Designation: E 2397 – 05

Standard Practice for Determination of Dead Loads and Live Loads associated with Green Roof Systems[1]

This standard is issued under the fixed designation E 2397; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers a standardized procedure for predicting the system weight of a green roof system.

1.2 The procedure addresses the loads associated with green roof systems. Components that are typically encountered in green roof systems include: membranes, non-absorptive plastic sheet components, metallic layers, fabrics, geocomposite drain layers, synthetic reinforcing layers, cover/recover boards, insulation materials, growth media, granular drainage media, and plant materials.

1.3 This procedure also addresses the weight of the green roof system under two conditions: *(1)* weight under drained conditions after new water additions by rainfall or irrigation have ceased (this includes the weight of retained water and captured water), and *(2)* weight when rainfall or irrigation is actively occurring and the drainage layer is completely filled with water. The first condition is considered the dead load of the green roof system. The difference in weight between the first and second conditions, approximated by the weight of transient water<usb> in the drainage layer, is considered a live load.

1.4 This procedure does not address point or line loads associated with architectural elements that are not essential components of a particular green roof system. These architectural elements may include pavement, walls, and masonry, and so forth.

1.5 This procedure does not address live loads associated with construction activities.

1.6 This procedure does not address live loads associated with snow or wind.

1.7 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 29/C 29M Test Method for Bulk Density (Unit Weight) and Voids in Aggregate

E 631 Terminology of Building Construction

E 2114 Terminology for Sustainability Relative to the Performance of Buildings

E 2396 Standard Test Method for Saturated Hydraulic Conductivity of Granular Drainage Media [Falling-Head Method] for Green Roof Systems

E 2398 Standard Test Method for Water and Media Retention of Geocomposite Drain Layers for Green Roof Systems

E 2399 Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems

3. Terminology

3.1 *Definitions:*

3.1.1 For terms related to building construction, refer to E 631.

3.1.2 For terms related to sustainability relative to the performance of buildings, refer to E 2114.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *captured water*, *n*—the quantity of water that is retained in the drainage layer of a green roof system after new water additions have ceased and that cannot escape the roof except through evaporation or plant transpiration.

3.2.1.1 *Discussion*—Water capture is a design technique for enhancing the water holding properties of a green roof system. Water may be captured using a number of techniques, including receptacles built into a geocomposite drain layer, trays, and restricting drainage in order to hold water within the drainage layer.

In some green roof systems a granular course at the bottom

[1] This Practice is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.71 on Sustainability.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

of the system provides both drainage and water capture functions. In this case the captured water applies only to the thickness of the granular course for which drainage is restricted.

A method for determining the captured water associated with geocomposites based on the unit water capture volume is provided in Test Method E 2398. The quantity of captured water will depend on whether or not the upper surface of the geocomposite drain layer is in-filled with granular media.

3.2.2 *geocomposite drain layer*, *n*—a synthetic sheet, mat, or panel that is specifically designed to convey water horizontally toward the roof deck drains, gutters, or scuppers.

3.2.2.1 *Discussion*—Geocomposite drainage layers include absorptive drainage mats whose principle function is drainage, but which will also contribute to water retention (see retained water). Some geocomposite drainage layers may incorporate receptacles on their upper surfaces that will capture water (see captured water)

3.2.3 *maximum media density*, *n*—the density of a mixed media material determined after it has been subjected to a specific amount of compaction and hydrated by immersion to simulate prolonged exposure to both foot traffic and rainfall.

3.2.3.1 *Discussion*—The maximum media density applies to media in a drained condition. The measurement of the maximum media density is provided in Test Method E 2396.

3.2.4 *maximum media water retention*—the quantity of water held in a media layer at the maximum media density.

3.2.4.1 *Discussion*—A procedure for measuring the maximum media water retention is provided in Test Method E 2399.

3.2.5 *retained water*, *n*—water which is held for a period of hours or days but would eventually drain out given enough time in the absence of evaporation or plant transpiration.

3.2.5.1 *Discussion*—Retained water is the quantity of water that is held for a prolonged period against gravity drainage in a green roof system, or in one of its components, after new additions by rainfall or artificial irrigation have ceased. Neglecting the effects of capillary rise, evaporation, and plant transpiration all of this water would eventually produce runoff. However, in practice most of this water will not become runoff but will be lost to evaporation and the plant-mediated processes of transpiration. This procedure describes standardized methods for estimating the quantity of water retained in a green roof system.

