to that of a rigid plate and is therefore similar to the concrete construction method. From the specific bearing behaviour of the rigid paving, numerous special features, requirements and special conditions result and these must be taken into consideration in the design, selection of the building materials, installation and quality control:

Movement joints:

Within the paving, at a spacing of 4 to 6 m crossways and lengthways as well as at fixed installations, movement joints should be planned at which thermally induced stresses can be reduced.

Drainage:

As the entire surface water has to be drained off the paving surface, in the planning of the installation, a drainage plan in compliance with RAS-Ew must be drawn up. The formation of hairline cracks at or in the mortared joints is basically unavoidable so that infiltration of water into the construction must be expected. The bedding and base course therefore have to be sufficiently water permeable.

Dimensioning of the superstructure:

The dimensioning of the superstructure in accordance with ZTV Wegebau is described in Section 5.5.3. As in accordance with ZTV Wegebau, the top base course without binders in usage category N 1 has to exhibit a static deformation modulus of $E_{v2} \geq 80$ MPa, for N 2: $E_{v2} \geq 100$ MPa, for N 3: $E_{v2} \geq 120$ MPa, Table 8 in RStO (Table A 1-15 in the annex) should be taken into account.

The thickness of the bedding should measure 4 to 6 cm in the compacted state. The thickness of the clinker pavers, in the case of on-edge laying, the thickness of the paving should, similar to the unbound construction, be matched to the (freight) traffic load.

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Clinker paver/mortar bond:

To obtain a paving surface that functions as a monolithic plate, it is of crucial importance that both the bedding mortar and the jointing mortar are composed such that sufficient tensile bond strength is obtained in the bond with the clinker pavers. Pre-treatment of the clinker pavers with an adhesion promoting agent or roughening or keying of the contact surfaces is generally necessary. Consultation with the producers of the mortar systems to obtain advice and the use of products from the same producer are recommended. To check whether the necessary adhesive tensile strength in line with requirements can be obtained with the chosen construction materials in the construction site conditions, a test area of at least 2 m² should be constructed and the adhesive tensile strength tested on samples taken from this.

7.1.4 Bedding mortar

The bedding mortar should be made from hydraulically bound or plastic-modified, hydraulically bound mortar. Synthetic resin-bonded mortars can be used providing their suitability has been proven. As starting materials, aggregates should be used in which fines (i.e. aggregates 0.063 mm bis 2 mm) are not contained in order to obtain better water permeability. Aggregates in accordance with TL Gestein StB, Table 2, should be used. As mortar produced on site can generally not be produced with the required quality, factory mortars should always be used.

The bedding mortar must be sufficiently water-permeable. The requirements for compressive strength, adhesive tensile strength of hydraulically bound bedding can be taken from the Additional Technical Specifications for the Construction of Paths and Squares outside Road Traffic Areas (ZTV Wegebau). Further details on performing the specific tests are described there.

	Usage category			Testing according to
	N1	N2	N3	
Compressive strength [N/mm²]	≥ 10.0	≥ 10.0	≥ 10.0	DIN EN 12390-3
Adhesive tensile strength [N/mm²]	≥ 0.4	≥ 0.8	≥ 0.8	FGSV working paper – "Surfacing with paving and slabs in bound construction", Section 7.2.4

Table 6-3: **Requirements for the bedding mortar as specified in ZTV Wegebau**

7.1.5 Joint mortar

In contrast to the bedding mortar, the joint mortar should be largely water-impermeable. The joint filling should consist of hydraulically bound or plastic-modified, hydraulically bound mortar. Synthetic resin-bonded mortars can be used providing their suitability is proven on a test surface. The starting materials have to comply with the requirements of the Technical Regulations. For joint filling, too, factory mortars should only be used. Jointing mortars that lead to a discolouration of the clinker pavers should not be used.

	Usage category			Testing according to
	N1	N2	N3	
Compressive strength [N/mm²]	≥ 10.0	≥ 20.0	≥ 30.0	DIN EN 12808-3
Adhesive tensile strength [N/mm²]	≥ 0.4	≥ 0.8	≥ 1.0	FGSV-working paper – "Surfacing with paving and slabs in bound construction"
Freeze-thaw resistance S_n	≤ 800 g/m²			DIN EN 12390-3 CF-test method
Freeze-de-icing salt resistance S_n [1), 2)]	≤ 800 g/m²			DIN EN 12390-3 CDF test method

[1)] Proof only if requirements for frost-de-icing salt resistance are agreed.
[2)] If resistance to frost-de-icing salt is proven, the requirement freeze-thaw resistance is also fulfilled.

Table 6-4: **Requirements for hydraulically bound jointing mortar as specified in ZTV Wegebau**

Jointing mortars must be composed such that joints can be filled completely, They must be sufficiently flowable and largely self-compacting. In the case of synthetic-resin-bonded jointing mortars, it is necessary to adhere to the manufacturer's instructions on use. More details on conducting the respective tests are described there.

7.1.6 Construction

The bedding must exhibit sufficient load-bearing capacity and adequate water permeability. The bound clinker paving is constructed from the bedding. The clinker pavers are always set manually into the bedding mortar to the correct height, firmly with a hammer. The thickness of bound bedding measures 4 cm to 6 cm. Pavers and slabs should be set with the use of a bonding bridge of cement-based mortar, while the bedding mortar is still wet. The bedding mortar should rise to a maximum of a third of the joint height. For laying of the bedding mortar, it is important to adhere to the permissible outside temperatures and workability time. Once they have been set, the clinker pavers cannot be adjusted horizontally or vertically. As the work progresses, the laid clinker pavers should be carefully cleaned to remove traces of bedding mortar and dirt. The unjointed paving must then be protected against damaging weathering influences and dirt.

During setting of the clinker pavers, the joints should be set at a width of 5 to 15 mm. Unlike with the unbound laying method, with the bound laying method, cross joints are expressly desirable with regard to easier joint filling and the creation of movement joints. Pavers and slabs set in bedding mortar may not be vibrated for compaction.

The time for jointing depends on the materials used, the weather conditions and the strength of the bedding mortar. First, if necessary, dust and other loose particles should be removed from the joints with the help of oil-free compressed air. Then the remaining joint space should be filled completely with joint mortar, the uncompacted bed mortar that has risen into the joints being bonded to it. If clinker pavers with chamfered or rounded edges are used, the joint spaces should only be filled to the bottom edged of the chamfer or rounding.

After jointing, the surfaces of the clinker pavers must be carefully cleaned. It is important to make sure that cleaning does not cause any loss in strength of the joint mortar and the mortar is not flushed out of the joints. A slightly lower joint filling than the surface of the clinker paving results from cleaning and is unavoidable.

Until the joint mortar has reached sufficient strength, the paving should be kept free of construction site, pedestrian and vehicle traffic. The requirements of ZTV Wegebau with regard to the properties of the bedding and joint filling in the installed state should be taken into account.

7.2 Permeable clinker paving

7.2.1 Water permeability, water retention and water drainage

For many years, specialized clinker pavers have been available and used for the installation of water-permeable clinker paving in the form of permeable paved surfaces. Such clinker pavers have gaps on or in the clinker paver. During laying of the pavers, the gaps are filled with special rock aggregate so that rainwater can permeate down through the gaps and down to the ground below (permeable paved surfaces).

The FGSV-Code of Practice for Water-Permeable Traffic Areas (M VV) says that experience has shown that a drainage coefficient of Ψ = 0.3 to 0.5 can be specified for water-permeable paving. This means that for the average rainfall, a run-off of 30 to 50 % of the precipitation from the paving can be expected. The run-off water is fed to the draining or adjacent infiltration systems. In the case of average rainfall, with permeable paving, 50 to 70 % of the average rainfall permeates through the surfacing. In the case of precipitation events of lower intensity than the average rain, much higher percentages of rain are taken up, allowing the rainwater to permeate through the paving and /or evaporate. This effectively relieves the load on the wastewater sewage system, reduces surface sealing and promotes the formation of new groundwater.

Permeable clinker paver surfaces are only suitable for trafficked surfaces with low traffic load, i.e. traffic surfaces of the Construction class Bk0.3 as specified in RStO as well as for cycle and pedestrian paths, private paths and other untrafficked surfaces. They may only be installed outside of water protection areas. To increase the efficacy in respect of water permeability and water retention, it is recommended to reduce the run-off slope of the surfaces, with consideration of traffic-safety-relevant aspects. The resulting drainage slope should not be lower than 1.0 %. In the case of heavy rain events, short-term accumulation of water on the surface must be expected. With regard to protection of ground water, de-icing salt should not be used in winter clearance services.

7.2.2 Clinker paver systems

Permeable clinker paver systems can – in addition to special shapes – be differentiated depending on the type water absorption:

Clinker paving – with permanently widened joints:

By means of appropriate laying, a joint generally measuring between 15 and 30 mm is formed. To ensure permanent permeability, the joints must be filled with water-permeable aggregate. In Construction class Bk0.3, clinker paving with widened joints may be used only to a dimensioning-related action effect of a maximum of 0.1 equivalent 10-t axles, the nominal thickness should measure 80 mm. For cycle and pedestrian paths as well as other trafficked areas, clinker paver with a lower nominal thickness can be used.

Brick paving with gaps in or at the edge of the pavers:

The seepage apertures can be in the form of holes, hollows, or chambers. Generally, an open area of at least 10 % is reached. For permanent seepage, the apertures should also be filled with water-permeable aggregate. These clinker paver systems include lawn pavers, drainage pavers, star pavers and clinker pavers with infiltration shafts. Clinker pavers with gaps in or at the edge of pavers can be used in Construction class Bk0.3 with a nominal thickness of 100 mm. If the dimensioning-related action effect is a maximum of 0.1 mill. equivalent 10-t axle, the nominal thickness should be 80 mm. For cycle and pedestrian paths as well as other traffic areas, clinker pavers with a lower nominal thickness can be used.

7.2.3 Dimensioning

The construction class is determined in accordance with RStO. For reasons of groundwater protection, application of permeable traffic area surfacing must be limited to Construction class Bk0.3. Determination of the thickness

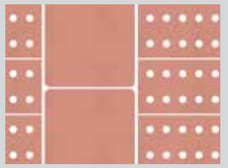
Fig. 6-3: **Different clinker paver formats for permeable paving**

Paving with infiltration shafts in a stack bond

Star pavers

Paving with infiltration shafts

Drainage pavers



Lawn clinker pavers

of the frost-resistant superstructure can, as derived from RStO, can be simplified (see Section 5.5.2.3).

For permeable paving, the code of practice M VV provides recommendations with regard to structure and installation thickness.

Basis for calculating the water drainage from a traffic surface, according to RAS-Ew, are the regionally available precipitation per unit areas from the KOSTRA tables of the Germany's National Meteorological Service. Insofar, determination of the consequently necessary water permeability of the permeable paving should be based on the basis of regional design rain events. In the sense of a standardization of the requirements for water permeability of the superstructure of permeable paving, however, for a design rain amount per unit area of uniform 270 l/(s·ha), the following minimum permeability coefficients are derived and defined in the FGSV Code of Practice for Permeable Traffic Areas:

- All superstructure courses
  Clinker paving and base courses:
  $k_f \geq 5 \cdot 10^{-5}$ m/s
  $k_i \geq 3 \cdot 10^{-5}$ m/s
- Subgrade/substructure:
  $k_f \geq 5 \cdot 10^{-5}$ m/s
  $k_i \geq 3 \cdot 10^{-5}$ m/s

Achieving of the required infiltration rate of the subgrade/substructure and the superstructure courses during installation should be monitored by means of infiltration measurements.

7.2.4 Subgrade/substructure and base courses

The subgrade/substructure must meet the requirements already described in Section 5.6.1. Deviating from this, under water-permeable paving, the subgrade/substructure must exhibit a water permeability coefficient of $k_f \geq 5 \cdot 10\text{-}5$ m/s or an infiltration coefficient of $k_i \geq 3 \cdot 10\text{-}5$ m/s. To achieve the necessary water removal and cleaning effect in the soil, the water-permeable subgrade must have at least a thickness of 1 m before reaching the mean highest groundwater level.

