2006 - 2008 Drought and the Discovery Place Green Roof Trials Charlotte, NC

A Research Project

Charles R. Friedrich, RLA, ASLA, Carolina Stalite Company
Debra Stringer, Horticulturist, Carolina Stalite Company

Abstract

In October 2006 a roof top adjacent to the parking deck at the Discovery Place Museum in Charlotte, NC became a proving ground for a non-irrigated green roof for the City of Charlotte. The research project took on a whole new direction during one of the most severe summer droughts in the city's history. Three systems were installed over a Siplast Teranap membrane system:

1. The Xeroflor Sedum Mat, a ¾" mesh fabric mat containing growing medium in which the sedums are pre-grown to provide an instant greening.
2. Three inches of a coarse Stalite blend containing 80% 3/8" Expanded Slate Lightweight Aggregate and 20% compost, one section with yard waste compost and one section with mushroom compost.
3. A 3" media of recycled bottom ash from Duke Power with the two types of compost (yard waste compost and mushroom compost).

- Minimal water was available by manual watering with a hose during the establishment period.

The prolonged drought of 2007 took its toll on the sedums. Only plants in the path of the condensation drainage from the HAVC units were able to establish growth. All others either died or went dormant. The second phase of the project began in October 2007 and included modifying the Xeroflor, modifying the Stalite blend to include 50% finer particles, replacing 3,000 plants, and adding a drip irrigation system. The summer of 2008 was also very dry but the drip irrigation system proved to be the answer to maintaining a southern green roof. By June the sedum plants were established and by August the plants had grown six to ten times the size they were when they were plugged. Spring of 2009 showed full development of roots and "filling in" of the spaces between plants.

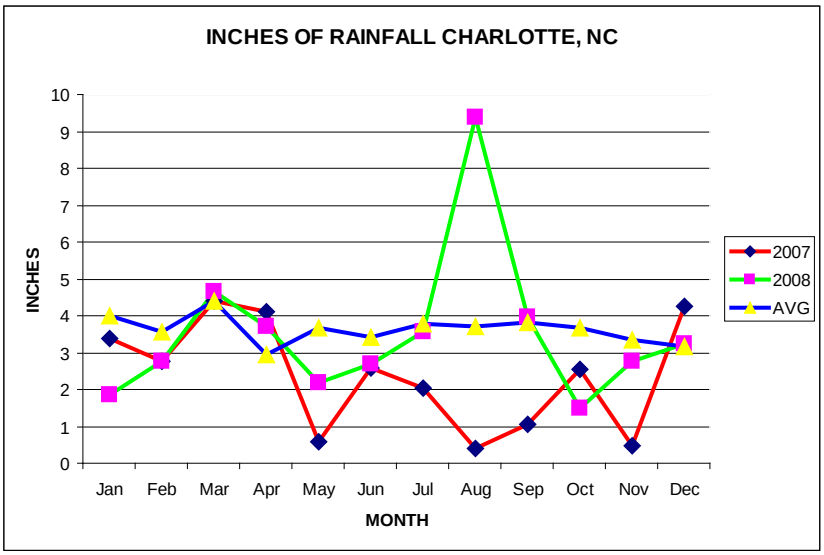
On November 19, 2007, a newspaper article was published in the *Charlotte Observer* titled "Green Roof Browns As Drought Drags On" in which report, Victoria Cherrie, seemed to berate the city for spending $225,000 to retrofit a roof section, adjacent to a parking deck, with a green roof for the purpose of an "energy-savings experiment."(Cherrie) Cherrie was not versed in green roof technology, along with some miscues on technical facts, the article also failed to mention that replacement growing materials, plants and maintenance of the plants was covered

with donated materials and labor. My interest in this project is to gain the acceptance of green roofs by municipalities and the public in general. In our society of manicured lawns and gardens, the mindset of "build it and they will come" does not make for a welcome site if the green roof is not green and lush. Though most green roof systems function even when sedums are dormant, the public perception of these flat mats of funny looking succulents covering rooftops usually never centers on the big picture. As a researcher, I have participated in research projects that have functioned with positive results for runoff quality only to be shamelessly exploited commercially by a competitor because aesthetically the sedums were not as eye popping as the sedums growing a few rows down in the nutrient fortified medium which also happened to discharge higher levels of pollutants. When so called industry professionals cannot understand the intent or respect the value of research projects then participation and donations will dry up along with green roofs.

