NOPHADRAIN®

GREEN ROOF INNOVATORS

EXTENSIVE GREEN ROOFS

DESIGN AND INSTALLATION MANUAL

0.2

NOPHADRAIN®
GREEN ROOF INNOVATORS

EXTENSIVE GREEN ROOFS

LOW MAINTENANCE

SHALLOW BUILD-UP DEPTH

MINIMAL DEAD LOAD

ECONOMICAL INSTALLATION

0 INTRODUCTION

An extensive green roof is a completely natural form of roof covering that uses a low-maintenance planting scheme consisting of hardy, drought-resistant plants. The plants used should be self-regenerating, predominantly short-growing, densely planted, and exhibit a high degree of adaptability to survive in relatively extreme climatic conditions (drought, sun, wind, frost, etc.). Ideally, the plants should originate from the Central European flora, although when choosing the plants, regional variations and local climatic conditions are to be considered.

Compared to intensive green roofs*, the range of potential uses along with the diversity of design and planting schemes are quite restricted. The plants selected should require minimal moisture and demand little from the growing medium in the way of nutrients. In general, irrigation systems are unnecessary for extensive installations, although irrigation may be required during the early stages to support germination and initial growth. An extensive green roof is chosen primarily for aesthetic and ecological reasons and as such, is not designed to be walked upon, except for occasional maintenance and control purposes. Since the types of plants used make comparatively modest demands on the layer configuration, the overall weight, the build-up depth, and the loading of the extensive green roof is relatively small.

Features of an extensive green roof:
- limited plant selection and design possibilities
- low maintenance - normally no more than two inspections per year
- shallow build-up depth - starting from 77mm
- minimal dead load - starting from approx. 30kg/m^2 including plants
- economical installation and maintenance

* *Intensive green roofs can be considered as comparable to more traditional soft landscaping schemes in terms of potential use and diversity of design. Planting can include lawn, shrubs, bushes and even the occasional tree.*

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.

FLL-Guideline for the Planning, Execution and Upkeep of Green Roof sites (2008)

There are no European standards which specify the design of green roofs. The FLL (a research institute in Germany) has drawn up a guide for the design, installation and maintenance of green roofs. This guide sets out the basic principles and requirements that, in general, apply to the design, installation and maintenance of green roofs. This guide is based upon scientific research and practical experience in building green roofs in Germany over the past 20 years.

In many countries throughout Europe this document has been accepted as the key guide for building green roofs. This Nophadrain brochure is also based upon this FLL Green Roof Guideline (2008).

* *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 Design loads

The structural deck should be able to withstand and absorb the static and dynamic loads imposed during construction and final use.

The load on a roof is determined by the:
- permanent imposed load by the weight of the construction
- permanent imposed load by the build-up of the green roof
- variable load due to e.g. maintenance work

The assumed permanent load of an extensive green roof at maximum water capacity is shown in table 1. Design loads.

Vegetation	Vegetation load kg/m²	ND DGS-E Growing Medium Extensive* depth mm/ load kg/m²	ND Drainage Composite depth mm/ load kg/m²	ND WSB-50 Root Barrier** load kg/m²	Surface load*** kg/m²	Total depth mm***
Mosses and Sedum	10	60/90 80/120	17/4.5	0.5	105 135	77 97
Sedum, mosses and herbaceous plants	10	60/90 100/150	17/4.5	0.5	105 165	77 117
Sedum, herbaceous plants and grasses	10	100/150 150/225	17/4.5	0.5	165 240	117 167
Grasses and herbaceous plants	10	150/225 200/300	17/4.5	0.5	240 315	167 217

Table 1. Design loads

* *weight approx. 1.5 tonne/m³ at maximum water capacity*

** *optional for usage in a non-root resistant waterproofing membrane*

*** *when using ND 5+1 or ND 6+1 Drainage Composite, the total depth increases by 10mm and the surface load with 2.5kg/m² (ND 5+1) or 4kg/m² (ND 6+1)*

When the ND DGS-E Growing Medium Extensive is substituted by the ND SM-25 or ND SM-50 Substrate Panels in combination with vegetation mats, the design load can be reduced to approx. 30kg/m² respectively 50kg/m² with a system depth of approx. 50mm (ND SM-25 Substrate Panels) or approx. 75mm (ND SM-50 substrate panels).

1.3 Roof constructions

The structural deck needs to be able to carry the extra load of the extensive green roof build-up. The waterproofing membrane should be root resistant and as with the thermal insulation, be able to carry the permanent load of the extensive green roof build-up.

The following roof constructions are recognized:

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. The load bearing capacity of the structural deck is generally minimal and must correspond to the calculated weight of the extensive green roof. The cooling effect of an extensive green roof can affect the physical properties of the structure. Freezing temperatures on the underside of the structural deck may result in frost damage to the vegetation. In general, all types of green roof systems and all forms of vegetation are suitable for use with this type of roof construction.

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. It is recommended that a vapour control layer be placed on top of the structural deck underneath the thermal insulation. In general, all types of green roof systems and all forms of vegetation are suitable for use with this type of roof construction.

Inverted roof construction

Insulation is placed on top of the waterproofing membrane. Should an inverted roof be selected for greening, moisture diffusion measures should be considered When an extensive green roof 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, all types of green roof systems and all forms of vegetation are suitable for use with this type of roof provided there is sufficient dead load to prevent uplift of the thermal insulation due to water and wind.

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. Basically all types of green roof systems and all forms of vegetation are suitable. Freezing temperatures on the underside of the structural deck may result in frost damage to the vegetation.

1.4 Thermal insulation

Thermal insulation needs to be CE-marked based upon 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 placed beneath the waterproofing membrane – warm roof deck construction
- IRC = insulation placed above the waterproofing membrane – inverted roof deck construction

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 extensive green roofs built on an insulated roof, the thermal insulation should meet minimum load class "dm". The suitability of thermal insulation is to be demonstrated by the manufacturer.

Recommendation
If an extensive green roof needs to build-up over an insulated roof, it can be done on either a warm roof construction with Fe. mineral wool or on an inverted roof construction.

Because the waterproofing membrane on a warm roof construction cannot be fully bonded with the structural deck (unless cellular glass is used) it is recommended that separate compartments within the vapour control layer be created. In case of any damage to the waterproofing membrane, any leakage can be located more easily.

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 green roof.

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.

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

Suitability of the various types of thermal insulation:

Thermal insulation classification	Roof construction	dm	dh	ds	dx
Pressure Resistant Mineral Wool (MW) in accordance with BS EN 13162 "Thermal insulation products for buildings. Factory made products of mineral wool. Specification"	WRC	50kPa*	–	–	–
	IRC	–	–	–	–
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"*

1.5 Waterproofing systems

Continuous waterproofing systems
Roof constructions are, in general, protected against the penetration of water by a waterproofing membrane (bitumen, synthetic, elastomer 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 membrane beneath the 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 or the BS EN 13948 "Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of resistance to root penetration".

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: an 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
An extensive green roof can be installed on a loose laid/mechanically fixed or fully bonded waterproofing system. In many installations leakage occurs due to incorrect detailing, poor choice of materials, or errors/damage incurred during installation. When a loose laid/mechanically fixed waterproofing system is damaged, the point of leakage is difficult to locate as the water can move freely over the structural deck. This problem can easily be overcome by creating separate compartments within the vapour control layer. Any damage to the waterproofing system can be located more easily.

Leakage of a fully bonded waterproofing system can be easily located if installed on a closed structural deck. For an insulated roof construction a fully bonded system can only be realized on a inverted roof construction with XPS insulation or on a warm roof construction with cellular glass.

Discontinuous waterproofing systems
Roof tiles
Roofs with roof tiles can only be covered with an extensive planting scheme if special green roof tiles are used. The pitch of the roof should be a minimum of 22°.

Attention should be paid to:
- execution of the overlaps
- extra permanent loading imposed by green roof build-up
- accessibility during installation and for maintenance purposes
- protection against wind erosion
- fixing of the roof tiles to the battens

As there is no root barrier, a green roof can only be installed if:
- there is sufficient air space behind the roof tiles and;
- an impermeable underlay is installed.

Corrugated roof sheets
An extensive green roof can only be installed on a corrugated roof sheet if this is approved by the manufacturer. Often, the loadbearing capacity of corrugated roof sheets is insufficient.

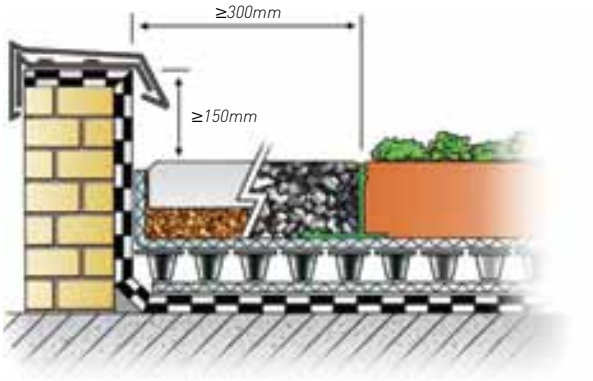
If a green roof is installed attention should be paid to:
- water tightness of the folded joints
- build-up height of the folded joints
- distribution of the permanent load of the green roof over the structural supports
- ventilation of the corrugated roof sheets
- lowering of the dew point
- soil slip protection

1.6 Details

Basically, the same waterproofing detail principles apply to green roofs as to flat roofs. The waterproofing membrane should be brought up above the surface level by at least 150mm at roof upstand details e.g. parapets, abutments, and roof protrusions.