Base courses without binders are particularly suitable as bedding for permeable paving as they are conceptually water-permeable. Starting from the subsoil, either a frost blanket and above this a gravel or crushed rock base course can be installed (construction method according to Line 1 or Line 2 of Chart 3 in RStO). On account of the special requirements for the water permeability ($k_f \geq 5 \cdot 10\text{-}5$ m/s), it is, however, recommended that only graded gravel and crushed rock base courses as specified in Section 2.3 of TL SoB StB be used, which are then installed directly on the subsoil (Line 3 of Chart 3 in RStO), cf. Section 5.5.1. Moreover, the base courses must meet the requirements already detailed in Section 5.6.2.1.

To test the infiltration rate of the subgrade/substructure and the base courses, a series of infiltrometers is available in accordance with TP Gestein-StB:

- the modified pipe infiltrometer
  (TP Gestein-StB, part 8.3.2),
- the drop infiltrometer
  (TP Gestein-StB, part 8.3.3),
- the double-ring infiltrometer
  (TP Gestein-StB, part 8.3.4)

Alternatively, the quick test described in Code of Practice M VV can be used for qualitative estimation of the infiltration rate. For this purpose, a measurement ring (e.g. soil pipe) with 300 mm inside diameter is placed on the surface of the course to be tested and sealed all around. The time is measured that 2 l of water requires to permeate into the course to be tested within the measurement ring (without water discharge over the surface). At an outflow time up to 6 minutes, the infiltration rate can be regarded as sufficient. An outflow time of over 6 up to 10 minutes necessitates determination of the infiltration coefficient with one of the above-mentioned processes. If the outflow time exceeds 10 minutes, the infiltration rate of the tested course can be regarded as insufficient.

7.2.5 Paving

The infiltration rate of the paving is largely determined by the water permeability of the aggregate in the joints and drainage apertures as only here can the surface water infiltrate the surfacing. The required permeability coefficient of the paving of $k_f \geq 5 \cdot 10\text{-}5$ m/s or $k_i \geq 3 \cdot 10\text{-}5$ m/s can only be achieved with the use of especially permeable aggregates as bedding and jointing material. These are crushed aggregates in 1/3, 2/4 or 2/5 grades. It should be emphasized that for permeable paving, the key criterion for the choice of the bedding and jointing material is the water permeability. As only a reduced stability of the paving can be achieved with the use of these aggregates, a lower deformation resistance of permeable paving must be accepted. A slight improvement of the deformation resistance can if required be achieved with the addition of around 10 mass% 0/2 aggregate to the above-mentioned bedding and jointing material. The construction of the paving is otherwise as described in Section 5.6.3.

Greened surfaces with perforated lawn clinker pavers

Drainage clinker pavers – permeable clinker paver systems

Gut Opherdicke, Holzwickede, Germany

8 | Reuse and recycling

8.1 Sustainability

A key feature of clinker pavers as a sustainable construction product is a good ratio of the energy, water and raw materials consumption needed for the production of the construction product and the expected lifetime. A long service lifetime always means that natural resources otherwise used in the production of new products are conserved.

8.2 Reuse

Clinker pavers that have been taken up and cleaned can be reused after visual inspection. It should be noted that the remaining lifetime of the relaid clinker pavers is dependent on previous use, the climatic conditions and the professional relaying of the pavers.

8.3 Removal of the clinker paving and recycling of the clinker pavers

8.3.1 Single-origin removal and collection of the waste

Clinker pavers (waste code 17 01 02) should be taken up, for example, with a screening bucket, separated as far as possible from bedding and joint material and sent for recycling. That means before removal of the superstructure courses of the paving and base course, the paved surface should be removed and collected in a separate container.

8.3.2 Impurities and adhering extraneous matter

The permissible content of extraneous matter, i.e. residue of jointing and bedding mortar or impurities such as wood or films or other acceptance criteria must be agreed first with the recycling company.

8.3.3 Recycling

The broken paver fragments are processed in specialist quality-monitored companies, e.g. for the production of aggregate for path and sports ground construction, for the production of growing substrate for roof greening, tree and plant substrates in gardening and landscaping. Waste from thermal production (fired rejects) can be used in part for preparation and mixing as raw material substitute for the production of new products.

Production of recycled aggregates for use as substrate in vegetation engineering.

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Dimensioning the superstructure

Traffic area surfacing with paving is generally dimensioned in accordance with the "Guidelines for the Standardization of Surfaces of Road Traffic Areas (RStO)". The procedure for dimensioning of the superstructure in stages is explained in the following:

Stage 1: Determining the construction class

In RStO, seven construction classes (Bk100 to Bk0.3) are defined depending on the traffic volume of the vehicle types in freight vehicle traffic. For carriageways, to determine the construction class, the dimensioning-related action effect B is calculated. The dimensioning-related action effect B corresponds to the number of the weighted equivalent 10 t-standard axles in the intended service lifetime.

The dimensioning-related action effect B can be calculated with two methods in accordance with RStO:

- Method 1
  If details on the average daily traffic frequency of freight traffic DTV(SV) are available,
- Method 2
  If detailed axle load data are available.

As no axle load data from axle load weighings or axle load estimations are generally available, here only Method 1 is described. It includes the calculation of the dimensioning-related action effect B according to the following equation:

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

with

$$DTA^{(SV)}_{i-1} = DTV^{(SV)}_{i-1} \cdot f_{A\,i-1}$$

B Equivalent 10 t standard axles in the service period on which the calculation is based

N Number of years in the service period on which the calculation is based; usually 30 years

q_{Bm} Mean load spectrum allocated to a particular road class (see Table A 1.2), which expresses the road class-specific mean action effect of the respective actual daily axles (quotient of the sum of the equivalent 10 t standard axles and the sum of the actual freight traffic standard axles for an established period of time in one lane)

f_3 Slope factor (see Table A 1-)

$DTV^{(SV)}_{i-1}$ Average daily traffic frequency of freight traffic in service year i-1 [vh/24h]

$DTA^{(SV)}_{i-1}$ Average number of daily standard axles (A) of freight traffic in service year i-1 [A/24h]

f_{Ai-1} Average number of axles per freight traffic vehicle (axle number factor) in service year i-1 [A/vh] (see Table A 1.1)

f_{1i} Lane factor in service year i (see Table A 1.3)

f_{2i} Lane width factor in service year i (see Table A 1.4)

p_i Median annual increase in freight traffic in service year i (see Table A 1.6).

If no changes in the traffic area surfacing are expected over the planned service lifetime (no additional lanes, no changes in the lane widths, etc.), the factors f_1, f_2, f_3, f_A, and q_{Bm} are constant. The above equation can then be simplified. The calculation can then be performed for the period in question with the constant values for f_1, f_2, f_3, f_A, and q_{Bm} and f_z. The equation is simplified for the period in question (N > 1) to:

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

with

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

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

p Mean annual increase in freight traffic (see Table A 1.6).

fz Mean annual increase factor for the freight traffic (see Table A 1.7)

Road class	Factor f_A
Federal motorways or municipal roads with freight traffic share > 6 %	4.5
Federal roads or municipal roads with freight traffic share > 3 % and ≤ 6 %	4.0
Municipal and district roads or municipal roads with freight traffic share ≤ 3 %	3.3

Table A1-1: **Axle number factor f_A in accordance with RStO 12**

Road class	Quotient q_{Bm}
Federal motorways or municipal roads with freight traffic share > 6 %	0.33
Federal roads or municipal roads with freight traffic share > 3 % and ≤ 6 %	0.25
Municipal and district roads or municipal roads with freight traffic share ≤ 3 %	0.23

Table A1-2: **Load spectrum quotient q_{Bm} in accordance with RStO 12**

Number of lanes in cross-section or direction of travel	Factor f_1 for recording $DTV^{(SV)}$	
	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 and over	0.40	–

Table A1-3: **Lane factor f_1 for determination of $DTV^{(SV)}$ in accordance with RStO 12**

Lane width [m]	Factor f_2
Less than 2.50	2.00
2.50 to less than 2.75	1.80
2.75 to less than 3.25	1.40
3.25 to less than 3.75	1.10
3.75 and over	1.00

Table A1-4: **Lane width factor f_2 in accordance with RStO 12**

Maximum longitudinal incline [%]	Factor f_3
Less than 2	1.00
2 to less than 4	1.02
4 to less than 5	1.05
5 to less than 6	1.09
6 to less than 7	1.14
7 to less than 8	1.20
8 to less than 9	1.27
9 to less than 10	1.35
10 and over	1.45

Table A1-5: **Slope factor f_3 in accordance with RStO 12**

Road class	p*)
Federal motorways	0.03
Federal roads	0.02
Municipal and district roads	0.01

*) In the determination of the traffic load of the lane to be dimensioned, its capacity must be taken into account.

Table A1-6: **Mean annual increase in freight traffic p*) in accordance with RStO 12**

	Mean annual increase in freight traffic p		
N [a]	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

Table A1-7: **Mean annual increase factor for heavy traffic f_z in accordance with RStO 12**

Accordingly, the dimensioning-related action effect B corresponds to the total number of the weighted equivalent 10-t axles in the planned service lifetime. From this results the derivation of the construction class in accordance with Table A1-8.

Dimensioning-related action effect B Equivalent 10 t standard axles in millions	Construction class
over 3.2[1)]	Bk100
over 1.0 to 3.2	Bk32
over 3.2 to 1.0	Bk10
over 1.8 to 3.2	Bk3.2
over 1.0 to 1.8	Bk1.8
over 0.3 to 1.0	Bk1.0
to 0.3	Bk0.3

[1)] Bei einer dimensionierungsrelevanten Beanspruchung größer 100 Mio. sollte der Oberbau mit Hilfe der RDO dimensioniert werden.

Table A1-8: **Dimensioning-related action effect B and assigned construction class in accordance with RStO 12**

Assignment of the construction class based on the typical design situation in accordance with RASt

In exceptional cases, if the dimensioning-related action effect cannot be determined, for roads in built-up areas the construction class can be assigned based on the typical design situation in accordance with RASt (Table A1-9). For bus traffic areas, secondary and service facilities and parking areas, the construction class is assigned in tables (Tables A1-10 to A1-12).

Typical design situation	Street category	Construction class
Road without surrounding structures	VS II, VS III	Bk10 to Bk100
Connecting road	HS III, HS IV	Bk3.2 / Bk10
Industrial road	HS IV, ES IV, ES V	Bk3.2 to Bk100
Commercial road	HS IV, ES IV, ES V	Bk1.8 to Bk100
Main business road	HS IV, ES IV	Bk1.8 to Bk10
Local business road	HS IV, ES IV	Bk1.8 to Bk10
Local entry road	HS III, HS IV	Bk3.2 / Bk10
Village main road	HS IV, ES IV	Bk1.0 to Bk3.2
Lodging road	HS IV, ES IV	Bk1.0 to Bk3.2
Trunk road	ES IV	Bk1.0 to Bk3.2
Residential road	ES V	Bk0.3 / Bk1.0
Residential street	ES V	Bk0.3

Table A1-9: **Possible construction classes for typical design situations according to the RASt 06**

Traffic load	Construction class
Over 1 400 buses/day	Bk100
Over 425 buses/day to 1400 buses/day	Bk32
Over 130 buses/day to 425 buses/day	Bk10
Over 65 buses/day to 130 buses/day	Bk3.2
Up to 65 buses/day [1)]	Bk1.8

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

Table A1-10: **Load for bus traffic surfaces and assigned construction class in accordance with RStO 12**

Traffic type	Construction class
Freight traffic	Bk3.2 to Bk10
Car traffic including low percentage of freight traffic	Bk0.3 to Bk1.8

Table A1-11: **Traffic areas in secondary and service facilities and assigned construction class in accordance with RStO 12**

Traffic type	Construction class
Freight traffic	Bk3.2 to Bk10
Surfaces not constantly used by freight traffic	Bk1.0 / Bk1.8
Passenger car traffic (Trafficking by maintenance service vehicles possible)	Bk0.3

Table A1-12: **Hard-stand areas and assigned construction class in accordance with RStO 12**

Stage 2: Determining the minimum thickness of the frost-resistant superstructure

The thickness of the frost-resistant structure of courses of the traffic area surfacing must be defined such that no damaging deformation is suffered during freeze and thaw periods. The required minimum thickness of the frost-resistant surfacing is calculated as a function of the

- the frost susceptibility of the soil in accordance with ZTV E-StB (see Annex 2),
- the local climatic conditions, including the frost action zone,
- the local conditions (general structural conditions) that influence frost penetration (see Table A1-14) as well as
- the previously determined construction class.

