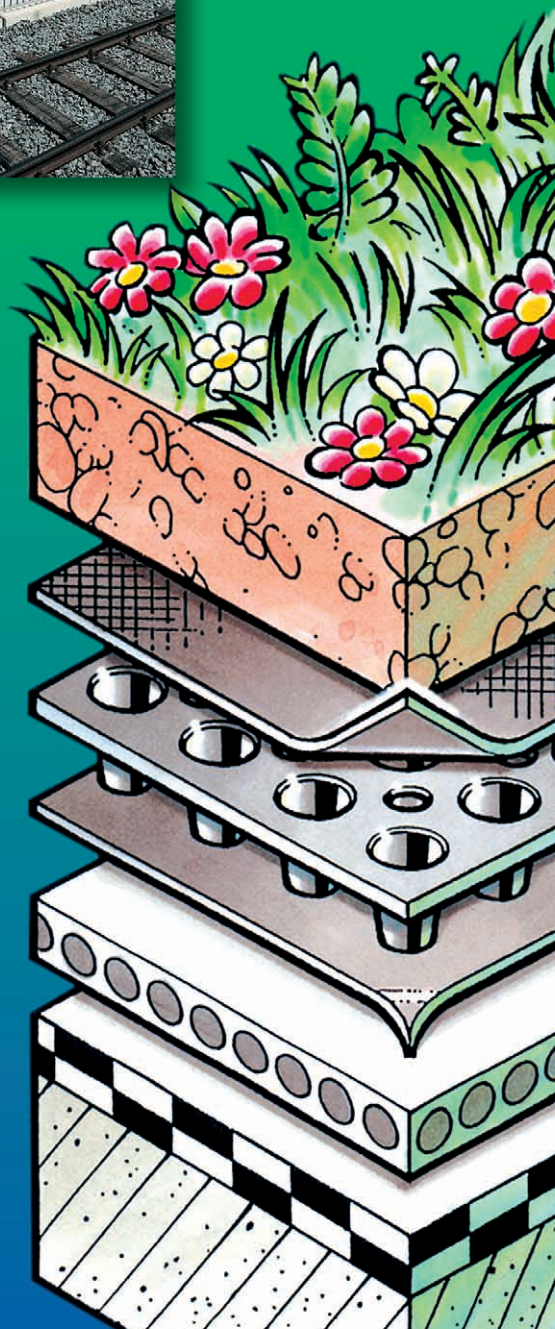


# Extensive green roofs



Maximise the open space!

Design and installation manual





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## 0. General

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 observed.

Compared to intensive green roofs, the range of potential uses along with the diversity of design and planting schemes are restricted. The plants selected require minimal moisture and demand little from the growing medium in the way of nutrients. In general, irrigation systems are not necessary 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 that are used make comparatively modest demands on the layer configuration, the overall weight, the build-up depth, and the loading of the extensive green roof are relatively small.

### Features of an extensive green roof:

- ◆ Limited plant selection and design possibilities
- ◆ Low maintenance - normally not more than two inspections per year
- ◆ Shallow build-up depth - starting from 71mm
- ◆ Minimal dead load - starting from approx. 50kg/m<sup>2</sup> including plants
- ◆ Economical to install and maintain

### The build-up of an extensive green roof comprises the following layers that are considered in subsequent sections:

- ◆ 1.1 Vegetation layer
- ◆ 1.2 Growing medium layer
- ◆ 1.3 Filter layer
- ◆ 1.4 Drainage layer
- ◆ 1.5 Separation and protection layer
- ◆ 1.6 Root barrier layer

Each layer has a specific function, although certain Nophadrain<sup>®</sup> products integrate the functions of several layers into one product.

### 0.1 Standard build-up - Multi-layer system

This type of system comprises a number of individual layers each with its own function. The growing medium layer is separated from the drainage layer by means of a filter fabric, which prevents finer particles from the growing medium entering the drainage layer. This filtration ensures that a fully functional horizontal 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 long-term healthy appearance of planting
- ◆ Excellent long-term horizontal 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

### 0.2 Non-standard build-up - Single-layer system

In a Single-layer system, 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 60mm. Since there is no separate filter layer in this system, the substrate must not contain any 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. The strips are laid flat, in parallel rows at approximately 2 metre intervals on top of the protection layer. The strips are linked into an inspection chamber that is placed on top of a roof outlet.

## 1. The build-up of an extensive green roof

### 1.1 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.nl](http://www.nophadrain.nl).

**The vegetation is supplied in the following formats:**

- ◆ Sedum cuttings
- ◆ Plug plants
- ◆ Vegetation mats

#### 1.1.1 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 they after scattering 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 100% mineral based material, the Sedum cuttings will need to be mulched with compost (approx. 10l/m<sup>2</sup>). 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 SM50 or ND SM25 Substrate Panels, the Sedum cuttings must be mulched with approx. 10mm of ND DGS-M Growing Medium Mineral.

### 1.1.2 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 50cc.

#### 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 acts also 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.

#### 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 SM50 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.

### 1.1.3 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.

#### Recommended amounts:

- ◆ Plug plants:  $\geq 16$  plants/m<sup>2</sup>
- ◆ Sedum cuttings:  $\geq 60$ g/m<sup>2</sup> a minimum of 100 Sedum cuttings/m<sup>2</sup> of at least 4 different types
- ◆ Vegetation mats: surface area + 2.5%

## 1.2 Growing medium layer

### 1.2.1 Using granular material as growing medium

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.

