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The Use of Growstone Recycled Glass Material as a Greenroof Media

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Abstract

Growstone is a recycled glass material that is heated and expanded to form lightweight porous foam like substance. This material was evaluated to determine whether it would be suitable for use as a green roof media. The material was blended with commercial potting soil to produce a typical green roof media, which was tested for its weight, dry, and at field capacity, with three different slopes and two roofing assemblies differing in the drainage layers used. Both roof assemblies were approximately 4” deep. In one assembly approximately 1” coarse Growstone aggregate was used. The other roof assembly used a 0.5” geotextile drainage layer (Enka drain). Physical characteristics such as bulk density, and water filled porosity were determined. Growstones were also subjected to a series of freeze thaw cycles under two different water content conditions. The roof assemblies were planted with an assortment of sedum species to observe the blended medium’s ability to support plant life. Growstones based medium adequately supported plant growth, was very light weight, and held adequate moisture and air. Growstones coarse aggregates and blended media were not damaged in freeze thaw tests where water was allowed to drain away from the material. Only when Growstones were submerged in water and frozen, were Growstones subjected to freeze fracture.

Introduction

Many companies are looking for new and improved products and materials for use in the growing green roof market in North America. Growstone, LLC produces an aggregate medium, Growstones, which is currently used as a soil amendment and a hydroponic growing medium.

Growstones aggregates are made from recycled glass powder blended with a natural foaming agent. The blend is heated and expanded to form a highly porous rigid foam-like material, which is marketed as a more environmentally friendly alternative to strip mined materials such as perlite, vermiculite, and expanded clay products. Growstones have already been tested and developed for the horticultural industry. At field capacity, Growstones aggregates are characterized by water holding capacity of about 30% and air filled porosity of 50%.

Other commonly used ‘lightweight’ green roof media aggregates include, expanded clay, slate, shale, lava-rock and various organic components like sytrofoam, and rubber tire crumb. One of the most important characteristics for these materials in a green roof media is the weight of the media both dry and wet. The total weight or bulk density of the media impacts the dead load associated with the green roof and is particularly important for retrofits where a green roof will be installed on an existing building with limited load bearing capacity. We have tested several hundred commercial blended media samples in the Agricultural Analytical laboratory using ASTM and FLL testing methods. The average weights and water holding capacity of these media are given in Table 1. Weights are the averages of all commercial media submitted to the lab for testing and thus include media with expanded slate, shale, clay, sand etc. These samples do not include those media with Styrofoam or rubber, or excessively high organic content since the ASTM and FLL test procedures are not appropriate for these materials. The numbers presented in this table represent the range in weights for blended media and should be used as a comparison for evaluating other aggregate materials such as Growstones. The purpose of this study was to evaluate Growstones and determine its suitability as a component of green roof media.

Table 1. Average, minimum and maximum bulk density (dry and wet), and water holding capacity for commercial light weight aggregate based green roof media tested in the Penn State Agricultural Analytical Lab between 2002 and 2008 using ASTM and FLL testing methods.

Medium type		Bulk density (dry) g/cc	Bulk density (wet) g/cc	Water holding capacity % volume
Intensive	Average	0.90	1.35	45.7
	Min	0.54	0.95	8.7
	Max	1.38	1.81	62.8
	StDev	0.22	0.21	13.4
	n	37	37	37
Multi-course extensive	Average	0.79	1.24	46.5
	Min	0.48	0.92	14.7
	Max	1.52	1.86	65.2
	StDev	0.19	0.17	10.5
	n	66	66	66
Single course extensive	Average	0.91	1.28	38.9
	Min	0.51	1.00	16.7
	Max	1.49	1.72	51.8
	StDev	0.31	0.22	12.8
	n	9	9	9
Drainage	Average	1.0	1.22	21.8
	Min	0.68	0.78	9.87
	Max	1.71	2.05	44.5
	StDev	0.38	0.48	13.8
	n	6	6	6

Intensive roof media is intended to be used on a roof with greater than 12” (30 cm), Multicourse extensive media is intended for roofs with 6” (15 cm) or less media depth and a distinct drain layer, Single course extensive media is for use without a drain layer, and drainage is course material intended for use in a granular drainage layer.

Materials and Methods

Several experiments were completed during the course of this study. These experiments consisted of evaluating:

1. Growstones stability during freeze thaw cycles when submerged in water and frozen, and when frozen at field capacity (after gravitational water had drained away).
2. Dry bulk density and dry weights of roof assembly components (drainage layer and blend medium).
3. Field capacity bulk density and water holding capacity of roof assemblies for 3 different slopes and 2 drainage configurations with and without plants.
4. Ability of the material to support the establishment and growth of sedum plants.

