



The GRO Green Roof Code

Green Roof Code of Best Practice for the UK 2011



The GRO Green Roof Code

Published by Groundwork Sheffield
www.groundwork.org.uk/sheffield

Groundwork Sheffield

The Innovation Centre
217 Portobello
Sheffield - S1 4DP

ISBN: 978-0-9568378-0-6

A catalogue record for this book is available from the British Library.

This document is also available online at:

www.greenroofcode.co.uk



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) as a body is facilitated by the National Federation of Roofing Contractors (NFRC).

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 Landschaftsbau'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 FLL Guidelines to hand, which can be purchased from www.fll.de.

GRO Technical Advisor Group to the Green Roof Code:

Peter Allnutt - Green Roof Product Manager, Alumasc Exterior Building Products Ltd.
Wendy Bussey - Deputy Executive Director, Groundwork Sheffield
Dusty Gedge - Livingroofs.org, Ltd European Federation of Green roof Associations (EFB)
Mark Harris - Blackdown Horticultural Consultants
Ian Henning - National Federation of Roofing Contractors (NFRC)
Simon Poë - Alumasc Exterior Building Products Ltd
Nick Ridout - Bauder Ltd.
Phil Singleton - Icopal Ltd.
Jeff Sorrill - The Green Roof Centre, University of Sheffield
Dr. Alun Tarr - Wildface
Stefan Zeller - Optigreen Ltd.

Date of 1st publication 18/01/2011

Editing and layout:
Groundwork Sheffield

Cover picture:
Alumasc Exterior Building Products Ltd.



Contents

1	Introduction to the Code	6
1.1	Scope	6
1.2	Who is this guidance for?	6
1.3	Steering Group	6
1.4	Code review procedures	6
1.5	Acknowledgements	6
2	Introduction to Green Roofs	7
2.1	Definition	7
2.2	Types	7
2.2.1	Extensive green roof	7
2.2.2	Biodiverse roof	7
2.2.3	Semi intensive green roof	7
2.2.4	Intensive green roof	7
2.3	Benefits	7
2.3.1	Sustainable drainage	8
2.3.2	Biodiversity	8
2.3.3	Countering climate change & the urban heat island	8
2.3.4	Building performance enhancements	8
2.3.5	Amenity & health & wellbeing	8
2.3.6	Financial	8
3	Design Considerations & Practical Implications	9
3.1	Configuration of a green goof	9
3.1.1	Root resistant material	9
3.1.2	Moisture retention/protection layer	9
3.1.3	Drainage/Reservoir layer	9
3.1.4	Filter layer	10
3.1.5	Growing medium	10
3.1.6	Vegetation	11
3.2	Structural Design	12
3.2.1	Wind	12
3.2.2	Dead loads	12
3.2.3	Shear forces	12
3.3	Waterproofing	13
3.4	Drainage	13
3.5	Fire	13
3.5.1	Extensive roofs	14
3.5.2	Intensive roofs	14
3.6	Irrigation	14
3.7	Safety & access	15
3.7.1	Extensive and biodiverse roofs	15
3.7.2	Intensive and semi-intensive roofs	15
4	Green Roof Installations	16
4.1	Site preparation & planning	16
4.2	Installation of system components	16
4.2.1	Protection sheets, drainage layers and filter sheets	16
4.2.2	Substrate installation	16
4.2.3	Plant layer installation	17
4.3	Installation of perimeter & penetration details	17

5	Green Roof Maintenance	18
5.1	General maintenance actions	18
5.1.1	Irrigation	18
5.1.2	Fertilizing	18
5.1.3	Plant management	18
5.1.4	General clearance/removal	18
5.2	Maintenance actions by roof type	19
5.2.1	Extensive	19
5.2.2	Biodiverse	19
5.2.3	Semi intensive	19
5.2.4	Intensive	19
6	Relevant Complementary Documentation	20
6.1	Building regulations	20
6.2	British Standards – Building design	20
6.3	British Standards – Structural design	20
6.4	British Standards – Maintenance	21
6.5	Health and Safety	21
6.6	Workmanship	21
6.7	British Standards – Metal Roofing specifications	22
6.8	British Standards - Bitumen waterproofing specifications	22
6.9	British Standards - Plastic & rubber waterproofing specifications	22
6.10	British Standards - Mastic asphalt waterproofing specifications	23
6.11	Liquid waterproofing specifications	23
6.12	British Standards – Timber specifications	23
6.13	British Standards – Insulation specifications	23
6.14	Green roof guidance	23
7	Glossary	24

1

Introduction to the code

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 annual 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 Landschaftsbau'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 living or green roof is a roof, deck or other structure onto which vegetation is intentionally grown or habitats for wildlife are established.