Consequently, the growing medium should contain a high proportion of mineral materials (92-94% by mass) and a low proportion (6-8% by mass) of organic material. The German FLL Directive for the planning, development and maintenance of green roofs 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 that is 100% mineral based.

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

Mosses and Sedum	60 - 80mm
Sedum, mosses and herbaceous plants	> 60 - 100mm
Sedum, herbaceous plants and grasses	> 100 - 150mm
Grasses and herbaceous plants	> 150 - 200mm

Table 1. 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

**Products:**

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

The Nophadrain® ND DGS Growing Media comply with the FLL Directive for the planning, development and maintenance of green roofs.

**Delivery:**

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

- ◆ 50 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.

**1.2.2 Using substrate panels as growing medium**

For extensive green roofs, the growing medium can be replaced by ND SM25 or by ND SM50 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.

The 100% mineral content and high density give these substrate panels a high degree of durability along with structural stability. They also have a high water-retention capacity that enables them to be used to grow taller herbaceous plants and grasses.

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. A 50mm substrate panel in combination with vegetation mats has a total weight of approximately 50kg/m<sup>2</sup>.

When used on pitched roofs, substrate panels have the advantage of eliminating any substrate slippage. Roofs with a slope greater than 20° (~36,4%) require cross battens to prevent slippage of the green roof system.

**Advantages:**

- ◆ Quick and easy installation
- ◆ Low weight
- ◆ High water retention

**Products:**

- ND SM25 Substrate Panels**
- ND SM50 Substrate Panels**
- ND PLS-Profi Plug Cutter**
- ND PS Template**

Nophadrain ND SM Substrate Panels can be used as green roof substrates and have been approved by the FLL Directive as an acceptable substrate substitute. The panels are structurally stable and have a water-retaining capacity of 30l/m<sup>2</sup> at a thickness of 50mm.

**Delivery:**

- ◆ ND SM25 Substrate Panels: set of 10 panels, 600 x 1,000 x 25mm (W x L x H) = 6m<sup>2</sup>
- ◆ ND SM50 Substrate Panels: set of 5 panels, 600 x 1,000 x 50mm (W x L x H) = 3m<sup>2</sup>
- ◆ ND PLS-Profi Plug Cutter: each
- ◆ ND PS Template: each

### 1.3 Filter layer - Nophadrain<sup>®</sup> ND Drainage Composite

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<sup>2</sup>, depending on load, and the pore size should correspond to the minimum particle size of the growing medium. In general, the geotextile should be CE marked and have a puncture strength of 0.5kN and a pore opening size of <200μ (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. At the edges of roof details, the filter fabrics should be brought up to the surface of the vegetation-free zone or "clear strip" in order to prevent fine particles being washed in to the drainage layer (see section 7. for fuller details).

### 1.4 Drainage layer - Nophadrain<sup>®</sup> ND Drainage Composite

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. The drainage capacity should be specified in l/(s·m) taking into account the roof gradient and the expected load pressure. A drainage composite as well as a geospacer, being part of a drainage layer should be CE marked.

### 1.5 Separation and protection layer - Nophadrain<sup>®</sup> ND Drainage Composite

The protection layer guards both the waterproofing membrane and the root barrier against mechanical damage. This layer can be a separate layer with a minimum weight of 300g/m<sup>2</sup>. When using a separate protection layer, this should be a protective membrane, a rubber mat, or a geotextile, and should be designed to suit the conditions to which the waterproofing membrane/root barrier will be subjected.

The protection layer also has the function of separating materials that are chemically incompatible (e.g. Polyvinyl Chloride (PVC) and Polystyrene (PS)).

If ND Drainage Composites are placed immediately following installation of the waterproofing membrane/root barrier layer, they can act as a protection layer for lightweight static loads such as an extensive green roof.

#### Nophadrain<sup>®</sup> ND Drainage Composites - sections 1.3 + 1.4 + 1.5

Nophadrain<sup>®</sup> ND Drainage Composites comprise the filter layer, the drainage layer, and the separation and protection layer as one integrated unit. The core of the ND Drainage Composite is a 11-25mm thick dimpled plastic sheet of high impact polystyrene (HIPS) with a filter fabric (woven or non-woven) bonded to each dimple. Depending on the application, the core may be perforated and provided with a plastic film or a geotextile on the back. The dimples of the ND 4+1/ND 5+1 Drainage Composite act as an additional water reservoir for the vegetation.

#### Products:

**ND 200 Drainage Composite**  
**ND 4+1 Drainage Composite**  
**ND 5+1 Drainage Composite**

#### Delivery:

- ◆ ND 200 Drainage Composite: roll, 1.25 x 32m = 40m<sup>2</sup> (W x L), dimple height approx. 11mm
- ◆ ND 4+1 Drainage Composite: roll, 1.25 x 32m = 40m<sup>2</sup> (W x L), dimple height approx. 11mm
- ◆ ND 5+1 Drainage Composite: roll, 1.25 x 20m = 25m<sup>2</sup> (W x L), dimple height approx. 25mm

### 1.6 Root barrier layer

The root barrier protects the waterproofing membrane from the ingress of roots growing through and is placed directly on top of the waterproofing membrane. Overlaps are heat-welded together 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 (e.g. PVC, EPDM or bitumen-copper waterproofing membranes certified by the FLL as being root resistant).

For the installation of a root barrier the same detail principles apply as for the installation of a waterproofing membrane.

