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Evaluation of Sustainable Roof from Various Aspects and Benefits of Agriculture Roofing in Urban Core

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Abstract

The purpose of this paper is to discuss the environmental load of three types of roofing systems, and to clearly identify the advantages and disadvantages of each by measuring various environmental factors. The three roofing systems each contain sustainable advantages to being “green.” First, roofing can be designed to collect rainwater and reduce potable water usage. Second, adapting a green roof can not only effectually decrease the amount of stormwater runoff, but also mitigate the heat island effect, extend roof life, and improve thermal and sound insulation performance. Third, agriculture roofing includes some of the benefits of green roof, and, as a by-product, food can be grown in an urban core, reducing the carbon footprint. This paper compares and evaluates these three systems to validate the benefits to society and environment.

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1. Introduction

“Green” architecture has been drawing attention in recent years. Loosely defined, "green” has some vaguely thinking it is a type of architecture environmentally friendly in some way. Several interpretations of “green” exist, with several ways to measure the validity of sustainable methodologies, or how “green” a building is. For example,

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buildings that are LEED® certified or made out of recycled and recyclable materials can be called "green." Other terminologies referring to "green" are net zero energy, low life cycle carbon dioxide ($LCCO_2$) emission, heat island effect mitigation, and stormwater runoff alleviation. Although, a building rated high by one measure can also be rated very low by another. To achieve fairness and accuracy, it is necessary to apply multiple methodologies when rating, or evaluating sustainability of, any architecture.

This paper covers the merit and burden of roofing that collects rainwater, the conventional green roof fully covered with lawn, and the agriculture roofing which grows edible plants such as fruits and vegetables.

2. Rainwater Catchment Roof

First type of roofing systems is roofing that is capable of collecting the rainwater for use. It can be wide variety of roofing materials such as asphalt shingles, clay tiles, built-up roofing, single-ply membranes, etc. Each roofing materials has different use, cost and environmental load. When the materials are carefully selected, it can greatly mitigate the heat island effect, harvest rainwater, and minimize the waste by recycling.

2.1. Heat Island Effect

Creating cool communities requires lowering the surface temperature. Surface characteristics such as albedo, roughness, and emissivity are relevant to the roof surface temperature in the sun. The surface temperature, T_s is obtained from the following equation (ASHRAE, 2013):

$$(1-a)I = \varepsilon\sigma(T_s^4 - T_{sky}^4) + h_c(T_s - T_a) \quad (1)$$

a	albedo of the surface
I	total solar radiation incident on the surface, W/m^2
ε	emissivity of the surface
σ	Stefan-Boltzmann constant, 5.6685×10^{-8} W $m^{-2}K^{-4}$
T_s	equilibrium surface temperature, K
T_{sky}	the effective radiant sky temperature
h_c	convection coefficient, W $m^{-2}K^{-1}$
T_a	air temperature, K

As shown in the equation, the most practical parameter to lower the surface temperature is to increase the albedo. It also indicates that selection of high-emissivity materials is effective.

Selecting a high-albedo roof instead of traditionally absorptive rooftops can be done at almost no cost. Currently, there are a number of high-albedo materials available. Built-up roofs can be surfaced with white gravel or a white roof coating, such as white single-ply roofing for example. White metal or concrete tile shingles can also be used in place of a conventional residential roof.

White concrete and paint are the most obvious and readily available choices for obtaining higher albedo; however, since roughly half of the solar radiation reaching the earth's surface is near-infrared radiation, significant improvements in conventional colors are also available (Berdahl & Bretz, 1997).

In addition to albedo, the roof surface emissivity also affects the temperature. A high-emissivity material maintains lower surface temperature in the sun than low-emissivity materials with the same albedo. Low-emissivity materials include, but not limited to, the unpainted metal shingles and aluminum coatings.

2.2. Recycling Materials

It is estimated 11,000,000 tons of asphalt roofing waste is generated annually in the United States. The greatest single source, estimated at 10,000,000 tons annually, is from roof replacements (Waller, 1993). If properly processed, the recycled materials could be mix with asphalt shingle roofing materials and save up to 50% and still maintain the standard structural strength (Grzybowski, 1993). In addition to new shingle manufacturing, attempts have been made