

# GREEN ROOF DURABILITY: LESSONS FROM SANDY

by

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## INTRODUCTION

Green roofs set in place over conventional roofing systems are a relatively recent phenomenon in North America. While the base of research into North American green roof performance is growing rapidly, not much data exists yet in regard to actual system performance during catastrophic weather events. The roofing industry is often left asking: What happens to green roofs in high wind conditions? This is often followed by other queries such as, “How do I know what is engineered is going to work? ... Is this over engineered?” To answer these questions completely will take years of research and testing, but in the meantime anecdotal evidence can provide some useful ‘lessons learned’ about the durability of vegetative roofing in high wind situations.

Superstorm Sandy, with its landfall occurring in the heart of one of the fastest growing U.S. markets for green roofs – metropolitan New York City – provides an unprecedented *in situ* opportunity to learn more about green roofs and their behavior during storms. Specifically, the effects of wind – uplift, scour, shear, etc. – can be clearly seen through the images of green roofs taken before, during, and after the storm.

Firestone Building Products offers a line of green roofing called the SkyScape Vegetative Roof System for a single-source warranty solution. Firestone SkyScape Vegetative Roof Systems come in five basic types: PreGrown Trays, Post-Planted Trays, Multilayer, Low Profile Multilayer, Hybrid and Steep Slope. The SkyScape system can be installed in conjunction with any of Firestone’s TPO, EPDM, SBS, or APP roofing systems to create versatile rooftop living spaces. As a vegetated roof provider, Firestone endeavors to advance the science of green roofing through investigations such as these.

## GREEN ROOF OVERVIEW

Green roofs, also known as vegetative roofs, are engineered systems designed to support plant life on top of conventional roofs. The numerous potential benefits associated with vegetative roofing include stormwater retention, mitigating urban heat-island effects, prolonging the life of the roofing materials, energy conservation and enhanced aesthetics.

Vegetative roofs are commonly divided into two categories. The first category is extensive green roofs, which contain 6-inches or less of growing media. Common goals of an extensive green roof include stormwater management, extending the life of the roof-membrane, or achieving LEED certification. Intensive roofs are 6-inches or greater in depth and can support a wider range of plant material such as large shrubs, or even trees. Intensive roofs are frequently referred to as roof gardens, and may incorporate elements such as lawns, decks, promenades, trellises, etc which exist for the primary enjoyment of people.

A further distinction can be made between the types of green roof assemblies, generally described as modular tray or built-in-place systems. Regardless of methodology, all green roof systems have components which address the following functionality:

- Vegetation- To stabilize the growing media, evapotranspire water and prevent wind scour.
- Growing Medium- Provide moisture and nutrients for plants, as well as retain stormwater.
- Moisture Retention- Provide additional moisture retention capabilities especially with thin, extensive soil profiles.
- Drainage- Remove excess water from the vegetative roof system and direct it to the roof drains.
- Roofing/Waterproofing- Provide a watertight barrier between the interior and exterior of a structure.

It may be helpful to describe the green roof systems that were used in the scope of this study. The two projects profiled in this study utilized different types of green roofs: namely trays and multilayer assemblies. However, these systems followed the same basic installation approach and they are quite representative of the typical types of green roofing in the marketplace:

- Following the completed installation of the roofing system, either individual layers (water retention, filter, and drainage layers, in the case of the Jersey City project) or trays (in the case of the Woodbine, NJ project) were set in place on the roofing membrane. Next, lightweight growing media is distributed and then plants are installed. An alternative method is to grow vegetation in trays for several weeks at a nursery prior to installation, then installing these pregrown trays directly on the roofing system. Finally, edge metal is placed around the perimeter of the completed green roof system.
- The hard goods and trays serve stormwater management and media retention functions. The engineered lightweight growing media provides the base needed for plant root establishment. Green roof systems are typically finished off with edge metal.
- Plantings were installed on only one of the green roofs, using pregrown sedum mats. The other roof was in process of being installed when the storm occurred.

## EXISTING WIND UPLIFT PERFORMANCE STANDARDS

Wind performance guidelines and testing for vegetative roofing are still in their infancy. The first standard to specifically address this topic is ANSI/SPRI-RP-14 “Wind Design Standard for Vegetative Roofing Systems”, published in June 2010 in conjunction with Green Roofs for Healthy Cities. RP-14 is modeled closely after ANSI/SPRI RP-4, “Wind Design Standard for Ballasted Single-ply Roofing Systems.” It is intended to provide a minimum design and installation reference for those individuals who design, specify, and install vegetative roofing systems. Users of RP-14 can determine the maximum allowable wind speeds for vegetative roof systems based on a specific building’s height, roof edge (parapet) height and exposure category.

