

GREEN ROOF SYSTEMS

In Germany there is a large number of system suppliers on the market.

An evaluation of the building materials available based on brochures and product data sheets published by the suppliers reveals that the various materials can hardly be compared with one another. On the one hand manufacturers refer to different standards and the test methods are different. On the other hand the people evaluating the products are often not aware of the requirements made of the building materials.

But help is in sight in the form of the building materials data sheets to be published next year by the Association for Greening Buildings (FBB Baustoffblätter). The standardisation of entries in these data sheets means that a direct comparison of building materials is possible. Additionally, the values given are allocated as far as possible to the corresponding standards and guidelines, so that planners and anyone preparing to award a contract can consult an excellent reference work.

However, planners not only have to select high-quality building materials while taking account of cost aspects. They must also choose the type of construction and/or the roof greening system.

Criteria for choosing the system

The following criteria for choosing the system are most important from a plant-physiological point of view:

- size of the root space
- quantity of water available to the plants
- type of water supply and storage
- nutrient supply over the short and long term
- long-term behaviour of the vegetation bearing layer and
- care requirement.

The following criteria relating to roof safety must be added to this list:

- protection of the sealing
- weight load
- drainage
- erosion behaviour
- working methods during installation.

This article will not evaluate the various roof greening systems. Each system has its advantages, and the market decides through free competition how well they sell.

However, we do recommend that parties who issue invitations to bid and who award contracts should view several large reference objects with the same system before opting for a particular system. That is because the real performance of the system can

only be seen in a practical example. Every construction contract should include approval of the vegetation in accordance with the FLL guidelines. What's more it would be a good way of driving a few black sheep out of the market if towns and municipalities which promote roof greening in their construction regulations would demand bank guarantees to the amount of the building sum for the roof greening from the property owners. In this way, the authorities could check after a certain period of time whether a correctly installed green roof has actually been built. If after a period of two years the necessary degree of cover has still not been established on the roof surface it can be assumed that the gardener entrusted with the job is not in a position to achieve this with the system in place.

Roof greening systems are available with loads of 24 kN/m² in a water-saturated condition. However, planners and parties awarding contracts should be aware before awarding the contract of what the vegetation will look like after a few years. That means there should be clear instructions in the invitation to bid about what kind of vegetation is required.

The roof greening options available range from greening with mainly mosses to some succulents (such as various types of sedum) and herbs on roofs with light boarding to underground garages with roofs resembling parks including large individual trees. Using the technology available today it is possible taking into account the demands of the vegetation to create almost any kind of vegetation on flat or slightly sloping roof surfaces.

Roof greening is carried out up to a roof inclination of about 45 degrees. However, when planning and installing green roofs it is important to appreciate that the work will be carried out on a roof surface. This means that all aspects relating to the vegetation are secondary to the roof safety in terms of stability and preventing water from leaking into the building.

In the following discussion of construction methods only a few well-known system manufacturers or product names which are well established on the market will be named (in brackets) as examples. Considering the large number of suppliers, giving any more examples would make this article too long.

Single-layer method

What is meant by the single-layer method is a single vegetation-bearing layer that is simultaneously the drainage layer. As a rule this is blown onto the roof as an extensive greening system in a layer thickness of 8 cm on top of a rot-resistant protective felt with a material weight of approx. 300g/m².

A difference has to be made between pure mineral substances, mineral mixes without organic substance and mineral mixes with a small proportion of organic substance. The capacity for storing water available to the plants, pF 1.8 - pF 4.2 and the long-term nutrient supply are two of the most important measures of quality.

As a rule the mixes without organic substance are superior to the pure mineral substances. Mixes with organic substance are usually superior to those without organic substance on roofs with an adequate inclination. However, mixes with organic substance on flat roofs where water puddles form cause substrate wetness after rainfall, which results in the vegetation in these areas dying off. Because the materials used in

the single-layer version simultaneously act as the vegetation bearing layer and the drainage layer, the drainage is limited (Bauder, Optima).

The liquid application of a mineral mix with organic substance plus a certain content of adhesive materials represent a special type of single-layer system. This system is generally supplied in a layer thickness of 2 cm (Xeroflor).

Things to look out for with any single-layer system are the correct salt content and the environment-friendliness of the materials.

Mulch layers (two-layer method)

Generally speaking, single-layer systems with a mulch layer produce better vegetation results than single-layer pure mineral systems and mineral mixes with organic substance. The fine-grain but filter-stable layer of mineral mix with organic substance, or pure mineral substance gives seeds and sedum shoots a better chance of germinating and rooting. Total layer thickness: usually 7-8 cm. (Zinco)

A special form of single-layer system with a mulch layer is also available, with the mulch layer sprayed on. (Bauder, Xeroflor)

Multiple-layer systems

All multiple-layer systems feature separate drainage layers and vegetation bearing layers. That means both of the layers are optimised for their particular function. As a rule the vegetation-bearing layer has a nutrient content which is available over a longer period of time than that in the materials used in single-layer systems. Apart from the N, P, K and Mg contents listed in the substrate certificate, what is important is the nitrogen available over the long term in the rooting zone of the vegetation bearing layer.

