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NEW HEAT MITIGATION AND WATER RETENTION CONCEPTS TO EXPAND GREEN ROOFING DEMAND

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Abstract

Within the past year, several new water retaining roofing systems have been introduced in North America. Typically employing stone or paver ballast in combination with a variety of water retention devices, these systems not only reduce storm water runoff but also lower roof surface temperatures to reduce peak cooling energy requirements and help mitigate the urban heat island effect. But the most important long-term benefit of these engineered water retention systems is that they may be combined and integrated creatively with vegetated roof areas to offer many of the environmental benefits of green roofs at a more favorable life cycle cost and return on investment.

This paper provides a brief review of recent research pointing to potential economic and environmental benefits of ballasted roofing systems when used in conjunction with green roofing systems. In addition, the paper offers suggestions for future research that could help building owners and designers optimize the benefits of green roof and ballasted roofs in their design and selection of roofing systems.

Introduction

Although the inclusion of live vegetation makes the green roof unique among roofing systems, green roofs share a distinctive feature with another popular roofing system, the *ballasted* roof. Both green roofs and ballasted roofs are designed to cover and protect the underlying roofing membrane. Green roofs provide this protection via the plant media and vegetation covering the membrane; while ballasted roofs achieve the same effect with a layer of stone aggregate or concrete pavers. In addition, both green roofs and ballasted roofs can incorporate additional protection materials, such as moisture-resistant insulation boards and a wide variety of woven and non-woven fabric mats. Because these various protective layers shield the roofing membrane from the ultraviolet rays of the sun, seasonal and daily temperature extremes, and direct abrasion and damage, it is widely believed that that the overall service life of the roofing system is extended, reducing long-term life cycle cost and environmental impact.

Beyond the characteristic of roof membrane protection, green roofs and ballasted roofs may also share other important functional features that suggest mutual synergies between the two roofing systems that may offer opportunities to expand market demand for green roofs and increase the environmental and energy benefits both systems offer.

Ballasted Roofs and Heat Load Reduction

Because they both shield the underlying roof system and the building from the sun's heat, green roofs and ballasted roofs may reduce building cooling requirements, especially during peak seasonal and daily solar loads. In addition, the cooling effect of green and ballasted roofs also may reduce ambient air temperatures above the roof surface and help mitigate the urban heat island effect. When compared to white reflective roofs commonly recognized as "cool roofs," ballasted roofs appear to provide very similar heat reduction properties, both in terms of internal building heat flux as well as external ambient temperature reduction.

In a study comparing ballasted roofing systems to highly-reflective roofs, researchers at Oak Ridge National Laboratories (Desjarlais et al 2008) demonstrated that ballasted systems may offer the same positive benefit as reflective roofing membranes currently classified as cool roofing products. In this three-year study, Oak Ridge researchers conducted side-by-side comparisons of identical roofing assemblies with the following roof surfaces:

- Black EPDM (Exposed)
- White TPO (Exposed)
- "Light" Stone Ballast (10 lb. / sq. ft.)
- "Medium" Stone Ballast (17 lb. / sq. ft.)
- "Heavy" Stone Ballast (22 lb. / sq. ft.)
- Unpainted Concrete Pavers (21 lb. / sq. ft.)
- White Painted Concrete Pavers (16 lb. & 21 lb. / sq. ft.)

At the time of the study, only one of the roofing assemblies – the White TPO roof – was classified as a cool roof within any of the U.S. cool roof rating standards. None of the other assemblies was considered to provide sufficient heat load reductions – either in internal building heat flux or in ambient external air temperature – to merit classification as a cool roof.

Data collection included continuous monitoring of temperatures, heat flows and weather conditions for each of the roofing assemblies. To compare each roofing system's potential to reduce interior air conditioning load, total heat flux was measured and recorded for each hour of the day, as summarized in Figure 1.