It is important to note that RP-14 treats green roofs as ballast, and applies principles gleaned from experience in testing ballasted roof assemblies to these systems. RP-14 does not take into account securement technologies employed by some manufacturers. The Firestone SkyScape Vegetative Tray Systems examined in this paper employs interlocking edges on all four sides of the trays. Furthermore, the trays are mechanically fastened together with pins for a monolithic tray assembly that even when empty displays considerable resistance to wind uplift. Similarly, Bio-Roof, a Canadian company, uses an interlocking technique in their tray design that provides uplift resistance as well. Other manufacturers appear to be following these design trends.

It should also be pointed out that while ANSI/SPRI RP-14 is the only standard addressing wind uplift, there are several other performance standards that apply to green roofs, most notably FM Loss Prevention Data Sheet 1-35, Green Roof Systems. This document provides basic design criteria and addresses fire resistance of green roof assemblies in particular. Another very helpful standard is the FLL Guideline for the Planning, Execution, and Upkeep of Vegetative-Roof Sites, created by the German Landscape Research, Development and Construction Society.

## HOW VEGETATIVE ROOFING SYSTEMS MITIGATE AGAINST WIND UPLIFT

As is evident in RP-14, green roofs act as ballast over the installed roofing system. Since green roofs vary widely due to their design (depth of media, types of plantings, additional securement, etc.), it is not possible to state an average weight of green roofs in pounds-per-square foot. However, most green roof systems weigh in excess of 20lbs per sqft when fully saturated, and many exceed this number by 7-14lbs. This far exceeds the standard spread rate weights for ballast rock, which typically is 10lbs/sqft-field, 12lbs/sqft perimeter, and 15-18lbs per sqft/corners. Therefore, by sheer weight, green roof systems are substantially heavier than traditionally-installed ballast, and could be expected therefore to remain in place more effectively than ballast.

Additionally, once a green roof has reached the point of root establishment, its holding power increases simply by virtue of the root network “locking in” to the growing media, and, in some cases of some multilayer green roof assemblies, also rooting down to the water retention layer components. This rooting can be considered to provide additional resistance against wind scour.

However, and as is obvious, wind events will occur at installations where green roofs have not had sufficient time to reach establishment, or where the green roof installation is still in progress, and no plant material, or even growing media, has yet been installed. As Mike Ennis pointed out in his paper, “Fire and Wind Resistance Standards for Vegetative Roofs,” presented to this body in 2010, “...the growth media used in vegetative roofs contains small particles. If left exposed, these small particles can be displaced at relatively low wind speeds.” Therefore, while well-established/fully saturated green roofs may logically be highly resistant to the effects of wind, less mature or drier green roof systems may be susceptible to detrimental effects.

#### HURRICANE SANDY

Hurricane Sandy became the second costliest hurricane in U.S. History when it struck the Atlantic Coast in October of 2012. Surpassed only by Hurricane Katrina, it quickly earned the nickname ‘Superstorm Sandy.’ As measured by diameter it became the largest Atlantic hurricane on record with winds spanning 1,100 miles.

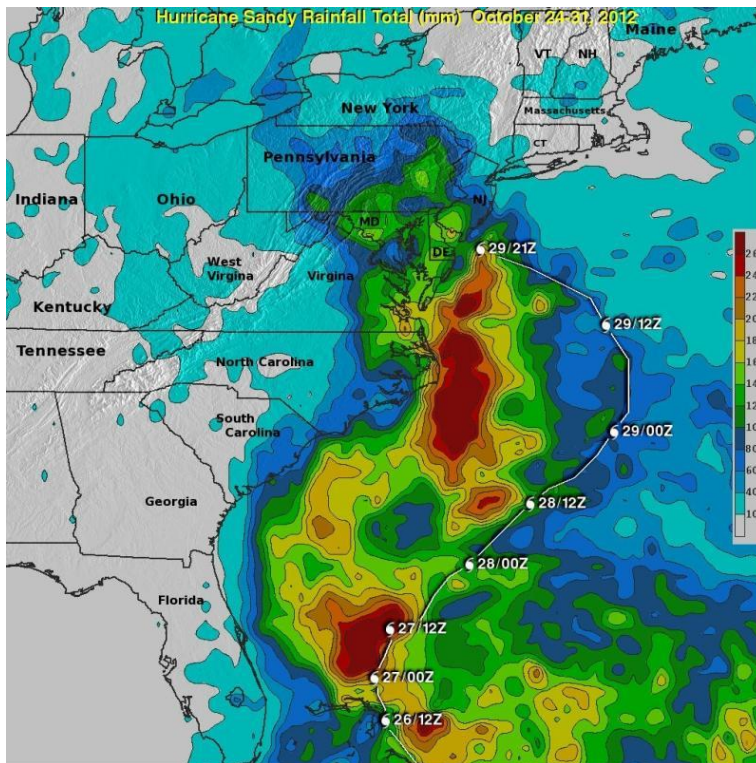


Figure 1: Hurricane Sandy Rainfall.