The mission should be to continue with research, to put out the best product available, find the desired design intent and ignore the uninformed criticism. The goal green roof professionals should hope to achieve is to provide an aesthetically pleasing product that also meets environmental and economic requirements that the public can also be proud and excited about. Easier said than done? The 5,400 square foot green roof research project at the Discovery Place Museum by the City of Charlotte is a dynamic step in the right direction. The objective of the project was to figure out, in advance, what it would take to green rooftops in the micro-climate known as Uptown Charlotte. It proved very beneficial as the Federal Reserve Bank, a few blocks away, embarked on a 48,000 square foot green roof project. The drought of 2007, one of the worst in Charlotte history, could not have come at a more opportunistic time for this case study. Though painful to watch, the knowledge gained from the extraordinary weather events will continue to give the city insight on how to approach and manage green roof projects in the future.

For the past several decades the performance of extensive green roof systems and growing medium have been evaluated in Europe and more recently in the United States. It has been determined that the most crucial physical property the medium should have is good drainage. The desire for green roof systems to retain additional water while reducing irrigation and reducing and cleansing runoff in urban areas has made this more challenging. LEED Credit 1.2 for Water Efficient Landscaping requires no potable water use for irrigation or no irrigation at all. LEED recommends the use of only captured rainwater, recycled wastewater or graywater for irrigation. However, it does stipulate that temporary potable water can be used during the plant establishment period but must be removed within one year. (USGBC, p.116) Unfortunately, LEED does not allow for extended water use during time of drought. When a "green industry" is in the business of promoting green roofs it seems it should be a high priority to keep it green. The best scenario for the healthy growth and maintenance of a green roof is to have an alternative system set up for periods of drought. Adopting a cistern for storing rainwater is a good idea during average climatic conditions so water is available between rain events, however, if an extended drought occurs such as the case of 2007, cistern reserves would simply fall short. If it does not rain there is no water to refill the cistern, therefore a combination of systems is recommended. Graywater utilization is by far the best application over the life of the project, however not all municipalities allow this and the filtration system is expensive to set up and maintain. At Discovery Place these alternative water systems were not available; this was a retrofit project on a conventional metal roof system. The decision was made to use a hose bib for manual watering to provide enough water when needed. Unfortunately, manual watering is not always efficient.

In Germany most green roof growing media is very coarse, sometimes made up of crushed roofing tiles. This system is amicable to climates that have heavy morning mist, dew, or fog usually associated with cool overnight temperatures; we are not so fortunate during Charlotte summers. Extensive green roofs also use a narrower range of species limited to herbs, grasses, mosses, and drought tolerant succulents such as *Sedum* – a succulent plant known for its tolerance for extreme conditions. These types of plants can potentially be sustained without automatic irrigation in a media layer as shallow as 1.0 inch (2.5 cm) and, therefore, they can often be installed on buildings without the cost of major structural alterations. They require less maintenance and are generally less expensive to install. (Snodgrass, p.53) The sedum plugs were installed during October of 2006 and over wintered without much water. By late spring of 2007 the drought was in full swing and threatening the Charlotte area water supply. By August water restrictions were in place. Between May, 2007 and through September 2007 only 6.69 inches of rain fell in Charlotte. For the whole month of August only 0.41 inches was measured; this amounted to only 1187 gallons on the roof for the entire month. Established plantings normally require about one inch of rain per week or 2893 gallons required for the Discovery roof. With the one inch per week requirement for the hottest 26 weeks, we received 19,351 gallons from Mother Nature which left us 55,857 gallons short of the 75,208 gallons required to maintain the roof. It became clear that some sort of automatic irrigation system would be needed for green roofs to thrive in Charlotte, NC. During October of 2007 a year after the project was installed a Toro drip irrigation system was installed by Cadell Turf Management. The system will be monitored and controlled using the Toro Intelli-Sense satellite weather station monitoring system. Based on a one inch application of water per week the cost for water for the established planting will only be $7.50 per week or about $200.00 per year, hardly enough to get the LEED folks all worked up about.