The freeze thaw cycles were conducted to evaluate the stability of the material in 3 different situations. In the first trial, the material was completely submerged in water in a heavy duty plastic bottle for the freezing and thawing cycle (Figure 1).

The coarse textured (largest sized) Growstone material was used for this test.

Figure 1. Growstone coarse aggregates after 6 freeze thaw cycles submerged in water.

The Growstones were placed in three one liter bottles which were partially filled with water completely submerging the material. The bottles were then frozen and thawed repeatedly for a total of six cycles. The condition of the Growstones was observed after each cycle and any deterioration of the material was recorded. For the second trial, the coarse material was placed in three 4” plastic plant pots which were saturated with water overnight. The material in the pots was then allowed to drain excess water before being placed in the freezer. To thaw the material, it was brought out of the freezer and was again saturated with warm water. During the repeated saturation processes, excess drained water was passed through filter paper to collect any broken down debris from the material. Observations were made and recorded on the collection of any broken down material. This process was repeated for six cycles. The third trial consisted of mixing a 1:1 ratio blend of Growstones and a peat based greenhouse potting media. The blend was then placed in three 4” plastic plant pots and was completely saturated overnight. The media was allowed to drain excess water before being placed in the freezer. To thaw the material, the pots were brought out of the freezer and were allowed to sit in a heated room for 48 hours. The material was then saturated again, drained, and placed back into the freezer. This process was repeated for six cycles. At the end of the process, the media in the pots was screened to collect the Growstone material. The volume of the Growstone was then measured, recorded and compared with the input volume of the Growstone material. The smaller material that passed through the screen was examined to determine if there was observable Growstones with smaller size particles.

The next study consisted of a series of trials evaluating the properties of 2 roofing assemblies constructed with two different drainage layers, both topped with Growstone based media. The medium used in both cases, was a 1:1:1 ratio mixture of the fine textured Growstone, medium textured Growstone, and a peat based greenhouse potting media. The roof assemblies were installed in four wooden boxes suspended from Omega Engineering 150 lb. load cells. One roof assembly consisted of a 0.5” thick ENKA drain drainage layer covered with the blended media to a total depth of approximately 4” (Table 2 and 3). The second assembly used a 1” thick layer of coarse Growstones covered with a non-woven geotextile fabric layer topped with the blended media to a total depth of 4” (Table 2 and 3).

Table 2. Lysimeter box dimensions and volume.					
Drainage	**Lysimeter box**	**Width (cm)**	**length (cm)**	**Depth (cm)**	**Volume (cc)**
Coarse Growstone	1	82.0	61.5	10.5	53,153
	4	82.6	61.4	10.8	54,976
	Average				54,064
	SD				1,289
Enka drain	2	81.5	61.0	10.5	52,325
	3	82.0	63.4	9.9	51,598
	Average				51,961
	SD				514

Table 3. Depth and volume of roof assembly's components.				
Drainage	**Lysimeter box**	**Drainage depth (cm)**	**Media depth (cm)**	**Media volume (cc)**
Coarse Growstone	1	2.54	8.0	40,344
	4	2.54	8.3	42,094
	Average			41,219
	SD			1,238
Enka drain	2	1.22	9.3	46,234
	3	1.22	8.7	45,229
	Average			45,732
	SD			711

Two identical boxes of each assembly were constructed. The weight of each empty box was recorded and the data were saved on a Cambell Scientific data logger. The load cell output from the empty boxes was subtracted from the cell output to zero the output of the empty boxes. The boxes were then loaded with the drainage layers and, the weights of the boxes were recorded. The boxes were then leveled (0% slope), and filled with the blended media and weighed (Table 4). The boxes were then saturated with water and allowed to drain for a two hour period. After two hours the weights the boxes were recorded. The wetting, draining and weighing process was repeated daily over a seven day period (Figure 2). The boxes were then set to an 8% slope and the same process was repeated daily over a five day period. Finally the boxes were set at a 16% slope and the process was repeated over a four day period.

Averages were calculated for the material weights at field capacity (Table 6), and weight of water retained at field capacity (Table 7) and the dry bulk density of the assemblies (Table 5).

