Planning Aid

for planning, laying and maintaining water permeable surface reinforcements made with the TTE® system from HÜBNER-LEE

Outside facilities

Building in Harmony with Nature

An ecological concept for surface reinforcement

- High load bearing capacity through load distribution
- Near-natural decentralised drainage system
- Maintains the living soil layer
- Treatment of polluted precipitation runoffs
- Groundwater protection and new creation

TTE® SYSTEM

for sustainable building

Protection of the soil life

www.tte.eu

HÜBNER-LEE

Introduction to the Planning Aid

The TTE® construction principle represents an innovative and very ecological form of surface reinforcement. Our mission statement "Building in Harmony with Nature" is not some kind of advertising slogan – it is our philosophy. The TTE® concept, in stark contrast to the conventional ecological construction principles, does not involve any major impairment (intervention in) of the ecosystem.

The top soil is usually retained or improved and built on by the system, whereby nature and her valuable ecological functions can be integrated into the system. Apart from sustainable handling of the protected resource the earth and preservation of the microorganisms living in it (up to 200 million per m²), this system also allows essential functions for the protected resource water, such as cleaning of rain water by means of degradation processes for materials, to be fulfilled. Thanks to TTE® paving areas which have a cleaning function this is now not only possible for greened reinforcements. The low demands on compacting of the soil and the base course layer and the resulting permanent water permeability and water storage capacity of the TTE® construction principle are setting new benchmarks in the ecology and functionality of permeable paved and green surfaces. One further feature which raises the TTE® construction principle above the others is creation of optimal vegetative conditions which has been the origin of the numerous "green references". This property also has a positive influence on our air and the microclimate due to cooling, an increase in the air humidity and binding of dust.

Creation of a near-natural soil, water and air balance without any significant intervention into the various protected resources allows compensation for interventions. The decentralized water management using the TTE® system avoids floods, new formation of the ground water is promoted and high investment costs for additional water drainage systems and rain water fees are usually completely unnecessary.

Floods, climate change and pollution of the ground as well as the ground water clearly show how much ecologically built on surfaces are becoming an urgent necessity and that we must go through a rethinking process – away from the reckless sealing of our landscape towards drainage surfaces with a biological cleaning function. In this respect the TTE® concept offers both an ecological and an economic solution.

The planning aid represents a practice-oriented supplement to the brochure "Building in Harmony with Nature". Detailed information, pictorial representations and explanation of typical errors made in practice should contribute to correct use of the TTE® system and both simplify and achieve an optimal function.

The TTE® construction principle is setting new benchmarks in the ecology and functionality of permeable paved and green surfaces.

User instructions

Our planning instructions reflect the status of our knowledge and our experience at the point in time of their printing. Therefore we ask you to always use the respective latest edition (www.huebner-lee.de/downloads/). If in doubt please feel free to contact us.

This planning aid is an important source of information for professional behaviour in normal cases. If does not make any claims to be absolutely complete and cannot include all conceivable special cases in which further or more limited measures could be necessary. Therefore the written recommendations are offered without any liability. They simply represent a standard for correct technical behaviour.

Use of the planning aid offered by HÜBNER-LEE does not exempt anyone from taking responsibility for their own actions.

In this sense everyone acts at their own risk. We only accept liability for planning, advisory and processing instructions etc. if we have responded to a written enquiry by sending binding and written instructions with reference to a particular construction project which we are familiar with. In all cases you are required to investigate the suitability of our suggestions using our goods for the concrete application you have in mind.

If you find errors or ambiguities in this planning aid which could lead to wrong use, please inform us about this immediately so that we are in a position to remove any deficit as quickly as possible.

Table of Contents

TTE® SYSTEM for sustainable building

HÜBNER-LEE

Fundamentals of Planning

This planning aid serves to explain and describe the TTE® construction principle, a concept for ecological surface reinforcement and decentralized drainage of rain water with a high load distributing and ecological function. Since the innovative TTE® construction principle is not considered in the current technical set of regulations, it deviates from the so-called standard construction methods and represents a special construction method. This is why this planning aid absolutely should be adequately studied before the planning process begins.

TTE® offers functions such as a good vegetation capability, biological and chemical cleaning capability, load distribution over a wide area and, above all, a high drainage capacity. These can only be sustainably secured through use of the TTE® construction elements according to the recommended TTE® construction principle and while observing the installation instructions. In this way also the potential for making savings from a building costs point of view will be exploited to the full.

The high performance of the system will not at all be realised through simply using the TTE® construction element as a pure surface layer, placed according to conventional construction principles and bodies of regulations. This would lead a loss of functionality in many respects (above all the drainage and the vegetation).

In the following planning aid planning, laying and maintenance of water permeable surface reinforcements and decentralized drainage systems using the TTE® system are explained. The technical information provided serves both planners and those installing the system as a manual for correct working, permanent functionality and security of planning when using the TTE® system.

In the following planning aid planning, laying and maintenance of water permeable surface reinforcements and decentralized drainage systems using the TTE® system are explained.

The technical information provided serves both planners and those installing the system as a manual for correct working, permanent functionality and security of planning when using the TTE® system.

The recommendations contained herein concerning the TTE® construction principle are based on numerous scientific investigations and expert reports undertaken and written in cooperation with independent institutes and experts (see brochure "Verifications and Test Certificates") as well as on constant exchange with specialists and many years of experience in the field of ecological surface reinforcement.

Technical Data

These planning instructions were created based on the set of regulations "Guideline for planning, laying and maintaining greenable surface area reinforcements" produced by Forschungsgesellschaft Landesentwicklung Landschaftsbau e. V. (FLL) as well as Worksheet 138 "Planning, building and operation of systems for seeping away of rain water" from the Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V. (DWA). These sets of regulations, with certain restrictions, should in particular be consulted along with the information provided in this planning aid.

The following technical regulations in their respective currently valid version should be consulted, possibly with certain deviations, as a basis for planning and execution of reinforcements using TTE®, (listed alphabetically):

- DIN 18915 Planting techniques in landscaping – ground preparation activities
- DWA-A 138 "Planning, building and operation of systems for seeping away of rain water"
- DWA-M 153 "Recommendations concerning handling rain water"
- FLL "Guideline for planning, laying and maintaining greenable surface reinforcements"
- ZTV E-StB 94 Additional technical specifications and guidelines for performing earthworks in road building
- ZTV E-StB 04 Additional technical specifications and guidelines for layers without a binding agent in road building

Additional guidelines and regulations (in alphabetic order):

- DIN 18318 Traffic route engineering work – paved and slabbed surfaces in an unattached design, borders
- DIN 483 Curb stones made out of concrete (national collateral standard to DIN EN 1340)
- DIN 1340 Curb stones made out of concrete - requirements and test methods
- FLL - Recommendations for tree plantations – Part 2
- FLL - Special report for planning, building and maintenance of water-bound paths
- FLL Standard seed mixtures for lawns (RSM)
- Leaflet for compaction of the substrate and substructure in road building, 2003
- RStO 01 / RStO 12 German Directives for the Standardization of Traffic Area Surfaces
- TL Stone StB 04 Technical delivery conditions for aggregates in road building
- TL SoB StB 04 Technical delivery conditions for construction material mixtures and soils for manufacture of layers without a binding agent in road building
- ZTV Paving StB 06 Additional technical delivery conditions and guidelines for creating paved surfaces, slabbed surfaces and borders

*) shortened in the following as: FLL Guidelines for greenable surface reinforcements

FLL guidelines serve, amongst other things, as a basis for this planning aid

Fundamentals of Planning

Use

TTE® is much more that just a normal turf grid for greened parking areas and entrances to fire stations. It offers an ecological solution both for greened surface reinforcements as well as for paved surface reinforcements of all kinds. Reinforcements capable of seepage using the TTE® system are used, above all, in communal, industrial and private areas of useful areas and ancillary areas, such as stationary traffic, storage and yard surfaces as well as walkway fortification, entrances to fire stations and local streets. Further examples of typical areas of application for TTE® construction principles can be taken from pages 12 and 13.

TTE® offers an optimal solution for poor building areas due to the high performance of the TTE® system concerning load distribution and the therefore very low requirements on the substrate. It can, therefore, also be used, particularly under these difficult conditions, as a load bearing structure for permanently permeable paving and slabbed surfaces. The individual TTE® solution also fulfils the highest demands on design and aesthetics.

The low construction thickness of TTE® makes it ideal for reinforcing public traffic carrying roofs. The strongly reduced load already allows its use for low requirements on the substructure or the building. It offers excellent vegetative conditions for greened public traffic carrying roofs. It is also possible to use it for extensive roof greening and steep roof greening.

As a result of its un-intrusive construction principle and retention or creation of a near-natural soil and water balance, the TTE® system is very suitable for surface and way reinforcements on the landscape and particularly for protected areas in nature and the landscape, as well water bodies conservation.

Temporary reinforcements, for example for events, can be created very easily using TTE® and can be removed without leaving any signs of having been there. In this case the system can be laid directly onto even meadow or lawn-type surfaces.

Requirements and usage options as a decentralized surface dewatering system which can be driven over are described in the "Drainage" section.

Usage restrictions

The requirements for use on the TTE® construction principles are usually the same as or less than the loading class Bk 1.8 according to RStO 12, which essentially represents the previous Building Class III/IV of RStO 01. Therefore use of TTE® surfaces should generally be restricted to a maximum traffic loading of 1.8 million 10 ton axle passages during their period of use.

The reinforcement achieved due to the TTE® construction principles may only be used in traffic areas if the speed of the traffic cannot exceed 30 km/h (with the exception of agricultural roads). After consultation with us it is possible to use the system up to a maximum speed of 50 km/h. Use of the TTE® system on ways carrying traffic should be restricted to use as an access road and adjacent owner/residential street.

At least TTE® Construction Principle 2 should always be selected for building projects in public areas (with the exception of pathways and cycle paths as well as areas which are restricted purely to use by passenger cars).

The TTE® system can be used without difficulty on slopes of up 10 %. Consultation with us is necessary for use on slopes which are steeper than this.

Compaction

The degree of compaction plays a decisive role when using the TTE® system. Functions such as permanent permeability, a high water storage capacity and ecological functionality can only be achieved when maintaining the prescribed degree of compaction. Therefore one must pay a good deal of attention to selection of suitable compaction devices. For mineral base course layers we recommend use of light to medium-heavy vibratory plates and for vegetation base course layers and for building ground one should use light rollers.

The details of the load carrying capacity and the compaction for the TTE® construction principles may appear inadequate at first glance compared to conventional standard construction methods. However, the low degree of compaction of the base course layer can be verified to be adequate, due to the very high load distribution function of the TTE® elements, in order to achieve the load carrying capacity and evenness of the surface (see also the brochure "Verifications and Test Certificates").

Verification of the load carrying capacity based on a plate pressure trial according to DIN 18134 can be obtained if necessary.

For countries in which one works with E_{v1}values, the requirements of the following table must be taken into account:

Tab. 1: Requirements on the load carrying capacity (in foreign countries in which the E_{v1} values apply)

Substrate	Base course layer/vegetation base course layer	TTE® construction principle
E_{v1} = 7 MN/m²	no base course layer required	TTE® Construction Principle 1
E_{v1} = 7 MN/m²	E_{v1} = 2 MN/m²	TTE® Construction Principle 2
E_{v1} = 7 MN/m²	E_{v1} = 15 MN/m²	TTE® Construction Principle 3

Environmental compatibility and disposal

The TTE® products are manufactured using recycled mixed plastics (Duales System Deutschland AG). They are demonstrably neutral for the environment and very UV resistant. TTE® is characterised by a long service life which exceeds that of many other usual products (e.g. concrete products). Therefore, after expiry of the service life or, if there is a change of one should check whether the ele- could possibly be reused or used with lower loading and intensity.

We orient ourselves on the "cradle to cradle" principle which is why TTE® products can be given back after expiry of their service life and again be returned into the product cycle. They can alternatively be disposed of in a recycling centre or brought to recycling in another way.

Requirements on the environmen- compatibility, health, safety and according to the FLL guideline for surface reinforcements should be account.

TTE® Construction Principles

Classification of the construction principles

The TTE® construction principle required for a given building project arises, in particular, dependent on the 10 t axle passages in millions occurring during the service life, the operational loads and the intensity of use. Adaptation of the layer thicknesses occurs through the classification of the building ground in the frost sensitivity classes (according to ZTV E-StB). The following evaluation criteria were developed based on the FLL guideline for greenable surface reinforcements and RStO 12.

Tab. 2: Measurement relevant loading B – equivalent 10 t axle passages in millions:	
up to 0.3 Bk	TTE® Construction Principle 2
up to 1.8 Bk	TTE® Construction Principle 3

Intensity of use

- Period of use
- Regularity of use
- Interval of use
- Frequency of use

Tab. 3: Operational load (axial load and permissible total weight of the vehicle type):	
Passenger cars, mobile homes, small transporters up to a 3.5 t permissible total weight*	TTE® Construction Principle 1
Occasionally lorries up to a 40 ton permissible total weight* (up to a 10 t axial load) Fire engines up to a 16 t permissible total weight*	TTE® Construction Principle 2
Lorries up to a permissible total weight of 40 t	TTE® Construction Principle 3

*) Permissible total weight

Sustainable and durable: TTE® parking spaces and driving tracks after being used daily for 10 years (TTE® Construction Principle 1).

