GREEN ROOF INNOVATORS

PODIUM ROOF DECKS
PARKING ROOF DECKS

0.4

DESIGN AND
INSTALLATION MANUAL

GREEN ROOF INNOVATORS

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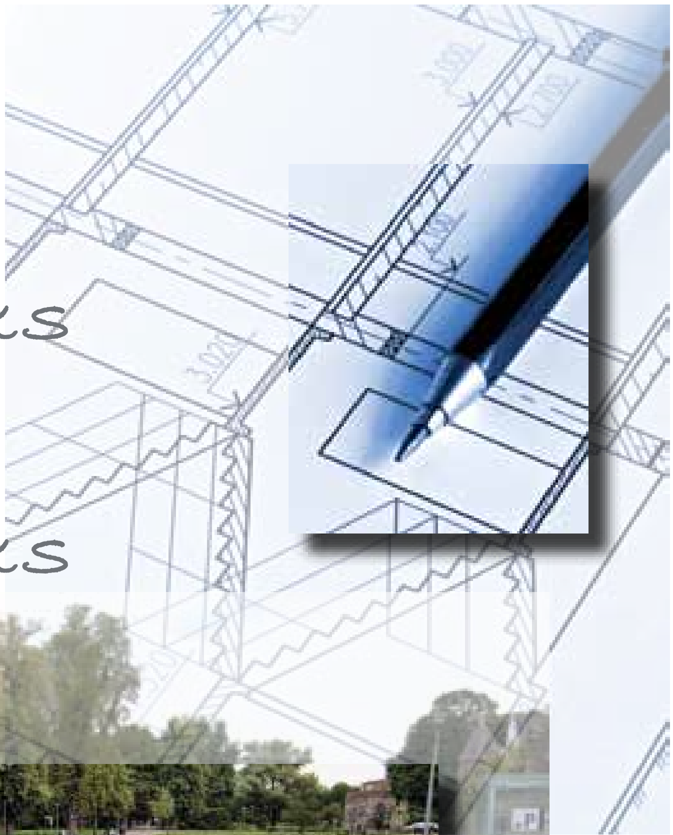


HIGH COMPRESSIVE STRENGTH

SIMPLE TO INSTALL

EASY TO COMBINE WITH SOFT LANDSCAPING

0 INTRODUCTION

As urbanisation expands and the number of cars on our streets continues to grow, the lack of parking places is forcing us to reconsider our use of space, to maximise its potential, and to investigate the possibility of vertical development. Modern offices, apartment blocks and shopping centres use a combination of hard and soft landscaping on their flat roofs and underground parking facilities to make the most of their limited open space. Careful planning and good design will improve overall living conditions within our cities by creating large, open green areas and places for recreation and leisure, while sub-surface structures provide the necessary underground parking that will prevent it from intruding into the urban environment.

Careful planning by architects and design engineers can maximise the use of valuable open spaces by covering roofs with extensive and/or intensive planting schemes that are combined with suitable hard-landscaping to provide access for vehicles and/or pedestrians. Any design will need to accommodate specific construction requirements such as the required build-up depth for elemental paving, the depth of growing medium required by the planting scheme, the maximum permissible surface loads, the provision of a suitable waterproofing system, and so on.

When paving of any type is used, it will not be constructed over a prepared sub-grade, as would normally be the case, but will be constructed on top of a structural deck, and so the design must address the following considerations:

- the difference in behaviour and reaction that can be expected between natural sub-grades and constructed roof decks
- the waterproofing system must be suitable for both static and the loadings
- the type of roof construction, whether it is a "warm roof", an inverted roof, or a "cold roof"
- the compressive strength of any thermal insulation
- the type and depth of any granular materials, such as sub-base layers or laying courses
- the type, depth and behaviour of any elemental paving
- the anticipated usage and the predicted intensity of use of the roof deck structure by both people and vehicles, and the loads imposed as a consequence of such use

1 DESIGN CONSIDERATIONS

1.1 Standards

CE-marking BS EN 13252

The European standard BS EN 13252 "Geotextiles and geotextile-related products. Characteristics required for use in drainage systems" specifies the relevant characteristics of geotextiles and geotextile-related products used in drainage systems, and the appropriate test methods to determine these characteristics. This standard provides procedures for the evaluation of conformity of the product to this European Standard and for factory production control procedures. Based upon this European standard, geotextiles and geotextile-related products used in drainage systems must carry a CE-mark. Drainage systems are defined as systems that collect and transport precipitation, ground water, and/or other fluids.

It is not only geotextiles such as woven and non-woven filter fabrics that fall within the scope of this European Standard (BS EN ISO 10318 "Geosynthetics – Terms and definitions"), it also includes geotextile-related products e.g. prefabricated sheet drains (geocomposites) and eggbox-shaped dimpled sheets (geospacers*).

As a responsible manufacturer, Nophadrain BV is required to prepare a declaration of conformity that the geotextiles and geotextile-related products placed onto the market fulfil the requirements as set forth in BS EN 13252. Part of this declaration of conformity is a statement of factory production control procedure. This procedure consists of a permanent internal production control system to ensure that the ND Drainage Composites comply with BS EN 13252 and that the measured values conform to the declared values. Nophadrain is audited annually by a notified body (an independently accredited body). The declaration of conformity entitles Nophadrain to affix the CE-marking to its drainage composites and to place its products onto the European market.

All geotextiles and geotextile-related products placed in the market by Nophadrain have the CE-marking affixed.

* *three-dimensional polymeric structure designed to create an air space in soil and/or other materials in geotechnical and civil engineering applications (BS EN ISO 10318)*

1.2 Load classification

There are no published standards governing the construction of elemental pavements over a roof deck in the UK or RoI. Through research in close cooperation with the Technical University in Munich, Germany, the following load classes can be distinguished based up on the intended use of the roof deck.

Load class	Use	Traffic	Axle load up to	Wheel load up to
1	Intensive green roofs, podium roof decks, patio roof deck	Pedestrian, bicycles	–	–
2	Parking roof deck	Cars	10kN Front axle 15kN Rear axle	5kN Front axle 7.5kN Rear axle
3	Parking roof deck	Heavy good vehicles (HGV)	100kN	50kN

Table 1. Load classification

1.3 Roof deck constructions

The structural deck needs to be able to withstand and to absorb the static and dynamic loads imposed during construction and final use. The following roof deck constructions are recognised:

Cold roof construction
This is a roof construction with an independent ceiling enclosing an air space between the structural deck and the ceiling. When insulation is used it should be placed below the structural deck with a ventilated airspace in between. Generally speaking, this type of roof deck construction is not suitable for vehicular trafficked decks; i.e. load classes 2 and 3.

Warm roof construction
This is a roof construction without a ventilated airspace beneath the structural deck. When insulation is used it should be placed on top of the structural deck. In general, this type of roof deck construction is suitable for both pedestrian and vehicular trafficked roof decks; i.e. load classes 1 to 3.

Inverted roof construction
Insulation is placed on top of the waterproofing membrane. Should an inverted roof be selected for paving, moisture diffusion measures should be considered. When a paving is installed, a damp-permeable drainage layer must be placed over the thermal insulation in order to protect the insulation from accumulating moisture (internal condensation) over time. In general, this type of roof deck construction is suitable for both pedestrian and vehicular trafficked roof decks; i.e. load classes 1 to 3.

Roof construction without thermal insulation
On top of the structural deck the waterproofing membrane is installed without any thermal insulation. A characteristic of this roof construction is that the space beneath the roof is not heated. In general, this type of roof deck construction is suitable for both pedestrian and vehicular trafficked roof decks; i.e. load classes 1 to 3.

1.4 Thermal insulation

Thermal insulation needs to be CE-marked based upon the BS EN 13162 – 13171 "Thermal insulation products for buildings. Factory made …… Specification".

There are two different methods for installing thermal insulation to a roof deck:

- WRC = insulation is placed beneath the waterproofing membrane – warm roof deck construction
- IRC = insulation placed above the waterproofing membrane – inverted roof deck construction

Suitability of the various types of thermal insulation:

A cold roof has been omitted as this type of roof construction is rarely used nowadays.

The waterproofing membrane and the applied thermal insulation should be able to withstand short and long term loadings. Should any deformations of the thermal insulation be expected, it should be taken into account when detailing the waterproofing membrane (roof outlet, roof edge, roof protrusion, etc.). For load class 1, the roofs built on an insulated roof, the thermal insulation should meet minimum load class "dh". For load classes 2 and 3 the thermal insulation should meet load class "ds" respectively load class "dx". The suitability of thermal insulation is to be demonstrated by the manufacturer.

Thermal insulation classification	Roof construction	dm	dh	ds	dx
Expanded polystyrene (EPS)* in accordance with BS EN 13163 "Thermal insulation products for buildings. Factory made products of expanded polystyrene. Specification"	WRC	100kPa*	150kPa*	–	–
	IRC	–	–	–	–
Extruded polystyrene(XPS)* in accordance with BS EN 13164 "Thermal insulation products for buildings. Factory made products of extruded polystyrene. Specification"	WRC	200kPa*	300kPa*	500kPa*	–
	IRC	300kPa*	300kPa*	500kPa*	700kPa*
Rigid polyurethane foam (PUR)* in accordance with BS EN 13165 "Thermal insulation products for buildings. Factory made products of rigid polyurethane foam. Specification"	WRC	100kPa*	100kPa*	150kPa*	–
	IRC	–	–	–	–
Cellular glass (CG)* in accordance with BS EN 13167 "Thermal insulation products for buildings. Factory made products of cellular glass. Specification"	WRC	400kPa*	400kPa*	900kPa*	1,200kPa*
	IRC	–	–	–	–

Table 3. Load class and compressive strength thermal insulation
** compressive strength at 10% deformation in accordance with BS EN 826 "Thermal insulating products for building applications. Determination of compression behaviour"*

Load classification	Description	Possible application
dm	Medium load bearing	Extensive green roof
dh	High load bearing	Intensive green roof/podium roof deck
ds	Very high load bearing	Parking deck with limited car traffic
dx	Extreme load bearing	Parking deck with car and truck traffic

Table 2. Load classification thermal insulation

Recommendation
If a paving needs to build-up over an insulated roof, it is recommended that an inverted roof construction with XPS insulation or a warm roof construction with cellular glass be chosen. With an inverted roof the waterproofing membrane should be fully bonded with the structural deck, in order that any leak in the waterproofing membrane can be easily located. The XPS insulation panels offer extra protection of the waterproofing membrane during installation of the paving build-up.

It is important that a damp-permeable drainage layer is placed on top of the XPS insulation. This allows the panels to dry. Water absorption due to internal condensation will be minimised. It is not necessary to install a separate vapour control layer as the waterproofing itself acts as one. The drainage layer should not damage the top of the insulation panels. Full bonding of the waterproofing membrane is also possible with a warm roof construction if cellular glass is used as thermal insulation. The cellular glass panels are fully bonded with the structural deck and all joints are filled with bitumen. The waterproofing system is thereby fully bonded with the cellular glass panels.

