NOPHADRAIN®

GREEN ROOF INNOVATORS

INTENSIVE GREEN ROOFS

DESIGN AND INSTALLATION GUIDE

0.3

NOPHADRAIN®
GREEN ROOF INNOVATORS

INTENSIVE GREEN ROOFS

TOTAL FREEDOM IN DESIGN

HIGH WATER RETENTION

EASY TO COMBINE WITH HARD LANDSCAPING

INTRODUCTION

Intensive greening of a roof can be considered 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. Once planted, the vegetation imposes a fairly high demand on the build-up layers and so needs regular irrigation (or a water retention system) as well as a regular supply of plant nutrients. This type of green roof can only thrive with regular maintenance. An intensive green roof can easily be combined with hard landscaping for pedestrians and vehicular traffic.

Due to the vegetation's demands for water and nutrients, along with the planting itself, the typical minimum weight of this type of green roof would be around 282kg/m^2 with a minimal layer depth of 217mm.

When designing intensive green roofs, these high loadings must be taken into consideration.

Features of an intensive green roof:
- wide choice of suitable vegetation
- total freedom of design
- easily combined with pedestrian and vehicle accessible areas
- build-up depth – starting from 217mm
- dead load – starting from approx. 282kg/m^2

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 eg. 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, published 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 to absorb the static and dynamic loads imposed during construction and final use.

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

The assumed permanent load of an intensive green roof at maximum water capacity:

Vegetation	Vegetation load kg/m²	ND DGS-I Growing Medium Intensive* depth mm/ load kg/m²	ND WSM-50 Water reservoir Panel depth mm/ load kg/m²	ND Drainage Composite depth mm/ load kg/m²	ND WSB-80 Root Barrier** load kg/m²	Surface load kg/m²***	Total depth mm***
Lawn	5	150/225 350/525	50/46	17/4.5	0.8	282 582	217 417
Low growing shrubs and bushes	10	150/225 500/750	50/46	17/4.5	0.8	287 812	217 567
Medium-sized shrubs and bushes up to 1.5m	20	200/300 500/750	50/46	17/4.5	0.8	372 822	267 567
Large-sized shrubs and bushes up to 3m	30	350/525 700/1,050	50/46	17/4.5	0.8	607 1,132	417 767
Large-sized bushes and small-sized trees up to 6m	40	600/900 1,250/1,875	50/46	17/4.5	0.8	992 1,962	667 1,317
Medium and large-sized trees up to 10m	60	1,000/1,500 2,000/3,000	50/46	17/4.5	0.8	1,612 3,112	1,067 2,067
Large-sized trees up to 15m	150	1,500/2,250 2,000/3,000	50/46	17/4.5	0.8	2,452 3,202	1,567 2,067

Table 1. Design loads

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

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

*** *when using ND 5+1/ND6+1 Drainage Composite, the total depth increases by 10 mm and the surface load with 2,5kg/m² (ND 5+1) or 4kg/m² (ND 6+1)*

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 upon the intended use of the roof deck:

Load class	Use	Traffic	Axle load	Wheel load
1	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 2. Load classification

The construction of elemental pavements over roof decks for the various load classes is described in the Nophadrain brochure "Design and Installation Guide Podium Roof Decks – Parking Roof Decks". The suitability of the Nophadrain Parking Deck Systems can be shown by extensive test reports in which the total build-up is subject to a dynamic performance test. These reports are available upon request.

1.3 Roof constructions

The structural deck needs to be able to carry the extra load of the intensive 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 intensive 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 intensive green roof. The cooling effect of an intensive 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 intensive 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 construction
- IRC = insulation placed above the waterproofing membrane – inverted roof 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 intensive green roofs built on an insulated roof, the thermal insulation should meet minimum load class "dh". The suitability of thermal insulation is to be demonstrated by the manufacturer.

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 3. Load classification thermal insulation

Suitability of the various types of thermal insulation:

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 4. 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"*

Recommendation
If an intensive green roof 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 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.

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 membrane beneath the intensive 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: 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

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 error/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 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.

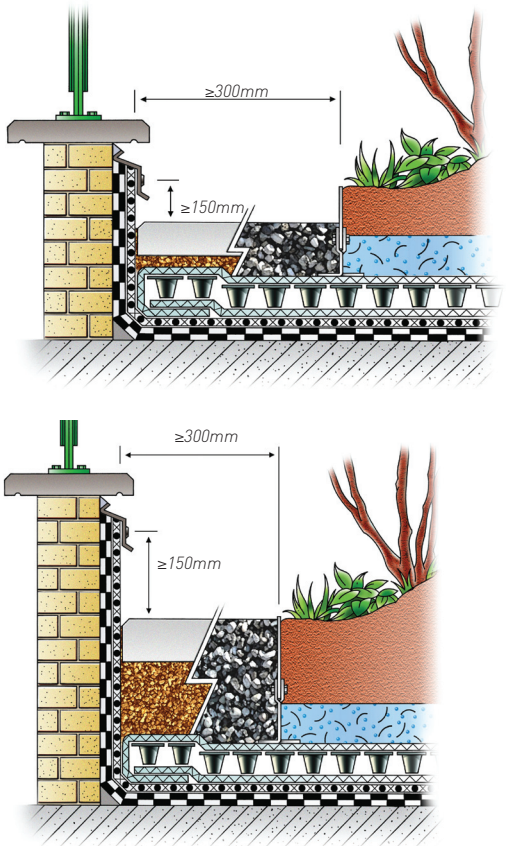
Roof edge

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.