2.2 Types

Traditionally there have been three broad classifications for green roofs - extensive, semi-intensive and intensive. However, whilst biodiverse roofs share many of the characteristics of an extensive roof, their increased specification merits a distinctly separate category:

2.2.1 Extensive green roof

Extensive roofs serve as an ecological covering that provides society with environmental benefits and the building owner with life cycle cost benefits. 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.

2.2.2 Biodiverse roof

A roof that is similar in composition to an extensive roof, but designed specifically to create a habitat that will attract a particular flora and fauna; whether replicating the original footprint of the building or enhancing the previous habitat. This category includes a brown roof, which is a non-vegetated version. The growing medium is purposely-selected to allow indigenous plant species to inhabit the roof over time.

2.2.3 Semi intensive green roof

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

2.2.4 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.

2.3 Benefits

Green, living and intentionally vegetated roofs are becoming more common in the UK. Green roofs are one of the most readily-accessible sustainable technologies available to the construction industry and can be included as part of new buildings and (subject to structural checks), retro-fitted to existing buildings to provide the following benefits to the occupants of buildings, as well as the local setting:

2.3.1 Sustainable Drainage

- Retention of water, through storage in the growing medium and evapotranspiration from the roof's plants and substrate, reduces and slows runoff volumes, reducing the burden on the sewer network and lowering water treatment costs.
- Detention of water, due to the time for water to infiltrate and permeate the substrate, reduces peak rates of runoff, helping to reduce the risk of flooding.
- Water quality improvements through the filtration of pollutants during the process of water infiltration.

2.3.2 Biodiversity

Green roofs can replace habitat that has been lost as a result of urban development or create habitats for enhanced biodiversity to actively encourage flora and fauna into the area, for example, by providing food, habitat, nesting opportunities or resting places for creatures, such as spiders, beetles, butterflies, birds and other invertebrates.

2.3.3 Countering climate change & the urban heat island

Vegetation consumes carbon during photosynthesis, positively removing emissions and helping to arrest climate change. The evaporative cooling of green roof vegetation also reverses the heat-reflecting effect associated with non-greened, impermeable surfaces that contribute to higher urban temperatures (known as the urban heat island effect)

By returning moisture to the environment through evapotranspiration, solar gain can be reduced. The trapping of particulates and capturing of gases, ensure that air pollution levels are also reduced by green roofs.

2.3.4 Building performance 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 & 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.

2.3.6 Financial

Whilst future government policy may further increase the financial benefit to owners of buildings with green roof installations, green roofs can be seen to payback the initial investment by:

- Increasing the life of the roof covering due to the vegetation cover protecting the membrane, thereby lowering thermal stresses induced by UV rays; and
- Reduced energy costs due to the lower energy consumption demands attributable to the insulating effect of the substrate, planting & drainage layer.

3 Design Considerations & Practical Implications

When designing a green roof, it is important to establish exactly what it is intended to achieve. The roof configuration can vary significantly, depending on the objectives sought from its installation. 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:

- Sunlight
- Moisture
- Drainage
- Aeration to the plants root systems
- Nutrients

The green roof system build-up should be configured to provide the requisite balance of the above requirements, including at least some 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 FLL 2008, Section 7.1.2.5 or EN 13948).

The important performance characteristics to evaluate suitability are:

- Density (kg/m³)
- Tensile strength (N/mm²)
- Elongation to break (%)

3.1.2 Moisture retention/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.

The important performance characteristics to evaluate suitability are:

- Water storage capacity (l/m²)
- Thickness (mm)
- Weight [dry] (kg/m²)
- Tensile strength (kN/m²)

3.1.3 Drainage/Reservoir layer

This is available in a variety of materials, including hard plastic, polystyrene, foam, coarse gravel and crushed recycled brick, depending on the functional requirements. It 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.