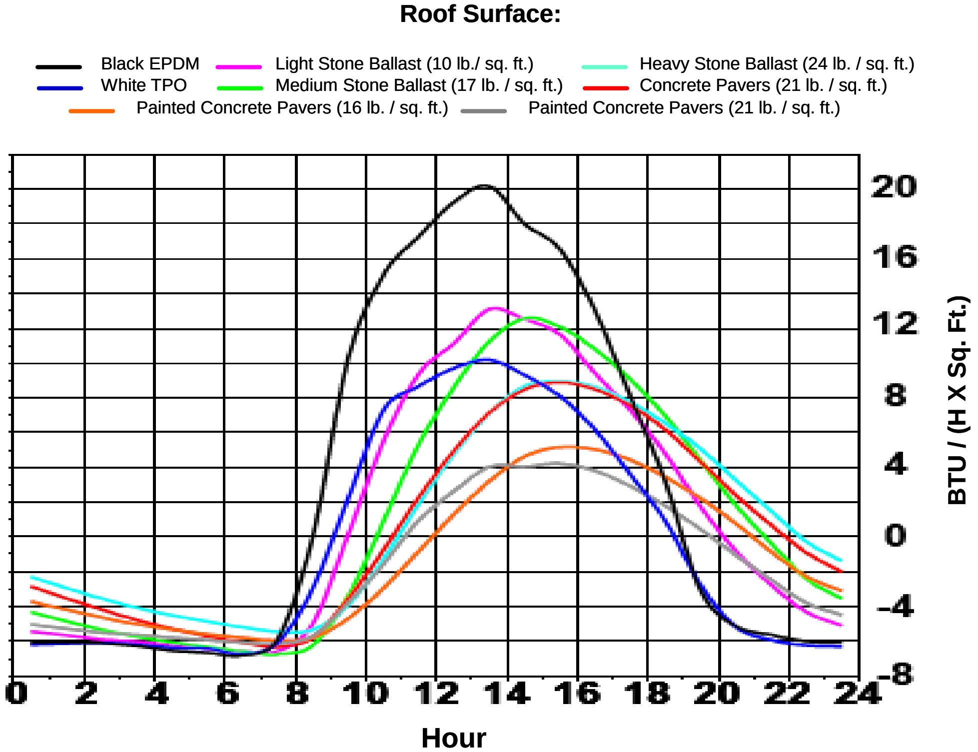

Figure 1: Heat Flux through Roof by Hour

As shown above, the average heat flux generated by the heavy and medium ballast systems and the precast paver system were approximately the same as for the "cool" white TPO system. And although the heat flux generated by the light ballast system was only slightly larger than for the white TPO system, the heat flux was still significantly less than for the black system. In addition, the ballasted systems tended to move a portion of the heat flux into the evening hours, potentially reducing peak electricity loads in the afternoon.

In order to compare the potential for each roofing system to lower external air temperatures and help mitigate the urban heat island effect, a comparison of roof surface temperatures was also recorded for each hour of the day, as shown in Figure 2.