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.

Products:

GreenLiner FSD Fixing Anchor
GreenLiner 100/4V Edge Retaining Profile
GreenLiner 150/4V Edge Retaining Profile
GreenLiner 200/4V Edge Retaining Profile



Detail 1. Parapet

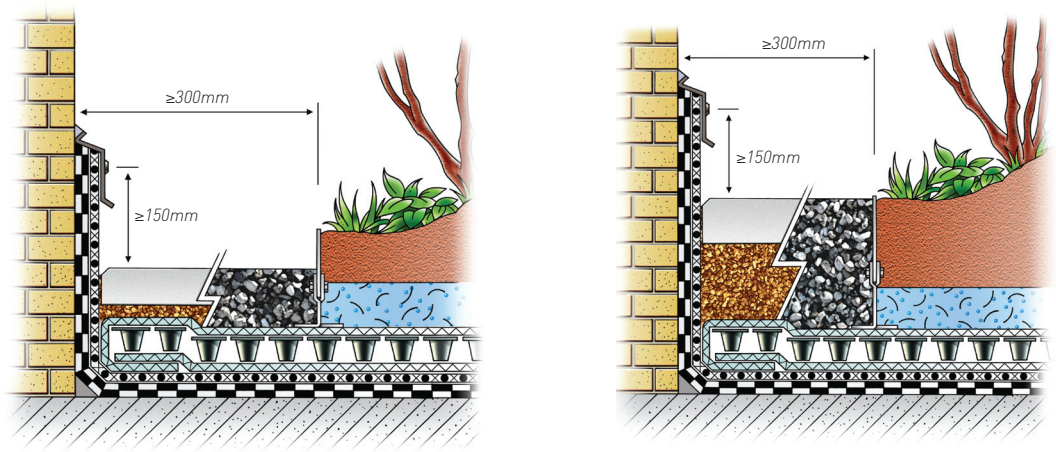
Facade

At facades, the waterproofing membrane should be brought up above the highest roof edge by a minimum of a 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 level by 50mm.

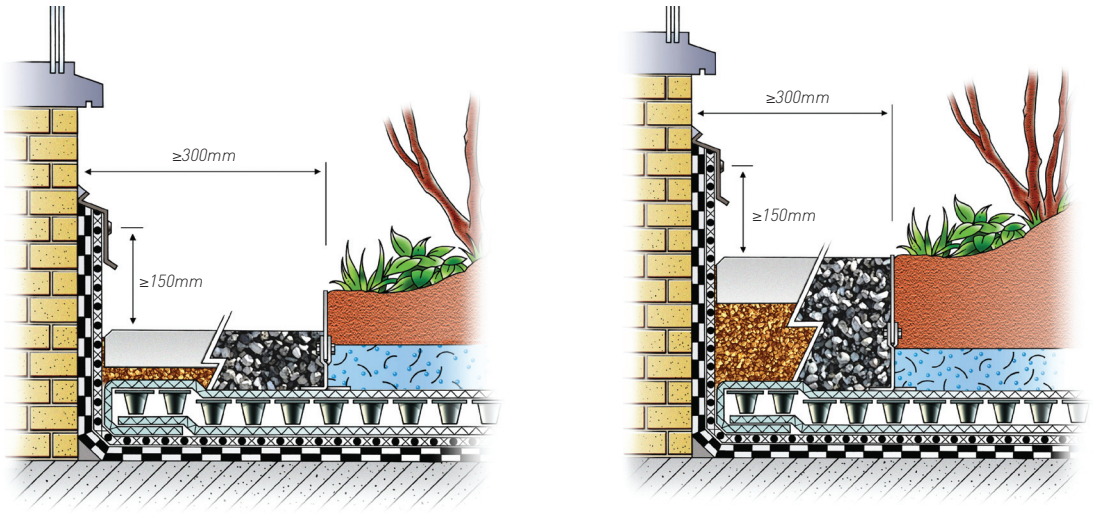
Along facades, a clear strip of clean gravel (min. 16-32mm) or concrete slabs should be installed for maintenance and inspection purposes, and to act as a splashguard. The clear strip between the facade and the vegetated area helps to prevent any water run-off adversely affecting the development of the 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.