The soils specified in the standard DIN 18196 are classified in respect of their frost susceptibility in ZTV E-StB in the frost susceptibility classes F1 (frost resistant), F2 (frost susceptible) and F3 (very frost susceptible).

2a) Thickness of the superstructure for a subgrade / substructure that is not frost resistant

For F2 and F3 soils, the minimum thickness of the frost-resistant superstructure is calculated based on the addition of the starting value (minimum thickness of the frost-resistant road structure (Table A1-13)) and the values derived from the local conditions. If no specific experience or individual studies are available, the increased or reduced thickness can be determined from the individual values for the different criteria in accordance with Table A1-14 as follows:

Increased or reduced thickness = A + B + C + D + E

For determination of the frost impact zones, a detailed map of the Federal Republic of Germany is available. It can be used to determine the frost impact zone for every location in Germany based on the geo-coordinates. This is available as a download from either the German Federal Highway Research Institute (www.bast.de) or from the Road and Transportation Research Association (www.fgsv.de).

	Thickness [cm] for construction class		
Frost susceptibility class	Bk100 bis Bk10	Bk3.2 bis Bk1.0	Bk0.3
F2	55	50	40
F3	65	60	50

Table A1-13: **Starting values for determining the minimum thickness for a frost-resistant road structure in accordance with RStO 12**

	Local conditions [1)]	A	B	C	D	E
Frost action	Zone I	± 0 cm				
	Zone II	+ 5 cm				
	Zone III	+ 15 cm				
Small-area climate changes	Unfavourable climate conditions e.g. due to north-facing hillside or in mountain ridges		+ 5 cm			
	No special climate influences		± 0 cm			
	Favourable climate influences due to closed structures along the road		- 5 cm			
Water conditions in the subgrade	No groundwater or formation water to a depth of 1.5 m below subsoil			± 0 cm		
	Groundwater or formation water permanently or temporarily higher than 1.5 m below subsoil			+ 5 cm		
Position of gradient	Cutting, face				+ 5 cm	
	Terrain height to embankment ≤ 2.0 m				± 0 cm	
	Embankment > 2.0 m				- 5 cm	
Drainage of carriageway/execution of border areas	Drainage of carriageway by means of basins, trenches or slopes					± 0 cm
	Drainage of carriageway and border areas through ditches and/or drains and pipes					- 5 cm

Table A1-14: **Increased or reduced thicknesses due to local conditions in accordance with RStO 12**

For cycle and pedestrian paths, in the case of soils in frost susceptibility classes F2 and F3, a minimum thickness of the frost-resistant superstructure of 30 cm is sufficient. Unfavourable climatic conditions and water conditions must be taken into account in calculating the total thickness of the superstructure of the pedestrian/cycle path. Here, local experience must be taken into consideration.

The paving thickness for crossing areas for motor vehicles (e.g. driveways to properties) must be calculated for the standard traffic load. If crossings lie at short distances from each other, the construction method and standard thickness selected for the crossing should be used over the entire pedestrian and cycle path area.

For surfaced private areas that are not trafficked by motor vehicles, e.g. paths and patios, according to RStO a minimum thickness of the frost-resistant superstructure of 30 cm can be specified to avoid freeze and thaw damage or subsidence as a result of static loads (e.g. planters, permanently installed barbecues …).

2b) Thickness of the superstructure with frost-resistant subgrade / substructure

If the subgrade / substructure consists of a frost-resistant soil (F1 soil), no frost protection measures are necessary. The thickness of the base course to be installed instead of the frost blanket is derived from the requirements for the load-bearing capacity.

- If the F1 soil meets all requirements for frost blankets with regard to the compaction level DPr and static deformation modulus E_{v2} and the F1 soil has at least the thickness that would be necessary for the frost blanket on a soil of the frost susceptibility class F2 or F3, the frost blanket is not required. The other courses are then arranged direct on the subgrade / substructure. The order and course thickness are derived for the selected construction method from Chart 3 of RStO.

- If the F1 soil meets all requirement for frost blankets except the requirement for the load-bearing capacity, then instead of the frost blanket, an additional base course is required. Its thickness is designed based on the static deformation modulus E_{v2} prevailing on the subsoil (surface of the F1 soil) and the requirement for the otherwise necessary frost blanket. Guide values can be obtained from Table A1-15.

E_{v2} value [MPa] on the surface BCOB	≥ 80	≥ 100	≥ 120	≥ 150	≥ 100	≥ 120	≥ 150	≥ 120	≥ 150	≥ 180	≥ 150	≥ 180
Type of base course material:	↑				↑			↑			↑	
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		20	
Frost blanket [cm] consisting of predominantly crushed material	15*	20	30		15*	25						
Frost blanket [cm] consisting of predominantly unbroken material	20	25	35		–	–						
	↑				↑			↑			↑	
E_{v2} value [MPa]	45				80			100			120	
Base	Subsoil							Frost blanket				

combination not possible – uncommon combination 15* technological minimum thickness 0/45 ** reduced thickness possible if proven locally

Table A1-15: **Guide values for the course thicknesses of the base course without binder (BCOB) to obtain the required load capacity as specified in RStO 12 depending on the E_{v2} values of the bedding and the type of base course (thicknesses in [cm])**

After determination whether and in what thickness a frost blanket is necessary, for the specific type of construction, the thickness of the other courses can be obtained from Chart 3 in RStO. The thickness of the superstructure is the sum of the course thicknesses.

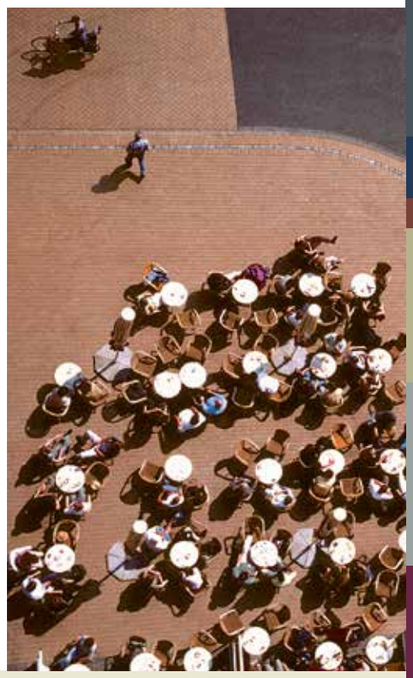
For cycle and pedestrian paths, for soils of the frost susceptibility class F1, no frost protection measures are necessary. However, a load-bearing capacity of $E_{v2} \geq 80$ MPa on the bedding of the paving must be ensured.

Stage 3: Selection of the construction method

The construction methods with paving for carriageways are listed in Chart 3 of RStO (Table A1-16). Construction methods with clinker pavers for carriageways can be used for construction classes Bk3.2, Bk1.8, Bk1.0 and Bk0.3. Each line in Table A1-16 represents one construction method.

Selection of the construction method that is technically and economically expedient for the construction project can be based on the following aspects:

- locally available construction materials,
- regional experience,
- capability of the potential construction companies,
- expected load.



Market square, Chojnice, Poland and Groningen, Netherlands

(thickness in cm; — E_{V2} minimum values in MN/m²)

Line	Construction class	Bk_{100}				Bk_{32}				Bk_{10}				$Bk_{3.2}$				$Bk_{1.8}$				$Bk_{1.0}$				$Bk_{0.3}$			
	B [million]	> 32				> 10-32				> 3.2 – 10				> 1.8 – 3.2				> 1.0 – 1.8				>0.3-1.0				≤ 0.3			
	Thickness of frost-resistant superstructure[1]	55	65	75	85	55	65	75	85	55	65	75	85	45	55	65	75	45	55	65	75	35	45	55	65	35	45	55	65
	Crushed rock base course on frost blanket course																												
1	Dry jointed sett pavement [9] / Crushed rock base course / Frost blanket course													180 / 120 / 45; 10 / 4 / 25 / Σ39				150 / 120 / 45; 10 / 4 / 25 / Σ39				150 / 120 / 45; 8 / 4 / 20 / Σ32				120 / 100 / 45; 8 / 4 / 15 / Σ27			
	Thickness of frost blanket course													-	-	26[3]	36		-	26[3]	36	-	-	33[2]	43	-	18[3]	28	38
	Gravel base course on frost blanket course																												
2	Dry jointed sett pavement [9] / Gravel base course / Frost blanket course																	150 / 120 / 45; 10 / 4 / 30 / Σ44				150 / 120 / 45; 8 / 4 / 25 / Σ37				120 / 100 / 45; 8 / 4 / 20 / Σ32			
	Thickness of frost blanket course													-	-	-	31[2]	-	-	-	31[2]	-	-	28[3]	38	-	-	23[2]	33
	Crushed rock or gravel base course on course made of material not susceptible to frost																												
3	Dry jointed sett pavement [9] / Crushed rock or gravel base course / Course made of material not susceptible to frost													180 / 45; 10 / 4 / 30[19] / Σ44				150 / 45; 10 / 4 / 30[19] / Σ44				150 / 45; 8 / 4 / 30[19] / Σ42				120 / 45; 8 / 4 / 25[11] / Σ37			
	Thickness of course made of material not susceptible to frost	From 12 cm and up from material not susceptible to frost, lower residual thickness to be levelled with material of course above it																											
	Asphalt base course on frost blanket course																												
4	Dry jointed sett pavement [9] / Water-permeable asphalt base course[10] / Frost blanket course													120 / 45; 10 / 4 / 14 / Σ28				120 / 45; 10 / 4 / 14 / Σ28				120 / 45; 8 / 4 / 12 / Σ24				100 / 45; 8 / 4 / 10 / Σ22			
	Thickness of frost blanket course													-	27[3]	37	47		27[2]	37	47		31[2]	41	51	-	23[2]	33	43
	Asphalt base course and crushed rock base course on frost blanket course																												
5	Dry jointed sett pavement [9] / Water-permeable asphalt base course[10] / Crushed rock base course / Frost blanket course													150 / 120 / 45; 10 / 4 / 10 / 15 / Σ39				150 / 120 / 45; 10 / 4 / 10 / 15 / Σ39				150 / 120 / 45; 8 / 4 / 8 / 15 / Σ35				150 / 120 / 45; 8 / 4 / 8 / 15 / Σ35			
	Thickness of frost blanket course													-	-	26[3]	36	-	-	26[2]	36	-	-	20[2]	30	-	-	20[2]	30
	Asphalt base course and gravel base course on frost blanket course																												
6	Dry jointed sett pavement[9] / Water-permeable asphalt base course[10] / Gravel base course / Frost blanket course													150 / 120 / 45; 10 / 4 / 10 / 20 / Σ44				150 / 120 / 45; 10 / 4 / 10 / 20 / Σ44				150 / 120 / 45; 8 / 4 / 8 / 20 / Σ40				150 / 120 / 45; 8 / 4 / 8 / 20 / Σ40			
	Thickness of frost blanket course													-	-	-	31[2]	-	-	-	31[2]	-	-	25[3]	35	-	-	15[3]	25
	Pervious concrete base course on frost blanket course																												
7	Dry jointed sett pavement [9] / Pervious concrete base course (DBT) [10] / Frost blanket course													120 / 45; 10 / 4 / 20 / Σ34				120 / 45; 10 / 4 / 20 / Σ34				120 / 45; 8 / 4 / 15 / Σ27				120 / 45; 8 / 4 / 15 / Σ27			
	Thickness of frost blanket course													-	-	31[2]	41	-	-	31[2]	41	-	-	18[3]	28	38	-	18[3]	28	38

1) In the event of deviating values, the thicknesses of the frost blanket course or the material not susceptible to frost shall be determined by forming the difference, see also Table 8
2) With round-particle aggregate only if proven effective under local conditions
3) With broken aggregate and if proven effective under local conditions only
9) For deviating rock thickness see point 3.3.5
10) See ZTV Pflaster
11) For gravel base course in construction classes $Bk_{1.8}$ and $Bk_{3.2}$ in 40 cm thickness, in construction classes $BK_{1.0}$ and $Bk_{1.0}$ in 30 cm thickness
15) Applicable with $E_{V2} \geq 150$ MN/m² and proven regional construction methods
19) Only crushed rock base course

Table A1-16: **Construction methods with paving surface for carriageways on F2 and F3 subgrade / substructure (RStO 12)**

(thickness in cm; — E_{V2} minimum values in MN/m²)