Roof edge
If the roof edge is too low, a roof edge profile is placed to retain the build-up of the green roof. The roof edge profile can also be used if a roof edge is not present.

At roof edge details, a clear strip of clean gravel (min. 16-32mm) or concrete slabs should be installed for maintenance and inspection purposes. The minimum recommended width is 300mm. To prevent the growing medium being washed into the clear strip, a GreenLiner Edge Retaining Profile should be installed.



Detail 1. Parapet

Products:
GreenLiner 45DK Edge Retaining Profile ND KL-80 Gravel Edge Profile ND RP-100 Roof Edge Profile ND RP-101 Roof Edge Profile with drainage slots

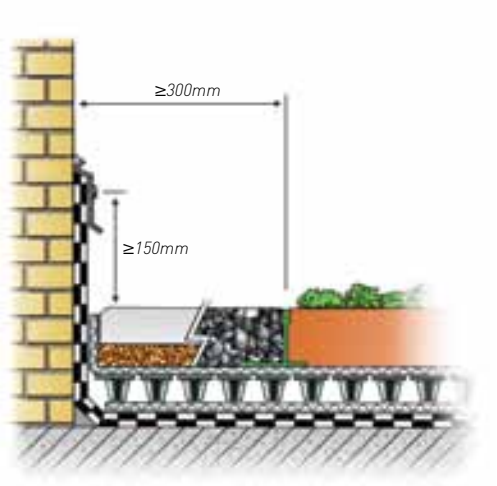
If the waterproofing membrane projects over the roof edge into the ground, it is recommended that the waterproofing membrane extends a minimum 500mm beyond the edge and at least 200mm over a joint.

Facade
At facades, the waterproofing membrane should be brought up above the highest roof edge by a minimum of 150mm above service level. This is not always possible at door thresholds, therefore at those door thresholds where a channel drain is installed, the waterproofing membrane can be brought up above the surface of the clear strip by 50mm.

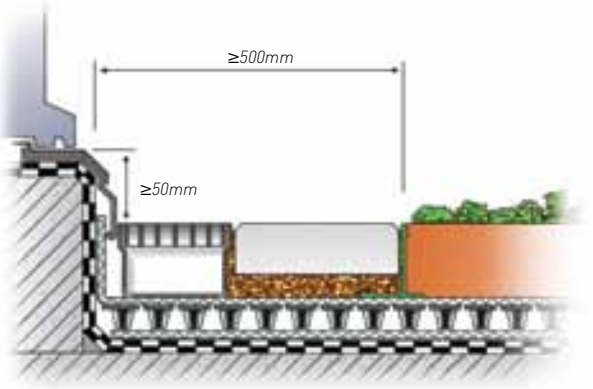
Along facades, a clear strip of clean gravel (min. 16-32mm) or concrete slabs should be installed for maintenance and inspection purposes, and to act as a splashguard. The clear strip between the facade and the vegetated area helps to prevent any water run-off adversely affecting the development of the plants. To prevent the growing medium being washed into the clear strip, a GreenLiner Edge Retaining Profile should be installed. The minimum recommended width of this clear strip is 300mm.

At facades with an opening (e.g. window, door, etc.) at ≤800mm above the surface level, a clear strip with width of ≥500mm is preferred for enhanced fire safety reasons.

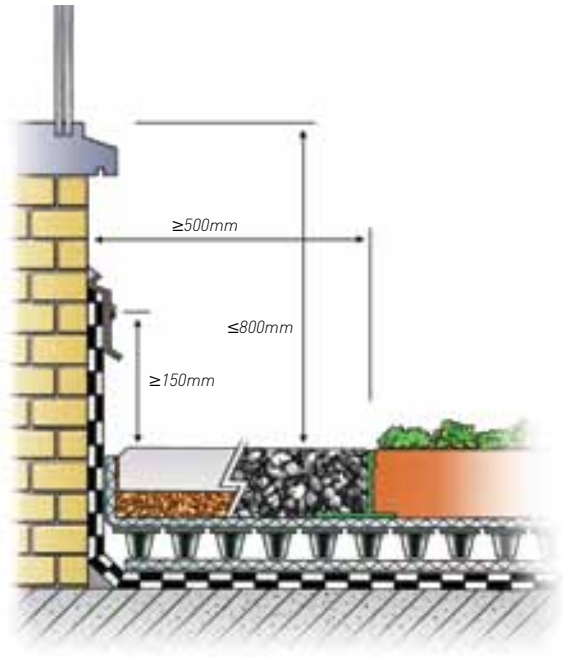
Products:
GreenLiner 45DK Edge Retaining Profile



Detail 2. Facade



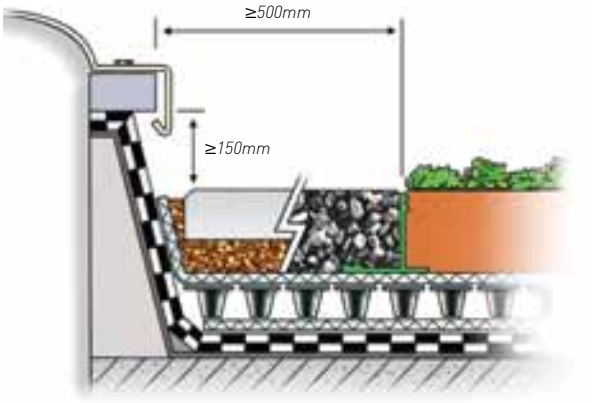
Detail 3. Door threshold



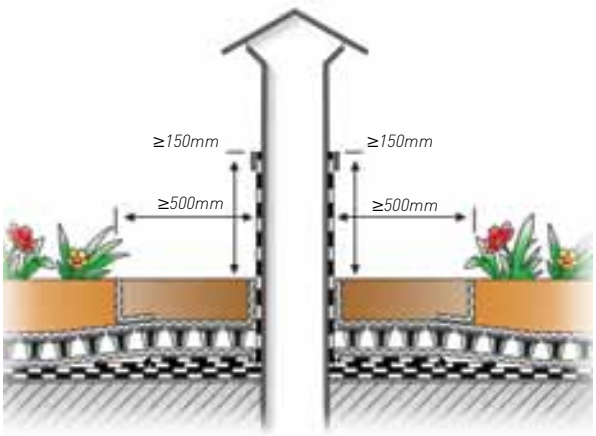
Detail 4. Facade with an opening at ≤800mm

Roof protrusion with or without roof upstand

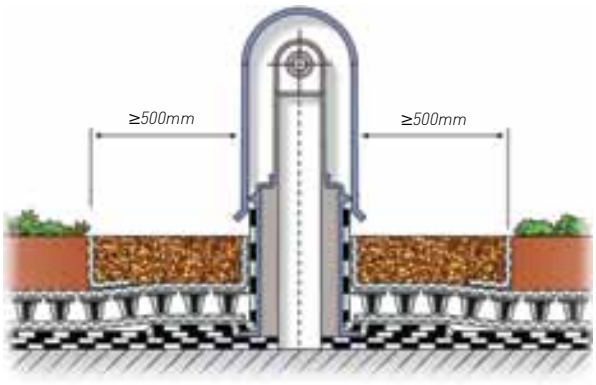
A minimum 300mm wide clear strip of clean gravel (min. 16-32mm) or concrete slabs should be installed for maintenance and inspection purposes. However, a width of 500mm or more is preferred for enhanced fire safety reasons. To prevent the growing medium being washed into the clear strip, a GreenLiner Edge Retaining Profile should be installed.



Detail 5. Roof light upstand



Detail 6. Cold vent pipe



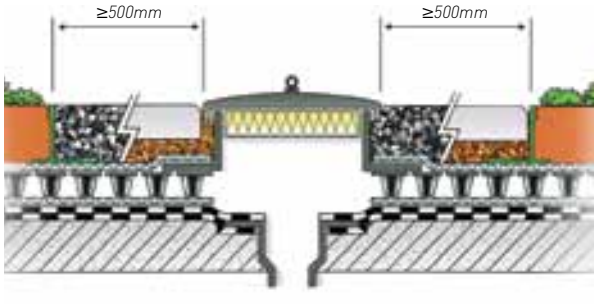
Detail 7. Anchor point

Products:

GreenLiner 45DK Edge Retaining Profile

Roof outlet

Where a roof outlet is positioned within a vegetated area, an inspection chamber complete with access cover is placed over the outlet to protect it from plant growth and impurities. The inspection chamber should not affect or impede drainage efficiency and must be accessible at all times.