Following the characterization of Growstones properties, the lysimeter boxes were planted to evaluate the growth of a mixture of sedums in the roof assemblies. The plants were given approximately four weeks to root and grow. After this time period, the plant material had rooted and begun to grow in the boxes and another evaluation of the assembly properties was conducted. Again, the boxes were saturated daily and data were collected for each of the three different slopes.

Results

The freeze thaw evaluation demonstrated that drained Growstones aggregates or a blended green roof media using Growstone aggregates survived a series of freeze cycles without disintegrating. The saturated and then drained Growstones in 4” pots resulted in almost no broken down material being collected on the filter paper over a total of 6 cycles. The total amount of fractured material collected was not significant enough to be of interest. The final evaluation with the blended material in 4” pots resulted in same volume of the Growstone material being collected as was put into the original media blend.

The freeze thaw cycle evaluation with completely submerged Growstones resulted in significant deterioration of the material. After three cycles the material showed signs of breaking down. By the end of the six cycles, 20% of the material was deteriorated to a fine powder (Figure 1).

The dry weight of the drainage layer, the media layer, and the total roof assembly for each box is given in Table 4.

Table 4. Dry weights of roof assembly's components.				
Drainage	**Lysimeter box**	**Drainage weight (kg)**	**Media weight (kg)**	**Total Roof assembly weight (kg)**
Coarse Growstone	1	2.14	8.47	10.61
	4	2.01	9.56	11.57
	Average	2.08	9.02	11.09
	SD	0.09	0.78	0.68
Enka drain	2	0.95	9.89	10.84
	3	0.89	10.58	11.48
	Average	0.92	10.23	11.16
	SD	0.04	0.49	0.45

Enka drain drainage layers weighed a little less than half as much as the Growstone drainage layer. The media layer in the coarse Growstone drainage layer assemblies weighed about 9 kg compared to a little over 10 kg for the Enka drain assemblies due to the extra 0.5" depth of media in these lysimeter boxes.

Dry weights of the total assemblies were about the same for both roofing assemblies. Dry bulk density for the total roofing assemblies was about the same for both systems at about 0.2 g/cc, which corresponded to a total roof weight of about 22 kg/m^2 for both assemblies (Table 5).

Table 5. Dry bulk density of roof assembly's components and total roof weight.					
Drainage	**Lysimeter box**	**Drainage (g/cc)**	**Media (g/cc)**	**Total Roof (g/cc)**	**Total roof (kg/m^2)**
Coarse Growstone	1	0.17	0.26	0.20	21.04
	4	0.16	0.27	0.21	22.82
	Average				21.93
	SD				1.26
Enka drain	2	0.16	0.23	0.21	21.80
	3	0.14	0.25	0.22	22.08
	Average				21.94
	SD				0.19

For both roof assemblies, total roof assembly weights about doubled with the first daily irrigation. Subsequent assembly weight after 2 hours of drainage at 0% slope increased for several days (watering cycles) approaching an asymptote of about 55 kg/m^2 after 3-4 days (Figure 2).