1.5 Waterproofing systems

Continuous waterproofing systems
Roof constructions are, in general, protected against the penetration of water by a waterproofing system (bitumen, synthetic or liquid-applied). When designing and choosing a waterproofing system, the intended use, applicable standards, regulations and standards of good practice have to be observed. Roof decks should be constructed with adequate falls. The waterproofing system should be designed to suit the anticipated use. To maintain the integrity of the waterproofing membrane, and to ensure proper construction of the paving, it is essential that the membrane system be laid as flat as possible.

On trafficked roof decks, horizontal loads caused by vehicle overrun can excessively compress the waterproofing membrane. Such loading should be avoided and therefore separation and slip layers should be built in to the structure.

The waterproofing membrane beneath any vegetation (intensive or extensive planting schemes) should be root resistant or protected against root penetration by a separate root barrier. Root resistance can be proven if the material has passed the FLL root resistance test.

The membranes can be applied in one or two layers and attached to the structural deck according to the following methods:
- loose laid and ballasted
- mechanically fixed
- fully bonded

The build-up of a fully bonded waterproofing system can be as follows:
Bitumen – modified bitumen waterproofing membranes (APP – SBS)
- at least two layers
- first layer: a polyester based roofing felt fully bonded to the structural deck (pour and roll)
- top layer: a root resistant APP or SBS waterproofing membrane fully bonded (torched)

Synthetic waterproofing membranes
- at least two layers
- first layer: a polyester based roofing felt fully bonded to the structural deck (pour and roll method)
- top layer: a EPDM, ECB, POCB or TPO waterproofing membrane fully bonded to the first layer

Liquid-applied roof waterproofing
- liquid-applied roof waterproofing is regarded as a single layer system
- it should adhere to the entire surface and be applied in at least two discrete layers
- a suitable geotextile should be placed in between the layers as a reinforcement
- the manufacturer should have European Technical Approval in accordance with ETAG 005 "Liquid Applied Roof Waterproofing Kits"

Mastic asphalt
- the concrete sub-structure needs to be primed before installation
- as a sub-layer – a root resistant APP – SBS torch-on membrane
- the asphalt layer with a minimum thickness of 25mm should be installed on top of the sub-base

Water-resistant concrete
- requirements for water-resistant concrete are specified in BS EN 206-1 "Concrete. Specification, performance, production and conformity "and BS 8500 "Concrete – Complementary British Standard to BS EN 206–1 Parts 1 and 2"
- cracks in any direction should be limited to ≤0.2mm

Recommendation
It is recommended that a waterproofing membrane is fully bonded with the structural deck. In many installations leakages occur due to incorrect detailing, poor choice of materials or errors/damage incurred during installation. When a loose laid waterproofing system is damaged, the point of leakage is difficult to locate as the water can move freely over the structural deck. Fully bonded waterproofing systems give much more security if they are installed on a closed structural deck. This means that with insulated roof constructions the choice is limited to a warm roof with cellular glass or an inverted roof with XPS insulation.

If it has been decided to install a warm roof construction in which the waterproofing membrane is not fully bonded with the structural deck, it is recommended that separate compartments within the vapour control layer be created. In case of any damage to the waterproofing membrane, any leak can be located more easily.

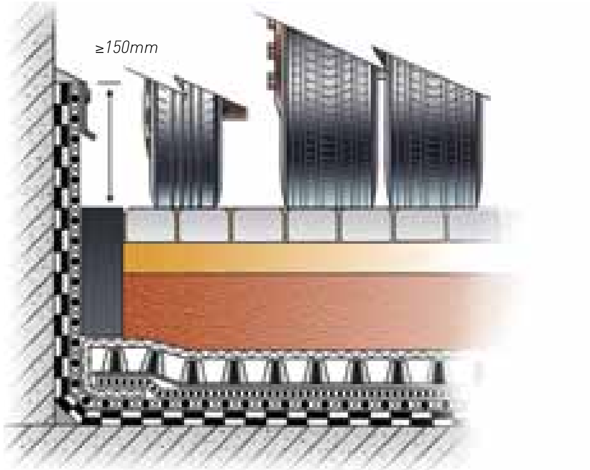
1.6 Details

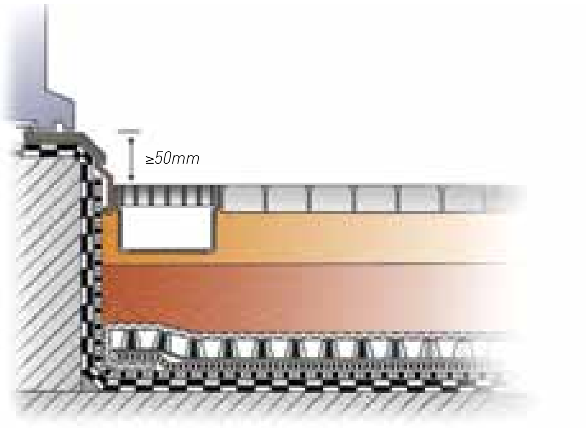
Basically, the same waterproofing detail principles apply to hard landscaped roof decks as to flat roof decks. The waterproofing membrane should be brought up above the surface level (paving) by at least 150mm.

At door thresholds where a drainage channel is installed, the waterproofing membrane can be brought up above the surface of the paving by 50mm.

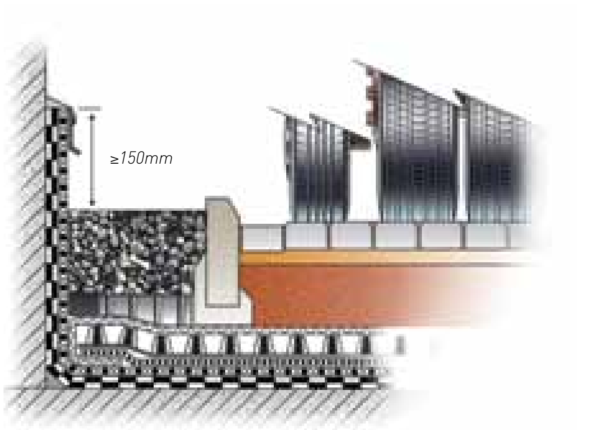
If the waterproofing membrane projects over the roof edge into the ground, it is recommended that the waterproofing membrane extends a minimum 500mm beyond the edge and at least 200mm over a joint.

When paving is placed against the façade, a rubber strip is placed between the paving and the waterproofing membrane to protect the waterproofing membrane against mechanical damage.





Detail 1. Door threshold



Detail 2. Facade

1.7 Design of falls – structural roof deck

The structural deck of a trafficked roof deck should be constructed with adequate falls to prevent water ponding on the waterproofing membrane, the sub-base, and/or the laying course. Falls should be such that surface water is directed off and away from the structural deck as quickly as possible.

In order to achieve satisfactory drainage, trafficked roof decks should have a fall of not less than 1 in 80 (~1.3%). However, because of the risk of settlement, roof deflection and construction inaccuracies, a fall greater than 1 in 80 should always be stipulated. It is both practical and economic to design using falls of 1 in 40. However, on some buildings this can prove to be an excessively severe design criterion. As an alternative, the designer may elect to use a fall of 1 in 80, and then add a further 25mm of fall for concrete roof decks or an additional 15mm of fall for metal roof decks.

Recommended falls of a structural deck:
- load class 1 ≥1 in 50
- load classes 2 and 3 ≥1 in 40

Falls beneath the water proofing membrane can be achieved:
- in the structural deck
- by screed to falls
- by tapered thermal insulation

Note
If water is ponding on the structural deck due to a lack of sufficient falls additional measures need to be taken in respect of the drainage and possible frost damage of the paving build-up.

Possible solutions are:
- the use of a geo-composite suitable for a roof with no fall with a specification of the drainage length
- the use of a "no fines" sub-base material (material with no part cles smaller than 1mm)
- the use of a "no fines" laying course material when the paving is placed directly on top of the ND Drainage Composite
- the use of a no-fines permeable concrete

The most suitable solution depends on the individual project.

Products:
ND 5+1lt Drainage Composite

1.8 Roof drainage

On roof decks carrying an elemental pavement, drainage of surface water and seepage water is achieved by means of roof outlets. The roof outlets are connected to a gravity drainage system within or outside the building that directs collected water to a conventional sub-surface stormwater system or over the edge of the roof deck. All surface and seepage water should be discharged at standard atmospheric pressure and without any attenuation.

Three discharge levels are identified:

- 1st level – waterproofing membrane
- 2nd level – elemental paving
- 3rd level – thermal insulation (inverted roof)

Stormwater discharge via gravity drainage inside a building – roof outlets

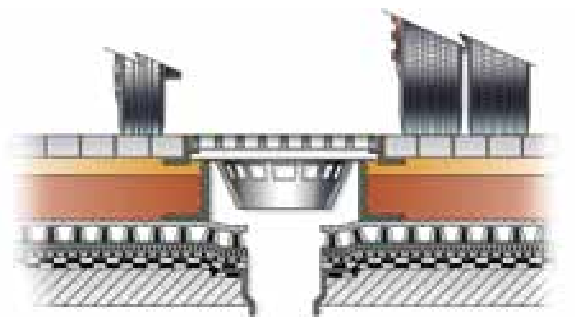
Roof outlets have to be placed at the lowest point of the roof. They have to be dimensioned in accordance with BS EN 12056-3 " Gravity Drainage Systems Inside Buildings" and be accessible for inspection at all times. The roof outlets must collect and discharge both the surface water run-off from the paving along with any water that penetrates the paving joints and enters the laying course.

Roof outlets located within a paved area should incorporate an inspection chamber with a gully top grating laid flush with the paving. The class of the inspection chamber and the gully top grating should match or exceed the load class of the overall roof deck. The inspection chamber should also incorporate a silt trap. Point loads on the inspection chamber should be dispersed over the sub-base or drainage layer.

The shaft of the inspection chamber should enable collection and discharge of water from the 1st discharge level (waterproofing membrane) and the 3rd discharge level (thermal insulation inverted roof). The gully top grating should be able to collect the water from the 2nd (elemental paving) discharge level.

The requirements of the gully top grating depend on the load class (BS EN 124 "Gully tops and manhole tops for vehicular and pedestrian areas"):

- load class 1 = gully top grating class A
- load class 2 = gully top grating class B
- load class 3 = gully top grating class D



Detail 3. Inspection chamber with gully top grating

Linear drainage channel

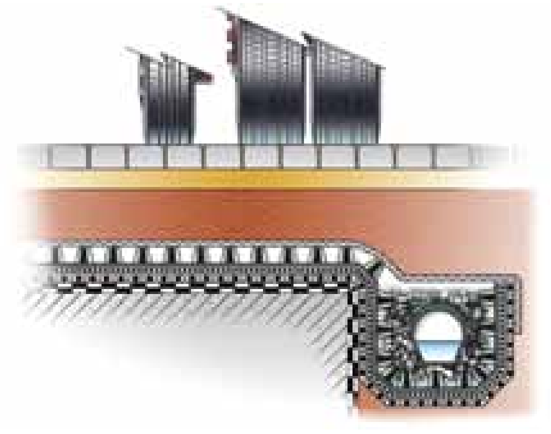
The laying course or support layer for a linear drainage channel must not obstruct or block the horizontal flow of the drainage layer. Linear drainage channels may be used as an alternative to inspection chambers with a gully top grating. The gratings of the linear drainage channel units should permit collection and discharge of the surface water without the need for any additional pressure or attenuation.

