The GRO Green Roof Code

Green Roof Code of Best Practice for the UK 2014

The Green Roof Organisation was established in 2008 in response to the demand for UK relevant guidance for the increasing number of green roofs being specified in the UK. In 2009 work began on the predecessor of this document, The GRO Green Roof Code of Best Practice for the UK 2011.

Significantly based on the German FLL guidelines, adapted to suit the UK market, the original GRO Code has gained widespread acceptance in the construction market, being used as a reference document by standards bodies, specifiers, manufacturers and contractors alike.

This update, the 2014 edition, is a development of the original GRO Code and addresses requests for further clarifications, more detailed installation information and changes within the industry. A collaborative production that has brought manufacturers, trade associations, non-profit organisations, Government Organisation's and independent experts together the Code is truly reflective of the green roof industry today.

That said, the green roof industry is constantly evolving, and work now begins on the next update of The GRO Green Roof Code of Best Practice for the UK. This will take into account the soon to be published European Codes from Austria and Switzerland, together with UK based research and developments to ensure The GRO Green Roof Code continues to provide information on Best Practice for the UK.

All that remains is to thank all those who helped create the original Code, those who use the Code as the defacto point of reference, those that have collaborated on this project, and of course those who will contribute to task of creating the next update.

Mark Harris
GRO Chairman

Notes for users of this Code

The information contained in this document may be freely used by any interested parties.

The Green Roof Organisation (GRO) operates as a body facilitated by the National Federation of Roofing Contractors (NFRC) and is supported financially by the NFRC, Liquid Waterproofing & Roofing Association (LRWA), Single Ply Roofing Association (SPRA) and its membership

The GRO Code is the result of unpaid technical cooperation across the UK green roof industry. Due to the manner in which this document was created it can be considered to be the result of professional expert work.

The GRO Code is intended to be recognised as a code of best practice and as such it should be used to guide behaviour relating to green roof design, specification, installation and maintenance. However, there will be special cases where additional considerations will need to be made.

Every user of the GRO Code is responsible for their own actions, and acts at their own risk.

GRO recognises that the FLL (Forschungsgesellschaft Landschaftsentwicklung Landschaftbau's (Landscape Research, Development and Construction Society)), Guidelines for the planning, execution and upkeep of green roof sites, is a sound base from which to establish a minimum recommendation for green roof specification, installation and maintenance. It is recommended that all parties using this Code and requiring greater technical detail, should have a copy of the most recent version of the FFL Guidelines to hand, which can be purchased from www.fll.de.

The GRO Code of best practice is a collaborative document produced with the input of a wide cross section of GRO members and supported by the GRO Advisory Technical Group.

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1.1 Scope

Groundwork Sheffield secured €457,206 of European LIFE+ funding (Note: LIFE+ is the EU's financial instrument supporting environmental policy development across Member States) to create a code of best practice; setting standards for the design, installation and maintenance of green roofs across the UK.

Green roofs perform a vital role in helping cities adapt to the effects of climate change by reducing the need for artificial cooling in hot weather and attenuating or capturing rainwater runoff, as well as providing a range of habitats for wildlife. However, green roofs can only provide these environmental benefits if designed and installed in a way that ensures that minimum performance criteria are met. This code therefore highlights the important green roof design, installation and maintenance considerations and provides guidelines as to how they can be accommodated in the final green roof scheme.

1.2 Who Is This Guidance For?

This code will help anyone who is designing, specifying, installing or maintaining a green roof.

1.3 Steering Group

This code has been developed in partnership with national and European experts, including The Green Roof Centre at the University of Sheffield, Livingroofs.org, GRO (Green Roof Organisation) members, the Environment Agency and Homes and Communities Agency and Groundwork Sheffield.

1.4 Code Review Procedures

On an regular basis this document will be reviewed and updated by the relevant members of the GRO group.

GRO is a partnership of Industry (green roof manufacturers and installers) and Stakeholders, coming together to develop guidance for the specification, design, manufacturing, installation and maintenance of green roofs.

1.5 Acknowledgements

GRO recognises that the FLL (Forschungsgesellschaft Landschaftsentwicklung Landschaftbau's (Landscape Research, Development and Construction Society)), Guidelines for the planning, execution and upkeep of green roof sites, is a sound base from which to establish a minimum recommendation for green roof specification, installation and maintenance in the UK. The FLL document has been used as the foundation for green roof guidance documents around the globe, including: Switzerland; Austria; North America; Japan.

This UK code of best practice will therefore refer to FLL guidance standards where appropriate.

2 Introduction to Green Roofs

2.1 Definition

A green roof is created when a planting scheme is established on a roof structure. The roof can be at ground level, often with an underground car park beneath, or many storeys higher. Green roofs can be designed as recreational spaces to be enjoyed by people, as visual, sustainable or ecological features to support wildlife or a combination of both.

2.2 Types

Green roofs have risen in popularity due mainly to the positive impacts they have on the environment. Although there seem to be numerous categories of green roofs talked about in the market, they can be broadly broken down into Intensive or Extensive systems. Intensive systems are generally those types which are used as recreational spaces and often include similar features to traditional parks and gardens such as shrubs, trees, paving, lawns and even water features.

Extensive green roofs are normally intended to be viewed from another location as visual or ecological features, and are usually not trafficked. The more prevalent types of green roof which have hardier, more drought tolerant species of plants such as sedums, mosses, and wildflowers fall within the Extensive sector.

Extensive green roofs designed specifically to create habitats for plants and animals can be termed Biodiverse (or Brown) roofs. These types of roofs are becoming increasingly specified in urban areas in order to recreate habitat lost by the development.

As the green roof sector rapidly moves forward and systems continue to develop there are now many designs which could fall into both the Intensive and Extensive “category”. These types of systems could be termed as Semi-Intensive.

2.2.1 Extensive Green Roofs

Extensive green roof systems generally provide a visual or biodiversity interest and are considered to be less suitable as an amenity or leisure space. They are generally designed to support plants with a lower maintenance requirement, e.g. sedums, grasses, mosses and some wildflower species. These planting types are able to survive on shallower substrate depths than other types of plants, require lower nutrient levels and little or no irrigation requirement (when correctly designed and installed irrigation is generally only required in the initial establishment phase, and then very rarely afterwards).

2.2.1.1 Extensive Sedum Roofs

Sedum species are well adapted to their use within extensive green roofs. They are drought tolerant, able to withstand extremes in climate and can grow on relatively shallow substrates. There are many species with a range of form and colour, and generally flower from early summer to autumn. Sedum are able to survive on shallow substrate depths, lower nutrient levels and little or no irrigation requirement (when correctly designed and installed irrigation is generally only required in the initial establishment phase, and then very rarely afterwards).

Sedum green roofs are generally planted using pre-grown mats/blankets containing mixes of sedum species and/or planted with species of young sedum plug plants and/or seeded with a mix of seed and/or sedum cuttings.

2.2.2 Biodiverse Roofs

As the name suggests Biodiverse roofs are created primarily for biodiversity purposes and can aim to recreate the habitat that was lost when the building was erected, or even enhance it.

A 'Green' biodiverse roof would generally be broadcast with an appropriate seed mix (often wildflowers and grasses), and/or planted with species of plug plants (often wildflowers, sedums and grasses) to encourage specific plant types that will support certain bird and invertebrate species. Pre-grown mats containing mixes of drought tolerant wildflowers, grasses and herbs can also be installed to provide a more "instant" cover.

This category includes the 'Brown' biodiverse roof or "Brown Roof" which is not purposefully planted. The growing medium is selected and installed to allow indigenous plant species to inhabit the roof over time.

Substrate depths may vary across the roof deck to promote a diversity of both shallow and deep rooted plants and ones which are more and less drought tolerant. Undulating substrate depths also create differing habitats for a greater range of invertebrate species. Pebbles, boulders, gravels, sands, branches and logs may also be placed within the system to offer suitable habitats.

The "management" of a biodiverse type green roof very much depends upon what the client requires. It can be managed more heavily to produce a controlled "wildflower meadow" type environment. Less management input may lead to the development of vegetation which progresses naturally relating to the prevailing conditions.

2.2.3 Semi Intensive Green Roofs

An intermediate green roof type that can include characteristics of both extensive and intensive roofs. Typically requiring a substrate depth of 100 - 200mm, a wider range of plants can be included compared to extensive green roofs, including shrubs and woody plants. Irrigation and maintenance requirements are dependent upon the plant species installed.

2.2.4 Intensive Green Roofs

Intensive green roofs (also termed Roof Gardens) are principally designed to create recreational and amenity spaces for people to enjoy. They are generally accessible and contain features similar to traditional gardens including lawns, trees, shrubs and hard landscaped areas. Intensive green roof systems involve using greater substrate depths (usually above 200mm) and often create a larger weight loading on the roof. Intensive green roof systems require a higher level of maintenance, including regular irrigation.

