Lab 7: Green Roofs

EE80S Fall 2016

Name: _______________________

Background
Architects, engineers and others are reworking how buildings fit into our current built environment, reducing their carbon and water footprints and even creating new habitat to replace what has been lost. Green roofs are part of that reimagining of these spaces, combining an old technology with materials advances and ecological knowledge, and providing a range of benefits, including carbon capture, increased stormwater retention, and reducing heat transfer into and out of buildings. What is needed to create green roofs, what challenges do we face in building them, and how can we estimate the services they provide?

Defining green roofs
An article about green roofs (Klinkenborg 2009) starts with this visual image:

If buildings sprang up suddenly out of the ground like mushrooms, their rooftops would be covered with a layer of soil and plants.

That’s not how humans build, of course. Instead we scrape away the earth, erect the structure itself, and cap it with a rainproof, presumably forgettable, roof. It’s tempting to say that the roofscape of every city on this planet is a man-made desert, except that a desert is a living habitat. The truth is harsher. The urban roofscape is a little like hell—a lifeless place of bituminous surfaces, violent temperature contrasts, bitter winds, and an antipathy to water.

“Green roofs are simply roofs that have had a layer of vegetation added to them” (Dunnett et al. 2011). The scale can run from garden sheds and bus shelters to homes and office buildings. One local(ish) example is at the living roof on the California Academy of Sciences.

Architect Renzo Piano's vision for the Academy is perhaps most perfectly expressed by the living roof. The goal, as he described it, was to "lift up a piece of the park and put a building under" — to blend seamlessly into Golden Gate's natural setting. (California Academy of Sciences 2015)

Watch the following two short films about the Academy's roof, one by Kohler, a plumbing fixture (or as they describe it, “gracious living”) company, and one by SWA Group, the architects that designed the building.

Thinking about costs and lifespans
A standard roof costs about $3.20/ft² for asphalt (or “composite”) shingles and $12.56/ft² for slate, which is thin slices of rock (homewyse 2015). The cost for the Academy's roof is $17/ft².

Composite roofs are guaranteed for 15-25 years (Miller 2013), so let's say their lifespan is about 20 years. Slate roofs last 50 to 100 years, so we'll use about 75 on average (Miller 2013). Dr. Frank Almeda estimates the roof on the Academy will last 45 years (Asterisk San Francisco).
What is the average cost per square foot per year ($ / ft²/yr) for each of the three roof types over their total lives?

Let's take a look at what goes into the higher initial costs of green roofs. First, you have to account for some kind of material for the plants to grow in. This includes options such as gravel, pebbles, sand, topsoil, and standard greenhouse potting materials such as perlite (a lightweight and excellent water-holding substance that is made from heating a volcanic glass, which then puffs up like popcorn does).

The choice of roofing material depends in part on how much weight the roof can bear. Melissa Jolly built a bike shed for five bikes and put a green roof on it, based on bike shelter examples from a book by Dunnett et al. (2011).

The shed is 4 ft x 6 ft and is 4 ft tall. What is the total square area for her roof?

The planting depth for the bike shed roof is about 5 inches. The weight of a saturated (fully wet) 1-inch layer of topsoil is about 9.7 lb/ft² and of perlite is 0.51 lb/ft².

If Jolly used an equal mix of topsoil and perlite, how much would her roof weigh? Note that this is without the weight of the plants.

Rain, rain, come and stay

One of the benefits of the Academy roof is its ability to retain stormwater. Based on the videos, how much stormwater does the roof retain, and why is this an advantage?
Several researchers from Oregon State University (Schroll et al. 2011) looked at the potential of green roofs to hold water. They compared a conventional roof, the growing medium only, and a vegetated roof across different total amounts of rain (measured here in mm), as shown in the figures. The top figure shows the performance of the three roof types during the wet season and the bottom figure shows their performance during the dry season.

Did the vegetated roof in the study increase or reduce runoff compared to just the growing medium and the conventional roof? How did that change in the wet season versus the dry season? Determine the approximate percent rainfall captured at 40 mm of rainfall during the wet season and at 9 mm of rainfall during the dry season as part of your answer.

Oregon has a similar Mediterranean climate season to Santa Cruz, with wet weather in the winter and dry weather in the summer – they just have much more total rainfall up north. Plants do their most photosynthesizing and using water in the summer (the dry season), and the least in the winter (the wet season), which affects the ability to catch and use the water on the roof. Yet the Academy roof captures much more water overall.

What could be two reasons that the Academy roof is able to retain so much stormwater? Make two good educated guesses. Consider that the vegetated test beds in the study were planted in July and runoff monitoring began in November, with an average of 69% cover by the plants.

Controlling heat dynamics
Another key feature of green roofs is their contribution to insulating the roof from temperature changes in both warm and cold weather.

Briefly describe how the Academy roof helps regulate temperatures inside the building.
An average house loses 25% of its heat through the roof. If a modern house of 2000 ft² uses 1400 kWh/ft² per year for heating, how many total kWh per year go just through the roof?

If a green roof provided even 10% improvement on insulation, how many kWh would it save per year?

(No calculation needed here, but remember that 1 gal of gas supplies about 33.7 kWh, which can give you some perspective on your answer).

Final thoughts
We have just scratched the surface of the benefits of green roofs. For example, you can see a little about the plants and what's going on in ecologically in an article by one of the green roof stewards and UCSC alumna (!) Kendra Hauser. However, not everyone can adopt a green roof on the spot.

Describe three constraints to green roofs. Think architecturally and in a socioeconomic framework for some key barriers that may need to be overcome for the green roof movement to grow (so to speak!).

This lab drew on the following sources:
Miller, R. 2013. The average life of roofing. SF Gate.