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Standard Practice for Determination of Dead Loads and Live Loads a~~A~~ssociated with Vegetative (Green) Roof Systems[1]

This standard is issued under the fixed designation E2397; 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 vegetative (green) roof system.

1.2 The ~~procedure~~practice addresses the loads associated with vegetative (green) roof systems. Components that are typically encountered in vegetative (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~~practice also addresses the weight of the vegetative (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~~drain layer is completely filled with water. The first condition is considered the dead load of the vegetative (green) roof system. The difference in weight between the first and second conditions, approximated by the weight of transient ~~water<usb>~~water in the ~~drainage~~drain layer, is considered a live load.

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

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

1.6 This ~~procedure~~practice 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] ~~*C29/C29M Test Method for Bulk Density (Unit Weight) and Voids in Aggregate*~~

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

E631 Terminology of Building Constructions

E2114 Terminology for Sustainability Relative to the Performance of Buildings ~~E2396~~

E2396 Test Method for Saturated Water Permeability of Granular Drainage Media [Falling-Head Method] for Vegetative (Green) Roof Systems

E2398 Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Vegetative (Green) Roof Systems

E2399 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 Terminology E631.

3.1.2 For terms related to sustainability relative to the performance of buildings, refer to Terminology E2114.

3.2 *Definitions of Terms Specific to This Standard:*

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[1] This Practice is under the jurisdiction of ASTM Committee E60 on Sustainability and is the direct responsibility of Subcommittee E60.01 on Buildings and Construction.
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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.

3.2.1 *captured water*, *n*—the quantity of water that is retained in the ~~drainage~~drain layer of a vegetative (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 vegetative (green) roof system. Water may be captured using a number of techniques, including ~~receptacles~~reservoirs built into a geocomposite drain layer, trays, and restricting drainage in order to hold water within the ~~drainage~~drain layer. ~~In~~ In some vegetative (green) roof systems a granular course at the bottom of the vegetative (green) roof 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~~ A method for determining the captured water associated with geocomposites based on the unit water capture volume is provided in Test Method E2398. 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~~drain layers include absorptive ~~drainage~~drain mats whose principle function is drainage, but which will also contribute to water retention (see *retained water*). Some geocomposite ~~drainage~~drain layers may incorporate ~~receptacles~~reservoirs 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 ~~E2396~~E2399.

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

3.2.4.1 *Discussion*—A procedure for measuring the maximum media water retention is provided in Test Method E2399.

3.2.5 ~~*retained water*~~module, *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.~~ —modular vegetative (green) roof systems combine many functional elements of vegetative (green) roof systems in a pre-manufactured module.

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.~~ —Independent modules are designed to be placed adjacent to one another and linked in order to tile larger surfaces.

3.2.6 *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.

3.2.6.1 *Discussion*—Retained water is the quantity of water that is held for a prolonged period against gravity drainage in a vegetative (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 vegetative (green) roof system.

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

~~3.2.7~~

3.2.8 *roofing system*, *n*—assembly of interacting components designed to weatherproof, and sometimes to insulate, the roof surface of a building. ~~———————————————————(E631)~~

~~3.2.7.1~~

3.2.8.1 *Discussion*—This term includes all components above the roof deck that are not part of the overlying vegetative (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~~3.2.9 *transient water*, *n*—the quantity of water that is required to completely fill the ~~drainage~~drain layer of a vegetative (green) roof system, less the quantity of captured water.

~~3.2.8.1~~3.2.9.1 *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 vegetative (green) roof system.

4. Summary of Practice

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

5. Significance and Use

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

5.2 Determining these performance characteristics of vegetative (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 vegetative (green) roof systems provides information to facilitate assessment of the performance of one vegetative (green) roof system relative to another.

6. Apparatus

6.1 *Apparatus*:

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

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

~~6.1.3Pan, and~~

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

~~7.1Weight 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~~

7.1 *Weight of All Non-Absorptive Sheet Component* —These materials include plastic or rubber membranes, closed-cell foam layers, and the rigid or semi-rigid plastic cores of geocomposite drain layers. Also included is insulation provided as part of protected membrane roofing (PMR) installation. Absorptive drainage mats and fabrics, including fabrics integrated with geocomposite drain layers, are excluded (see 7.2 and 7.3). As needed, remove fabrics bonded to geocomposite drain layers for separate measurement according to 7.2. 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.~~, 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~~ Weight of All Fabrics—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~~, and record. This is the dry unit weight of the fabric. Immerse the sample in a water bath for 15 min. Withdraw from the bath and drain for 15 min by laying the fabric flat on a suspended U.S. #30 (0.6 mm) wire cloth or sieve. Weigh the sample, convert to 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.~~ , and record. This is the unit weight of the fabric. The difference between the two measurements is the unit weight of the retained water associated with the fabric, *Wr* .

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~~ Weight of Absorptive Drain Mats Used as Drain Layer Components—These materials include open-cell foam layers, porous mats fabricated from particles of plastic or rubber, and mats manufactured from coir or other organic fibers. Weigh the pan using the scale. 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 as the dry unit weight of the sample. 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~~ Multiply this weight ~~of the water contained in the mat when filled~~ by 9 (100) to convert to ~~capacity~~unit weight in lb/ft^2 ~~(kg/m~~ and record as the unit weight of the water contained in the mat when filled to capacity. Dry the pan. Allow the mat to drain for an additional two hours by laying the mat flat on a suspended U.S. #30 (0.6 mm) wire cloth or sieve. Return the mat to the pan. Weigh the pan and its contents. Subtract the weight of the pan. Convert to unit weight in lb/ft^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.~~ , and record. This is the unit weight of the sample. Subtract the dry unit weight of the sample, and record. This is the unit weight of the retained water, *Wr*, in the mat. 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 drain mat, *Wt*.