Construction principles in 3 categories

- TTE® Construction Principle 1: surfaces exclusively for passenger car traffic up to a total weight of 3.5 t
- TTE® Construction Principle 2: for movement of passenger cars and occasional heavy goods traffic (corresponds to RStO 01 BKL V/VI or RStO 12 Bk 0.3)
- TTE® Construction Principle 3: for heavy goods traffic up to 40 t total weight (corresponds to RStO 01 BKL III/IV or RStO 12 Bk 1.8)

Vegetation loading for TTE® Green 1

The loading from vegetation for greenable TTE® construction principles is dependent on the following factors:

- Pressure and shear loading (due to underfilling of the TTE® elements with filling substrate and therefore protection of the lawn covering, by the webs of the elements, are negligible)
- Shading
- Dryness and heat under vehicles

Sub-division into TTE® Green and TTE® Paving

- TTE® Paving: for highly intensive use and loading (e.g.: ways carrying traffic, strongly frequented driving lanes and parking places)
- TTE® Green: for an average intensity of use and vegetation loading (e.g.: entrances to fire stations, not intensively used driving lanes and parking places)

If necessary the TTE® Green construction principles can also be used with 50 % paving stones in a chessboard arrangement in cases of intensive use.

TTE® Construction Principle 2: public parking spaces as TTE® paving stones and TTE® Green (with root protection for tree plantations at the same time)

TTE® Construction Principles

TTE® Green

Figure 1: TTE® Green 1

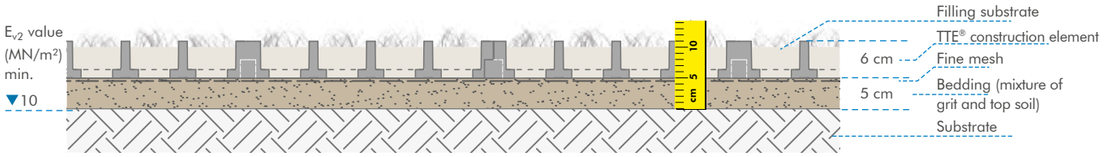


Figure 2: TTE® Green 2

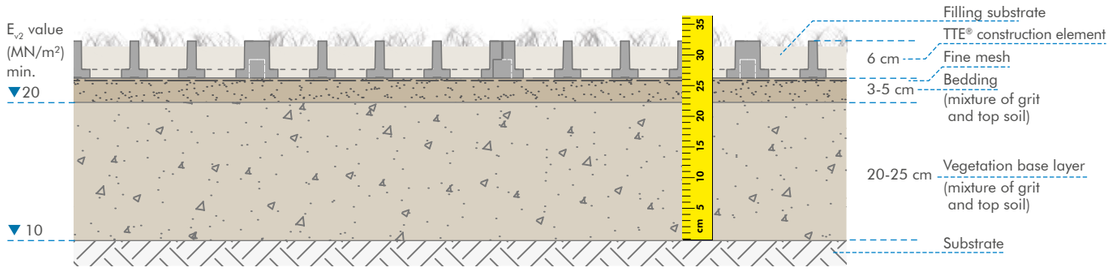
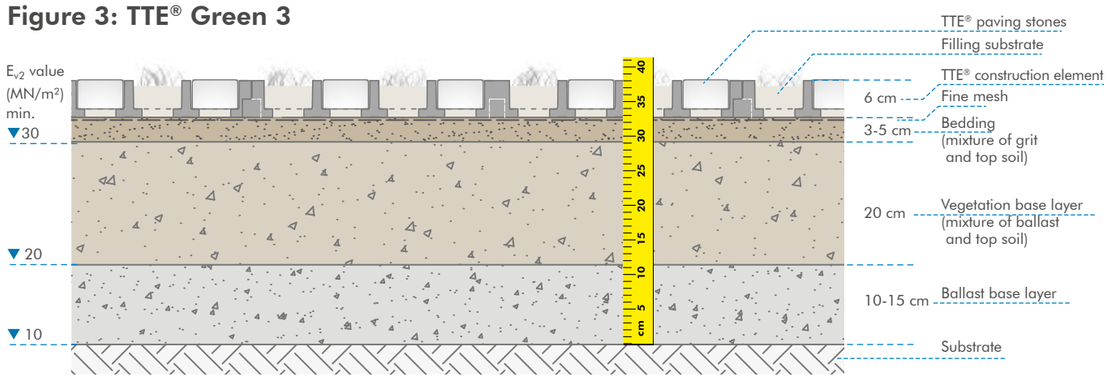


Figure 3: TTE® Green 3



TTE® Paving

Figure 4: TTE® Paving 1

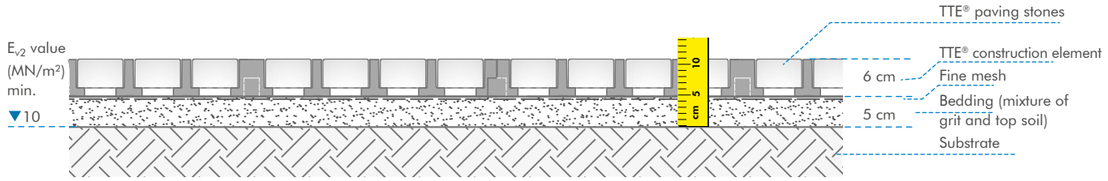


Figure 5: TTE® Paving 2

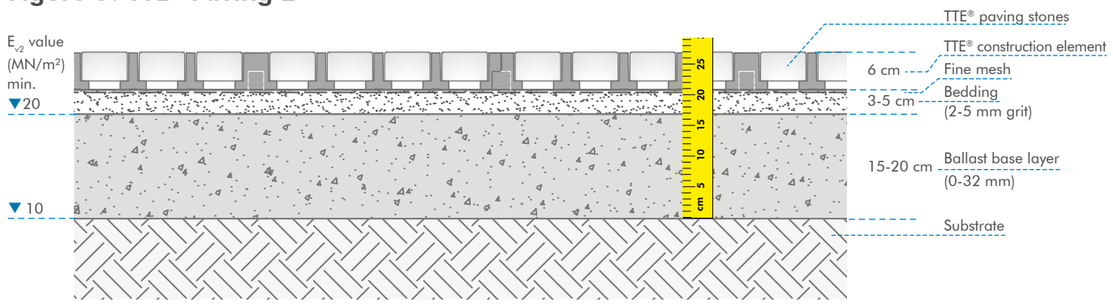
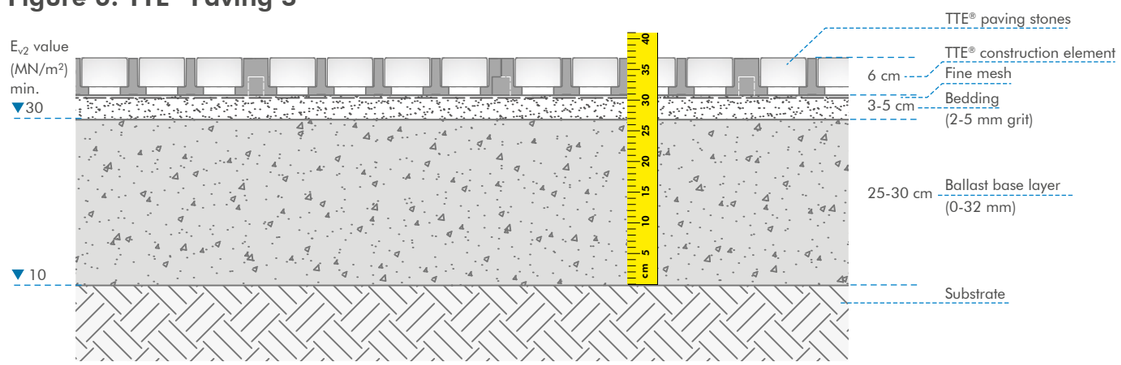


Figure 6: TTE® Paving 3



TTE® SYSTEM for sustainable building

HÜBNER-LEE

Tab. 4: TTE® Construction Principles at a Glance

TTE® construction principle		Use	Range of application	Load bearing capacity E_{v2} value*)	Base course layer according to sensitivity to frost	Bedding	Chamber filling	Ecological value
1	Green	Lower daily change of vehicle, for example private parking spaces; permissible total weight: 3.5 t	■ Private passenger car garage entrances ■ Garage entrances ■ Camping van garage entrances ■ Bicycle parking spaces ■ Footpaths & bike lanes ■ An ecological base course layer for terraces and pavements with a paving covering or floor paving	Building ground a minimum of 10 MN/m²	No base course layer required	40 % grit 2 - 5 mm 30 % sieved top soil 20 % lava 2 - 4 mm 10 % ready to use compost	50 % sieved top soil 20 % washed sand 20 % lava 2 - 4 mm 10 % ready to use compost	VERY HIGH No significant intervention, natural soil is built over, no compaction, ecosystem virtually unchanged, filter and cleaning function remain maintained
	Paving				No base course layer required	Grit 2 - 5 mm about 5 cm thick	TTE® paving stones	
2	Green	For frequent daily change of vehicle, vehicles used by the maintenance services, very rare heavy goods traffic, e.g. public parking spaces; permissible total weight: 3.5 t (occasionally 40 t)	■ Public car parking spaces ■ Industrial workers and visitor parking spaces ■ Private courtyard fortifications and access roads ■ Entrances to fire stations and bypass roads with/without greening ■ Rural roads ■ Service roads ■ An ecological base course layer for a paving covering or floor paving	Building ground a minimum of 10 MN/m² Vegetation base course layer[1] min.: 20 MN/m²	Vegetation base course layer[1] F1: 20 cm, F2/F3: 25 cm	see Green 1	see Green 1	HIGH to VERY HIGH Very little intervention, the filter function remains intact, very low compaction With a vegetation base course layer: cleaning function remains intact, use of the top soil, near-natural ecosystem
	Paving			Building ground a minimum of 10 MN/m² Gravel base course layer[2] min.: 20 MN/m²	Gravel base course layer (0-32 mm)[2] F1: 15 cm, F2/F3: 20 cm	Grit 2 - 5 mm 3 - 5 cm thick	TTE® paving stones	
3	Green	Frequent, daily change of vehicle, increased heavy goods traffic; permissible total weight: 40 t	■ Industrial warehouse spaces and entrances ■ Lorry and bus parking places ■ Service pathways at motorway service stations ■ Ecological base course layer for traffic area surfaces with a surface layer of a paving covering or floor paving ■ Exhibition sites for temporary use	Building ground minimum of 10 MN/m² Gravel base course layer min. 20 MN/m² Vegetation base course layer[1] min. 30 MN/m²	Vegetation base course layer[1] 20 cm Gravel base course layer (0-32 mm) F1: 10 cm, F2/F3: 15 cm	see Green 1	see Green 1 50 % TTE® paving stones in a chess-board arrangement[3]	MEDIUM to HIGH Little intervention, the filter function remains intact, low compaction With a vegetation base course layer: cleaning function remains intact, use of the top soil, near-natural ecosystem
	Paving			Gravel base course layer[2] min.: 30 MN/m²	Gravel base course layer (0 - 32 mm)[2] F1: 25 cm, F2/F3: 30 cm	Grit 2 - 5 mm 3 - 5 cm thick	TTE® paving stones	

*) MPa = MN/m² (the unit MPa should be used outside Germany and then according to RStO 12)
1) Vegetation base course layer: 60 % ballast (for example 0 - 32 mm, 40 % top soil soil group 2 or 4 according to DIN 18915

2) Alternatively, an actively cleaning base course layer can be used for a higher ecological functionality (of the respective TTE® Green construction principle)
3) Alternate filling of the TTE® construction elements with TTE® paving stones and substrate in chessboard design

An example: BV Airport parking facility Bern-Belp

TTE® Green 2 (vegetation base course layer through direct incorporation)

Removal of turf; delivery of gravel base course material

Application and distribution of the gravel sand mixture directly onto the existing top soil

Rolling on the gravel sand into the top soil in the ratio 60 % gravel sand: 40 % top soil

Creation of the terrain modeling and rough grading

Applying and levelling of the bedding (grit-top soil-mixture)

Laying of elements on the fine network as a laying aid and separating mesh

Inserting the TTE® paving stones in the TTE® construction elements as a parking place marking and footpath

Introduction of the substrate (top soil-sand-mixture) as a chamber filling; seeding and completion

Protection of the vegetation by using higher webs

Building Ground / Planum

TTE® Construction Principle 1

This construction principle does not require a base course layer. The firm, grown over top soil forms the building ground, in as far as it meets the requirements. The ecological soil functions, the ground structure and a near-natural condition of the surface are maintained. In order to achieve an adequate thickness of the living soil layer (cleaning function) its removal should be kept to a minimum, in as far as this is compatible with the level adaptations.

TTE® Construction Principles 2+3

In as far as it meets the requirements apply the top soil according to the profile, cultivate it and possibly leave it stacked in heaps for later creation of a vegetation base course layer/actively cleaning base course layer in an orderly fashion. Excess material should be disposed of.

When creating the vegetation base course layer for the TTE® Construction Principle 2 through direct integration of mineral structural components in the existing top soil, the building ground is prepared as for use with the TTE® Construction Principle 1.

Creation

The building ground or the planum should essentially fulfil requirements according to ZTV E-StB. By way of derogation the specifications according to Table 5 should be used. The question of whether compaction is required to achieve the set requirements upon the load carrying capacity should be clarified in advance. If the load carrying capacity of the building ground is higher from the very beginning then the amount of base course layer material used could be reduced (obtaining of advice on this is essential). One should check that there is adequate water permeability. One should avoid excessively strong compaction of the soil wherever possible. For this reason it is preferable to use tracked vehicles for creation of the planum.

Improving the building ground

No improvement of the building ground is normally necessary when using the TTE®construction principle due to the low requirements on the load carrying capacity. If improvement of the building ground is necessary then use of geogrids, replacement of the earth or fillings are suitable measures. One should not use binding agents.

A medium-dense compactness of the soil is adequate and should not be increased through further compaction since the drainage performance will be significantly reduced by this.

To ensure the drainage performance of the substrate and to secure the system one should ensure that no uncontrolled compaction occurs in the drainage areas before and also during the building operations due to dynamic overloading or large additional loads (for example driving delivery vehicles over it or storing (heavy) materials on it).