Both drainage channel and grating must match or exceed the load class of the roof deck BS EN 1433 "Drainage channels for vehicular and pedestrian areas – Classification, design and testing requirements, marking and evaluation of conformity" and BS EN 124. The linear drainage channels should be connected through appropriate inspection chambers to roof outlets and when placed in front of façades/door thresholds can discharge through the drainage layer.

Stormwater discharge over the roof edge

Surface water can also be collected by a roof-edge gutter system, or discharged over the roof edge into the adjacent ground. A filter or fin drain construction (trench of clean, free-draining, inert aggregate surrounding a perforated pipe that is wrapped in a geotextile) must be placed along the edge to prevent inundation and damage to the sub-base of the paved area.

Where vertical walls are present, such as in a basement structure, they must be protected with a suitable drainage composite that will prevent any build-up of hydrostatic pressure against the sub structure.



Detail 4. Stormwater discharge over the roof edge

Surface water from adjacent roofs and facades

When determining the surface water discharge requirement of a roof deck, it is essential that any potential discharges from adjacent roofs and façades are accommodated. If such accommodation is not possible, adequate provision for independent drainage of these adjacent roofs must be made. Run-off from adjacent facades can be collected and discharged using aggregate strips and/or linear drainage channels connected to appropriate roof outlets or the drainage layer.

2 THE BUILD-UP OF A PODIUM AND PARKING ROOF DECK

The build-up of elemental paving comprises the layers listed below, each of which is considered in subsequent sections:

- separation layer
- slip layer
- protection layer
- drainage layer
- filter layer
- sub-base layer
- levelling layer
- laying course
- paving

The compatibility and co-operation of each of the individual layers is critical to determining a reasonable life-span for a flexibly paved surface. Each layer must have the ability to absorb and constrain the potential dynamic and static loadings, have adequate compressive strength, and must not exhibit any unacceptable short-term flexion. Normally each layer has its individual function in the total system build-up.

However it is possible that:

- a single product integrates the function of several layers – e.g. the slip layer can also fulfil the function of the separation and protection layer
- certain layers use more than one product – e.g. the slip layer needs to have two separate non-adhesive surfaces to enable slippage to occur

2.1 Separation Layer

Chemically incompatible building materials need to be isolated by a separation layer (e.g. Polyvinyl Chloride (PVC) and Polystyrene (PS)).

A separation layer can consist of a:

- plastic sheet
- geotextile

Incompatible building materials need to be separated (covered) completely.

The ND Drainage Composites can be provided with a factory-installed separation and slip film, or a moisture diffusion open geotextile on the back.

Products:
ND Drainage Composites ND TGF-20 Slip Film ND TSF-100 Slip and Protection Sheet

2.2 Slip layer

During construction, and when in use, flexible pavements impose both vertical and horizontal loads. Horizontal loads are generated by temperature changes within the structure and from external dynamic sources such as braking, acceleration, and turning of vehicles. These vertical and horizontal loads must be borne by the underlying layers. However, it should be noted that waterproofing materials/systems are not capable of withstanding the horizontal loads typical of a flexible pavement and therefore care must be exercised when specifying.

Where there is concern regarding the horizontal load-bearing capacity of the waterproofing membrane, a slip layer, comprising two, smooth, non-sticky surfaces that can move with respect to each other, will be required.

In general plastic sheets manufactured from the following materials are used as a slip layer:

- PET (Polyethylene terephthalate)
- PP (Polypropylene)
- PE (Polyethylene)
- PS (Polystyrene)

In the Nophadrain Podium Deck System, this 'slip' function is achieved using the ND TGF-20 Slip Sheet which is placed underneath the ND Drainage Composite fitted with a separation and slip film. In this particular Nophadrain system, the essential separation and protection layer is formed by the ND Drainage Composite which is also the second smooth surface of the slip layer.

In the Nophadrain Parking Deck System-Cars/Trucks (load classes 2 and 3), a ND TSF-100 Slip and Protection Sheet forms one surface while the protection and slip film of the ND Drainage Composite forms its counterpart. The ND TSF-100 Slip and Protection Sheet also fulfils the function of the protection layer in the Nophadrain Parking Deck System-Cars/Trucks.

On an inverted roof construction, the slip layer consists of two layers of the ND TGF-20 Slip Sheet installed underneath the thermal insulation.

Products:
ND Drainage Composites ND TGF-20 Slip Sheet ND TGF-100 Slip and Protection Sheet

2.3 Protection layer

The protection layer guards the waterproofing membrane against any damage caused by static and dynamic loads and simultaneously isolates materials that are chemically incompatible. When this layer has a smooth, non-sticky surface it can form part of the slip layer.
At heavier loadings (load classes 2 and 3), and when a sub-base layer (load class 1) is installed, heavy geotextiles, plastic

sheets, concrete layers, and the like are needed to guard the waterproofing membrane against damage from static and dynamic loads occurring during installation and when in use.

For lightweight static and dynamic loads (load class 1) the ND Drainage Composite can act as a protection layer when fitted immediately after installation of the waterproofing layer, the root barrier, or the separation and slip film. On roofs of load class 1 (podium roof decks), and load classes 2 and 3 (trafficked roof decks) where a levelling layer or sub-base is installed, or when wheel loaders are being used during installation, it is recommended that a ND TSF-100 Slip and Protection Sheet be installed above the waterproofing system. The ND TSF-100 Slip and Protection Sheet should be installed in such a way that no granular material can get underneath and damage the waterproofing membrane.

The protection layer can also fulfil the function of the separation and slip layer. Loose-laid separation and protection layers must overlap by at least 100mm, and the layer may not creep by more than 5% with a maximum of 2mm.

An assessment of the level of protection provided by the protection layer on trafficked decks (load classes 1 to 3) can be made through index tests (see appendix A) of the individual products or through a performance test (see appendix B) of the complete build-up.
Index test ND TSF-100 Slip and Protection Sheet (Load classes 1 to 3) see appendix A, table 11.

The ND TSF-100 Slip and Protection Sheet can be used on top of an insulating layer or a waterproofing membrane with a greater a long-term tolerable elongation in %. The long-term elongation of the insulation or the waterproofing has to be demonstrated by manufacturer.

Performance tests – Nophadrain Park Deck System-Cars/Trucks (load classes 2 and 3) see also appendix B. Performance test data for the various build-up options for load classes 2 and 3 are available on request.

Products:
ND Drainage Composites ND TSF-100 Slip and Protection Sheet

2.4 Drainage layer

The drainage layer relieves hydrostatic pressure from the waterproofing membrane. It discharges excess water underneath the sub-base layer/laying course and prevents the ponding of water in these layers and the risk of frost heave affecting the paving. The drainage layer must have good vertical permeability combined with the ability to transport surface water horizontally away from the roof area to the roof outlets or over the roof edge. Retention of water in the sub-base layer and/or laying course is to be avoided at all times.

The drainage layer must maintain full functionality for a period of 50 years, in compliance with DIN 4095 "Drainage and protection of sub-structures – design, dimensioning and installation".

The drainage capacity should be specified in litres per second per linear metre l/(s.m) taking into account the roof gradient and the expected load pressure. See Nophadrain brochure: "Designing the drainage layer"

Any drainage composite, including eggbox-shaped dimpled plastic sheets (geospacers), that forms part of a drainage system, must be CE-marked according to BS EN 13252.

The drainage capacity of the ND Drainage Composites (max. flow length) increases in line with the amount of stormwater discharged over the surfacing.

2.5 Filter layer

The filter layer guards the drainage layer against clogging by fine particles carried down from the sub-base layer or laying course, and so ensures effective horizontal drainage. The pore size of the woven and non-woven geotextiles should be matched to the grain size and grading envelope of the granular materials used for the sub-base layer and laying course. When topsoil is being used, special measures should be taken to prevent soil fines clogging the filter layer e.g. by installing ND WSM-50 Water Reservoir Panels.

Woven and non-woven filter fabrics (geotextiles) must be CE-marked according to BS EN 13252 when placed on top of a geospacer.

Note
Both woven and non-woven filter fabrics must overlap by least 100mm, and at the edges the filter fabrics should be brought up to the surface of the paving in order to prevent washing-out of the granular materials. The filter layer should be covered within one week of installation and should be protected against wind scour.

The filter layer, whether it is a non-woven or woven geotextile, forms part of the ND Drainage Composites. The geotextile is bonded to each dimple of the plastic sheet and overlaps the core by 100mm.

Load class*	Sub-base layer	Puncture resistance BS EN ISO 12236 in kN
1	without	1.0
1	with	1.5
2 and 3	with/without	2.5

Table 4. Filter layer
* *see table 1. Load classification*

2.6 Nophadrain ND Drainage Composites

ND Drainage Composites comprise the filter layer, the drainage layer, and the separation and protection layer as one integrated unit. The core of the ND Drainage Composite is a 13mm-27mm thick dimpled plastic sheet with a filter fabric (woven or non-woven) bonded to each dimple. Depending on the application, the core may be perforated and provided with a pressure dividing slip film, or a moisture diffusion open geotextile on the back.

ND Drainage Composites comprise the filter layer, the drainage layer, and the separation and protection layer as one integrated unit. The core of the ND Drainage Composite is a 13mm-27mm thick dimpled plastic sheet with a filter fabric (woven or non-woven) bonded to each dimple. Depending on the application, the core may be perforated and provided with a pressure dividing slip film, or a moisture diffusion open geotextile on the back.

ND Drainage Composites on inverted roof constructions
Certain ND Drainage Composites have a perforated core. These drainage composites prevent the formation of a vapour control layer on top of the XPS thermal insulation.

The top of the XPS insulation panels can dry out and therefore internal condensation is minimised. The insulation value (R-value) over time is not affected.