Detail 8. Roof outlet

A clear strip of clean gravel (min. 16-32mm) should be placed around the inspection chamber. The width of this strip should not be less than 300mm; clear strips of 500mm offer an enhanced degree of fire safety. To prevent growing medium being washed into the gravel strip, a GreenLiner Edge Retaining Profile should be installed.

Roof outlets lying outside the vegetation area are normally positioned within a gravelled area, with a gravel guard covering the outlet. When a roof outlet is located within a hard-landscaped area, an inspection chamber fitted with a suitable grating should be placed over this outlet.

Products:

ND RS-VarioBasic Inspection Chamber
ND GD-30 Grid
GreenLiner 45DK Edge Retaining Profile

1.7 Design of falls – roof slope

For an extensive green roof, falls should ensure that no water is allowed to pond on the roof construction. The construction should be as such that any accumulated water or ponding is prevented from getting into direct contact with the growing medium layer at any time.

In order to achieve this, flat roofs should be constructed to a minimum fall of 1 in 80 (~1.3%). This means that the design fall should be greater, to take into account deflections and inaccuracies in construction. Some designers take a fall of 1 in 80 (~1.3%) and add an arbitrary adjustment for construction inaccuracies of 25mm for concrete roofs and 15mm for metal decks. Roofs with falls of less than 1 in 50 (2%) are not suitable for single-layer green roof systems. In such cases a separate drainage layer should be installed to ensure that no excess water accumulates in the growing medium.

It should be noted that water might pond on the roof covering even though the roof was designed with sufficient falls. This may be due to overlaps of the waterproofing membrane or unexpected inaccuracies in construction or deflection of the roof construction. Consequently, where the growing medium has direct contact with standing water, the growing medium will become saturated due to capillary action. A healthy growing environment for the vegetation cannot be guaranteed in such circumstances. By using ND 5+1/ND 6+1 Drainage Composites with a build-up height of 27mm, direct contact between standing water and the growing medium can be avoided.

Roofs with a fall ratio of 1 in 20 or more (≥5%) should have an increased water retention capacity as such relatively steep pitches can result in accelerated and/or excessive water removal from the growing medium. This is achieved by increasing the depth of the growing medium layer.

Fall ratio	Slope angle	Slope
1:120	~0.5°	~0.8%
1:100	~0.6°	~1.0%
1:80	~0.7°	~1.3%
1:60	~1.0°	~1.7%
1:40	~1.4°	~2.5%
1:38.2	~1.5°	~2.6%
1:28.6	~2.0°	~3.5%
1:19.1	~3.0°	~5.2%
1:14.3	~4.0°	~7.0%
1:11.4	~5.0°	~8.7%
1:9.5	~6.0°	~10.5%
1:8.1	~7.0°	~12.3%
1:7.1	~8.0°	~14.1%
1:6.3	~9.0°	~15.8%
1:5.7	~10.0°	~17.6%
1:3.8	~15.0°	~26.8%
1:2.3	~25.0°	~46.6%
1:1	~45.0°	~100.0%

Table 4. Relationship between fall – angle – slope

Products:

Roofs with sufficient fall ≥1 in 80
ND 4+1 high Drainage Composite
ND 200 Drainage Composite
ND 220 Drainage Composite
ND 6+1 Drainage Composite with additional water reservoir

Roofs with insufficient fall <1 in 80
ND 5+1 Drainage Composite
ND 5+1lt Drainage Composite
ND 6+1 Drainage Composite with additional water reservoir

Soil anchorage measures
With increased roof pitch, appropriate soil anchorage measures should be taken against slippage of the loose laid green roof build-up layers. An extensive green roof should not be applied if the roof pitch is more than 45°, due to technical difficulties with the vegetation.

Depending on the degree of pitch:
- structural measures and/or
- vegetation technical measures should be taken

The slip loading forces should not be transferred to the waterproofing membrane. If necessary, separation and slip layers should be installed. The anchorage measures should have drainage openings when installed at the bottom of the roof. When dimensioning the roof outlets, accelerated and/or excessive water discharge has to be taken into account due the increased roof pitch.

Roof slope – falls <1 in 80
Structural measures:
- roof without a roof edge: a roof edge profile should be installed to restrain the growing medium layer and the clear strip
- the width-height ratio of the roof edge profile should be 1:1 with the build-up height of the extensive green roof
- the green roof build-up layers are placed loose on the waterproofing membrane
- when the green roof build-up is not chemically compatible with the waterproofing membrane a separation layer should be installed
- there are no special vegetation technical measures necessary

Products:

ND KL-80 Gravel Edge Profile
ND RP-100 Roof Edge Profile
ND RP-101 Roof Edge Profile with drainage slots

Roof slope – falls 1 in 80 (~0.7°) to 15°
Structural and vegetation technical measures:
- roof without a roof edge: a roof edge profile should be installed to restrain the growing medium layer and the clear strip
- if stormwater is discharged through a roof gutter, soil anchorage measures at the bottom of the roof should have drainage slots
- the growing medium layer should have a higher water retention capacity (higher organic material content or a thicker layer) as the roof pitch can result in accelerated and/or excessive water removal from the growing medium
- soil erosion mat or soil erosion glue for improved stability of the growing medium

Products:

ND KL-80 Gravel Edge Profile
ND RP-100 Roof Edge Profile
ND RP-101 Roof Edge Profile with drainage slots
ND ESK-600 Erosion Protection Glue
ND ESG-60/60 Erosion Protection Grid

Roof pitch 15° to 25° (medium pitched roof)
Based upon the increased slippage forces of the green roof build-up layers, structural and vegetation technical measures are necessary to improve the stability of the growing medium layer.

Structural measures:
- soil anchorage measures at the roof gutter
- installing ND Drainage Composites
- reinforcing the drainage layer when a single-layer green roof system is installed
- using concrete pavers instead of aggregate at the clear strips

Vegetation technical measures:
- using substrate panels instead of granular material as growing medium layer
- reinforcing the growing medium layer with geotextiles and geocomposites
- reinforcing the top of the growing medium with soil erosion glue
- increasing the number of plug plants
- using vegetation mats

Products:

ND 5+1esn Dimpled Sheet
ND 200 Drainage Composite
ND SM-50 Substrate Panels
ND WSF-24 Film Strips
ND ESK-600 Erosion Protection Glue
ND DGS-M Growing Medium Mineral
ND Vegetation Mats Sedum
ND Plug Plants Sedum
ND Plug Plants Herbs/Grasses

Roof pitch 25° to 45° (steep pitched roof)
For roofs with a pitch of 25° or more, soil anchorage measures should be taken at the top of the growing medium layer. When dimensioning the aggregate strip, the drainage composite and the channel drain at the bottom of the pitched roof, accelerated and/or excessive water removal from the roof has to be taken into account.

Basically, the same structural and vegetation technical measure apply to roofs with a pitch of 25° to 45° as for roofs with a pitch of 15° to 25°. In addition the following measures should be taken:

Structural measures:
- assessment of the permanent load at the bottom of the roof
- limiting the permanent load at the bottom of the roof by installing soil anchorage measures
- distributing the slip loading forces of the growing medium layer over both sides of the roof (saddle roof)
- limiting of the slip loading by fixing geotextiles, drainage composites, geogrids at the top of the roof
- use of grass pavers to prevent aggregate and growing medium slippage at the edges of the green roof
- special ladder systems need to be installed for maintenance
- installing GreenLiner 45DC Erosion Protection Profile Clip in combination with ND ESG-60/60 Erosion Protection Grid

Vegetation technical measures:
- use of substrate panels instead of granular material as growing medium layer
- use of vegetation mats

Products:

GreenLiner 45DC Erosion Protection Profile Clip
ND Clic Fixing Profile
ND 100 Drainage Composite
ND 120 Drainage Composite
ND Strip 150 Strip Drain
ND SM-25 Substrate Panels
ND SM-50 Substrate Panels
ND WSF-24 Film Strips
ND ESK-600 Erosion Protection Glue
ND ESG-60/60 Erosion Protection Grid
ND Vegetation Mats Sedum

1.8 Designing for stormwater

Roof drainage
BS EN 12056-3 "Gravity drainage systems inside buildings. Roof drainage, layout and calculation" provides for a run-off coefficient to allow for absorbent roofing surfaces where national and local regulations, and practice, permit. However, at present in the United Kingdom, no guidance is available, and so the designer is forced to adopt alternative methods if the run-off reduction effect of a green roof is to be taken into account.

For roofs with a fall of 1 in 40 (2.5%) or flatter (nominally flat roofs) the designer should use a BS EN 12056-3 Category 1 storm event for design purposes. This storm event will occur on average once per year in the United Kingdom, and will generate rainfall intensities which vary from 0.01l/(s.m^2) to 0.022l/(s.m^2) depending on geographical location. This is a very short duration thunderstorm rain, and will occur on average for 2 minutes, usually in summer, when a green roof build-up could be expected to be at its driest. In using this method, it is assumed that any storm greater than this intensity would be absorbed into the green roof build-up, or would pond on any hard surfacing between green areas. The roof deck should however be strong enough to resist the loads imposed by minor ponding, as it should have been designed to cope with the loadings from the green roof.