At all roof upstand details the waterproofing and the root barrier should be extended above surface level by at least 150mm.

**Note**

On inverted roof systems lacking a root-resistant waterproofing membrane, the root barrier is positioned directly beneath the thermal insulation and on top of the waterproofing membrane.

**Product:**  
**ND WSB50 Root Barrier**

The root barrier is a 0.5mm modified LDPE membrane. Quick and easy installation is guaranteed by use of large sheets of up to 200m<sup>2</sup>.

**Delivery:**

- ◆ ND WSB50 Root Barrier: roll, 25 x 6m = 150m<sup>2</sup> (L x W)
- ◆ ND WSB50 Root Barrier: roll, 25 x 8m = 200m<sup>2</sup> (L x W)

## 2. Roof constructions

### 2.1 Cold roof

On a cold roof the thermal insulation is usually placed below the structural deck. A ventilated air space between the structural deck and the ceiling allows any moist air to escape. 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. In principle, all types of green roofs and all forms of vegetation are possible with this type of roof construction.

### 2.2 Roof without thermal insulation

Basically, on roofs without thermal insulation, all types of green roof systems and all forms of vegetation are possible. Freezing temperatures on the underside of the structural deck may result in frost damage to the vegetation.

### 2.3 Warm roof

The thermal insulation in this type of roof construction lies directly on top of the structural deck beneath the waterproofing membrane. Ensure that there are no voids where moisture could accumulate. In general, all types of green roof systems and all forms of vegetation are possible with this type of roof construction.

### 2.4 Inverted roof

With an inverted roof construction the insulation is laid on top of the waterproofing membrane. Should an inverted roof be selected for greening, moisture diffusion measures should be observed. A filter layer and a drainage layer must be installed over the thermal insulation in order to protect the insulation from accumulated moisture. In general, all types of green roof systems and all forms of vegetation are possible with this type of roof provided there is sufficient dead load to prevent uplift due to water and wind.

#### Nophadrain® ND Drainage Composites for inverted roof constructions

The ND 4+1/ND 5+1 Drainage Composites have a perforated core and allow moisture diffusion to take place. The use of these drainage composites will not create a vapour barrier that could cause the thermal insulation to lose R value. Consequently it is not necessary to increase the thickness of the thermal insulation when an extensive green roof is installed.

## 3. 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 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.

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 plants cannot be guaranteed in such circumstances.

By using ND 5+1 Drainage Composites with a dimple height of 25mm, direct contact of standing water and the growing medium can be avoided.

Roofs with a fall ratio of 1 in 20 or more ( $\geq 5\%$ ) 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.

When a green roof is installed on a roof with a slope angle of  $>20^\circ$  ( $\sim 36,4\%$ ), appropriate anchorage measures must be undertaken to avoid slippage of the completed green roof.

## 4. Design loads

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

Vegetation	Vegetation load kg/m <sup>2</sup>	ND DGS-E Growing Medium Extensive* depth mm/ load kg/m <sup>2</sup>	ND Drainage Composite depth mm/ load kg/m <sup>2</sup>	ND WSB50 Root Barrier load kg/m <sup>2</sup>	Surface load kg/m <sup>2</sup>	Total depth mm**
Mosses and Sedum	10	60/90 80/120	11/3.0	0.5	104 134	71 91
Sedum, mosses and herbaceous plants	10	60/90 100/150	11/3.0	0.5	104 164	71 111
Sedum, herbaceous plants and grasses	10	100/150 150/225	11/3.0	0.5	164 239	111 161
Grasses and herbaceous plants	10	150/225 200/300	11/3.0	0.5	239 314	161 211

\* Weight approx. 1.5tonne/m<sup>3</sup> at maximum water capacity

\*\* When using ND 5+1 Drainage Composite, the total depth increases by 14mm and the surface load with 4kg/m<sup>2</sup>

Table 2. Design loads

When the granular growing medium is substituted by ND SM50 Substrate Panels in combination with vegetation mats the design load can be reduced to approx. 50kg/m<sup>2</sup> with a system depth of approx. 75mm.

## 5. Design for storm conditions

### 5.1 Roof drainage

EN 12056-3:2000, the European roof drainage standard, provides for a runoff coefficient to allow for absorbent roofing surfaces if 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 runoff 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 12056-3:2000 Category 1 storm event for design purposes. This storm event will occur on average once every 1 year in the United Kingdom, and will generate rainfall intensities which vary from 0.01l/(s·m<sup>2</sup>) to 0.022l/(s·m<sup>2</sup>) 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.

It is assumed by using this method 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 12056-3:2000 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 absorbing all the storm water. 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·m²) to 0.088 l/(s·m²)).

For further guidance on rainfall intensity in the United Kingdom see National Annex NB of BS EN 12056-3:2000.