Table 5: Requirements on the building ground/planum

Property	Requirements	Checking according to
Deflection module E_{v2}	≥10 MN/m²	DIN 18134
Water permeability k_f	≥ 1,0 × 10^{-6} m/s	DIN 18130-1
according to ZTV E-StB		
Gradients	Gradient producing a runoff effect ≥ 1 % and ≤ 5 %; according to the substrate	Levelling
Altitude	Limit deviation from the nominal height ± 2 cm	Levelling
Flatness	Actual dimension as a threshold value for the distance between measuring points of 4 m ≤ 2 cm	DIN 18202

Vegetation Base Course Layer

Structural component

Aggregates according to the TL Stone StB should be used as mineral structural components. Suitable materials are open-pored, frost resistant, pressure-resistant, broken materials. For unbroken aggregates the layer thicknesses of the vegetation base course layer may be increased in order to achieve an adequate load carrying capacity. Pure round grain mixtures are not suitable as a structural component (FLL guidelines for greenable surface reinforcements).

According to our experience large pore gravel mixture of 2/16 mm to 2/45 mm are tendentially suitable for (closely spaced) soils of the BG 4. A gravel mixture of 0/16 mm to 0/45 mm with a low proportion of fine grains < 0.063 mm (≤ 5 percentage by weight) can be mixed with (widely spaced) soils of the Building Ground 2.

Grain size for direct integration (harrows) ≤ 32 mm.

Soil

Top soils of the soil groups 2 and 4 according to DIN 18915 are used for creation of the vegetation base course layer. For both economic and ecological reasons the existing top soil should be used wherever possible, in as far as it meets the requirements.

If a vegetation base course layer made at a works or top soil for a mixed-in-place mixing of the vegetation base course layer is delivered, one should use a sieved top soil with a mesh width of 20 mm.

Soil additives

The properties of the substrate can be achieved based on DIN 18915 by addition of organic and open-pored mineral soil additives.

Lava, pumice stone and brick powder are suitable for improving the water storage capacity as well as ready to use compost according to FLL or with an RAL quality mark.

Furthermore it is possible, according to the FLL "Recommendations for Tree Plantations - Part 2" , for substances to be added for promotion of soil life for binding of pollutants and growth of the roots, for example alginate, humic materials and similar auxiliary materials.

Table 6: Granulometric composition of the vegetation base course layer: 0/16 mm to 0/45 mm (FLL guidelines for greenable surface reinforcements)

Mixture of building materials	Passage in percentage by weight through the sieve (mm)								
	0.063	0.5	1	2	4	8	16	31.5	45
0/16 to 0/45	5-10	16-36	20-45	25-50	30-55	37-63	47-100	73-100	100

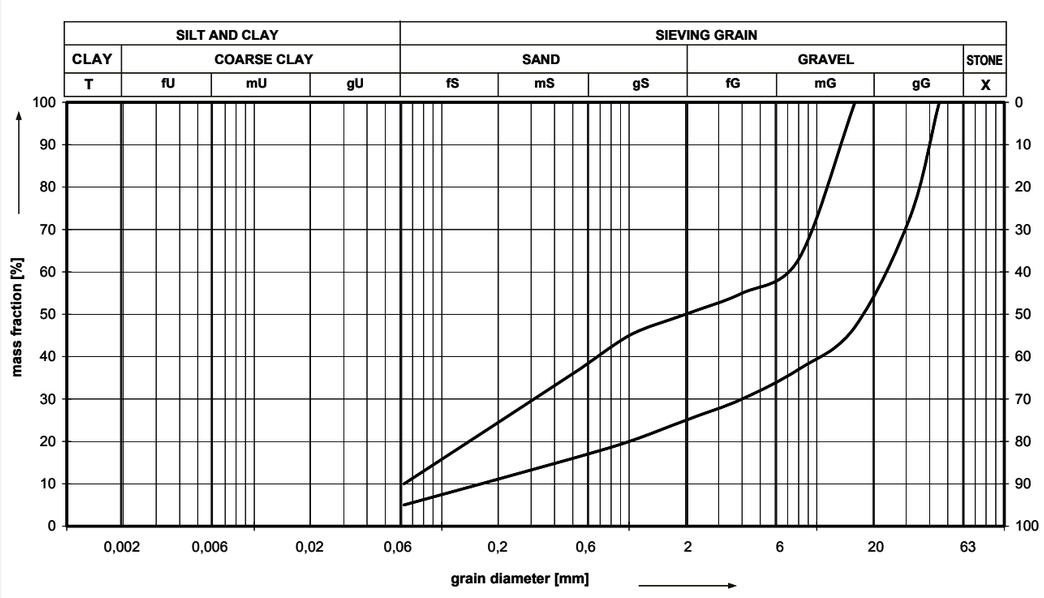


Figure 7: Grading curve ranges 0/16 to 0/45 (FLL guidelines for greenable surface reinforcements) The mixture should be in the lower area of the recommended grading curve band. Functional requirements must override this.

Vegetation Base Course Layer

Table 7: Requirements on the vegetation base course layer

Property	Requirements	Checking according to
Grain size	0/16 to 0/45 mm	DIN 18123 or DIN EN 933-1 DIN EN 933-4 DIN EN 932-3
Deflection module E_{v2}	see Table 9	Static according to DIN 18134
Compaction ratio D_{pr}	≥ 93 % ≤ 95 %	DIN EN 13286-2
Water permeability k_f	≥ 1.0×10^{-5} m/s	DIN 18130-1
Gradients	≤ 2 %	Levelling
according to FLL		
Installation water content	In an earth-moist condition, usually with a water content of 0.5 to 0.7 W_{Pr}	DIN 18121
Water storage capacity	≥ 20 % by volume ≤ 40 % by volume	FLL - Recommendations for tree plantations – Part 2 (however with a middle test cylinder made out of steel)
Organic substance	≥ 1≤ 3 mass ratios as a %	DIN 18128
Salt content	≤ 150 mg/100 g	VDLUFA A 10.1.1
pH value	5 to 9	DIN ISO 10390
Altitude	Limit deviation from the nominal height ± 2 cm	Levelling
Flatness	Actual dimension as a threshold value for the distance between measuring points of 4 m ≤ 20 cm	DIN 18202

Table 8: Layer thicknesses for construction principles according to the frost sensitivity class

TTE® construction principle	for F1 soils:	F2/F3 soils
TTE® Green 1	No base course layer required	No base course layer required
TTE® Green 2	Vegetation base course layer 20 cm	Vegetation base course layer 25 cm
TTE® Green 3	Vegetation base course layer 20 cm, on gravel base course layer (0/32 mm) 10 cm	Vegetation base course layer 20 cm, on gravel base course layer (0/32 mm) 15 cm

Table 9: Load carrying capacity and compaction according to the construction principle

TTE® construction principle	Deflection module E_{v2}	Proctor density D_{pr}
TTE® Green 1	No base course layer required	No base course layer required
TTE® Green 2	Vegetation base course layer min. 20 MN/m²	≥ 93 % ≤ 95 %
TTE® Green 3	Vegetation base course layer min. 30 MN/m² gravel base course layer min. 20 MN/m²	≥ 93 % ≤ 95 %

Wherever possible the base course layers should not be compacted significantly more than the recommended values suggested since this could impair the drainage and cleaning performance.

Notes on creation

The appropriate method of creating the vegetation base course layer should be established while taking account of all local conditions and the availability of suitable machines and building materials. The mixing process can occur through direct integration into the installation surface, through mixing-in-place outside the area to be built on or as a vegetation base course layer made at a works which is ready to use. This decision should be made early on in the planning process due to the, in part, very different building processes involved. One should generally ensure that one obtains an homogeneous mixture through use of suitable devices.

The components of the mixture, the grading curve range and the mixture ratio quoted are simply recommendations and should be checked in each individual case based on the materials used. Only the specified functional requirements are decisive for the assessment.

Creation of the vegetation base course layer should take place based on the FLL guideline for greenable surface reinforcements. According to this one should particularly ensure observance of the optimal water content (for an earth-moist condition 0.5 to 0.7 wPr), prompt even installation and protection against moisture. It is furthermore not permissible to use separated out and clumpy material.

The TTE® and FLL specifications for vegetation base course layers should be fulfilled for the general requirements (Table 7), the layer thickness (Table 8) and compaction (Table 9) The sealing should take place statically.

During checking of the building material ensure that the soil used is top soil from a "living" layer of top soil (not sub-soil). This is a prerequisite for a good vegetative and ecological functionality of the system.

Guidelines for creating Vegetation Base Course Layers

Variant A - direct integration (harrows)

Suitability

- Construction Principle 2
- If there is no strong change foreseen in the crop heights or the topography
- If the existing top soil meets the requirements
- Limitation of the structural components to a grain size of 32 mm (dependent on the machine)

Advantages

- A low construction effort and costs → low level or even no removal of soil required, no storage required, no delivery fees and low to even no removal removal fees for top soil
- Direct integration of the mineral structural components in the existing top soil of the area to be built on without previous removal of soil (for example to adapt the height)
- In special cases also integration of the top soil into the existing gravel base course layer (for example integration into building roads, rehabilitation of existing surfaces with a conventional base course)
- Economic methods for creation of the vegetation base course layer
- A very homogeneous mixture of the components

Creation

- Take away the turf and create the planum on the existing top soil
- Create the vegetation base course layer from: a 60 % by volume gravel mixture, 2/32 mm, 40 % by volume existing top soil of the building ground. 2 or 4 according to DIN 18915, layer thickness 20-25 cm (measured in the installed and compacted condition)
- Deliver a 2/16 to 2/32 mm gravel mixture, put on (distribute above the top edge) and skim
- Harrow soil layers using a suitable rotary harrow (alternatively a miller) about 25-30 cm deep (15-18 cm of gravel mixture (about 60 % by volume)+ 10-12 cm of top soil (about 40 % by volume))
- Compact vegetation base course layer, compaction ratio $D_{Pr} \geq 93\ \% \leq 95\ \%$, deflection module Ev2 $E_{v2} \geq 20$ MN/m²
- Create the planum (preferably by using tracked vehicles)

It is preferable to use rotary harrows rather than millers for the mixing process. This allows a more gentle mixing system and therefore better protection of the soil life.

Variant B - the mixed-in-place mixture

Suitability:

- TTE® Construction Principle 2, alternatively, if direct integration is not possible due to a lack of availability of suitable machines
- TTE® Construction Principle 3
- If the existing top soil meets the requirements

Advantages

- Reuse of the removed top soil
- No delivery fees and low to even no removal removal fees for top soil

Creation

- Remove the top soil for creation of the vegetation base course layer, store it and create the planum
- Only TTE® Construction Principle 3: a 10-15 cm gravel base course layer for a two-tier base course construction
- Mix the vegetation base course layer together homogeneously (for example through use of a pug mill mixer), install and compact which is made out of: 60 % by volume ballast, for example the 2/32 mm or 0/32 mm type, 40 % by volume layered top soil of the building ground. 2 or 4 according to DIN 18915. layer thickness 20-25 cm (measured in the installed and compacted condition)
- Compact vegetation base course layer, compaction ratio $D_{Pr} \geq 93\ \% \leq 95\ \%$, deflection module Ev2 Ev2 ≥ 20 MN/m2
- Create the planum (preferably by using tracked vehicles)

Variant C - the vegetation base course layer which is ready to use

This method of creation can be used as an alternative if direct integration or mixing-in-place is not possible due to poor suitability of the existing top soil or a lack of availability of the machines. The ready to use vegetation base course layer should be made on-site, delivered and installed according to the specifications described. Ready to use mixtures which are offered by building materials suppliers can be used as long as they meet the requirements of the FLL.

Detailed invitations to tender are available online at www.tte.eu

Direct integration of the vegetation base course layer shown using the communal car park in Betzigau as an example

(Construction Principle Green 2)

1. In this case simply mow the grass (the topography was sufficiently even)

2. Application and skimming of the mineral structural component

3. Harrowing in the components (60 % by volume ballast and 40 % by volume existing top soil)

4. Compaction and creation of the planum

Mineral Base Course Layer

Building materials

Aggregates made according to TL Stone-StB are suitable building materials to make base course layers. The TL SoB-StB also apply for mixtures of building materials. According to the FLL guideline for greenable surface reinforcements, open-pored, frost resistant, pressure-resistant as well as unsorted mixtures of building materials (for example recycled materials) can be used after checking them from an environmental and building point of view.

Apart from the recommended mixtures of building materials, 0/32 mm and 0/45 mm according to FLL, also mixtures of building materials, 0/56 mm, can be used for base course layers from a thickness of 20 cm according to the distribution of the grain size specified in the FLL guideline for greenable surface reinforcements. The nominal largest grain should be less than 1/3rd of the layer thickness.

In order to simplify the sequence of building operations it is possible, for changing plots of land, for a continuous vegetation base course layer to be made of TTE® Paving and TTE® Green. However, bedding materials should be used according to the construction principle used.

Creation

Installation of the mixtures of building materials should take place based on ZTV SoB-StB. For the layer thickness (Table 12), compaction (Table 13) and further requirements (Table 14), the recommended values for the TTE® construction principles should be used. One should avoid separation out of the components.

Figure 8 and Table 10 serve as an orientation aid for a suitable grain size distribution of the mixtures of building materials . These are only recommendations; it is only the specified functional requirements which are decisive for the assessment.

The cleaning-active base course layer

The mineral base course layer material for the construction principles TTE® Paving 2+3 can be replaced for ecological reasons, and due to laws concerning the protection of ground water, by a "cleaning-active base course layer". As a living layer of soil this achieves cleaning of seepage water and also removes materials which have entered the ground.

Please note that the requirements, creation and structural thickness of a cleaning-active base course layer must match those for a vegetation base course layer (if necessary with a lower proportion of top soil). One should always use a purely mineral material for the bedding. This prevents any unwanted growth arising in the joints in the paving.

