



Member of the FM Global Group



American National Standard for Roof Mounted Rigid Photovoltaic Modules

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Foreword

NOTE: This foreword is introductory only and is not part of American National Standard FM 4478.

This standard is intended to verify that the product as described will meet minimum specific stated conditions of performance, safety and quality, useful in determining the potential suitability for end-use conditions of these products. It describes minimum performance requirements for materials that are intended for use in roof assemblies by evaluating the ability of the materials and, in turn, the system components to withstand simulated wind uplift resistance.

This American National Standard has been developed according to the essential requirements of due process for standards development of the American National Standards Institute (ANSI). FM Approvals is an ANSI-accredited standards developer (ASD).

Approval of an American National Standard requires verification by ANSI that the principles of openness and due process have been followed and that a consensus of those directly and materially affected by the standard has been achieved. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution. Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached.

The American National Standards Institute does not develop standards nor will it in any circumstances give an interpretation of any American National Standard. Requests for interpretations of this test standard should be addressed to FM Approvals.

ANSI regulations require that this American National Standard shall be revised, reaffirmed or withdrawn within five years of the date of publication.

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1 INTRODUCTION

1.1 Purpose

This standard states test requirements for roof mounted rigid photovoltaic modules that are used with a roof assembly.

1.2 Scope

1.2.1 This standard applies to all rigid photovoltaic modules intended to be 1) mechanically fastened through or adhered to a single-ply, polymer-modified bitumen sheet, built-up roof, liquid applied roof cover or steep slope roof, 2) mechanically fastened or adhered to a metal roof cover assembly using clamps or other types of fasteners, adhesive or welding or 3) loose laid and ballasted over a fully adhered single-ply, polymer-modified bitumen sheet or built-up roof cover assembly.

1.2.2 This standard also applies to panels secured to racks and/or rack framing which are independently secured to the building structure, roof deck or metal roof cover or ballasted. It also applies to the rack itself and its securement.

1.2.3 The standard is intended to evaluate only those hazards investigated and is not intended to determine suitability for the end use of a product.

1.2.4 This standard evaluates rigid photovoltaic modules for their performance in regard to fire from above the structural deck, simulated wind uplift, susceptibility from hail storm damage, and seismic performance requirements.

1.2.5 This standard only addresses the photovoltaic module and racking, it does not address any other electrical component utilized to supply the generated electrical power to the building.

1.2.6 This standard does not apply to flexible photovoltaic modules.

1.3 Basis for Requirements

1.3.1 The requirements of this standard are based on experience, research and testing, and/or the standards of other organizations. The advice of manufacturers, users, trade associations, jurisdictions and/or loss control specialists was also considered.

1.4 System of Units

Units of measurement used in this Standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Appendix A lists the selected units and conversions to SI units for measures appearing in this standard. Conversion of U.S. customary units is in accordance with *Standard for Use of the International System of Units (SI): The Modern Metric System*, BSR/IEEE/ASTM SI 10.

1.5 Applicable Documents

The following standards, test methods, and practices are referenced in this standard:

ASTM International

- *Fire Tests of Roof Coverings*, ASTM E108

- *Standard Specification for Concrete Roof Pavers*, ASTM C1491

American National Standard Institute

- *Evaluating the Simulated Wind Uplift resistance of Roof Assemblies Using Static Positive and/or Negative Differential Pressures*, ANSI/FM Approvals 4474.

American Iron and Steel Institute

- *North American Specification for the Design of Cold-Formed Steel Structural Members*, 2007 Edition, AISI S100-200

American Society of Civil Engineers

- *Minimum Design Loads for Building and Other Structures*, Standard ASCE/SEI 7-05

1.6 Definitions

For purposes of this standard, the following terms apply:

Adhesive – Adhesive is used in roof construction to adhere roof coverings to roof coverings as in lap construction. It is also used to bond roof coverings to the substrate below, to adhere insulation to the substrate or to adhere flexible photovoltaic modules to the roof covering. Depending on the use, the adhesive could be in either a liquid form, semi liquid form or a solid form as in a seam tape or as in hot asphalt which is solid until heated

Ballast – for the purposes of this document, the only acceptable ballast shall be concrete paver blocks.

Coefficient of Friction – The ratio of the force that maintains contact between an object and a surface and the frictional force that resists the motion of the object.

Crack – During wind uplift testing, when a component is stressed to the point that it separates from itself while continuing to maintain the applied uplift pressure without catastrophic failure of the test assembly.

Crease - During wind uplift testing, when a component is stressed to the point that it bends at a sharp, defined angle, without breaking. For insulation boards, often a crack will form on the opposite face.

Deck - The deck is the structural component of the roof assembly to which the roof system is secured.

Delamination - Separation of the plies in a roof membrane or system in any laminated roofing material or component, e.g., laminated layers of rigid insulation or the felt plies in a built-up roof or separation of any membrane from the substrate to which it is adhered. This includes the separation of the photovoltaic modules from the roof cover.

External Seam Clamps – A securement for attaching photovoltaic modules or racking to the seams of a standing seam roof.

Fasteners - A fastener is a mechanical securement device used alone or in combination with other components such as a stress distributor to secure various components of a roof assembly.

Fully Adhered - Fully adhered describes components such as photovoltaic modules that have been bonded to the substrate using a compatible adhesive throughout the entire surface.

Lap Seam Roof Cover – A lap seam roof cover consists of metal or plastic panels which are through fastened to structural members. A lap seam occurs where overlapping materials are seamed, sealed or otherwise bonded.