Products:

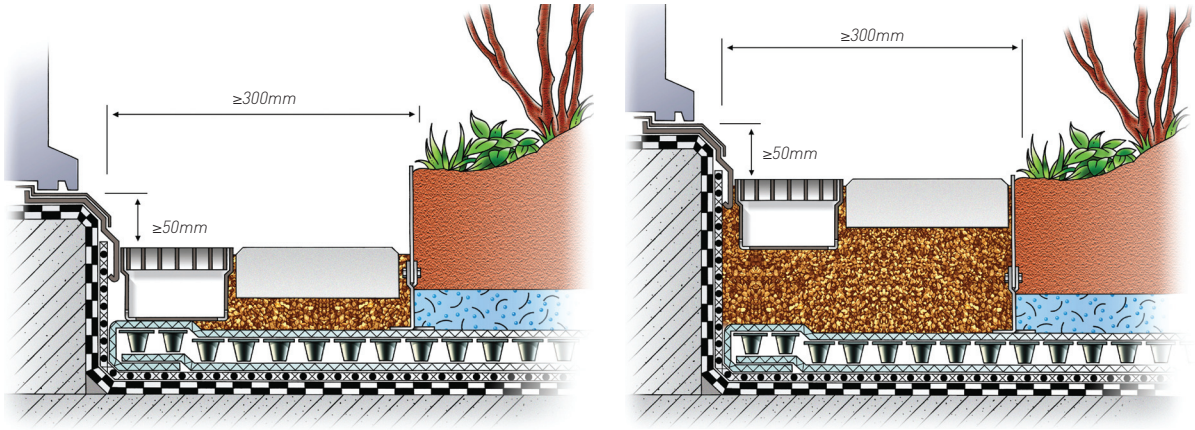
GreenLiner FSD Fixing Anchor
GreenLiner 100/4V Edge Retaining Profile
GreenLiner 150/4V Edge Retaining Profile
GreenLiner 200/4V Edge Retaining Profile



Detail 2. Facade



Detail 3. Facade with an opening



Detail 4. Door threshold

Roof protrusion with or without roof upstand

The roof upstand of e.g. roof lights, ventilation shafts and other roof protrusions must be higher than the roof edge or the emergency overflow. The waterproofing membrane must be brought up to a minimum of 150mm above service level.

Around roof protrusions with or without a roof upstand, a clear strip of clean gravel or concrete slabs should be installed for maintenance and inspection purposes. 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.

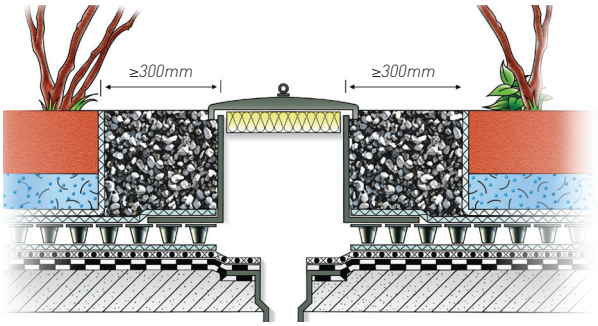
Products:
GreenLiner Fixing Anchor GreenLiner 100/4V Edge Retaining Profile GreenLiner 150/4V Edge Retaining Profile GreenLiner 200/4V Edge Retaining Profile

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.

A clear strip of clean gravel (min. 16-32mm) should be placed around the inspection chamber. The recommended width of this clear strip should be a minimum of 300mm. To prevent the growing medium being washed into the clear 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 the outlet.



Detail 5.Roof outlet

Products:
ND RS-VarioBasic Inspection Chamber ND RSA-10 Elevation Element ND RSA-20 Elevation Element ND GD-30 Grid ND RS-30 Inspection Chamber ND RS-50 Inspection Chamber

Width of clear strips (vegetation-free zones):

Detail	Clear strip e.g.: gravel (minimum 16/32)/concrete slabs	Recommended width
Roof outlet	Yes	≥300mm all around
Facade	Yes	≥300mm
Roof edge	Yes	≥300mm
Roof protrusion	Yes	≥300mm

Table 5. Width of clear strips

1.7 Design of falls – roof slope

For an intensive green roof, falls should ensure that no water is allowed to pond on the roof construction. The construction should be such that any accumulated water or ponding is prevented from coming 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 in to 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.

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 plants 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 of 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 falls 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.

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

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 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 in the event of the green roof area not be capable of absorbing all 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 (0.029l/(s.m^2) to 0.088l/(s.m^2)).

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

Run-off coefficients

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

Growing medium layer depth in mm	Roof slope ≤ 5° (~8.8%)	Roof slope >5° (~8.8%)
150-250	C = 0.3	–
250-500	C = 0.2	–
>500	C = 0.1	–

Table 7. Run-off coefficient

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

Guide figures for Category 1, 2 and 3 storm event:

Area	Rainfall intensity l/(s.m^2) category 1	Rainfall intensity l/(s.m^2) category 2	Rainfall intensity l/(s.m^2) 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 6. Category 1, 2 and 3 storm event

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:

Build-up depth mm	Type of vegetation	Annual average stormwater retention %	Annual run-off coefficient Ca
150-250	Lawn, shrubs, small sized bushes	60	0.40
250-500	Lawn, shrubs, bushes	70	0.30
>500	Lawn, shrubs, bushes, trees	>90	≤0.10

Table 8. Annual average stormwater retention capacity

At a higher (>800mm) or lower (<650mm) annual precipitation rate the annual average stormwater retention will be lower or higher as stated in table 8.