Sandy began as a tropical depression in the Caribbean Sea off the coast of Nicaragua. On October 24th it became a hurricane and gained strength as it moved past Haiti and Jamaica to Cuba, where it struck the historic city of Santiago de Cuba and was upgraded to a Category 3 Hurricane. By October 27th Sandy had reached the southern coast of the United States, although it mostly stayed well offshore as it passed Florida, Georgia and the Carolinas. An unusual convergence of weather factors, including a high-pressure cold front and high-tides associated with the full moon combined to morph the storm into a powerful super-storm as it churned northwest. On October 29th Sandy made a sharp turn to the northwest on a direct path for the coast of New Jersey. The eye of the storm struck near Atlantic City, New Jersey bringing with it high winds and drenching rains. The extraordinarily high storm surge of nearly 14 feet was a direct hit to New York Harbor, which overtopped the seawall in Lower Manhattan and flooded the subway system. Because of Sandy's huge size its punishing winds, rains and flooding pound New Jersey and New York throughout the night. Sustained wind speeds of 60 mph with gusts at 80 mph were common.



Figure 2: This satellite image from NOAA shows Sandy on the morning of October 29, 2012 as it was about to begin its approach to the coast of New Jersey.

The two case studies presented in this study are located in Jersey City and Woodbine, New Jersey, 121 miles and 35 miles respectively from the epicenter of Superstorm Sandy's landfall.

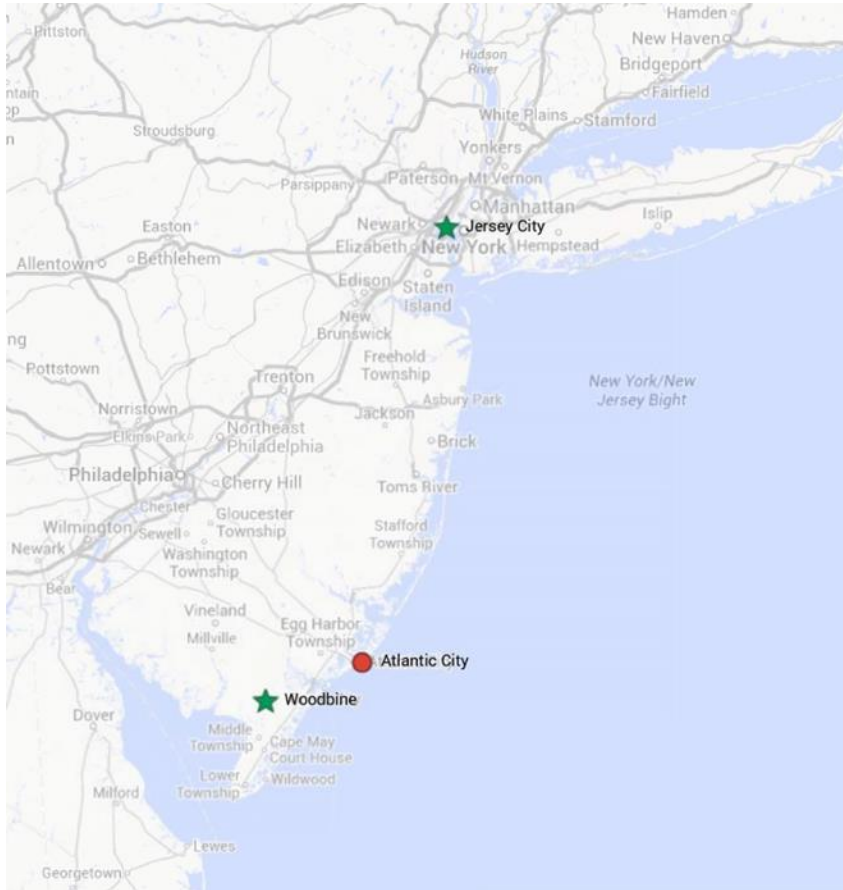


Figure 3: Case Study sites relative to landfall of Hurricane Sandy at Atlantic City, NJ.

### CASE STUDY #1- BEACON APARTMENTS

The Beacon Apartments are located in Jersey City, NJ. The art-deco style building was erected in the early 1930's. It lies 1.7 miles inland from Upper New York Bay, directly northwest of Ellis Island and Liberty Island. The green roof is located above the 8<sup>th</sup> floor, with a roof height of 65-feet.

