Characterisation of Mineral Wastes, Resources and Processing technologies – Integrated waste management for the production of construction material

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Case Study:

Green Roof Substrate using Aerated concrete waste

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Introduction

Green Roofs

Green roofs are vegetated layers that sit on top of the conventional roof surfaces of a building. Usually a distinction is made between ‘extensive’ and ‘intensive’ roofs. These terms refer to the degree of maintenance the roofs require. Intensive green roofs are composed of relatively deep substrates and can therefore support a wide range of plant types: trees and shrubs as well as perennials, grasses and annuals. As a result they are generally heavy and require specific support from the building. Intensive green roofs (what most people think of as roof gardens) have in the past been rather traditional in their design, simply reproducing what tends to be found on the ground, with lawns, flower beds and water features. As intensive green roofs require deeper substrates they would benefit from lightweight substrates. However, more contemporary intensive green roofs can be visually and environmentally exciting, integrating water management systems that process waste water from the building as well as storing surplus rainwater in constructed wetlands. Because of their larger plant material and horticultural diversity, intensive green roofs can require substantial input of maintenance resources – the usual pruning, clipping, watering and weeding as well as irrigation and fertilization.

Conversely, the green roofs that have received the greatest interest recently are extensive green roofs. They are composed of layers of free-draining material that support low-growing, tough drought-resistant vegetation. Generally the depth of growing medium is from a few centimetres up to a maximum of around 10cm. These roof types have great potential for wide application because, being lightweight, they require little or no additional structural support from the building, and because the vegetation is adapted to the extreme roof top environment (high winds, hot sun, drought, and winter cold) they require little in the way of maintenance and resource inputs. Extensive green roofs can be designed into new buildings, or ‘retro-fitted’ onto existing buildings. Whilst these are reasonably lightweight when compared to the intensive green roofs, they still can exert quite a substantial load when at 100mm in depth and saturated. Therefore, the development of new lightweight recycled waste materials as substrate would not only help reduce waste from industries and reduce landfill, but would also allow more buildings to retrofit their existing roofs, with little additional support needing to be included and thus reducing the costs of implementing green roof systems.

A standard green roof system is constructed of several discrete layers (see Figure 1).

- The roof general waterproofing
- A drainage layer (often corrugated looking like eggboxes to ensure water storage)
- A filter fabric layer to stop the drainage layer becoming clogged with fines
- The substrate layer (with added organic matter content, usually between 10 -20%)

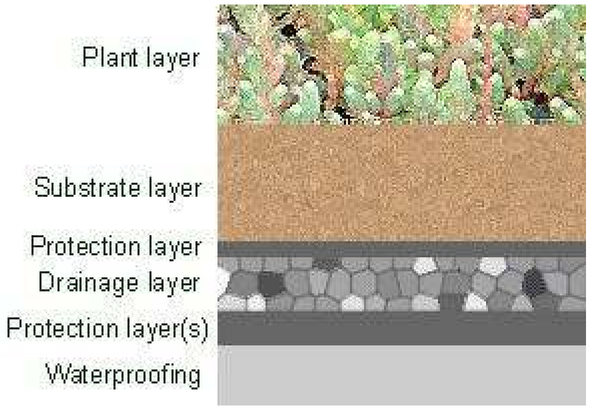

Figure 1: Diagram illustrating the layers in a standard green roof system showing the substrate layer - which will be provided by aerated concrete. (The Green Roof Centre, 2007)

The role of the substrates in green roof systems is incredibly important for several aspects. First it is the substrate that supports the plant growth on the roofs, thus the pH of the substrate can affect which plant species can grow and therefore the habitat that is created. For example an acidic substrate would encourage growth of acid grassland species, whilst an alkaline substrate would allow the growth of a calcareous grassland, both very different, with very different associated vegetation, invertebrate and avian communities. Secondly, the characteristics of the substrate can affect the amount of water the green roof can hold and therefore affects how good the roof is in reducing urban runoff and helping in flood amelioration. Different substrates have different levels of water holding capacity, and thus produce different effects when utilised as a green roof. To date the majority of commercial systems use a crushed brick substrate, mixed with organic matter.

Currently existing research, at the Green Roof Centre and further afield, is testing the characteristics of industrial waste materials to examine their suitability as a green roof substrate. The research centres on several aspects of the substrate, it examines their maximum water holding capacity, the speed at which these substrates dry out in drought conditions, and the amount and health of the vegetation that survives on the different substrates. Further research on the Air-crete substrate investigates how the substrate acts, as a growing medium, with different amounts of organic mater, when calcareous species are grown.