Drainage Composite	Load class*	Roof construction			
		With insulation	Without insulation	Water resistant concrete	Inverted roof
ND 5+1lt	1	■	■	■	–
ND 200	1	■	■	■	–
ND 200s	1	–	–	–	■
ND 200sv	1	–	–	–	■
ND 220	1	■	■	■	–
ND 600	1/2**	■	■	■*	–
ND 600s	1	–	–	–	■
ND 600sv	1/2	–	–	–	■
ND 620	1/2	■	■	■	–
ND 600hdsv	2/3	–	–	–	■
ND 620hd	2/3	■	■	■	–

Table 5. Applications ND Drainage Composites

** see table 1. Load classification*
*** only load class 2 on a roof construction of water resistant concrete*

..20 = with pressure dividing slip film
s = perforated core (moisture diffusion open)
v = moisture diffusion open geotextile
hd = high compressive strength (> 1,100kN/m²)

Designing the drainage layer
On those roofs with a hard landscaping build-up, storm/surface water is partly drained over the surfacing (q_o), referred to as the 2nd discharge level. The drainage layer or the 1st discharge level has to intercept the stormwater that has penetrated the surfacing ($q_{a,s}$).

$$q_{a,s} = r - q_o$$

$q_{a,s}$ = stormwater penetrating the surfacing l/(s.m²) (table 6)
r = rainfall intensity l/(s.m²) in accordance with BS EN 12056-3
qo = stormwater discharged over the surfacing l/(s.m²)

Based upon a 15 minute rainfall intensity happening once every 10 years of $r_{(15)}^{(0,1)}$ = 0.03l/(s.m²) the following values can be used to determine the amount of stormwater penetrating the surfacing ($q_{a,s}$):

Surface	$q_{a,s}$ (l/(s.m²))
Concrete block pavers	0.01
Self-binding gravel	0.015
Turf paving on water permeable sub-base	0.03

Table 6. Stormwater penetrating the surfacing $q_{a,s}$

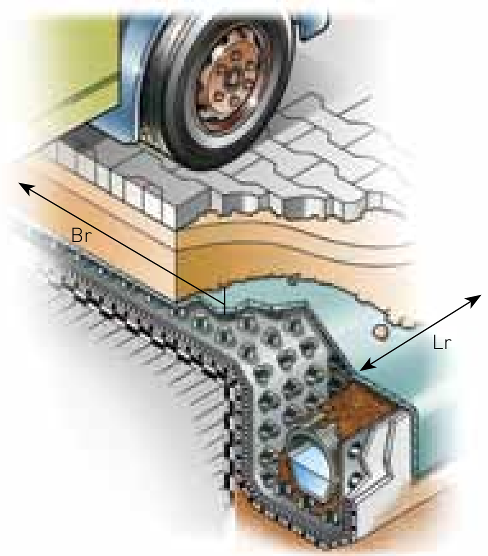


Figure 1. Effective roof area m²
Lr = length of the roof to be drained m
Br = the plan width of roof from gutter to ridge m

The amount of water that needs to be collected and discharged by the drainage layer (q´) can be calculated in units of per l/(s.m) using the following equation:

$$q´ = \frac{q_{a,s} \times A}{Lr} \text{ in l/(s.m)}$$

q´ = quantity of water to be discharged by the drainage layer l/(s.m)
$q_{a,s}$ = stormwater penetrating the surfacing l/(s.m^2) (table 6)
A = effective roof area m^2 (Lr x Br)

2.7 Sub-base layer

The function of the sub-base layer is to absorb and spread any static and dynamic loads and so prevent deformation of the elemental paving. To ensure proper functioning of the sub-base layer, a stable drainage composite should be installed as a drainage layer. By proper dimensioning of the sub-base layer, the loading of the layers beneath it is reduced. The depth of the sub-base layer should be designed to suit the expected static and dynamic loading and the strength of the layers beneath it.

A sub-base layer can be installed to spread the static and dynamic load (load classes 2 and 3) and/or to create falls (load classes 1 to 3).

Depending on the anticipated load class, the sub-base layer needs to be compacted to meet the following deformation modules:

Load class*	Static deformation modules E_{V2} in MN/m^2
1	≥80
2	≥120
3	≥150

Table 7. Deformation modules
* *see table 1. Load classification*

To check compaction is complete and correct, static or dynamic plate load tests should be undertaken. The most suitable type of vibrating plate compactor needs to be agreed with the design engineer.

Sub-base layer on a warm roof construction / roof construction without thermal insulation
The sub-base material should consist of crushed natural material with a granular size of 0-22mm, 0-32mm or 0-45mm. In order to prevent damage to the roof outlets, only a limited amount of calcium hydrate may be leached from the sub-base material. This requirement can be relaxed in those cases where the collection and discharge of stormwater does not take place by roof outlets but is directed over the roof edge.

Load class*	Material	Granular size in mm	Layer depth in mm
1	Crushed natural material	0-22	≥100
2	Crushed natural material	0-32	≥150
3	Crushed natural material	0-32/0-45	≥150

Table 8. Sub-base layer warm roof construction
* *see table 1. Load classification*

Sub-base layer on an inverted roof construction
In the design of an inverted roof construction, moisture diffusion measures should be observed at all times. The installation of a vapour control layer on top of the thermal insulation is not permitted.

As compaction of non-hydraulically bonded "no-fines" sub-base material (i.e.: a material with no particles smaller than 1mm) is difficult, the depth of the sub-base layer should be increased accordingly.

For each individual object it must be determined whether the moisture diffusion of the ND Drainage Composites Type sv, is compatible with the installation of a "no-fines" sub-base layer.

Load class*	Material	Granular size in mm	Layer depth in mm
1	Crushed natural material	2-22	≥100
2	Hydraulically bound crushed material	–	≥100
2	Crushed natural material	0-32**	≥150
2	Crushed natural material	2-32	≥150
3	Hydraulically bound crushed material	–	≥100
3	Crushed natural material	0-32**/ 0-45**	≥150

Table 9. Sub-base layer inverted roof construction
* *see table 1. Load classification*
** *suitability to be demonstrated by the manufacturer of the thermal insulation*

2.8 Levelling layer

In order to overcome height differences and/or to create falls, it may be necessary to install a levelling layer beneath pedestrian-only elemental pavements (load class 1)

The levelling layer is a combination of the laying course and the sub-base layer. The paving is laid directly onto the levelling layer.

Joint filling materials need to be carefully graded to suit both the actual joint width and the grading of the levelling layer material.

This layer can consist of natural crushed material with a granular size of:

- 2-8mm
- 3-9mm

The layer depth is a minimum of 50mm and a maximum of 150mm. Once the paving layer has been placed and cut-in as necessary, the whole build-up is compacted.

Where the levelling depth is greater than 150mm, the levelling layer consists of crushed natural material with a granular size of 2-22mm. The paving is laid on a separately installed laying course of crushed natural material with a granular size described above.

2.9 Laying course

The laying course is required to accommodate variation in thickness of the paving units and to even out irregularity in the sub-base layer, as well as providing stability to the paving units. The laying course should be as shallow as possible; however, when the loads are reduced the depth of the laying course can increase slightly, because the risk of deformation is reduced.

The bedding material used can consist of crushed natural material with a granular size of:

- 0-4mm
- 0-5mm
- 0-11mm*
- 1-3mm
- 2-5mm

On an inverted roof construction it might be necessary to use bedding material that is classed as moisture diffusion open or "no-fines" i.e. no particles smaller than 1mm granular size. Jointing materials need to be carefully graded to suit the grading of the bedding material.

Granular sizes of bedding materials that can be used for a moisture diffusion build-up:

- 1-3mm
- 2-5mm

The depth of the laying course following compaction should be 30-50mm. When paving blocks are installed with a thickness of ≥120mm the laying course should be ≥40mm with a granular size bedding material of 0/11mm. Depending on the expected load and the type of paving to be used, the bedding material can be installed directly on top of ND Drainage Composite.

* *Paving blocks thickness ≥120mm – depth laying course ≥40mm*

2.10 Paving

For roof decks, some form of elemental paving (e.g.: block paving, small element paving) laid onto a flexible or granular laying course is normally used in preference to a rigid or semi-rigid paving (e.g.: concrete, macadam or asphalt).

The main reasons for this choice of paving are:

- ease of access to the roof structure and the waterproofing system for inspection and maintenance
- the ability to continue and/or extend the use of adjacent hard or soft landscaping schemes over the surface of the deck, rendering it 'invisible' to users
- protection of the waterproofing system against excessive static or dynamic loads
- low installation and maintenance cost

A flexible pavement is permeable and consists of individual prefabricated elements. A flexible pavement is also referred to as an "open" pavement in comparison to a "closed" pavement such as concrete or asphalt. The thickness of the paving is based up on the load class, the paving units, the laying pattern and the bearing capacity of the layers beneath. There are more than 200 different types of paving units on the market.

Falls

As far as possible, stormwater should run across the surface of the paving and be collected by a suitable drainage system. Penetration of the paving, laying course and sub-base layers by surface/stormwater must be minimised by ensuring the paving is laid to adequate falls with relatively tight joints.

Depending on the type of paving the following minimum falls need to be observed:

• concrete flags and natural stone flags	1: 50
• concrete pavers and clay pavers	1: 40
• natural stone paving	1: 33
• open permeable paving (turf paving)	1:100
• hydraulically bonded paving	1: 50

Falls can be created in:

- the structural roof deck
- the sub-base layer
- the levelling layer

In elemental pavements (ICBPs, clay pavers, etc.) it is possible for as much as 30-40% of the surface water to penetrate the joints and find its way to the underlying layers. Infiltration can be even higher in newly constructed pavements where the jointing has not had the opportunity to settle and self-seal with detritus, or on pavements with inadequate falls.

Pavers and flags

The paving units can be prefabricated pavers e.g. small element pavers, clay pavers, concrete block pavers, concrete flags, setts, or large format slabs. The width and depth of the joint, along with the material used to fill the joint, will determine whether surface water can be directed to the sub-surface layers.

Small element pavers

- due to the small size and the inevitably generous size tolerances that occur with all natural paving units these pavers can only be used for load class 1 pavements

Clay pavers

- clay pavers can be used for load class 1 pavements
- the pavers can be installed without a separate sub-base layer onto a levelling layer or laying course directly on top of the ND Drainage Composites. The pavers should have a minimum thickness of 40mm

Concrete pavers

- concrete pavers are used for load class 1 and 2 pavements. On vehicular-trafficked decks (load class 2) the concrete pavers are laid in 90º and 45º herringbone pattern. These patterns have the highest level of stability over the long term
- the pavers can be installed without a separate sub-base layer onto a levelling layer or laying course directly on top of the ND Drainage Composites. For load class 2 pavements the use of large format concrete flags/slabs is recommended at locations such as sharp curves, turning heads and entrance/exit ramps, because these have been shown to spread the imposed dynamic loads
- the pavers should have a minimum thickness of 40mm for load class 1 pavements and a minimum of 80mm for load class 2 pavements

Concrete flags

- concrete flags can be used for load class 1 pavements
- the flags can be installed without a sub-base layer onto a levelling layer or laying course directly on top of the ND Drainage Composites
- the minimum thickness of the flags should be 40mm

Permeable paving

- permeable paving can be used on roof decks designed as load class 1 to 3 pavements
- due to its open structure this type of paving facilitates 100% infiltration of surface water, therefore the load-bearing capacity is restricted for vehicular traffic
- it is recommended that permeable paving not be used for pavements in load class 2 or load class 3 that carry regular vehicular traffic

Interlocking concrete block pavers

- interlocking concrete block pavers (ICBPs) can be used for load class 1 to 3 pavements. However they are mostly used for vehicular areas subjected to heavy loads (load class 2 and 3), where the forces generated by acceleration, braking (deceleration) and turning can be considerable
- ICBPs are also used for load class 2 pavements, where they may be laid onto a laying course that is placed directly over the ND Drainage Composites, that is, with no specific sub-base layer
- the minimum thickness of ICBPs should be for:
  - load class 1 min. 60mm
  - load class 2 min. 80mm
  - load class 3 min. 100mm

Large format concrete flags/slabs

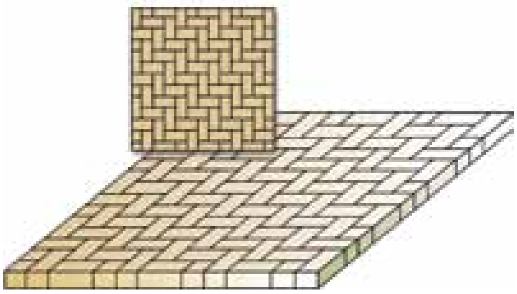
- large format concrete slabs can be used for load class 1 to 3 pavements.
- at locations such as sharp curves, turning heads and entrance/exit ramps, large format concrete flags/slabs are preferred as they are better able to bear and spread the imposed dynamic loads
- these larger concrete flags are also used on load class 2 and 3 vehicular-trafficked pavements where there is insufficient build-up depth to accommodate a separate sub-base layer. In such cases, the slabs can be laid onto a suitable laying course directly over the ND Drainage Composite
- the suitability of large format concrete flags/slabs for the appropriate load class is to be proven by the manufacturer

Laying patterns

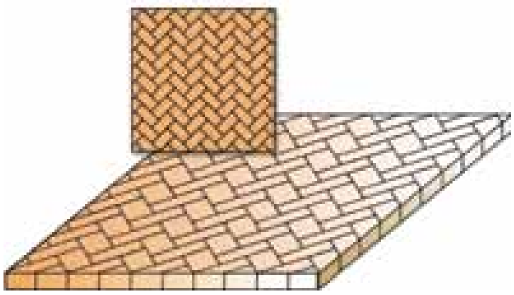
Pedestrian areas can be laid to almost any laying pattern but those areas intended to carry vehicular traffic should use an interlocking pattern to maximise the lifespan of the pavement and to minimise maintenance.