3.2.6 *roof system*, *n*—see *roofing system.*

3.2.7 *roofing system*, *n*—assembly of interacting components designed to weatherproof, and sometimes to insulate, the roof surface of a building. **(E 631)**

3.2.7.1 *Discussion*—This term includes all components above the roof deck that are not part of the overlying green roof system. In practice this usually means the waterproofing membrane and all materials below the waterproofing membrane, down to the structural deck. It may include structural materials such as cover/recover board, insulation, protective layers, fire-suppressing materials, and waterproofing materials. The weight of these components (assumed dry) must be obtained from the manufacturer of the roofing system.

3.2.8 *transient water*, *n*—the quantity of water that is required to completely fill the drainage layer of a green roof system, less the quantity of captured water.

3.2.8.1 *Discussion*—Transient water fills the open space, including pore spaces. This water can only be held for a period of minutes and drains immediately when rainfall additions end. This moisture contributes to the live load of the system.

4. Summary of Practice

4.1 This practice describes a systematic procedure for estimating the dead load and transient water live load of green roof systems using information about the green roof components that are available from laboratory analysis.

5. Significance and Use

5.1 This practice addresses performance characteristics for green roof systems with respect to the dead load and transient water live load of the entire system.

5.2 Determining these performance characteristics of green roof systems provides information to facilitate the assessment of related engineering aspects of the facility. Such aspects may include structural design requirements, mechanical engineering and thermal design requirements, and fire and life safety requirements.

5.3 Determining these performance characteristics of green roof systems provides information to facilitate assessment of the performance of one green roof system relative to another.

6. Apparatus

6.1 *Apparatus*:

6.1.1 Scale , accurate to 0.005 oz (0.14 g),

6.1.2 Metal mesh with sieve opening size of U.S. #30 (0.6 mm), or larger, suspended from a drain stand,

6.1.3 Pan, and

6.1.4 Water bath.

6.2 Units of measure: $lb/ft^2 (kg/m^2)$.

7. Procedure

7.1 Weight of all non-absorptive plastic sheet components, excluding fabrics: Using the scale, weigh a 4-in. by 4-in. (10-cm by 10-cm) piece. Multiply this weight by 9 (100) to convert to unit weight in lb/ft^2 (kg/m^2) and record.

7.2 *Weight of all fabrics:* Weigh a 4-in. by 4-in. (10-cm by 10-cm) sample in the dry condition. Multiply this weight by 9 (100) to convert to unit weight in lb/ft^2 (kg/m^2), and record. This is the dry unit weight. Immerse the sample in a water bath for 15 min. Withdraw from the bath and drain for 15 min. Weigh the sample and record the unit weight in lb/ft^2 (kg/m^2). This is the wet unit weight. The difference between the two measurements is the unit weight of the retained water associated with fabric.

7.3 *Weight of absorptive drainage mats used as drainage layer components:* Weigh the pan using the scale. Weigh a 4-in. by 4-in. (10-cm by 10-cm) sample in the dry condition. Record the dry unit weight of the sample in lb/ft^2 (kg/m^2). Immerse the mat in the water bath for 24 hours. Withdraw the mat from the water bath and without delay place the mat into the pan. Weigh the pan and its contents. Subtract the weight of the pan and the dry weight of the mat. Record the unit weight of the water

contained in the mat when filled to capacity in lb/ft^2 (kg/m^2). Dry the pan. Allow the mat to drain for an additional 2 hours and return the mat to the pan. Weigh the pan and its contents. Subtract the weight of the pan and record the unit weight in lb/ft^2 (kg/m^2). This is the unit wet weight of the sample. Subtract the dry unit weight of the sample from its wet unit weight. This is the unit weight of the retained water in the mat, in lb/ft^2 (kg/m^2). Subtract the unit weight of the retained water from the unit weight of the water when the mat was filled to capacity. This is the unit weight of the transient water associated with the absorptive drainage mat.

7.4 *Weight of the growth media:* Use Test Method E 2396 to determine the maximum media density (MMD) in lb/ft^3 (kg/m^3) and the maximum media water retention (MMWR). Multiply the maximum media density times the depth of the media layer in feet (metres). Record the unit weight in lb/ft^2 (kg/m^2). To determine the weight of the retained water multiply the MMWR by the depth of the media layer in feet (metres) and by 0.624 (98.10). Record the unit weight in lb/ft^3 (kg/m^3).