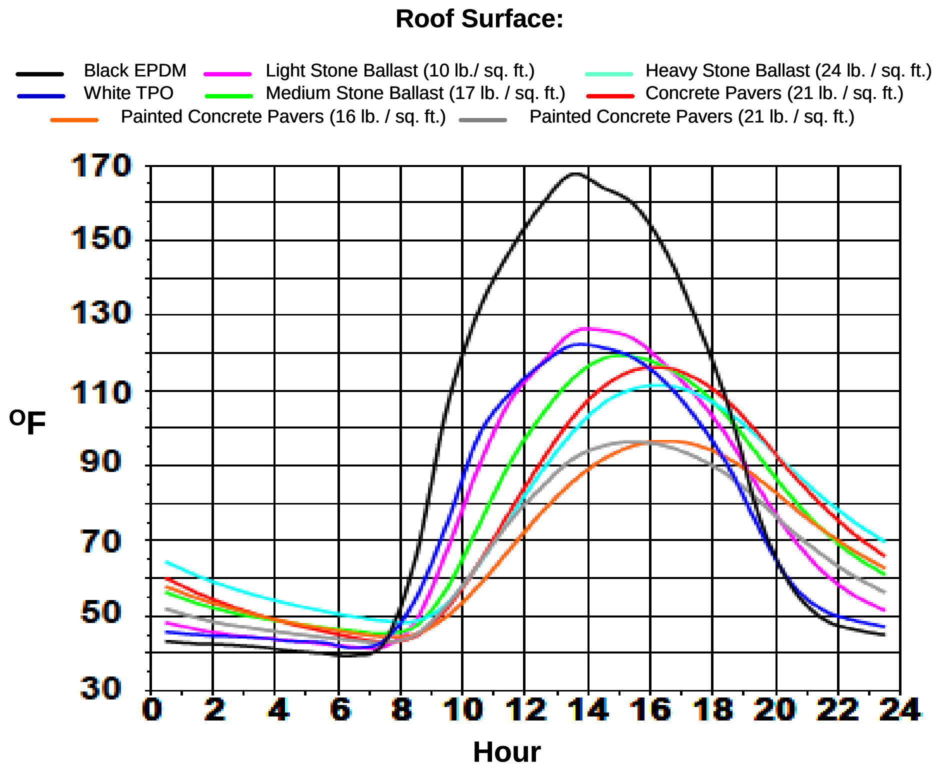

Figure 2: Roof Membrane Temperature by Hour

As illustrated above, the roof membrane temperatures (and by extrapolation, ambient outdoor air temperatures) generated by the heavy ballast, medium ballast and precast paver systems were generally lower than for the white TPO system. In addition, the roof membrane temperature generated by the light ballast system was approximately equal to that generated by the white TPO system. In a similar manner as overall heat flux, the ballasted systems also tended to move peak membrane temperature later in the day.

Based in part on these research findings, several U.S. rating standards have begun to recognize that ballasted roofing systems may provide benefits in internal heat load reduction and external ambient temperature reduction equivalent to other roofing systems previously classified as cool roofs. Examples of the increasing acceptance of ballasted roofs as a cool roof alternative include the inclusion of ballasted systems in California's Commercial Building Energy Standard (2008 Building Energy Efficiency Standards, Title 24, Part 6 of the California Code of Regulations) and in the Chicago Energy Code (Chicago Energy Code Ordinance 01-01-2009). In addition, the inclusion of ballasted roof system as a cool roof alternative has been proposed for the next revision of ASHRAE 90.1 "Energy Standard for Buildings" (U.S. Department of Energy Building Technologies Program, 2007).

Ballasted Roofs and Storm Water Retention

Both green roofs and ballasted roofs also may be designed to absorb and retain stormwater. In green roofs, stormwater may be absorbed and retained within the vegetation and the planting medium as well as in supplemental layers of moisture retention mats. In ballasted roofs, stormwater may be retained within the layer of stone ballast and moisture retention mats. Although past research suggests that levels of stormwater retention within green roofs may exceed similar levels in typical ballasted roofs, the retention capabilities of several new ballasted roofing systems designed purposefully to retain stormwater appear to approach the retention capabilities of many green roofing systems, especially relatively shallow green roof systems.

Within the past year, two new ballasted roofing systems with water-retention capabilities have been introduced into the market. Both of these systems rely upon water retention techniques developed originally for use with shallow or extensive green roofs. Extensive green roofs rely on relatively thin layers of planting medium (typically 2" to 4" total medium depth), and as a consequence may frequently require additional water-retention capabilities to provide adequate moisture for their vegetation. One method of expanding water-retention capacity is to add one or more layers of moisture-retention mats between the planting medium and the underlying drainage board. This method as applied to both an extensive green roof and a ballasted water-retaining roof system is illustrated in Figure 3.