Table 10: Distribution of the grain size for base course layers without a binding agent 0/32 (FLL guidelines for greenable surface reinforcements)

Mixture of building materials	Passage in percentage by weight through the sieve (mm)								
	0.063	0.5	1	2	4	8	16	31.5	45
0/32	3 - 7	7 - 26	11 - 33	18 - 40	26 - 51	40 - 64	58 - 80	90 - 99	100

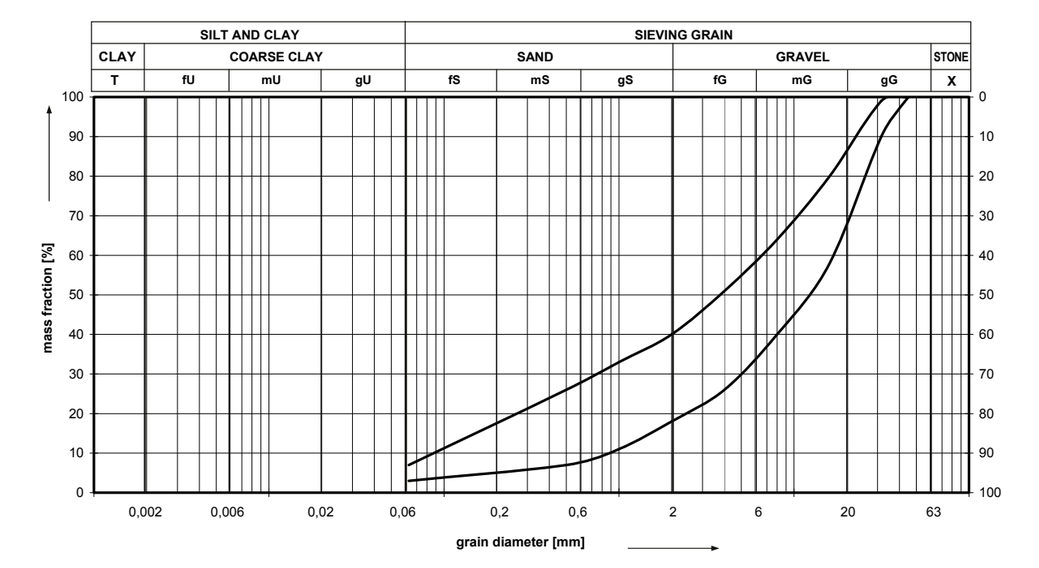


Figure 8: Grading curve ranges 0/32 (FLL guidelines for greenable surface reinforcements) The mixture should be in the lower area of the recommended grading curve band. Functional requirements must override this.

Mineral Base Course Layer

Table 11: Distribution of the grain size for base course layers without a binding agent 0/45 (FLL guidelines for greenable surface reinforcements)

Mixture of building materials	Passage in percentage by weight through the sieve (mm)								
	0.063	0.5	1	2	5.6	11.2	22.4	45	63
0/45	3 - 7	7 - 27	10 - 33	16 - 40	28 - 52	40 - 64	58 - 81	90 - 99	100

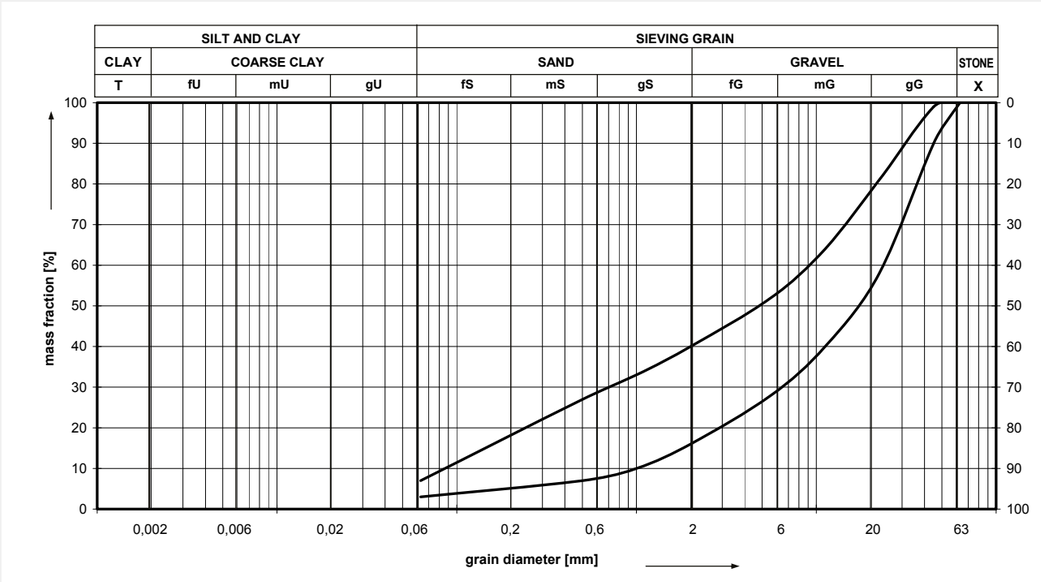


Figure 9: Grading curve ranges 0/45 (FLL guidelines for greenable surface reinforcements) The mixture should be in the lower area of the recommended grading curve band. Functional requirements must override this.

Table 12: Base course layer thicknesses for construction principles according to the frost sensitivity class

TTE® construction principle	for F1 soils:	F2/F3 soils
TTE® Paving 1	No base course layer required	No base course layer required
TTE® Paving 2	Gravel base course layer 15 cm	Gravel base course layer 20 cm
TTE® Paving 3	Gravel base course layer 25 cm	Gravel base course layer 30 cm

Table 13: Compaction ratio and load carrying capacity

TTE® construction principle	Deflection module E_{v2}	Proctor density D_{pr}
TTE® Paving 1	No base course layer required	No base course layer required
TTE® Paving 2	Gravel base course layer min. 20 MN/m²	approx. 95 %
TTE® Paving 3	Gravel base course layer min. 30 MN/m²	approx. 95 %

Table 14: Requirements on base course layers without a binding agent

Property	Requirements	Checking according to
Grain size	0/32 mm to 0/45 mm	DIN EN 933-1
Deflection module E_{v2}	see Table 13	DIN 18134
Compaction ratio D_{pr}	approx. 95 %	DIN EN 13286-2
Water permeability k_f	$\geq 1.0 \times 10^{-5}$ m/s	FLL - Recommendations for tree plantations – Part 2 (however with a middle test cylinder made out of steel)
Gradients	≤ 2 %	Levelling
according to TL SoB-StB		
Ratio E_{v2}/E_{v1}	2.5	
Altitude	Limit deviation from the nominal height ± 2 cm	Levelling
Flatness	Actual dimension as a threshold value for the distance between measuring points of 4 m ≤ 2 cm	DIN 18202

Bedding

Building materials

Aggregates according to TL Stone-StB and top soils of the soil group 2 and 4 according to DIN 18915 are suitable for creating the vegetation base course layer. Known soil additives can be used to achieve targeted improvement of the substrate properties (see p. 16). The filter stability of the mixture must be verified according to ZTV Paving-StB.

TTE® Paving

Based on experience 2/5 mm grit mixtures are suitable, alternatively 0/5 mm (proportion of fine material of < 0.063 mm ≤ 5 % by weight). It is also possible to use grit mixtures of up to 4 mm or 8 mm, if necessary.

Use of grit mixtures without finer sediments as a bedding material for TTE® Paving surfaces is, in contrast to conventional paving and slab coverings, easy to achieve due to the load distributing properties and binding together of the individual elements. The good permeability of this material contributes to a permanently higher drainage performance.

The requirement upon the water permeability $k_f \geq 1.0 \times 10^{-5}$ m/s also applies to the mineral bedding material.

TTE® Green (an example)

- 40 % by volume, 2/5 mm grit
- 30 % by volume sieved top soil (mesh width: 5 mm)
- 20 % by volume, 2/4 mm lava
- 10 % by volume nutrient rich ready-to-use compost

An alternative

- 60 % by volume, 2/5 mm grit
- 40 % by volume sieved top soil (mesh width: 5 mm)
- Soil fertilisation 50 g/m² on an N-basis before laying

Creation of the bedding substrate

The bedding substrate should be supplied as a made on-site mixture of building materials. Installation should take place based on the FLL guideline for greenable surface reinforcements. According to this one should particularly ensure observance of the optimal water content (for an earth-moist condition 0.5 to 0.7 wPr), prompt even installation and protection against moisture. It is furthermore not permissible to use separated out and clumpy material.

According to FLL specifications the recommended values for the bedding material to be used according to the shown requirements (Table 16.)

Figure 10 and Table 15 serve as an orientation aid for a suitable grain size distribution of the mixture of building materials . The components of the mixture, the grading curve range and the mixture ratio quoted are simply recommendations and should be checked in each individual case based on the materials used. Only the specified functional requirements are decisive for the assessment.

We strongly recommend that you do not use purely mineral mixtures for the bedding of greenable TTE® surfaces since they do not supply adequate nutrients and water for the vegetation. The take up of water is strongly impaired by the capillary breaks.

Table 15: Granulometric composition of the bedding material / filling material 0/4 mm to 0/8 mm for greenable coverings

Mixture of building materials	Passage in percentage by weight through the sieve (mm)								
	0.063	0.125	0.25	0.5	1	2	4	5.6	8
0/45	5 - 15	10 - 20	15 - 28	22 - 51	42 - 76	72 - 95	87 - 100	94 - 100	100

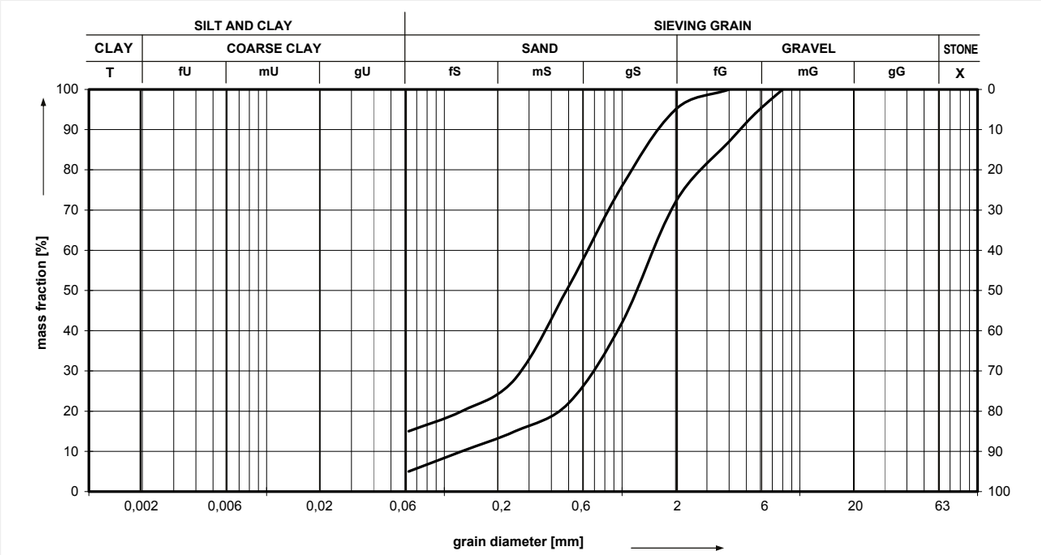


Figure 10: Recommended grading curve range for the vegetation base course layer / filling material for greenable coverings. The mixture should be in lower area of the recommended grading curve band. Functional requirements must override this.

Table 16: Requirements on the bedding substrate / filling material

Property	Requirements	Checking according to
Grain size of the filling material	0/2 to 0/4 mm	DIN EN 933-1
according to FLL		
Grain size of the bedding material	0/4 - 0/8 mm	DIN EN 933-1
Organic substance	≥ 1≤ 3 mass ratios as a %	DIN 18128
Water permeability k_f	≥ 1.0×10^{-5} m/s	FLL - "Recommendations for tree plantations – Part 2"[1)]
Installation water content	in an earth-moist condition, usually with a water content of 0.5 to 0.7 W_{Pr}	DIN 18121
Water storage capacity	≥ 20 % by volume ≤ 40 % by volume	FLL - "Recommendations for tree plantations – Part 2"[1)]
Salt content	≤ 150 mg/100g	VDLUFA A 10.1.1

[1)] however with a middle test cylinder made out of steel

Laying Instructions

Laying instructions in general:

- Adapt the laying width as far as possible to the grid size of the TTE® elements (+ laying + expansion joints)
- Laying of the slabs on the border with a spacer (expansion joints) when beginning laying in order to avoid shifting and uneven joint guidance
- Lay TTE® elements with their wider contact surfaces downwards, in true alignment, at the same height and in the prescribed lattice
- The direction of laying is transverse to the direction of driving
- A fine network as a laying aid for rapid and clean laying of the TTE® elements (normal fleeces are not suitable)
- Lay from the already laid area outwards; do not stand on or drive over prepared bedding
- Keep regularly pushing palleted TTE® elements onto the covering up to the current laying point
- Avoid any strong movements over unfinished laid, filled and riddled areas wherever possible (delivery, construction vehicles)
- An installation height of 15-20 mm above the connection height (before riddling the surface)
- There are spacers to take into account expansion joints (e.g. battens) in the border areas
- Check regularly for straightness of the joints and the size of the joints; correct the straightness of the joints and the size of the joints with square sawn timber and a sledge hammer if necessary
- Riddle the completed laid and filled TTE® surface using a light vibrator

Fine network: During laying this prevents the bedding material from finding its way between the joints of the TTE® construction elements, optimises the laying performance and forms a separating layer. Overlap by about 30 – 50 cm when laying.
Characteristics: weight 24 g/m², mesh size ≤ 4mm, roller width 3.20 m, material: PE

Laying performance per worker of about 20-25 m²/hour (without TTE® paving stones)

Expansion

The expansion behaviour of the TTE® construction elements is relatively low due to filling with TTE® paving stones and particular for greening. Small joints of 1-2 mm which arise through laying the elements offer adequate space for expansion so it is not necessary to arrange for additional expansion joints within the surface. Only the edge areas which possess a border are to be created with an expansion joint in order to avoid moving of the border.