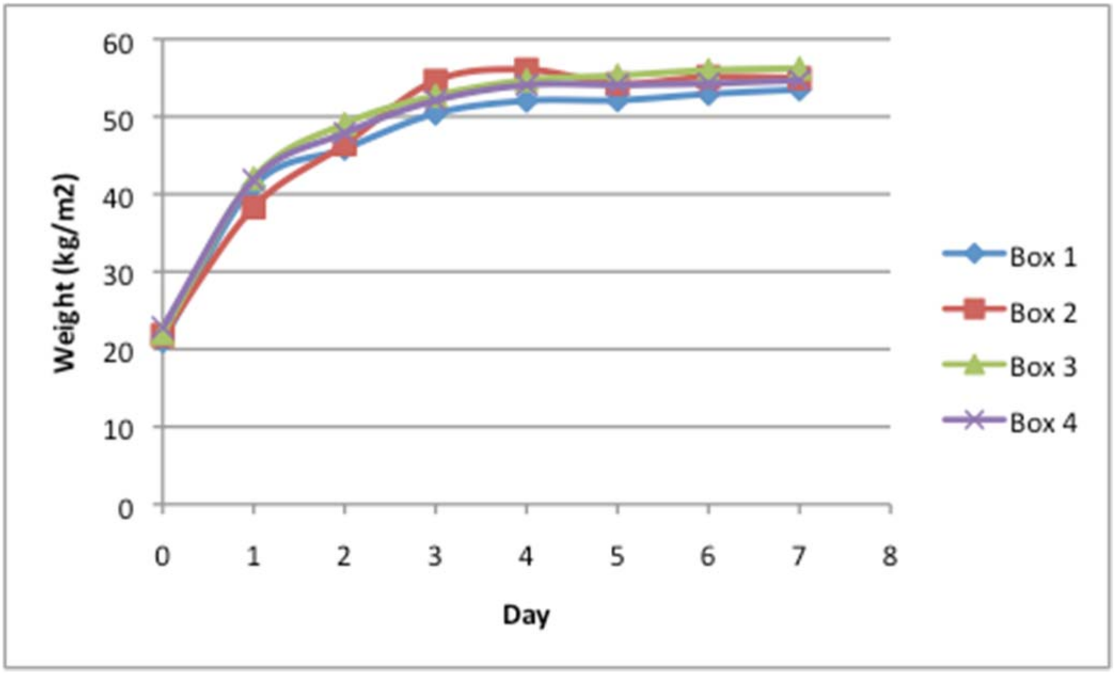

Figure 2. Increase in box weight at 0% slope with daily watering to runoff. Boxes were weighed 2 hours after irrigation each day.

The average field capacity weight for the roof systems at 3 slopes is given in Table 6. The average weight of unplanted roof assemblies with Growstone drainage layer at field capacity increased by from 53.8 kg/m^2 to 55.7 kg/m^2 as the slope increased from 0 to 16%.

The average weight of the Enka drain assemblies at field capacity decreased from 55.6 kg/m^2 to 54.5 kg/m^2 with increasing slope (Table 6, Figure 3).

Table 6. Bulk density and total weight at field capacity of roof assemblies before planting. Average of 2 measurements for each lysimeter.							
Drainage	Lysimeter box	0% Slope		8% Slope		16% Slope	
		Total Roof weight (g/cc)	Total Roof weight (kg/m²)	Total Roof weight (g/cc)	Total Roof weight (kg/m²)	Total Roof weight (g/cc)	Total Roof weight (kg/m²)
Coarse Growstone	1	0.50	53.2	0.52	54.7	0.53	55.7
	4	0.50	54	0.51	55.7	0.51	55.6
	Average	0.50	53.8	0.51	55.2	0.52	55.7
	SD	0.00	0.9	0.00	0.6	0.01	0.04
Enka drain	2	0.52	55.1	0.53	56.3	0.53	56.0
	3	0.57	56.1	0.54	53.9	0.54	53.0
	Average	0.54	55.6	0.54	55.1	0.53	54.5
	SD	0.03	0.7	0.01	1.7	0.00	2.1

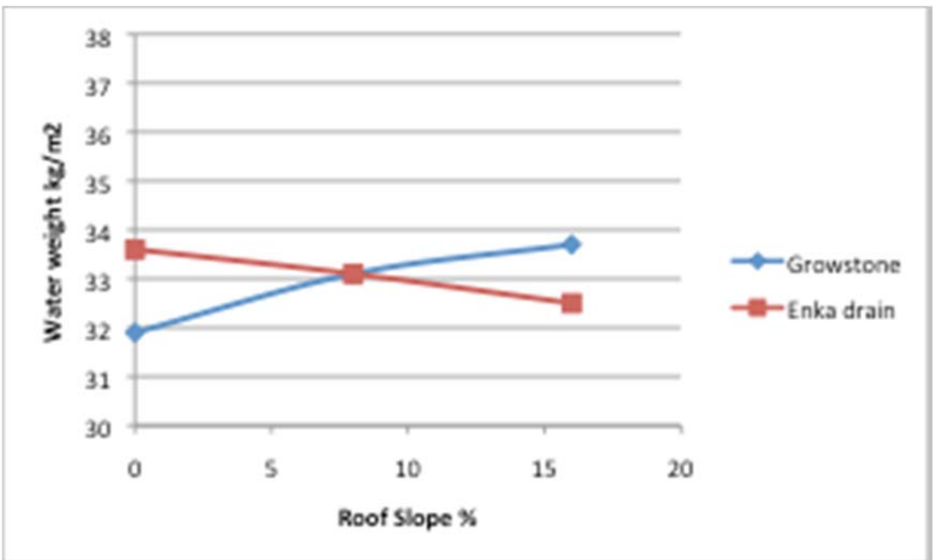

Figure 3. Change in water storage with increasing slope for unplanted roof assemblies.

