INSTALLING A SEDUM BLANKET ROOF

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The 'Guidelines for the Planning, construction and Maintenance of Green roofs' - *better known as the FLL Guidelines*, are widely accepted 'Codes of Practice' for Green roofing in the UK, adopted by the Green Roof Organisation (GRO) as a body is facilitated by the National Federation of Roofing Contractors (NFRC). 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.

According to the FLL 2008 the following are forms of extensive greening

- Moss and sedum
- Sedum-moss-herbaceous planting
- Sedum-grasses-herbaceous planting
- Grasses-herbaceous plants

Extensive greening is defined as involving apparently native vegetation which requires hardly any external input for either maintenance or development. The plants that are used are well suited to coping with the extreme conditions of the locations where they will be planted and they will have the ability to regenerate easily.

As a general rule, extensive greening is not difficult to implement and maintain. Depending on the greening objective, any regional climatic conditions and the type of construction, certain selected maintenance activities will be required.

For sedum roofs it is assumed that there is a gradient and about 2% is considered to be the norm. Such controlled drainage generally meets the basic needs of the vegetation in extensive greening such as sedum roofs. Where the slope is less than 2% special measures for roof dewatering are normally needed - *unless damp areas are sought for particular reasons but these are not good for most species of sedum*.

Starting with waterproof roof

According to the FLL Guidelines the following are suitable for sedum blanket roofs, but they offer extra cautions for each roof type.

- Non-ventilated roofs without thermal insulation. *In the case of structures in which the underside of the roofing is exposed to sub-zero temperatures there is a potential risk of frost damage to plants.*
- Non-ventilated roofs with thermal insulation. *There is a need to make sure that the load bearing capacity of the heat insulator is suitable for the load of the vegetation layer, including the weight of the sedum blanket.*
- Non-ventilated roofs with thermal insulation on lightweight structures. Only types of greening with low design loads should be used (e.g. use of Ultralite substrate), but bear in mind the safety margins could be so low as to exclude the installation of a sedum roof, so check this out.

- Ventilated roofs with thermal insulation. The load-bearing capacity of the top layer may be very low so this should be checked and an Ultralite solution may be needed. The cooling effect of the roof greening has the potential to affect the physical construction of the building so ensure that this risk has been assessed.
- Inverted roofs. Where a sedum roof is to be installed on an inverted roofs, or other specially-shaped roofs fitted with thermal insulation above the waterproofing attention needs to be paid to moisture diffusion. Each site will need to have been assessed to see whether or not a levelling or breathing course is needed. Also after a refurbishment it could be necessary to employ extra measures prior to a sedum roof being commissioned.

Roofs made from waterproof concrete ("WP-Concrete")

- Roofs made from waterproof concrete with or without a thermal insulation underlay. Generally, additional surface treatment for concrete is not needed in order to prevent root penetration but do make sure the concrete is sound and waterproof.
- Roofs made from waterproof concrete with thermal insulation overlay. Treat these as inverted roofs.

Roofs with coverings

Some of the coverings employed may not be suitable for a green roof to be installed directly, but much depends on the scale of the building as to the measures taken (most would agree that much greater care needs to be taken for an extension than the roof of a garden shed for tools) so there is a judgement call to be made involving the contractor and client but in many of these cases a waterproof underlay may be needed as an added measure to ensure that there are no leaks. Also, consider the loading requirements of the roof.

Diffusion of moisture

As a general comment, common sense must apply to roof structures which may have originally been designed to allow the diffusion of moisture. For instance this might be the function of a tiled roof and to prevent the designed diffusion of moist air could cause to the building if the normal ventilation of a building is handicapped in any way. If in any doubt investigate matters further before agreeing to install a green roof.

Design loads

Also mentioned in the context of the above roof types, the design loads are the critical factor in deciding the type and construction of the green roof. Sedum mat is probably the lightest weight green roof option but there is still a load to consider. The FLL 2008 Guidelines refer to the load at maximum water capacity. This is the FLL Maximum Water Capacity figure given by our data sheets but in practice structural engineers want to know the worst case scenario value which is the Fully Saturated figure. In practice the substrate density normally lies somewhere between the Dry value and the FLL Maximum.

The weight of the water saturated sedum blanket also needs to be taken into account along with the "load generated by any water stored in an integral reservoir will also need to be added to the figures". This is quoted directly from the FLL 2008 as it DOES NOT imply that additional water storage is a requirement of the Guidelines, rather it recognises that additional storage can be provided – *for instance by drainage layer materials.* It is important

to remember that the loading of the roof is not temporarily exceeded during storage of materials during the construction of the roof.