Expansion joints:

Expansion joints should be filled up to the upper edge of the grid. The width of the expansion joints should be adapted to the size of the area. It should measure about **1 cm per 10 m** (for example a length of 30 m -> 1.5 cm per side). The distance applies from the outer-most point of the bordering slabs (staggered teeth: 1.5 cm) to the border. It can be created when beginning the laying by using spacers. One can use battens for example to do this.

- TTE® Green: create expansion joints with a filling substrate.
- TTE® Paving: create expansion joints with EPDM infill granules (rubber granules); 0/2 mm washed sand can be used as an alternative.

Installation for high outside temperatures (≥ 20 °C):

When the outside temperature is relatively high during installation one must pay attention to achieving the tightest and seamless laying of the TTE® elements possible. The elements should be regularly fitted together densely as described in the laying instructions. The width of the expansion joints should be reduced by half in this case.

Connections

Borders

Surfaces reinforced using the TTE® system usually only require a border on the sides which lie parallel to the slab longitudinal side since the transverse sides lock in place due the three-sided interconnection and the offset itself. Borders are further edge areas which attach to other coverings and which will probably be subjected to strong shearing and pushing forces.

The clearance for the borders should be matched as much as possible to the grid size of the TTE® elements in order to avoid unnecessary cutting work. Here the width of the expansion joints should be put into the calculation, from the outermost point of the edge slabs to the border as well as joints which depend on the laying (for example 1-2 mm) between the individual TTE® elements. Expansion joints should be created according to the description given on page 28. For TTE® paving surfaces the staggered teeth along the borders can be cut away for an optically smaller expansion joint.

A suitable type and dimension for the borders should be selected according to the planned construction principle and the use. The products must meet the requirements of DIN EN 1340 and DIN 483. Curbstones and analogously also edge and border stones should be installed in accordance with DIN 18318.

As an **alternative** to conventional borders, for low loading conditions, edge slabs which are not locked in by the three-sided interconnection are also fixed in place and clamped in, point by point, by earth anchors. On safety grounds this should have an as wide as possible rounded head and be hammered in at least 3 cm under the edge of the grid. The steel nails should have a minimum length of 50 cm.

Curves

In tight curve areas one should prevent wandering of the TTE® elements through shearing forces on at least one side through installation of an appropriate edge limitation (Figure 16). For very low loading conditions or large curve radii, above all for greening or locking of the edge areas, one can dispense with use of a border.

Adaptation

TTE® elements can be well adapted by simple and rapid cutting work into various forms (see p.32).

One great design adaptation option, without cutting of the TTE® construction elements, is plastering in of the residual spaces between the slab and border.

Transition regions

Base course layers at transition regions which are passed over should be compacted more strongly due to the high stresses present and the lack of any interconnection on the border side. In the case of TTE® Construction Principle 1 the permanent evenness of the surface could possibly be improved through use of a wedge shaped base course layer (Figure 11). The installation height of the surface before riddling should be created as 15 – 20 mm above the connection height.

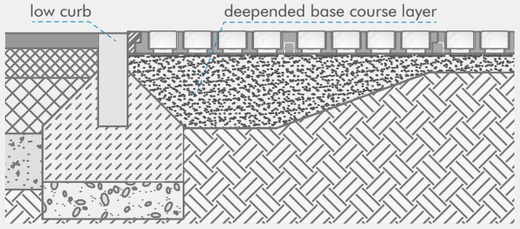


Figure 11: TTE® Construction Principle 1 with a wedge shaped base course layer for better evenness in border areas which are passed over.

Types of Lattice

Figure 12: Herringbone lattice

Self-locking — high/low curb if necessary, or locking of the edge slabs

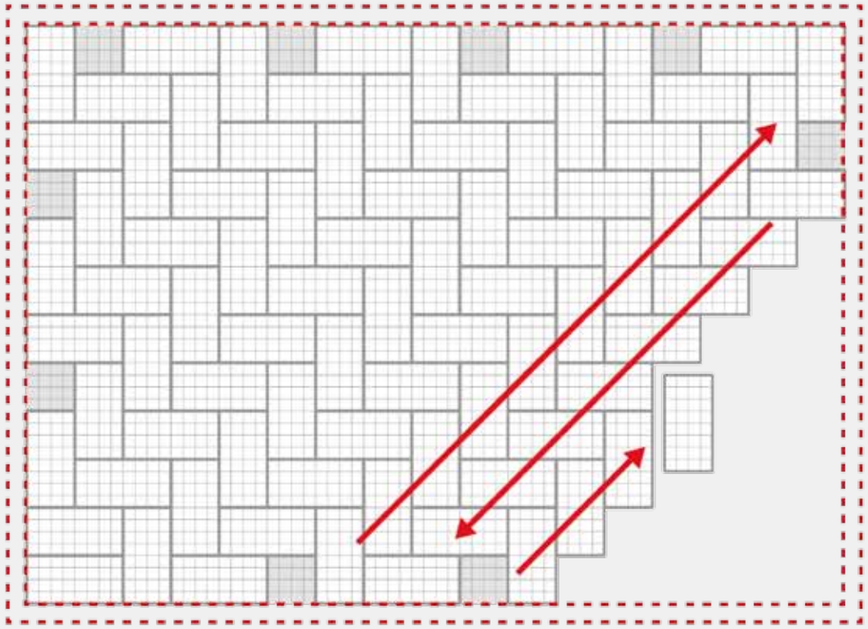


Figure 13: Stretching lattice

High/low curb, or alternatively locking of the edge slabs

The sides are self-locking due to toothing

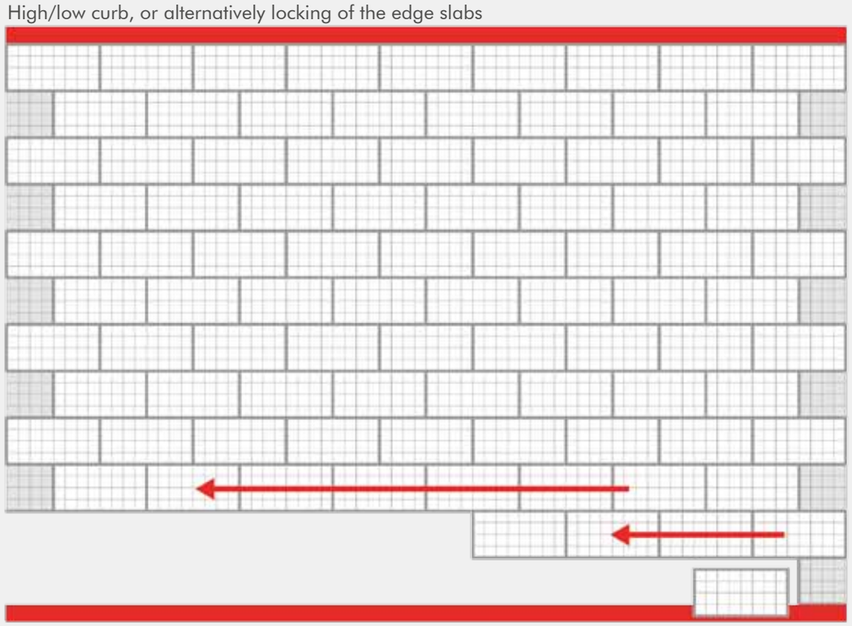


Figure 14: Offset block lattice

High/low curb, or alternatively locking of the edge slabs

The sides are self-locking due to the toothing

Types of lattice and suitability

Herringbone lattice

The Herringbone lattice represents the standard way of laying. This laying variant offers optimal and even load distribution of the TTE® system in all directions, whereby the Herringbone lattice offers very good conditions for use by heavy goods vehicles and areas which are put under load over a wide area such as commercial yard and warehouse areas. Through self-locking on all four sides of the area it can also be made for low loading without a border. Only the corner slabs must be fixed in place.

Stretching lattice

The individual elements are offset by a half (at least a quarter) slab. The load distribution operates primarily transverse to the laying direction which is why this variant is particularly suitable for linear stressed reinforcements such as driving lanes for parking spaces, roads and ways.

Laying on a cross-joint, that is with an offset, should be avoided due to the reduced load distribution.

Offset block lattice

Due to the offset the block lattice allows gaps in the edge areas to be filled without cutting half slabs. As a decorative lattice, it offers a further design variant. Due to the cross joints which arise the load distribution is slightly reduced, which is why this type of lattice is only foreseen for low loading (max. up to TTE® Construction Principle 2, for low loading).

Laying TTE® elements in curves

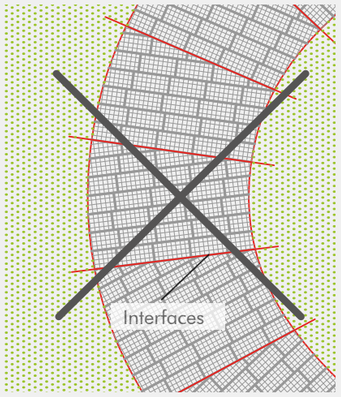


Figure 15: Cutting of the elements causes one to lose the lattice and therefore the load distribution. It is normally not necessary to cut the edge areas.

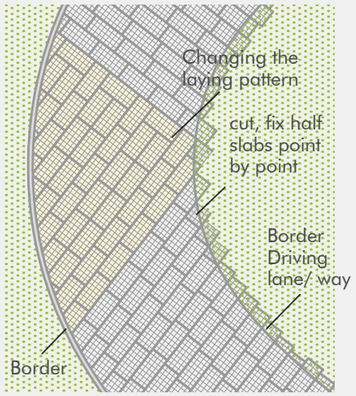


Figure 16: For a tightly curved laying direction there is the option to change the laying direction. A one sided border is necessary according to the loading.

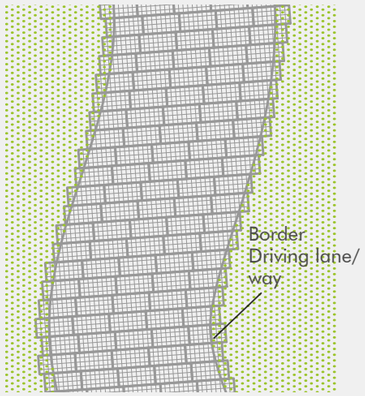


Figure 17: Projecting edges outside the driving lane are greened for natural connecting areas and are therefore invisible.

Cuts

The elements can be very easily cut and adapted using suitable saws. One should generally avoid cuts within a surface which would lead to a loss of function concerning load distribution (Figure 15). The laying direction for a tightly curved laying direction can be turned through 90° by changing the laying pattern (Figure 16). As an alternative they can also be laid in an undirected Herringbone lattice. Wherever possible no cutting should occur on connecting areas which are passed over. Cutting of edge areas transverse to the laying direction is usually not necessary for adjacent greening because of the interconnection. Edge areas which project over the edge of the driving lane or the planned reinforced area are concealed by greening and overtime form improved locking of the edge elements (Figure 17). Furthermore damage to the verge area is prevented for exceeding the border and the road-traffic safety is reinforced.

Suitable devices according to the cutting direction:
straight: Circular saw with a tungsten carbide tipped saw blade
round: Saber jig saw (take the element height into account)

Parking place marking / entry and leaving area / lane

Parking place markings, entry and leaving areas and driving lanes are simply and quickly realised by inserting TTE® paving filling stones.

A parking place with a four row parking place marking requires 40 stones per running metre. This allows comfortable loading and unloading. (Mounting during the construction phase)

Lay double parking rows continuously and optically separate from each other by a line of stones on the front side. (Mounting during the construction phase)

Create parking place markings and driving lanes simply and rapidly using TTE® paving stones. Different alignments are possible without difficulty due to its grid-type structure.

For a wider design of the parking place markings this also, at the same time, offers a reinforced entry and leaving area which can be used under all weather conditions.

Driving lane and footpath reinforcement with TTE®. Greened and paved areas in an interconnected system.

Preferably create the entry and leaving area shorter (4 m long) rather than too small (at least 4 chamber widths) in order to achieve good visibility.

Filling

TTE®Green

Filling substrate (an example)

50 % by volume sieved top soil (mesh width: 5 mm)
20 % by volume 0/2 mm washed sand
20 % by volume 2/4 mm lava
20 % by volume nutrient rich ready-to-use compost

An alternative

70 % by volume sieved top soil (mesh width: 5 mm)
30 % by volume 0/2 mm washed sand
depot fertiliser, 50 g/m²

TTE® construction principle Green 3: insert before filling to 50 % with paving stones in a chessboard arrangement

Building materials

Aggregates according to TL Stone-StB and top soils of the soil group 2 and 4 according to DIN 18915 can be used as building materials. Known soil additives can be used to achieve targeted improvement of the substrate properties (see p.16). The filter stability of the building material mixture must be verified according to ZTV Paving-StB.

Bedding material can also serve as a chamber filling for a investment of time and effort. The recommended filling substrate does, however, offer better conditions for the vegetation and reduced risk of gap formation.

Creation

The substrate mixture should be made at the factory. Creation should take place based on the FLL guideline for greenable surface reinforcements. According to this one should particularly ensure observance of the optimal water content (for an earth-moist condition 0.5 to 0.7 wPr), prompt even installation and protection against moisture. It is furthermore not permissible to use separated out and clumpy material.

The building material mixtures should essentially fulfil the requirements on bedding/filling material according to FLL (p.27, Table 16)

Figure 10 and Table 15 serve as an orientation aid for a suitable grain size distribution of the mixture of building materials . The components of the mixture, the grading curve range and the mixture ratio quoted are simply recommendations and should be checked in each individual case based on the materials used. Only the specified functional requirements are decisive for the assessment.

Finishers are particularly suitable for filling the grid elements due to the even and loose application of the filling substrate. Small and compact loaders for up to 7.5 t with a scoop without teeth can be used as an alternative. The TTE® elements should be filled wherever possible above the upper edge. Strong movements over the unfilled grid and high loads, such as those produced by a delivery vehicle, should be avoided. Wherever possible the parking place markings should be covered to keep them free from growth.