1.9 Fall protection

On flat roofs, all necessary safety measures required for use of the roof by the public, carrying out inspection and maintenance work should be considered at the planning 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 is not suitable for an intensive green roof as this type of green roof is designed to be accessible to the public.

1.10 Fire prevention

Properly maintained intensive green roofs are classified as "hard roofs" and as such, are regarded as resistant to flying sparks and radiating heat.

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 Design features

Some design features that could be included in an intensive green roof are:
- fences
- pergolas and arbours
- lamps and lighting
- ponds, rills, fountains and other water features
- benches, seating, tables, etc.

The installation and construction of design features often require object-specific detail solutions which are determined by considering their construction, the static and dynamic loads they may impose, and their physical properties.

The structural stability, weight distribution, and anchorage must be secure at all times. Stresses on the protection and drainage layers should be prevented at all times. During the design process, surface loads and stress points as well as wind stress should be considered.

1.14 Protection from calcium deposits

Carbonates released from the protection layers (i.e. cement or concrete floor screeds, plant borders, covers or design features) may cause damage to the roof drainage system.

Note
These layers should be densely formed or treated in such a way to minimise the amount of carbonate discharge. Alternatively one could choose for different materials such as metal or plastic e.g. GreenLiner Edge Retaining Profiles made out of plastic or metal.

1.15 Maintenance

It is recommended that a maintenance contract be drawn up between the owner and contractor involving a long-term care plan.

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 and the inspection chambers for the drainage/irrigation system
- inspection for impurities, deposits and root growth in the inspectionchambers
- stability of plant borders, surface fasteners and other components; to make sure they are in good condition to maintain the integrity of the green roof
- inspection of the waterproofing system on damages

2 THE BUILD-UP OF AN INTENSIVE GREEN ROOF

2.1 Build-up

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

The various layers need to be geared in such away 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
An intensive green roof system is a multi-layered construction comprising of a number of individual layers each with its own function. Within the construction, the growing medium is separated from the drainage layer by 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 horizontal 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

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 "Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of resistance to root penetration".

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-80 Root Barrier

The root barrier is a 0.8mm 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 200 m^2.

2.3 Separation and slip layer

The separation layer separates materials that are chemically incompatible (e.g. Polyvinyl Chloride (PVC) and Polystyrene (PS)). The separation layer can also act as a part of the slip layer. The ND Drainage Composites are available with pressure dividing slip film or separating geotextile to suit individual applications.

No forces are to be passed on to the waterproofing system by the overlying installed layers. Should such forces occur as a result of the intended use, a slip layer must be installed. A slip layer consists of two smooth surfaces installed over the waterproofing system. In the Nophadrain Green Roof Systems, the slip layer is formed by using the ND TSF-100 Slip and Protection Sheet and the ND Drainage Composites.

Products:

ND Drainage Composites
ND TSF-100 Slip and Protection Sheet

2.4 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. The protection layer can also fulfil the function of the separation layer and form part of the slip layer.

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

Recommendation
On roofs of load class 1. (podium roof decks), load class 2. and load class 3. (trafficked roof decks) where a levelling layer or sub-base is installed, or when wheeled loaders are used during installation of the growing medium on a green roof, 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.

Products:

ND Drainage Composites
ND TSF-100 Slip and Protection Sheet

2.5 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, BS EN 13252.

2.6 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 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 at 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).

2.7 Nophadrain ND Drainage Composites

ND Drainage Composites comprise the filter layer, the drainage layer, protection layer (lightweight static loads) and the separation and slip layer as one integrated unit. The build-up height of the ND Drainage Composite is 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/ND 600sv 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 over time is not affected.

Type ND Drainage Composite	ND 4+1 high	ND 5+1 ND 5+1lt	ND 6+1	ND 200 ND 220	ND 600 ND 620	ND 600s ND 600sv
Intensive green roof – falls ≥1 in 80	■	■	■	■	■	–
Intensive green roof – falls ≥1 in 80 (inverted roof)	■	■	■	–	–	■
Intensive green roof – falls <1 in 80	–	■	■	–	–	–
Intensive green roof – falls <1 in 80 (inverted roof – exception)	–	■	■	–	–	–
Intensive green 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 m^2 (Lr x Br)
C = run-off coefficient (see table 7)
r = rainfall intensity l/(s.m^2)
Lr = length of the roof to be drained m