7.4 ~~*Weight of the growth media:* Use Test Method E2396 to determine the maximum media density (MMD) in lb/ft~~ Weight of Growth Media—Use Test Method E2399 to determine the maximum media density (MMD) and dry media density, D^{dry}, both measured 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~~, and the maximum media water retention (MMWR), measured in volume percent. Multiply the maximum media density times the thickness of the media layer in feet (metres) to convert to 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).~~), and record. This is the unit weight of the growth media. Multiply the dry media density times the thickness of the media layer in feet to convert to unit weight in lb/ft^2, and record. This is the dry unit weight of the growth media. To determine the unit weight of the retained water, *Wr*, multiply the MMWR by the thickness of the media layer in feet and by 0.624 (10) and record this unit weight in lb/ft^2.

7.5 ~~*Weight of granular drainage media*. Use Test Method E2396 to determine the maximum media density (MMD) in lb/ft~~Weight of Granular Drainage Media:

7.5.1 *Drain Layers Consisting Entirely of Granular Drainage Media*—Use Test Method E2399 to determine the MMD and dry media density, D^{dry}, both measured 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~~), and the MMWR of the granular material, measured in volume percent. Multiply the MMD times the thickness of the granular drainage media in feet (metres). Record the unit weight of the granular drainage media 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~~). Multiply the dry media density times the thickness of the media layer in feet to convert to unit weight in lb/ft^2, and record. This is the dry unit weight of the granular drainage media. To determine the unit weight of the retained water, *Wr*, multiply the MMWR by the thickness of the layer in feet and by 0.624 (10). Record this unit weight in lb/ft^2.

7.5.2 *Drain Layers Incorporating Geocomposite Drain Layers*—In many vegetative (green) roof systems, granular drainage media is in-filled on the upper surface of a geocomposite drain layer. In these instances, the effective thickness of the granular drainage media, *ET*, is the unit media retention volume, *Rm*, measured in ft^3/ft^2 (cm^3/cm^2), as determined using Test Method E2398~~, 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~~, plus any supplemental thickness of granular drainage media above the geocomposite drain layer, measured in feet (metres). Use Test Method E2399 to determine the MMD and dry media density, D^{dry}, both measured in lb/ft^3 (kg/m^3), and the MMWR of the granular material, measured in volume percent. Multiply the MMD times the effective thickness of the granular drainage media in feet and by 0.624 (10). Record the unit weight of the granular drainage media in lb/ft^2 (kg/m^2)~~.~~). Multiply the dry media density times the effective thickness of the granular drainage layer in feet to convert to unit weight in lb/ft^2, and record. This is the dry unit weight of the granular drainage media. To determine the weight of the retained water, *Wr*, multiply the MMWR by the effective thickness of the granular drainage media layer in feet and by 0.624 (98.1). Record this unit weight in lb/ft^2.

7.6 ~~*Weight of captured water:* For systems that incorporate geocomposite drain layers with water capture, use Test Method~~ Unit Weight of Captured Water:

7.6.1 *Drain Layers Consisting Entirely of Granular Drainage Media*—One strategy for capturing water in vegetative (green) roof systems is to impound water in the drain layer by restricting drainage. In these cases water will accumulate in the granular drainage media layer at the base of the vegetative (green) roof system. Use Test Method E2399 to determine the air-filled porosity (AFP) of the granular drainage media, reported in percent. Multiply AFP times the average depth of impounded water layer in feet (metres) and by 0.624 (10). Record the unit weight of captured water, *Wc*, in lb/ft^2 (kg/m^2).

7.6.2 *Geocomposite Drain Layers, Without Granular Drainage Media*—For vegetative (green) roof systems that incorporate geocomposite drain layers with water capture, use Test Method E2398 to determine the weight of captured water based on the unit water ~~retention volume.~~capture volume (*Rw*). 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~~, by 62.4 (10). Record the unit weight of captured water, *Wc*, in lb/ft^2 (kg/m^2)~~. For systems that incorporate a granular retention layer, use Test Method C29/C29M 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~~).

7.6.3 *Drain Layers That Incorporate In-Filling of Granular Media on the Upper Surface of a Geocomposite Drain Layer*—Use Test Method E2399 to determine the AFP of the granular drainage media, reported in percent. To determine the weight of captured water, multiply AFP times *Rw* and by 62.4 (10). Record the unit weight of captured water, *Wc*, in lb/ft^2 (kg/m^2).

~~7.7*Weight of transient water in the drainage layer in granular materials:* Use Test Method C29/C29M 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~~

7.7 *Unit Weight of Transient Water*:

7.7.1 *Drain Layers Consisting Entirely of Granular Drainage Media*—Use Test Method E2399 to determine the AFP of the granular drainage media, reported in percent. Multiply AFP times the thickness of the drain layer in feet (metres) and by 0.624 (10). Subtract the unit weight of captured water, determined in 7.6.1. Record the unit weight of transient water, *Wt*, 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~~

7.7.2 *Drain Layers Incorporating Geocomposite Drain Layers*—For vegetative (green) roof systems using absorptive drain mats, the method for determining the weight of transient water is described in 7.3~~. For other geocomposite drain layers, use Test Method E2398 to determine the unit volume of the geocomposite drain layer in ft~~. For other geocomposite drain layers, measure the thickness of the geocomposite drain layer in feet (centimetres). Add any supplemental thickness associated with the granular drainage media above the geocomposite drain layer. Record as the unit volume, *UV*, 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~~