The chambers which are filled up to the upper edge of the webs should be swept using a suitable sweeper to 1.5 - 2 cm below the upper edge of the grid in order to protect and obtain better development of the vegetation.

Material requirements [m³] ≈ Area [m²] × 0.03 m

The grid elements can be slightly overfilled for fire station approaches and TTE® surfaces with very low loading during use.

TTE® Paving

The paving stones can be supplied in the colours light grey, ruby red and anthracite:

Weight: 610 g/piece.

Material: strengthened, break-resistant concrete

Dimensions: 74 × 74 × 48 mm

100 paving stones/m²

Installation instructions

To achieve an efficient laying process we recommend filling the TTE® elements with the TTE® paving stones parallel to laying before bedding them in. Keep pushing the pallets onto the covering regularly up to the current laying point using a lifting truck or a wheel loader to obtain the shortest possible distances to move to do the work.

TTE® paving stones should not be rubbed out or split since the mobility of the paving stones prevents clogging of the joints and therefore contributes to permanent permeability. The paving stones should be locked into place if necessary (for example for traffic speeds in excess of 30 km/h and verge reinforcements) through light sprinkling with grit.

Seeding for TTE®Green

Seed mixtures must meet the requirements of DIN 18917 "Planting techniques in landscaping – working on lawns and seeding" or the FLL-"Standard seed mixtures for lawns (RSM)".

Recommended seeds:

RSM 5.1 Park space lawns;

RSM 7.2 Landscape lawns (for dry storage facilities)

Creation

According to the FLL guideline for greenable surface reinforcements the suitable time for seeding recommended is when the ground temperatures are at least 8°C and when there is sufficient moisture in the soil (normally from May to September).

Seeding should be done according to DIN 18917. The quoted standard seed rates issued by RSM should be observed. According to the FLL guideline for greenable surface reinforcements the seeds should be applied over the ground without working them into the ground as a wet or dry seeds and must not separate out in the process.

Mixtures of dryness-tolerating, low growing herbs can be used for a species-rich, ecological plantation. These are suitable as an addition to the named lawn mixtures or for areas of low usage and low loading. RSM 2.4 home lawns – herb lawns can be used for example; also RSM 6.1 extensive roof greening for very low loaded areas, above all in low loading.

DIN 18918 "Planting techniques in landscaping; bioengineered securing techniques – securing through sowing, plantation, construction methods with living and non-living materials and components, combined construction methods" when using wet seeds. Addition of sand is recommended when using herb seeds.

Mineral Surface Layers

TTE® is capable of significantly increasing the functionality and load bearing capacity of mineral surface layers. As a reinforced and separating layer it permanently secures the evenness and prevents damage and mixing of the material layers. The construction thicknesses as well as costly upkeep and repair measures can be reduced very significantly.

Crushed gravel, gravel and sand surfaces using TTE®

Unbound cover layers with the TTE® system secure a permanently high drainage performance. Maintenance-free, non-slip and loadable reinforcements are made in a natural look.

Building materials

Large pored crushed gravel and gravel 16/32 mm (optimal is 18/22 mm) as well as sand with a low proportion of fine grains (< 0,063 mm ≤ 5 percentage by weight) are suitable. Aggregates made according to TL Stone-StB. Also decorative gravels and grits can be used for higher design expectations.

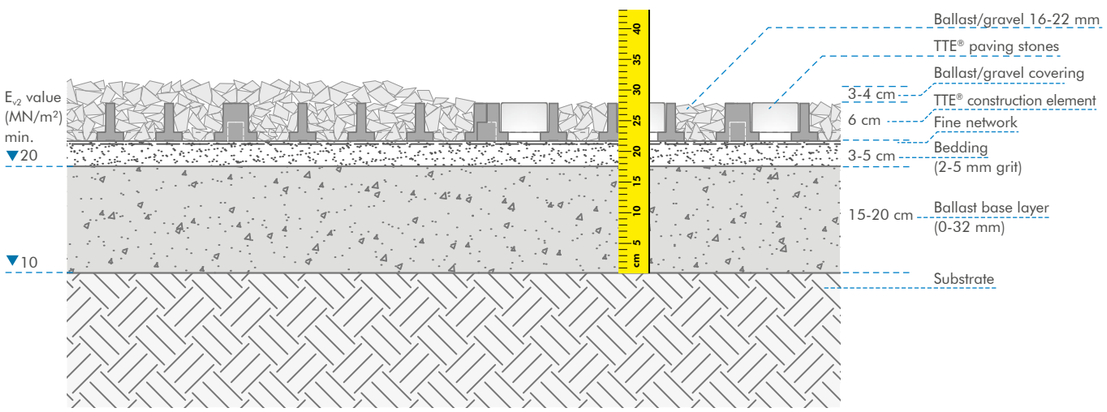
Creation

The bulk materials should be filled or over-filled above the upper edge into the chambers of the TTE® elements. While overfilling apply the material mixture about 3 - 4 cm above the upper edge of the grid. Broken materials should be compacted using a light vibrating machine. In the case of a high intensity of use and loading (for example heavy goods traffic) the TTE® elements should be laid with about 50 % paving stones and filled flush with the surface.

Unsuitable building materials

Mineral building materials with components in them in the grain size range 2-16 mm are only of limited suitability for filling TTE® element chambers. They can settle in the joints between the plates/slabs and block the free joint space required for expansion of the elements as well as lead to disturbing joint formation. The expansion behaviour is not problematic for a case of **over**filling the TTE® elements.

Figure 18: TTE® with a gravel surface layer (e.g. TTE® Construction Principle 2)



Water-bound covering with TTE®

The drainage performance of the TTE®construction principle is only of limited interest for water-bound surface layers since rain fall primarily runs off over the surface, over the surface layer. However, the functionality is improved due to the good permeability in comparison to conventional methods of construction, since the surface layer is less likely to soften.

Based upon this as well as the reinforcing dynamic functionality, water-bound TTE® construction principles are also suitable for bicycle and slow moving to stationary vehicle traffic. It is ideal for use on sports places and cinder surfaces. When combined with paving and slab coverings on TTE® it is possible to realise economic, barrier-free and intensively usable walkways and bicycle paths.

The upkeep and repair costs of hard covers are significantly reduced with TTE®.

The performance and load bearing capacity of a water-bound covering realised as a TTE® construction principle is comparable with the conventional triple layer construction principle.

Bedding/filling building materials

0/3 mm to 0/5 mm grit mixtures with a proportion of fine material of < 0.063 mm ≤ 7 % by weight are suitable. The building materials should be selected according to the requirements placed on dynamic layers according to FLL.

Building materials for a surface layer

0/3 mm to 0/8 mm building material mixtures with a proportion of fine material of < 0.063 mm ≤ 21 % by weight are suitable for TTE® .

The requirements on the building material mixtures for the surface layer should be observed according to "FLL - Special report for planning, building and maintenance of water-bound paths".

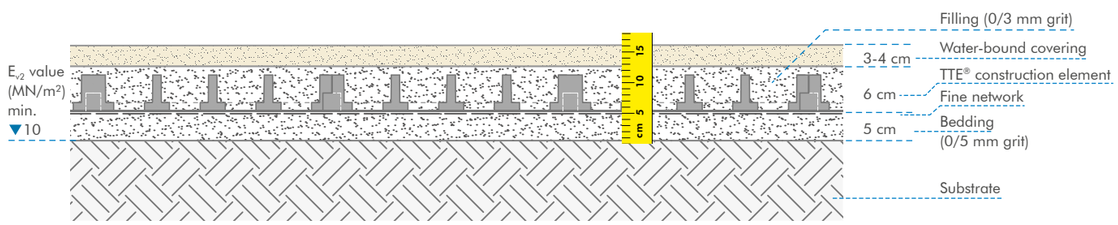
Creation

Generally speaking the TTE® Construction Principle 1 with mineral bedding material can be taken as a basis as support structure (Figure 19). One should install a base course layer according to the TTE®-Construction Principle 2 for intensive passenger car traffic.

The grid elements should be slightly over-filled above the upper edge of the grid with a filler (by about 1.5 - 2 cm) and vibrated or rolled down if necessary. Creation of the surface layer should occur according to FLL - Special report for planning, building and maintenance of water-bound paths. The surface layer material should be applied earth-moist and rolled firmly using a suitable smooth drum roller. The layer thickness should be 3 - 4 cm in the compacted, installed condition.

Finishers are more suitable for larger areas for even application of the filler and surface layer.

Figure 19: TTE® with a water-bound surface layer (e.g. TTE® Construction Principle 1)



TTE® SYSTEM for sustainable building

HÜBNER-LEE

Mineral Surface Layers

Laid and filled TTE® elements BEFORE installation of the water-bound covering.

A finished water-bound covering as a pathway reinforcement in the All-weather Zoo in Münster.

Easy to maintain and permanently flat water-bound pathway coverings with the TTE® system. They are also suitable for safe and comfortable bicycle traffic in all weathers.

TTE® paving with gravel: permanently loadable, even and permeable

A company car park at Hans Ihro GmbH with the company logo made out of TTE® paving (the ballast is filled flush with the surface).

Non-slip gravel surfaces with a natural look. There are TTE® elements under a gravel
covering which improve the flatness and walk-on stability.

Drainage

Near-natural decentralized drainage systems with TTE®

General points

The innovative rain water resources management system using the TTE® system combines the virtues of surface reinforcement with those of the decentralised surface or French drain seepage. This achieves near-natural, decentralized drainage systems over a wide area with a high cleaning and retention function, which can also be used as surfaces for vehicle traffic.

There is no loss of area as is the case with conventional area drainage or troughs and French drain systems and water flow off areas can be replaced or kept to a minimum. Since the base course layer at the same time forms the French drain of the TTE®drainage system, the material consumption which is already low because of the construction thicknesses can be reduced even further. As a surface French drain seepage system the TTE® system also allows effective use for a low water seepage capacity of the substrate due to its water storage function and the seepage over a wide area. One can normally dispense with use of additional drainage equipment.

One can normally completely dispense with waste water fees when using the TTE® construction principles. This should be clarified in advance since the wastewater regulations and the accreditation procedures of the municipalities are all different.

As regards the environmental protection impact mitigation procedure, use of the TTE® system does not represent a negative intervention since the performance and functionality of the ecosystem and the landscape are not strongly impaired. Interventions (such as sealing surfaces) can be strongly minimised or compensated for through surface drainage (§ 14 BNatschG).

Prerequisites:

Drainage away of rain water basically needs checking by the responsible lower water authority. In the case of targeted introduction into bodies of water it is necessary to obtain permission in line with water management laws according to Section 7 of the Water Resources Act. One should ensure before announcement or application for permission according to water management laws, that one can be released from any compulsory connection and usage.

Soil and water conservation should generally be taken into account for the drainage scheme. Drainage may only take place outside water protection areas I and II and when there is dispensing with use of road salt for winter road maintenance. Observe the requirements on drainage systems according to DWA-A 138. This states that for buildings without a waterproofing layer the distance from the drainage system to the foundation pit foot should be at least 1.5 times the depth of the foundation pit. One should take note of other restricted areas.

When checking the hydrogeological situation, topographic influences, strata water consisting of slopes, backwater, ground water and the effects of these should be taken into account.

Loading by precipitation runoffs

For targeted drainage of rain water, the runoffs should be assessed according to DWA-A 138, 3.1.2, Table 1 concerning the concentration of substances dissolved in it and possible influences of these on the ground water. They are subdivided into three property categories (see Table 17).

Table 17: Loading by precipitation runoffs

Category	Evaluation	Suitability
A	harmless – can be drained off without any pretreatment	all TTE® construction principles
B	tolerable – can be drained off after adequate pretreatment	usually all TTE® construction principles (TTE® Paving 2 + 3 only in combination with a cleaning active base course layer)
C	not tolerable – should usually be directed into the sewer network	–

Drainage

Treatment of polluted precipitation runoffs

According to the surface overflow rate (A_U : A_S) the TTE® surface is to be classified as "seepage over a wide area" or as "decentralized area and trough drainage".

For classification as a "decentralized area and trough drainage" it can be essential, due to strong material discharges from roof surfaces and traffic surfaces which affect the qualitative and quantitative evaluation of the precipitation runoffs, their effect on the underground and surface water and the determination, to employ adequate pretreatment measures according to DWA-M 153 (see also DWA-A 138, 3.1.2, Table 1). This can, for example, be the case for car parking places with frequent change of vehicles, metal roofs without coating or roads with an average daily traffic density of above 15,000 vehicles.

In as far as the built on surfaces or the substrate used meet the qualitative requirements according to DWA-A 138/M, the cleaning active TTE® superstructure can, in compliance with the water authorities, the surface passages, be classified according to DWA-M 153, Table A.4a (see Table 18).

For construction principles 2 + 3 with a vegetation base course layer we recommend adding about 5 cm as a safety margin to the required layer thicknesses.

The vegetation of a surface passage acts, above all, as erosion protection due to the root penetration, aeration as well as to secure the permeability of the surface (DWA-A 138). These functions are primarily secured by the surface layers for TTE® paved areas with a cleaning active base course layer. As can be understood from the classification, its cleaning performance can be considered as low compared to grown over soil layers.

One should generally seek to achieve the drainage capability of a grown over soil layer. A good compromise between a higher intensity of use and a good cleaning performance is the combination of the TTE® Green construction principles with 50 % TTE® paving stones in the chambers.

Table 18: Through-flow figures for the TTE® construction principles

TTE® construction principle	Layer	Thickness	Category
TTE®Green	Assign the through-flow figure according to the total layer thickness of the structure (existing top soil or vegetation base course layer + bedding material + filling substrate) according to the layer thicknesses of the "overgrown topsoil"	≥ 30 cm	D1
		≥ 20 cm	D2
		≥ 10 cm	D3
TTE® Paving 1	Top soil passage	≥ 30 cm	D2
		≥ 20 cm	D3
TTE® Paving 2 + 3	with a cleaning-active base course layer	≥ 25 cm	D3

Qualitative prerequisites:

For pollution by substances of Property Category B (tolerable), pretreatment of the precipitation runoffs is a prerequisite for the drainage. While taking account of the requirements on the soil passages according to DWA-A 138/M 153 for creation of the top soil or the substrate or the load carrying substrate, the effect and function of the TTE® top layer is that of an overgrown, living ground zone. A **DIBt approval** is therefore not needed for the TTE® system .