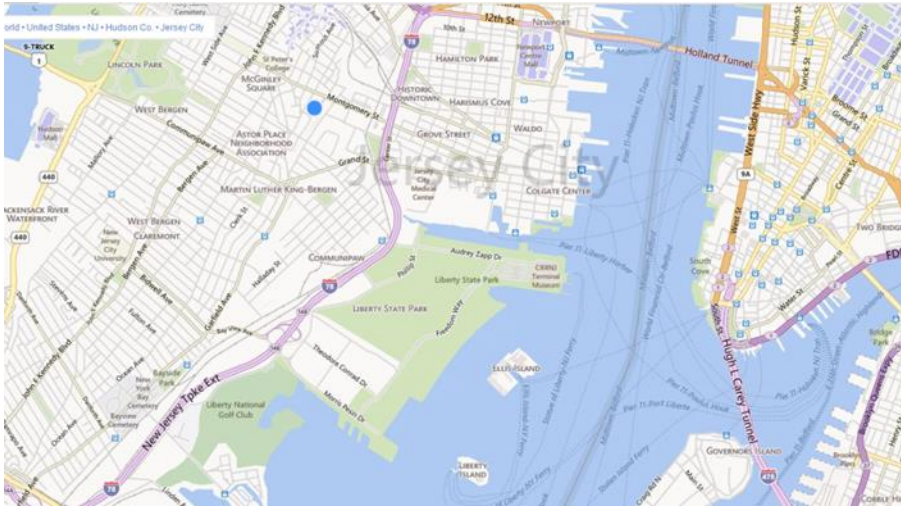


Figure 4: Location of the Beacon Apartments.



Figure 5: Aerial view of the Beacon Apartments rooftop.

The roofing system at The Beacon consists of a styrene-butadiene-styrene modified bitumen roofing membrane and base ply adhesivlve attached to a glass mat gypsum board and polyisocyanurate insulation. The roof height is 65', and the parapet around the rooftop ranges from 24"-48" above the deck. The green roof was in the process of being installed using the previously-mentioned Multilayer System. The hard goods and approximately 4" depth of growing media were already in place; however plant material was not installed at the time of the storm. This "built-up" extensive green roof assembly

is quite typical of built-up systems and can found throughout the US and Europe. It consists of three primary layers placed below the growing media and plants. The layers are as follows from the membrane up:

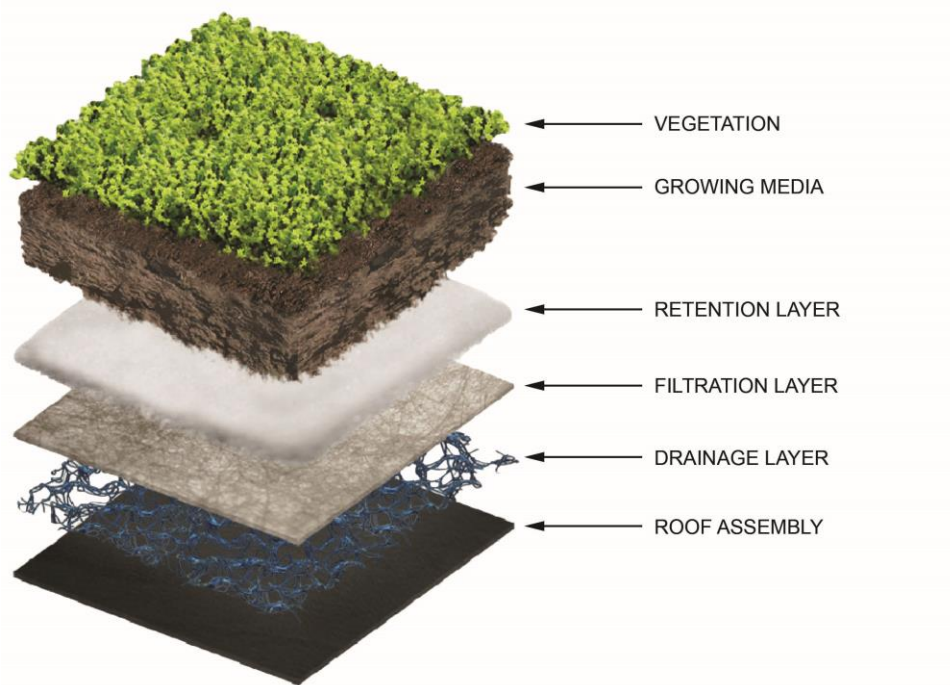


Figure 6: Multilayer Green Roof Assembly.