Guide figures for Category 1 storm event

Area	Rainfall intensity l/(s·m²)
England	0.022
Scotland, Wales, and Northern Ireland	0.016
Northern Scotland, Shetlands and Orkneys	0.010

Table 3. Category 1 storm event

5.2 Drainage layer

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:

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

q' = required amount of water to be discharged by the drainage layer l/(s·m)

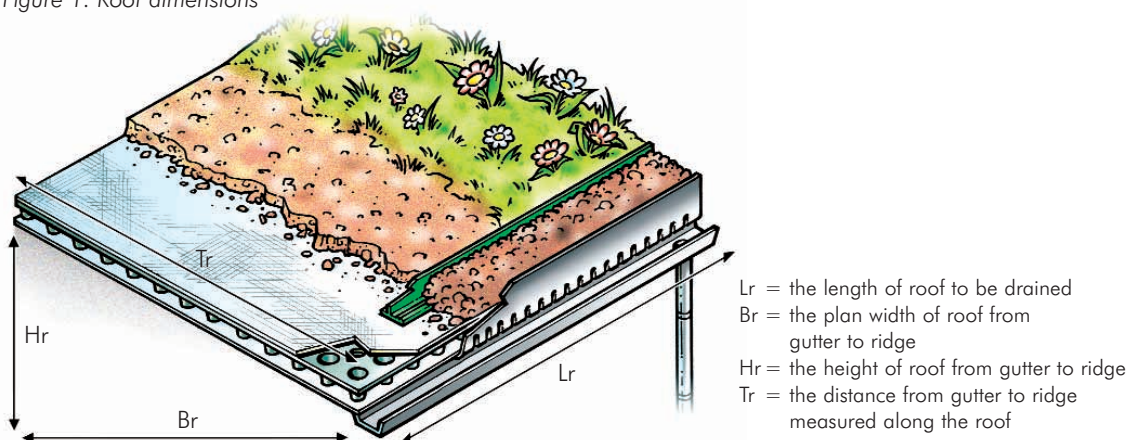
A = effective roof area m² (Lr x Br)

C = runoff coefficient

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  
 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

For extensive green roofs, the following runoff coefficients (C) can be used. The values depend on the depth of the growing medium and the roof slope:

Single-layer system:

Growing medium layer depth in mm	Roof slope ≤ 15° (~26.8%)
≥ 80	C = 0.3

Multi-layer system:

Growing medium layer depth in mm	Roof slope ≤ 15° (~26.8%)	Roof slope > 15° (~26.8%)
60	C = 0.6	C = 0.7
> 60 -100	C = 0.5	C = 0.6
> 100 -150	C = 0.4	C = 0.5
> 150 -200	C = 0.3	-

Table 4. Runoff coefficient

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

## 6. Annual storm water retention capacity

The annual average percentage of storm water 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 runoff coefficient  $C_o$ . The annual storm water 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 storm water retention and the runoff 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 storm water retention %	Annual runoff coefficient $C_o$
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 5. Annual storm water retention capacity

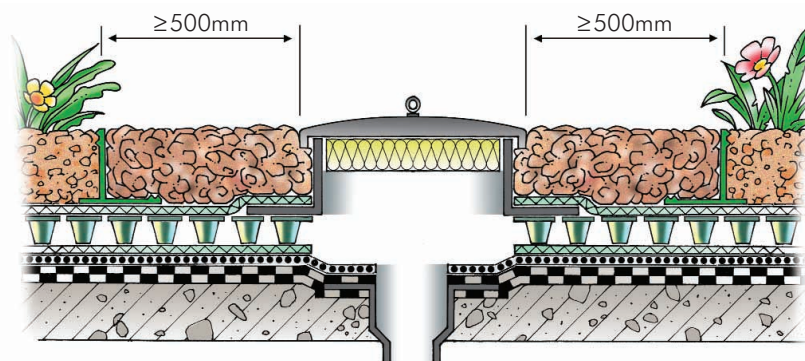
At a higher (>800mm) or lower (<650mm) annual precipitation rate the annual average storm water retention will be lower or higher as stated in table 4.

## 7. Details

### 7.1 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 A - roof outlet



A clear strip of clean gravel (min. 16-32mm) should be placed around the inspection chamber. The width of this strip should be not less than 300mm; clear strips 500mm offer an enhanced degree of fire safety. To prevent growing medium being washed into the gravel strip, a ND GreenLiner® Separation Profile should be installed or a filter fabric should be placed in between and brought up to the surface of the growing medium.

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.

**Product:**  
**ND RS8 Inspection Chamber**  
**ND GreenLiner® 45 Separation Profile**

**Delivery:**

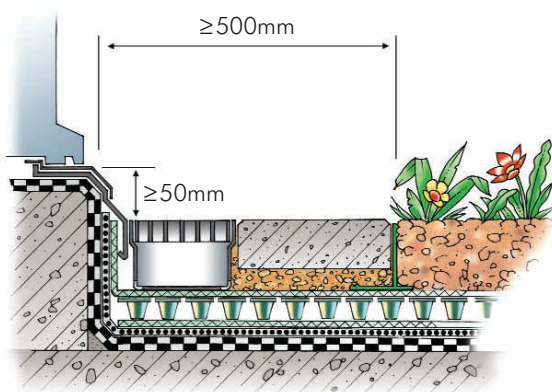
- ◆ ND RS8 Inspection Chamber: each, 300 x 300 x 80mm (L x W x H)
- ◆ ND GreenLiner® 45 Separation Profile: set of 10 pieces each, 2,500 x 90 x 45mm (L x W x H).

## 7.2 Roof upstand

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

At door thresholds where a channel drain is installed, the waterproofing membrane and root barrier can be brought up above the surface of the clear strip by 50mm.