Precipitation runoffs can also be seeped away in the case of strong pollution by substances through roof and traffic areas which conform with guidelines and standards. The seepage over a wide area obtained for the TTE® construction principle favours a high cleaning performance.

The load carrying capacity and compaction required for the TTE® construction principle lies well below the requirements of conventional construction principles, (10-30 MN/m² instead of 100-150 MN/m²), and represents the compaction of naturally occurring soils. The physical, chemical and biological cleaning processes in the soil are not negatively effected.

The requirements on the ground and substrate to secure an appropriate pretreatment measure according to the DWA can deviate from the general requirements in this planning aid. These simply serve to secure the required vegetative and building properties.

The following should be observed in line with the relevant qualitative requirement according to **DWA-A 138**, 3.1.3 for soils, substrate and the seepage space:

- No pollution in the hydraulic inflow area (for example old neglected deposits of toxic waste)
- No negative changes in the seepage and ground water by installed materials
- The drainage relevant k_f range 1×10^{-3} m/sup to 1×10^{-6} m/s (unsaturated zone)
- The thickness of the seepage space is at least 1 m based on the average highest ground water level
- A min. of a 10 cm top soil covering

Large grained sandy and gravelly soil materials are not suitable according to DWA. This is, however, due to the permeability of the materials in a loose layer density (DWA-A 138, Picture 1). Solidification of the recommended TTE®mixtures in a medium compactness usually causes the infiltration capacity in the area relevant to drainage to be lowered.

If there are any concerns, large pored components can be replaced by suitable (preferably carbonate rich) sands, for example 0/4 mm size sand, or can be enriched with such material.

According to **DWA-M 153** the following properties should be confirmed, before installation, on the basis of an expert report for the top soil or for the substrate before delivery, or for retention or reuse of existing soil:

- pH value 6-8
- Humus content 1-3 % by weight
- Proportion by weight of fine components < 0.063 mm under 10 % by weight
- k_f value generally > 1×10^{-6} m/s, for water seepage into side spaces of reinforced areas > 2×10^{-5} m/s

If the top soil or the vegetation base course layer is adequately thick then it is sufficient to have verification, apart from the permeability, just for this layer.

Improvement of the substance binding capacity

The DWA-A 138 suggests a number of measures to improve soil, in order to promote the filtration and absorption processes as well to increase the breakdown of the substances in the earth. One should note any effects this has on the permeability and limit any reduction in this value to values ≥ 1.0×10^{-5} m/s.

Any increase in the substance binding capacity by adding Bentonite or clay-rich earth should be limited to a < 10 % by weight of fine components.

Chalk can be used to adjust the pH value range. Slightly soluble chalks are not suitable. It is recommended to use carbonate rich sands if the permeability of the ground needs to be increased.

The proportion of organic substances can be increased by adding humus or compost. This should lie between 1-3 % by weight.

According to the FLL "Recommendations for Tree Plantations - Part 2", substances can be added for promoting soil and binding of pollutants such as alginate, humic materials and similar auxiliary materials.

Drainage

The runoff coefficient

If the TTE® system is just used as a surface reinforcement system then a runoff coefficient C = 0.15 can be used according to lawn grid stone surfaces. However, an independent investigation showed that the high water permeability of the TTE® construction principles allows rapid channelling of rain water into the construction without any measurable surface runoff (see report from LWG: Veitshöchheimer report 115 (2008), Opportunities and risks associated with grass covered parking spaces, Jürgen Eppel)

According o **DWA-A 138** it usually very easy to verify that the looked at seepage surface remains free of any runoff (see p. 43).

Surface slopes and a drain line

Since no relevant surface runoff occurs and it is usually not necessary to install additional drainage equipment, one can usually dispense with a complex surface drainage system. If a variable downward slope is planned for surface channeling of rain water into an additional drainage system then this is achievable by means of the slightly, joint-like flexibility in the interconnection between the TTE® elements without making any cuts. If the shaping of the surface is very pronounced then a smaller offset of the elements is necessary. Changes in the slope formation at the vertices are to be achieved in such a way that the individual elements lie close together. One should avoid making cuts as far as possible.

The surface slopes should be ≤ 2 % in order to secure full water seepage on the surface. Formation of a strong slope is only meaningful for an inadequate seepage capacity and integration of a French drain or connection to a drainage system. The slope of the covering, bedding and base course layer should normally be made the same.

If channeling of rain water in the TTE® drainage system is not possible by means of direct connection then suitable surface transport elements must be selected such as open gullies and grass troughs. If it is necessary to have subterranean channelling away of the runoffs (for example by using pipe elements), one must also take the expected operational loads into account.

Use of the TTE® system as a surface wide decentralized French drain seepage system with a storage function is only possible if the superstructure as well as the substrate are formed without a slope.

Drainage from the side

The option of having subterranean channeling of seepage water at the side into natural neighbouring surfaces improves the seepage capability. Therefore, when planning borders, formation of a trough through use of a closed, peripheral border should be avoided wherever possible. Based on the interconnection and the toothing of the individual elements, borders can also be interrupted in places (distance between a max. of 1 m).

Water permeability

When using the TTE® system as a decentralized drainage system we recommend creating a superstructure with a permeability ≥ 5.0×10^{-5} m/s.

Permeability* of TTE® surface layers with bedding:

- TTE® Green + bedding substrate (2/5 mm grit + top soil): 31200 l/s × ha
- TTE® Paving + 2/5 mm grit bed: 328000 l/s × ha

*) values only serve to provide orientation - determined by LWG, see Verifications and Test Certificates

Precipitation water must seep, after some time, into the substrate after inflow into the TTE® construction. To obtain a permanently high water absorbance capability and permeability the recommended degree of compaction for the building ground and the base course layer should be observed as far as possible.

One should dispense as far as possible with use of separating and filter fleece materials since these can impair the long-term drainage capacity. If they must be used (for example the TTE® surface infiltration ditch), then a filter measurement should be created according to the "Leaflet on the use of geosynthetics in earthworks for highway construction (M Geok E)" .

Dimensioning

TTE® as a decentralized drainage system

The TTE® construction principle 1 as well as TTE® surfaces with gradients are to be dimensioned and verified as surface seepage/drainage according to DWA-A 1381). Area drainage systems can be used particularly effectively for good permeability of the substrate. The TTE® construction principle favours very efficient use for these areas of application through its very low requirements on the compaction and a resultant high seepage rate.

The TTE® construction principle 2 + 3 should be planned as a surface French drain seepage system and dimensioned to effectively use its drainage potential.

Dimensioning according to DWA-A 138 (surface drainage)

Determination of the required seepage surface

The required seepage surface A_S can be determined according to DWA-A 138 through use of the following equation for a rainfall measure $r_{D(0.2)}$ with the time intervals D = 10 – 15.

$$A_S = \frac{A_u}{\frac{k_f \times s_f \times 10^7}{2 \times r_{D(n)}} - 1}$$

A_u = attached reinforced surface (in m²)

k_f = permeability coefficient for the saturated zone (in m/s)

$r_{D(n)}$ = decisive rainfall intensity (in l/s × ha)

s_f = number of joints of a permeable area reinforcement (TTE® = 1)

Verification of flooding and surface runoff

A prerequisite for the above design equations is that the precipitation intensity does not exceed the current seepage rate of the substrate and the superstructure so that no flooding of the surface can occur. The following equation should be fulfilled:

$$k_f \geq 2 \times r_{D(n)} \times 10^{-7}$$

If this condition cannot be fulfilled the permeability of the respective layer(s) should be increased by taking suitable measures, or analogously to integrate a French drain according to Figure 18.

This formula can also be used if no impermeable area is connected to the system. In this way there is verification that the viewed seepage surface itself remains free of runoff.

Drainage

TTE® as a surface decentralized French drainage system

The drainage function of the TTE®construction principles 2 + 3 is to be compared with a French drainage system due to the low compaction of the substrate and the superstructure, apart from an area-wide instead of a linear formation and a low porosity. For this reason the dimensioning should be undertaken based on DWA-A 138 for French drains.

The required storage volumes can be created through adaptation of the height of the base course layer or vegetation base course layer. Therefore the base course layer forms the French drain. The usable porosity for storage of the covering and bedding layer is not taken into account. It represents a form of safeguarding for a possible re-compacting through use. According to the chosen construction principle this additional safety margin represents a factor of 1.3 - 1.6 of the storage capacity of the (vegetation) base course layer.

Table 19: Precipitation heights and rainfall intensities for 83224 Grassau

(KOSTRA-DWD-2000 evaluation period: 1951 - 2000)

Period continued for	Recurrence interval (years) 5	
	N	R
5 min.	14.2	472.6
10 min.	20.4	340.4
15 min.	24.7	274.8
20 min.	28.0	233.1
30 min.	32.5	180.7
45 min.	36.9	136.8
60 min.	40.0	111.2
90 min.	**43.5**	**80.6**

N = Precipitation height in millimetres
R = Rainfall intensity in litres per second and hectare

If only precipitation water is drained off, which itself falls directly onto the TTE® surface, then the layer thicknesses of the (vegetation) base course layer of the TTE® construction principles 2 + 3 are usually adequate as a storage space. This under extreme conditions for kf = 1.0 × 10^{-6} m/s (minimum requirement on the permeability) of the substrate and a low storage coefficient of 0.2 of (vegetation) base course layer is even **capable of absorbing the highest possible rainfall intensities experienced in Germany (83224 Grassau)*.** Thus the required base course layer height for a rainfall intensity of 80.6 l/(s × ha) with a period of raining of 90 minutes (= 43.5 l/m² total precipitation amount) is about **20.4 cm.**

*) determined by the German Weather Service, Hydrometeorology Department (DWD), see Table 19

Storage coefficient

The storage coefficient (s) represent the usable porosity for storage of a certain material mixture and is primarily influenced by grain composition and the compression ratio.

The effective pore volumes of a certain material can be determined from the difference between the total pore volumes and unfree water. Using larger vessels with known volumes allows determination over a volume or weight difference (Sieker, F. (publisher): Near-natural rain water resources management Berlin: Analytica, 1998).

The storage coefficient for the vegetation base course layer can be calculated during measurement of the water storage capacity/max. water capacity according to the FLL-"Recommendations for tree plantations – Part 2" – Annex A according to the air volume for a maximum water capacity.

The following values are intended to provide orientation (see Table 20).

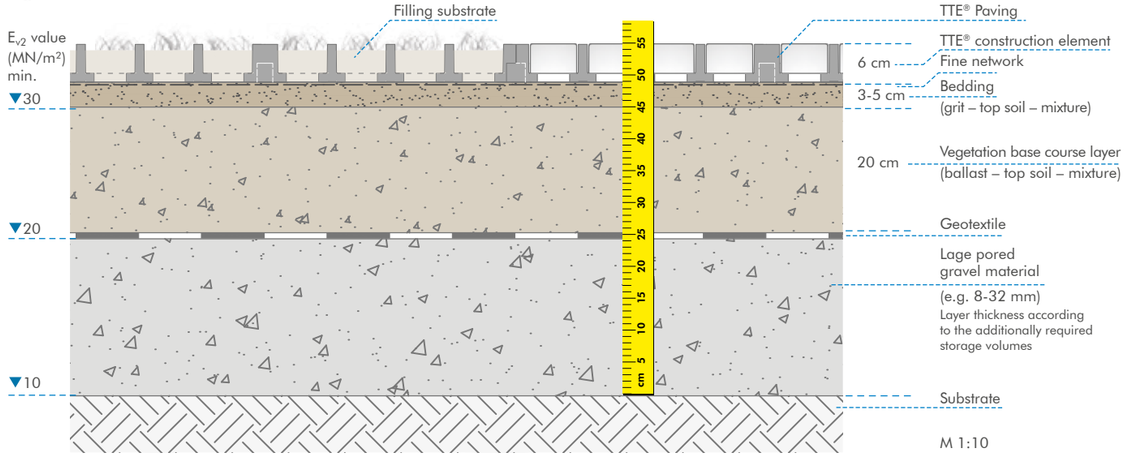
For gravel base course layers of the TTE®construction principle one can assume, based on the smaller compression ratio, that the storage coefficient s is greater than 0.2. Based on experience s can also be taken as at least 0.2 for vegetation base course layers.

Table 20: Storage coefficients of various building materials

Material	Storage coefficient (s)
0/32 mm or 0/45 mm crushed gravel for D_{Pr} 100 %[1)]	approx. 0.2
8/16 gravel[2)]	approx. 0.28
16/32 gravel	approx. 0.4
8/56 Grauwacken crushed gravel[2)]	approx. 0.38

[1)] Based on experience
[2)] *Sieker, F. (publisher): Near-natural rain water resources management. Berlin: Analytica, 1998).*

Figure 20: Surface Infiltration Ditch



The TTE® Surface Infiltration Ditch (with geotextile and open pored gravel material can be used for higher demands on the storage capacity, for example 8/32 mm). If TTE® paved areas are used as a surface French drain seepage system for harmless runoffs according to DWA-A 138, the base course layer material can be replaced for a higher storage capacity by the 2/32 mm or 8/32 mm gravel mixture.

An up to 40t TTE® surface infiltration ditch (FR) which can be driven over

Drainage

Dimensioning should be undertaken based on DWA-A 138 (French drains)

Determination of the required base course layer or French drain height

The required length of the French drain l_R is determined during dimensioning of French drains according to DWA-A 138. For the TTE® construction principle the formula was resolved according to h_R in order to be able to determine the required base course layer or French drain height.