YR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
2007	3.38	2.77	4.4	4.12	0.6	2.57	2.04	0.41	1.07	2.54	0.47	4.24	28.61
2008	1.84	2.76	4.64	3.7	2.19	2.69	3.57	9.38	3.98	1.49	2.75	3.23	42.22
AVG	4	3.55	4.39	2.95	3.66	3.42	3.79	3.72	3.83	3.66	3.36	3.18	43.51

Charlotte Rainfall Amounts from the National Weather Service

To address the performance issues the project became more that just a trial run; it became a green roof proving ground. The purpose for the Discovery Place green roof is to study how the sedums perform in the micro climate provided. Observations will include;

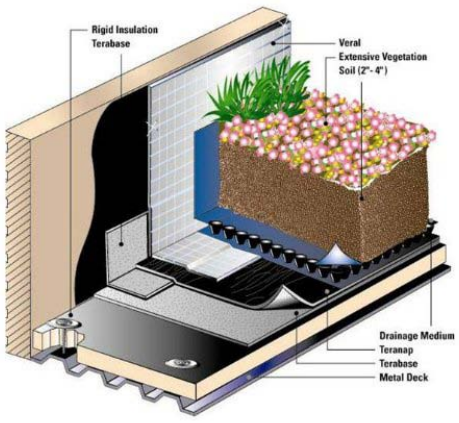
1. Plant growth and survival
2. Weed count
3. Drought tolerance
4. Plant response to irrigation
5. Root rot
6. Sedum variety dominance
7. Energy Savings

Cyclone Roofing was awarded the first Green Roof contract for the city of Charlotte, NC. The green roof is part of a re-roof of 8,000 square feet over the museum offices adjacent to the top floor of the parking deck. It consists of six specific areas of totaling approximately 5,400 square feet of various sedum varieties over a Siplast Teranap membrane and drainage board. An Vector leak mapping system was also installed by LID Inc. Steve Marlowe with the City of Charlotte is the Project Manger. David Madonia of Roof Engineering Inc. is the roofing consultant assisted in the design of the project. The dead load weight of the green roof could not exceed 35 pounds per square foot because the existing roof consists of a flutes and rib metal roof deck.

Phase I of the Study (Season One October 2006 – October 2007)

The green roof was installed October 2006 covering about 5,400 square feet over the Siplast membrane and drainage board:

1. 2145 square feet of Xeroflor Sedum Mat, a ¾" matt of layers of fabric, and absorption mat, and mesh containing growing medium in which the sedums are pre-grown to provide an instant greening.
2. 440 square feet of 3" media of 80% recycled bottom ash from Duke Powers Marshall Steam Plant amended with 20% mushroom compost and 625 square feet with 80% bottom ash and 20% yard waste compost.
3. 1250 square feet of three inches of coarse Stalite blends of 80% 3/8" Expanded Slate and 20% mushroom compost and 960 square feet of the same gradation with yard waste compost.



Siplast Teranap
Extensive Green Roof System

Xeroflor installation October 2006

Phase I Results:

The HVAC equipment on the roof drained condensation water under the drainage board of the bottom ash plots and then it ran over the membrane along the edge of the Stalite plots to the drains. Along that path the sedum did very well where the water evaporated up into the different media. This interesting unplanned circumstance showed us that sedums will survive with at least some minimal moisture during long periods of drought. The lack of rain took its toll on the sedums in all six sections of the experiment. By June is was observed that 70% of the sedums would fail to establish during the first growing season with at least 1800 plants perishing in the 104 degree F heat.
The sedums went completely dormant in XeroFlor system where no water from the HVAC system was available. Only a few hardy patches of green, yellow a green stood out with no significant count of individual species like Sedum kamtschaticum and Sedum sexangular to qualify for selection

XeroFlor August 2007

XeroFlor after drip irrigation April 2008

The bottom ash plot had wind scouring issues with losses of to ¾" off the surface with some of the material filling the spaces in between the pavers slowing down drainage.

3/8" Stalite/Compost Blend Oct. 2006

Bottom Ash / Compost Blend Oct. 2006

The coarse gradation of the Stalite media only a few of the species of the sedum established in the drier locations. Sedum reflexum 'Blue Spruce', Delosperma nubigenum, Sedum album and a few Allium schoenoprasum and Sedum spurium made it through the drought but struggled. The plants in the mushroom compost got more of a head start than those in the yard waste compost sections; however that had no affect on drought tolerance. The Sedum tetractinum and Sedum kamtscaticum completely died out of the dry Stalite mix but survived where the media retained the water from the HVAC condensation.