Detail B - door threshold



### Products

ND FR81 Channel Drain  
 ND FR82 Channel Drain  
 ND TR80 Telescopic Channel

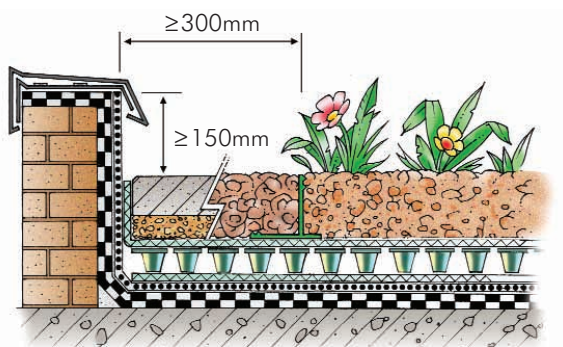
### Delivery:

- ◆ ND FR81 Channel Drain: each, 1,000 x 120 x 80mm (L x W x H)
- ◆ ND FR82 Channel Drain: each, 2,000 x 120 x 80mm (L x W x H)
- ◆ ND TR80 Telescopic Channel: each, 1,000 x 120 x 80mm (L x W x H).

## 7.3 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 ND GreenLiner® Separation Profile should be installed or a filter fabric should be placed in between and brought up to the surface of the growing medium.

Detail C - parapet

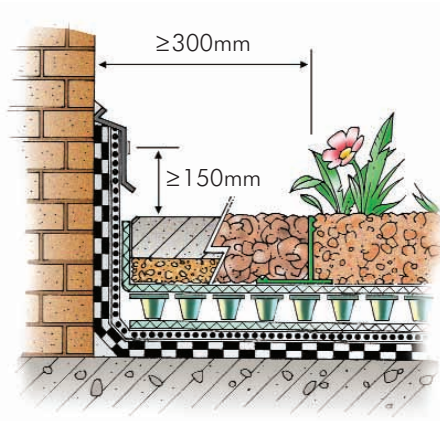


## 7.4 Facade

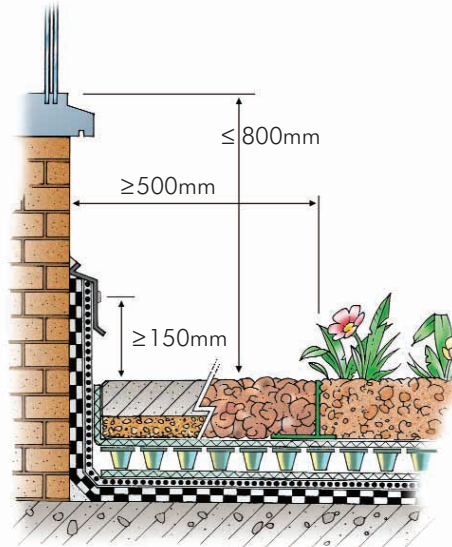
Along facades, a clear strip of clean gravel (min. 16-32mm) or concrete slabs should be installed for maintenance and inspection purposes, and to act as a splashguard. The clear strip between the facade and the vegetated area helps prevent any water runoff adversely affecting the development of the plants.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

At facades with an opening (e.g. window, door, etc.) at  $\leq 800\text{mm}$  above the surface level, a clear strip with width of  $\geq 500\text{mm}$  is preferred for enhanced fire safety reasons.

Detail D - facade



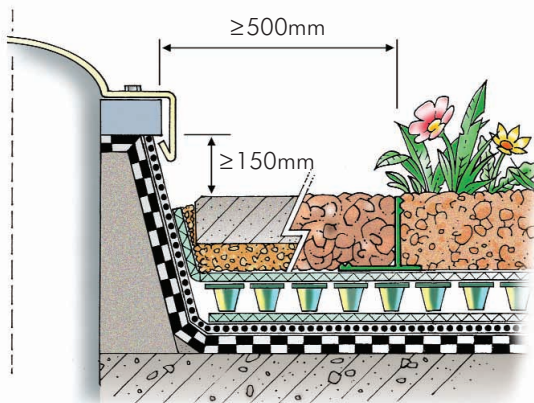
Detail E - facade with an opening at  $\leq 800\text{mm}$



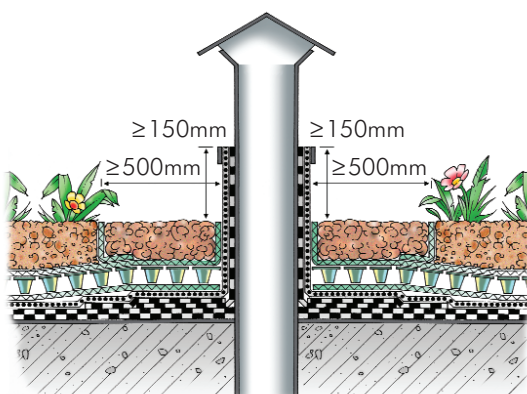
## 7.5 Roof protrusion

Again, 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.