For roof falls greater than 1 in 40 (2.5%), a BS EN 12056-3 Category 2 or 3 storm event should be used, as there is a risk of structurally significant ponding when the green roof area would not be capable of absorbing all of the stormwater. Category 2 and 3 storm events are based on the building life multiplied by a factor of safety of 1.5 or 4.5, and results in much higher rainfall intensities (0.029 l/(s.m^2) to 0.088 l/(s.m^2)).

For further guidance on rainfall intensity in the United Kingdom see National Annex NB of BS EN 12056-3.

Area	Rainfall intensity l/(s.m²) category 1	Rainfall intensity l/(s.m²) category 2	Rainfall intensity l/(s.m²) category 3
England	0.022	0.066	0.088
Scotland, Wales, and Northern Ireland	0.016	0.053	0.065
Northern Scotland, Shetlands and Orkneys	0.010	0.029	0.034

Table 5. Guide figures category 1, 2 and 3 storm event

Run-off coefficients
For extensive green roofs, the following run-off coefficients (C) can be used. The values depend on the depth of the growing medium and the roof slope/pitch:

Growing medium layer depth in mm	Roof slope ≤5° (~8.8%)	Roof slope >5° (~8.8%)
60	C = 0.6	C = 0.7
60-100	C = 0.5	C = 0.6
100-150	C = 0.4	C = 0.5
150-250	C = 0.3	–

Table 6. Run-off coefficient

These figures apply for the stated layer depth at a 15 minute rainfall intensity of r = 0.03l/(s.m²). The growing medium has previously been saturated with water and drip-dried for 24 hour prior to testing.

Annual stormwater retention capacity
The annual average percentage of stormwater actually retained by a green roof is calculated as the difference between the amount of rainfall and the amount of water discharged. The inverse of this is the annual run-off coefficient, Ca. The annual stormwater retention depends more on the depth of the growing medium layer than on the type of build-up and composition of the layers. The annual average percentage of stormwater retention and the run-off coefficient of a green roof system at various build-up depths, assuming an annual precipitation rate of 650-800mm:

At a higher (>800mm) or lower (<650mm) annual precipitation rate the annual average stormwater retention will be lower or higher as stated in table 7.

Build-up depth mm	Type of vegetation	Annual average stormwater retention %	Annual run-off coefficient Ca
60	Mosses and Sedum	45	0.55
60-100	Sedum, mosses and herbaceous plants	50	0.50
100-150	Sedum, herbaceous plants and grasses	55	0.45
150-200	Grasses and herbaceous plants	60	0.40

Table 7. Annual stormwater retention capacity

1.9 Fall protection

On flat roofs, all necessary safety measures for carrying out inspection and maintenance work should be considered at the design stage. Planning for adequate safety precautions at the design stage eliminates potentially higher costs that may be incurred should fall protection safety measures need to be installed at a later date.

Collective preventive measures, e.g. guard-rails, toe-boards, barriers, etc., should be installed. Personal fall protection equipment to prevent or minimise the consequences of a fall should only be considered when collective preventive measures are not practical. Personal fall protection equipment that prevents a fall, e.g. a work restraint system, should always take priority over personal equipment which only limits the height and/or consequences of a fall, e.g. a fall arrest system.

The products and systems must meet the relevant safety standard including BS EN 795 "Protection against falls from a height. Anchor devices. Requirements and testing" and EN 353-1 "Personal protective equipment against falls from a height. Guided type fall arresters including a rigid anchor line".

The following safety systems should be installed depending on suitability:
- collective preventive systems – guard rails, toe boards, barriers, etc.
- work restraint systems enable the user access to conduct his duties but prevent him from reaching a point where a fall could occur
- work positioning systems equipment enable the user to work intension or suspension to prevent or limit a fall
- fall arrest systems and equipment limit the impact force of a fall on the user and prevent them hitting the ground

Products:
ND ParaSave P1 Fall Protection ND ParaSave P2 Fall Protection ND ParaSave P1S Fall Protection - wire ND ParaSave P2S Fall Protection - wire

1.10 Fire prevention

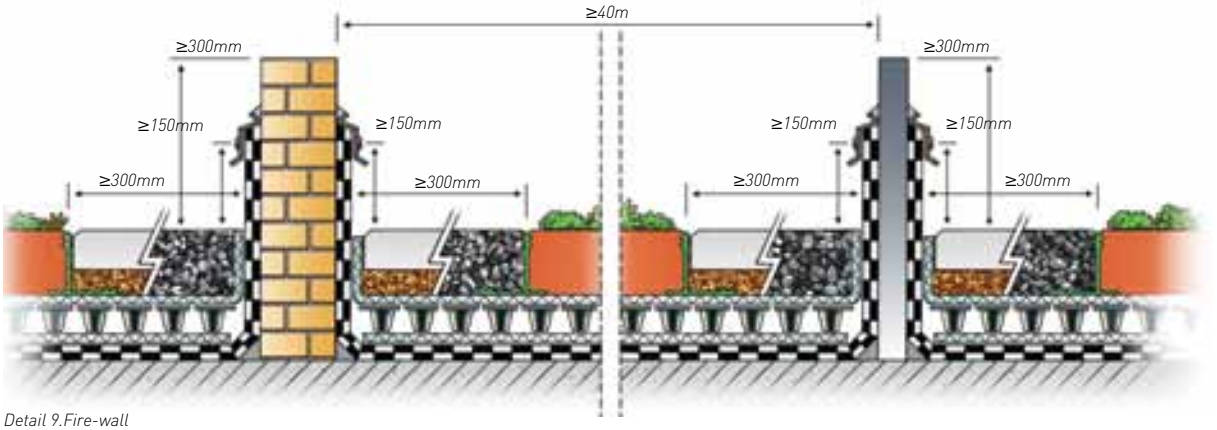
Enhancing fire safety

Green roofs with an extensive planting scheme are regarded as fire-resistant to radiant heat or flying sparks if:

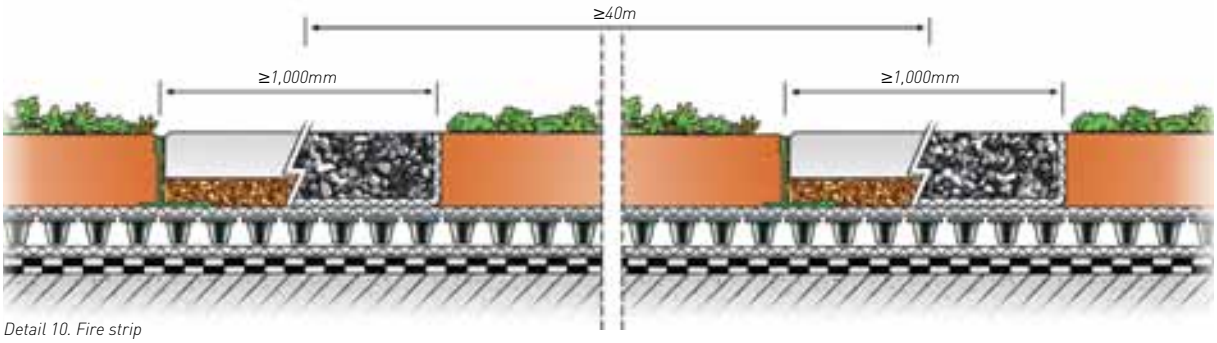
- the depth of the growing medium layer is not less than 30mm and contains a maximum of 20% organic material by weight
- a strip of clean gravel (min. 16-32mm) or concrete slabs with a minimum width of 500mm is installed around roof protrusions (e.g. skylights, vent pipes, outlets, etc.)
- along facades with an opening (e.g. window, door, etc.) at ≤800mm above the surface level, a clear strip of clean gravel (min. 16-32mm) or concrete slabs with a minimum width of 500mm is installed
- at separations not exceeding 40 metres, there is a fire-wall with a height of not less than 300mm, or there is a strip of clean min. 16-32mm gravel or concrete slabs measuring not less than 1,000 mm in width
- for adjoining, gabled buildings, the first 1,000mm from the eaves is kept free of vegetation and the area is covered with a non-combustible roof covering

Products:

GreenLiner 45DK Edge Retaining Profile



Detail 9.Fire-wall



Detail 10. Fire strip

Width of clear strips (vegetation-free zones):

Detail	Clear strip e.g.: gravel (minimum 16/32)/concrete slabs	Recommended width	Recommended width for enhanced fire safety
Roof outlet	Yes	–	≥500mm all around
Facade	Yes	≥300mm	–
Facade with an opening ≥800mm above surface level	Yes	–	≥500mm
Roof edge	Yes	≥300mm	–
Roof protrusion	Yes	–	≥500mm

Table 8. Width of clear strips

1.11 Wind loads

Waterproofing membranes and green roof layers have to be designed to take into account wind loads. It is the engineer's responsibility to determine the appropriate dead loads and the position thereof. It should be noted that the potential for wind uplift is greatest at the roof perimeters and so protective measures, such as gravel strips or concrete slabs, may be required. Where waterproofing membranes are laid loose without being permanently fixed to the deck structure, the green roof layers may act as a ballast. The determining factor will be the dry weight of these layers.