Multiple-layer systems are used for extensive, simple intensive and complex intensive greening projects. Where the roof only has a low load-bearing capacity, systems with a water storage function open up design opportunities otherwise only available at ground-based locations. Roof greening substrates can be blown on, making it easier to actually get them onto the roof surface. Underground car parks and roofs which can bear heavy loads can be covered with drainage layers strong enough to withstand loading vehicles driving over them, and these layers ensure adequate protection of the roof sealing as well as good drainage.

Where the vegetation-bearing layer has a thickness of approx. 40-cm and more over large, continuous areas, it is possible to use humus-rich, sandy and improved topsoil

Systems with drainage mats

Drainage mats are supplied in rolls and laid on top of the root-resistant roof surface. Depending on the system used, they are then covered with a layer of felt, or the filter felt is already attached to the drainage mat. Drainage mats protect the sealing against mechanical damage. Some types store additional water in cavities in the filter layer or in the material of the drainage mat. As a rule, simple extensive greening systems have a 6-7 cm thick layer of substrate with organic content. Depending on the type of system, the

drainage mats used for complex intensive greening projects can be driven on with loading vehicles after these have applied substrates or topsoil at the front, ahead of their own wheels. Several system suppliers market their products with an emphasis on the protective layer.

It is important to check the level of protection, pressure resistance, drainage capacity and flammability. A protective felt covering must be used where there are hard materials with sharp edges or a risk of chemical reactions between high-polymer sealing materials and drainage mats.

Combination panels / mats

Instead of drainage mats, these systems use capillary-action water-retaining panels or mats which the roots can penetrate and which feature corrugations on the underside so that the excess water drains off. The drainage and substrate panels or mats consist of mineral fibres or thermally/chemically bound PUR soft foam chips. Some makes contain integrated fertiliser. Depending on the material used and the system supplier the combination drainage and substrate panels/mats are used with or without a filter felt layer underneath the substrate. Usually these drainage and substrate panels/mats, mainly used in extensive greening, are covered according to the location with a minimum layer of 3-4 cm of substrate. If the cover is too thin the panels or mats made of PUR soft foam tend to shrink as a result of thermal influences. So-called rootstock weeds with underground shoot parts (rhizomes) or residual roots from weeds with strong sprouting behaviour are difficult to remove. Mineral wool mats with an insufficient material density tend to become irreversibly compressed following pressure applied when they are wet. The water retaining capacity of the rock-wool material improves if the panels are laid exactly horizontally. Drainage and substrate panels or mats made of rock wool are 100% recyclable. Systems with combined drainage and substrate panels/mats are characterised by their low weight on the roof. (Daflor, Grodan, Icoflor, Tektoflor)

With drainage panels

Multiple layer systems with drainage panels are subject to the same principles as described in the section "Multiple system with drainage mats". Compared to drainage mats of the same type, their drainage performance is better because of the increased thickness of the panels. The greater overall height means that there is less risk of the vegetation layer being affected by puddles on flat roofs. During cold weather it is easier to handle the panel form of these elastic materials, which are manufactured by the deep-drawing method, than the rolls of similar drainage mats. There are a large variety of very different plastics used to manufacture drainage panels and some of them also store water in smaller cavities. Contrary to the water storage/drainage elements, which are provided with a large water store, the main function of drainage panels is to drain off water. (Bauder, OBS, Zinco)

Substrate panels / mats plus drainage layer

This type of system is overwhelmingly used for simple and complex intensive greening of roofs with a low load-bearing capacity. In contrast to combination drainage and substrate panels/mats the drainage layer here is always separated from the vegetation-bearing layer by means of a filter felt. Some systems have round planting holes cut in the material - mineral wool or thermally/chemically bound PUR soft foam chips - so that the plants are planted directly in the material. Alternatively, the substrate panels/mats serve as a weight-reducing water store underneath the substrate layer. Where the vegetation is planted in holes in the panels, the surface is mulched with inorganic bulk substances

or mixes without organic substance. This system requires regular fertilisation with multiple-nutrient fertiliser with a longer-term effect and a balanced application of trace elements. (Daflor, Grodan, Icoflor, Tektoflor, Plantener)

Water storage/drainage elements made of hard plastic

Generally, water storage/drainage elements made of deep-drawn plastics are provided with water retention hollows and openings for drainage, ventilation and diffusion. A continuous canal system ensures efficient drainage. These pressure-resistant elements are used, according to the size of the water storage volume, in extensive greening, in simple intensive greening and in complex intensive greening. There are three types:

1. The water retention hollows fill up exclusively with water and are covered by a filter felt and substrate layer consisting of a mineral mix with organic substance for extensive or intensive greening.
With this system the water in the store reaches the vegetation-bearing layer through diffusion and condensation as the substrate cools down during the night. The water store holds water for a long time and is independent of the capillary conditions in the vegetation-bearing layer. As a rule, the vegetation-bearing layer remains drier than in systems with capillary water supply and, depending on the layer thickness and water storage volume of the elements, it is suitable for extensive and intensive roof greening.
2. The water retention hollows are filled with bulk substances or mixes without organic substance and without any filter-felt covering. The usual method here is to apply a substrate consisting of a mineral substance mix without organic substance for extensive greening.
Here, the water in the hollows is transported into the vegetation-bearing layer above by means of the capillary effect. After rainfall it remains longer in the saturation area $pF_0 - pF_{1.8}$ than would be possible in the relatively coarse-grain substrate without organic substance with free drainage. This means the root level remains moist for longer. This version is combined with water storage/drainage elements for extensive greening which have a relatively small water store.
3. The water retention hollows are filled with bulk substance mixes without organic substance but covered with a filter felt. The substrate applied on top of this consists of a mineral mix with organic substance for intensive greening.
This system, using elements with large water storage cavities, is used for simple and complex intensive greening.
After rainfall, the capillary water supply from the water storage cavities keeps the substrate moist for longer, and an additional feature of this system is often that water is stored above the sealing layer for a long-term water supply to the vegetation bearing layer and therefore the vegetation. (Zinco)

Water storage/drainage elements made of foam plastic

This system includes two of the three types already described under the section on multiple layer systems with water storage/drainage elements made of hard plastic.

1. The water storage hollows are filled exclusively with water with a filter-felt covering and substrate consisting of mineral mix with organic substance, for extensive or intensive greening.

2. The water storage hollows are filled with bulk material or bulk material mixes without organic substance without a filter-felt covering. The substrate consists of a mineral mix without organic substance for extensive greening.

An additional advantage is the heat insulation effect of the water storage/drainage elements from some system suppliers, a feature, which is approved by construction supervisory authorities. The flame-resistant expanded polystyrene elements with a high density are water storage, drainage and protection layer in one. On non-ventilated roofs with heat insulation (warm roofs) the roof sealing is enclosed on both sides with materials with the same or similar expansion behaviour. The additional heat insulation effect means that the roof surface is subjected to more even and lower temperatures than is the case with many other systems of the same layer thickness.

Usually a roof-sealing contractor lays the elements where no filling with bulk mixes is required. Once the elements are filled with water the roof surface is protected and there is a clear separation between the trades of roof sealing and roof greening. The multiple-layer method with foam plastic water storage/drainage elements is suitable for extensive greening as well as simple and complex intensive greening.

A separating sheet of felt must be laid underneath the elements when they are used on root-resistant PVC soft roof membranes with less thick vegetation bearing layers. If these elements are to be used for complex intensive greening, their pressure resistance should be tested. If the water retention chambers are filled with bulk substances or bulk mixes a protective layer of felt should be laid underneath the elements to prevent grains of the bulk material from getting into the building substance below. (Daku, Zinco)

Drainage and vegetation bearing layer made of bulk building materials

The multiple layer method with drainage and vegetation bearing layer consisting of bulk material is the method with which most experience has been gained in roof greening. Almost all other systems use plastic products for the drainage layer, whereas here high-pore mineral bulk materials are used. This method makes it easy to smooth out uneven roofs or unwanted slopes. Depending on the height of the system this method is used for extensive greening, simple or complex intensive greening.

Where it is used for extensive greening, the drainage layer is also penetrated by the roots in the course of time, making it also available to the plants as root space.

Frequently with simple or complex intensive greening, the roof area is fully or partly dammed up with water using solitary wooded areas. Irrigation with control systems that work according to the pressure/float principle is a good way of achieving inexpensive automatic irrigation for intensive green roofs. The distance between the water surface and the filter felt depends on the capillary behaviour of the bulk substance used in the water storage/drainage layer and the capillary performance of the vegetation bearing layer consisting of a material mix with organic substance. In order to increase the drainage performance of the drainage layer, improve the water distribution speed and increase the water catchment area on large roof areas, drainage pipes are installed. As the water supply depends entirely on the capillary performance of the water storage/drainage layer and the vegetation bearing layer, the water damming height should be reduced after a few years and the dammed water completely removed in winter. (Optima)

Sloping roofs

Usually, where the roof surface is sufficiently rough, roof greening structures are not provided with slippage barriers on the roof surface at inclinations of up to 20 degrees where the distance between the ridge and the eaves is small and on slopes of up to 15 degrees where this distance is long. Roofs with greater inclinations must be provided with special devices to prevent vegetation-bearing layers of bulk material from slipping. Depending on the type of use, the transition between structural methods and parts for other structural methods is fluid.