Line	Construction methods using	Bitumen macadam		Concrete surface		Dry jointed sett pavement (slab cover)		Unbound surfacings	
	Thickness of the frost-resistant superstructure	30	40	30	40	30	40	30	40
	Crushed rock or gravel base course on course made of material not susceptible to frost								
1	Surface / Crushed rock or gravel base course / Course made of material not susceptible to frost	20) 60 / 10[6] / 15 / Σ25 / 45		20) 60 / 12[17] / 15 / Σ27 / 45		20) 60 / 8[14] / 4 / 15 / Σ27 / 45		120 / 4 / 25 / Σ29 / 45	
	Thickness of course made of material not susceptible to frost[16]	-	**15**	-	13	-	13	-	11
	Base course without binders on plane								
2	Surface / Crushed rock, gravel base course or frost blanket course	20) 60 / 10[6] / Σ10 / 45		20) 60 / 12[17] / Σ12 / 45		20) 60 / 8[14] / 4 / Σ12 / 45		120 / 4 / Σ4 / 45	
	Thickness of the crushed rock or gravel base course	20	30	18	28	18	28	26	36

6) Base course surface, see also Point 3.3.3
14) Lower thickness possible
16) From 12 cm and up from material not susceptible to frost, lower residual thickness to be levelled with material of course above it
17) Dowelled joining or anchoring of a 12 cm thick concrete surface is not possible
20) On loading by vehicles(repair and maintenance) $E_{v2} \geq 100$ MPa

Table A1-17: **Construction methods for cycle and pedestrian paths on F2 and F3 subgrade / substructure (RStO 12)**

Extracts from the FGSV specification RStO 12 – Guidelines for the Standardisation of Surfaces of Road Traffic Areas published in 2012 have been reproduced with the permission of the German Road and Transportation Research Association (FGSV). For application of the FGSV Specification, the authoritative version of the specification is that with the latest publication date, which is available from FGSV Verlag, Wesselinger Strasse 17, 50999 Köln, www.fgsv-verlag.de.

Stage 4: **Definition of the course thicknesses**

For the chosen construction method, from the relevant field (Tables A1-16 and A1-17) the recommended course thicknesses can be obtained. RStO gives the nominal thicknesses of the paving for loading classes Bk3.2 and Bk1.8 as 10 cm, for the loading classes Bk1.0 and Bk0.3 as well as for cycle and pedestrian paths as 8 cm. For carriageways of the loading classes Bk3.2 to Bk0.3 clinker pavers with larger thickness (if required for upright laying) can be used. Smaller thicknesses, however, no less than 6 cm, can be used if sufficiently positive experience is available with proven regional construction methods. For cycle and pedestrian paths and corresponding privately used surfacing, clinker pavers with a lower thickness than 6 cm, e.g. 45 to 52 mm, can be used.

The values for the thickness of the frost-resistant superstructure contained in Charts 3 and 6 of RStO (Table A1-16 und A1-17) should be used for a frost-susceptible subgrade/substructure (F2 or F3 soil). The defined thickness of the frost-resistant superstructure must be maintained also with the use of clinker pavers that deviate from the standard thickness. The deviation is offset by a change in the thickness of the frost blanket or the course of frost-unsusceptible material. The thickness of the frost blanket results from the defined dimension of the frost-resistant superstructure less the course thicknesses of the paving, bedding and the specified thickness of the base course. The minimum thickness of the base courses without binder necessary for reasons of load-bearing capacity is specified in Table A 1-15. Based on this table, it is necessary to check whether the determined thickness of the frost blanket is sufficient to obtain the E_{v2} value to be proven on the course. If necessary, the thickness of the frost blanket should be increased to the minimum value in Table A1-15.

If a frost-resistant soil (F1 soil) is available as subgrade/substructure in a sufficient thickness, no frost blanket is necessary. Often, however, for reasons concerning the load-bearing capacity, it is necessary to specify a base course instead of a frost blanket. For definition of the thickness of the base course, Table A1-15 serves as a guide.

10 | Annex 1 – Superstructure dimensions

Stage 5: **Minimum values for load-bearing capacity on courses without binders**

For the subsoil and the individual base courses without binders, minimum load-bearing capacity values (static deformation moduli E_{v2} in MPa) are specified in Tables A1-16 and A1-17. These are recommendations. For paving construction, the requirements in ZTV E-StB, ZTV SoB-StB and ZTV Pflaster-StB apply.

It ZTV SoB-StB are stipulated in the construction contract, on crushed rock base courses with a thickness of at least 20 cm and on gravel base courses from a thickness of at least 25 cm (insofar that a frost blanket with E_{v2} ≥ 120 MPa is installed below this). a static deformation modulus E_{v2} of ≥ 180 MPa should be obtained (cf. ZTV SoB-StB, Section. 2.3.4.2). This applies irrespective of the recommendations in RStO 12. It is, however, imperative to ensure that the required water permeability is not endangered by excessive compaction. For this reason, first a test installation on construction-site scale is recommended. If the required E_{v2} values are not obtained, other, more suitable aggregate mixes should be used for the crushed rock or gravel base course.

Carlsberg Quarter, Copenhagen-Valby, Denmark

Soil classification (DIN 18196)

Table A2-1a:
Soil classification for civil engineering purposes DIN 18196, edition 05/2011 - (Part 1)
(right)

Table A2-1b:
Soil classification for civil engineering purposes DIN 18196, edition 05/2011 - (Part 2)
(bottom right)

10 | Annex 2 – Frost susceptibility classes

Sp	1	2	3	4	5	6	7	8			9	10	11	12	13	14	15	16	17	18	19	20	21
	Definition und Benennung							Erkennungsmerkmale (u.a. für Zeilen 15 bis 22)				Anmerkungen*											
Zeile	Hauptgruppen	KorngrößenMassenanteil Korndurchmesser ≤ 0,063 mm	KorngrößenMassenanteil Korndurchmesser ≤ 2 mm	Lage zur A-Linie (siehe Bild 1)	Gruppen		Kurzzeichen Gruppensymbol*	Trockenfestigkeit	Reaktion beim Schüttelversuch	Plastizität beim Knetversuch	Beispiele	Bautechnische Eigenschaften: Scherfestigkeit	Verdichtungsfähigkeit	Zusammendrückbarkeit	Durchlässigkeit	Erosionsempfindlichkeit	Frostempfindlichkeit	Bautechnische Eignung als Baugrund für Gründungen	Baustoff für Erd- und Baustraßen	Baustoff für Straßen- und Bahndämme	Baustoff für Dichtungen	Baustoff für Stützkörper	Baustoff für Dränagen
1	grobkörnige Böden	kleiner 5 %	bis 60 %	—	Kies (Grant)	eng gestufte Kiese	GE	steile Körnungslinie infolge Vorherrschens eines Korngrößenbereichs			Fluss- und Strandkies	+	+o	++	--	++	++	+	-	+		+	++
2						weit gestufte Kies-Sand-Gemische	GW	über mehrere Korngrößenbereiche kontinuierlich verlaufende Körnungslinie			Terrassenschotter	++	++	++	-o	+	++	++	++	++	--	++	+o
3						intermittierend gestufte Kies-Sand-Gemische	GI	meist treppenartig verlaufende Körnungslinie infolge Fehlens eines oder mehrerer Korngrößenbereiche			vulkanische Schlacken	++	+	++	-	o	++	++	+	++	--	++	+o
4			über 60 %	—	Sand	eng gestufte Sande	SE	steile Körnungslinie infolge Vorherrschens eines Korngrößenbereichs			Dünen- und Flugsand Fließsand Berliner Sand Beckensand Tertiärsand	+	+o	++	-	-	++	+	--	+o	--	o	+
5						weit gestufte Sand-Kies-Gemische	SW	über mehrere Korngrößenbereiche kontinuierlich verlaufende Körnungslinie			Moränensand Terrassensand	++	++	++	-o	+o	++	++	+	+	--	+	+o
6						intermittierend gestufte Sand-Kies-Gemische	SI	meist treppenartig verlaufende Körnungslinie infolge Fehlens eines oder mehrerer Korngrößenbereiche			Granitgrus	+	+	++	-o	+o	++	++	o	+	--	+	+o

Table A2-1a: **Soil classification for civil engineering purposes – DIN 18196, edition 05/2011 - (Part 1)**

Sp	1	2	3	4	5	6	7	8			9	10	11	12	13	14	15	16	17	18	19	20	21
	Definition und Benennung							Erkennungsmerkmale (u.a. für Zeilen 15 bis 22)				Anmerkungen*											
Zeile	Hauptgruppen	KorngrößenMassenanteil Korndurchmesser ≤ 0,063 mm	KorngrößenMassenanteil Korndurchmesser ≤ 2 mm	Lage zur A-Linie (siehe Bild 1)	Gruppen		Kurzzeichen Gruppensymbol*	Trockenfestigkeit	Reaktion beim Schüttelversuch	Plastizität beim Knetversuch	Beispiele	Bautechnische Eigenschaften: Scherfestigkeit	Verdichtungsfähigkeit	Zusammendrückbarkeit	Durchlässigkeit	Erosionsempfindlichkeit	Frostempfindlichkeit	Bautechnische Eignung als Baugrund für Gründungen	Baustoff für Erd- und Baustraßen	Baustoff für Straßen- und Bahndämme	Baustoff für Dichtungen	Baustoff für Stützkörper	Baustoff für Dränagen
7	gemischtkörnige Böden	5 % bis 40 %	bis 60 %	—	Kies-Schluff-Gemische	5 % bis 15 % ≤ 0,063 mm	GU	weit oder intermittierend gestufte Körnungslinie Feinkornanteil ist schluffig			Moränenkies	++	+	++	o	+o	-o	++	++	+	-	+	-
8						über 15 % bis 40 % ≤ 0,063 mm	GU*				Verwitterungskies	+	+o	+	+	-o	--	+	+o	-o	+o	-	--
9					Kies-Ton-Gemische	5 % bis 15 % ≤ 0,063 mm	GT	weit oder intermittierend gestufte Körnungslinie Feinkornanteil ist tonig			Hangschutt	+	+	+	+o	+o	-o	++	++	+	-o	+o	-
10						über 15 % bis 40 % ≤ 0,063 mm	GT*				Geschiebelehm	+o	o	+o	++	+o	-	+o	+o	+o	+	--	--
11			über 60 %	—	Sand-Schluff-Gemische	5 % bis 15 % ≤ 0,063 mm	SU	weit oder intermittierend gestufte Körnungslinie Feinkornanteil ist schluffig			Tertiärsand	++	+	+	o	o	o	++	o	+o	o	-o	-
12						über 15 % bis 40 % ≤ 0,063 mm	SU*				Auelehm Sandlöss	+	o	+o	+	-	--	o	-o	-o	+o	--	--
13					Sand-Ton-Gemische	5 % bis 15 % ≤ 0,063 mm	ST	weit oder intermittierend gestufte Körnungslinie Feinkornanteil ist tonig			Terrassensand Schleichsand	+	+o	+o	+o	o	-o	+	+	+o	o	-	--
14						über 15 % bis 40 % ≤ 0,063 mm	ST*				Geschiebelehm und -mergel	+o	-o	+o	++	-o	-	o	o	o	+	--	--
15	feinkörnige Böden	über 40 %	—	$I_p \leq 4$ % oder unterhalb der A - Linie	Schluff	leicht plastische Tone $w_L < 35$ %	UL	niedrige	schnelle	keine bis leichte	Löss Hochflutlehm	-o	-o	+o	+o	--	--	+o	--	-o	o	--	--
16						mittelplastische Tone 35 % ≤ w_L ≤ 50 %	UM	niedrige bis mittlere	langsame	leichte bis mittlere	Seeton Beckenschluff	-o	-	-o	+	-	--	o	-	-o	+o	--	--
17						ausgeprägt plastische Schluffe $w_L > 50$ %	UA	hohe	keine bis langsame	mittlere bis ausgeprägte	vulkanische Böden Bimsboden	-	-	-	++	-o	-o	-o	-	-	-o	--	--

Table A2-1b: **Soil classification for civil engineering purposes – DIN 18196, edition 05/2011 - (Part 2)**