In addition, the following is to be taken into consideration:
- the variable height, thickness and density of the vegetation
- the weight of the vegetation
- the open, airy nature of the planting that reduces the wind uplift of the vegetation layer

These criteria are to be included in the design wind loads calculations.

1.12 Protection from emissions

The plants may be subjected to dehydration and frost damage due to exposure to excessive warmth, cold air and/or air currents caused by ventilation systems and air conditioning. Further, gases from chimneys and exhaust systems can cause direct damage to the vegetation. A clear strip, the area/width depending on the effect of the emission, is to be observed.

1.13 Maintenance

It is recommended that a maintenance contract and a long-term care plan is drawn up between the property owner and the landscape contractor. The care plan should, naturally, cover essential maintenance of the plants, but it is essential that the following points are also considered:

- functionality of the drainage system
- inspection for impurities, deposits and root growth in the inspection chambers
- inspection of the waterproofing system on damages

2 THE BUILD-UP OF AN EXTENSIVE GREEN ROOF

2.1 Build-up

The build-up of an extensive green roof comprises the following layers that are considered in subsequent sections:
- root barrier layer
- separation and protection layer
- drainage layer
- filter layer
- growing medium layer
- vegetation layer

The various layers need to be geared in such a way that the functionality of the total build-up is guaranteed. Each layer has a specific function in the green roof system build-up. It is possible that one product integrates the functions of several layers or that one layer consists of more than one product e.g. the ND Drainage Composites integrate the drainage and filter layer and, in certain build-ups, also include the separation and protection layer.

Multi-layer green roof build-up – Standard
In a multi-layer green roof build-up the growing medium layer is separated from the drainage layer by means of a filter fabric. The filter fabric prevents finer particles from the growing medium entering the drainage layer. This filtration ensures that a fully functional horizontal and vertical drainage is maintained at all times.

As the growing medium layer does not function as a drainage component it can be mixed with organic-based material to improve moisture retention and nutrient supply, thereby increasing the buffering action and simultaneously improving plant growth.

Advantages of a multi-layer system:
- enhanced moisture-retention of the growing medium promotes healthy plants over the longer term
- excellent long-term horizontal and vertical drainage preventing additional dead loads on the roof structure caused by rainwater ponding
- good buffering action in the growing medium provided by the presence of both finer particles and organic material
- suitable for both flat and pitched roofs

Single-layer green roof build-up – Non-standard
In a single-layer green roof build-up, a mineral substrate undertakes the functions of the growing medium, the filtration, and the drainage. The substrate should be filter-stable, that is it should be inert, non-degradable and remain of a size that will not compromise the filtration function of the layer, while allowing good vertical and horizontal drainage. The minimum roof fall of a single-layer system should be 1 in 50 (2%) and the substrate should have a minimum depth of 80mm. Since there is no separate filter layer in this system, the substrate may contain only very little organic material. It should be noted that, as the substrate is a natural material, it is difficult to quantify drainage performance, and care should be exercised as the inevitable growth in root density and the ingress of finer particles will probably reduce performance over time.

Disadvantages of a single-layer system:
- poor long-term horizontal drainage, and the permitted design loads may be exceeded due to water accumulation
- poor/inefficient drainage increases the accumulation of moisture

in the substrate. Excessive humidity leads to the growth of mosses and attracts maintenance-intensive plants
- reduced buffering action from water and nutrients as the substrate does not contain any organic material
- significant fluctuations in water and nutrient balance leads to stress within the vegetation layer, which in turn, can result in poor growth or even death of the plants
- not suitable for roofs with falls of less than 1 in 50 (2%)
- the anticipated cost savings made by omitting a separate filter and drainage layer are cancelled out by the need for increased levels of maintenance

Where the roof fall is less than 1 in 50 (2%), the horizontal drainage should be improved by installing ND Strip 150 Drainage Composite. The strips are laid flat, in parallel rows at approximately 2 meters intervals on top of the protection layer. The strips are linked into an inspection chamber that is placed on top of a roof outlet.

2.2 Root barrier layer

The root barrier layer prevents the ingress of roots into the waterproofing layer. The root barrier layer can be integrated in a root resistant waterproofing membrane (e.g. PVC, EPDM or bitumen-copper waterproofing membranes tested in accordance with the FLL root resistance test or BS EN 13948). If the waterproofing membrane is not root resistant, a separate root barrier should be placed directly on top of the waterproofing membrane. Overlaps have to be heat-welded along the lapped joints. Use of a separate root barrier on top of the waterproofing membrane is not required in those situations where the waterproofing membrane is root resistant.

Note
For the installation of a separate root barrier the same detail principles apply as for the installation of a waterproofing membrane. On inverted roof constructions lacking a root-resistant waterproofing membrane, the root barrier is positioned directly beneath the thermal insulation and on top of the waterproofing membrane.

Products:

ND WSB-50 Root Barrier

The root barrier is a 0.5mm modified LDPE sheet tested in accordance with the FLL root resistance test. Quick and easy installation is guaranteed by use of large sheets of up to 200m^2.

2.3 Separation and protection layer

The separation layer separates materials that are chemically incompatible (e.g. Polyvinyl Chloride (PVC) and Polystyrene (PS)). The separation layer also acts as a protection layer. The protection layer guards the waterproofing membrane against mechanical and dynamic loadings. When using a separate protection layer, this should be a protective membrane, a rubber mat, or a geotextile with a minimum weight of 300g/m^2 and a puncture resistance of 1.5kN. The protection layer should be designed to suit the conditions to which the waterproofing membrane will be subjected.

If ND Drainage Composites are fitted immediately after installation the waterproofing membrane, they can act as a separation and protection layer for lightweight static loads such as an extensive green roof.

Products:

ND SV-300 Protective Geotextile
ND SV-500 Protective Geotextile
ND Drainage Composites

2.4 Drainage layer

The drainage layer relieves the waterproofing membrane of hydrostatic pressure. In addition, any excess water in the growing medium layer is led away, preventing potential ponding of water in the growing medium that may damage the vegetation. The drainage layer must have a good vertical permeability combined with the ability to transport excess water horizontally away from the roof area. It 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 l/(s.m) taking into account the roof slope/pitch and the expected load pressure. 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.

2.5 Filter layer

It is essential that the drainage layer should be permanently protected against clogging by fine particles present in the growing medium. This is achieved by using a woven or a non-woven filter fabric to retain these fine particles. The weight of this geotextile is approx. 100-200g/m^2, depending on load, and the pore size should correspond to the minimum particle size of the growing medium. In general, the geotextile should have a puncture strength of 0.5kN and a pore opening size of <200mμ (0.2mm). The filter layer should allow roots to grow through into the drainage layer.

Note
The woven/non-woven filter fabrics must overlap by least 100mm. In situations where the filter layer (geotextile) as part of a drainage system is placed on top of an eggbox-shaped dimpled plastic sheet (geospacer) or a granular material, the geotextile as well as the geospacer must be CE-marked (BS EN 13252).

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 build-up height of the ND Drainage Composite is 8mm/13mm/17mm/27mm. A filter fabric (woven or non-woven) is bonded to each dimple. Depending on the application, the core may be perforated and provided with a plastic film or a geotextile on the back.

The dimples of the ND 4+1 high/ND 5+1 Drainage Composite act as an additional water reservoir for the vegetation. The ND 6+1 Drainage Composite has ribs between the dimple for additional water reservoir.

ND Drainage Composites on inverted roof constructions
The ND 4+1 high/ND 5+1/ND 6+1 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.