HVAC condensation drainage path	**Aug. 07**	**Bottom Ash HVAC condensation benefit**

Phase II of the Study (Season Two October 2007 to October 2008)

Phase II of the study became a salvage operation allowing us to provide a drip irrigation system to all the test plots. This added opportunity allows us to monitor watering using the Toro Intelli-Sense satellite weather station monitoring system. To compare the growth with the rest of the

sections, the drip system was also installed over the media and around the living sedums within the path of HVAC condensation drainage. To salvage the Xeroflor the bottom retention mat was removed to allow the roots to grow into the Stalite drainage layer below the mat. Except where the HVAC drainage occurred the coarse 3/8" Stalite blend was replaced with 3 inches of 80% recycled belt fines/20% Mushroom compost blend and 2,800 sedums were replanted. The Stalite pre-consumer recycled material is a byproduct from the crushing and screening operation at the Stalite plant. The 20% component of mushroom compost was added on site. The 2,800 new sedums were planted in a pattern where each variety can be studied as a grouping. The 3" bottom ash mixture was left in place and dead sedums replaced. The bottom ash was covered with the left over 3/8" Stalite as a mulch to prevent wind scouring.

Phase II Results:

With monitored drip irrigation the sedums flourished, some growing to four times their plug size in four months and another two inches through July.

The XeroFlor plants definitely responded to the irrigation bringing the sedums out of dormancy and recovered approximately 70% by late spring 2008. The sedums continued to grow back out during the summer of 2008; by fall 90% of the mat filled back in. The Sedum acre which had gone completely dormant during the 2007 drought in the XeroFlor plot was taking over any remaining bare spots. Some S. kamtschaticum over wintered and grew 12 times larger by fall in the XeroFlor. The XeroFlor plots also had enough weeds to fill a five gallon bucket every 6 weeks. Because the XeroFlor are pre-grown mats the opportunity for weed to establish from wind blown seeds is greater than planting on-site operations The XeroFlor initially had a substantial weed count early as a result of nursery production time in the field.

From the surface to the filter fabric, the bottom ash stayed wet over a longer period of time. This was a benefit during hot dry summer months when the HVAC condensation kept the media moist. The irrigation was shut off in November 2008, however water continued to build up in the media causing some root rot and moss growth. This became a problem during longer wet periods of the winter. The bulk of the drought survivors in the bottom ash was Sedum album, Sedum spurium and the Sedum kamtschaticum which seems to prefer the wetter media during the drought but was showing signs of rot by March 2009. The wind scouring is no longer a problem now that the plants have filled in. Weeds were major problem in the finer blend of bottom ash where up to 5 gallons of weeds per month had to be removed during the growing season from both bottom ash plots.

Bottom Ash weed count Aug 2008

Bottom Ash moss growth March 2009

Changing the Stalite to a finer gradation along with adding the irrigation allowed most of the plants (August 2008) to show an average growth of six times their diameter from the plus size at time of planting (October 2007). The coarse Stalite growing media germinated very few weeds of less than one gallon per month. The Stalite growing media allows the surface to dry quickly thereby germinating the fewest weeds. The weed count did not increase in the Stalite beds as the summer progressed. However, in September, two weeks after a heavy rain event, 3 full buckets of weeds were removed from the Stalite beds. Two spurge varieties were prominent, the reddish prostrate spurge which roots at the nodes and was impossible to eradicate 100%. The worst areas with weed infestations had the highest organic and moisture content. The spotted spurge does not root at the nodes and is easier to remove. Spotted spurge was less prominent and was found in better draining, less organic areas. The excess moisture in the bottom ash allowed for more weed growth during the summer months, by September the prostrate spurge had taken over the bottom ash beds. The XeroFlor system also continued to germinate weeds during the summer months; XeroFlor beds had more grassy weeds than spurge and by spring 2009 had a good infestation of chickweed. The 3/8" Stalite beds had just a handful of weeds during the drought of 2007; however the finer mixture with the drip irrigation activated did allow for some spurge to take over some open areas where the sedum tetractinum had died out. With proper maintenance the weed problem can be controlled. The spring and summer of 2009 will allow for pre-emergent herbicide studies to take place.