2.3 Benefits

Green roofs offer many advantages for building developers, owners and their users. They benefit the wider environment through their positive impact on sustainability, biodiversity and the attenuation of storm water. They create visual enhancement of the landscape and fully exploit the spatial opportunities for visual and recreational benefit with the possibility of planning gain. In economic terms green roofs can have long term financial benefits. Combined with Solar Photovoltaic (PV) panels they can enhance the power production of the PV units due to the cooling nature of the green roof.

2.3.1 Sustainable Drainage (reducing flood risk)

More and more impermeable surfaces such as roads and buildings are constructed at the expense of permeable surfaces such as fields and meadows. The result of rain falling on hard surfaces is that it runs straight off through the drainage systems into rivers.

Therefore, in times of heavy or prolonged rainfall, existing drainage systems have to cope with large volumes of water which often, when built, were not designed to do so. This can result in them backing up and subsequent flooding especially during summer storm events.

The major flooding seen over recent years can be partly attributed to the increase in built up areas and reduction of vegetated areas. Therefore developers are 'strongly encouraged' by planners to employ Sustainable urban Drainage Systems (SuDS) on new developments.

SuDS are "A sequence of management practices and control structures designed to drain surface water in a 'more sustainable' fashion than some conventional techniques" (CIRIA 2000).

The Environment Agency can request that local authorities put conditions on planning permission such that the developer must restrict run off from the site to greenfield levels for a 100 year storm event.

PPG 25 (Development and Flood Risk) recommends that SuDS should be considered for new developments and encourage local authorities to include them in their development plans.

The inclusion of a green roof system can be looked at as one method of source control for SuDS:

- Water falling as rainfall onto a green roof is held within the pore spaces of the growing medium.
- Water is taken up and used by the plants.
- Some of the water held within the plant is lost back to the atmosphere by evapotranspiration.
- Rain droplets are often trapped within the vegetation and can then evaporate back into the atmosphere.
- Water can be held within the drainage system of the green roof build up.
- The drain water run-off rate is very much reduced due to the time it takes for the water to percolate through the green roof build up and out via the drainage outlets. This, therefore, releases any excess water over a longer time period enabling the terrestrial drainage systems to cope better.

The table below highlights the reduction in rainfall run-off, as the depth of substrate increases.

Roof Type	Run-off Percentage
Standard	81%
Standard + 50mm of Gravel	77%
Green Roof + 50mm of Substrate	50%
Green Roof + 100mm of Substrate	45%
Green Roof + 150mm of Substrate	40%

Source: Green roofs as a tool for solving the rainwater runoff problem in the urbanised 21st century?
Mentens, J.; Raes, D.; Hermy, M.
Revised 2005.

2.3.2 Biodiversity

Green roofs can help to create new wildlife habitats within urban environments, or recreate habitats that were lost during development. The type of system chosen can be designed to provide a habitat to encourage a broad range of species to flourish. However it could also be created to support more specific species of flora or fauna for conservation purposes.

Extensive green roofs which are designed not to be trafficked and are therefore relatively undisturbed, can offer a very good habitat for plants, birds and insects. There is evidence throughout Europe, that with the right design, green roofs can encourage ground nesting birds such as lapwings, skylarks, oystercatchers and plovers.

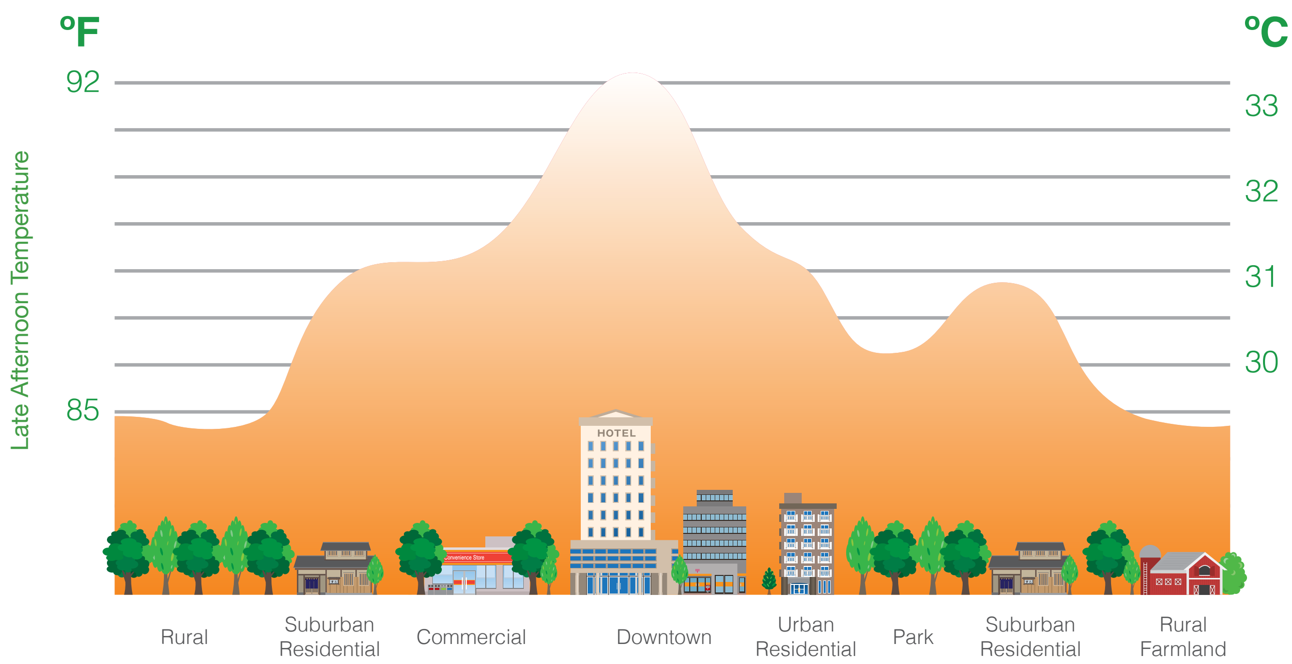
Green roofs are able to create a “green corridor” through an urban environment helping the movement and dispersal of wildlife.

2.3.3 Countering Climate Change and the Urban Heat Island Effect

During the day, heat from the sun is absorbed by the hard surfaces within a city, which is then radiated back during the night creating a hotter city microclimate. Therefore urban temperatures are often many degrees warmer than the surrounding countryside, which can lead to a higher energy demand to cool city buildings through the night. This difference in temperature is called the urban heat island effect.

Rises in temperature can lead to increased levels of air pollution which may exacerbate health problems especially in the old, young and susceptible. However, evaporation of water from soil surfaces and the leaves of plants on a green roof create a cooling effect of the surrounding air leading to a reduction in the urban heat island effect. The many layers within a green roof system also prevent solar radiation increasing roof surface temperatures and therefore subsequently radiating any heat back at night.

Urban Heat Island Diagram:



2.3.4 Building Performance and Enhancements

The evaporative cooling effect of green roofs, combined with the increased thermal mass of the build-up, can reduce the need for summer cooling (i.e. air conditioning), with a resultant reduction in carbon emissions. This additional mass also serves acoustic purposes, providing additional sound attenuation benefits.

2.3.5 Amenity, Health and Wellbeing

Green roofs can benefit building occupants by providing valuable additional outdoor recreational areas, for a variety of possible uses, including amenity and recreation. Indeed, research suggests that such green space can improve the productivity of the workforce, reduce hospital patients' convalescence times etc.

Recreational Spaces - If the roof structure is able to take the weight of the proposed recreational system above it, then green roofs can play a very important role in providing useable spaces for people where there is little available at ground level. Green roofs designed as recreational areas have the advantage that access to them can be controlled making the space less prone to vandalism and other anti-social issues which can be common place in public spaces at ground level.

Aesthetics - In many locations the view looking across a series of city roofs can be very uninspiring. Green roofs, rather than hard flat roofs are not only more pleasant to the eye; they are very likely to be seen as a positive selling point for developers wishing to sell property to potential buyers.

Health - It is known that people who live in high density urban environments are less susceptible to illness if they have a balcony or terrace garden. This is due to a number of associated benefits such as more oxygen, better air filtration and humidity control which plants can supply. There are also therapeutic benefits associated with the mixture of smells, colours, sounds and movement created by plants and their associated fauna, which can reduce stress, lower blood pressure, relieve muscle tension and increase positive feelings.

2.3.6 Financial

Energy Savings - Reduction of Solar Heat Ingress - Although the addition of a green roof cannot as yet be quantified to influence the thickness of insulation required for a building, its thermal mass can reduce the amount of solar heat entering a building through the roof. This is more pronounced when the building is poorly insulated. The various layers within a green roof system help to absorb the heat of the sun, reducing its transmission into the building below. This in turn reduces the air-conditioning costs required to keep the temperature at a suitable level.