Type ND Drainage Composite	ND 4+1 high	ND 5+1	ND 6+1	ND 100 ND 120	ND 200 ND 220	ND 5+1esn
Extensive green roof – falls ≥1 in 80	■	■	■	–	■	–
Extensive green roof – falls ≥1 in 80 (inverted roof construction)	■	■	■	–	–	–
Extensive green roof – falls <1 in 80	–	■	■	–	–	–
Extensive green roof – falls <1 in 80 (inverted roof construction – exception)	–	■	■	–	–	–
Extensive green roof – roof pitch 15° tot 25° (medium pitched roof)	–	–	–	■	■	–
Extensive green roof – roof pitch 25° tot 45° (steep pitched roof)	–	–	–	–	–	■
Extensive green roof - roof with additional water reservoir	–	–	■	–	–	–

Table 9. Applications ND Drainage Composites

Dimensioning ND Drainage Composites
The amount of water that needs to be discharged by the drainage layer (q˙) can be calculated per l/(s.m) by using the following equation:

$$q^{\cdot} = \frac{A \times C \times r}{Lr} \text{ in l/(s.m)}$$

q˙ = required amount of water to be discharged by the drainage layer l/(s.m)
A = effective roof area m² (Lr x Br)
C = run-off coefficient (see table 6.)
r = rainfall intensity l/(s.m²)
Lr = length of the roof to be drained m

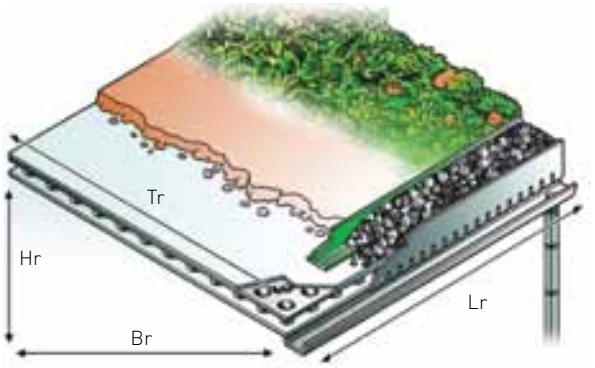


Figure 1. Roof dimensions
Lr = the length of roof to be drained
B = the plan width of roof from gutter to ridge
Hr = the height of roof from gutter to ridge
Tr = the distance from gutter to ridge measured along the roof

The composition of the growing medium is important for the health and growth of the plants. The growing medium needs to be capable of retaining water, making sufficient quantities of water accessible to the plants whilst allowing any water surplus to be discharged to the drainage layer.

Granular material
The growing medium layer for an extensive green roof should contain a low proportion of organic materials (≤65g/l). The FLL Green Roof Guideline (2008) has defined the exact requirements of such a substrate. The high mineral content

is designed to minimise possible shrinkage of the growing medium during prolonged dry periods, and consequent damage to roots. An excessively high organic content may result in a significant degree of settlement or "sag" that will require regular "topping-up".

A single-layer system uses a growing medium with a very low proportion of organic material (≤40g/l). On roofs with falls of more than 1 in 19 (roof pitch 5%), a thicker growing medium layer should be installed to achieve a higher water retention capacity. Due to the falls water is discharged more quickly from the growing medium layer.

The depth of the growing medium is determined by the vegetation's requirements for water, nutrients and root space:

Type of vegetation	Growing medium layer depth mm
Mosses and Sedum	60-80
Sedum, mosses and herbaceous plants	60-100
Sedum, herbaceous plants and grasses	100-150
Grasses and herbaceous plants	150-200

Table 10. Growing medium layer depth

When calculating the required layer depth, the following should be taken into consideration:
- characteristics of the various materials to be used
- roof slope
- exposure of the roof surface (sun, shadow, wind, etc.)
- regional climate
- object-specific conditions
- structural dead load and superimposed load
- target water retention

Note
Improved topsoils and/or sub-soils are likely to contain a significant proportion of finer particles that can clog the drainage and filter layer. In view of this, it is recommended that soils and soil-based substrates should not be used with extensive green roofs. The ND DGS Growing Media comply with the FLL Green Roof Guideline (2008).

Products:

ND DGS-E Growing Medium Extensive
ND DGS-M Growing Medium Mineral

Delivery
ND DGS-E Growing Medium Extensive/ND DGS-M Growing Medium Mineral:
- 20 litre sacks
- 1,000 litre bulk bags
- loose: delivered by tipper wagon - distributed by crane or conveyor system
- loose: delivered as silo load - forced air distribution

The most appropriate form of delivery is determined by the size and location of the project. There may be losses of approx. 15% due to settlement.

Substrate panels
For extensive green roofs, the growing medium can be replaced by ND SM-25 or by ND SM-50 Substrate Panels. Due to their low weight, substrate panels manufactured using a hydrophilic (water-absorbing) mineral wool are ideal for use in constructing lightweight green roofs.

ND SM Substrate Panels in combination with vegetation mats reduce the total weight of an extensive green roof to 30kg/m^2 for the SM-25 and to 50kg/m^2 for the SM-50 Substrate Panel. The substrate panels offer an economic solution for small roof surfaces (no need for a heavy crane). When the ND SM-25 Substrate Panels are used extra maintenance is to be expected (fertilising and watering) due to the shallow build-up height.

The 100% mineral content and high density give these substrate panels a high degree of durability along with structural stability. It makes these panels ideal for constructing extensive green roof on pitched roofs. Where granular material may slide off, the mineral wool panels remains in place. At a roof pitch of more than 15° structural measures need to be taken.

By using the ND PLS-Profi Plug Cutter with the ND PS Template, holes can easily be formed into the substrate panels, and the root balls of the plug plants fit exactly into the prepared holes. It is also possible to scatter Sedum cuttings or to unroll vegetation mats on top of the substrate panels. When Sedum cuttings or plug plants are used, the substrate panels should be mulched with 10-20mm of ND DGS-M Growing Medium Mineral. The high water retention capacity of the mineral wool panels enables the planting of more demanding vegetation like taller herbaceous plants and grasses.

Advantages:
- quick and easy installation
- low weight
- high water retention

ND SM Substrate Panels can be used as green roof substrates and have been approved by the FLL Green Roof Guideline (2008) as an acceptable substrate substitute. The panels are structurally stable and have a water-retaining capacity of 30l/m^2 at a thickness of 50mm.

Products:

ND SM-25 Substrate Panels
ND SM-50 Substrate Panels
ND PLS-Profi Plug Cutter
ND PS Template

2.8 Vegetation layer

Plants used on extensive green roofs should be self-regenerating and be able to adapt to both the local environment and the extreme climatic conditions on a roof. They should originate from the Central European flora although regional bio-diversity and prevailing climatic conditions should be taken in to account.

Planting communities used on an extensive green roof:
- mosses and Sedum
- Sedum, mosses and herbaceous plants
- Sedum, herbaceous plants and grasses
- grasses and herbaceous plants

More information about the variety of plant types can be found on the Nophadrain website - www.nophadrain.com.

The vegetation is supplied in the following formats:
- Sedum cuttings
- plug plants
- vegetation mats

The following circumstances are of concern when determining the extensive planting scheme and in determining the success and the durability of an extensive green roof:

Climatic circumstances
- local climate
- hours of sun
- periods of drought
- annual precipitation
- principal wind direction

Structural circumstances
- exposure to sun – shade
- position of the roof
- slope/pitch of the roof
- wind flow

Vegetation technical circumstances
- resistance against wind flow
- demand on the growing medium layer
- suppression resistance

Sedum cuttings
Cuttings can be taken from existing Sedum plants without causing any long-term harm to the donor plant. Sedum cuttings should be around 20mm in length, and after scattering they will root quite easily into the ND DGS-E Growing Medium Extensive, quickly developing into new plants.

Planting on a multi-layer system
After scattering the Sedum cuttings on top of the growing medium, ensure good contact by carefully rolling them in.

Planting on a single-layer system
Since the growing medium (substrate) is mainly mineral based, the Sedum cuttings will need to be mulched with compost (approx. 10l/m^2). Do not cover the entire area.

Planting on top of a lightweight green roof build-up
After scattering the Sedum cuttings on top of the ND SM-25 or ND SM-50 Substrate Panels, the Sedum cuttings must be mulched with approx. 10mm of ND DGS-M Growing Medium Mineral.

Recommended amount:
Sedum cuttings: 75-100g/m^2 a minimum of 100 Sedum cuttings/m^2 of at least 4 different types

Products:

ND Sedum Cuttings
ND DGS-M Growing Medium Mineral
ND ESK-600 Erosion Protection Glue

Plug plants
Sedum, herbaceous plants and grasses are specially cultivated as plug plants in flat-bottomed trays for extensive green roofs. The plug plants should be grown in containers of not less than 50cm^3.

Planting in a multi-layer system
Plant the plug plants into a growing medium layer having a depth of at least 60mm.

Planting in a single-layer system
The mineral-based growing medium also acts as the drainage component and so there should be a minimum of 20mm beneath the root-ball of the plug plant to prevent roots being in direct contact with the drainage layer.

Recommended amount
- plug plants: 15-20 plants/m^2

Planting in a lightweight green roof build-up
By using the ND PLS-Profi Plug Cutter in conjunction with the ND PS Template, holes large enough to accommodate the root-ball of the plug plant can be created in the ND SM-50 Substrate Panels. It's important to ensure the holes created penetrate to the full thickness of the substrate panels. Following planting, the substrate panels should be mulched with 10-20mm of ND DGS-M Growing Medium Mineral.

Products:

ND Plug Plants Sedum
ND Plug Plants Herbs/Grasses
ND PLS-Profi Plug Cutter
ND PS Template

Vegetation mats
Vegetation mats are pre-cultivated mats of Sedums, herbaceous plants and grasses. The mats should have at least 75% of their surface area covered, and up to 20% of the vegetation may consist of non-intentional vegetation, such as weeds, stray plants, etc.