Whenever a sloping roof greening system is considered, the quality demands on the system should be precisely checked. The vegetation required should be specified in the invitation to bid alongside the degree of cover. After the seeds and shoots have been planted, the approval of the vegetation should only take place with a projective soil covering of 60 percent. Where pre-cultivated vegetation mats are used, the vegetation should be approved at the earliest three months after installation within a growth season. The roof exposure should be taken into account when selecting the vegetation. Although these roofs require hardly any care if they are properly installed, it is expedient to provide fixing points on very steep roof surfaces for the safety of maintenance personnel in future.

Pre-cultivated, tension-proof vegetation mats

Unlike vegetation mats with parts subject to rotting, pre-cultivated, tension-proof vegetation mats have a core of rot-proof plastic mesh or looped fabric. Mineral bulk mixes with organic substance are filled into this three-dimensional structure and prevented from slipping out by the roots of the vegetation. These vegetation mats are laid on top of the vegetation bearing layers of other systems. The structural methods available include direct laying on top of the roof sealing in a layer thickness of approx. 2.5 cm. Thicker pre-cultivated, tension-proof vegetation mats are also available which contain integrated mineral mixes with organic substance as well as substrate mats. Tension-proof vegetation mats can be rolled over the roof ridge of sloping roofs and laid on both sides of saddle roofs. The mats can be fixed to the roof ridge of pitch roofs. (Optima, Xeroflor)

Roof coverings suitable for greening

The latest products on the market are roof coverings, which are laid like roof tiles onto roof battens. These plastic elements are divided into compartments so that the substrate cannot slip off. Pre-cultivated elements are available for sloping roofs. Another option is covering the substrate with pre-cultivated vegetation mats. (Atka, OBS)

Sloping roofs

Security against slipping

Slippage prevention systems made of recycled plastic are available for greater roof inclinations and higher substrate thicknesses. They consist of barriers and barrier supports. The barriers are inserted into the supports at varying intervals according to a pre-determined pattern to suit the inclination of the roof. This prevents the substrate from slipping. It is advisable on steeper roofs to cover the vegetation-bearing layer with a pre-cultivated, tension-proof vegetation mat. Roofs with inclinations of up to 45 degrees can be greened in this way. (Daku, Optima)

Conclusion

Plant-physiological criteria are the dominant factors in selecting the system to use. They include: size of the root space, quantity of water available to the plants, type of water

supply and storage, short and long-term nutrient supply, the long-term behaviour of the vegetation bearing layer and the care requirement. Important factors from the viewpoint of roof safety are the protection of the sealing, the weight load, the drainage, the erosion behaviour and the method of installing the roof greening.

An exact description of roof greening systems for greening flat, slightly inclined and sloping roofs in the form of extensive greening, simple intensive greening or complex intensive greening provides an overview of the materials and systems used. The FBB building materials data sheets, published at the beginning of 1999, provide help in assessing the quality of the materials that can be used.

Single layer system

Mineral bulk material or Mineral bulk material mix without organic substance or Mineral bulk material mix with organic substance

Single layer system with mulch layer

Extensive or Mineral bulk material

Multiple-layer system with drainage mats

Extensive or intensive

Filter layer, geo-textiles

Drainage mats

Multiple-layer system with combined drainage and substrate panels/mats

Extensive

Filter layer, geo-textiles

Drainage and substrate panels/mats

Multiple-layer system with drainage panels

Extensive or intensive

Filter layer, geo-textiles

Drainage panels

Multiple-layer system with substrate panels/mats and separate drainage layer

Mulch layer

Drainage and substrate panels/mats

Substrate panels/mats

Filter layer, geo-textiles

Bulk material

Multiple-layer system with hard plastic water storage/drainage elements

Water store

Water dam (depending on the system)

Filter layer, geo-textiles

Drainage element, hard plastic

Extensive or intensive

Multiple-layer system with foam plastic water storage/drainage elements

Water store

Filter layer, geo-textiles

Drainage element, foam plastic

Extensive/mineral bulk material

Multiple-layer system with bulk building material drainage and vegetation bearing layer

Water dam (depending on the system)

Filter layer, geo-textiles

Bulk material

Extensive or intensive

Pre-cultivated, tension-proof vegetation mats

Tension-proof pre-cultivated vegetation mat

Roof coverings for greening

Mineral bulk material with or without organic substance, extensive

Roof covering suitable for greening

Sloping roof slippage protection

Mineral bulk material with or without organic substance, extensive

Slippage protection consisting of barriers and supports

1. Mineral bulk material mix with organic substance
2. Mineral bulk material mix without organic substance