Bulk density at field capacity of the roof systems ranged between 0.50 g/cc and 0.52 g/cc for Growstones drainage layer assembly and between 0.53 g/cc and 0.54 g/cc for the Enka drain assembly. Water retention at field capacity was very similar between the two assemblies, varying from 0.30 g/cc to 0.32 g/cc for the Growstone assembly and from 0.33 g /cc to 0.32 g/cc for the Enka drain assembly (Table 7). This corresponded to a water retention increase from 31.9 kg/m^2 to 33.7 kg/m^2 for the Growstone drainage assembly and a decrease from 33.6 kg/m^2 to 32.5 kg/m^2 for the Enka drain assembly as the slope increased from 0 - 16%.

Table 7. Water retained at field capacity of roof assemblies before planting. Average of 2 measurements for each lysimeter.							
Drainage	Lysimeter box	0% Slope		8% Slope		16% Slope	
		Water (g/cc)	Water (kg/m²)	Water (g/cc)	Water (kg/m²)	Water (g/cc)	Water (kg/m²)
Coarse Growstone	1	0.31	32.2	0.32	33.5	0.33	34.7
	4	0.29	31.7	0.30	32.7	0.30	32.8
	Average	0.30	31.9	0.31	33.1	0.32	33.7
	SD	0.01	0.4	0.01	0.5	0.02	1.3
Enka drain	2	0.32	33.3	0.33	34.4	0.32	34.2
	3	0.34	34.1	0.32	31.8	0.32	30.9
	Average	0.33	33.6	0.32	33.1	0.32	32.5
	SD	0.02	0.5	0.01	1.9	0.01	2.3

Total system weight with plants was about 2-3 kg/m^2 higher than the systems without plants (Table 8).

Table 8. Weight at field capacity of roof assemblies with plants (kg/m^2). Average of 2 measurements for each lysimeter.							
Drainage	Lysimeter box	0% Slope		8% Slope		16% Slope	
		Water + Plants	Total	Water + Plants	Total	Water + Plants	Total
Coarse Growstone	1	34.7	55.7	34.9	55.9	34.2	55.3
	4	34.4	57.2	34.7	57.5	33.3	57.5
	Average	34.5	56.5	34.8	56.7	33.8	55.7
	SD	0.2	1.1	0.1	1.2	0.7	0.6
Enka drain	2	38.4	60.2	37.6	59.4	35.5	57.3
	3	37.5	59.5	34.7	56.8	32.6	54.7
	Average	37.9	59.9	36.2	58.1	34.1	56.0
	SD	0.7	0.5	2.0	1.8	2.0	1.8

The weight of water plus plants was 34.5 kg/m^2 for roof assemblies with Growstone drainage at 0% slope and decreased slightly by 2% to 33.8 kg/m^2 with 16% slope. The corresponding water plus plants weight for roof assemblies with Enka drain at 0% slope was 37.9 kg/m^2 and 34.1 kg/m^2 with 16% slope, a 10% variation (Figure 4).

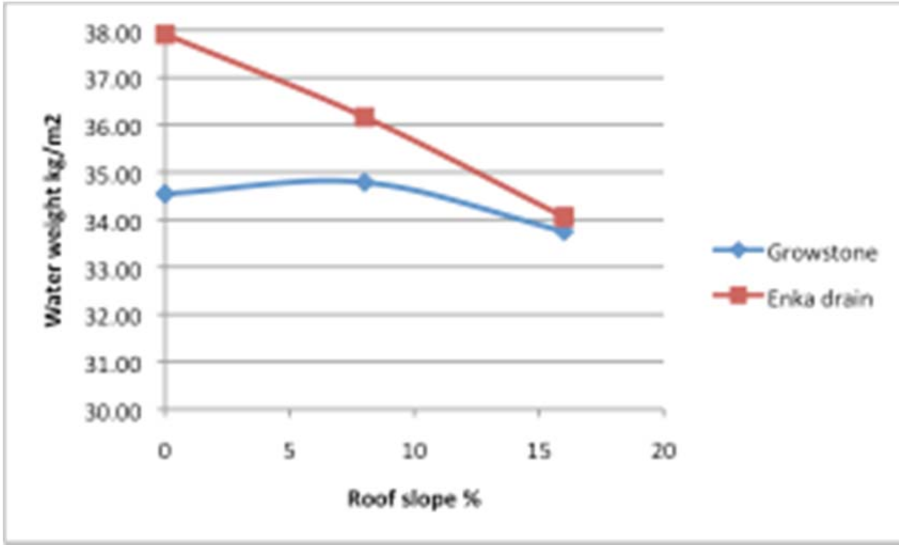

Figure 4. Change in water storage with slope for planted roof assemblies.
(Change in weight is water plus plant weight).