Planting
The vegetation mats should be unrolled over the growing medium within 48 hours of delivery. When mats need to be stored temporarily, they must be stored in a cool, dry and shaded location, as the vegetation may be damaged if the rolled mats are allowed to become too warm. For best coverage, the mats should overlap by at least 25mm. Once laying is complete, the entire build-up should be watered until saturated.

Products:

ND Vegetation Mats Sedum
ND Vegetation Mats Herbs/Grasses

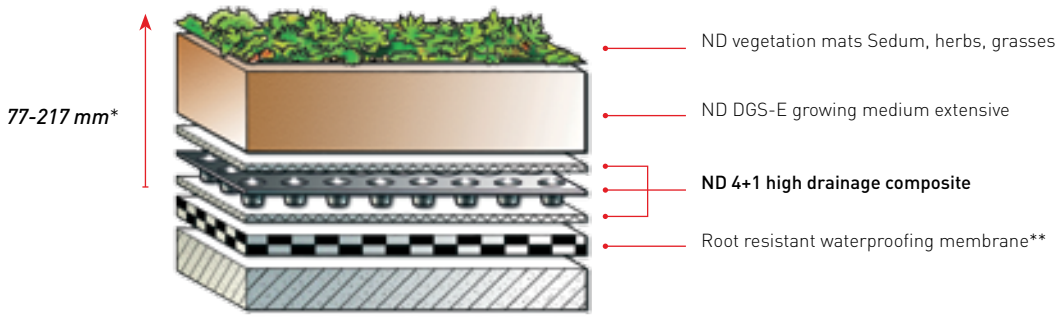
Recommended amount
- vegetation mats: surface area + 2.5%

3 NOPHADRAIN EXTENSIVE GREEN ROOF SYSTEMS

3.1 Roof with sufficient fall 1 in 80 (~0.7°) to 15°

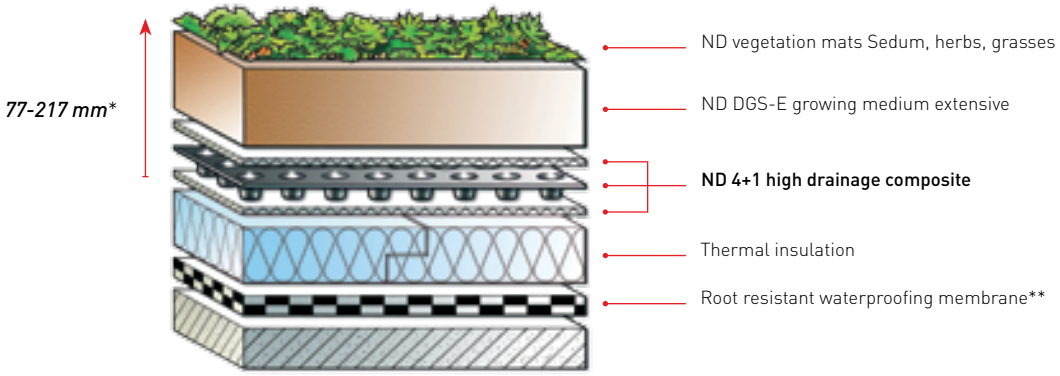
a. Warm roof construction / Roof construction without thermal insulation

Surface load*: 105-315kg/m²



b. Inverted roof construction

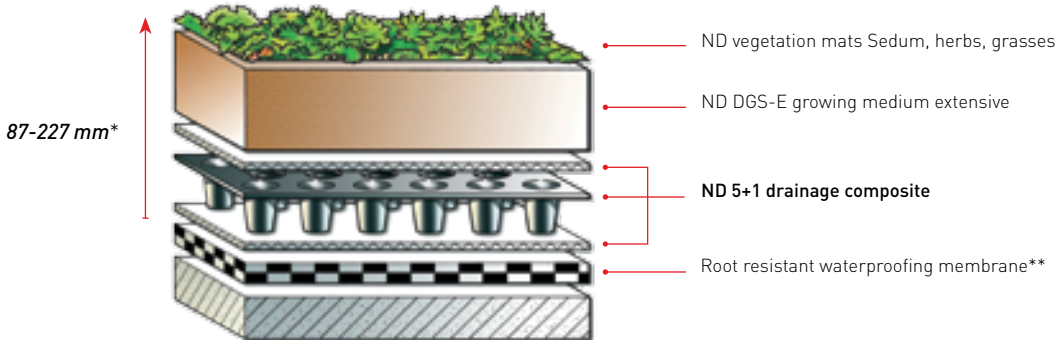
Surface load*: 105-315kg/m²



3.2 Roof with insufficient fall <1 in 80

a. Warm roof construction / Roof construction without thermal insulation

Surface load*: 118-318kg/m²

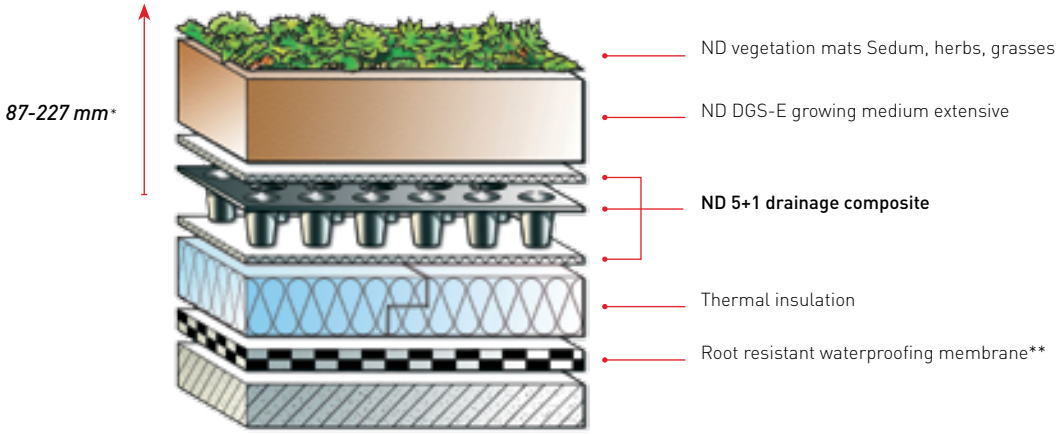


* *build-up depth and surface load depend on the type of vegetation; the values quoted are typical values*

** *optional ND WSB-50 Root Barrier*

b. Inverted roof construction

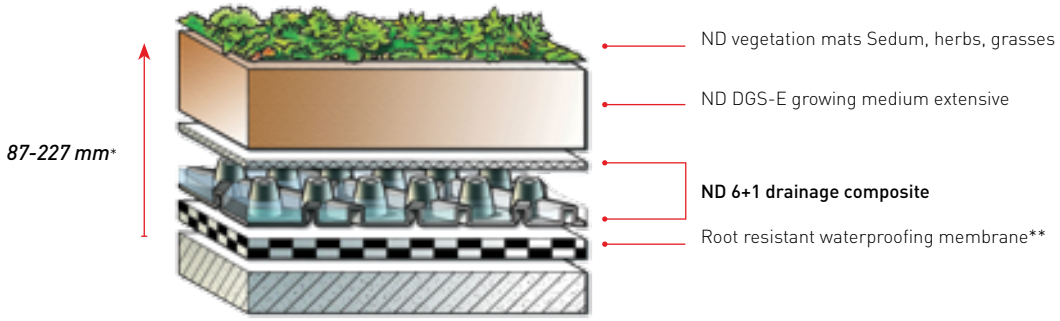
Surface load*: 108-318kg/m²



3.3 Roof with additional water reservoir

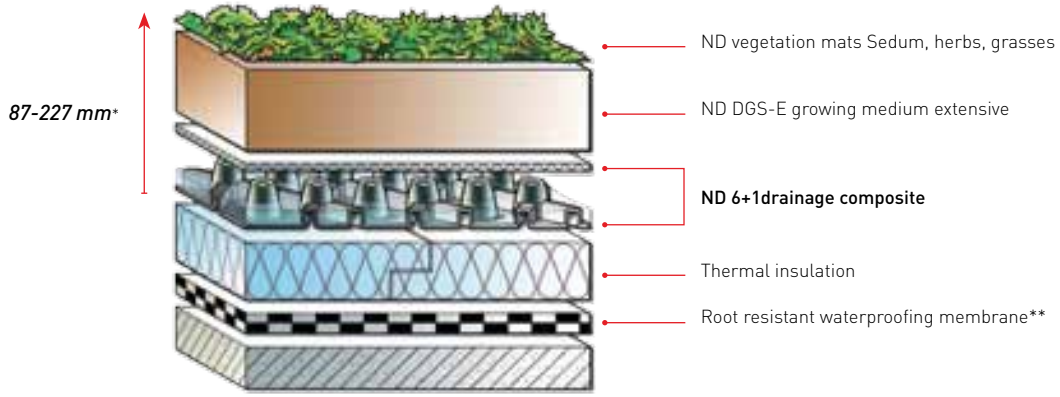
a. Warm roof construction / Roof construction without thermal insulation