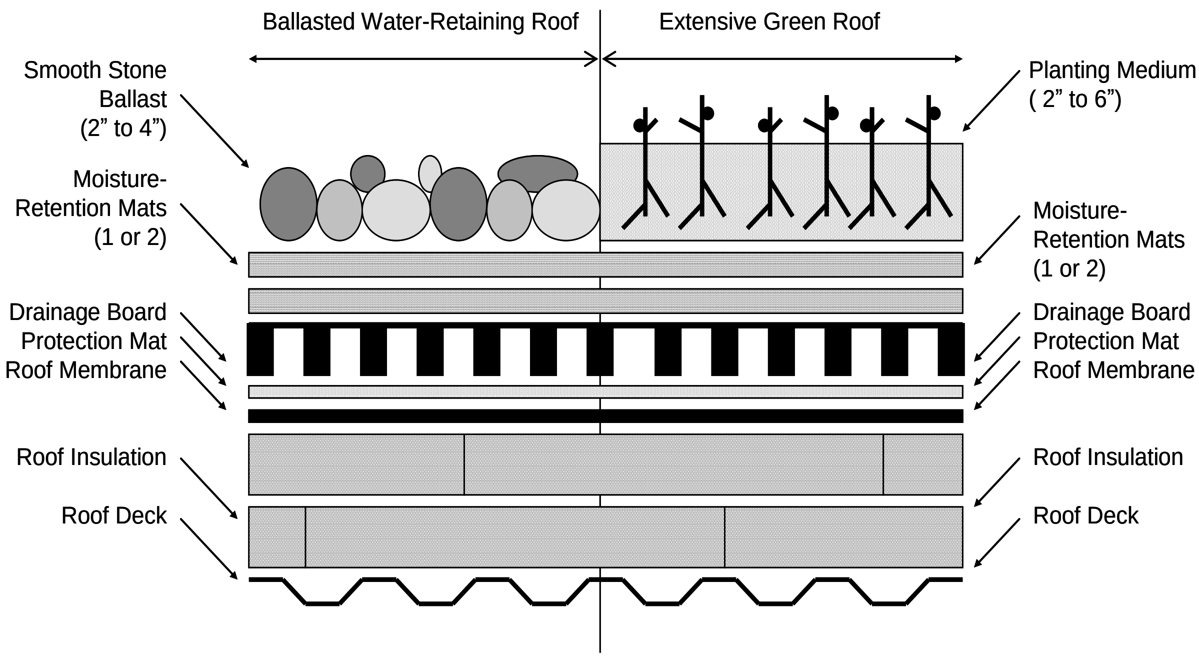

Figure 3: Water-Retention Using Moisture Retention Mat(s)

An alternative method to enhance water-retention capacity is to place the planting medium in a modular tray that is designed to restrict the flow of water from the tray. This method as applied to both an extensive green roof and a ballasted water-retaining roof system is illustrated in Figure 4.