The important performance characteristics to evaluate suitability are:

- Water storage capacity (l/m²)
- Filling volume (l/m²)
- Flow rate (l/s/m²)
- Weight [dry] (kg/m²)
- Compressive strength (kN/m²)

3.1.4 Filter layer

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

The important performance characteristics to evaluate suitability are:

- Weight (kg/m²)
- Tensile strength (kN/m²)
- Flow rate under hydraulic head of 10 cm (l/s/m²)
- Effective pore size (µm)
- 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 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 fertilizers) 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
Depth	Minimum 80 mm (see note 1)	Typical \geq 200 mm
Porosity	-	-
Pore-size Distribution:		
$d \leq 0.063$ mm	$\leq 15\%$ (by mass)	$\leq 20\%$ (by mass)
$d \geq 4.0$ mm	$\leq 50\%$ (by mass)	$\leq 40\%$ (by mass)
Maximum Water Holding Capacity (MWHC)	$\geq 25\% \leq 65\%$ (by volume)	$\geq 45\%$ (by volume)
Air Content at MWHC	$\geq 10\%$ (by volume)	$\geq 10\%$ (by volume)
Water permeability	0.6 – 70 mm/min	0.3 - 30 mm/min
pH value	6.0 – 8.5	6.0 - 8.5
Organic content	≤ 65 g/l	≤ 90 g/l

Note:

A depth of aggregate-type material not less than 80 mm is recommended on a green roof installation. There are, however, certain applications where lesser depths can be used:

1. Where pre-grown vegetation mats are being used, the aggregate-type materials may be reduced to 60 mm average depth plus a minimum mat thickness of 20 mm (FLL 2008, **7.2.1**); or
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].

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 utilize sedum species, due to the water consumption pattern associated with their crassulacean acid metabolism. Contrarily, a roof seeking to fulfill 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 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 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).

3.2 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.

General Actions:

- Densities, self-weight, imposed loads for buildings (EN 1991-1-1:2002)
- Snow Loads (EN 1991-1-3:2003); and
- Wind Actions (EN1991-1-4:2005).

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

3.2.1 Wind

Where green roof elements are being used as ballast to prevent items that are not mechanically-fixed from wind uplift, sufficient weight must be incorporated into the green roof build-up. In this instance, dry weights 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. 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.

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.

3.2.3 Shear forces

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 20°; however the green roof manufacturer should be consulted for case-specific advice.

The anti-shear measures must be designed to avoid imposing unintentional loads on the waterproofing below. Common solutions include retention baffle systems and slip barriers.

3.3 Waterproofing

A wide range of options are available for the waterproofing of a green roof. A range of membranes, liquid-applied waterproofing and metals can be installed beneath a green roof.

It is important that the installing waterproofing contractor is aware that a green roof will be installed over the roof covering, thereby allowing the detailing (e.g. upstands) to accommodate the increased build-up.

Remedial works to the waterproofing require extensive investigations simply to locate the point of fault. Combined with the fact that the removal (and subsequent replacement) of the green roof build-up is so labour intensive, significant costs can arise from problems with the waterproofing layer. The inspection and testing of the water integrity of the roof covering prior to the green roof installation is therefore imperative.

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).

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.

3.5 Fire

Green roofs, like any vegetation-covered surface, need to be designed to provide the necessary resistance to the external spread of fire, even when subjected to prolonged periods of drought.

This resistance is increased by:

1. Increasing the content of non-combustible components (e.g. mineral aggregates)
2. Reducing combustible component (e.g. organic matter)
3. Preventing the system from drying out

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:

3.5.1.1 Green roof build-up

Substrate should have:

- a depth in excess of 80 mm
- 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 pebbles (20 – 40 mm) or concrete paving stones, should be kept clear of encroaching plants (FLL 2008, 6.9); and
- Installed in 500 mm strips at all openings of the roof (skylights, windows) or any vertical elements such as a wall with windows; and
- Installed in 1 m strips (or 300 mm heights) at 40 m intervals across the roof.