Longevity of Roofing Membranes - Ultraviolet radiation falling upon certain waterproofing membranes can change its characteristics and accelerate the aging process. However as the membrane is buried below the green roof system, this premature ageing cannot take place.

During the day an unprotected membrane heats up, and releases that heat back to the atmosphere during the night. This daily fluctuation of temperature causes the membrane to expand and contract which over time creates stresses within the membrane affecting its long term performance. During the summer months exposed membranes could reach 50-60ºC, and in winter, temperatures below freezing. A green roof acts as a buffer and reduces the severity of maximum and minimum temperatures, thereby extending the life of the membrane.

2.3.7 Policy / Planning Consent

Some council's and local authorities, e.g. the London boroughs have stated that they expect green roofs to be designed for new developments, where feasible. Other regions throughout the UK are now moving towards implementing similar policies.

Living Roofs and Walls - Technical Report: Supporting London Plan Policy (Feb 2008)
This document was released to provide guidance in helping London combat the effects of climate change. It was recognised by the Mayor of London that green roofs have the potential to improve London's resilience to the impacts of climate change by reducing storm water run-off velocity and volumes, and by increasing the cooling effect during London's hotter summers. They also bring many other wider environmental benefits.

Therefore in brief the document states: "The Major will and boroughs should expect major developments to incorporate living roofs and walls where feasible and reflect this principle in LDF policies.

It is expected that this will include roof and wall planting that delivers as many of these objectives as possible:
- Accessible roof space
- Adapting and mitigating climate change
- Sustainable urban drainage
- Enhancing biodiversity
- Improved appearance

Boroughs should also encourage the use of living roofs in smaller developments and extensions where opportunity arises"

2.3.8 Improvement of Air and Water Quality

2.3.8.1 Air Quality

It is widely recognised that green roofs play a positive role in the improvement of air quality. In the process of photosynthesis, plants absorb carbon dioxide from the atmosphere and release oxygen back.

2.3.8.2 Water Quality

Vegetation can filter out airborne particulates as the air passes over the plants, settling on leaves and stems. These particles are then washed down into the growing substrate via natural rainfall or irrigation. They are then held within the green roof substrates / filter fleeces and prevented getting into water courses. Heavy metals such as lead, zinc and copper are recognized pollutants within urban areas, but green roofs play a major role in limiting their potential to contaminate water supplies.

2.3.9 Quieter Buildings

Hard roof surfaces tend to reflect sound, rather than absorb it. Green roofs absorb sound through the substrate, drainage and vegetation layers. This is especially significant in busy locations such as built up areas, near airports or flight paths and alongside busy roads. Buildings such as schools, hospitals and offices could benefit from the noise reduction properties of green roofs.

2.3.10 Food Production

Green roofs can provide new opportunities for urban agriculture, however they need to be specifically designed for this application and require significant nutrition.

There can be many benefits associated with growing and distributing food locally including:
- Support of the local economy in growing, processing and distributing;
- Increased access to food by everyone
- Fresher produce
- Decreased travel time to market and related environmental costs
- Localised control of fertiliser and pesticides

2.3.11 Green Roofs and Solar Power

Photovoltaic (PV) panels work more efficiently at a set operating temperature. Once there is a deviation either above or below this level, the electricity generation becomes less efficient. As a green roof is able to maintain a more constant temperature regime with less daily fluctuations, the PV panels are able to work more efficiently throughout the day.

2.3.12 Green Roofs and BREEAM

BREEAM - Building Research Establishment's Environmental Assessment Method is an assessment method based on performance to set standards for best practice in sustainable design. Credits are awarded in 10 categories and then added together to produce a single overall score which is then given a rating of Unclassified, Pass, Good, Very Good, Excellent or Outstanding.

Green roof installation in general can directly assist in getting credits in the following categories:
1. **POL5: FLOOD RISK** - To encourage development in low flood risk areas or to take measures to reduce the impact of flooding on buildings in areas with a medium or high risk of flooding.
2. **LE4: MITIGATING ECOLOGICAL IMPACT** - To minimise the impact of a building development on existing site ecology
3. **LE5: ENHANCING SITE ECOLOGY** - To recognise and encourage actions taken to maintain and enhance the ecological value of the site as a result of development.
4. **LE6: LONG TERM IMPACT ON BIODIVERSITY** - To minimise the long term impact of the development on the site's and surrounding area's biodiversity. Green roofs can also have a more indirect impact on other sections of BREEAM.

3 Design Considerations & Practical Implications

When designing a green roof, it is important to establish exactly what it is intended to achieve as the component within the green roof build-up may vary i.e. the acidity of the growing medium and/or the depth of the drainage board. This section introduces the different components in a green roof build-up, highlighting their function and important performance characteristics. Key green roof design issues are subsequently introduced.

3.1 Configuration of a Green Roof

All materials used within a green roof system or build-up should, where applicable, have been tested following the appropriate testing protocols (e.g. FLL, British Standards) and deemed to be fit for purpose by meeting the relevant performance criteria.

A green roof requires appropriate levels of each of the following in order to flourish:
- Daylight
- Moisture
- Drainage
- Aeration to the plants root systems
- Nutrients

The green roof system build-up should be configured to provide the appropriate balance of the above requirements to sustain plant life. This can be achieved by including the appropriate combination or combinations of the following components.

3.1.1 Root resistant material

A membrane that permanently protects the roof's waterproof covering by preventing plant roots or rhizomes from growing into or through it. It can take the form of an independent membrane or a monolithic root resistant version of a waterproofing membrane. The root resistant element may be a chemical or a physical barrier (tested in accordance with most current FLL, Section 7.1.2.5 or EN 13948 relating to root penetration of the membrane).

The important performance characteristics to evaluate suitability are:
- Density (kg/m3)
- Tensile strength (N/mm^2)
- Elongation to break (%)

3.1.2 Moisture retention/protection layer

A geotextile blanket, available in varying thicknesses (typically between 2-12 mm) that performs the dual functions of protecting the waterproof membrane during and after construction and supplementing the reservoir and layers water holding capacity.

In addition to ensuring the moisture retention/protection continues to function over the design life of the roof it must also meet the performance demands of the construction process.

The following performance characteristics should be assessed for suitability:
- Water storage capacity (l/m^2)
- Thickness (mm)
- Weight [dry] (kg/m^2)
- Tensile strength (kN/m^2)
- Durability measure as per EU Norm

3.1.3 Drainage/Reservoir layer

Drainage/reservoir layers can be manufactured from a variety of materials, including hard plastic, polystyrene and foam. Coarse gravel and crushed brick may also be used depending on the functional requirements. Demolition waste is not suitable. To function correctly the drainage/reservoir layer must allow excess water to drain away, thereby preventing the water logging of the substrate. Drainage/reservoir layers may also incorporate water storage cells to retain additional water that can be diffused to the plant support layer during prolonged dry periods.

The important performance characteristics to evaluate suitability are:
- Water storage capacity (l/m^2)
- Filling volume (l/m^2)
- Flow rate ($l/s/m^2$)*
- Weight [dry and saturated] (kg/m^2)
- Compressive strength (kN/m^2)

Note: flow rate may be affected when used on a pitched roof as opposed a flat roof, check water storage capacity and flow rate when used at pitch...

3.1.4 Filter layer

A woven or non woven geotextile that prevents fines and sediments from being washed out of the green roof into the drainage/reservoir layer so as to maintain permeability.

The important performance characteristics to evaluate suitability are:
- Weight (kg/m^2)
- Tensile strength (kN/m^2)
- Flow rate under hydraulic head of 10 cm ($l/s/m^2$)
- Effective pore size (^2m)
- Penetration force (N)

3.1.5 Growing medium

An engineered soil replacement that contains a specified ratio of organic and inorganic material; specifically designed to provide green roof plants with the rooting zone, air, water and nutrient levels that they need to survive, whilst facilitating the release of excess water.

A green roof substrate should have a composition that provides the following properties:
- Lightweight
- Resistance to wind and water erosion
- Free from weeds, diseases and pests
- Good plant anchorage to reduce the risk of wind uplift due to the binding effect of the roots within the growing medium
- Fire resistance through avoiding high proportions of organic matter
- Appropriate water retention/release tendencies to retain sufficient water to meet the plants' needs, yet facilitating permeation to avoid water logging of the substrate
- Good aeration at water saturation to prevent the roots from suffering the detrimental effects of water logging
- Resistance to compaction to prevent saturation due to removed drainage paths
- Appropriate supply of nutrients (e.g. slow-release fertilisers) to allow development in accordance with the plants' needs (Note: extensive roofs have a low nutrient requirement, whilst intensive and semi-intensive roofs have higher nutrient requirements).