The FLL 2008 Guidelines deal with the construction of the drainage elements, gravel strips etc., and in the section that deals with execution they talk of fittings to the façades it states (6.6.31) *"where vegetation areas are to be created which do not come into contact with the façades, there are different construction options available:*

- *Continuous drainage layer and / or filter layer beneath the vegetation support layer and the safety margin;*
- *Separation of the vegetation support layer and safety margin by means of a surround, e.g. metal grills;*
- *Separation of the vegetation support layer and safety margin, with separate arrangements for water removal;*
- *Installation of drainage conduits functioning as the safety margin".*

Fire Characteristics

A point worthy of note concerning the measures recommended by the FLL 2008 Guidelines is that they make the point that extensive greening is adequately resistant to sparks and radiated heat when a number of properties can be proven. These include a requirement for the vegetation support layer to be of a specific mineral composition and no less than 3 cm deep. Of course there are also the other well-known fire precautions such as the gravel strips, but the key point here is that there is a minimum substrate thickness of a mineral composition.

Attention is also drawn to the UK Government report which provides useful information and guidance on fire and green roofs - https://www.gov.uk/government/publications/fire-performance-of-green-roofs-and-walls.

Requirements for the Construction of the sedum vegetated area

The FLL2008 Guidelines differentiate between the following layers that are encountered in green roofs:

- Vegetation support layer. *This is the substrate layer which builds the basis for the plant growth and must allow good root penetration.*
- Filter layer/fleece. *This is designed to prevent fine substrate particles from being washed out of the substrate and into the drainage layer.*
- Drainage course. *This contains sufficient cavities to take up any excess water which it then channels to roof outlets.*
- Protective layer. *This provides additional protection for the waterproof lining or root-resistant membrane. Providing that suitable materials are used it can also be used as a separation layer.*
- Root-resistant membrane. *This layer stops plant roots or rhizomes from growing into or through the waterproof lining of the roof.*
- Separation layer. *These are to keep chemically incompatible materials apart.*

- Anti-bonding layer. *These are layer materials that are used to prevent unwanted stress between different materials and / or to reduce friction between two layers.*

Although this list of layers implies that each layer might be necessary that is not the stated case as the Guidelines go on to describe different construction types. For instance there is a mistaken belief by many that drainage layers must also include an element of acting as a water reservoir but this is clearly not the case since the Guidelines states simply that they can also fulfil this function.

Quoting the FLL 2008 Guidelines directly section **7.2 Construction techniques, thicknesses** states:

The construction of vegetation areas consist of several functional layers/courses. These layers are made from various materials and fulfil clearly defined roles in the construction. They are combined in a way to achieve full functionality and harmonise together to the best possible effect.

Depending on the material make up, individual courses may satisfy several functional demands.

A distinction has to be made between the following construction types:

- *Multi-course construction, consisting of separate drainage, filter and vegetation support layers, or drainage and vegetation support layer which, through their material composition, perform the filter function as well.*
- *Single-course construction, consisting of a vegetation support layer with a drainage and filter function*

For all types of construction a root-resistant membrane and protection layer are necessary to protect the waterproofing/root-resistant membrane.

This passage in the FLL 2008 permits a wider range of options for installing sedum blanket roofs. On one hand it is permissible to go for a single layer option with the proviso that the substrate should have at least 60mm depth and the substrate should have low organic content (SOM of 4% or less).

The advocacy of simple greening is also to be found in section 7.4 of the guidelines referring to water storage in the context of simple intensive greening.

In the case of thin-course simple intensive greening, it only makes sense to use standing water in the drainage course if additional watering is carried out during periods of low precipitation to avoid drought damage.

The use of standing water for watering arrangements at extensive greening sites has plant physiology drawbacks.

This passage is hardly a ringing endorsement of many drainage layer systems that hold standing water, since once the water is gone from these storage reservoirs there is nothing to aid the plants. It also seems that some irrigation is needed in combination with standing water and this seems to negate any benefit brought by the standing water reservoir. It can

be argued that the equivalent substrate depth can hold the water more tenaciously in the aggregate pores that are integral to the substrate.

Multilayer construction is the other option with a separate drainage course. But in describing suitable drainage materials there is also some latitude that is not widely recognised. In section 8 of the Guidelines different material groups and types of materials are listed with the main objective as already stated to facilitate water run-off, preventing standing water. It may also act as an additional source of water for the plants and provide for increasing the depth available for root penetration.