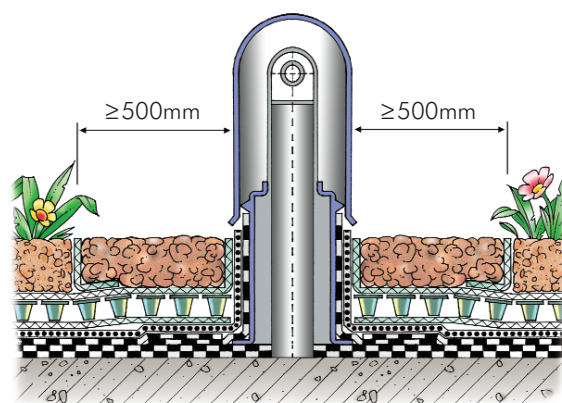
Detail F - roof light upstand



Detail G - cold vent pipe



Detail H - anchor point



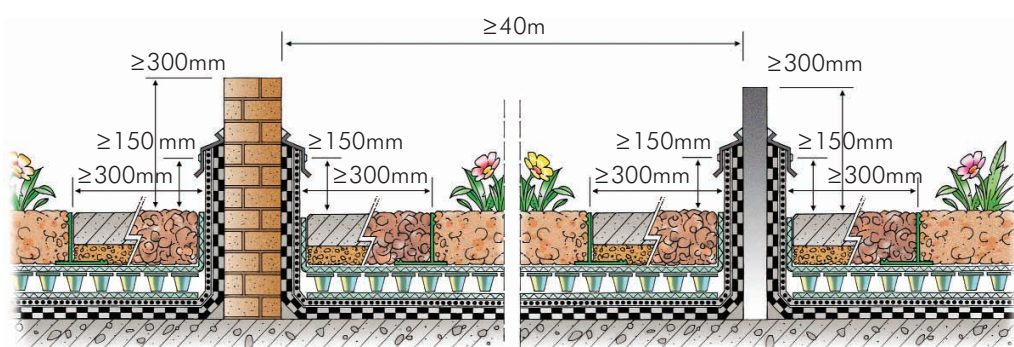
## 8. Fire prevention

### 8.1 Enhancing fire safety

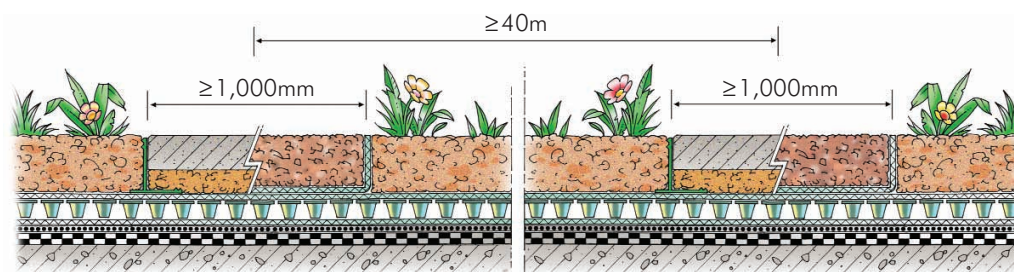
Green roofs with an extensive planting scheme are regarded as fire-resistant to radiant heat or flying sparks if:

- ◆ 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 1,000mm 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

Detail I - fire-wall



Detail J - fire strip



### 8.2 Width of clear strips (vegetation-free zones)

Detail	Clear strip e.g.: gravel (min. 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 6. Width of clear strips

## 9. 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.

## 10. 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, gasses 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.

## 11. Fall protection

On flat roofs, all necessary safety measures for carrying out inspection and maintenance work should be considered at the planning stages. Full compliance with BS EN 795 is essential.

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.

The following safety measures can be included during construction, depending on suitability:

- ◆ Integral sleeve-jointed tubular-section edge railings fitted to all free roof and deck edges as fall protection measures. Also, measures to enable secure fixing of capping beams, edge cables and/or safety nets
- ◆ Fixed anchor points for safety cables within the build-up layers or within the supporting structure
- ◆ Tensioning cables conforming to requirements, for a safety cable system

## 12. Maintenance

It is recommended that a maintenance contract and a long-term care plan be 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 also be considered:

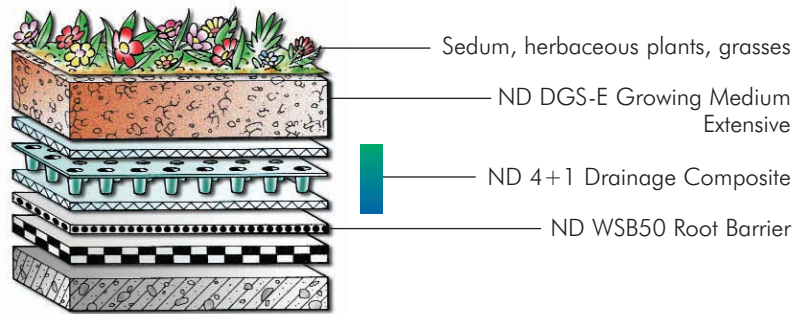
- ◆ Functionality of the drainage system
- ◆ Inspection for impurities, deposits and root growth in the inspection chambers

**13. Examples of green roof build-up for various roof constructions**

**13.1 Multi-layer system**

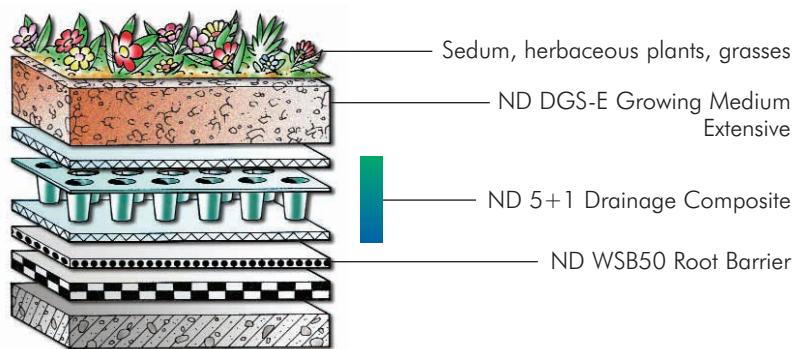
**13.1.1 Standard build-up**

Fall:  $\geq 1$  in 80  
 Build-up depth\*: 71-211mm  
 Surface load\*: 104-314kg/m<sup>2</sup>