Sp	1	2	3	4	5	6	7	8			9	10	11	12	13	14	15	16	17	18	19	20	21
	Definition und Benennung							Erkennungsmerkmale (u.a. für Zeilen 15 bis 22)				Anmerkungen[a]											
Zeile	Hauptgruppen	Korngrößenanteil Korndurchmesser ≤ 0,063 mm	Korngrößenanteil Korndurchmesser ≤ 2 mm	Lage zur A-Linie (siehe Bild 1)	Gruppen		Kurzzeichen Gruppensymbol[b]	Trockenfestigkeit	Reaktion beim Schüttelversuch	Plastizität beim Knetversuch	Beispiele	Bautechnische Eigenschaften: Scherfestigkeit	Verdichtungsfähigkeit	Zusammendrückbarkeit	Durchlässigkeit	Erosionsempfindlichkeit	Frostempfindlichkeit	Bautechnische Eignung als Baustoff für: Baugrund für Gründungen	Erd- und Baustraßen	Straßen- und Bahndämme	Dichtungen	Stützkörper	Dränagen
18	feinkörnige Böden	über 40 %	—	$I_P \geq 7$ % und oberhalb der A - Linie	Ton	leicht plastische Tone	$w_L < 35$ % TL	mittlere bis hohe	keine bis langsame	leichte	Geschiebemergel Bänderton	-o	-o	o	+	-	--	o	-	-o	++	--	--
19						mittelplastische Tone	35 % < w_L < 50 % TM	hohe	keine	mittlere	Lösslehm, Seeton, Beckenton Keuperton	-	-	-o	++	-o	-o	o	-	-o	+	--	--
20						ausgeprägt plastische Tone	$w_L > 50$ % TA	sehr hohe	keine	ausgeprägte	Tarras, Lauenburger Ton, Beckenton	--	--	--	++	o	+o	-o	--	-	-	--	--
21	organogene[c] und Böden mit organischen Beimengungen	über 40 %	—	$I_P \geq 7$ % und unterhalb der A - Linie	nicht brenn- oder nicht schwelbar	Schluffe mit organischen Beimengungen und organogene[c] Schluffe	35 % ≤ w_L ≤ 50 % OU	mittlere	langsame bis sehr schnelle	mittlere	Seekreide Kieselgur Miutterboden	-o	-	-o	+o	--	--	--	--	--	--	--	--
22						Tone mit organischen Beimengungen und organogene[c] Tone	$w_L > 50$ % OT	hohe	keine	ausgeprägte	Schlick, Klei tertiäre Kohletone	--	--	-	++	-o	-o	--	--	--	-	--	--
23		bis 40 %		—		grob- bis gemischtkörnige Böden mit Beimengungen humoser Art	OH	Beimengungen pflanzlicher Art, meist dunkle Färbung, Modergeruch, Glühverlust bis etwa 20 % Massenanteil			Mutterboden Paläoboden	o	-o	-o	o	+o	-o	-	o	-	--	--	--
24						grob- bis gemischtkörnige Böden mit kalkigen, kieseligen Bildungen	OK	Beimengungen nicht pflanzlicher Art, meist helle Färbung, leichtes Gewicht, große Porosität			Kalk Tuffsand Wiesenkalk	+	o	-o	-o	o	+o	-o	o	-o	--	--	--

Table A2-1c: **Soil classification for civil engineering purposes – DIN 18196, edition 05/2011 - (Part 3)**

Sp	1	2	3	4	5	6	7	8			9	10	11	12	13	14	15	16	17	18	19	20	21
	Definition und Benennung							Erkennungsmerkmale (u.a. für Zeilen 15 bis 22)				Anmerkungen[a]											
Zeile	Hauptgruppen	Korngrößenanteil Korndurchmesser ≤ 0,063 mm	Korngrößenanteil Korndurchmesser ≤ 2 mm	Lage zur A-Linie (siehe Bild 1)	Gruppen		Kurzzeichen Gruppensymbol[b]	Trockenfestigkeit	Reaktion beim Schüttelversuch	Plastizität beim Knetversuch	Beispiele	Bautechnische Eigenschaften: Scherfestigkeit	Verdichtungsfähigkeit	Zusammendrückbarkeit	Durchlässigkeit	Erosionsempfindlichkeit	Frostempfindlichkeit	Bautechnische Eignung als Baustoff für: Baugrund für Gründungen	Erd- und Baustraßen	Straßen- und Bahndämme	Dichtungen	Stützkörper	Dränagen
25	organische Böden	—	—	—	brenn- oder schwelbar	nicht bis mäßig zersetzte Torfe (Humus)	HN	an Ort und Stelle aufgewachsene Humusbildungen	Zersetzungsgrad 1 bis 5 nach DIN 19682-12, faserig, holzreich, hellbraun bis braun		Niedermoor-, Hochmoor-, Bruchwaldtorf	-	--	--	o	+o	-	--	--	--	--	--	--
26						zersetzte Torfe	HZ		Zersetzungsgrad 6 bis 10 nach DIN 19682-12, schwarzbraun bis schwarz			--	--	--	+o	-	--	--	--	--	--	--	--
27						Schlamme als Sammelbegriff für Faulschlamm, Mudde, Gyttja, Dy und Sapropel	F	unter Wasser abgesetzte (sedimentäre) Schlamme aus pflanzenresten, Kot und Mikroorganismen, oft von Sand, Ton und Kalk durchsetzt, blauschwarz oder grünlich bis gelbbraun, gelegentlich dunkelgraubraun bis blauschwarz, federnd, weichschwammig			Mudde Faulschlamm	--	--	--	+o	-	--	--	--	--	--	--	--
28	Auffüllung	—	—	—	Auffüllung aus natürlichen Böden (jeweiliges Gruppensymbol in Klammern)		[ ]	—			—	—											
29					Auffüllung aus Fremdstoffen[d]		A	—			Müll, Schlacke Bauschutt Industrieabfall	—											

a Die Spalten 10 bis 21 enthalten als grobe Leitlinie Hinweise auf bautechnische Eigenschaften und auf die bautechnische Eignung nebst Beispielen in Spalte 9. Diese Angaben sind keine normativen Festlegungen.
b An den Kurzzeichen U und T darf anstelle des Sterns auch der Querbalken verwendet werden, siehe Tabelle 3.
c Unter Mitwirkung von Organismen gebildete Böden.
d Die Klassifizierung ist kein Ersatz für die abfalltechnische Bewertung.

Table A2-1d: **Soil classification for civil engineering purposes – DIN 18196, edition 05/2011 - (Part 4)**

Legende: Bedeutung der qualitativen und wertenden Angaben							
Spalte 10		Spalte 11		Spalten 12 bis 15		Spalten 16 bis 21	
--	sehr gering		sehr schlecht	--	sehr groß	--	ungeeignet
-	gering	-	schlecht	-	groß	-	weniger geeignet
-o	mäßig	-o	mäßig	-o	groß bis mittel	-o	mäßig brauchbar
o	mittel	o	mittel	o	mittel	o	brauchbar
+ o	groß bis mittel	+o	gut bis mittel	+o	gering bis mittel	+o	geeignet
+	groß	+	gut	+	sehr gering	+	gut geeignet
++	sehr groß	++	sehr gut	++	vernachlässigbar klein	++ t	sehr gut geeigne

Frost susceptibility classes (ZTV E-StB)

	Frost susceptibility	**Soil groups (DIN 18196)**
F1	No frost susceptibility	GW, GI, GE SW, SI, SE
F2	Low to medium frost susceptibility	TA OT, OH, OK ST[1)], GT[1)] SU[1)], GU[1)]
F3	High frost susceptibility	TL, TM UL, UM, UA OU ST*, GT* SU*, GU*

[1)] Classed as F1 with a content of grains under 0.063 mm of 5.0 mass% at $C_U \geq 15.0$ or 15.0 mass% at $C_U \leq 6.0$
In the range $6.0 < C_U < 15.0$, the permissible content of grain under 0.063 for an F1 classification can be interpolated linearly (see Fig. 2)

Table A2-2: **Frost susceptibility classes in accordance with ZTV E-StB 17**

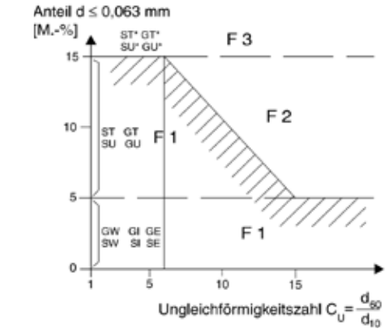


Fig. A2-1: **Assignment of frost susceptibility classes**

House entrance, Freising, Germany

PRODUKTDATENBLATT ***Bettungsmaterial B0/4G*** | Sorten-Nr. .....

Baustoffgemisch aus gebrochenen Gesteinskörnungen für Pflasterdecken und Plattenbeläge in ungebundener Ausführung gemäß den TL Pflaster-StB und den ZTV Pflaster-StB

Gesteinsart .....
(Hüttensand (HS) und Hochofenstückschlacke (HOS) dürfen gemäß den TL Pflaster-StB 06, Abschn. 2, nur in geeignetem Gemisch mit natürlichen Gesteinskörnungen eingesetzt werden)

Anwendungsbereich

Pflasterdecken bis einschließlich Belastungsklasse Bk3,2 gemäß den „RStO 12“ und Plattenbeläge

Gesteinsspezifische Eigenschaften[1)]

Kornform grober Gesteinskörnungen	nicht zutreffend	- -	
Schlagzertrümmerungswert bzw. Los Angeles Koeffizient	Soll: ≤ 26[2)] Ist:	Soll-Kategorie SZ_{26}[2)] Ist-Kategorie	TL Gestein-StB 04, Fassung 2007, Anhang H
	Soll: ≤ 30[2)] Ist:	Soll-Kategorie LA_{30}[2)] Ist-Kategorie	TL Gestein-StB 04, Fassung 2007, Anhang H

[1)] Alle hier nicht aufgeführten gesteinsspezifischen Eigenschaften gemäß den TL Gestein-StB 04, Fassung 2007, Anhang H, werden ebenfalls eingehalten.

[2)] Gesteine, die zur Herstellung von Bettungsmaterial für Pflasterdecken der Belastungsklasse Bk1,0 oder höher (RStO 12) verwendet werden, sollten mindestens der Kategorie SZ_{22} (LA_{25}) entsprechen. Bei Pflasterdecken mit besonderen Beanspruchungen gemäß den „RStO 12“ oder solchen mit einer Tragschicht mit Bindemittel mindestens SZ_{18} (LA_{20}) (ZTV Pflaster-StB 06, 1.5.1.1).

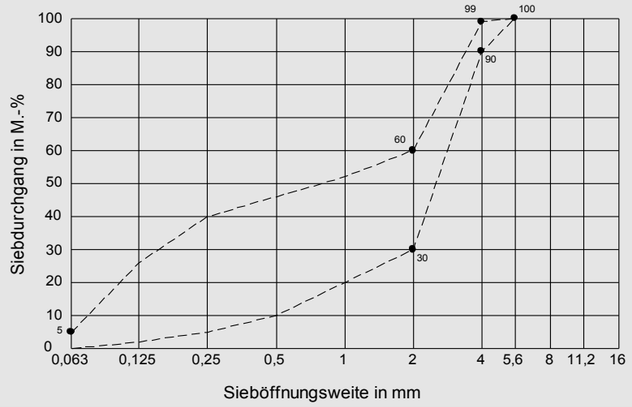
Gemischspezifische Eigenschaften

Anteil gebrochener Oberflächen	Anteil vollständig gebrochener und teilweise gebrochener Körner 90-100 M.-%; Anteil vollständig gerundeter Körner 0-3 M.-%	Kategorie $C_{90/3}$	ZTV Pflaster-StB 06, 1.5.1.1
Fließkoeffizient	≥ 35	Kategorie $E_{CS}35$	ZTV Pflaster-StB 06, 1.5.1.1
max. Feinanteil	Durchgang 0,063 mm ≤ 5 M.-%	Kategorie UF_5	TL Pflaster-StB 06, 3.2.2
min. Feinanteil	keine Anforderung	Kategorie LF_{NR}	TL Pflaster-StB 06, 3.2.2
Überkornanteil	Durchgang bei 2 D - - Durchgang bei 1,4 D 100 M.-% Durchgang bei D 90-99 M.-%	Kategorie OC_{90}	TL Pflaster-StB 06, 3.2.3

Die Kornzusammensetzung des Baustoffgemisches liegt innerhalb des nebenstehenden Sieblinienbereiches.