7.5 *Weight of granular drainage media*. Use Test Method E 2396 to determine the maximum media density (MMD) in lb/ft^3 (kg/m^3), and the maximum media water retention (MMWR) of the granular material. Multiply the maximum media density times the depth of the drainage media in feet (metres). Record the unit weight in lb/ft^2 (kg/m^2). In some green roof systems granular media is in-filled on the upper surface of a geocomposite drain layer. In these instances, the effective depth of the drainage medium is the unit media retention volume in ft^3/ft^2 (cm^3/cm^2), as determined using Test Method E 2398, plus any supplemental thickness of drainage media above the geocomposite drain layer. To determine the weight of the retained water multiply the MMWR by the effective depth of the media layer in feet (metres) and by 0.624 (98.1). Record the unit weight in lb/ft^2 (kg/m^2).

7.6 *Weight of Captured Water:* For systems that incorporate geocomposite drain layers with water capture, use Test Method E 2398 to determine the weight of captured water based on the unit water retention volume. Multiply the unit water capture volume, stated in ft^3/ft^2 (cm^3/cm^2), by 62.4 (98.1). Record this unit weight in lb/ft^2 (kg/m^2). For systems that incorporate a granular retention layer, use Test Method C 29/C 29M to determine the porosity, reported in percent, of the drainage media. Multiply the porosity times the depth of the drainage layer in feet (metres) and by 0.624 (98.1). Record this unit weight in lb/ft^2 (kg/m^2).

7.7 *Weight of transient water in the drainage layer in granular materials:* Use Test Method C 29/C 29M to determine the porosity, reported in percent, of the drainage media. Multiply the porosity times the depth of the drainage layer in feet (metres) and by 0.624 (98.1). Record this unit weight in lb/ft^2 (kg/m^2).

7.8 *Weight of transient water in a geocomposite drain layers:* For systems using absorptive drainage mats, the method for determining the weight of transient water is described in Section 7.3. For other geocomposite drain layers, use Test Method E 2398 to determine the unit volume of the geocomposite drain layer in ft^3/ft^2 (cm^3/cm^2). Multiply this unit volume by 62.4 (98.1). Subtract the unit weight of captured water associated with the geocomposite drain layer. Record the resulting unit weight in lb/ft^2 (kg/m^2).

NOTE 1—A method for measuring the effective open space in a geocomposite drain layer has not been introduced at this time. In the absence of standard method use the full thickness of the geocomposite drain layer, measured in ft and reported as ft^3/ft^2 (cm^3/cm^2).

7.9 *Weight of Retained Water in a Green Roof System:* For purposes of comparison between systems, the weight of the retained water in a green roof system shall be determined as the sum of the following unit weights:

7.9.1 Retained water in fabrics (see 7.2),

7.9.2 Retained water in absorptive drainage mats (see7.3),

7.9.3 Retained water in the growth media layer (see 7.4),

7.9.4 Retained water in the drainage media layer (see7.5), and

7.9.5 Captured water (see 7.6).

7.10 The volume of retained water, reported in inches (centimetres), associated with a green roof system is the total weight of retained water, reported in lb/ft^2 (kg/m^2), divided by 62.4 (9,810), and multiplied by 12 (100).

8. Report

8.1 Use the Report Format (ANNEX) to record the unit weights determined for each green roof component.

9. Keywords

9.1 dead load; green roof; live load; sustainability; water retention

ANNEX

(Mandatory Information)

A1. REPORT FORMAT:

SYSTEM DESIGNATION:_____ VOLUME OF RETAINED WATER, IN.
TOTAL SYSTEM THICKNESS, IN. (CM):_____ (CM):_____

Component	Thickness, in. (cm)	Comment	Unit Weight, lb/ft^2(kg/m^2)
		DEAD LOAD SUMMATION	
A. Roof System	_____	dry weight	_____
B. Root-barrier		dry weight	_____
B. Protection fabric or system	_____	wet weight	_____
C. Moisture retention fabrics		wet weight	_____
D. Geocomposite drain layer		dry weight	_____
E. Absorptive drainage mats[A]	_____	wet weight	_____
G. Granular drainage media	_____	@maximum media density	_____
H. Growth media	_____	@maximum media density	_____
I. Separation fabric		wet weight	_____
J. Captured water			_____
K. Extensive plant material			use 2 lb/ft^2 (96 kg/m^2
L. Intensive plant material, excluding large perennials and trees			use 3 lb/ft^2 (144 kg/m$^{2)}$
M. Other, describe_____			_____
		Total Dead Load	_____
		TRANSIENT WATER LIVE LOAD SUMMATION	
A. Weight of transient water contained in granular drainage materials			_____
B. Weight of transient water contained in geocomposite drain layers (including absorptive drainage mats)			_____
		Total Transient Water Live Load	_____

[A] This is a special case of geocomposite drain layers