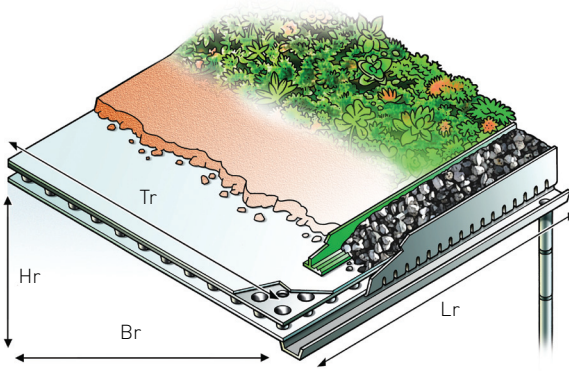


Figure 1. Roof dimensions
Lr = the length of roof to be drained
Br = the plan width of roof from gutter to ridge
Hr = the height of roof from gutter to ridge
Tr = the distance from gutter to ridge measured along the roof

2.8 Water reservoir layer

Intensive green roof planting generally has a large surface area that results in high levels of transpiration and there is, therefore, a high demand for water. A system of irrigation-on-demand is unlikely to be successful, because, by the time the need for water has been recognized (i.e. by the wilting of the plants), damage has already occurred. Water retained by the mineral and organic content of the growing medium is only partly accessible to the plants. In order to meet the plants' need for water, the depth of the growing medium layer needs to be increased, which thereby increases the loading on the deck structure.

An alternative strategy is to provide irrigation of the growing medium through moisture diffusion by the evaporation of stored water on the structural deck, or through the evaporation of water stored in plastic drainage composites (e.g. in the eggbox-shaped dimpled sheets). The disadvantage of relying on moisture diffusion is that the stored water is not in direct contact with the growing medium, and consequently water is not available on demand for the planting by means of capillary action.

By installing ND WSM-50 Water Reservoir Panels, up to 40 litres of water per square metre can be retained naturally, similar to the manner in which clay or sub-soils retain water. Water is transported by direct contact of the water reservoir panels with the growing medium. The growing medium itself will not become oversaturated because the retained water is restricted to the lower 40mm of the 50mm thick water reservoir panels and is only transported to the upper area by capillary action when needed.

Through direct contact of the water reservoir panels with the growing medium, the vegetation is able to regulate its own water balance, as nature intended. When the water reservoir panels become saturated, surplus water is discharged into the drainage layer. By using the ND WSM-50 Water Reservoir Panels there is no build-up of hydrostatic pressure against the waterproofing membrane.

Products:

ND WSM-50 Water Reservoir Panels

The ND WSM-50 Water Reservoir Panels are manufactured from hydrophilic mineral wool. Long-term stability is achieved due to the high density (120kg/m^3). The panels have a water retention capacity of 40l/m^2 at a build-up depth of only 50mm. Due to the limited amount of compressibility, the panels have been approved as a substrate substitute by the FLL Green Roof Guideline (2008).

2.9 Growing medium layer

The composition of the growing medium is important for the health and growth of the plants. It 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 as growing medium

The growing medium consisting of granular material contains a very low proportion of organic material (≤40g/l). The FLL Green Roof Guideline (2008) has defined the exact requirements of such a substrate. The organic content improves moisture retention and nutrient supply, thereby increasing the buffering action and simultaneously improving plant growth. The high mineral content prevents clogging of the drainage and the filter layer by small fine particles.

The depth of the growing medium varies between 150mm and 2,000mm, depending on the type of vegetation selected. When the growing medium layer exceeds a depth of approx. 350mm, it will be necessary to reduce the organic matter content. At depths greater than 500mm, a pure, mineral-based substrate should be installed beneath the growing medium layer. Because the substrate has little water retaining capacity due to the high mineral content, ND WSM-50 Water Reservoir Panels should be installed.

Topsoil

Even though topsoil is a much better growing medium for intensive planting schemes than a manufactured substrate, it is not often used because the high organic content causes reduced filter stability.

Over time, small organic fines will clog the drainage layer and the filter layer.

Research by Nophadrain shows that the use of topsoil in combination with the ND WSM-50 Water Reservoir Panels is possible. However, it is important that a soil analysis is undertaken to determine the suitability of the available topsoil. Based upon research, soil analyses and extensive testing, Nophadrain can advise if it is possible to use a particular topsoil with the Nophadrain Intensive Green Roof Systems.

The ND WSM-50 Water Reservoir Panels not only act as a 40l/m^2 water reservoir but also as an additional filter to prevent clogging of the drainage layer and filter layer.

The use of topsoil offers a considerable cost saving compared to an expensive substrate, which often has to be imported. Furthermore soil excavated on-site may be reused as a growing medium layer for an intensive green roof.

Foamed glass

Foamed glass makes it possible to create structurally stable banks and slopes on a roof with a minimum dead load. The specific weight of this material is only 150/350kg/m^3 (depending on the particle size and the method of compaction). The use of foamed glass offers landscape architects maximum flexibility in their designs.