Load class	1 with/without sub-base layer	2 with sub-base layer	2 without sub-base layer	3 with sub-base layer
Stretcher or running bond	■	–	–	–
Basket weave	■	■	–	–
45º Herringbone	■	■	■	–
90º Herringbone	■	■	■	–
Interlocking concrete block pavers	■	■	■	■

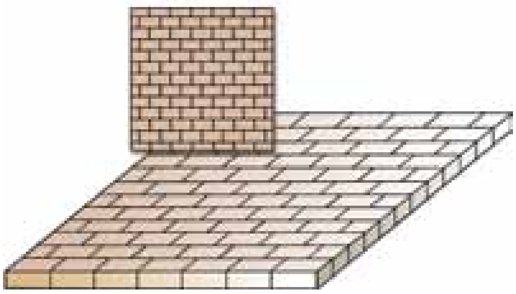
Table 10. Laying patterns



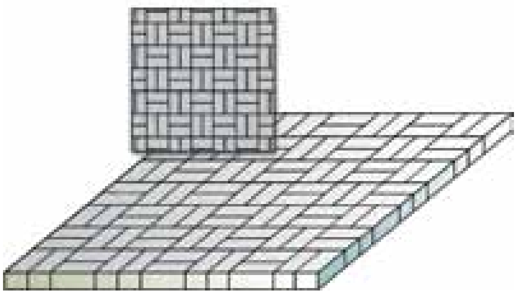
90º Herringbone



45º Herringbone



Stretcher or running bond



Basket weave

Figure 2. Examples of laying patterns

Herringbone patterns and interlocking concrete block pavers give the greatest degree of interlock, as movement/creep is checked in both the transverse and longitudinal direction, and therefore these patterns and paving blocks have the highest level of stability over the long term.

Joint filling

Joint width is usually determined by Load Class and type of paving unit being laid. Jointing materials need to be carefully graded to suit both the actual joint width and the grading of the bedding material. When joint width is too tight, it can prevent proper filling of the joint and may allow adjacent paving units to be in direct contact, which can result in spalling or damage to the arisses (edges) of the units. Joints that are excessively wide may not be capable of generating the inter-unit friction that provides a significant proportion of the pavement's load-bearing capability.

Granular sizes of joint filling materials:

- 0-4mm
- 0-5mm
- 0-8mm
- 0-11mm (joint width >10mm)

Granular sizes of joint filling materials that can be used for a moisture diffusion build-up:

- 1-3mm
- 2-5mm

Proper joint filling is critical to the long-term performance and lifespan of pavements subject to vehicular traffic. Concrete pavings perform exceptionally well at distributing point loads to the underlying layers. This ability is dependent on the paving units being manufactured to keen dimensional tolerances that enables them to be accurately positioned and to have uniform joints widths. When these joints are properly filled, imposed loads, such as those created by vehicular traffic, generate a high level of frictional resistance (rotation resistance) between adjacent paving units and so the load is dispersed by partial transference to those adjacent units.

To ensure full and proper filling of the joints, dry jointing sand should be scattered over the surface of the newly-laid pavement and swept into the joints with a brush, filling each joints as far as practical after consolidating the pavement using a vibrating plate compactor.

The joints should be checked and topped-up as necessary following consolidation and will need to be checked again every few weeks for the first 3-4 months following completion, ensuring any partially-filled or 'hungry' joints are topped-up with additional jointing material. After this initial period, the pavement should be checked three or four times a year as joints can be emptied by scour from wind and surface water, by the action of street cleaning machinery, and from day-to-day wear from traffic.

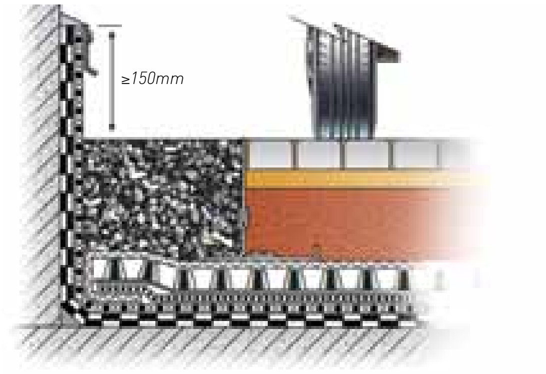
Retaining edges

Elemental pavements, such as those constructed from flexibly-laid concrete blocks pavers, must be properly restrained at the edges in order to prevent lateral slip and failure of the pavement as a whole. Properly constructed edge courses are vital to the performance, integrity and lifespan of any such pavement. The edge courses must "lock in" the body (or field) of the paving and so prevent any creep or looseness of the individual units.

The most appropriate type of edge course is most often determined by the type of paving units and the planned use of the pavement; that is, whether it will be used for pedestrians only, or for both pedestrian and vehicular traffic. For vehicle standard pavements, the edge course units will require restraining in both the horizontal and vertical directions. This can best be achieved by laying the edge course units onto a bed of concrete and haunching with the same, so that the risk of creep or rotation is eliminated.

When concrete is used, however, there is a risk of calcium hydrate being leached and this could potentially cause damage to the roof deck drainage outlets. Consequently, for such applications it is recommended that the concrete is treated, or that a denser concrete (C20/C25 standard) is used. Further, any concrete bed and haunch must not obstruct the horizontal drainage function of the pavement roof deck, and so must be placed on top of the filter and drainage layer. A possible alternative to the use of concrete bed and haunch is the GreenLiner Edge Retaining Profile. This product is eminently suitable for use with pavements of load class 1 and 2.

Products:
GreenLiner 100/4V Edge Retaining Profile GreenLiner 150/4V Edge Retaining Profile GreenLiner 200/4V Edge Retaining Profile



Detail 5. Edging with the GreenLiner Edge Retaining Profile

3 PODIUM AND/OR PARKING ROOF DECKS COMBINED WITH INTENSIVE GREEN ROOFS

By combining hard landscaping on a roof deck with soft landscaping features such as a lawn, perennials, shrubs, bushes and trees, the quality of life and the integration of the roofscape with the surrounding environment is considerably improved. The Nophadrain systems make these combinations easy to achieve by using water reservoir panels within the filter and drainage layer. The layer of growing medium is placed on top of these panels and planted-up with a suitable intensive planting scheme. The Nophadrain "Design and installation manual Intensive green roofs", available on request, gives a detailed description and fuller guidance on this type of construction.