- **DRAINAGE LAYER-** 0.375" inch Drainage Layer composed of extruded polyester woven into an entangled cusped geometric patterned matrix with heat-welded junctions forming a resilient structure specifically designed to promote proper drainage and ventilation of growing media in vegetative roof assemblies.
- **FILTER LAYER-** 2.0 oz./yd<sup>2</sup> Nonwoven polypropylene filter layer attached to Drainage Layer.
- **WATER RETENTION LAYER-** 0.5" high loft nonwoven geotextile consisting of durable thermal bonded polyester fibers treated with insoluble polymer resins to form an evenly distributed, three dimensional blanket matrix specifically intended for water retention, drainage and anchorage points for promoting solid root structures for plants.
- **GROWING MEDIA-** The growing media for project was rooflite® Extensive MC. Product was transported to the site using standard 2-cubic yard capacity totes and was hand broadcasted with wheel barrows and graded to an approximate 4" depth in those areas completed prior to the storm event (primarily west side of roof). This media is blended to meet FLL standards and testing of material from the blending facility yielded the following data:

Analysis (completed 08/15/12)	Units	Result
Bulk Density (dry weight)	lbs./ft3	49.31 lbs./ft3
Bulk Density (at max. water-holding capacity)	lbs./ft3	75.63 lbs./ft3
Moisture	Mass %	12.6
Total Pore Volume <sup>2</sup>	Vol. %	55.5
Maximum Water Holding Capacity	Vol. %	43.80
Air Filled Porosity	Vol. %	11.70
Water Permeability	In./min.	0.45
Organic Matter Content	Mass %	3.8

Figure 6: Growing Media Analysis.

## STORM DATA

Although Sandy steadily weakened once it made landfall it brought with it significant winds prior to and following it making landfall near Atlantic City, NJ roughly 96 miles SSW of the project site. At 9:00pm EST on October 29th, Sandy was roughly 15 mi. NW of Atlantic City and winds gusts of 79 mph. had been reported nearly 80 mi. north at JFK Airport.

Because no wind measurement device was available on site, data from the two closest NOAA sites have been collected (see map below). It should be noted that instrumentation at Robbins Reef is located on buoy in the upper harbor and the Bergen Point instrumentation is located on and inlet relatively protected by land to the north and south. Given the proximity to each other (4.5 mi. apart) it is clear that the Robbins Reef buoy had greater wind exposure particular with the predominant E-NE direction through the highest intensity of the storm.



Figure 7: NOAA data points.

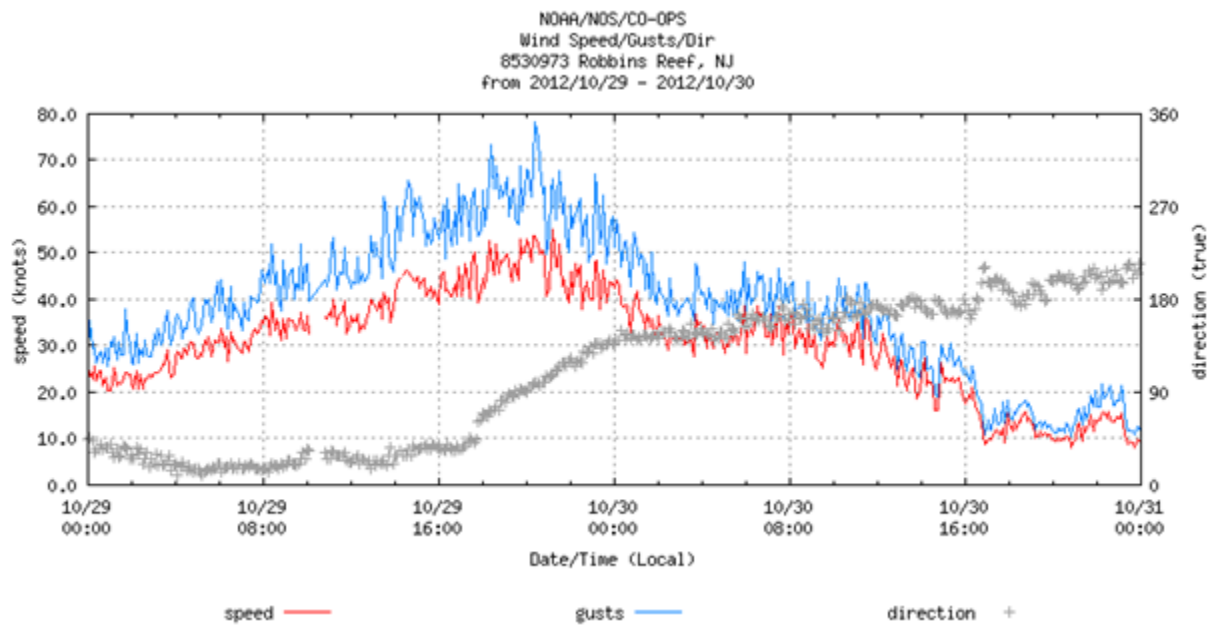


Figure 8: Wind speeds recorded at Robbins Reef NOAA buoy.

