Green Infrastructure Fact Sheet

Substrates for green roofs

Green Infrastructure Research Group

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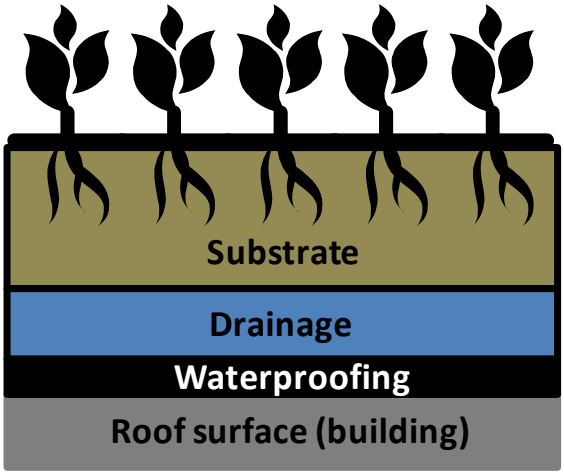
How are green roofs constructed?

Green roofs are gardens constructed on the roofs and podiums of buildings. A typical green roof profile has three layers; a waterproofing layer at the base (to protect the building), a drainage layer (to ensure water run-off), and a substrate layer (to support plants). Usually, a geotextile separates the drainage and substrate layers, to prevent clogging.



What is a substrate?

Green roof substrates provide a growing medium for plants and are critical to success. Most substrates are specifically designed to meet performance requirements that will support plant growth, drain readily, and hold water. To ensure these outcomes and other requirements, green roof substrates are usually mineral-based mixes. Alternatives, such as potting mix substrates with large proportions of organic components such as pine bark, can result in poor plant performance through decomposition and shrinkage over time.

To maximize the environmental benefits of green roofs, mineral-based substrates often utilise recycled or waste components, such as crushed roof tiles and brick. The exact composition of substrates will vary according to local availability of materials. For example, many components used in European and North American green roofs are either not available or not feasible (e.g. cost) for use in Australia[1].

Requirements of green roof substrate

- Holds enough water and nutrients to support plant survival and growth.
- Free draining and good aeration; so that plant roots are not saturated and plants are able to respire.
- Lightweight; so that the green roof is not too heavy for the building.
- Stable (chemically and physically) and long-lasting; so that the substrate does not have to be replaced regularly.

How important is substrate depth?

Substrate depth is linked to the type of green roof; described as either intensive or extensive. Intensive green roofs have relatively deep substrates (> 20 cm), while extensive green roofs have substrates less than 20 cm deep. Usually, green roofs retrofitted to existing buildings are extensive, because weight loading restrictions limit the potential depth of the substrate.

Typical mineral-based substrate materials in Europe and North America

- Recycled crushed brick & roof tiles.
- Steel mill slag.
- Light expanded clay aggregate (LECA).
- Pumice; light volcanic rock.
- Heat expanded shale & slate.

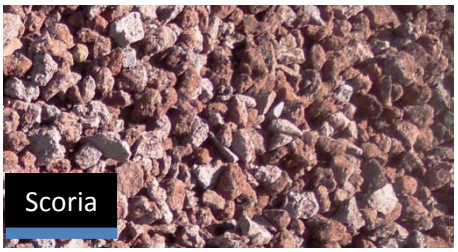
Characteristics of the two types of green roof

	Extensive	Intensive
Substrate depth	Less than 20 cm	More than 20 cm
Typical vegetation types that are supported	Succulents, herbs, grasses	Grasses, perennials, shrubs, trees
Structural reinforcement of building required?	No, or little	Yes
Irrigation and maintenance required?	No, or little	Yes

[1] Williams, N.S.G., J.P. Rayner, and K.J. Raynor, *Green roofs for a wide brown land: Opportunities and barriers for rooftop greening in Australia.* Urban Forestry and Urban Greening, 2010. **9**: p. 245-251.

The shallow depth of the substrate means that water availability can fluctuate dramatically, particularly following periods of very low or very high rainfall. Together with the physical properties of the substrate, this makes green roofs a tough environment for plants to prosper. In Europe and North America, substrate depths may be as little as 3 cm. It is unlikely that any plants could grow in less than 10 cm of substrate in Australia's drier conditions, unless irrigation is provided[2]. Many green roofs with substrate depths between 10 and 20 cm depth will still require supplementary irrigation using harvested rainwater or recycled water.

Substrates research at Burnley


Scoria

Research at Burnley has mainly focused on evaluating mineral and recycled materials. Crushed roof tiles have proven to be a successful component for use in a number of mixes, but two products in particular have shown promise for more widespread use in green roof substrates across Australia; scoria and furnace bottom ash. Scoria is a lightweight volcanic rock similar to, although heavier than, pumice. Pumice is widely used across European green roofs. Scoria has excellent physical properties, and is very accessible and comparatively cheap in Melbourne. Furnace bottom ash is produced by burning black coal for electricity (in power stations). Its light weight and range of particle sizes make it an ideal material for green roofs.

The performance of these substrates has been assessed in a greenhouse experiment[3]. Three different substrates were tested; each comprising crushed roof tiles, scoria or bottom ash at 80%, and then 20% composted coir (coconut fibre). The three substrates differed in their physical and chemical properties. The bottom ash substrate had a significantly greater water holding capacity than either the scoria or roof tile mixes. This is particularly important for plant survival. Under drought conditions, plants survived 12 days longer in the bottom ash than in the scoria. Also of note in this experiment was that the *Sedum* species survived significantly longer than the other two species that were tested (see the "Planting for survival" Fact Sheet).

Performance criteria of the three substrates

	Water holding capacity (%)	Air-filled porosity (%)	Bulk density (g cm^{-3})
Scoria	45.9	13.8	1.26
Roof tile	44.0	7.14	1.56
Bottom ash	51.7	7.65	1.11

Number of days that plants survived in the three substrates during 113 days of drought

Species	Scoria	Roof tile	Bottom ash
Carpobrotus modestus	72	82	99
Disphyma crassifolium	67	81	81
Sedum pachyphyllum	113	113	113
Sedum spurium	102	95	103
Sedum clavatum	95	113	113

Recommendations

To assist plant survival in hot and dry climates, green roof substrates should have a high water holding capacity. Further studies have found that plant survival was greater with the increased plant available water that came from increased water holding capacity, or from deeper substrates. Lightweight substrates with a high water holding capacity should continue to be developed to improve plant survival and broaden the range of species suitable for green roofs. This can be aided with the use of water retention additives such as hydrogel or biochar (see the "Additives for green roof substrates" Fact Sheet).

[2] Farrell, C., et al., *Hot, high, dry and green? Research supporting green roof plant selection for arid environments*, in *CitiesAlive!: 10th Annual Green Roof and Wall Conference*. 2012: Chicago.

[3] Farrell, C., et al., *Green roofs for hot and dry climates: Interacting effects of plant water use, succulence and substrate.* Ecological Engineering, 2012. **49**: p. 270–276.

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