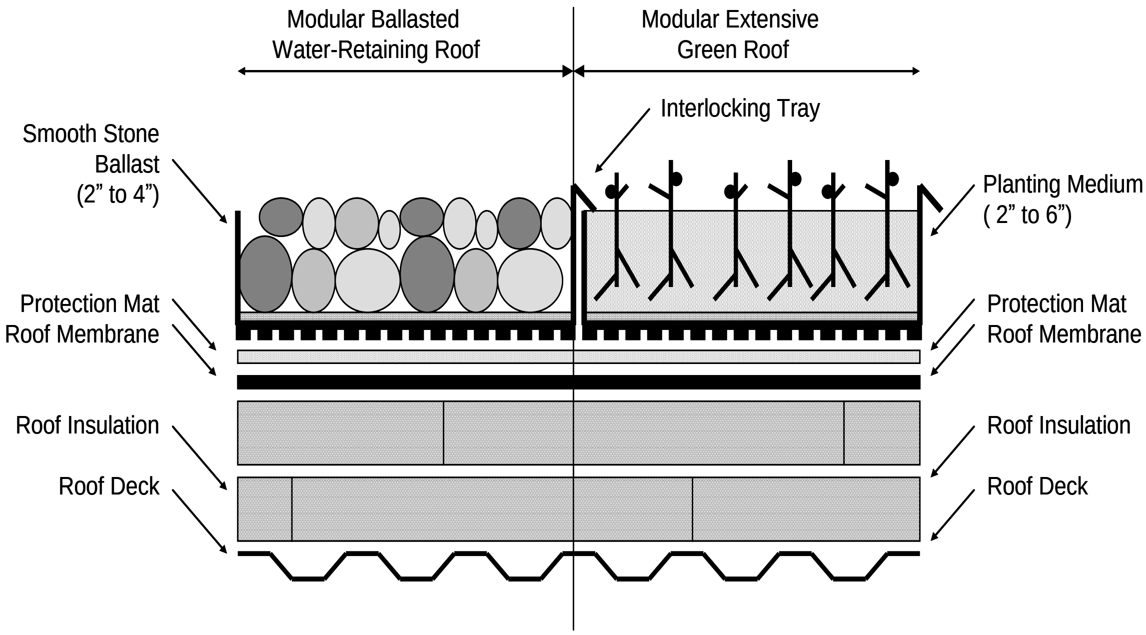

Figure 4: Water-Retention Using Modular Trays

An examination of water-retaining properties of a ballasted roofing system using moisture retention mats was recently conducted by an independent testing laboratory (Architectural Testing, 2008) at the request of a roofing system manufacturer currently marketing a roofing system similar to the system illustrated on the right-hand side of Figure 3. The moisture retention mats were installed in either one or two layers directly over a typical ballasted roofing membrane (60 mil EPDM), and the entire assembly was covered with the equivalent of #2 stone ballast at a rate of 12 lb. / sq. ft. In addition to the test assemblies, the ballast stone was also applied directly over the EPDM membrane as a control. The test assemblies were installed in waterproof trays 4 feet wide by 4 feet long, elevated to facilitate water drain collection and sloped at 1/4 in 12 to a drain located at the lowest end of the tray.

Each test assembly was subjected to a simulated one-hour rain event at rates of 1 inch, 2 inches, and 4 inches per hour. Water runoff was measured every 15 minutes, with final water runoff measured 3 hours after the end of the simulated rain event. Test results are provided in Table 1.

Table 1: Percent Water Retention 3 Hours after Simulated Rain Event

Rain Event	One Moisture Retention Mat	Two Moisture Retention Mats
1” / hr.	22.4%	37.8%
2” / hr.	6.2%	11.5%
4” / hr.	5.9%	5.6%

Although the amount of water retention with heavy rains of 2" and 4" per hour was relatively modest, the amount of water retained after a moderate rain of 1" per hour appears to offer a significant potential benefit. According to a representative of the testing agency, this water-retention concept "has substantial potential to reduce the peak runoff in approximately 75% of the country, based upon 5 year, 1-hour rainfall charts." (Architectural Testing, 2008: Summary Conclusions.)

The level of water retention provided by the ballasted water-retaining roof illustrated in Figure 3 would appear to be lower than studies have documented for many green roofing systems. However - especially for moderate rainfall events - ballasted roofing systems using moisture retention mats appear to perform significantly better than offered by ordinary roofing systems. In addition, the formal introduction of a ballasted water-retaining roof system raises some interesting questions regarding the function and benefit of the various water-retaining elements of a green roof including moisture retention mats, planting media, and the vegetation itself. How much of the overall water-retention capabilities of a green roof are attributable to each of these elements? Past research suggests that moisture retention mats and the planting media are responsible for the great majority of water retention. As stated in the conclusions of a recent research study of roof stormwater retention, VanWoert et al. (2005, p. 1043) suggest, "While vegetation did affect stormwater retention, it was minimal relative to the effects of growing media."

The Economics of Green and Ballasted Roofs

Although the levels of stormwater retention provided by current ballasted roofing systems may not yet provide the equivalent of many green roofing systems, ballasted roofs may offer a potentially significant benefit in terms of economics. Compared to the complex materials required for a well-designed green roof, a simple ballasted roof requires only a waterproofing membrane and a layer of relatively inexpensive river-washed stone. The material economies of a ballasted roof in turn translate into reduced installation costs. In addition, research suggests that the maintenance costs of ballasted roofing systems are relatively minimal, typically amounting to less than 2% of the original installation costs over the first ten years of service (Hoff, 2003). Finally, life-cycle cost studies of roofing systems suggest that the overall life cycle cost of ballasted roofs may be lower than many other low-slope roofing alternatives (Hoff, 2007).

In order to optimize the benefits offered by green roofs and ballasted roofs, perhaps the two alternatives should not be viewed as exclusive choices. The scope of this paper is too small to provide a detailed examination of comparative system costs between ballasted and green roofing systems, but most available construction cost information would appear to suggest that the cost differential between the two systems is significant. If the installed cost of a typical green roofing system is somewhere between $10 and $24 per square foot, as suggested by Green Roofs for Healthy Cities (2009), it is likely that the ballasted water-retaining systems described in this paper may cost somewhere between and $4.00 and $6.00 (Author estimate).