Products:

ND DGS-I Growing Medium Intensive
ND DGS-M Growing Medium Mineral
ND Foamed Glass
ND WSM-50 Water Reservoir Panels

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
Lawn	150-350
Low-growing shrubs and bushes	150-500
Medium-sized shrubs and bushes up to 1.5m	200-500
Large-sized shrubs and bushes up to 3m	350-700
Large-sized bushes and small-sized trees up to 6m	600-1,250
Medium and large-sized trees up to 10m	1,000-2,000
Large-sized trees up to 15m	1,500-2,000

Table 10. Growing medium layer depth

Delivery

ND DGS-I Growing Medium Intensive/ND DGS-M Growing Medium Mineral:

- 20 litre sacks
- 1,000 litre bulk bags
- loose: delivered by tipper wagon - distributed by crane or con veyor 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. 20% (ND DGS-I)/15% (ND DGS-M) due to settlement.

2.10 Vegetation layer

An intensive green roof may include one or more of the following vegetation communities:

- lawn
- low-growing shrubs and bushes
- medium-sized shrubs and bushes up to 1.5m
- large-sized shrubs and bushes up to 3m
- large-sized bushes and small-sized trees up to 6m
- medium and large-sized trees up to 10m
- large-sized trees up to 15m

The structure and specification of the roof determine the most appropriate selection of plants. Careful planning taking in to account the structural, climatic and vegetation aspects determine the success of an intensive green roof. More information about choosing suitable plants can be found on the Nophadrain website www.nophadrain.com.

Trees and bushes are secured against heavy wind by cables anchored to a steel or plastic grid positioned beneath the growing medium layer.

3 INTENSIVE GREEN ROOFS COMBINED WITH HARD LANDSCAPING

Intensive green roofs can easily be combined with hard landscaping for pedestrian and vehicular traffic. The most suitable ND Drainage Composite to be used is determined by the imposed weight/ loads. The ND TSF-100 Slip and Protection Sheet protects the waterproofing membrane against the imposed loads.

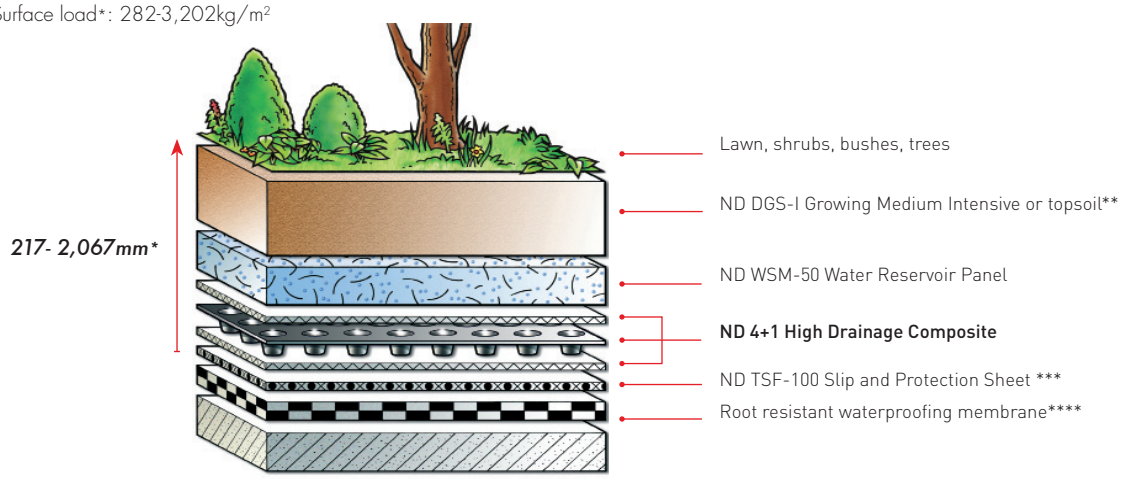
Flexible paving is placed on a bedding layer directly on top of the ND Drainage Composite. An additional sub-base should be installed beneath the bedding layer when larger loads are anticipated (e.g. trafficked areas) or when additional falls need to be created. For fuller details, please refer to the brochure "Design and installation guide – Podium Roof Decks Parking Roof Decks".