The tabulated reference values are approximate only, and represent some of the key physical properties for substrates, as derived from the FLL guide (Section 16):

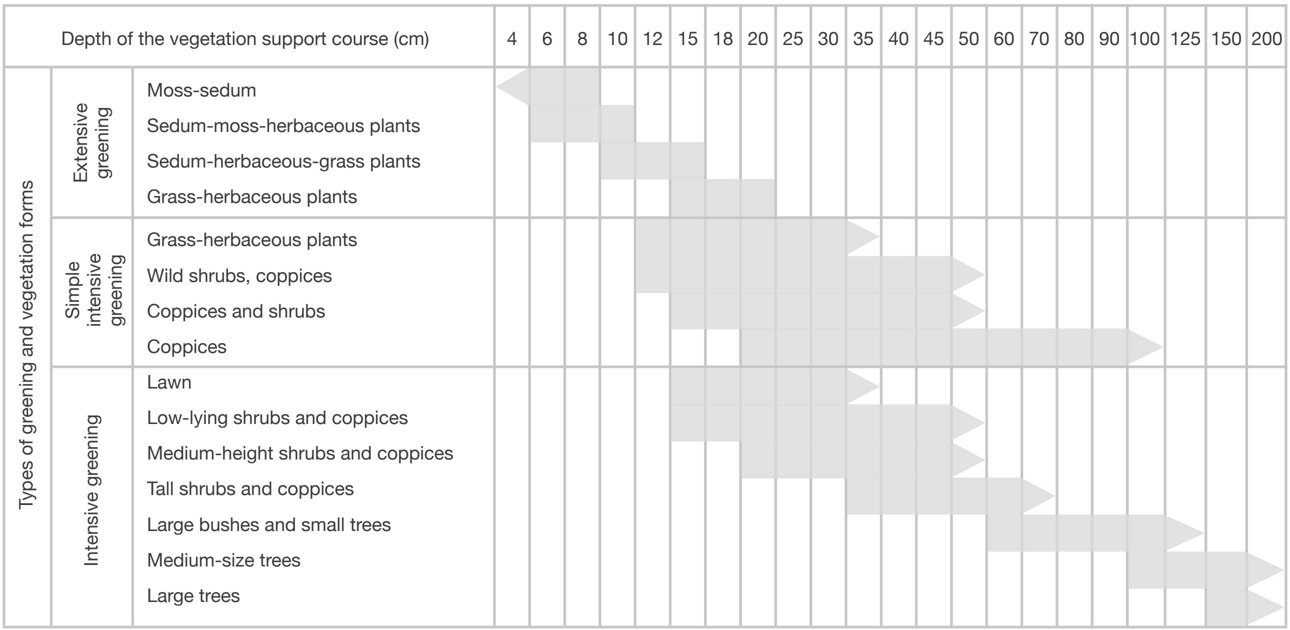
Properties	Reference Values	
	Extensive	**Intensive**
d ≤ 0.063mm	≤ 15% (by mass)	≤ 20% (by mass)
d > 4.0mm	≤ 50% (by mass)	≤ 40% (by mass)
Maximum Water Holding Capacity (MWHC)	≥ 25% ≤ 65% (by volume)	≥ 45% (by volume)
Air Content at MWHC	≥ 10% (by volume)	≥ 10% (by volume)
Water Permeability	0.6 - 70mm/min	0.3 - 30mm/min
pH Value	6.0 - 8.5	6.0 - 8.5
Organic Content	≤ 65 g/1	≤ 90 g/1

Acknowledgement to FLL Guidelines 2008

A depth of green roof substrate not less than 80mm is recommended on a sedum based green roof installation. For wildflower based systems a minimum depth of 100mm to 150mm will be required depending on the plant species specified. There are, however, applications where greater or lesser depths can be used based on individual manufacturers recommendations.

1. Where pre-grown vegetation mats are being used, the substrate depth may be reduced due to the depth of the substrate contained within the mat. For pre-grown sedum mats the minimum mat thickness should be 20 mm (most recent edition of FLL, 7.2.1). Pre-grown wildflower or biodiverse mats will be deeper.
2. Where manufacturers have developed systems for particular applications, providing a more limited range of benefits, but reducing the weight of the system. [In this instance, designers and installers should consult the manufacturer of these systems to confirm their performance and any increased maintenance and irrigation requirements].

A guide to typical minimum substrate depths is shown below, this is derived from the FLL guidelines. When specifying the appropriate substrate depth suitable allowance must be included for settlement post installation.



3.1.6 Vegetation

3.1.6.1 Plant selection

Key factors in specifying green roof plant layers include:

- Objective: Different plant physiological composition translates into different performance traits. For example, roofs seeking to improve stormwater retention will often utilise sedum species (due to the water consumption pattern associated with their crassulacean acid metabolism) whilst a roof seeking to fulfil a particular biodiversity objective (e.g. habitat creation) may require a specific mix of indigenous species (often selected by an expert ecologist).
- Plant characteristics: the plant's architecture (e.g. leaf size, shape and coverage) and physiology (e.g. transpiration tendencies etc) will affect the roof's performance and its tolerance to drought, wind, light, shade and pollutants.
- Climate: Variations in sunshine, and the resulting differences in solar radiation and air temperature, can affect the length and time of growing seasons and the risk of frost. Precipitation patterns affect the demands placed on the roof by rainfall and snow.
- Microclimate: The orientation of the building and that of any surrounding buildings in the vicinity will affect the shading levels on the roof, whilst also affecting wind levels.

3.1.6.2 Managed Plant types

A wide range of plants, mosses, herbs, flowers, grasses, shrubs and trees; selected according to the particular green roof application:

- Extensive roofs mostly comprise self-sustaining, low-growing plants, such as sedums, or other frost and drought tolerant species.
- Semi-intensive or green biodiverse roofs typically include plant species such as wild flowers, herbaceous perennials and shrubs.
- Intensive roofs typically resemble a residential garden or small urban park and can include a wider range of planting, such as shrubs, lawns and trees. Vegetation cover and content should be in line with Clause 12.6.2 of the FLL Guidelines (2008).

3.1.6.3 Non Managed Plant types

Where a self vegetating 'Brown' biodiverse roof is specified the suitability of the composition of the substrate to support the desired local species must be carefully considered to ensure appropriate nutrient levels are achieved and maintained. Consideration should also be given to the maintenance regime that may be required to manage unwanted invasive species.

Note: Where a roof is not initially seeded or planted the development of the vegetation cannot be foreseen and so thorough inspections should be undertaken to ensure that no locally invasive materials become prevalent if unwanted.

3.2 Structural Design

A green roof design must comply with all relevant structural design criteria, as per BS EN 1990:2002 'Eurocode - Basis of Structural Design.' As such, designs must be in accordance with all appropriate Eurocodes, with a notable emphasis on EN 1991 - Eurocode 1: Actions on structures.

On projects covered by NHBC warranty the structural design shall be undertaken in accordance with recognised standards.

Items to be taken into account include:
(a) Dead and imposed loads - these should be calculated in accordance with BS EN 1991-1-1, BS EN 1991-1-3 and BS EN 1991-1-4. Where a flat roof is to act as a roof terrace, roof garden or will have vehicle access, appropriate provision should be made for additional loading conditions. Intensive green roofs should only be used in conjunction with concrete decks.

General Actions:
- Densities, self-weight, imposed loads for buildings (BS EN 1991-1-1:2002)
- Snow Loads (BS EN 1991-1-3:2003); and
- Wind Actions (BS EN 1991-1-4:2005 +A1:2010 Eurocode 1. Actions on structures. General actions. Wind actions)

The building structure and any loaded roof components (e.g. insulation, waterproofing) must be designed accordingly.

3.2.1 Wind Loads

Wind loads should be calculated according to BS EN 1991-1-4:2005+A1:2010 Eurocode 1. Actions on structures. General actions. Wind actions. The design should resist uplift from wind forces either by anchorage to the main structure or by having sufficient self weight to prevent the occurrence of uplifting in worst case design conditions

Where green roof elements are being used as ballast to provide the roofing system with resistance from wind uplift (i.e. the roofing system is not mechanically fastened or bonded) sufficient weight must be incorporated into the green roof build-up. In these instances the dry weights of the green roof components must be used to calculate the weight of the green roof system.

Subject to wind suction loads, erosion control measures, such as netting, may be required whilst the planting establishes.

With highest wind load areas occurring at roof perimeters, and corners in particular, heavier materials, such as larger ballasting aggregates or paving slabs should be used to prevent wind scour of the green roof substrate.

3.2.2 Dead loads

Dead loads must account for the saturated weight of the green roof, snow loads and any further imposed service loads, such as pedestrian access loads and point loads from features such as water features and large trees. The underlying roofing system (deck, insulation, waterproofing, geotextile layer and drainage/retention layer must all be capable of withstanding any point loads from the green roof installation and from any support elements included such as decking or paving.