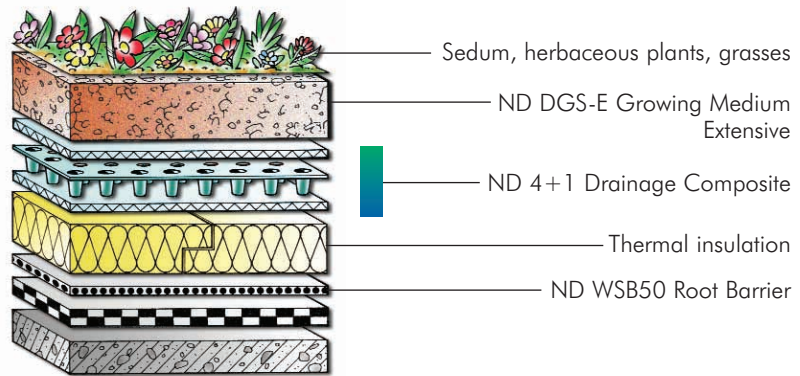
**13.1.2 Roof with insufficient fall**

Fall:  $\geq 1$  in 80  
 Build-up depth\*: 85-225mm  
 Surface load\*: 108-318kg/m<sup>2</sup>



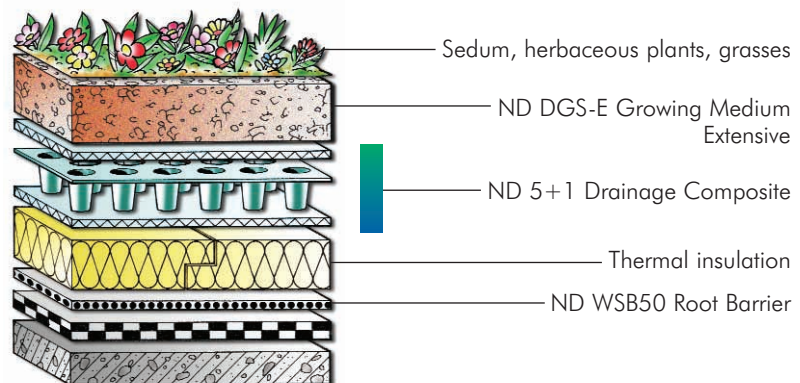
**13.1.3 Inverted roof**

Fall:  $\geq 1$  in 80  
 Build-up depth\*: 71-211mm (excluding thermal insulation)  
 Surface load\*: 104-314kg/m<sup>2</sup> (excluding thermal insulation)



**13.1.4 Inverted roof with insufficient fall**

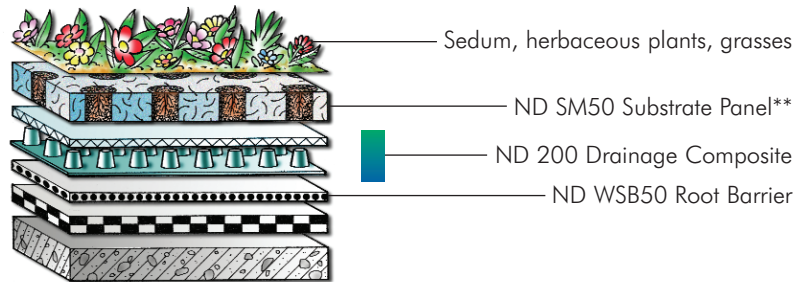
Fall:  $< 1$  in 80  
 Build-up depth\*: 85-225mm (excluding thermal insulation)  
 Surface load\*: 108-318kg/m<sup>2</sup> (excluding thermal insulation)



\*Build-up depth and surface load depend on the type of vegetation. The values quoted are typical values.

### 13.1.5 Lightweight roof construction

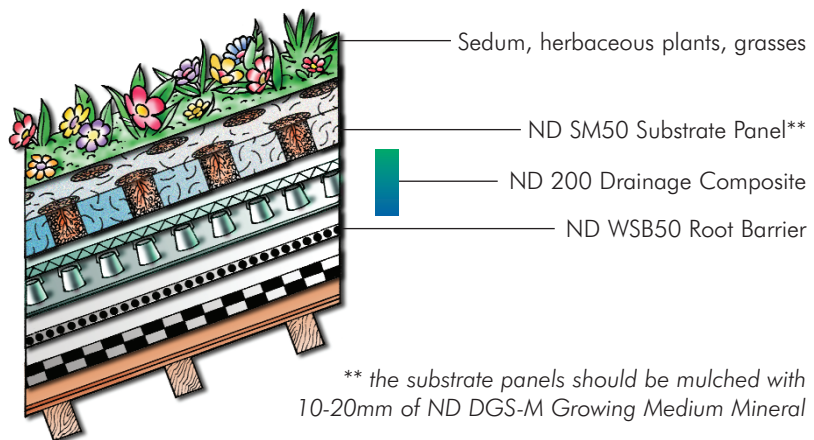
Fall:  $\geq 1$  in 80  
 Build-up depth\*: 80mm  
 Surface load\*: 50kg/m<sup>2</sup>



