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GREEN ROOFS — AN OVERVIEW

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- Green roofs have become an increasingly common feature in the 'greening' of cities, especially in Europe and the United States of America.
- Although the technology is not particularly complicated, care needs to be taken in design and construction.
- This *Bulletin* presents an overview of design considerations for green roof systems.

1.0 INTRODUCTION

1.0.1 Green roofs are basically roofs with plants. Also described as 'ecoroofs' or 'living roofs', they are characterised by plants growing in an (often) lightweight growing medium over a waterproof membrane.

1.0.2 Green roofs are not new – there is a long history of sod roofs in Scandinavia and the Faroe Islands, where peat sods and turf provided insulation.

1.0.3 Since the 1980s in Germany and since the 1990s in the USA, there has been a proliferation of green roofs spurred by an increased awareness of their environmental benefits.

1.0.4 While they have desirable attributes, green roofs can be expensive to build and maintain. Many cities in Europe and the USA offer incentives such as reduced levies for stormwater collection or direct monetary subsidies for developers who offer green roof projects.

1.0.5 Many recent examples of green roofs smaller than 250 m^2 can be found in New Zealand, but in the USA, Canada, London and Germany, very large roofs and multi-roof complexes are increasingly common. In a village of nine city blocks constructed for the 2010 Winter Olympics in Vancouver, British Columbia, half the buildings have green roofs. Chicago's 10-hectare Millennium Park is built on a concrete roof deck over a car park and railway tracks.

1.0.6 There is no New Zealand standard for green roofs. However, on-going research is being carried out in New Zealand on lightweight green roof technology and environmental benefits, led by The University of Auckland and Landcare Research.

2.0 ADVANTAGES OF GREEN ROOFS

2.0.1 Green roofs offer benefits ranging from local microclimate level to catchment and city scale.

2.0.2 Green roofs, particularly on low-rise buildings, can contribute to a reduction of the 'urban heat island' effect. Their reduced solar reflection counters the increased temperature of urban hard surfaces.

New Zealand toilet block with a green roof.

2.0.3 Research at The University of Auckland shows that even 50 mm deep green roofs retain 50–70% of rainfall within the substrate. The effect is better stormwater management through a more gradual release of excess water and less water is directed to drains.

2.0.4 The high air-filled space in modern lightweight substrates provides some insulation value. Rigid thermal insulation can be easily incorporated into green roof structures to improve a building's energy efficiency.

2.0.5 Internationally, a benefit of green roofs is improved long-term performance of the roof structure because it is protected from ultraviolet radiation and extremes of temperature. Because the roof membrane is not readily accessible for repair or replacement, it must meet the 50-year durability requirement of the New Zealand Building Code.

2.0.6 Green roofs can provide therapeutic value and, where accessible to building users, a useful recreational space or a peaceful environment.

2.0.7 Plant communities on rooftops can provide much needed habitat for animal life in urban environments, especially under low-maintenance (low-disturbance) regimes.

2.0.8 Soil and plants absorb sound. For example, the reduction in sound levels provided by green roofs has benefitted a primary school near Queenstown airport (reducing noise getting in) and the Tasmanian University student centre (reducing noise getting out).

3.0 TYPES OF GREEN ROOFS

3.0.1 Green roofs are classed according to soil depth.

3.0.2 Extensive green roofs have a shallow substrate about 75–150 mm deep and a weight of 75–200 kg/m^2. Because of the lighter supporting structure required, extensive roofs are reasonably economical, and even timber-framed roof construction may be adequate to support such loads. A thin substrate can store very little water and cannot support plants taller than 100–300 mm, so irrigation is usually required and appropriate plants must be selected.

3.0.3 Intensive green roofs have a deeper soil profile of more than 200 mm. This means that a greater range of plants can be considered. The heavier structure required to support the weight of deeper soils and plant material results in higher initial costs. Intensive roofs are often used for landscaped terraces over underground car parks and can accommodate lawns, shrubs and even trees.

3.0.4 Trees will require at least 300 mm and usually 500–1000 mm of substrate, possibly in localised areas. Alternatively, larger specimen planting can be accommodated in planters or tubs. The increased concentrated loads need to be considered in the structure design.

4.0 DESIGN CONSIDERATIONS

4.1 STATUTORY REQUIREMENTS

4.1.1 The design of a green roof will normally be submitted as part of a building consent application as an alternative method. If accepted, the design will become an Alternative Solution when consented.