Wind data (above) acquired roughly 4.5 mi. from the project site at NOAA buoy Robbins Reef, NJ during the most extreme portions of Sandy showed sustained winds of over 46 mph. (40 knots) with sustain wind gusts over 69 mph. (60 knots) and peak wind gusts nearing 90 mph. (78 knots).

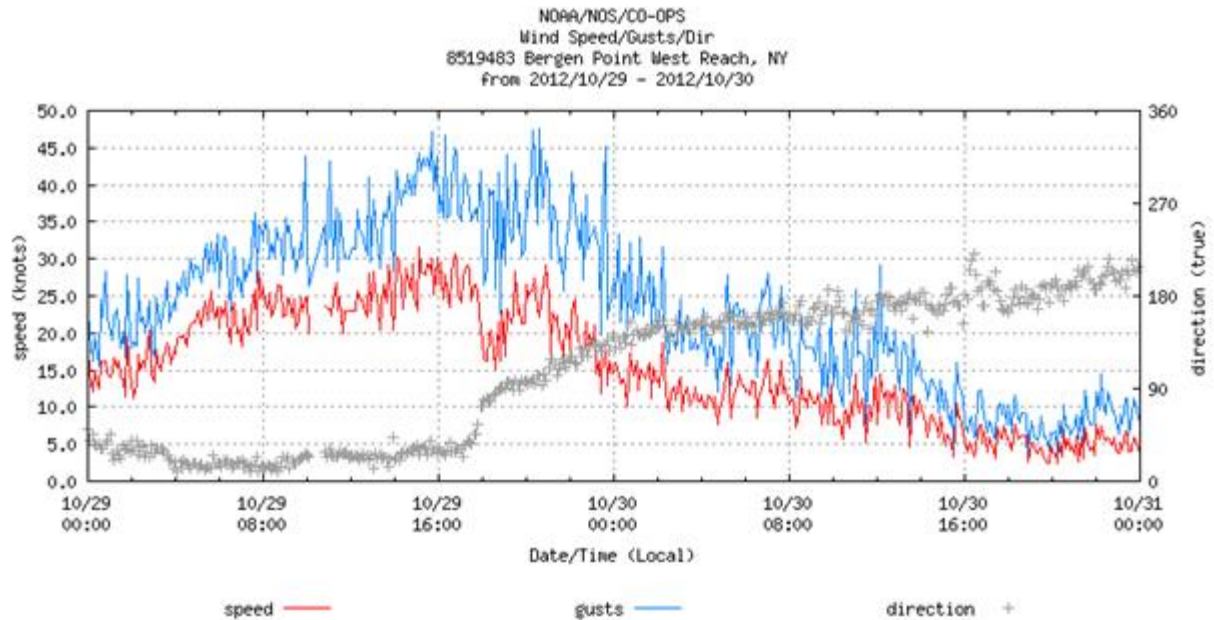


Figure 8: Wind speeds recorded at Bergen Point NOAA buoy.

Wind data (above) acquired roughly 7.1 mi. from the project site at NOAA buoy Bergen Point, NY during the most extreme portions of Sandy showed sustained winds of over 34 mph. (30 knots) with sustain wind gusts over 46 mph. (40 knots) and peak wind gusts nearing 58 mph. (50 knots)

## OBSERVATIONS

As described above, the roof was in various stages of completion at the time of the storm which can be seen in the photo below which illustrates the impacts from the storm:

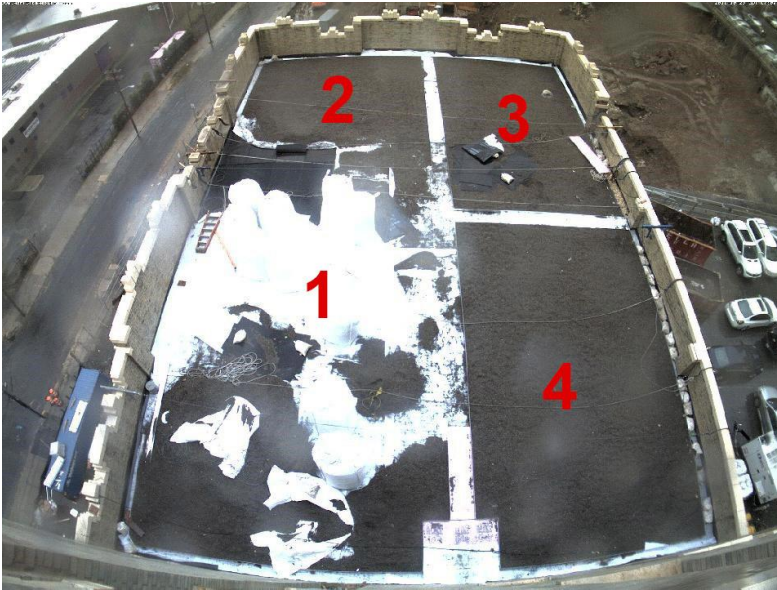


Figure 9: Post-storm conditions at Beacon Apartments green roof.

1. Roll-up of system components where edge metal system installation was unfinished, displacement of loose laid insulation; note the edges of green roof areas 2, 3, and 4, where at least some edge metal was already in place.
2. Displacement of loose laid insulation, windblown debris present.
3. Windblown debris present, but slight impact to the green roof system.
4. No significant impact.

## CASE STUDY #2- SAM AZEEZ MUSEUM

This 1,860sf green roof is located on the Sam Azeez Museum of Woodbine Heritage in Woodbine, New Jersey. Woodbine is located in far southern New Jersey, 9.8 miles inland of the Atlantic Ocean, and about halfway in between the cities of Cap May to the south, and Ocean City to the north. The one story building with a roof height of approximately 20-feet, is in a suburban setting and the roof is inaccessible to the general public. The parapet ranges from 0-inches to 18-inches in height.

The vegetative roof was built with the Skyscape tray system, a patented interlocking and overlapping tray system. This modular solution consists 2-foot by 2-foot by 4-5/8" plastic trays which have been specially designed by landscape architects, stormwater engineers, horticulturists and roofing experts for the unique challenges of the rooftop environment.

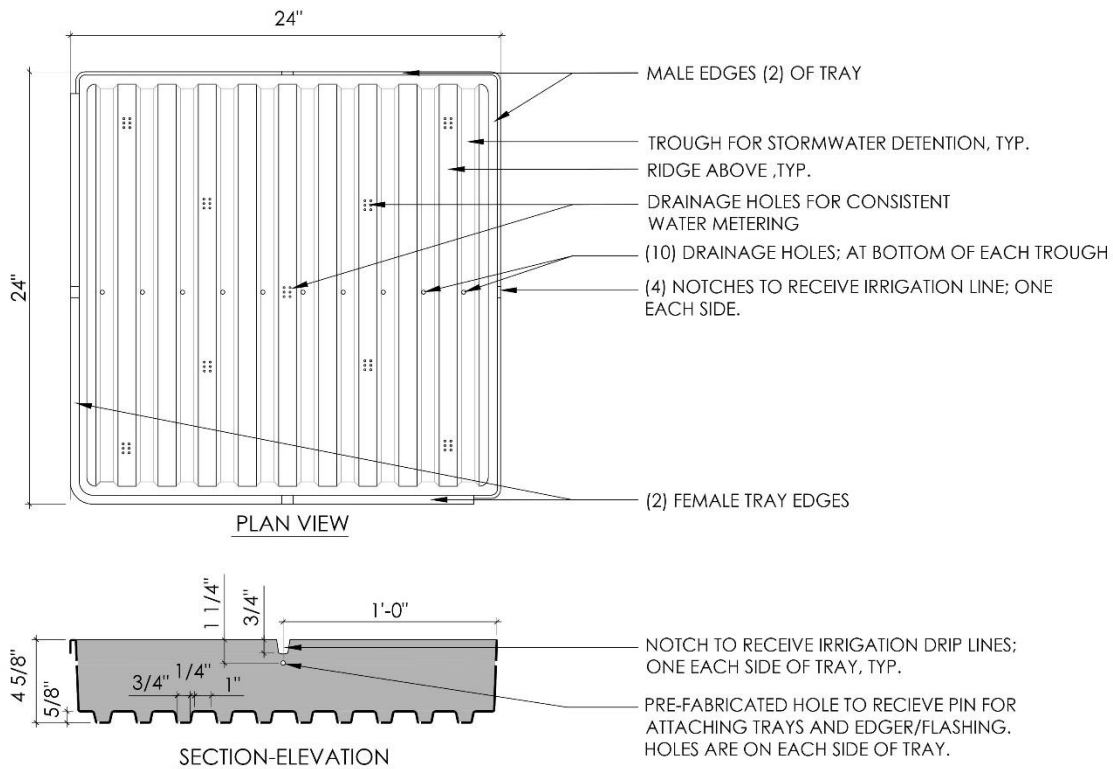


Figure 10: Illustration of Firestone SkyScape Tray used on Sam Azeez Museum.