Material groups and types for drainage course

Aggregates

- Gravel and fine chippings
- Lava and pumice
- Expanded clay and shale, broken and unbroken
- Expanded slate, broken and unbroken

Recycled aggregates

- Tiles, broken
- Slag
- Foamed glass

Drainage matting

- Structured fleece matting
- Studded plastic matting
- Woven fibre matting
- Foam matting

Drainage boards

- Studded rubber boards
- Shaped rigid plastic boards
- Shaped plastic foam boards

Drainage and substrate boards

- Boards made from modified foam.

As an additional note it is stated that the layer materials and dimensions will depend upon construction requirements and objectives for vegetation. Generally for sedum blanket the layer structures are kept relatively thin compared to other types of green roof, but this indicates that if desired there is no specific discouragement from the FLL to have a drainage layer depth compatible with the material used.

It also suggests that if certain products show a characteristic value for thermal performance as specified by the relevant authorities, the green roof could then be considered to have a calculable heat insulation value.

Clearly there are some more defined requirements for the drainage layer materials listed above and these are also listed in a general way but some are not applicable to all of the material types listed above.

- Compatibility of materials – *meaning no adverse chemical or other reactions that may compromise the function of the roof structure*.
- Environmental compatibility – *this includes all aspects, including gaseous emissions.*
- Plant compatibility / risk of phytotoxicity – *mustn't harm or kill the plants.*
- Fire characteristics – *low flammability.*
- Granulometric composition – *low silt and granular size compatible with depth.*
- Frost resistant – *should not be liable to frost damage.*
- Structure and layer stability – *largely specific to drainage mats and boards, they must retain their shape and function*.
- Behaviour under compressive loads – *largely specific to drainage mats and boards. Once laid compression cannot interfere with function.*
- Water permeability – *this is an essential and obvious characteristic and a calculation method is give, but basically water must flow unimpeded.*
- Water-storage capacity / maximum water capacity – *this only applies if a water reservoir is specifically required.*
- pH-value – *the pH value should be similar to the substrate layer (pH 6 to 8.5).*
- Salt content – *this is specific to aggregates the soluble salts are to be avoided.*

In practice most many architects and contractors have the mistaken impression that a drainage mat is an FLL requirement but this is not so. It does not even seem to be a recommendation since the FLL 2008 Guidelines record permissible options for the construction of green roofs.

Various alternative drainage layers are proposed by various people / organisations that are based on recycled materials. For instance, carefully graded crushed hard brick is regularly used by some contractors with good effect. We are supportive of all those that are compatible with the above requirements indicated by the FLL Guidelines, but it is for the suppliers of these to verify and provide evidence of suitability.

Amongst the other layers that may be provided they need to comply and be laid in accordance with the FLL 2008 Guidelines. A filter fleece of some sort or another is normally specified for most commercial drainage layers, but some recycled material drainage layers may not need a filter fleece and this is not contradicted by the Guidelines. Follow any installation instructions provided by the supplier of the drainage layer material.

Substrate types

We offer a range of substrates that are each designed to provide optimal results for the green roofs made with them. This paper deals with sedum blanket construction for which most of our substrates have been used to good effect.

For single layer construction the Guidelines give a limit of 4% for the Soil Organic Content but they state that greater proportion of organic matter may be required where special forms of vegetation, such as humus rooting plants, are used.

Our view is that the default substrate for sedum blanket is our **extensive substrate**, with the others alternative choices where particular circumstance dictates.

If a client demands strict adherence to the letter of the FLL Guidelines chose **simple extensive substrate** for single layer roofs. This avoids any debate about exact conformity to the Guidelines.

For structures described in the section titled “Starting with waterproof roof” as requiring low design loads it may be advisable to opt for **ultralite substrate**, but this depends on the precise loading capability of the roof.

Table 1. *Summary of Soil Organic Material content (SOM), water-holding capacities and bulk density of Shire Green Roof Substrate Ltd substrates.*

	SOM	Maximum Water Holding Capacity	Bulk density kg/m^3		
			Dry Driest days in summer	**FLL At maximum water capacity**	**Fully Saturated**
Simple Sedum	3.7	33%	935	1264	1500
Extensive	6.5	30%	870	1170	1445
Ultralite	6.0	43%	490	924	1014
Intensive	9.2	38%	890	1270	1493
Ultralite Intensive	10	43%	490	924	1014

Sedum blanket can be sold in various forms and with varying number of sedum species. The FLL Guidelines also make it clear that blanket can also have a mixture of sedum with herbaceous plants, sedum with grass species and mixed with grass and herbaceous plants.

Table 2 synthesises Table 2 of FLL 2008 with different types of greening but focusses solely on options with sedum as this indicates the standard course depths for each category of vegetation.