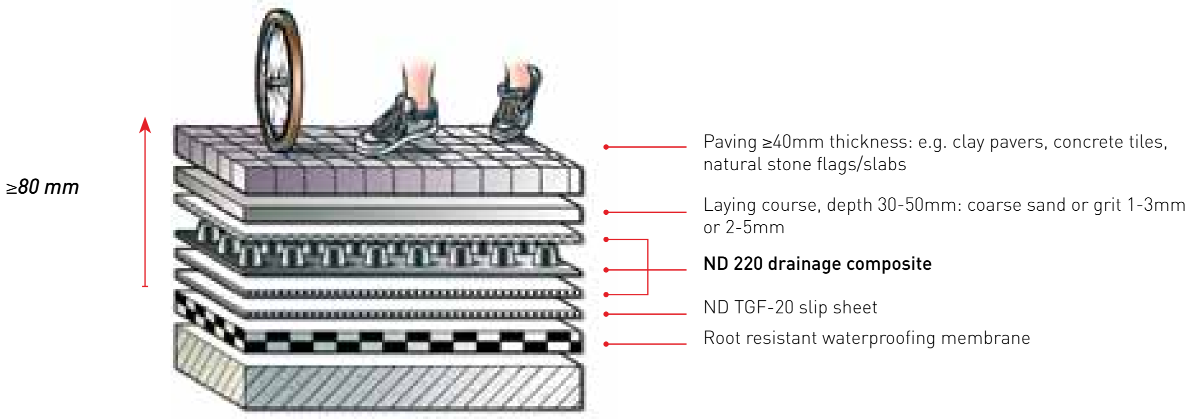
4 PODIUM DECK AND PARKING DECK SYSTEMS

4.1 Nophadrain Podium Deck System – load class 1

Warm roof construction/roof construction without thermal insulation

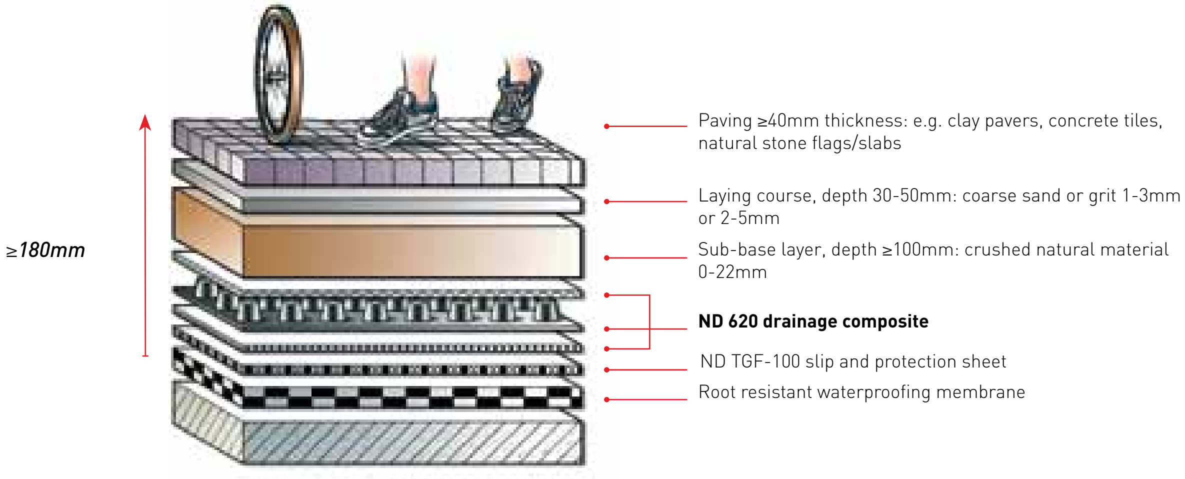
a. Build-up without sub-base layer

Falls for paving are created by the roof construction



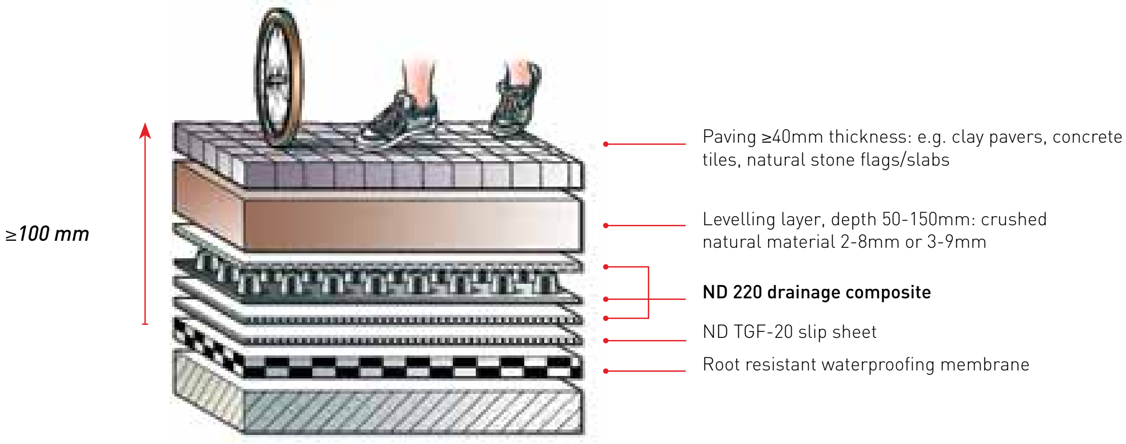
b. Build-up including sub-base layer

Falls for paving created by roof construction and/or by grading of sub-base layer



c. Build-up including levelling layer

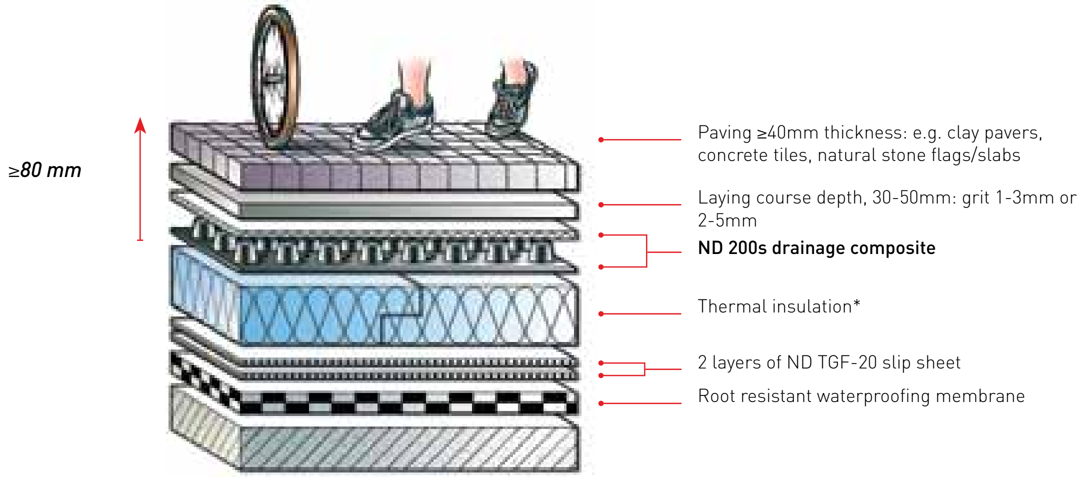
Falls for paving created by roof construction and/or by grading of levelling layer



Inverted roof construction

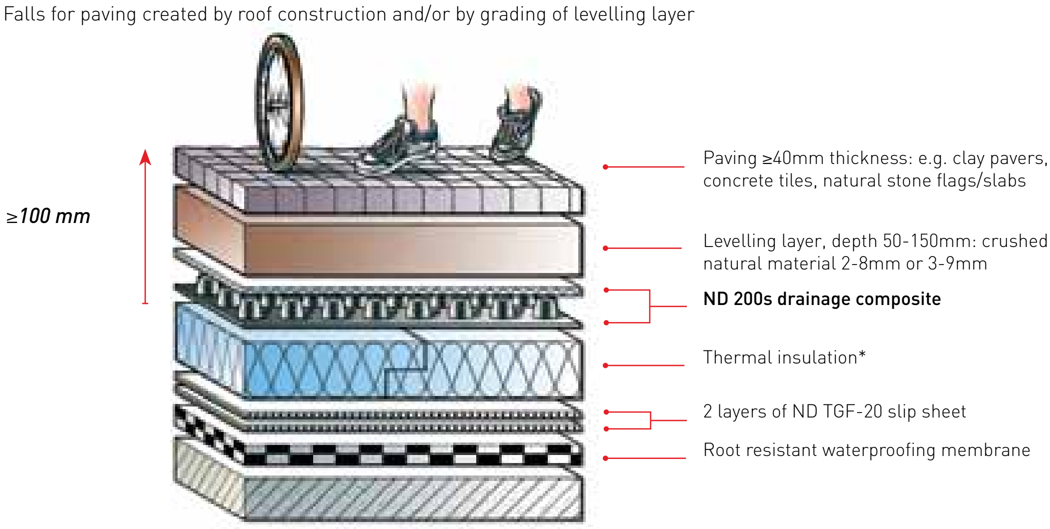
a. Build-up without sub-base layer

Falls for paving are created by the roof construction



b. Build-up including levelling layer

Falls for paving created by roof construction and/or by grading of levelling layer



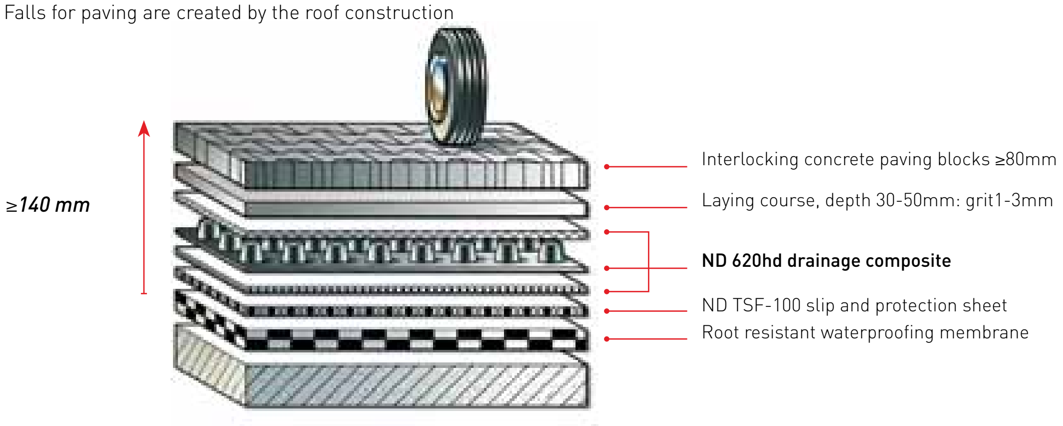
* *suitability of thermal insulation to be demonstrated by manufacturer*

4.2 Parking Deck System-Cars – load class 2

Warm roof construction/roof construction without thermal insulation

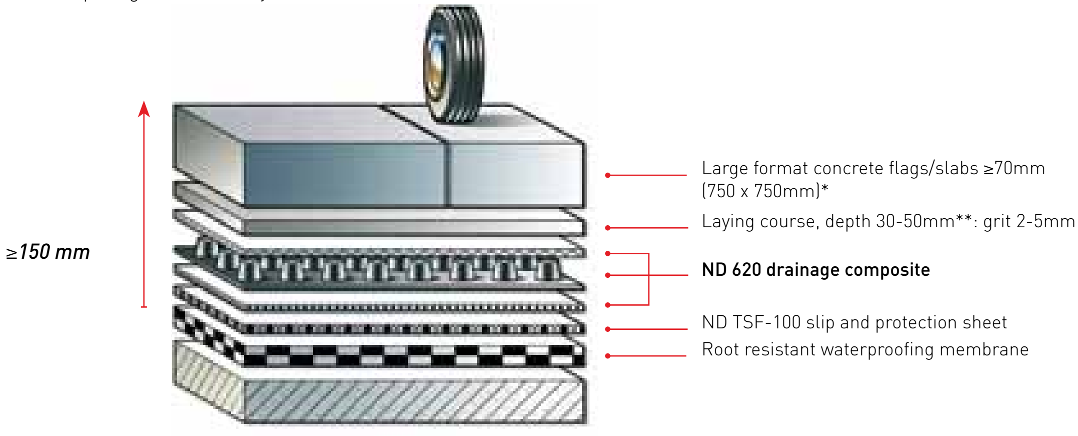
a. Build-up without sub-base layer

Falls for paving are created by the roof construction



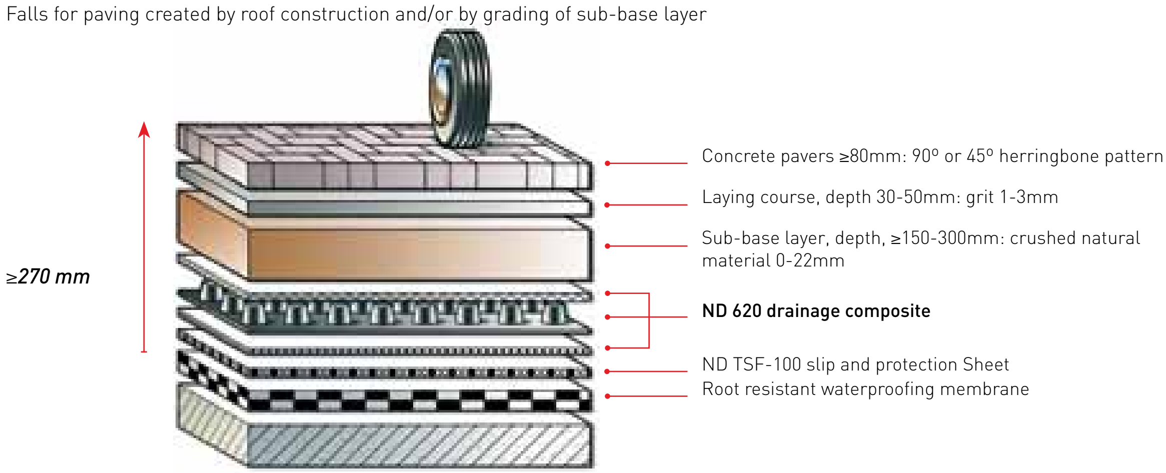
b. Build-up using larger concrete flags/slabs without sub-base layer

Falls for paving are created by the roof construction



c. Build-up including sub-base layer

Falls for paving created by roof construction and/or by grading of sub-base layer