4 NOPHADRAIN INTENSIVE GREEN ROOF SYSTEMS

4.1 Roof with sufficient fall 1 in 80 to 5°

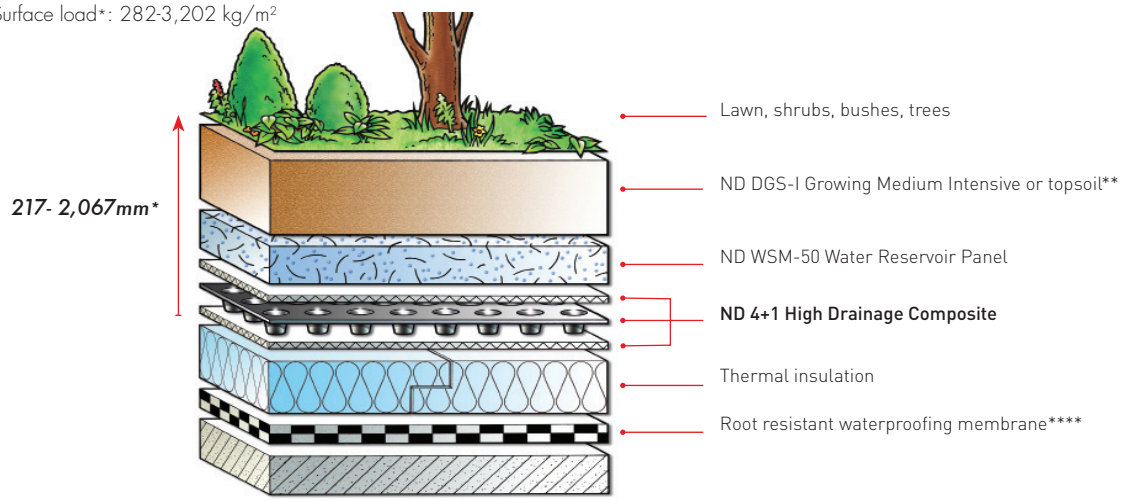
a. Warm roof construction/roof construction without thermal insulation

Surface load*: 282-3,202kg/m²



b. Inverted roof construction

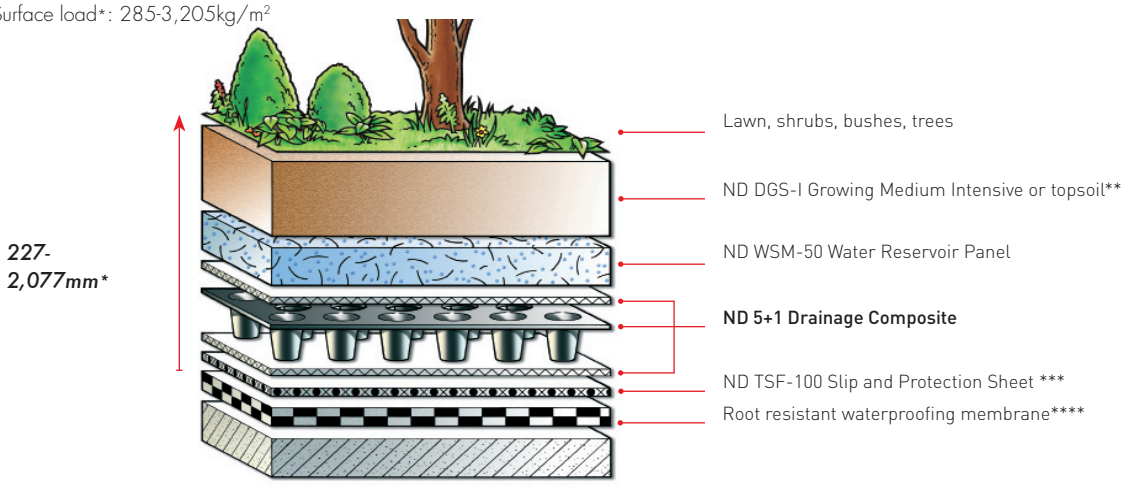
Surface load*: 282-3,202 kg/m²



4.2 Roof with insufficient fall <1 in 80

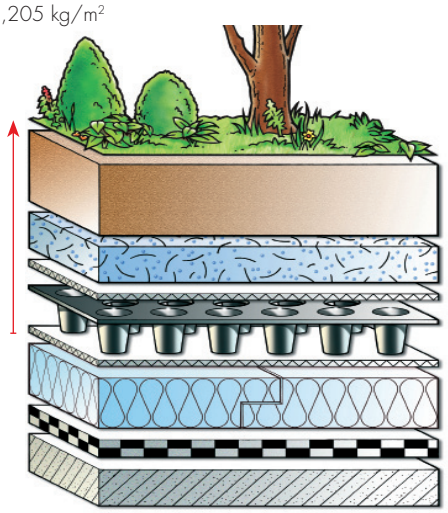
a. Warm roof construction/roof construction without thermal insulation