The green roof consists of a Post-Planted Tray System, over a fully-adhered EPDM roofing system. Empty trays were set in place on the roof and interlocked according to the manufacturer's instructions. Each tray was overfilled with +/- 5.33" of growing media. Once the growing media was fully wetted, Sedum tiles were installed by simply laying them on the growing media. Green roof tray systems, when fully saturated, weigh between 25-35lbs per square foot. The vegetated portion of the roof was edged in aluminum and the remainder of the roof was ballasted with rock. The installation of the vegetated roof was completed just four days before Hurricane Sandy.

The site experienced significant winds during Hurricane Sandy. The nearest data points taken from the Cape May Weather Station suggest the area in the vicinity of this project experienced sustained winds of 60 mph and gusts estimated to be 75 mph.

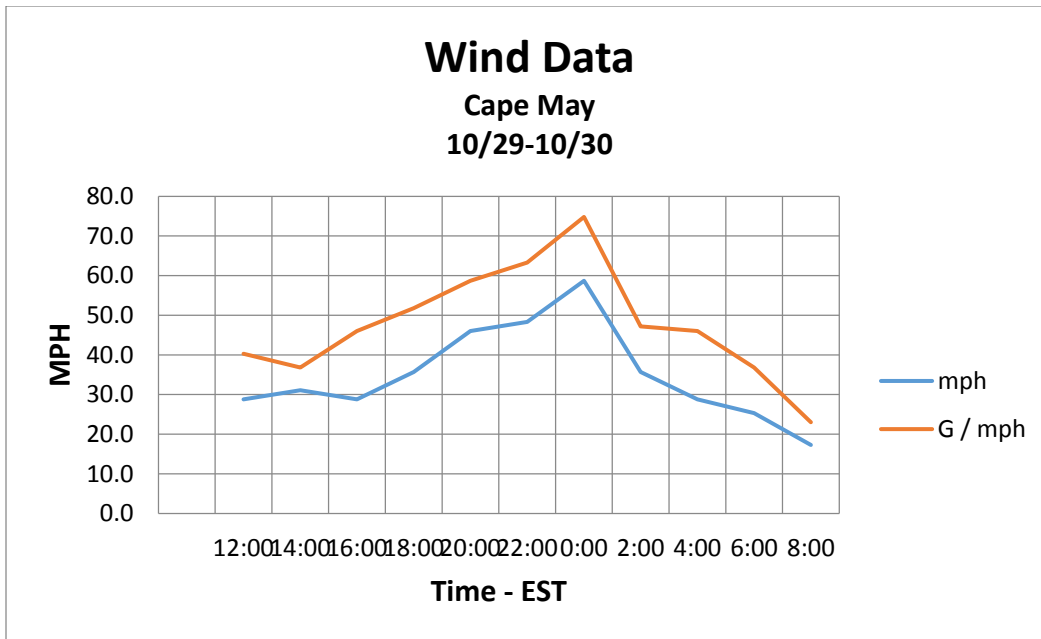


Figure 11: Wind Data from Cape May weather station.

The photos that follow were taken on November 8th, 2012 approximately one week after the storm had passed and no remedial work had been performed. The green roof remained completely intact. There was no evidence of movement or peel-back of the vegetated sedum mats. While the plants appear slightly weather-beaten, they are in good health with no sign of dieback. The underlying tray system remained in its original position with little to no shifting or misalignments observed despite sustained winds estimated at 60 mph and gusts estimated to be 75 mph. The team which visited the site to inspect for damages surmised that the significant amounts of rainfall associated with Superstorm Sandy had saturated the sedum mat and growing media such that it was very heavy and therefore had little susceptibility to the high winds caused by the storm.



Figure 12: Post-storm photo of the Sam Azeez Museum green roof.



Figure 13: Post-storm photo of the Sam Azeez Museum green roof.

## CONCLUSIONS

While, clearly, the fully installed green roof system performed better than the partially-installed system, both green roofs showed significant resistance to the effects of hurricane-force winds. Understanding that situations and conditions vary project-to-project, the results of these two roofs form a case study that sheds experientially-based light on potential expected results of green roof performance in future wind events.

## REFERENCES

References:

National Hurricane Center – Post tropical Cyclone Sandy Discussion Number 31, 11:00 PM EDT MON OCT 29 2012

<http://www.nhc.noaa.gov/text/refresh/MIATCDAT3+shtml/232035.shtml>

National Geographic: A Timeline of Hurricane Sandy's Path of Destruction