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.

3.6 Irrigation

Irrigation is typically required for the initial establishment of the green roof. 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

Rainfall is the typical source of water, however complementary irrigation options include hoses, sprinklers, overhead irrigation and automated systems that pump from some reservoir storage.

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. Localized 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.

The need to have fall arrest systems 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.

3.7.1 Extensive and biodiverse roofs

With access generally only required for the conductance of maintenance works, some form of 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.

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 roof type, however fall arrest systems may also provide benefit.

4 Green Roof Installations

Contractors should be fully trained in the installation of green roofs and must have a specialist understanding of the green roof system as well as general construction knowledge.

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 support system to the plants
- Installation of plants
- Post 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 supplier will be essential to ensuring that materials arrive on site in a timely fashion, whilst minimizing 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. 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

Due to the diversity of products available from the various green roof manufacturers, 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

The choice of lifting substrate up to the roof level and subsequent dispersion of it across the roof has significant budgetary and scheduling implications. Each project should be assessed for its specific conditions (i.e. roof area, slope, structure, access, plant equipment availability etc) to determine the most time- and cost-efficient installation method:

Bags - whether small sacks (e.g. 25 litres) or larger (e.g. 1.25 m³) 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.

Bulk deliveries offer economies of scale on large projects, with deliveries made either via silos, allowing 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 realize the feasible cost efficiencies.

4.2.3 Plant Layer Installation

The choice of vegetation is a function of cost, time and the requirement for instant greening.

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. It is strongly recommend that planting is not installed during the months of June to August.

The plant layer can be installed using the following methods:

4.2.3.1 Sedum mat

A carpet of sedum species is field-grown to maturity, enabling it to be rolled directly on to the prepared substrate.

The installed sedum mats should be thoroughly watered in and kept moist thereafter for 4 - 5 weeks, until the sedum mats become 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), typically sedum species, are individually grown (in trays) and planted, with the opportunity to provide a greater diversity of planted species.

Subject to the plant species selected, plants should be installed at a typical coverage rate of 15 - 20 plants per m². For optimum establishment, a minimum of six varieties of species are recommended per m².

- Prior to installation of the planting, the substrate, drainage layer and any moisture mat should be saturated
- Pre-water the plants before removing them from their trays
- Apply an approved slow release fertiliser on to the substrate (at an approximate rate of 50 grams per m²)
- Insert plants and gently water them in
- Ensure that the substrate is kept moist for an initial period of 4-5 weeks to allow the plants to sufficiently establish themselves.

4.2.3.3 Hydroplanting and seeding

A mixture of sedum cuttings and seeds are spread on the prepared substrate, with mulch applied to allow cuttings to root and seeds to germinate.

A minimum of six sedum species should be represented in the mix of cuttings and seeds, applied at a rate of approximately 150 grams per m² onto the surface of the substrate.

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

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 Fertilizing

Fertilization 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 fertilization requirement will therefore depend on the type of green roof and its plant specification. 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 fertilization.

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

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.
- Fertilization: Extensive green roofs typically have low nutrient requirements and are therefore often fertilized on an annual basis, each spring, using a slow-release fertilizer.
- 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 – very low to low nutrition substrate

- Irrigation: Typically not required
- Fertilization: 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 – 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.
- Fertilization: With a wider range of planting, using a more fertile growing medium, more regular fertilization 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 – 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.
- Fertilization: With a wider range of planting, using a more fertile growing medium, more regular fertilization 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

- BS7562-3:1995 – Planning, design & installation of 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 & -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)
- Code of Practice: Specification and Use of Liquid Waterproofing Systems (ELWA 1998)

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 Waterproofing Specifications

- Specification and Use of Liquid Waterproofing Systems: Code of Practice (ELWA 1998)

6.12 British Standards - Timber 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

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 Landschaftsentwicklung 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 Landschaftsbau’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 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.



SHEFFIELD

Published by Groundwork Sheffield
www.groundwork.org.uk/sheffield

ISBN: 978-0-9568378-0-6