Surface load*: 285-3,205kg/m²



b. Inverted roof construction

Surface load*: 285-3,205 kg/m²



227-
2,077mm*

Lawn, shrubs, bushes, trees

ND DGS-I Growing Medium Intensive or topsoil**

ND WSM-50 Water Reservoir Panel

ND 5+1 Drainage Composite

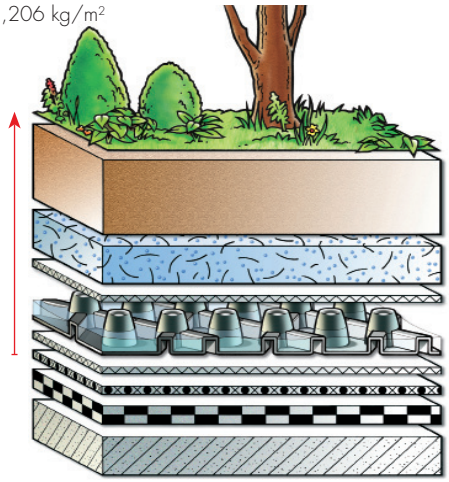
Thermal insulation

Root resistant waterproofing membrane****

4.3 Roof with additional water reservoir

a. Warm roof construction/roof construction without thermal insulation

Surface load*: 286-3,206 kg/m²



227-
2,077mm*

Lawn, shrubs, bushes, trees

ND DGS-I Growing Medium Intensive or topsoil**

ND WSM-50 Water Reservoir Panel

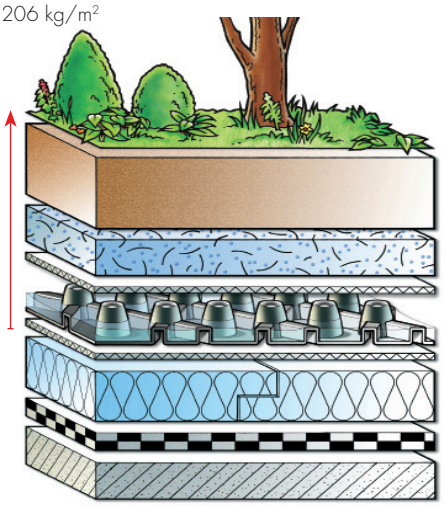
ND 6+1 Drainage Composite

ND TSF-100 Slip and Protection Sheet ***

Root resistant waterproofing membrane****

b. Inverted roof construction

Surface load*: 286-3,206 kg/m²



227-
2,077mm*

Lawn, shrubs, bushes, trees

ND DGS-I Growing Medium Intensive or topsoil**

ND WSM-50 Water Reservoir Panel

ND 6+1 Drainage Composite

Thermal insulation

Root resistant waterproofing membrane****

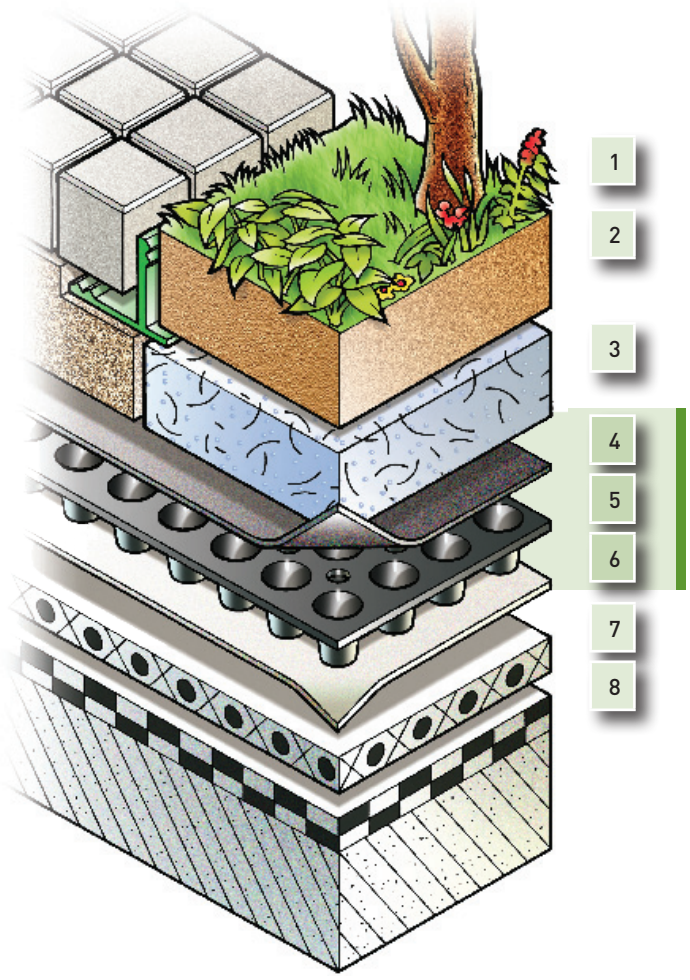
* *build-up depth and surface load depend on the type of vegetation; the values mentioned are typical values*

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

*** *optional as extra protection of the waterproofing membrane*

**** *optional ND WSB-80 Root Barrier*

BUILD-UP OF AN INTENSIVE GREEN ROOF



1	Vegetation layer	Intensive planting scheme: lawn, shrubs, bushes, trees
2	Growing medium layer	ND DGS-I Growing Medium Intensive/topsoil*
3	Water reservoir layer	ND WSM-50 Water Reservoir Panel
4	**Filter layer**	**ND 4+1 High Drainage Composite**
5	**Drainage layer**	
6	**Separation and protection layer**	
7	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 as extra protection of the waterproofing membrane*

*** *optional ND WSB-80 Root Barrier*

NOPHADRAIN®
GREEN ROOF INNOVATORS

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