4.1.2 The consent application will need to address the following New Zealand Building Code clauses:

- B1 *Structure*: The green roof design should take into account the combination of both dead and live loads likely to be encountered during construction (or future alteration) for the duration of its existence.
- B2 *Durability*: "… building materials, components and construction methods shall be sufficiently durable to ensure that the building, without reconstruction or major renovation, satisfies the other functional requirements of this Code throughout the life of the building. The main roof components must be provided with a durability of not less than 50 years …"
- D1 *Access routes*: Where green roofs are accessible, Building Code requirements for adequate and safe access routes, including provision for disabled persons, must be considered. Acceptable Solution D1/AS1 describes in detail the various design requirements for access paths, ramps, stairs, handrails and slip resistance of surfaces.
- E1 *Surface water*: Green roofs must be constructed to collect and dispose of surface water in a way that protects people and other property.
- E2 *External moisture*: Green roofs must be designed to shed precipitated moisture.
- H1 *Energy efficiency*: Building Code requirements for energy efficiency may or may not apply, depending on whether or not the green roof encloses work spaces or habitable spaces. Significant exceptions are listed in NZBC clause H1, where thermal insulation is not critical. These include assembly service buildings, industrial buildings, outbuildings or ancillary buildings. Where required, rigid thermal insulation (such as polystyrene or polyurethane) can be readily incorporated into the green roof design.
- F4 *Safety from falling*: Roofs with permanent access must be provided with continuous safety barriers of approved design. Barriers must also be provided where falls of 1 metre or more could occur. The Acceptable Solution F4/AS1 describes types of barriers and height requirements.

4.2 STRUCTURAL REQUIREMENTS

4.2.1 The building structure's loadbearing capacity must be increased to take into account the added weight of substrates, the amount of water retained by the system, plants and, where applicable, snow. Point loads produced by such items as trees, planters, tubs and water features must also be considered. Where the roof is accessible, live loads (of say 1.5–2 kPa) produced by green roof users must also be considered, or green roof areas must be isolated from accessible areas. During the construction phase, care must be taken to avoid concentrated point loads, particularly from substrate mounding. Advice from a structural engineer is essential.

4.2.2 On steeply pitched roofs, battens and edge restraints (essentially a heavy bargeboard fixed to angled brackets) should be included in the design to resist shear forces between the soil and underlying structure. Although steeply pitched green roofs are quite common in Europe, the technology should be applied with extreme caution on roof pitches over 10–15 degrees.

4.3 VISUAL ASPECTS

4.3.1 A building's appearance can be enhanced when the green roof can be seen from a higher view point. Green roofs (and green walls, too) can help to visually integrate buildings with the landscape. Buildings with green roofs may be designed to almost completely merge with the surrounding landscape. This approach is common in areas with outstanding natural landscapes.

4.3.2 Planting design should consider the viewer's aspect. Roof gardens are mostly viewed from the roof itself or from windows that face the green roof area. Careful design can feature view shafts from windows or entryways.

4.3.3 Where the green roof garden is viewed from above, planting design can take into consideration patterns and colours, textures, clusters or groupings (formal or informal) or natural swathes.

4.4 SAFETY AND ACCESSIBILITY

4.4.1 Where roofs are accessible, access routes must meet the requirements of Building Code clause D1, and barriers complying with clause F4 may be required at the perimeters of roof areas. NZS 4121 *Design for access and mobility: Buildings and associated facilities* details mandatory provisions for accessible paths, stairs and ramps for disabled persons, but these requirements should be applied generally.

4.4.2 Where roof areas are not accessible to building occupants, some form of edge barrier system (and how it might be incorporated in the roof design) or restraint system may need to be considered for the safety of maintenance personnel. Planting need not extend to the exterior building line (to form a drainage edge, for example), and some form of parapet may provide adequate protection.

4.5 COSTS

4.5.1 As an example the extensive roof at a civic centre in Auckland completed in 2006 is estimated to have cost $192 per square metre for elements specific to the green roof. The intensive green roof areas at a Wellington convent completed in 2010 (including drainage cells, soils, planting and mulch) had an estimated cost of $170 per square metre. The figures quoted do not include costs for additional structure.

4.5.2 Budgeting should also consider life cycle costs including maintenance.

4.6 WARRANTIES AND INSURANCE

4.6.1 Because of the potential risks associated with green roofs, warranties and insurance should be carefully considered. Limiting responsibility for construction and initial maintenance of the green roof to a single main contractor minimises risks.