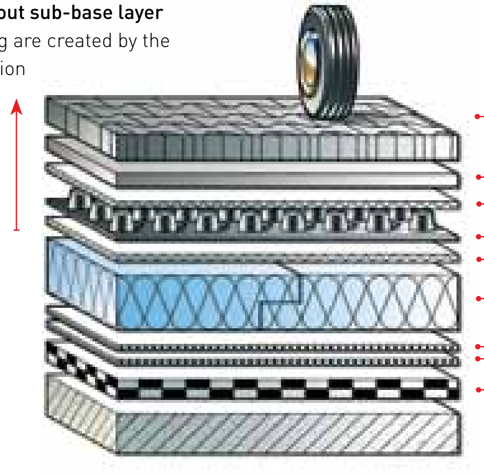
* *suitability of large format concrete flags/slabs to be demonstrated by manufacturer*

** *layer depth in accordance with recommendations of the manufacturer of the concrete flags/slabs*

Inverted roof construction

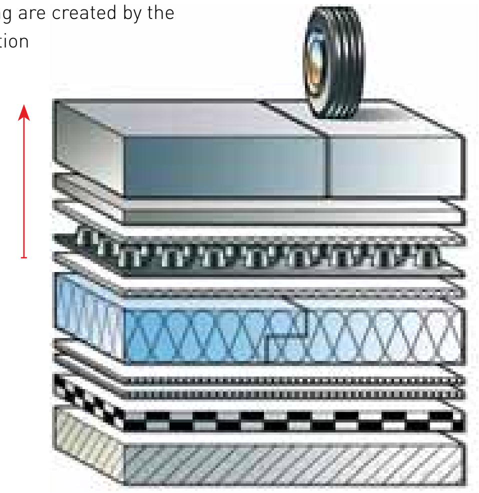
a. Build-up without sub-base layer

Falls for paving are created by the roof construction



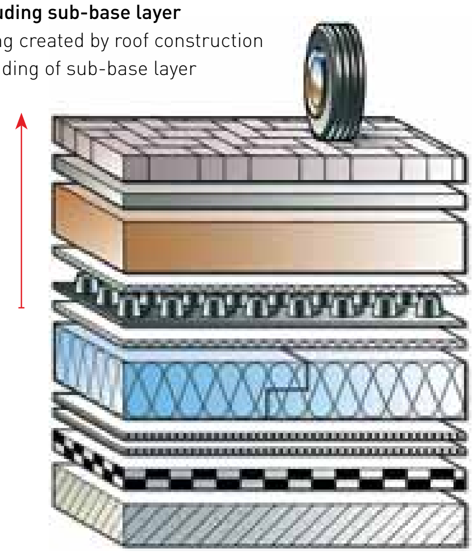
b. Build-up using large format concrete flags/slabs without sub-base layer

Falls for paving are created by the roof construction



c. Build-up including sub-base layer

Falls for paving created by roof construction and/or by grading of sub-base layer



* *suitability of paving flags/slabs to be demonstrated by manufacturer*

** *layer depth in accordance with recommendations of the manufacturer of the concrete flags/slabs*

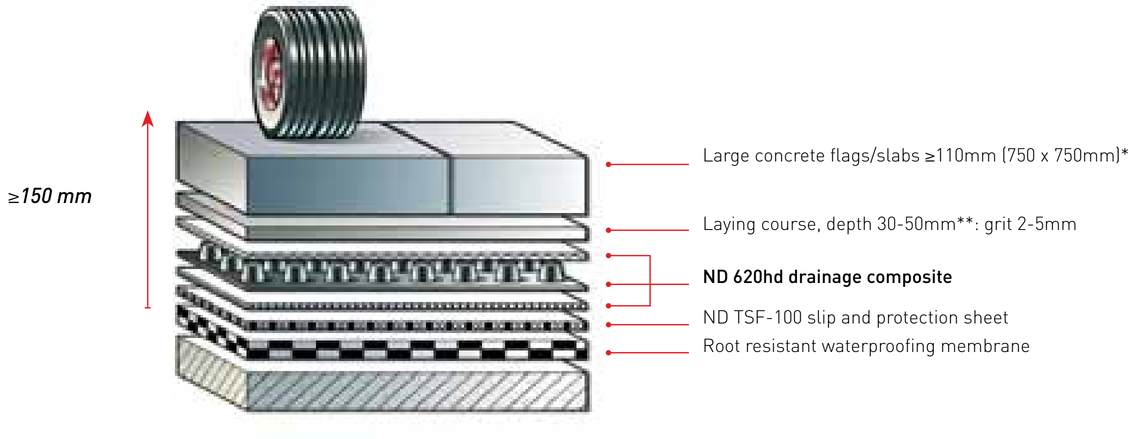
*** *suitability of thermal insulation to be demonstrated by manufacturer*

4.3 Parking Deck System-Trucks – load class 3

Warm roof construction/roof construction without thermal insulation

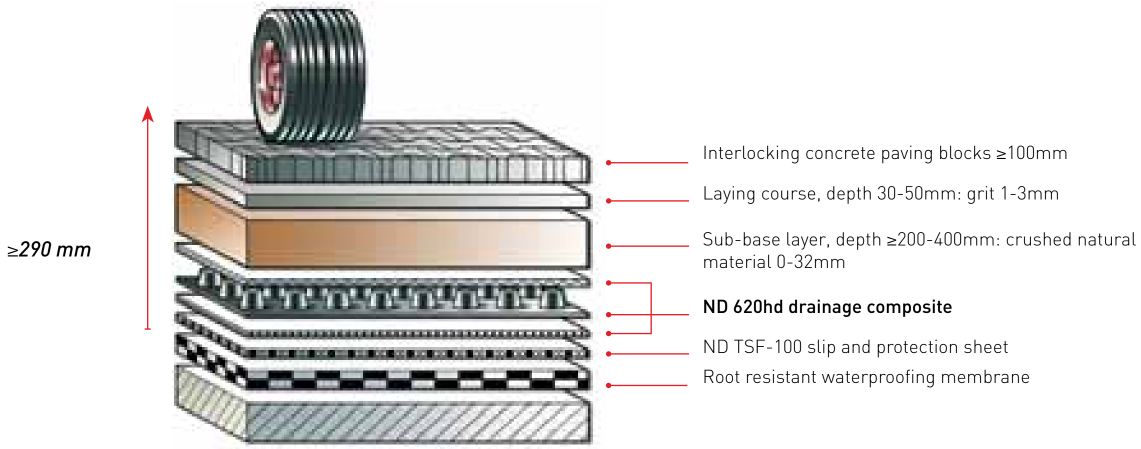
a. Build-up using large format concrete flags/slabs without sub-base layer

Falls for paving are created by the roof construction



b. Build-up including sub-base layer

Falls for paving created by roof construction and/or by grading of sub-base layer



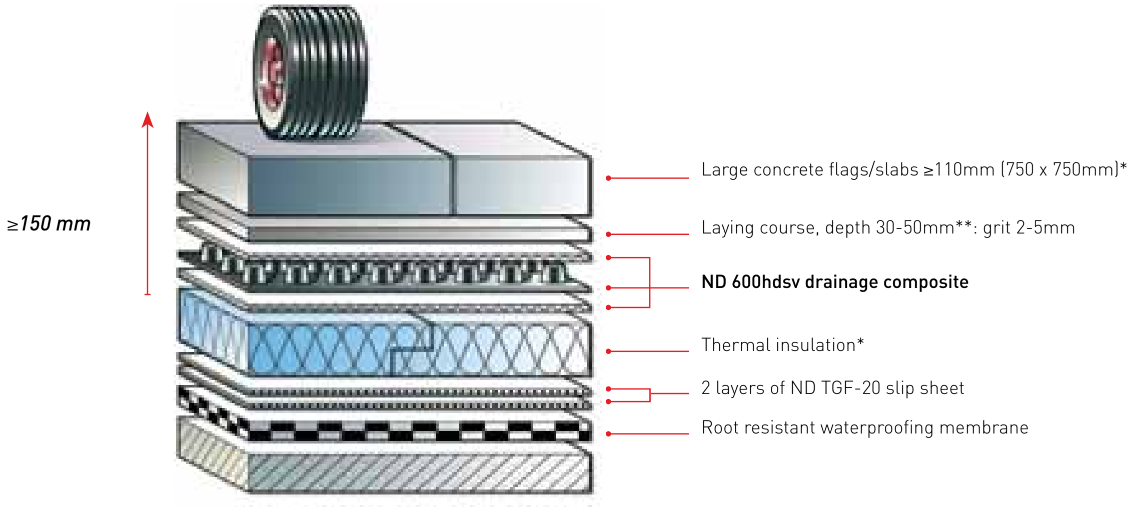
* *suitability of paving flags/slabs to be demonstrated by manufacturer*

** *layer depth in accordance with recommendations of the manufacturer of the concrete flags/slabs*

Inverted roof construction

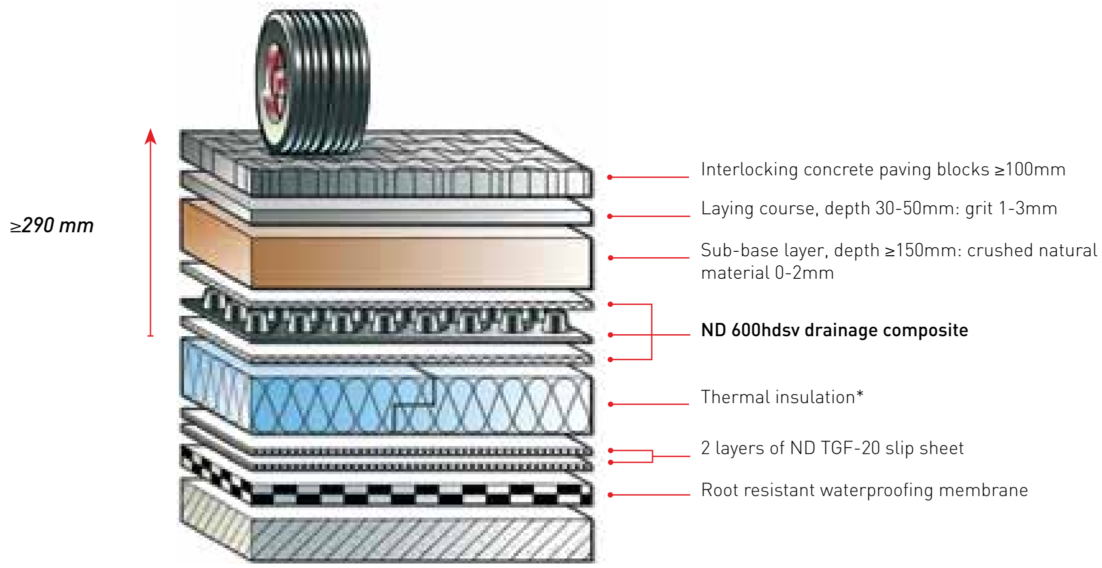
a. Build-up using larger concrete flags/slabs without sub-base layer

Falls for paving are created by the roof construction



b. Build-up including sub-base layer

Falls for paving created by roof construction and/or by grading of sub-base layer



* *suitability of thermal insulation to be demonstrated by manufacturer*

** *layer depth in accordance with recommendations of the manufacturer of the concrete flags/slabs*

*** *suitability of thermal insulation to be demonstrated by manufacturer*

Appendix A – Index test: assessment of the level of protection provided by the protection layer

Determination of the efficiency of protection layers – test sequence based on BS EN 13719-2002 "Geotextiles and geotextiles related products – Determination of the long term protection efficiency of geotextiles in contact with geosynthetic barriers".