The TTE® area should be added to the impermeable area since this is itself loaded with the measured rainfall. Any seepage at the sides of the construction is not considered here, which is different to the approach taken by the DWA.

The required base course layer height can be determined through iterative use of the equation for the different time intervals. The measured rainfall should be taken according to DWA-A 138 with $r_{D(0.2)}$ for D = 10/20/30/45/60/90 using a safety factor fZ = 1.2.

$$h_R = \frac{[\,(A_u + A_s) \times 10^{-7} \times r_{D(n)}\,] - (l \times b \times k_f/2) \times D \times 60 \times f_Z}{b \times l \times s}$$

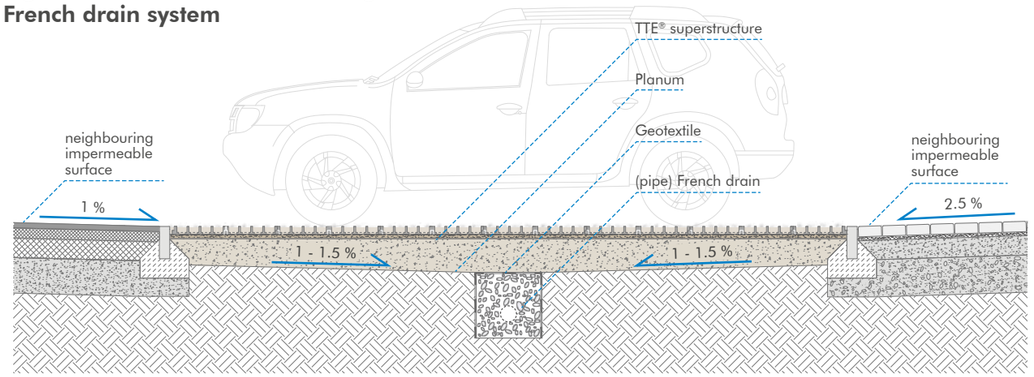
The local rainfall intensity must not exceed the seepage rate of the TTE® superstructure. Therefore the following equation should be fulfilled for this using the measured rainfall $r_{10(0.2)}$:

$$k_f \geq 2 \times r_{D(n)} \times 10^{-7}$$

A_u: Attached reinforced surface (in m²)
A_s: Drainage surface (TTE® surface) (in m²)
k_f: Permeability coefficient for the saturated zone (in m/s) according to DWA A 138 (Annex B)
$r_{D(n)}$ = decisive rainfall intensity (in l/s × ha)
D: Period of incidence of the measured rainfall (in min)

f_Z: Safety factor according to DWA-A 117 (f_Z =1.2)
l: Length of the layer (in m)
b: Width of the layer (in m)
h_R: Required height of the French drain (in m)
s: Storage coefficient of the material

Figure 21: Combination consisting of TTE® and a French drain system



Combination with conventional French drain systems

TTE® offers many-faceted options to make combinations for decentralized drainage elements. Thus also additionally conventional (pipe) French drain systems can be integrated in under the required TTE® superstructure (Figure 21). Precipitation waters primarily seep naturally into the substrate. They are pretreated by the living soil layers over a wide area. Seepage water which the upcoming soil can no longer take up directly can be stored intermediately in the French drain and the TTE® construction. Instead of flowing into a trough the runoffs are taken up over a wide area and channelled into the French drain. For channeling through a direct connection to a TTE® surface the length of the French drain should be adapted wherever possible to the attached area in order to ensure even channelling. The French drain should be dimensioned regularly according to DWA-A 138.

A width which is as narrow as possible should be selected for the French drain. We recommend laying in a Herringbone lattice. The building material 8/32 gravel is suitable as a filler for the French drain due to its grading.

The combination of the TTE® construction principle with a French drain is also available for TTE® surfaces with a slope in order to allow storage if required.

Functional and design integration of the TTE® system

The TTE® drainage can be applied, distributed over the areas to be drained, in order to channel the precipitation runoffs directly into the drainage area.

At the same time the system in this form is used as a means for green area design and serves as optical upgrading and structuring.

Operation of drainage systems

Drainage systems should be subjected to regular checking. Please note the following for operation of drainage systems according to DWA-A 138:

In order to maintain permanent permeability, work should be performed as part of upkeep of the greenery as well as removal of grass cuttings and, in particular, foliage items from the drainage area.

If the cleaning and retention capacities are overloaded by a long-term and increased entry of non-degradable substances, the upper infiltration layer should be exfoliated.

For the TTE® drainage system this represents removal and new installation of the surface layer including the filling substrate and also the bedding if necessary. The removed elements can usually be reinstalled according to the previous period of use and intensity of use. The removed material should be disposed of in an orderly manner.

If there is a change of use one should check whether the drainage system continues to fulfil the required qualitative requirements.

Example Layouts

Use of TTE® opens up new possibilities for combining lawns and paving. It is very easy for green, living structures to be weaved into paved surfaces.

The TTE® construction principle as a permanently seepage-providing and even surfaced load bearing structure for paving and slabbed surfaces. The innovative solution for poor building ground.

A rounded edge with a clean separation between the filled and the greened TTE® surface

Use of differently coloured paving stones allows one to create borders, markings and designs very easily.

Checks/tests and Test Methods

The required properties must be verified according to the pertinent guidelines and information leaflets.

It is recommended to perform suitability checks, above all for vegetation base course layers, early on using test mixtures which match the planned features of the building material mixture. In this way the design data relevant to the planning such as the permeability and the storage coefficient are available in advance and there remains some flexibility if necessary for adaptation of the substrate.

For similar building measures one can refer to the results obtained from an existing suitability check which is no older than 2 years old.

The type and properties of the building materials and building material mixtures used must not change, however. The verification will have to be produced again if that is the case.

According to statements made in a leaflet concerning additional technical regulations for creation and application of improved vegetation base course layers (ZTV Vegtra-Mü), the time required to determine the water storage capacity has significantly increased the checking period. One can possibly dispense with this investigation to avoid this.

Upkeep and Maintenance

General points

Acceptance testing and claims for defects, finishing as well as development and maintenance and upkeep should be performed according to the FLL guideline for greenable surface reinforcements. There are also the following measures for maintenance and upkeep of surface reinforcements with the TTE® system:

Winter service

One should dispense with spreading of road salt since this has a negative effect on the vegetation, the soil and the ground water. Grit can be used instead as a dulling material. However, only small amounts should be used for the TTE® paving construction principles. The material should be removed from the surface when Winter is over.

Removal of snow by vehicles not using snow chains with a plastic/rubber lip on the snow blade is possible. The maximum vehicle weight should be taken into account according to the construction principle. For greened TTE® areas the blade should be set higher in order to avoid damaging the vegetation. If the lawn covering is covered by about 5-10 cm with snow then it will be better protected against frost.

Navigability

Navigability according to the selected construction principle:

TTE® Construction Principle 1:
Vehicles up to a maximum of 3.5 t

TTE® Construction Principle 2:
Vehicles up to a maximum of 16 t and a maximum of a 10 t axial load, occasionally up to 40 t permissible GG (of a 10 t axial load)

TTE® Construction Principle 3:
Vehicles up to a maximum of 40 t and a maximum of a 10 t axial load

Care instructions for TTE®Paving

Larger items of dirt should be removed as soon as they are discovered in order to maintain the water permeability of the covering. Dirt particles arising from normal vehicle traffic do not usually impair the water permeability. One might consider cleaning the joints with a high pressure cleaner.

Care instructions for TTE®Green

For greenable TTE® construction principles one must watch out for changes occurring due to use and influences of the weather. Regular care and upkeep is necessary to ensure the quality remains constant. Therefore it is recommended to inform the client adequately.

After-sowing

After-sowing may become necessary. After-sow as required in Spring after the first Winter with the already used seed mixture according to RSM, using about 15-20 g/m².

Irrigation

Watering should be undertaken, if necessary, after longer dry periods. Parking spaces where the vehicles remain stationary for longer periods of time, for example: employee parking spaces, should be watered if necessary during free unused periods in order to avoid dryness damage due to rain shadows.

Using fertiliser

Use of fertiliser as part of the follow-up care should be undertaken according to the FLL guideline for greenable surface reinforcements. Further use of fertiliser should take place according to the amount of greenery present. We recommend use of a fertiliser once a year in the Spring using slow release fertiliser. This can be necessary to ensure that there is a sufficient supply of nutrients available. Notes on the properties of fertilisers can be obtained from the FLL "Descriptive register of fertilisers for landscaping and sports field construction".

Mowing

Mow TTE® greened areas with a cutting height of 4 cm at least two to four times a year. The frequency of cutting should be adapted to the amount of greenery desired and the usage.

The cut grass should be removed to avoid felting of the turf. Furthermore, parts of plants which have died should be loosened once a year (after the Winter) using a suitable sweeping machine and then removed. This prevents felting and growing out of the turf.

Bibliography

DIN 18121: Examination of soil samples – water contents – Part 1: Determination through drying in the oven

DIN 18123: Building ground; examination of soil samples – determination of the grain size distribution

DIN 18124: Building ground; examination of soil samples – determination of the grain density Capillary pyknometer, wide throated pyknometer, gas pyknometer

DIN 18123: Building ground; examination of soil samples – determination of the density of the soil – Part 1: Laboratory investigations

DIN 18128: Building ground - examination of soil samples – determination of the annealing loss

DIN 18128: Building ground; examination of soil samples; determination of the water permeability coefficient – Part 1: Laboratory investigations

DIN 18134: Building ground; trials and test equipment – plate bearing test

DIN 18202: Tolerances in building construction – buildings

DIN 18299: General regulations for construction works of every type

DIN 18300: Earthworks

DIN 18315: Traffic route engineering work – surface layers without a binding material

DIN 18318: Traffic route engineering work – paved and slabbed surfaces in an unattached design, borders

DIN 18320: Landscape construction work

DIN 18915: Planting techniques in landscaping – ground preparation activities

DIN 18917: Planting techniques in landscaping – working on lawns and seeding

DIN 18918: Planting techniques in landscaping - bioengineered securing techniques – securing through sowing, plantation, construction methods with living and non-living materials and components, combined construction methods

DIN 18919: Planting techniques in landscaping – development and maintenance and upkeep of green areas

DIN 483: Curb stones made out of concrete (national collateral standard to DIN EN 1340)

DIN EN 13286-2: Unbound and hydraulically bound mixtures – Part 2: Laboratory test methods for the dry density and the water contents – the Proctor test

DIN EN 1340: Curb stones made out of concrete - requirements and test methods

DIN EN 932-3: Test methods for general properties of aggregates – Part 3: Performance and terminology of a simplified petro-graphic description

DIN EN 933-1: Test methods for geometric properties of aggregates – Part 1: Determination of the grain size distribution – the sieving process

DIN EN 933-4: Test methods for geometric properties of aggregates – Part 4: Determination of the grain shape; grain shape classification number

DIN ISO 10390: Property of the soil – determination of the pH value

DWA-A 138: Planning, building and operation of systems for seeping away rain water

DWA-M 153: Recommendations concerning handling rain water

FLL: Recommendations for tree plantations – Part 2

FLL: Special report for planning, building and maintenance of water-bound paths

FLL: Standard seed mixtures for lawns (RSM)

FLL: Guideline for planning, laying and maintaining greenable surface reinforcements

M Geok E: Leaflet on the use of geosynthetics in earthworks for highway construction

RStO 12: German Directives for the Standardization of Traffic Area Surfaces

TL Stone-StB 04: Technical delivery conditions for aggregates in road building

TL SoB-StB 04: Technical delivery conditions for construction material mixtures and soils for manufacture of layers without a binding agent in road building

VDLUFA: Verband Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten, A10.1.1, Determination of salt levels in soils, garden earth and substrates

ZTV E-StB 94: Additional technical specifications and guidelines for performing earthworks in road building

ZTV Paving-StB 06: Additional technical delivery conditions and guidelines for creating paved surfaces, slabbed surfaces and borders

ZTV SoB-StB 04: Additional technical specifications and guidelines for layers without a binding agent in road building

ZTV Vegtra-Mü: Additional technical regulations for creation and application of vegetation base course layers

Sustainable ground reinforcements on the basis of over 16 years of practical experience

Individual TTE® solutions

The HÜBNER-LEE team is available to you at all times to answer questions and are happy to advise you during your planning phase. We are happy to visit you onsite in special cases and for large building projects and to accompany you with advice during execution.

TTE® and its European partners:

(A) Austria
ZAHRER GmbH & Co KG TTE-Bodensysteme
4974 ORT in Innkreis No. 60
Tel: +43 (0)7751-89250
Fax: +43 (0)7751-892516
E-Mail: tte@zahrer.at, Web: **www.tte.at**

(CH) Switzerland
KELLER Bodensysteme GmbH
Rebberghof, 5330 Zurzach
Tel: +41 (0)56-249 3473
Fax: +41 (0)56-249 0181
E-Mail: info@keller-bodensysteme.ch
www.keller-bodensysteme.ch

(AZ) Azerbaijan
AZ Warenhandelsgesellschaft mbH & Co. KG (registered offices in Germany)

(DK) Denmark
Skandinavisk Byggeplast

(F) France
O2D - Sol & Aire

(KZ) Kazakhstan
ParCoS - www.ecoparking.kz

(LT) Lithuania
Žaliasis Rojus

(NL) Netherlands
North: TONN Nederland
South: S.P.M. Lintzen vof

(RU) Russia
Russkoe Pole - www.russpole.ru

(SE) Sweden
TTE-Sweden

(UA) Ukraine
Right Solutions Ltd.
www.ecoparkovka.com.ua

(UK) Great Britain
TTE Global Limited

www.tte.eu

HÜBNER-LEE

HÜBNER-LEE GmbH & Co. KG
Gewerbestrasse 1, D-87752 Holzgünz
Tel: +49 (0)8393-9229-0, Fax: +49 (0)8393-9229-22
Email: info@huebner-lee.de

Per QR code
direct to the website TTE®
outside facilities

07-2013