(Siebdurchgänge mit Wertangabe gemäß den TL Pflaster-StB 06, 3.2.2, 3.2.3 und 3.2.4, Tabelle 4, Zeile 1, Kategorie $G_{U,B}$.

Siebdurchgänge ohne Wertangabe in Anlehnung an die Empfehlungen der Herausgeber.)



Das Baustoffgemisch wird gleichmäßig durchfeuchtet und gleichmäßig gemischt ausgeliefert (TL Pflaster-StB 06, 3.1)

Fig. A3-1: **Example of product datasheet for bedding material (here: bedding material B 0/4 G consisting of crushed rock aggregate)**

PRODUKTDATENBLATT ***Bettungsmaterial B0/5G*** | Sorten-Nr. .....

Baustoffgemisch aus gebrochenen Gesteinskörnungen für Pflasterdecken und Plattenbeläge in ungebundener Ausführung gemäß den TL Pflaster-StB und den ZTV Pflaster-StB

Gesteinsart .....
(Hüttensand (HS) und Hochofenstückschlacke (HOS) dürfen gemäß den TL Pflaster-StB 06, Abschn. 2, nur in geeignetem Gemisch mit natürlichen Gesteinskörnungen eingesetzt werden)

Anwendungsbereich

Pflasterdecken bis einschließlich Belastungsklasse Bk3,2 gemäß den „RStO 12“ und Plattenbeläge

Gesteinsspezifische Eigenschaften[1)]

Kornform grober Gesteinskörnungen	Kornformkennzahl ≤ 50 bzw. Plattigkeitskennzahl ≤ 50	Kategorie SI_{50} bzw. Kategorie FI_{50}	TL Gestein-StB 04, Fassung 2007, Anhang H
Schlagzertrümmerungswert bzw. Los Angeles Koeffizient	Soll: ≤ 26[2)] Ist:	Soll-Kategorie SZ_{26}[2)] Ist-Kategorie	TL Gestein-StB 04, Fassung 2007, Anhang H
	Soll: ≤ 30[2)] Ist:	Soll-Kategorie LA_{30}[2)] Ist-Kategorie	TL Gestein-StB 04, Fassung 2007, Anhang H

[1)] Alle hier nicht aufgeführten gesteinsspezifischen Eigenschaften gemäß den TL Gestein-StB 04, Fassung 2007, Anhang H, werden ebenfalls eingehalten.

[2)] Gesteine, die zur Herstellung von Bettungsmaterial für Pflasterdecken der Belastungsklasse Bk1,0 oder höher (RStO 12) verwendet werden, sollten mindestens der Kategorie SZ_{22} (LA_{25}) entsprechen. Bei Pflasterdecken mit besonderen Beanspruchungen gemäß den „RStO 12“ oder solchen mit einer Tragschicht mit Bindemittel mindestens SZ_{18} (LA_{20}) (ZTV Pflaster-StB 06, 1.5.1.1).

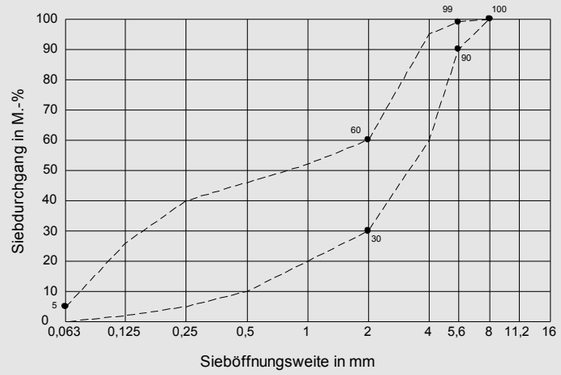
Gemischspezifische Eigenschaften

Anteil gebrochener Oberflächen	Anteil vollständig gebrochener und teilweise gebrochener Körner 90-100 M.-%; Anteil vollständig gerundeter Körner 0-3 M.-%	Kategorie $C_{90/3}$	ZTV Pflaster-StB 06, 1.5.1.1
Fließkoeffizient	≥ 35	Kategorie $E_{CS}35$	ZTV Pflaster-StB 06, 1.5.1.1
max. Feinanteil	Durchgang 0,063 mm ≤ 5 M.-%	Kategorie UF_5	TL Pflaster-StB 06, 3.2.2
min. Feinanteil	keine Anforderung	Kategorie LF_{NR}	TL Pflaster-StB 06, 3.2.2
Überkornanteil	Durchgang bei 2 D 100 M.-% Durchgang bei 1,4 D 100 M.-% Durchgang bei D 90-99 M.-%	Kategorie OC_{90}	TL Pflaster-StB 06, 3.2.3

Die Kornzusammensetzung des Baustoffgemisches liegt innerhalb des nebenstehenden Sieblinienbereiches.

(Siebdurchgänge mit Wertangabe gemäß den TL Pflaster-StB 06, 3.2.2, 3.2.3 und 3.2.4, Tabelle 4, Zeile 1, Kategorie $G_{U,B}$.

Siebdurchgänge ohne Wertangabe in Anlehnung an die Empfehlungen der Herausgeber.)



Das Baustoffgemisch wird gleichmäßig durchfeuchtet und gleichmäßig gemischt ausgeliefert (TL Pflaster-StB 06, 3.1)

Fig. A3-2: **Example of product datasheet for bedding material (here: bedding material B 0/5 G consisting of crushed rock aggregate)**

PRODUKTDATENBLATT ***Fugenmaterial F0/4G***	Sorten-Nr. .....

Baustoffgemisch aus gebrochenen Gesteinskörnungen für Pflasterdecken und Plattenbeläge in ungebundener Ausführung gemäß den TL Pflaster-StB und den ZTV Pflaster-StB

Gesteinsart .....
(Hüttensand (HS) und Hochofenstückschlacke (HOS) dürfen gemäß den TL Pflaster-StB 06, Abschn. 2, nur in geeignetem Gemisch mit natürlichen Gesteinskörnungen eingesetzt werden)

Anwendungsbereich

Pflasterdecken bis einschließlich Belastungsklasse Bk3,2 gemäß den „RStO 12“ und Plattenbeläge

Gesteinsspezifische Eigenschaften[1)]

Kornform grober Gesteinskörnungen	nicht zutreffend	- -	
Schlagzertrümmerungswert bzw. Los Angeles Koeffizient	Soll-Wert: ≤ 26 Ist-Wert:	Soll-Kategorie SZ_{26} Ist-Kategorie	TL Gestein-StB 04, Fassung 2007, Anhang H
	Soll-Wert: ≤ 30 Ist-Wert:	Soll-Kategorie LA_{30} Ist-Kategorie	TL Gestein-StB 04, Fassung 2007, Anhang H

[1)] Alle hier nicht aufgeführten gesteinsspezifischen Eigenschaften gemäß den TL Gestein-StB 04, Fassung 2007, Anhang H, werden ebenfalls eingehalten.

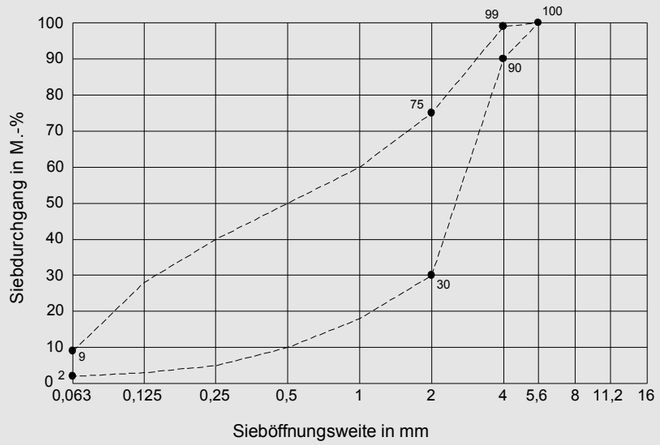
Gemischspezifische Eigenschaften

Anteil gebrochener Oberflächen	Anteil vollständig gebrochener und teilweise gebrochener Körner 90-100 M.-%; Anteil vollständig gerundeter Körner 0-3 M.-%	Kategorie $C_{90/3}$	ZTV Pflaster-StB 06, 1.5.1.2
Fließkoeffizient	≥ 35	Kategorie $E_{CS}35$	ZTV Pflaster-StB 06, 1.5.1.2
max. Feinanteil	Durchgang bei 0,063 mm ≤ 9 M.-%	Kategorie UF_9	TL Pflaster-StB 06, 3.3.2
min. Feinanteil	Durchgang bei 0,063 mm ≥ 2 M.-%	Kategorie LF_2	TL Pflaster-StB 06, 3.3.2
Überkornanteil	Durchgang bei 2 D - - Durchgang bei 1,4 D 100 M.-% Durchgang bei D 90-99 M.-%	Kategorie OC_{90}	TL Pflaster-StB 06, 3.3.3

Die Kornzusammensetzung des Baustoffgemisches liegt innerhalb des nebenstehenden Sieblinienbereiches.

(Siebdurchgänge mit Wertangabe gemäß den TL Pflaster-StB 06, 3.3.2, 3.3.3 und 3.3.4, Tabelle 11, Zeile 1, Kategorie $G_{U,F}$.

Siebdurchgänge ohne Wertangabe in Anlehnung an die Empfehlungen des Merkblattes M FP 1.)



Das Baustoffgemisch wird gleichmäßig durchfeuchtet und gleichmäßig gemischt ausgeliefert (TL Pflaster-StB 06, 3.1)

Fig. A3-3: **Example of product datasheet for jointing material (here: jointing material F 0/4 G consisting of crushed rock aggregate)**

PRODUKTDATENBLATT ***Fugenmaterial F0/2G***	Sorten-Nr. .....

Baustoffgemisch aus gebrochenen Gesteinskörnungen für Pflasterdecken und Plattenbeläge in ungebundener Ausführung gemäß den TL Pflaster-StB und den ZTV Pflaster-StB

Gesteinsart .....
(Hüttensand (HS) und Hochofenstückschlacke (HOS) dürfen gemäß den TL Pflaster-StB 06, Abschn. 2, nur in geeignetem Gemisch mit natürlichen Gesteinskörnungen eingesetzt werden)

Anwendungsbereich

Pflasterdecken aus Verbundsteinen mit systembedingt geringen Fugenbreiten (ca. 3 mm) bis einschließlich Belastungsklasse Bk3,2 gemäß den „RStO 12“.

Pflasterdecken bis einschließlich Belastungsklasse Bk3,2 gemäß den „RStO 12“ und Plattenbeläge, bewittert oder unbewittert, die nicht maschinell gereinigt werden; Fugenbreite 3 bis 5 mm.

Gesteinsspezifische Eigenschaften[1)]

Kornform grober Gesteinskörnungen	nicht zutreffend	- -	
Schlagzertrümmerungswert bzw. Los Angeles Koeffizient	Soll-Wert: ≤ 26 Ist-Wert:	Soll-Kategorie SZ_{26} Ist-Kategorie	TL Gestein-StB 04, Fassung 2007, Anhang H
	Soll-Wert: ≤ 30 Ist-Wert:	Soll-Kategorie LA_{30} Ist-Kategorie	TL Gestein-StB 04, Fassung 2007, Anhang H

[1)] Alle hier nicht aufgeführten gesteinsspezifischen Eigenschaften gemäß den TL Gestein-StB 04, Fassung 2007, Anhang H, werden ebenfalls eingehalten.

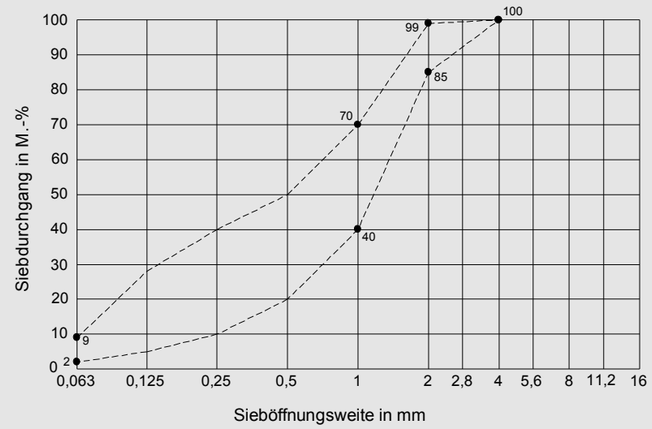
Gemischspezifische Eigenschaften

Anteil gebrochener Oberflächen	nicht zutreffend	- -	- -
Fließkoeffizient	≥ 35	Kategorie $E_{CS}35$	ZTV Pflaster-StB 06, 1.5.1.2
max. Feinanteil	Durchgang bei 0,063 mm ≤ 9 M.-%	Kategorie UF_9	TL Pflaster-StB 06, 3.3.2
min. Feinanteil	Durchgang bei 0,063 mm ≥ 2 M.-%	Kategorie LF_2	TL Pflaster-StB 06, 3.3.2
Überkornanteil	Durchgang bei 2 D 100 M.-% Durchgang bei 1,4 D 95-100 M.-% Durchgang bei D 85-99 M.-%	Kategorie G_F85	TL Gestein-StB 06, Fassung 2007, 2.2.2 und Anhang H

Die Kornzusammensetzung des Baustoffgemisches liegt innerhalb des nebenstehenden Sieblinienbereiches.