3.2.3 Shear forces

Green roof systems are suitable for flat and pitched roof applications. When used in pitched applications the risk of substrates being exposed to excessive shear forces, as a result of steep roof pitches, and slipping down the slope must be considered in the design. Anti-shear measures are typically required for roof pitches in excess of 10°; however the waterproofing and (where different) the green roof manufacturer should be consulted for project specific advice. The requirements of the anti-shear measures should be considered during the structural design phase.

The anti-shear measures must be designed to suit the individual waterproofing system employed and avoid imposing unintentional loads on the structure and waterproofing below. Common solutions include retention baffle systems and slip barriers. Where the attachment of the retention system penetrates the waterproofing the retention measure itself should be waterproofed, refer to the waterproofing manufacturer for specific recommendations as failure to waterproof correctly will impact the guarantee and/or waterproofing integrity.

3.3 Waterproofing

Waterproofing systems for use beneath green roofs should form part of a structure designed to BS EN 1991 Eurocode 1 and/or NHBC Standards Chapter 7.1.

In all applications the primary waterproofing layer is critical to successful performance of the roof as a whole, therefore its function and performance characteristics, and its suitability for use within a green roof system must be assured. At a minimum the specified waterproofing system should be certified to FLL Guidelines against root resistance and/or be covered by British Board of Agrément (BBA) Certification for green roof applications. A wide range of waterproofing options fall within these requirements including reinforced bitumen systems, hot melt monolithic systems, single ply systems, liquid applied systems and standing seam aluminium systems.

When designing and specifying the waterproofing system it is important that the detailing (e.g. upstands, pipe penetrations, rooflight upstands etc) are designed to take into account the increased build-up of the green roof construction. Building Regulations typically requirements the waterproofing detailing to finish 150mm above the finished roof surface i.e. the green roof surface not the surface of the waterproofing.

In all instances the manufacturer of the waterproofing membrane should confirm the compatibility of the waterproofing system for use in green roof applications and installation should be in accordance with the generic design and the waterproofing manufacturers recommendations.

Where the roof covering does not provide the necessary root resistance, the installation of an independent root barrier is required (see Section 3.1.1).

During installation consideration should be given to the action of wind loads (3.2.1). Where a loose laid waterproofing membrane is being installed suitable temporary ballasting measures must be put in place. Where mechanical fastened or adhered waterproofing membrane in used this will generally not be required but attention should be paid to the security of any overnight joints.

During installation the waterproofing membrane should be protected from other trades and any other activity by means recommended by the waterproofing manufacturer. Sufficient storage and workspace should also be provided, the roof should not be used as a storage area or work platform.

3.3.1 Waterproofing Inspection

Completed roof waterproofing should not be used as a working platform for any trade other than those installing the green roof. In the event of damage to the waterproofing leading to ingress of water into the building post green roof installation remedial works will require extensive investigations to locate the point of damage. Typically this will require the removal (and subsequent replacement) of the green roof build-up, a process that is labour intensive and can lead to significant costs. The inspection and testing of the waterproofing integrity prior to the green roof installation is therefore imperative.

Testing and inspection can consist of electronic leak detection (if appropriate) and/or visual inspection. Regardless of which method(s) are used the height of upstands, roof light flashings etc should be thorough inspection to ensure correct heights prior to installation of the green roof. Where an inspection of the waterproofing system is required by the manufacturer prior to the issue of a guarantee this should be scheduled appropriately so as to minimise risk of damage of wind action. Where handing over to a specialist green roof contractor there should be a noted handover of the area which recognises the change of responsibility between the waterproofer and the green roof installer.

3.4 Drainage

Roof drainage designs should comply with the requirements of BS EN 12056-3:2000 Gravity drainage systems inside buildings. Roof drainage, layout and calculations.

The UK's National Annex to BS EN 12056 does permit the use of a coefficient to factor down the drainage infrastructure, to account for factors such as the additional retention performance of green roofs.

However, the coefficient that is used to reflect this reduction would be based on average annual retention and not on responses to dynamic storm events. Any drainage infrastructure designed to accommodate this reduced flow rate may not accurately account for seasonal differences or individual storm events. Any reductions in drainage capacity would therefore need to be countered by alternative measures (e.g. appropriate detailing) to ensure that any attenuation of water at the roof level will not be detrimental to the building structure or fabric.

The exact nature of this drainage benefit will be dependent upon the specific build-up of the green roof, particularly in respect of its permeability and capacity for storage, as governed by the growing medium and drainage/reservoir board, where installed. (See section 2.3.1 for details of sustainable drainage benefits of green roofs.) Inspection chambers are required to ensure that outlets are kept free of blockages.

See Technical Appendix 1 for more information.

3.5 Fire

Many green roof systems will provide a positive contribution to the resistance of penetration by fire due to the non-combustible nature of mineral/brick based growing media.

Green roof systems can also provide a positive contribution to resistance of spread of flame provided they are correctly designed, installed and maintained. However, like any vegetation-covered surface consideration must be given to methods preventing the external spread of flame during prolonged periods of drought include the use of temporary irrigation system to prevent drying out.

Depending on the system specified the season maintenance requirements can impact on fire risk. Tall grasses and/or wildflower species that die back seasonally leaving large volumes of organic material on the roof can increase fire risk if the correct maintenance regimes are not followed.

All green roof systems should be designed to incorporate gravel fire breaks at perimeters and penetrations i.e. Rooflights, soil pipes, rainwater outlets etc. These fire breaks should be a minimum of 300mm wide and 50mm deep (see 3.5.1.2).

3.5.1 Extensive roofs

Extensive roofs do not tend to be irrigated and the fire risk must therefore be mitigated by the specification of the build-up and the incorporation of fire breaks. On-going maintenance should take into account any dry spells that could impact on the volume of dry vegetative material on the roof (especially for wildflower system), and appropriate action taken to ensure no significant volume of dry material is left on the roof. This is particularly important on roofs overlooked, where an ignition source such as a burning cigarette could be discarded onto the roof causing a fire.

3.5.1.1 Green roof build-up

Substrate should have:
- a depth in excess of 80 mm
- a minimum depth of 80mm
- a maximum of 20% organic matter
- Plants such as succulents retain water within their structure, reducing the risk of drying out

3.5.1.2 Fire breaks

Non-vegetated strips comprising 20 - 40mm rounded pebbles or concrete paving stones that should be kept clear of encroaching vegetation during maintenance visits. The width of these strips should be a minimum of 300mm but should be increased to a minimum of 500mm where the strip is providing pre-vetative fire protection such as opening rooflights and vertical walls with windows or opening doors, On large roofs a one metre wide pebble strip should be installed at 40 metre intervals across the roof. To help maintain the vegetation barrier a retention angle should be included between the growing medium and the pebble margin/paving. This area should also be subjected to routine maintenance to remove any invasive plant species.

3.5.2 Intensive roofs

DIN Standards (the German equivalent to British Standards) have designated 'intensive greening which is irrigated, regularly maintained and has a thick substrate layer' as a "hard roof". This implies that it has no greater fire risk than a conventional roof finish. On this basis GRO believes that Intensive Roofs should be deemed to meet BS 476-3: 1958 designation EXT. FAA. For Extensive and Biodiverse green roofs the manufacturer/supplier should be consulted, as should Agrément or other relevant certification.

3.6 Irrigation

Irrigation is typically required for the initial establishment of the green roof for a period of 6 - 8 weeks until established depending on natural rainfall during this time. However, once plant cover is achieved, irrigation can be reduced (for intensive and semi-intensive roofs) or avoided (for most extensive roofs, subject to plant selection). The more intensive the roof, the more likely it will be that an artificial irrigation system is required.

The requirement for irrigation depends on many factors, particularly:
- The planting layer's water demands
- Water storage capacity of the green roof configuration (e.g. growing medium, drainage layer)
- Local precipitation patterns

In all instances advice should be sort from the green roof system supplier.

Once established rainfall is the typical source of water for green roof system, however complementary irrigation options include hoses, sprinklers, overhead irrigation and automated systems that pump from a storage reservoir.

The establishment of a need for an irrigation system, and the design of an irrigation scheme, should be in accordance with the principles of BS 7562-3:1995 Planning, design and installation of irrigation schemes - Part 3: Guide to irrigation water requirements.

Standards relevant to the design of specific irrigation systems include BS EN 15099-1:2007 - Irrigation techniques. Remote monitoring & control system, BS EN 15097:2006 - Irrigation techniques. Localised irrigation hydraulic evaluation and BS EN 13742-1:2004 - Irrigation techniques. Solid set sprinkler system - selection, design, planning & installation.

3.7 Safety & Access

Legislation requires, amongst other things, safe working platforms and protection against falls to be provided for roof installation works.