Stalite low weed count August 2008

Stalite March2009 S. album 'Coral Carpet'

Conclusion:

Sedums can survive drought once the root system is established as this study has shown. They go dormant and patiently wait for a few tiny drops of water to suck up and recover the rigidity in the leaves. What sedums cannot recover from is rot, if the media stays too wet. In my view, it is better to provide a well-drained material with supplemental irrigation than to have plant loss during a long rainy season. The controversy over irrigation of extensive green roof systems is beginning to subside now that enough projects in the U.S. are beginning to mature. It has been discussed that in order to meet LEED certifications and sustainability efforts, no potable irrigation should be used after the establishment period. With new technology using runoff

cisterns, HVAC condensation, graywater, shallow wells, monitored high tech drip systems, etc., the availability of water to maintain green roof plants should be greatly considered. The health and diversity of the plants, plus the beauty of the lush growth on the roof that watering provides is definitely a benefit. Green roofs that are not watered during periods of very dry weather can look unsightly which does little for the promotion of green roofs. Green roof growing media should be designed to encourage roots to grow deeper in the profile even when irrigated. If too much moisture is retained on the surface due to higher organics or finer media, the roots have no reason to grow deeper. For extensive green roofs, a media that stays dry on the surface makes it harder for weeds to germinate. The media should retain moisture at a deeper layer which will promote deeper roots, protecting them from hot surface temperatures. If there is air available the roots will seek it out, but without air they cannot grow. If the roots are encouraged to go deep the plants will do better during hot, dry periods when the surface temperatures can get up over 120 degrees F. If the roots are only on the surface because of poor irrigation practices they will suffer during hot spells. Good drainage is important for sedums and other plants. Too much water retention will rot a sedum quickly, too dry is better than too wet. You will be amazed how fast a sedum will recover with a little water. To wait out a slower establishment period or create an environment for fast green lush growth requiring more cost and maintenance? That is a question for debate.

Appendix

Discovery Green Roof Plant Evaluations

PLANT LIST	Dry Phase I	Watered Phase II	Dry Phase I	Watered Phase II	Dry/AC Phase I	Watered Phase II
Plant Type	XeroFlor	Xeroflor	Stalite	Stalite	Bottom Ash	Bottom Ash
Sedum						
S. acre	DORMANT	PASS	NA	NA	NA	NA
S. album varieties	DORMANT	PASS	DORMANT	PASS	PASS	PASS
S. ellacombium	FAIL	FAIL	NA	NA	NA	NA
S. floriferum	FAIL	FAIL	FAIL	NA	FAIL	NA
S. kamtschaticum	PASS	PASS	FAIL	PASS	PASS	PASS
S. pulchellum	FAIL	PASS	NA	NA	NA	NA
S. reflexum	FAIL	FAIL	PASS	PASS	PASS	ROT
S. rupestre	NA	NA	NA	PASS	NA	ROT
S. granulata	FAIL	FAIL	NA	NA	NA	NA
S. sexangulare	PASS	PASS	FAIL	PASS	FAIL	PASS
S. spurium	DORMANT	PASS	DORMANT	PASS	PASS	PASS
S. tectractinum	NA	NA	NA	FAIL	NA	FAIL
Allium schoenoprasum	NA	NA	PASS	PASS	PASS	FAIL
Delosperma nubigenum	NA	NA	PASS	PASS	PASS	PASS

Plants listed include species installed October of 2006 and replants installed October 2007 Irrigation was activated October 2007. The plants were evaluated on October 2007 (end of Phase I) then again in October 2008 and again March 2009 (Phase II). Plants were considered DORMANT if 70% of the plants returned to a green growing condition by spring of 2008. Plants listed as FAIL if 30% did not survive the drought by October 2007. Plants listed as ROT showed signs of decline due to a root rot condition. Replacement plants received an NA or FAIL ranking in PHASE I and were only evaluated during Phase II.

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Wallace Farms Compost
N.B. Handy Co., www.nbhandy.com
DMI, www.dmimetals.com
Caddell Turf Management & Irrigation
Duke Power

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