(Siebdurchgänge mit Wertangabe gemäß den TL Gestein-StB 04, Tabelle 2, Zeile 2, und den ZTV Pflaster-StB 06, 1.5.1.2.

Siebdurchgänge ohne Wertangabe in Anlehnung an die Empfehlungen des Merkblattes M FP 1.)



Das Baustoffgemisch wird gleichmäßig durchfeuchtet und gleichmäßig gemischt ausgeliefert (TL Pflaster-StB 06, 3.1)

Fig. A3-4: **Example of product datasheet for jointing material as joint sealing (here: jointing material F 0/2 G consisting of crushed rock aggregate)**

Example of superstructure dimensioning according to RStO 12

The examples should not be implemented in specific project planning without professional planning consultation!

1.) Residential trunk roads with low public bus traffic

Planning data:

- Urban trunk road in the Osnabrück region; Heavy traffic load only due to the bus traffic, waste-collection vehicles and light commercial vehicles
- Bus traffic (approx. 25 buses/day and direction) with stops at the side of the carriageway
- No special climate influences
- Subgrade / substructure: Silty sand (S_U in accordance with DIN 18196) with a content of cohesive components of 10 mass% and a non-uniformity coefficient C_U of 13:
  F2 soils (low to medium frost susceptibility)
- Groundwater conditions: No ground- and formation water to a depth of 1.50 m below subsoil

Construction class:

As the freight traffic load $DTV^{(SV)}$ of the carriageway is not known and bus traffic constitutes the relevant heavy traffic load, the construction class is estimated based on Table A1-9 "Trunk road" and Table A1-10. The Construction class Bk1.8 results. In addition, owing to buses braking, starting up or turning on tight radii, special action effects must be taken into account!

Minimum thickness of the frost-resistant superstructure:

As the subgrade does not consist of a frost-resistant F1 soil, the minimum thickness of the frost-resistant superstructure results from the addition of the starting value and increased or reduced thickness based on local conditions:

Starting value	Construction class Bk1.8	50 cm
	Subgrade/substructure: F2 soil	

Table A4-1: **Minimum thickness of the frost-resistant superstructure, derived from RStO 12, Table 6 (see A1-13)**

Zu-/ Abschläge	Frost action zone I	A =	± 0 cm
	No climate influences	B =	± 0 cm
	No ground- and formation water to a depth of 1.50 m below subsoil	C =	± 0 cm
	In built-up areas (same terrain)	D =	± 0 cm
	Dewatering of the carriageway with ditches, drains and pipes	E =	- 5 cm
Total	Increased or reduced thickness (A+B+C+D+E)		- 5 cm

Table A4-2: **Increased or reduced thickness due to local conditions, derived from RStO 12, Table 7 (see Table A1-14)**

Example: Carriageway structure, from RStO 12, Chart 3, Line 1, Bk1.8 (see Table A1-16):

10 cm Dry jointed pavement
4 cm Bedding
25 cm Crushed rock base course, $E_{v2} \geq 150$ MPa
Frost blanket, $E_{v2} \geq 120$ MPa

45 cm Minimum thickness of the frost-resistant superstructure, from RStO 12,
Table 6 with 50 cm and the minimum thickness due to local conditions of -5 cm

Defining the thickness of the frost blanket

On account of the construction-related requirements in DIN 18318, ZTV Pflaster-StB and ZTV SoB-StB, the minimum thickness of the frost-resistant superstructure must be verified against the thickness necessary to ensure the required load-bearing capacity. Depending on the load-bearing capacity on the subsoil, guide values for the thickness of the overlying base courses without binders can be obtained from Table A1-15.

The thickness of the frost blanket is defined with provision for the minimum thickness required to achieve the load-bearing capacity on its surface as no thickness for the frost blanket is specified in Table A1-16. Based on a static deformation modulus of $E_{v2} \geq 45$ MPa on the subsoil, on the frost blanket a static deformation modulus of $E_{v2} \geq 120$ MPa must be proven. From Table A1-15, for the frost blanket comprising predominantly unbroken material selected here, a guide value of 35 cm for the thickness of the frost blanket can be obtained.

In this example, as a result of the above, the thickness of the superstructure easily exceeds minimum thickness of the frost-resistant superstructure determined in accordance with RStO.

Thickness of the frost blanket (FB), as specified in RStO 12, Table 8 (see Table A1-15):

35 cm Frost blanket (FB) = of mainly unbroken material for
$E_{v2} \geq 45$ MPa (subsoil)
$E_{v2} \geq 120$ MPa (surface BCOB)

Tactile surface indicators in a ribbed structure combined with clinker pavers (square shape) in a diagonal bond

Course thicknesses and typical selection of the construction materials with provision for special requirements (only the essential specifications):

10 cm Clinker pavers, 10 cm thickness or as rowlock course (laid on edge), laid in diagonal herringbone bond, joint width: 3 to 5 mm, joint filling of crushed rock grade 0/5 in accordance with product datasheet F 0/5 G
4 cm Paver bedding (3 to 5 cm) of a crushed rock grade 0/8 in accordance with product datasheet B 0/8 G;
25 cm Crushed rock base course 0/45 in accordance with TL and ZTV SoB-StB, Section 2.3, E_{v2} on the surface ≥ 150 MPa in accordance with ZTV Pflaster-StB
35 cm Frost blanket 0/32 in accordance with TL and ZTV SoB-StB, Section 2.2 of round-grained . aggregate grade, E_{v2} on the surface ≥ 120 MPa

74 cm Mean superstructure thickness

Alternative carriageway structure in accordance with RStO 12, Chart 3, Line 4 (only the essential specifications):

10 cm Clinker pavers, 10 cm thick or rowlock course (laid on edge), bond and joint filling as above
4 cm Paver bedding (3 to 5 cm) as above
14 cm Water-permeable asphalt base course 0/22, with geotextile on top (e.g. mechanically consolidated fleece GRK 4, 250 g/m²)
30 cm Frost blanket 0/45 in accordance with TL and ZTV SoB-StB, Section 2.2, comprising aggregate mix, E_{v2} on the surface ≥ 120 MPa

58 cm Mean superstructure thickness

From a comparison of the two alternative superstructure structures specified, it can be seen that the construction methods specified in RStO can be different in respect of the construction costs as well as the expected behaviour over the service lifetime. In the selection of the construction method, regional experience with the respective construction method, the availability of the construction materials and competence and capabilities of the regional construction contractors should be taken into consideration.

Use of alternating formats

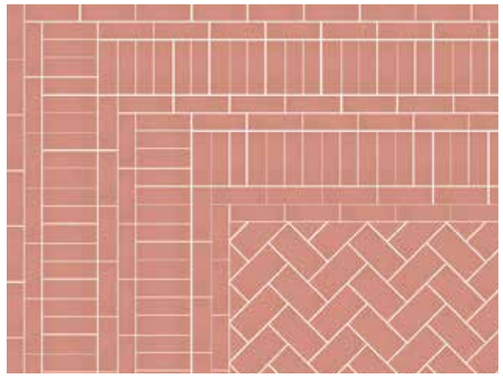


Fig. A5-1: **Edging with upright, offset clinker pavers laid in alternating patterns next to a flat-laid herringbone bond**

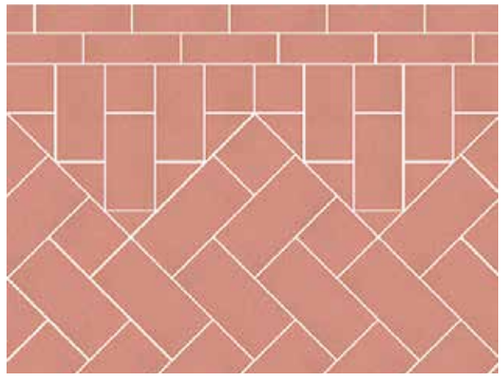


Fig. A5-2: **Edging with upright and flat-laid clinker pavers next to a flat-laid herringbone bond**

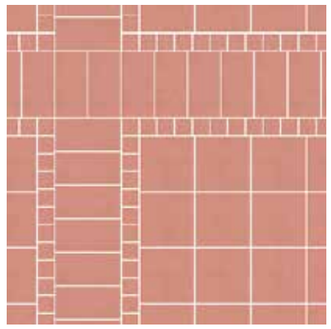


Fig. A5-3: **Ornamental arrangement of paved sections with three different clinker paver formats**

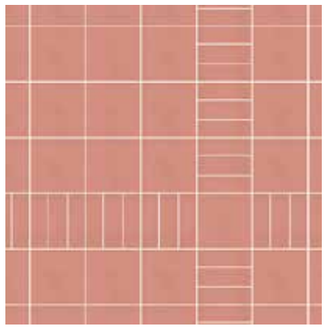


Fig. A5-4: **Paving of square-shaped pavers with friezes of pavers set on edge**

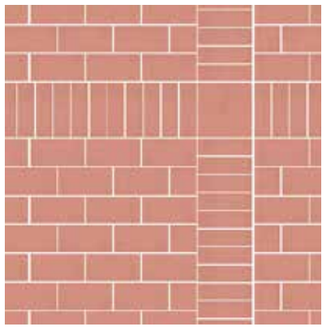


Fig. A5-5: **Square-shaped pavers at the intersections pf paving laid in a half bond**

Odense, Gronnegade, Denmark

Installation as round edgings or in curves

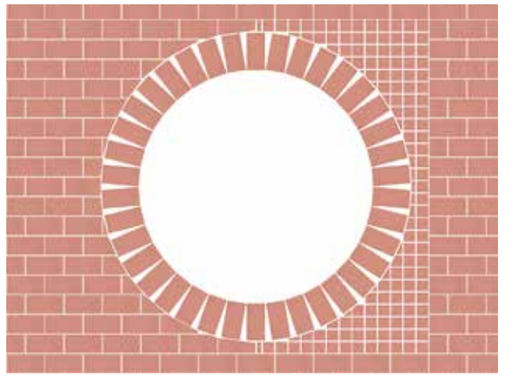


Fig. A5-6: **Tree ring consisting of standard-format clinker pavers laid flat with a wedge joint, adjoining standard-size or mosaic clinker pavers**

Fig. A5-7: **Tree ring with wedge-shaped clinker pavers**

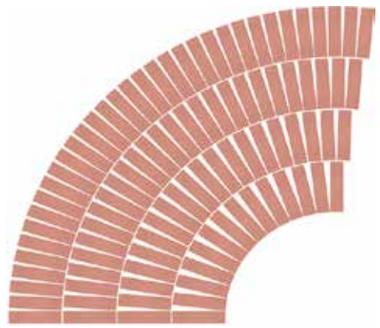


Fig. A5-8: **Paved curve with long-format clinker pavers or clinker pavers set on edge**

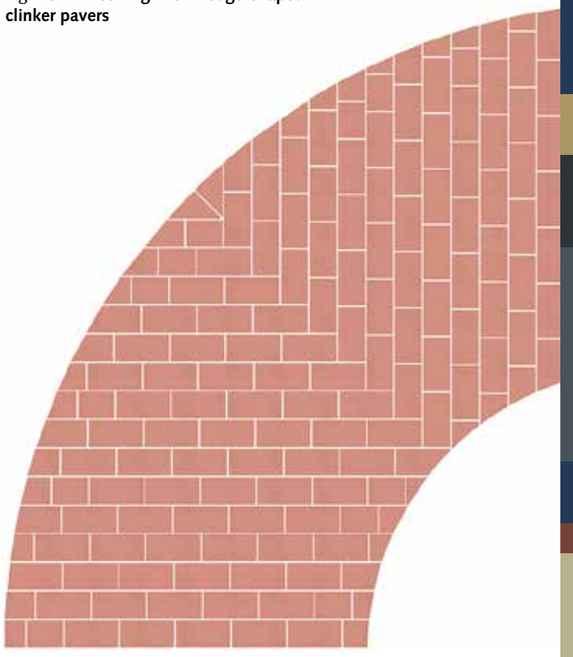


Abb. A5-9: **Curve laid with rectangular pavers. The edging and adapter pavers must be cut to fit**