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

### 13.1.6 Pitched roof

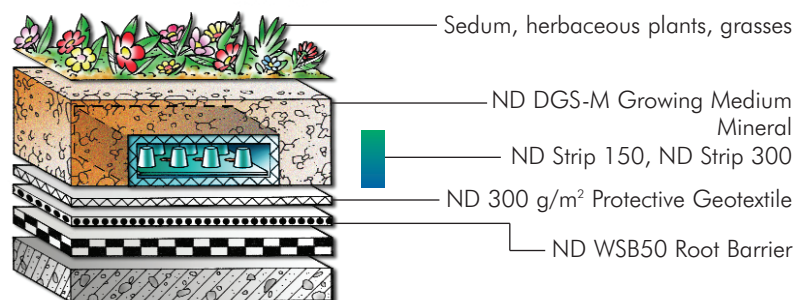
Pitch:  $> 15^\circ$  (~26,8%)  
 Build-up depth\*: 80mm  
 Surface load\*: 50kg/m<sup>2</sup>



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

### 13.2 Single-layer system

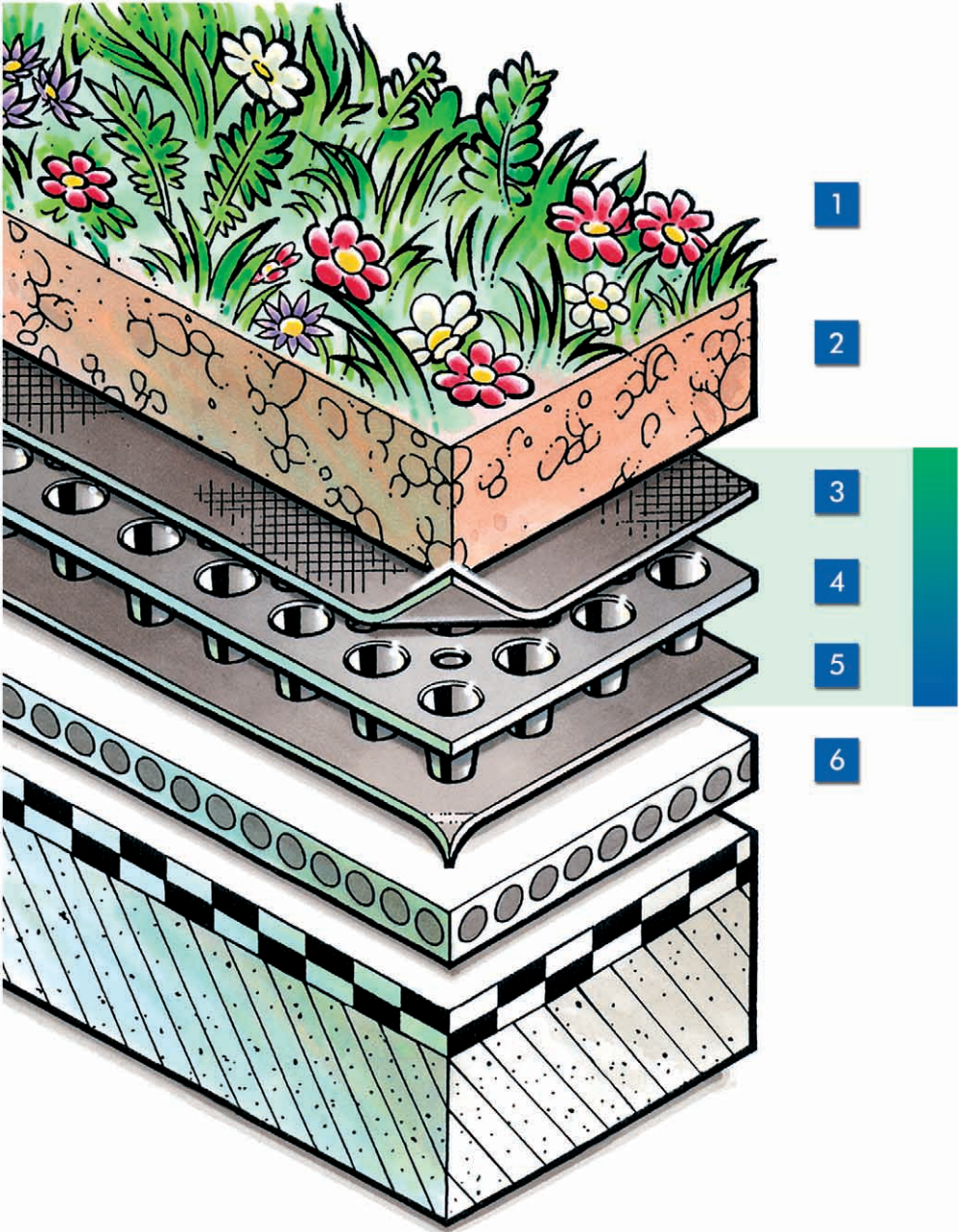
Fall:  $\leq 1$  in 50  
 Build-up depth\*: 60-200mm  
 Surface load\*: 90-300kg/m<sup>2</sup>



\*Build-up depth and surface load depend on the type of vegetation. The values quoted are typical values.

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**Standard build-up of an extensive green roof**



- 1
1. Vegetation layer
- Extensive planting scheme: Sedum, herbaceous plants, grasses
- 2
2. Growing medium layer
- ND DGS-E Growing Medium Extensive
- 3
3. Filter layer
- 4
4. Drainage layer
- ND 4+1 Drainage Composite
- 5
5. Separation and protection layer
- 6
6. Root barrier layer
- ND WSB50 Root Barrier





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