5.0 DRAINAGE AND WATERPROOFING MEMBRANES

5.0.1 Green roof technology is not particularly complicated. An increasing range of green roof-specific materials is available in New Zealand.

5.0.2 The design of the waterproof membrane, its protective layers and drainage is critical to a successful installation.

5.0.3 Minimise the number of protrusions, or cluster protrusions in an area that will not be green-roofed. This makes waterproofing simpler and allows easy access without damage to plants if these areas leak.

5.0.4 The primary function of any waterproof membrane is to prevent water ingress and to protect the underlying building structure. The membrane must be robust and resistant to plant root penetration (using a chemical or physical root barrier) to prevent damage to the building structure.

5.0.5 The waterproof membrane typically consists of double-layer torch-on bituminous, rubber or liquid-applied membrane applied to a substrate constructed to a fall. Before drainage cells, growing medium and planting are installed, the membrane installation should be tested – usually by flood test – or an electronic leak detection system should be installed. Ensure that a low-slope installation is properly detailed and constructed and that no leaks occur before the roof is planted. Locating and repairing defects to membranes after completion of the green roof installation could be difficult and costly.

5.0.6 Falls of at least 1:60 must be provided to the substrate with drainage via an exposed silt trap or sump to a stormwater network or, preferably, on-site storage. After the first flushes of rain from a newly installed roof, the amount of sediment collected in sumps should be minimal.

5.0.7 Traditional gravels have been superseded by lightweight plastic drainage cells that are either rolled out or laid out in panels (usually of about 500 x 500 mm) over the waterproof membrane (or where applicable, over rigid insulation). If the drainage material does not have a bonded filter cloth, a suitable geotextile filter cloth is loosely laid over the plastic cell panels. Depending on the coarseness of the substrate, a 20 mm layer of coarse sand may be spread over the area, but most lightweight substrates do not require this. When the soil drains after rainfall, the excess water drains through the filtering geotextile cloth and drainage cells to the stormwater system.

5.0.8 The drainage mat also acts to protect the membrane against physical penetration. Green roof-specific drainage mats may also have a geotextile layer that lies between the plastic and waterproofing membrane as a further protection against rubbing.

Public space green roof.

6.0 MEDIA AND MULCHES

6.0.1 Lightweight growing media, while not commonly used for extensive green roofs, are typically mostly pumice and are prone to drying out quickly, as they must drain rapidly. Organic matter, zeolite, perlite and vermiculite may be added to increase water and nutrient retention.

6.0.2 Typically, extensive green roof growing mediums consist of (by volume) 10–20% organic and 80–90% mineral material. Deeper, intensive roofs can have higher proportions of organic material and finer substrates, depending on the tolerance for shrinkage of substrate and weight. Controlled or slow-release fertilisers should be used to minimise the downstream effects.

6.0.3 Bark, gravels or expanded (lightweight) clays or a combination of these are sometimes used as a mulch to conserve moisture and suppress weeds. Organic mulches will break down over time and potentially add additional weight to the structure, so factor this in to the loading, particularly if maintenance involves regular additions of mulch. A biodegradable erosion blanket is an effective alternative (although perhaps not as visually acceptable). Bark and weedmat products can be dislodged by wind, especially before spreading plants have become established. Substrates with a high proportion of coarse pumice tend to form their own surface layer of pumice mulch after the first few rainfalls.

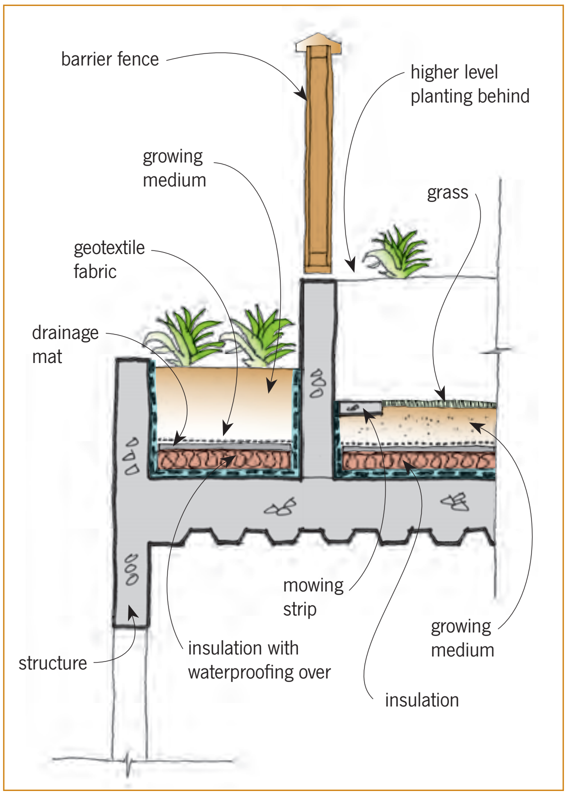
6.0.4 On most extensive roofs, a 200–500 mm wide edge of pebbles replaces substrate around the margins of the greened roof as additional (back-up) drainage and to reduce the growth of plants near upstands.