Baroque Garden, Münster, Germany

Laying pavers in corners

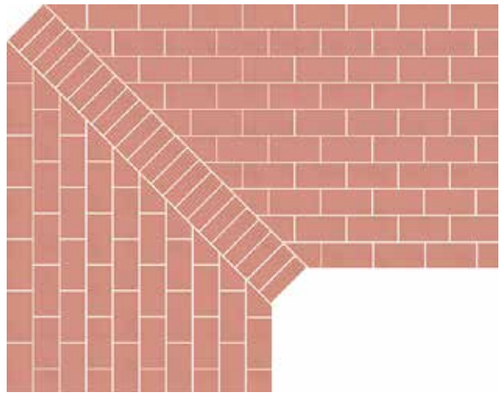


Fig. A5-10: **Mitre joint with clinker pavers in a rowlock**

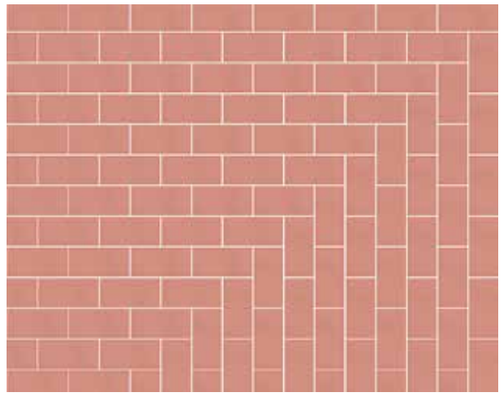


Fig. A5-11: **Mitre joint with clinker pavers with offset joint**

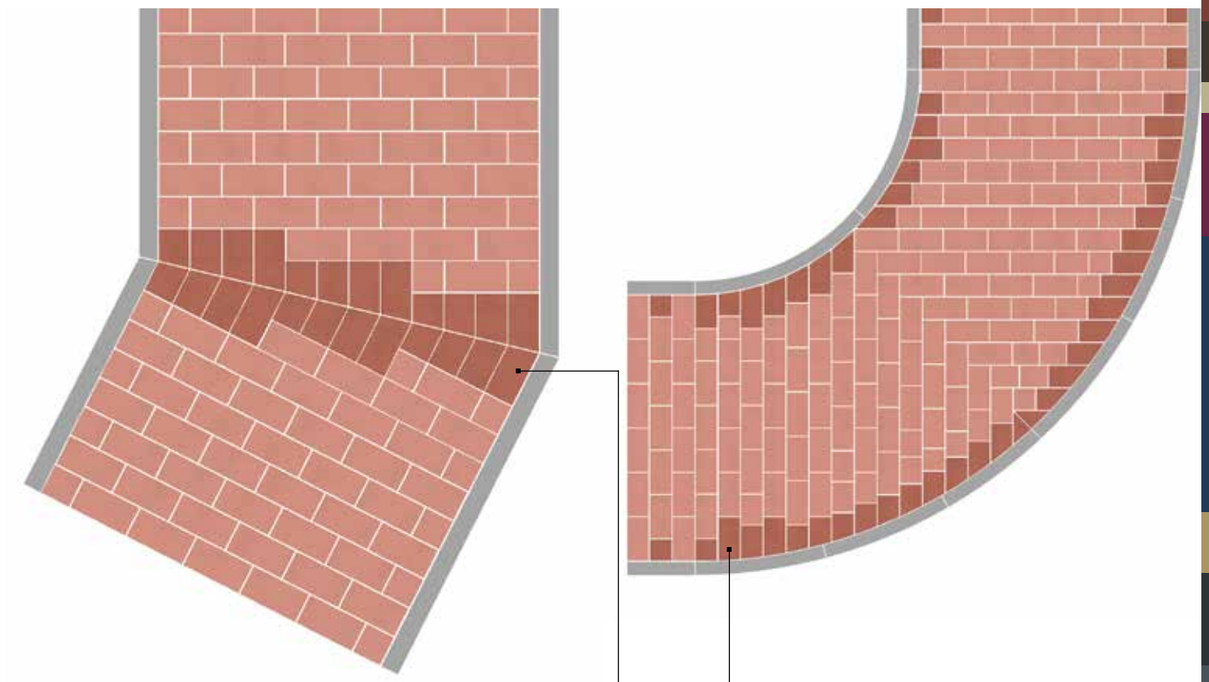


Fig. A5-12: **Mitre joint with cutting of the adapter pavers**

Joint detail – drainage gutter, Barsinghausen, Germany

Mosaic clinker bricks in bound construction

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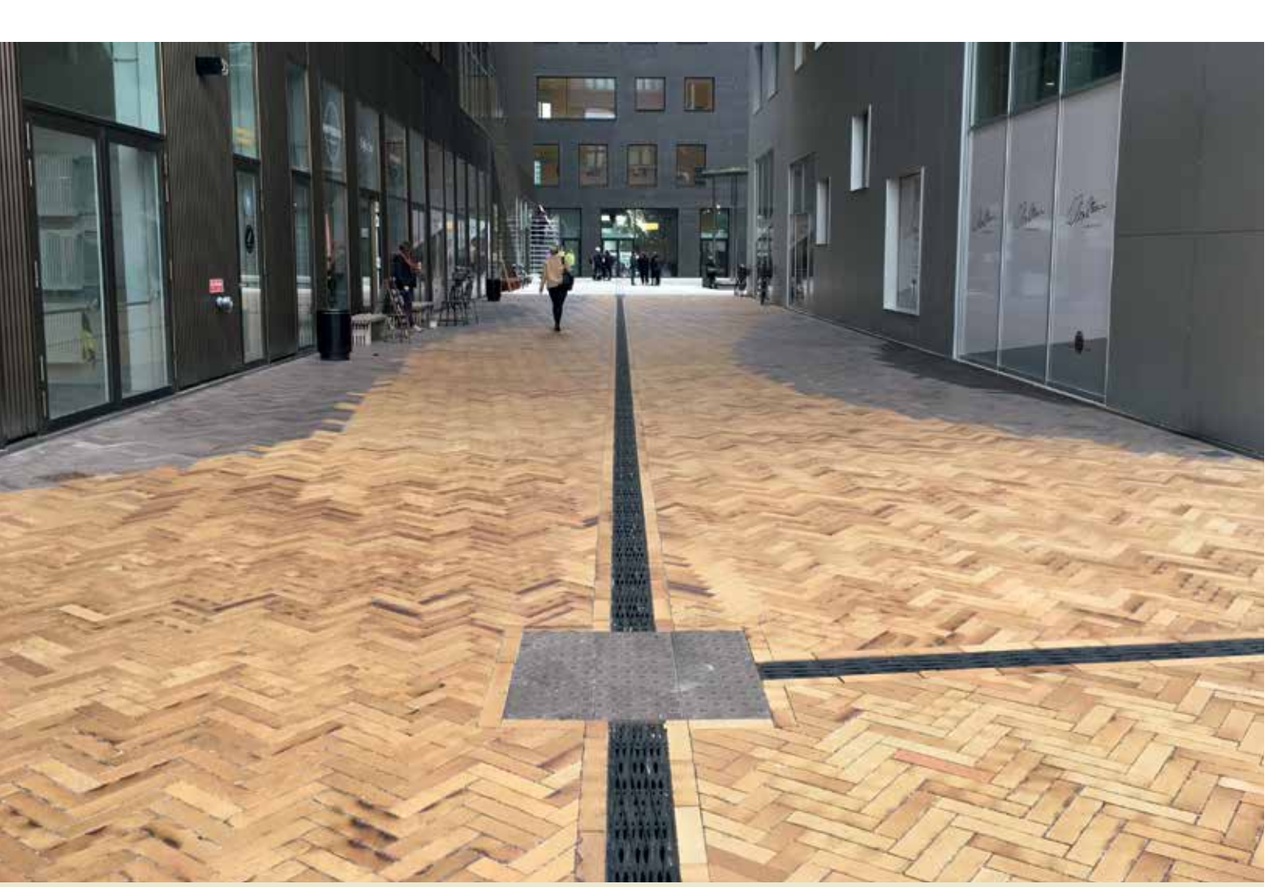

Carlsberg Quarter, Copenhagen-Valby, Denmark

Paving with clinker pavers – how to do it right!

1. The base course as the base supporting the bedding material must be able to withstand expected loads, be frost-resistant and water permeable. The base course installed as layers and compacted in line with requirements must already have the 2.5 % gradient required for the clinker paver surface. To meet the requirement for a level thickness of the bedding, it is recommended that a maximum unevenness of 1 cm is permitted below a 4-m bar. If a base already exists, it may need to be prepared accordingly.

2. The edging, e.g. a rowlock set in mortar with external haunch (rear support), prevents displacement of the clinker pavers in the edge areas. For unimpeded drain-off of the surface water, the top edge of the edging should be set at about 1 cm below the final height level of the vibration-compacted clinker paving.

3. Suitable bedding material are construction material mixes consisting of crushed aggregate 0/4, 0/5 and 0/8 mm with sufficient strength, e.g. crushed sand/chippings/mixes of hard rocks like basalt, diabase, etc. It is recommended that limestone with its weaker grains is not used as bedding material. For traffic areas with low loads and private areas, natural sand/gravel/mixes in 0/4 and 0/5 mm grades are also suitable. No bedding material containing substances with potential efflorescence should be used. The paving bed in the compacted state should have a thickness of no less than 2 cm and no more than 5 cm.

4. Clinker pavers should be laid with joints of at least 3 mm in width. The planned width of the joints should not exceed 5 mm. If clinker pavers are laid with their edges touching, there is a danger of edge chipping, that is spalling. The run of the joints should be uniform and preferably aligned to a line during laying of the pavers. The joint is used to offset unavoidable material tolerances. The jointing material should be matched to the bedding material in respect of its grain size distribution. Suitable for carriageways are crushed aggregate in the grades 0/3, 0/4 and 0/5 mm, as well as the grade 0/2 mm, which is swept into the joint and washed in with limited addition of water to seal the joints.

5. The clinker pavers are laid from the already finished paving on the precompacted and screeded paving bed. Clinker pavers should be wet-cut. The pavers should not be dry-cut under any circumstances on account of a potential harmful respirable dust exposure. During laying of the paving, several packs of clinker pavers should be opened and the pavers from the different packs randomly mixed. To prevent displacement of the clinker pavers, the joints of the laid paving must be filled with jointing material continuously as the laying of the pavers progresses.

6. For vibration of the paving, a plate vibrator with plastic protective skirt should preferably be used. After vibration, the joints should be closed again with the washing in of jointing material. If the edges of the pavers become chipped, the damaged clinker pavers should be replaced. To allow consolidation of the jointing and bedding material, the clinker paver surface should not be trafficked for several days before use. Paving joints should be inspected regularly and, where necessary, refilled with jointing material without delay. Only a closed and compacted joint can keep the clinker paver firmly in place in the paved surface. The use of sweepers with suction facility should not be used in the first months after laying of the paving.

7. Despite all precautionary measures, a slight grey bloom can form on the paving. This disappears naturally when exposed to weather elements. In covered areas, under roof overhangs or under carports that are not reached by natural weathering, any deposits should be removed by sweeping, brushing or washing the paving. In the case of the stubborn deposits, it may be necessary to remove these semi-mechanically with brushers or commercially available stone cleaners.

8. Paved surfaces should be cleaned carefully. Cleaning devices with rotating brushes have proven effective. For machine cleaning, suction should be avoided. If cleaning agents are used, the manufacturer's instructions should be followed. Suitability of the cleaning agent should be tested first on a less prominent area of the paving. Wet-cleaning machines with rotating brushes are the preferred option. If jointing material is removed during cleaning the joints must be refilled without delay. Suction sweepers should only be used after the paving has been installed for one year at least.

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