Test procedure
Inside a smooth-sided steel cylinder, a 20mm thick rubber pad with a hardness of 50 shore A is placed beneath a 1.3mm thick circular disc of lead over which is placed the test specimen (Nophadrain protection layer). A 200mm deep layer of 20mm diameter steel balls is then placed on top of the test specimen and the whole build-up stressed 200,000 times at a frequency of 2.3Hz in the servo-hydraulic test apparatus.

Assessment
On completion of the test cycle, the apparatus is dismantled and the six deformations displaying the greatest strain are recorded. From this data, the largest and smallest deformation readings are disregarded and the remaining values are averaged to determine a mean value for percentage deformation.

Using this test procedure, a sample is declared to have provided satisfactory protection when the calculated average elongation of the protection layer is less than the maximum tolerable long-term elongation of the waterproofing membrane.

Applied dynamic stress
The test is repeated three times, with each test run imposing the different applied stresses stated in table 11 below. These applied dynamic stresses are in accordance with the recommendations for the design and construction of trafficked roof decks of the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V. (FLL).

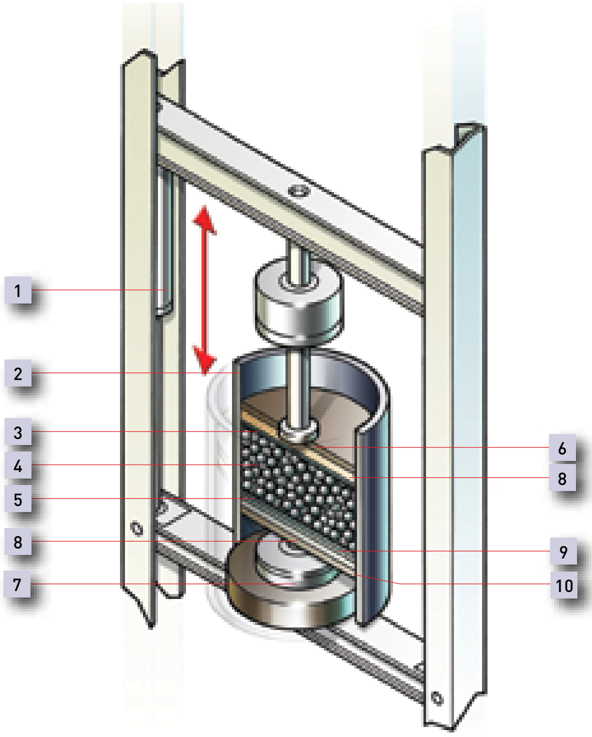


Figure 3. Servo hydraulic test apparatus

1. *Applied load*
2. *Cylinder*
3. *Geotextile separator*
4. *Steel balls (Ø 20mm)*
5. *Test specimen - protection layer*
6. *Upper and lower steel plate*
7. *Load cell*
8. *Sand*
9. *Lead disc, d=1.3mm*
10. *20mm thick rubber pad*

Load Class	Use	Dynamic loading in kN	Elongation in %
1	Intensive green roofs, podium roof deck, patio roof deck	8.2	1.01
2	Parking roof deck for cars with a max. gross mass of 2.5tonne=25kN	17.1	2.70
3	Parking roof deck for heavy good vehicles (HGV) with a max. gross mass of 16tonne=160kN	43.7	7.91

Table 11. Applied dynamic stress

Appendix B – Performance test: Assessment of the performance and behaviour of a pavement structure under simulated trafficking conditions performed at the Technical University Munich

Test procedure
The test apparatus and component cross-section used for this test is shown diagrammatically in figure 4 below.

The desired axle load is generated hydraulically via a fixed vertical cylinder. Adjustment of the tyre pressure at the given axle load simulates the type of loading generated by vehicular traffic. Lateral movement of the wheels equivalent to approximately 20mm from true is generated during the test procedure by means of horizontally positioned hydraulic controls. The roll-over test procedure involves repeatedly moving the assembled test frame 900mm backwards and then 900mm forwards beneath the static axle at an average speed of 1km per hour.

Test frame and build-up
The road construction build-up to be tested by the roll-over procedure is prepared within the test frame (1,510mm long x 1,410mm wide). Strips of dense rubber are placed to the internal edges of the test frame to allow minor movement of the pavement construction and so simulate conditions expected on a much larger section of pavement.

Assessment
Deformation of the pavement is measured and recorded both during and on completion of the test procedure. During subsequent dismantling of the test frame and build-up, each layer and component are closely examined for any evident deformation and consequent changes in characteristics.

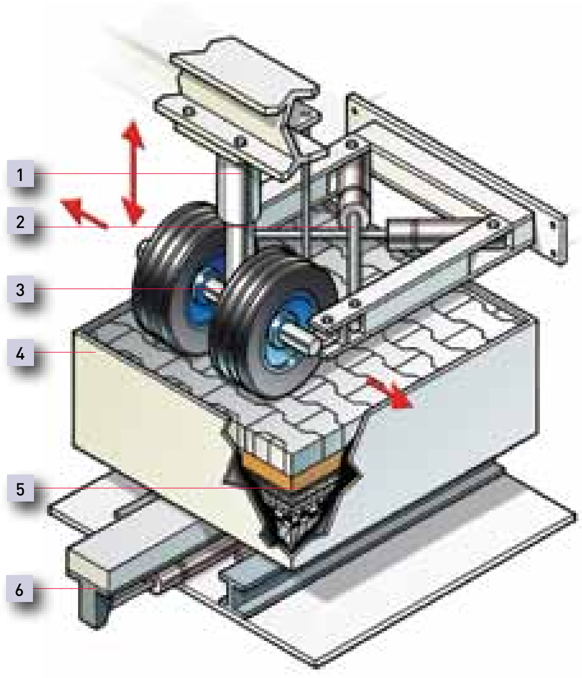
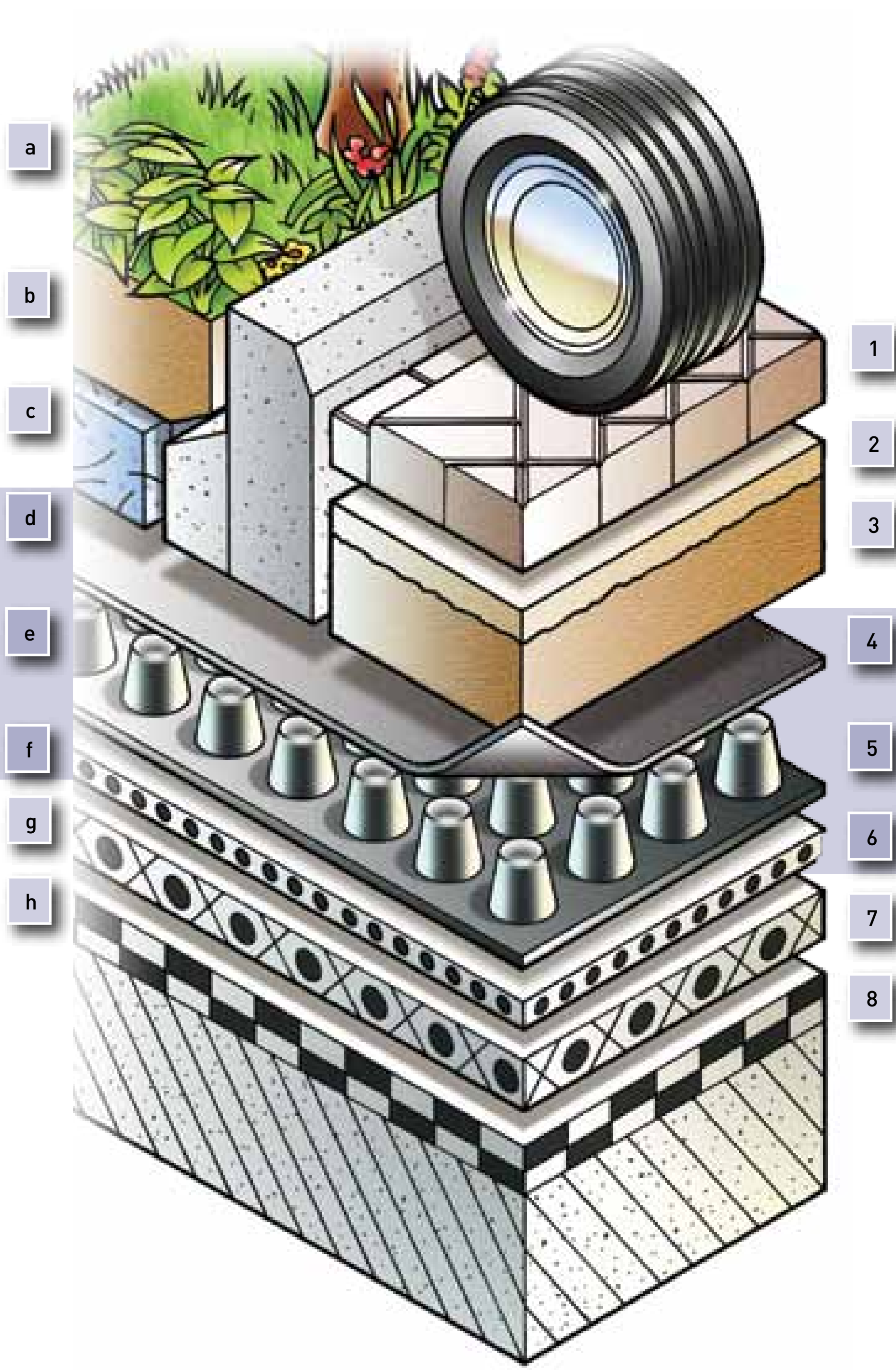


Figure 4. Test apparatus performance test
1. Vertical cylinder - desired axle load
2. Horizontal cylinder - lateral movement
3. Axle with tyres
4. Test frame
5. Road construction build-up
6. Rails to move test frame

Notes:

BUILD-UP PARKING DECK – LOAD CLASS 2 COMBINED WITH AN INTENSIVE PLANTING SCHEME



a	Vegetation layer	Intensive planting scheme: lawn shrubs, bushes, trees
b	Growing medium layer	ND DGS-I growing medium intensive/topsoil*
c	Water reservoir layer	ND WSM-50 water reservoir panel
d	**Filter layer**	**ND 620 drainage composite**
e	**Drainage layer**	
f	**Slip layer**	
g	Separation and Protection layer	ND TSF-100 slip and protection sheet
h	Root barrier layer	Root resistant waterproofing membrane**

1	Paving layer	Concrete pavers ≥80mm: 90º or 45º herringbone pattern
2	Laying course	30-50mm: coarse sand, grit 1-3mm
3	Sub-base layer	≥150mm: crushed natural material 0-32mm
4	**Filter layer**	**ND 620 drainage composite**
5	**Drainage layer**	
6	**Slip layer**	
7	Separation and protection layer	ND TSF-100 slip and protection sheet
8	Root barrier layer	Root resistant waterproofing membrane*

** at depths greater than 500mm (350mm with topsoil), a pure, mineral-based substrate should be installed beneath the growing medium*

*** optional ND WSB-80 Root Barrier*

Dutch Green Building Council

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