Table 2. *Summary of information given by Table 2 of the FLL Guidelines 2008*

Matting Plants	Depth of substrate bed (cm)													
	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Moss-sedum	■	■	■	■	■									
Sedum-moss-herbaceous plants			■	■	■	■	■							
Sedum-herbaceous-grass plants							■	■	■	■	■	■		

Various blanket types are available within the UK and extend to include wild flower blankets so a correct interpretation of the above can include a more diverse assortment of plant species. Several customers have used **intensive substrate** to good effect on pitched roofs where available depth of substrate has been restricted and the somewhat higher organic content has compensated for lack of depth or in situation where the development of a more diverse set of plants, including grasses is sought in time as the vegetation matures. If there is a loading consideration **ultralite intensive substrate** might be considered instead. Nevertheless, bear in mind that in certain situations (e-g. low pitch or greater substrate depth) this option may result in more grass than desired.

Discussion

Having reviewed what the FLL 2008 Guidelines say about the construction of sedum roofs and others, it is clear that a drainage layer is needed in cases where the pitch of the roof is very low, or flat. In the section on roof pitch the Guidelines state that a gradient of at least 2% should be considered the norm. They further state that controlled drainage will meet the basic needs of the vegetation in extensive greening and since most plants used for extensive greening, including sedum, need good drainage for the wellbeing of the roots it follows that this basic need is for the substrate not to become waterlogged.

The Guidelines go on to caution that below 2% special measures are required for roof dewatering and drainage! Indeed it states *"where extensive greening is being applied to roofs where the gradient is <2%, ponding in the vegetation substrate can form. This can lead to plant failure, vegetation change and foreign plant settling such as sapling seedling."*

Nothing is said about a need for a water reservoir at such low gradients, but it does go on to point out that as the gradient increases, so does the water runoff rate of the roof. Of course the above statement in the Guidelines assume that the owner of the roof does not want waterlogged areas on the roof, but there are instances where this is wanted for instance for a particular vegetation type. But assuming that ponding is not required a suitably formed drainage layer is used to help dewatering the roof where the pitch is low as stated above.

However as pitch increases dewatering is no longer an issue and a properly formulated substrate will not require drainage layer to assist the dewatering process. Nevertheless, some suppliers of drainage layers have allowed a myth to perpetuate that their drainage layers have a dual function of providing a water reservoir for pitched roofs and specifications for green roofs include drainage layer. Most drainage layers are at a higher cost per m^2 than the substrate used, and this is often at the expense of the equivalent thickness of substrate.

For the sake of cost comparison we are assuming a cost of £8 per m^2 for drainage layer (an estimate based on average advertised costs for different brands) and a cost of £90 per m^3, for a sedum substrate. At 60mm thickness the cost of substrate per m^2 is £5.40 per m^2.

We have found the following typical data from online retailers of a well-known brand of "egg carton type" drainage layer material. The product in question is widely used and the data provided online seems to fit well with other brands. The data confirms that the reservoir holds less water as it is laid on a slope and this is a straight forward to understand on the basis of the analogy that if a full cup of water is tipped at an angle some water will run out.

Table 3. *Core storage capacity (l/m$^{2)}$*

Product	Pitch angle (degrees)					
	0°	5°	10°	15°	20°	25°
Drainage layer 20mm	5.7	5.0	4.3	3.6	2.9	2.2
Drainage layer 40mm	14.5	12.5	10.8	9.2	7.8	6.6

The water held at the maximum water holding capacity by the substrate is held more tightly in the pores of the aggregates and on the surfaces so the pitch of the roof does not make

any difference to the water held. It is measured by a method quoted by the FLL that is measured after draining for 2 hours so the value is the same whatever the pitch of the roof.

The water holding capacities of our substrates is given by Table 1 and from this it is possible to compare various scenarios for each substrate. Different customers use different substrate bed thicknesses but when drainage layer is specified they typically use 60mm of substrate so total thickness for 20mm drainage layer is 80mm (20mm+60mm) or for 40mm drainage layer it is 100mm (40mm+60mm), so it is possible to compare the water holding capacity of drainage layer and substrate with 100% substrate of the same overall thickness.

Table 4 and 5 provides this comparison for our substrates and in every case the pure substrate seems to be able to hold more water than replacing 20mm of substrate by the drainage layer.