Surface load*: 111-321kg/m²



b. Inverted roof construction

Surface load*: 111-321kg/m²

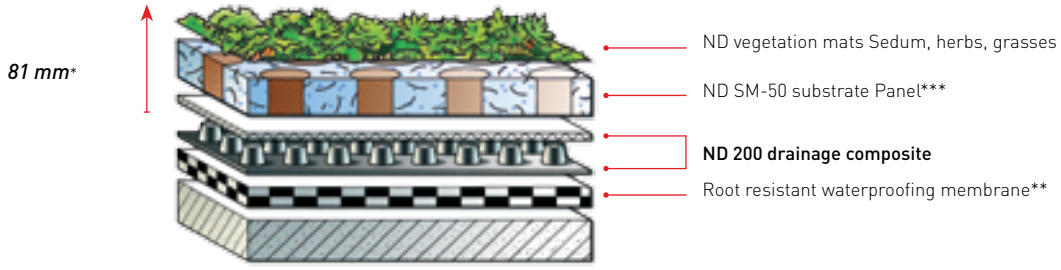


* *build-up depth and surface load depend on the type of vegetation; the values quoted are typical values*

** *optional ND WSB-50 Root Barrier*

3.4 Lightweight roof construction falls 1 in 80 (~0.7°) to 15°

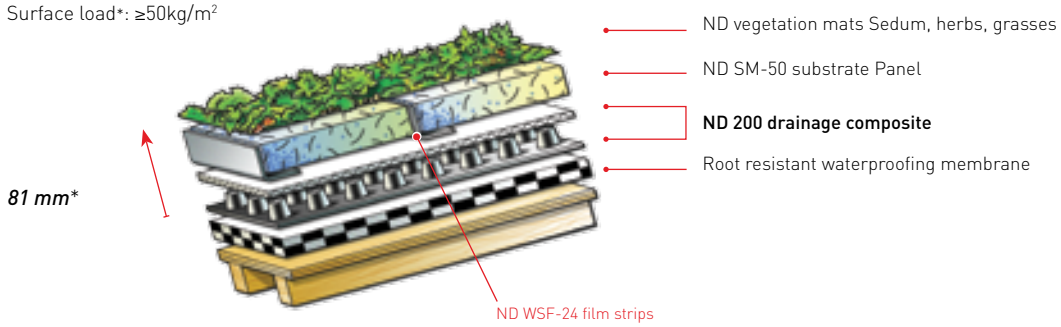
Surface load*: ≥50kg/m²



3.5 Medium pitched roof falls 15° to 25°

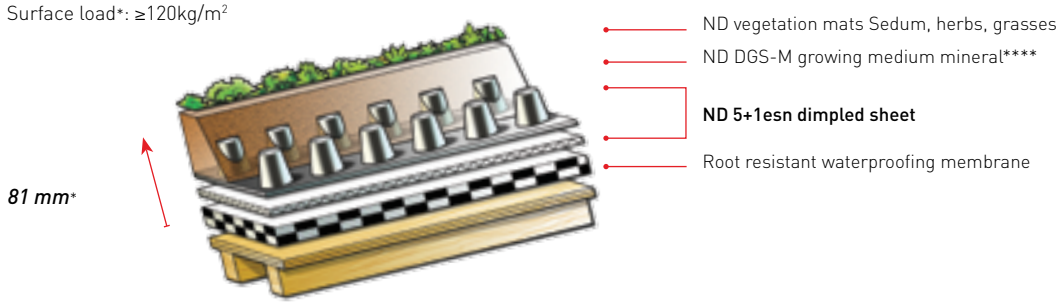
a. Multi-layer system

Surface load*: ≥50kg/m²



b. Single-layer system

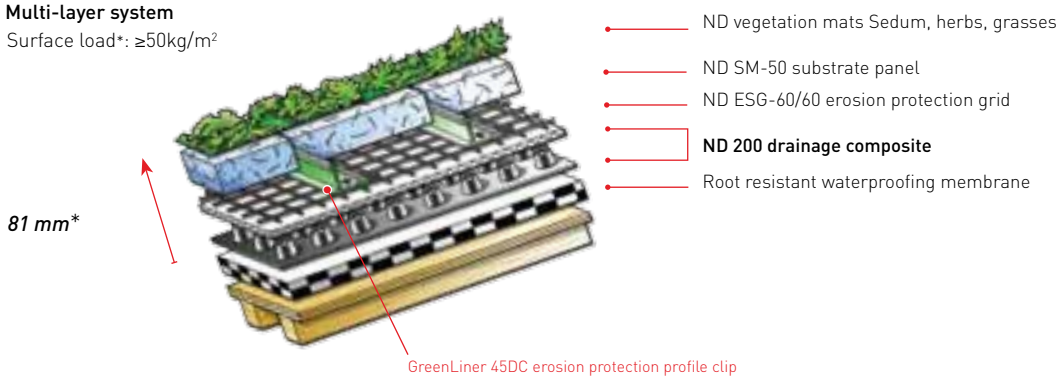
Surface load*: ≥120kg/m²



3.6 Steep pitched roof 25° to 45°

a. Multi-layer system

Surface load*: ≥50kg/m²



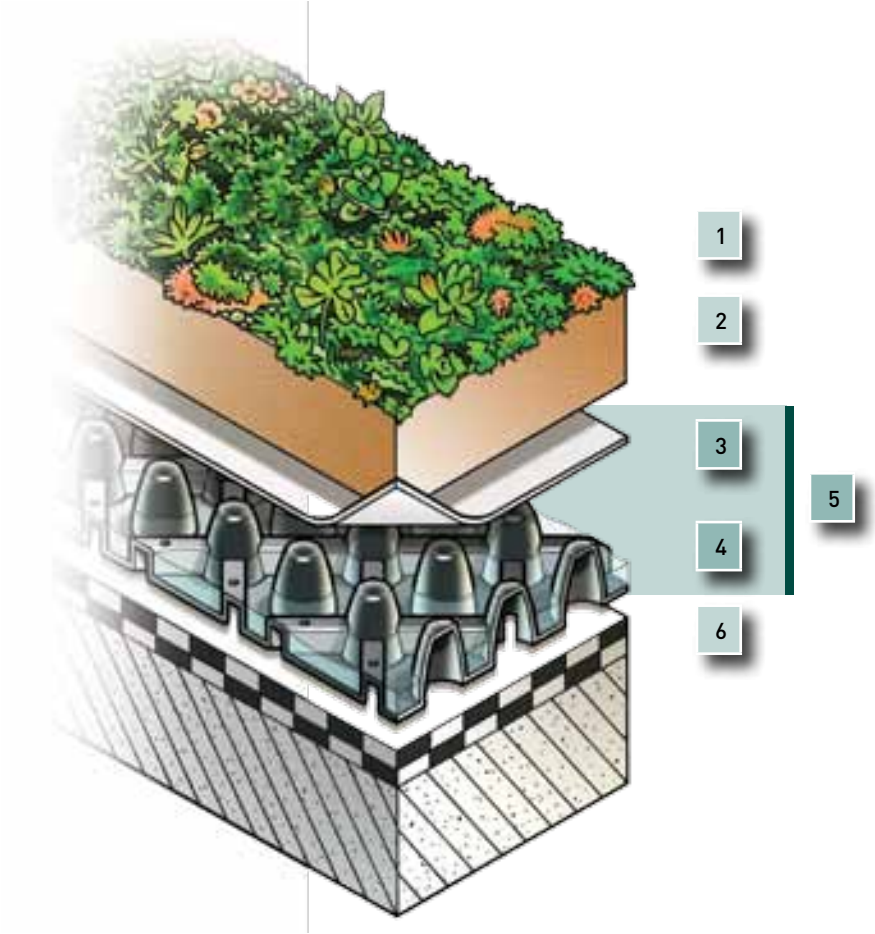
* *build-up depth and surface load depend on the type of vegetation; the values quoted are typical values*

** *optional ND WSB-50 Root Barrier*

*** *the substrate panels should be mulched with 10-20mm of ND DGS-M Growing Medium Mineral*

**** *the substrate panels should be mulched with 10-20mm of ND DGS-M Growing Medium Mineral and ND ESK -600 erosion etc*

BUILD UP OFF AN EXTENSIVE GREEN ROOF



1	Vegetation layer	ND vegetation mats Sedum, herbaceous plants, grasses
2	Growing medium layer	ND DGS-E growing medium extensive
3	**Filter layer**	**ND 6+1 drainage composite**
4	**Drainage layer**	
5	**Protection layer**	
6	Root barrier layer	Root resistant waterproofing membrane*

* *optional ND WSB-50 Root Barrier*

Notes:

NOPHADRAIN®
GREEN ROOF INNOVATORS

Dutch Green Building Council

Nophadrain BV
Mercuriusstraat 10
P.O. Box 3016
NL-6460 HA Kerkrade
T +31(0)45 535 50 30
F +31(0)45 535 39 30
E info@nophadrain.com
S www.nophadrain.com