There are numerous relevant statutory documents:
1. The Construction (Design and Management) Regulations - requiring risk assessments to identify and mitigate potential risks during the construction and post-construction phases leading to the preparation and implementation of safe working practices;
2. The Construction (Health, Safety & Welfare) Regulations - requiring safe access and egress, including fall prevention measures;
3. The Health and Safety at Work Act - generally placing an onus on employers and employees to ensure safe work places, including requirements for measures to protect against the risk of falling when working at height.

In addition the need to have fall restraint and/or fall arrest systems for post installation maintenance is universal for green roof systems. However the type of system required varies depending on the type of green roof and the resultant requirement for maintenance. The fall arrest specification should account for the guidance provided within BS 7887: 2005 - Code of practice for the design, selection, installation, use and maintenance of anchor devices conforming to BS EN 795.

Whatever type of fall restraint and/or fall arrest systems are installed they should be designed specifically for the appropriate maintenance requirements of the green roof system, which will generally be different from the requirements of other trades such a window cleaners.

3.7.1 Extensive and biodiverse roofs

With access generally only required for the conductance of maintenance works, some form of fall restraint and/or fall arrest system will typically be sufficient to provide safe access to and egress from roof edges, penetrations, lights or any bordering fragile surfaces.

The specific maintenance requirement and the layout of the roof will determine the most appropriate system type. A single point anchorage device may suffice in many cases, however for greater mobility; guided type fall arrest systems may be more suitable. Systems can be designed to suit all movement directions (i.e. vertical, horizontal) and for different numbers of operatives.

Whatever type of fall restraint and/or fall arrest systems are installed they should be designed specifically for the appropriate maintenance requirements of the green roof system, which will generally be different from the requirements of other trades such a window cleaners.

3.7.2 Intensive and semi-intensive roofs

Require a higher standard of safety due to the increased frequency and density of visitors, whether to conduct maintenance or to derive an amenity benefit from the use of the roof space. Typically, additional measures, such as safety rails or barriers, are therefore required for this type of roof and are included as part of the original design. Fall restraint and/or fall arrest systems may also be suitable subject to the amenity intention.

4 Green Roof Installations

Contractors should be trained in the installation of green roofs and must have a specialist understanding of the green roof system as well as general roof care and construction knowledge. Incorrect installation may result in a variety of failures including but not limited to the loss of plant life, damage to the waterproofing, slippage from the roof, failure to achieve BREEAM ratings, failure to meet planning requirements, failure to perform as designed etc.

4.1 Site Preparation & Planning

Contractors should have training in the following areas:

- Site preparation prior to installation
- Preparation - Logistics
- Essential system components
- Growing medium
- Planting program
- Installation of essential system components
- Installation of Growing medium (including settlement %)
- Installation of support system for the plants
- Installation of plants (mat, plug and/or seed)
- Application of any feeds or fertilisers
- Temporary IrrigationPost installation maintenance

Project Management is critical to delivering successful green roof installations:

- Scheduling works to comply with the project programme (and the waterproofing installation in particular) and close collaboration with the green roof materials delivery and installation will be essential to ensuring that materials arrive on site in a timely fashion, whilst minimising the storage time of plant materials on site.
- Selecting the method of installation for the substrate and planting layer that is most appropriate to the roof layout and objectives.

Before commencing installation works, the integrity of the waterproof covering must be tested and approved (see 3.3.1). All drainage works, flashings etc should be finished prior to the application of the green roof covering.

4.2 Installation of System Components

4.2.1 Protection sheets, drainage layers and filter sheets

Protection sheets, drainage layers and filter sheets should be installed edge to edge across the entire roof area to be greened to ensure the waterproofing is protected and the drainage layer functions consistently. Due to the diversity of products available from the various green roof manufacturers/suppliers, it is recommended that specific installation advice is sought from the specified system provider to ensure compliance with manufacturer’s recommendations.

4.2.2 Substrate Installation

Typically supplied in either small sacks (containing 25 litres and weighing 20 to 25kg each) or larger bulk bags (containing 1.25 m^3 and weighing 1.25 tonnes) the selection of one or the other, or a combination of both, packaging methods will depend on the roof size and/or access and lifting limitations. Generally smaller projects suit sacks and large projects and/or multiple roof spaces suit bulk bags.

When supplied in bulk bags the bags should be certified for multiple lifts and be disposed of once the substrate has been discharged at roof level. Confirmation of the suitability of bottom discharge (as opposed to closed bottom) bags should be sort from the projects Health & Safety officer at the earliest opportunity as should any other lifting restrictions.

The method choice of lifting the substrate up to the roof level, and its subsequent dispersion of it across the roof, haves significant access, budgetary and scheduling implications. Typically a crane is required for the duration of the installation of the substrate. Each project should be assessed for its specific conditions (i.e. access, hard standing, roof area, slope, structure, access, plant/ equipment availability, loading limits etc) to determine suitable logistic, time the most time- and cost-effective icient installation method.:

Bags - whether small sacks (e.g. 25 litres) or larger (e.g. 1.25 m^2) bulk bags - are conducive to smaller projects or large projects with multiple roof spaces, as they are readily lifted up to the roof via crane or similar lifting equipment.

Some suppliers offer bulk deliveries via silos or tippers, which can offer economies of scale on large projects or overcome access restrictions. Deliveries made either via silos, allow the substrate to be immediately pumped onto the roof, or via tipper loads for pumping to the roof in stages. Such deliveries must be carefully scheduled to realise the feasible cost efficiencies.

Substrate should be applied to the required depth (including the appropriate settlement volume) using grading bars. Depth checking should be undertaken throughout the installation.

Once the green roof is installed it should be saturated to capacity using suitable temporary irrigation equipment prior to on-going temporary irrigation depending on the time of year.

4.2.3 Plant Layer Installation

The choice of vegetation is a function of many factors including planning conditions, ecological requirements, client’s requirements, BREEAM ratings, cost, time and the time required to achieve full greening of the roof. The commercial availability of particular species at any given time may also be a factor.

The optimum periods to install green roofs are late September/early October or late March/early April as the cooler and wetter conditions will typically reduce the need (and cost) for irrigation to keep plants moist. Planting in late March/early April matches the natural growth periods for plants, facilitating the establishment of the green roof eco-system in harmony with nature.

Planting at other times of year to suit the construction programme is possible but it will impact on a number of factors including:
- Increased irrigation requirements due to the higher temperatures/dryer climate.
- Longer establishment period for the green roof eco-system.

Planting during periods of frost or drought should be avoided.
Remember the plants used for green roofing are affected by the seasons in the same way as ground level plants.

The plant layer can be installed using the following methods:

4.2.3.1 Pre/off-site Grown Vegetation Blanket/Mat

A plant carpet that is field-grown to maturity, providing instant greening of the roof on installation. Many varieties exist with the most common being sedum or wildflower.

Shipped in rolled form the pre-grown mats must be rolled directly on to the prepared substrate within 24 to 48 hours of packaging. Once installed the pre-grown mats should be thoroughly watered and irrigated thereafter for 4 - 6 week period subject to weather conditions, until thoroughly established. Mat edges are typically butt-jointed, although the specific manufacturer should be consulted to establish any shrinkage risk.

4.2.3.2 Plug planting

Rooted young plants (plugs) are individually grown (in trays) and planted into a prepared substrate. Plug planting provides the opportunity for a greater diversity of planted species than a pre-grown mat but only provides 5 to 10% plant cover on installation. Full plant cover should develop over 2 to 3 seasons depending on the time of year installed and subject to care/maintenance.

Subject to the plant species selected, plants should be installed at a typical coverage rate of 15 - 20 plants per m^2. For optimum establishment, a minimum of six varieties of species are recommended per m^2.

1. Prior to installation of the planting, the substrate, drainage layer and any moisture mat should be saturated
2. Pre-water the plants before removing them from their trays
3. Insert plants and gently water them in
4. Ensure that the substrate is irrigated for an initial period of 4-6 weeks to allow the plants to sufficiently establish themselves.

4.2.3.3 Hydroplanting and/or seeding

A mixture of cuttings (if sedum is used) and/or seeds are spread on the prepared substrate, with mulch applied over the cuttings to resist wind scour and enable the cutting/seeds to root and seeds to germinate. No plant cover is visible at installation, full cover should develop over 2 to 3 seasons depending on the time of year installed and subject to care/maintenance.

A minimum of six species should be represented in the mix with the application rate specified to suit the seed mix (consult supplier).

The plant mix is typically spread by hand and covered with a liquid-applied mulch and an appropriate organic nutrient source.

Irrigation is typically not required post installation.

4.3 Installation of Perimeter & Penetration Details

Details for perimeters (e.g. eaves, verge, ridge), drainage outlets, fire breaks, fall arrest system incorporation and penetrations (e.g. rooflights, flues) should be installed as per the relevant standard detail specific to the manufacturer’s system.