Table 4. *Comparison of water holding ability measured in kg/m^2 of 20mm drainage layer plus 60mm substrate compared with 80mm of the substrate on its own.*

Product combination	Pitch angle (degrees)					
	0°	5°	10°	15°	20°	25°
Simple Sedum @ 80mm No drainage layer	**26.4**	**26.4**	**26.4**	**26.4**	**26.4**	**26.4**
Simple Sedum @ 60mm + Drainage layer 20mm	25.5	24.8	24.1	23.4	22.7	22.0
Extensive @ 80mm No drainage layer	**24**	**24**	**24**	**24**	**24**	**24**
Extensive @ 60mm + Drainage layer 20mm	23.7	23.0	22.3	21.6	20.9	20.2
Ultralite @ 80mm No drainage layer	**34.4**	**34.4**	**34.4**	**34.4**	**34.4**	**34.4**
Ultralite @ 60mm + Drainage layer 20mm	31.5	30.8	30.1	29.4	28.7	28.0
Intensive @ 80mm No drainage layer	**30.4**	**30.4**	**30.4**	**30.4**	**30.4**	**30.4**
Intensive @ 60mm + Drainage layer 20mm	28.5	27.8	27.1	26.4	25.7	28.0
Ultralite Intensive @ 80mm No drainage layer	**34.4**	**34.4**	**34.4**	**34.4**	**34.4**	**34.4**
Ultralite Intensive @ 60mm + Drainage layer 20mm	31.5	30.8	30.1	29.4	28.7	28.0

The are other factors to consider in deciding substrate depth and this might depend on the Soil Organic Material (SOM) but it is clear that as the pitch increases the 100% substrate option offers for water holding as the drainage layer holds less water.

Table 5 shows the same comparison but with 40mm drainage layer and in this scenario the results with completely flat roofs the best result can be obtained with 40mm drainage layer, but this advantage is lost with steeper pitch. In the case of the substrates with more water holding capacity, that is Ultralite, Intensive and Intensive Ultralite the greatest water holding is with 100% substrate, even with 0° pitch.

Table 5. *Comparison of water holding ability measured in kg/m^2 of 40mm drainage layer plus 60mm substrate compared with 100mm of the substrate on its own.*

Product combination	Pitch angle (degrees)					
	0°	5°	10°	15°	20°	25°
Simple Sedum @ 100mm No drainage layer	33	**33**	**33**	**33**	**33**	**33**
Simple Sedum @ 60mm + Drainage layer 40mm	**34.3**	32.3	30.6	29.0	27.6	26.4
Extensive @ 100mm No drainage layer	30	30	**30**	**30**	**30**	**30**
Extensive @ 60mm + Drainage layer 40mm	**32.5**	**30.5**	28.8	27.2	25.8	24.6
Ultralite @ 100mm No drainage layer	**43**	**43**	**43**	**43**	**43**	**43**
Ultralite @ 60mm + Drainage layer 40mm	40.3	38.3	36.6	35.0	33.6	32.4
Intensive @ 100mm No drainage layer	**38**	**38**	**38**	**38**	**38**	**38**
Intensive @ 60mm + Drainage layer 40mm	37.3	35.3	33.6	32	30.6	32.4
Ultralite Intensive @ 100mm No drainage layer	**43**	**43**	**43**	**43**	**43**	**43**
Ultralite Intensive @ 60mm + Drainage layer 40mm	40.3	38.3	36.6	35.0	33.6	32.4

Overall looking at the data presented in tables 4 and 5 we see values of water holding between 20.2 kg/m^2 and 43.0 kg/m^2 but there seems to be no test data published that tells us what this means in terms of the health of a sedum roof. Intuitively, one may imagine that the more the better but at the same time is there a point that there can be too much water held… This may be a good topic for a research team to derive the optimum for the good health of sedum.

Another, aspect of this comparison is relative cost (Table 6) of a simple single layer solution assuming the same price for all the substrates and that the drainage layer is the same price irrespective of depth. We normally recommend at least 60mm of substrate and certainly not less less than 40mm of substrate.

Table 6. *The relative cost per m2 of different Drainage Layer and Substrate combinations*

Total thickness	Substrate only	20mm Drainage layer plus Substrate	40mm Drainage layer plus Substrate
100 mm	£9.00	£15.20	£13.40
80 mm	£7.20	£13.40	£11.60
60 mm	£5.40	£11.60	Not recommended
40 mm	£3.60	Not recommended	Not recommended

Considering what is stated by the FLL Guidelines 2008, the water storage capacity and cost of various options we feel that it is entirely justified to install sedum roofs with simple, single layer structures with drainage layers only used where there is a need to improve roof dewatering.

Closing Comments

Various interpretations are expressed about the FLL Guidelines 2008 and these views can reflect some commercial interest of the suppliers concerned. The choice of how to construct sedum roofs is that of the client, specifier/architect and contractor but a careful reading of the Guidelines is recommended to all those interested in green roofs and in some cases this will dispel certain myths that have evolved about how sedum mat roofs should be constructed.