Aerated concrete

Aerated concrete is a factory produced product which is cured in an autoclave process during which the main ingredients (including the finely divided aggregates), react together chemically. Aerated concrete comprises cement, lime, fine aggregates, with a few per-cent of aluminium powder added to the mix to aerate the product. The aggregate comprises the major constituent of the mix. Manufacturers produce blocks, jumbo blocks and larger reinforced elements.

During production there may be some off-cuts and lower standard product. The nature of the material makes it unsuitable for normal fill due to its low density and relatively high water absorption.

Figure 2: Aircrete as being used for test as a green roof substrate, sometimes with organic matter added

Barriers and Benefits

The many benefits of green roof are:

- Research from around the world indicates that Green Roofs reduce annual run-off from roofs by at least 50%, and more usually by 60-70% - contributing to urban drainage and flood alleviation schemes. Moreover, the rate of release following heavy rainfall is slowed, reducing the problems associated with storm surges. With an increasing need for developments to have limited water run off, the Environment Agency now highlight the use of green roofing in their May 2003 publication "Sustainable Drainage Systems (SUDS) – an introduction" and the Agency have been supportive of supplementary planning documents which refer to green roofs – such as the Leeds Biodiversity and Waterfront Development SPD (2005) (Villarreal *et al* 2004, Carter and Rasmussen 2006, Mentens *et al* 2006, Carter and Jackson 2007).

- Green roofs (and other practices such as natural ventilation) reduce the need for air conditioning in the summer and as a result reduce CO^2 emissions (Onmura *et al* 2001, Liu and Baskaran 2003, Takahashi *et al* 2004).

- New developments lead to a loss of habitats – green roofs can contribute to biodiversity and address local biodiversity action plans. In particular they have been shown to favour many rare invertebrates found on brownfield sites, as well as ground-nesting birds such as skylarks (Jones 2002, Brenneisen 2003, Gedge 2003, Kadas 2006).

- Green roofs contribute to a greener urban environment and quality of life for communities in high density developments.

- A roof life is at least doubled with the addition of a green roof, thereby reducing resource use in roof replacement and repair.

A commentary on generic constraints and benefits of using aerated concrete as a green roof substrate using the five main headings used in the project for the characterisation of 'alternative materials' is provided below:

- Material related
  i. A 'high' grade use of a low grade material / waste.
  ii. High water absorption and water retention capacity (when mixed with organic matter).
- Legal
- Economic
  i. Maintenance may be need form time to time.
  ii. Only suitable for certain roof types so some buildings may need retro-fitting.

- Environmental
    1. Reduced heating and cooling demand from building
    2. Increased biodiversity - in urban areas

- Organisational
    1. Whether retro-fitted or used in new buildings the green roof will need to be specified by the organisation / architect.
    2. Improves organisations environmental credentials

Specific materials characterisation results

The characterisation required of a green roof substrate with specific reference to aerated concrete are as shown in Table 1:

Characterisation	Indicative values required
Percent Solids	80 %
Percent Organic matter	20 %
Particle size distribution	A well graded material
Density	< 1000 kg/m^3 dry weight / < 1,500 kg/m^3
Maximum water holding capacity	
Water permeability	
Porosity	c. 30 % dry weight
pH	Variable - not too extreme
Chemical composition: Percent soluble salts, Phosphorous, Potassium, Magnesium, Nitrate and Ammonium	Primarily for plant nutrition purposes, but also so potential loading to run-off water can be evaluated

The methodologies for testing these characteristics have been created in America (Agricultural Analytical Services, 2006)

Results of Laboratory / Pilot product demonstration test-work

Work is currently being undertaken at the University of Sheffield's Green Roof Centre (http://www.thegreenroofcentre.co.uk/). Two Master's theses have been undertaken on the character of material required and in particular the characteristics of aerated concrete.

These results are not available at the time of writing. This includes ecological studies. Results are however promising.

Conclusions and further work required

Aerated concrete is a material that is suitable for use as a light weight green roof substrate. It has the appropriate density and water absorption. Further work is needed to assess the water retention (when mixed with organic matter), the chemical composition of the run-off and the ecology that develops as the roof matures.

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