Sedum cuttings rooted well in the Growstones based medium. Cuttings were fully rooted about 2 weeks after planting. Plants grew well in the medium achieving 50-60% coverage after 4 weeks (Figure 5) and 80-90% coverage after 7 weeks (Figure 6).

Figure 5. Plant growth in roof assembly boxes 4 weeks after planting cuttings.

Figure 6. Plant growth in roof assembly boxes 7 weeks after planting.

There were no differences in plant growth between roof assemblies with the different drainage materials. If the experiment was to be continued, it would be interesting to see how herbaceous perennials and grasses would grow in the Growstone based media. The results from this type of study would determine which types of plant material could grow in the Growstone at various depths of media.

Discussion

Results suggest that Growstones are a suitable material for use in a green roof media, presenting the same advantages as other currently used green roof material, with the added advantage of being considerably lighter weight than other lightweight media (Table 1).

Freeze thaw cycles resulted in little or no breakdown when Growstones were drained to field capacity, either by itself or in a blended media. Only when the material was submerged in a plastic bottle filled with water was it fractured and eventually pulverized after three or more freeze thaw cycles. It appears that the external pressure of water freezing in an enclosed container where all the Growstones macro-pores were filled with water was sufficient to fracture the material. Since a green roof assembly is designed to drain excess water, it is unlikely that the media would ever be exposed to freezing with water filled macro-pores under normal roof conditions. It should however be noted that if a roof were to be flooded as a result of non-functioning drains and then subjected to freezing and thawing, media breakdown might be possible. However, if this were to occur there would be many other problems with the roof, including death of the plants from flooding and potential roof failure from weight beyond the rated loading.

The distinguishing characteristic of Growstone roofing assemblies was its very light weight. The dry weight of both roofing assemblies was about 22 kg/m^2 (4.5 lbs. $/ft^2$), and the weight at field capacity was about 53 to 56 kg/m^2 (11 to 11.5 lbs. $/ft^2$). In contrast the same lysimeters with Enka drain drainage layer and an expanded clay based medium recorded during a previous experiment weighed 53 kg/m^2 (10.8 lbs./ft^2) dry and 82 kg/m^2 (16.7 lbs./ft^2) at field capacity. Therefore, even at field capacity, the weight of the Growstone media roof assemblies was not much greater than the weights of the expanded clay based media assemblies when completely dry.

Total water storage for the roofing assemblies with Growstone was about the same as for the similar assembly using expanded clay aggregate (about 30 kg/m^2). The volumetric water content was thus about 30% at field capacity, so the roof assemblies would be expected to retain the first 2.5 - 3 cm (1 - 1.2 inches) of a rain event when dry. This is comparable to storage for most 3.5 - 4 inch thick roof systems reported in the literature. Water storage in the Enka drain roof assemblies before planting decreased as expected as slope was increased from 0-16% presumably due to increased gravitational forces on the media and drainage in the lysimeter boxes (Figure 3). In contrast, in the Growstone drain roof assembly, the water storage increased slightly as slope increased. This result was not what was expected. It would be expected that more gravitational water would drain from the higher sloped situation thus resulting in lower overall weights. It is possible that the Growstones drainage layers continued to accumulate water over time due to its characteristic high porosity. As the boxes were repeatedly saturated, Growstones aggregates may have continued to accumulate water as water slowly reached deeper into the less accessible internal pores thus increasing the overall weights of those boxes. This difference was not observed when the characteristics were measured with planted roof assemblies (Figure 4). With plants, the water weight decreased for both assembly types as the slope increased from 0 to 16%. However, in the Growstone drainage assemblies this decrease was only 2%, while in the Enka drain assemblies a 10% decrease was observed. These results suggest Growstone assemblies hold more water than Enka drain assemblies, for each slope, and against increasing gravitational forces (Figure 6). This result merits additional study.

Conclusion

Growstones based media performed much the same as other media we have evaluated for green roofs, regarding resistance to freeze thaw cycles, drainage and water holding capacity, with the extra advantage of being considerably lighter.

Growstone blended media supported plant growth as well as other media we have evaluated. All of the sedum species planted were rooted and growing in approximately two weeks. The plants had completely filled in the growing boxes after just 7 weeks. Also, at the end of the trials, all of the plants appeared to be healthy.

In conclusion, Growstones based media proved to be a suitable light weight material for green roofs.