7.0 PLANT MATERIALS

7.0.1 Plant selection is dependent on geographical location, the type of green roof (substrate depth), shading, exposure and water availability. In New Zealand, plants that have adapted to our rocky, exposed shorelines and cliffs are often good candidates. Plants are selected for toughness and drought tolerance. Irrigation allows a wider selection of plant material and reduces plant losses. Selection of wind-tolerant plants is critical for roofs on high buildings.

7.0.2 Extensive roofs usually have low-growing (50–300 mm high) spreading ground covers or grasses. Intensive roofs, because of the deeper soil profile, can accommodate a wider variety of plants.

7.0.3 Locally sourced native plants can be used to promote the ecological uniqueness of an area, particularly in areas of outstanding landscape value.



Schematic cross section of a typical green roof installation.

7.0.4 Exotic drought-tolerant succulents such as *Sedum* species are commonly used and have proved to be the most resilient plants to date on unirrigated roofs of less than 100 mm depth in Auckland. As some *Sedum* species are considered weeds in New Zealand, the species must be carefully identified.

7.0.5 The Waitakere Central Civic Centre (an extensive roof) was planted in 2007 entirely with native plants such as the prostrate form of *Coprosma acerosa* (sand dune coprosma, tataraheke), *Pimelea prostrata* (New Zealand daphne, pinatoro), *Festuca coxii* (bluegrass), *Disphyma australe* (iceplant, horokaka), *Libertia peregrinans* (New Zealand iris, mikoikoi), *Calystegia soldanella* (sand convolvulus, rauparaha) and *Selliera radicans* (remuremu).

7.0.6 The green roof at St Mary's Convent, Thorndon, Wellington – an intensive roof with 300 mm deep soil – was constructed on a concrete deck over a car park. A wide selection of mostly natives was used in the raised planting areas.

7.0.7 Plants on living roofs should rapidly establish wind-resistant cover. This means plant spacings of 4–10 PB3 size or 10–25 root trainer/plug size per square metre. Irrigation can accelerate the development of cover in the first year, but both irrigation and fertilisers should be managed to avoid creating over-lush plants.

8.0 MAINTENANCE

8.0.1 Beyond the initial maintenance (including watering) immediately after installation, weeds must be removed before they establish and vegetation should be trimmed so it does not invade edges or drains. Regular checks should be made to ensure drains are functioning and overflows are clear of obstructions.

8.0.2 Occasional applications of slow-release fertiliser may be needed if plant vigour decreases (determined by soil tests).

8.0.3 For obvious reasons, tools should be used with care, especially when digging close to waterproof membranes, and workers should be made aware of the risks.

9.0 FURTHER READING

9.0.1 Publications/books:

- Cantor SL, 2008, *Green roofs in sustainable landscape design,* WW Norton, New York.
- Dunnet N and Kingsbury N, 2008 *Planting green roofs and living walls* (2nd edition), Timber Press, Portland, Oregon.
- Lewis M, Simcock R, Davidson G and Bull L, 2010, *Landscape and ecology values within stormwater management.* Prepared by Boffa Miskell for Auckland Regional Council. ARC Technical Report TR2009/083.
- Peck S, 2008, *Award-winning green roof designs*, Schiffer Publishing, Atglen, Pennsylvania.
- Snodgrass EC and McIntyre L, 2010, *The green roof manual: A professional guide to design, installation, and maintenance.* Timber Press, Portland, Oregon.
- National Roofing Contractors Association, 2009, *The NRCA vegetative roof systems manual (2nd edition)*, National Roofing Contractors Association, Rosemont, Illinois.

9.0.2 Useful websites:

- www.livingroofs.org
- www.greenroofs.net
- www.greenroofs.co.nz

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