The significance of this cost differential would appear to be reflected in the comparative market share for these two roofing systems. In 2007, it is estimated that approximately 4 million square feet of green roofs were installed in North America[1]. In that same year, it is likely that hundreds of millions of square feet of ballasted roofs were installed in North America, based in industry market surveys and shipment reports. Assuming the annual low-slope roofing market in North America includes approximately four billion square feet of installations each year, the market share of green roofs is significantly less than 1%, while ballasted roofing systems may enjoy a market share close to 10% of all low-slope roofing installations.

To the extent that demand for green roofing may be limited by high relative costs and demand for ballasted roofs may be supported by low relative costs, it is possible that creative combinations of the two systems may accelerate overall demand for green roofing. If more quantifiable information about the heat-reducing and water-retaining properties of ballasted roofs were developed and made available to building designers, the initial cost of the green roof portion of a green/ballasted roof hybrid could be spread over a larger level of identified benefit. And if the overall ratio of benefit to cost could be made more favorable, it is very possible that many building owners would select green/ballasted roof hybrids in order to obtain the additional benefits of a green roof.

Conclusions: The Potential for Hybrid Green / Ballasted Roofs

Although green roofs and ballasted roofs may offer similar functional benefits in terms of roof service life extension, heat load reduction, and stormwater retention, both roof systems offer distinctive benefits that must be considered by the roofing designer. As previously suggested, the amount of heat load reduction and stormwater retention offered by ballasted roofs may not be as large as similar levels offered by green roofs. And in addition to mitigating stormwater runoff and atmospheric heat build-up, green roofs may also cleanse the water and remove significant atmospheric pollutants. Green roofs also offer many important public benefits by incorporating more natural aesthetics, increasing habitat diversity, and adding recreational space in the urban environment. Because ballasted roofing systems tend to be monolithic in both appearance and material usage, they likely cannot offer similar aesthetic, ecological or recreational benefits as compared to green roofs. However, as previously discussed, ballasted roofs may offer a potentially significant benefit in terms of lower installed cost.

The building designer should not view roof system selection to be an either/or proposition between the two systems, but rather as a professional design decision regarding how these two roofing systems may be combined to best meet the functional requirements of the building owner. In reality, the combination of ballasted and green roofs may be a relatively common practice. Almost every green roof installed across the world includes ballasted areas to accommodate roof traffic and add design variety to the overall roof landscape. But because there has been little quantifiable discussion of the value of this hybrid approach, it is likely that the overall benefits of green/ballasted roofs are not fully understood by building designers and the public.

Suggestions for Future Research

The potential benefits of green/ballasted roofing hybrids may only be increased with additional research into the performance features of ballasted roofing systems. In regard to water-retention, research should be expanded to include current water-retaining ballasted systems. With such additional laboratory and field research, current work on stormwater modeling could be expanded to include water-retaining ballasted systems as well as combinations of green/ballasted system designs.

In a similar manner, energy modeling of green roofing systems should be expanded to include the findings of Oak Ridge laboratories so that comprehensive roofing energy models could be developed that can address green/ballasted roofing hybrids. Such models would in turn allow building designers to examine combinations of ballasted and green roofs in order to optimize overall building energy savings.

Finally, additional research should be undertaken to fully quantify the comparative costs of green roofs and ballasted roofing systems with water-retention features. Such research would allow building designers to conduct an effective cost-benefit analysis of hybrid green/ballasted roof combinations to maximize overall environmental, energy, and economic benefits for the building owner.

Footnotes:

[1]The 4 million square foot estimate is derived from the Green Roofs for Healthy Cities 2007 Industry Survey (http://www.greenroofs.org/resources/2007%20Green%20Roof%20Survey%20Results.pdf), which reported that approximately 2.4 million square feet of green roof systems were reported to have been installed in 2007, with the assumption that this survey number represented approximately 60% of total green roofing activity in 2007.

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