Green Roofs Increase Structural Loading Costs

Richard K. Sutton
UN-Lincoln, rsutton1@unl.edu

Follow this and additional works at: https://digitalcommons.unl.edu/arch_land_facultyschol

This Article is brought to you for free and open access by the Landscape Architecture Program at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Landscape Architecture Program: Faculty Scholarly and Creative Activity by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.
Introduction

The extra skill, design, and material needed for green building all increase costs. Green roofs are a prime example of this phenomenon. Because buildings will always have some type of waterproof membrane roofing system they do not need green roofs to repel moisture. So when green roofs are added above that roof membrane, it adds to building costs. While green roofs certainly add value for their owner and to the public, that value is only recouped in the future after those additional initial costs have already been incurred.

Green Roofs for Healthy Cities' annual survey of its green roof industry members gives a snapshot of installed green roofs. Trends reflect a steady, (but very modest) growth in North American green roof square footage. (Figure 1) All that being said, each year installed green roofs cover only a tiny fraction of newly built roofs.

Figure 1. Estimate of installed green roof growth 2004-2016

Additionally many more square feet of green roof gets programmed and designed than actually gets installed. This is because green roofs’ added costs are reduced during the value-engineering phase found in most building construction processes, by eliminating green roofs all together.

This brief article examines the issue of green roof costs. It provides some estimates not typically or easily found about added cost for increasing structures to physically support green roofs. Because green roof costs largely remain in the sphere of proprietary information for design and installation firms and their clientele, increased structure cost caused by green roof loading remains largely difficult to find. For example, Sproul et al (2014) used $16 per square foot median cost for a green roof but were only able to find eleven published examples of per square foot costs.
Costs

Costs mostly likely drive square footage installed and only much later might those costs be recouped through private benefits. Estimates of benefit values vary widely because of varying local environment, policies. Incentives, and regulations, for example, heating and cooling cost reduction, stormwater utility charges (Banting et al. 2005), or municipal mandates for coverage (e.g. Snow 2016, Denver Co. 2018) and biodiversity (Torrance 2013). Therefore the Cost-Benefit ratio also varies (Clark et al 2008, Evans & Associates 2008, GSA 2015)

Available costs for materials and labor can be estimated by searching local sources. A rough idea for those costs can broken into categories (Figure 2): Drainage layer, Substrate, Seeding, 1-year Maintenance, and Overhead and Profit. Substrate usually makes up about 40-50 percent of green roof costs (e.g., see Evans and Associates 2008). Above the membrane installation (i.e., labor) costs vary by contractor and geographically by wage scales, but can still be estimated. However, the additional costs for beefing up a building’s structural loading capacity as required by a proposed green roof are not readily available.

Objective and Procedures

The objective of this study was to find an approximate square foot cost for increasing the structural loading created by a green roof. It required an engineering analysis and used the example of a small commercial building (Figure 3). Loadings for no green roof, 4-inch, and 8-inch deep green roof depths were computed and the requirements for roofing loads incorporated. These increases were then used in three cost estimates, plotted and fitted to a cost per square foot curve.

Model Building

The model building was a typical small warehouse of 2-1/2 stories and with 50-foot by 50-foot dimensions. It had joists spaced at 6-ft OC supporting triple span, of 18-gage corrugated steel N-Deck overlain with Dens-deck™ and a 60 mil EPDM fully adhered membrane with no ballast. A 40-inch high by 6-inch thick concrete parapet with two scuppers per side surrounded the roof. The roof

---

**Estimated, Partitioned, Per Square Foot Green Roof Cost**

Above the membrane, 4-inch deep, monolithic, 3-story

- **$0.58** Drainage Layer
- **$1.71** Substrate
- **$1.11** Seeding
- **$1.85** 1-yr Maintenance
- **$5.00** 20% Overhead & Profit

**$10.25 per square foot**

Figure 2 estimated green roof costs partitioned by installation and materials costs.
Figure 3. Modeled building constructed of concrete block with a steel truss roof structure and had a 6-inch crown. HVAC was not located on the roof of warehouse. Two scenarios, one a 4-inch and the other and 8-inch green roof, were added to the standard roof load (Figure 4). Additional loading from green roof weights on the footings and soil bearing capacity were considered as negligible as were any associated costs. However, in extremely expansive clay soil, the footing areas might need to be increased. No green roof should be installed without a complete engineering analysis.