5 Green Roof Maintenance

Maintenance, conducted by qualified personnel will ensure the initial establishment and continued health of the green roof system. It is strongly recommended that the installing contractor remains responsible for the maintenance of the green roof during this establishment stage (between 12 - 15 months) and prior to the assignation of maintenance duties to the building owner's representative. Maintenance contractors with specialist training in green roof care from organisations such as GRO (The Green Roof Organisation) should be used, where possible.

When designing a green roof, it is important that the green roof system is specified accounting for any budgetary constraints. The costs of roof maintenance should therefore form part of the life cycle cost analysis for the building, allowing the most appropriate green roof specification to be realised.

5.1 General Maintenance Actions

All maintenance actions carried out at roof level must be in full compliance with the appropriate health and safety regulations, and particularly those specifically dealing with working at height. BS 4428:1989 - Code of practice for general landscape operations (excluding hard surfaces) and BS7370-4:1993 Grounds maintenance - Part 4: Recommendations for maintenance of soft landscape (other than amenity turf) provide guidelines for maintenance actions.

5.1.1 Irrigation

(See Section 3.6 for details).

5.1.2 Fertilising

Fertilisation is the process by which additional nutrients can be supplied to the plants, enhancing germination, flowering and resistance to weather extremes. The regularity and type of fertilisation requirement will therefore depend on the type of green roof and its plant specification. If using non slow release fertiliser the potential impact on the sewage system must be considered, and the rainwater system isolated from the mains for the first flush if necessary. (See Section 5.2 for further details).

Intensive and simple intensive roofs are based on a more fertile growing medium and the planting installed will require regular fertilisation.

5.1.3 Plant management

Undesirable plant species are best avoided by establishing a complete coverage of the desired plant species. Any wind-blown seeds or cuttings should be removed before they have the opportunity to take root. (See Section 5.2.2 for exemptions).

5.1.4 General clearance/removal

Generally the removal of dead material is desirable as it allows plants the space to develop a greater coverage, improving the finished appearance of the roof, whilst also reducing the risk of fungal disease forming and spreading. However, in some biodiverse applications, removing plant debris could be counter-productive in creating habitat.

5.2 Maintenance Actions by Roof Types

All maintenance actions carried out at roof level must be in full compliance with the appropriate health and safety regulations, and particularly those specifically dealing with working at height. BS 4428:1989 - Code of practice for general landscape operations (excluding hard surfaces) and BS7370-4:1993 Grounds maintenance - Part 4: Recommendations for maintenance of soft landscape (other than amenity turf) provide guidelines for maintenance actions.

5.2.1 Extensive roof maintenance - < 100mm low nutrition substrate

Irrigation: Post-establishment, irrigation should not be required for most extensive green roofs, although the water storage capacity of the system and the plants' water demands should be appropriately assessed.
Fertilisation: Extensive green roofs typically have low nutrient requirements and are therefore often fertilised on an annual basis, each spring, using a slow-release fertiliser.
Plant management: Removal of undesirable plant species and fallen leaves should take place twice each year
General: Drainage outlets (including inspection chambers) and shingle/gravel perimeters to be cleared of vegetation, twice yearly

5.2.2 Biodiverse roof maintenance - very low to low nutrition substrate

Irrigation: Typically not required
Fertilisation: Generally not required, particularly where indigenous species are being encouraged to replicate native habitats. Whilst a low vegetative density is common, zero vegetation is generally undesirable
Plant Management: A maintenance programme should be drawn up to follow the biodiversity hypothesis, ensuring that no materials are removed from the roof that may adversely affect the biodiversity potential of the roof
General: Drainage outlets (with inspection chambers) and gravel/shingle perimeters should be inspected twice yearly and cleared of any living or dead vegetation

5.2.3 Semi intensive roof maintenance - 100mm to 200mm low to medium nutrition substrate

Irrigation: Periodic irrigation is expected, depending upon the plant specification and the climatic and microclimatic conditions prevailing at roof level.
Fertilisation: With a wider range of planting, using a more fertile growing medium, more regular fertilisation is required.
Plant management: Removal of undesirable vegetation on the greened area twice yearly.
General: Drainage outlets (including inspection chambers) and shingle/gravel perimeters to be cleared of vegetation, twice yearly

5.2.4 Intensive roof maintenance - 200mm + medium nutrition substrates and top soils

Irrigation: Regular irrigation is often required, subject to the plant specification and the climatic and microclimatic conditions prevailing at roof level.
Fertilisation: With a wider range of planting, using a more fertile growing medium, more regular fertilisation is required.
Plant management: The intensive maintenance of lawns, hedges, borders etc is required on a regular basis, so as to maintain the roof aesthetics. Undesirable vegetation should be removed from the green areas at least twice yearly. Failed plants in excess of 5% of the plants installed should be replaced.
General: Drainage outlets (including inspection chambers) and shingle/gravel perimeters to be cleared of vegetation, twice yearly. Where excessive substrate settlement has occurred, this should be replenished.

6 Relevant Complementary Documentation

6.1 Building Regulations

- The Building Regulations Approved Document B (2006 edition) Fire safety
- The Building Regulations Approved Document F Ventilation (1995 Edition, amended 2006) (F1-Means of ventilation, F-2 Condensation in roofs)
- The Building Regulations Approved Document Part H (2002 Edition) Drainage and waste disposal
- The Building Regulations Approved Document Part L1 (2010 Edition) Conservation of fuel and power in dwellings
- The Building Regulations 2001 Approved Document Part L2 (2010 Edition) Conservation of fuel and power in buildings other than dwellings
- The Building Standards (Scotland) Regulations 2004

6.2 British Standards - Building Design

- BS EN ISO 6946:2007 - Building components and building elements. Thermal resistance and thermal transmittance. Calculation method.
- BS 8233:1999 - Code of Practice for sound insulation & noise reduction for buildings
- BS 5250:2002 - Code of practice for control of condensation in buildings
- BS EN 12056-3:2000 - Gravity drainage systems inside buildings. Roof drainage, layout and calculation.
- BS 7543:2003 - Guide to durability of buildings & building elements, products & components
- BS 8207:1985 - Code of practice for energy efficiency in buildings
- BS 8210:1986 - Guide to building maintenance management
- BS 8207:1985 - Code of practice for energy efficiency in buildings
- BS 476-3:2004 - Fire tests on building materials & structures. External fire exposure roof test
- BS EN 1363-1:1999 - Fire resistance tests. General requirements
- BS EN 62305-1:2006 - Protection against lightning. General principles

6.3 British Standards - Structural Design

- BS EN 1990:2002 - Eurocode 0: Basis of structural design
- BS EN 1991-1-1:2002 - Eurocode 1: Actions on structures. General actions : Densities, self-weight, imposed loads for buildings
- BS EN 1991-1-3:2003 - Eurocode 1: Actions on structures. General actions : Snow loads
- BS EN 1991-1-4:2005 - Eurocode 1: Actions on structures. General actions : Wind actions
- BS EN 1991-1-6:2005 - Eurocode 1: Actions on structures. General actions : Actions during execution
- BS EN 1991-4:2006 - Eurocode 1: Actions on structures. General actions : Silos and tanks
- BS EN 1993-1-3:2006 - Eurocode 3: Design of steel structures. General rules. Supplementary rules for cold formed members and sheeting.
- BS EN 1995-1-1:2004 - Eurocode 5: Design of timber structures. General. Common rules and rules for buildings (and Appendix A1, 2008)
- BS EN 1997-1:2004 - Eurocode 7: Geotechnical design. Part 1: General rules.
- BS 6915: 2001 - Design & construction of fully supported lead sheet roof & wall coverings

6.4 British Standards - Maintenance

- BS 7562-3:1995 - Planning, design & installation or irrigation schemes. Guide to irrigation requirements.
- BS EN 15099-1:2007 - Irrigation techniques. Remote monitoring & control system
- BS EN 15097:2006 - Irrigation techniques. Localized irrigation hydraulic evaluation
- BS EN 13742-1:2004 - Irrigation techniques. Solid set sprinkler system - selection, design, planning & installation
- BS7370-4:1993 - Grounds maintenance - Part 4: Recommendations for maintenance of soft landscape (other than amenity turf)
- BS 4428:1989 - Code of practice for general landscape operations (excluding hard surfaces)

6.5 Health & Safety

- The Construction Safety and Welfare Regulations 1966 statutory no.1592 Regulation 6
- The Construction Design and Management Regulations 2007 (CDM)
- Fire Precautions (Workplace) Regulations: 1997 (As amended 1999)
- Control of Substances Hazardous to Health Regulations 2005 (COSHH)
- Work at Height Regulations 2005.
- BS EN 12811-1:2003 - Temporary works equipment. Scaffolds. Performance requirements and general design.
- BS EN 363:2008 - Personal fall protection equipment. Personal fall protection system
- BS EN 795:1997 - Protection against falls from height. Anchor devices. Requirements & testing
- BS 7887:2005 - Code of practice for the design, selection, installation, use and maintenance of anchor devices conforming to BS EN 795
- BS EN 516:2006 - Prefabricated accessories for roofing. Installations for roof access. Walkways, treads and steps
- BS EN 517:2006 - Prefabricated accessories for roofing. Roof safety hooks
- BS EN 1263-1 & 1263-2:2002 - Safety nets. Safety requirements, test methods and positioning