**Three Loading Cases**

*Without green roof*

Analyzing the loading along one beam support a three-foot width of decking found 33 pounds per linear foot dead load and 151 pounds per linear foot live load totaling 184 pounds per linear foot. Dead load on 18 Gage N-Deck is 11 psf and less than the 126 psf allowed.

From Span Tables (SJI 2015) a 28LH7 steel joist will support a 186 pounds per linear foot with a joist weight of 17 pounds per linear foot. It was assumed that steel in the joist cost $1.00 per pound so 17 pounds per linear foot times a 50-foot joist resulted in $850 for cost of steel.

*4 inches of substrate*

A green roof with 4 inches of substrate and plantings adds 28 psf to dead load. So analyzing the loading along one beam support a three-foot width of decking found 498 pounds per linear foot dead load and 348 pounds per linear foot live load totaling 446 pounds per linear foot. Dead load on 18 Gage N-Deck is 58.5 psf and less than the 126 psf allowed.
From Span Tables (SJI 2015) a 32LH10 will support 332 pounds per linear foot with a joist weight of 21 pounds per linear foot. It was assumed that steel in the joist cost $1.00 per pound so 21 pounds per linear foot times a 50-foot joist resulted in $1050 for cost of steel.

8 inches of substrate
A green roof with 8 inches of substrate and plantings adds 56 psf to dead load. So analyzing the loading along one beam support a three-foot width of decking found 498 pounds per linear foot dead load and 348 pounds per linear foot live load totaling 446 pounds per linear foot. Dead load on 18 Gage N-Deck is 85 psf and less than the 126 psf allowed.

From Span Tables (SJI 2015) a 40LH14 will support 900 pounds per linear foot with a joist weight of 35 pounds per linear foot. It was assumed that steel in the joist cost $1.00 per pound so 35 pounds per linear foot times a 50-foot joist resulted in $1750 for cost of steel.

Increased structural steel costs for tested joists
4” of green roof increases costs: $33.33/sf for steel or $200/lf
8” of green roof increases costs: $150.00/sf for steel or $900/lf

Outcome
The costs were plotted with a fitted curve (Figure 5) with a 6” green roof loading cost interpolated. Linear foot steel joist costs were $33 at 4-inch depth and $150 at 8-inch depth, the square foot costs were $175 and $291.67 Respectively. Interpolated 6-inch depth showed steel at $72 per linear foot and $213.67 per square foot.

Summary
This studied aimed to provide a reasonable approximation of green roof costs, especially the additional costs that might be expected for increasing structure cost incurred by green roof loading.

Figure 4. Load analysis for a green roof impact on a building’s structure
Figure 5. Increase in steel structure costs for various green roof depths.

While costs vary depending on actual roof design, location, building type, knowledge and ability of installers, this study used a typical commercial warehouse as its focus. Adding a 4-inch green roof to the model building required increased structure costs of $33 per square foot and 8-inch green roof increased structure costs of $150 per square foot. Interpolated from the graph, a 6-inch green roof increased structure costs would add $72 per square foot.

Acknowledgements

King Little, P.E., S.E., FASCE helped with the structural loading analysis. An errors, however, remain the responsibility of the author. Some of this information was presented at the October 2015 Cities Alive Conference in Brooklyn, NY.

References


https://www.gsa.gov/cdnstatic/Cost_Benefit_Analysis.pdf


Snow, J. 2016 Green roofs take root around the world. National Geographic