6.6 Workmanship

- BS 8000-4:1989. Workmanship on building sites. Code of practice for waterproofing
- BS 6229:2003. Flat roofs with continuously supported coverings. Code of practice
- Reinforced bitumen membranes for roofing. Code of practice
- Design Guide for Single Ply Roofing (SPRA 2012)
- Code of Practice: Specification and Use of Liquid Applied Waterproofing Systems for Roofs, Balconies and Walkways (LRWA 2010)
- Code of Practice: Specification and Use of Hot Melt Monolithic Waterproofing Systems for Roofs, Balconies and Walkways (LRWA 2014)

6.7 British Standards - Metal Roofing Specifications

- BS 5427-1:1996 - Code of practice for the use of profiled sheet for roof and wall cladding on buildings - Design
- BS EN 501:1994 - Specifications for fully supported roofing products of zinc sheet
- BS EN 502:2000 - Specification for fully supported roofing products of stainless steel sheet
- BS EN 504:2000 - Specification for fully supported roofing products of copper sheet
- BS EN 505:2000 - Specification for fully supported products of steel sheet
- BS EN 506:2008 - Specification for self-supporting roofing products of copper or zinc sheet
- BS EN 507:2000 - Specification for fully supported products of aluminium sheet
- BS EN 508-1:2008 - Specification for self supporting products of steel, aluminium or stainless steel sheet - Steel
- BS EN 508-2:2008 - Specification for self-supporting products of steel, aluminium or stainless steel sheet - Aluminium
- BS EN 508-3:2008 - Specification for self-supporting products of steel, aluminium or stainless steel sheet - Stainless steel
- BS EN 988:1997 - Zinc & zinc alloys. Rolled flat products for building
- CP 143 - Code of practice for sheet roof & wall coverings
- BS 4868:1972 - Specification for profiled aluminium sheet for building

6.8 British Standards - Bitumen Waterproofing Specifications

- BS EN 13707:2004+A2 Flexible sheets for waterproofing. Reinforced bitumen sheets for roof waterproofing. Definitions and characteristics.
- BS EN 1928:2000 Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of water tightness.
- BS EN 13583:2001 Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of hail resistance
- BS EN 13416:2001 Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Rules for Sampling

6.9 British Standards - Plastic & Rubber Waterproofing Specifications

- BS EN 13956:2005 Flexible sheets for waterproofing - Plastic and rubber sheets for roof waterproofing. Definitions and characteristics
- BS EN 1928:2000 Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of water tightness.
- BS EN 13583:2001 Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of hail resistance
- BS EN 13416:2001 Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Rules for Sampling

6.10 British Standards - Mastic Asphalt Waterproofing Specifications

- BS 8218:1998 - Code of practice for mastic asphalt roofing

6.11 Liquid Applied Waterproofing Specifications

- Code of Practice: Specification and Use of Liquid Applied Waterproofing Systems for Roofs, Balconies and Walkways (LRWA 2010)
- Specification and Use of Hot Melt Monolithic Waterproofing Systems for Roofs, Balconies and Walkways (LRWA 2014)

6.12 Single Ply Membrane Waterproofing Specifications

- BS EN 313-1:1996 - Plywood Classification
- BS EN 313-2:2000 - Plywood Terminology
- BS EN 636:2003 - Plywood Specifications
- BS EN 300:2006 - Oriented Strand Board (OSB): Definitions, classification and specifications
- Code of Practice: Design Guide for Single Ply Roofing (SPRA 2012)

6.13 British Standards - Insulation Specifications

- BS EN 13162:2008 Thermal insulation products for buildings. Factory made mineral wool (MW) products. Specification
- BS EN 13163:2008 Thermal insulation products for buildings. Factory made products of expanded polystyrene. Specification
- BS EN 13164:2008 Thermal insulation products for buildings. Factory made products of extruded polystyrene foam (XPS). Specification
- BS EN 13165:2008 Thermal insulation products for buildings. Factory made rigid polyurethane foam (PUR) products. Specification
- BS EN 13166:2008 Thermal insulation products for buildings. Factory made products of phenolic foam. Specification
- BS EN 13167:2008 Thermal insulation products for buildings. Factory made cellular glass (CG) products. Specification
- BS EN 13168:2008 Thermal insulation products for buildings. Factory made wood wool (WW) products. Specification
- BS EN 13169:2008 Thermal insulation products for buildings. Factory made products of expanded perlite (EPB). Specification

6.14 Green Roof Guidance

- Green Roofing Guidelines: 2008 Guidelines for the Planning, Construction and maintenance of green roofing. FFL (Forschungsgesellschaft Landchaftsentwicklung Landschaftsbau e.V.)

7 Glossary

Biodiverse roof
A roof that is designed to create a desired habitat that will attract a particular flora and fauna; whether replicating the original footprint of the building or enhancing the previous habitat.

Brown roof
A biodiverse roof where the growing medium is purposely-selected to allow local plant species to inhabit the roof over time.

BS
British Standards formulated by the British Standard Institute (BSi).

Drainage layer/Reservoir board
Available in a variety of materials, including hard plastic, polystyrene, foam, coarse gravel and crushed recycled brick, depending on the functional requirements. Allows excess water to drain away, thereby preventing the water logging of the substrate. Some drainage layers also incorporate water storage cells to retain additional water that can be diffused to the plant support layer during prolonged dry periods.

DIN Standards
Deutsches Institut für Normung which means “German Institute for Standardization.” DIN Standards are the published results of DIN’s work.

Extensive green roof
A lightweight, low-maintenance roof system, typically with succulents or other hardy plant species (often sedum) planted into a shallow substrate (typically less than 100 mm) that is low in nutrients. Irrigation is not normally required.

Filter fleece/ fines layer
Prevents fines and sediments from being washed out of the green roof into the drainage system.

FLL
Forschungsgesellschaft Landschaftsentwicklung Landschaftbau’s (German Landscape Research, Development and Construction Society).

Green roof
A roof or deck onto which vegetation is intentionally grown or habitats for wildlife are established, including: extensive, intensive and semi intensive roofs; roof gardens; biodiverse roofs; brown roofs; public and private amenity spaces.

Green roof plants
Plants chosen and cultivated for their resistance to the harsh conditions of a roof environment. These can be introduced as seeds, plug plants or pre-grown or off-site grown mats.

Green roof system
The component layers of a green roof build-up.

Growing medium/Substrate
An engineered soil replacement that contains a specified ratio of organic and inorganic material; specifically designed to provide green roof plants with the air, water and nutrient levels that they need to survive, whilst facilitating the release of excess water.

GRO
Green Roof Organisation: The industry forum for green roof development and promotion in the UK. GRO is facilitated by the NFRC and acts as the technical arm of Livingroofs.org.

Hydro seeding
Spraying a specially designed blend of seeds and growing medium.

HSE
Health and Safety Executive.

Inspection chambers
Situated over all internal rainwater outlets to constrain the surrounding landscaping but allow easy access for maintenance. Unit allows water entry, but helps prevent unwanted silt, debris or vegetation from entering and obstructing free drainage.

Intensive green roof
A version of a green roof, often referred to as a roof garden, that provides benefits akin to a small urban park or domestic garden. Designed primarily for recreational use, intensive roofs are typically configured with 200 mm+ of substrate and often require regular maintenance and irrigation.

Moisture / Protection layer
A geotextile blanket, available in varying thicknesses (typically between 2-12 mm), performs a dual function. Firstly, protecting the waterproof membrane during the installation of the green roof system; and secondly, increasing the water holding capacity of the green roof system.

Root barrier
A layer (membrane) designed to prevent roots from penetrating the waterproofing layer and building fabric.

Sedum
A genus of about 400 species of low-growing, leafy succulents that are wind, frost and drought tolerant and found throughout the northern hemisphere. Not all species are suitable for roofs.

Semi Intensive green roof
Intermediate green roof type with characteristics of both extensive and intensive green roofs. Typically 100mm to 200mm substrate depth, sometimes irrigated, occasionally managed, and usually planted with a range of species.

Standard/traditional/conventional roof
Un-vegetated and non-absorbent roofs i.e. asphalt, single ply, mineral felt, liquid applied, metal deck etc.

SUDS
Sustainable (Urban) Drainage Systems

Vapour barrier
A layer, typically a plastic or aluminium foil cored bituminous sheet that resists diffusion of moisture through the building fabric.

The GRO Green Roof Code

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