Mechanically Fastened - Mechanically fastened describes components that have been attached to the substrate at defined intervals using fasteners with, or without, stress distributors.

Minor delamination – In wind uplift testing, an area approximately 1% of the test sample. For a 12 x 24 ft (3.7 x 7.3 m) test an area of 3 ft² (0.28 m²); for a 5 x 9 ft (1.5 x 2.7 m) test an area of 0.5 ft² (0.05 m²), whereby two adhered components which are intended to be in contact are not in contact.

Permanent Deformation—Any displacement of a panel or component that remains after the load has been removed. Panel deflection that can be removed by mechanical means not involving special equipment and without additional displacement shall not be considered permanent deformation.

Photovoltaic Module – A device that converts solar energy into electricity using the photovoltaic effect.

Rigid Photovoltaic Module –An arrangement of photovoltaic cells or material, mounted on a surface and/or in a frame that are not able to be bent or flexed without damage with the cells exposed freely to incoming sunlight.

Roof Assembly - A system of interacting roof components (including the roof deck) designed to weatherproof and, normally, to insulate a building's top surface.

Roof Cover - The exterior surface of a roof assembly designed to protect the building components from the weather.

Roof System - A group of interacting roof components (not including the roof deck) designed to weatherproof and, normally, to insulate a building's top surface.

Service Wind Load – The uplift load resulting from a windstorm that a roof assembly must resist. The service load is equal to one half of the rated load in psf (kPa).

Standing Seam Roof Cover - The standing seam roof cover generally consists of metal sheets or panels, field seamed to adjacent sheets by a roll-forming machine to create an upstanding seam (rib) of folded metal along the sheet sidelaps. The panels are secured to the building framing with clips. The clip, which contains metal tabs, is roll-formed into the panel seam.

Stress Distributor/Plate - A stress distributor/plate is metal or plastic disk or bar designed to distribute a concentrated load over a larger surface area.

Wind Deflector – A component of the photovoltaic panel or racking system that is designed to turn the flow of air away from the underside of the photovoltaic panel.

2 GENERAL INFORMATION

2.1 Product Information

Rigid photovoltaic modules are submitted in panels or a panel array. They can be installed using either mechanical fasteners, clips, mounting brackets, adhesives, loose laid and/or ballasted.

3 GENERAL REQUIREMENTS

3.1 Review of Documentation

During the initial investigation and prior to physical testing, the manufacturer's specifications and details of installation shall be reviewed.

3.2 Calibration

All examinations and tests performed in evaluation to this standard shall use calibrated measuring instruments traceable and certified to acceptable national standards.

3.3 Markings

3.3.1 Marking on the product or, if not possible due to size, on its packaging or label accompanying the product, shall include the following information:

- name and address of the manufacturer or marking traceable to the manufacturer;
- date of manufacture or code traceable to date of manufacture or lot identification;
- model number, model type, and/or product name, as appropriate.

When hazard warnings are needed, the markings shall be universally recognizable and permanent.

3.3.2 The product trade name, model number, or model type identification shall correspond with the manufacturer's catalog designation. The manufacturer shall not place this trade name or model type identification on any other product unless covered by a separate agreement.

3.3.3 All markings shall be legible and durable.

3.4 Manufacturer's Installation Instructions

The manufacturer shall provide the user with printed instructions to demonstrate proper installation procedures to be followed by installers.

3.5 Test Sample Production

All products submitted for testing shall be representative of production run material.

3.6 Seismic Loads

Rigid photovoltaic modules, installed at locations within Zones 50 year, 100 year, 250 year or 500 year, shall be designed in accordance the Design Procedure for Seismic Design of Rigid Photovoltaic Modules to withstand the seismic loading experienced in these areas. Rigid photovoltaic modules located in >500 year zones are considered non-seismic and do not require analysis for seismic design. The design shall be certified by a Professional Engineer competent in this area of practice. Calculations shall be submitted to verify compliance with design requirements for the range of rigid photovoltaic modules.

The Design Procedure for Seismic Design of Rigid Photovoltaic Modules is as follows:

3.6.1 General

The rigid photovoltaic modules and racking systems (if used) shall be rated for a base shear coefficient (acceleration). The manufacturer shall demonstrate (through tests or analysis) that the rigid photovoltaic modules and racking systems (if used) shall remain intact and operational when subjected to the rated base

shear coefficient. A seismically rated rigid photovoltaic module can be erected in earthquake zones 50-through 500-year as long as the rated base shear coefficient is greater than the design base shear coefficient calculated according to this standard. The anchorage of the rigid photovoltaic modules and racking systems (if used) to the supporting structure shall be designed for the base shear, overturning moment about the two principal axes and torque about the vertical axis. The supporting structure shall be designed for the loads transmitted from the rigid photovoltaic modules. The seismic loads calculated according to this standard are intended for use in Load and Resistance Factor Design (LRFD) or Strength Design, also known as Ultimate Limit State Design, and should, therefore, be used in LRFD load combinations with a load factor of 1.0 applied to the seismic loads.

If the weight of the rigid photovoltaic module and racking systems (if used) exceeds 10% of the weight of the supporting structure, the dynamic interaction between the rigid photovoltaic modules and the supporting structure shall be considered in calculating the base shear coefficient; the simple procedure presented in this standard cannot be used for such rigid photovoltaic modules.

3.6.2 Nomenclature

A_p – base shear coefficient (acceleration in g's).

S_{DS} – 0.2 second (short period) 5% damped design spectral response acceleration (g's)

a_p – dynamic amplification factor. Equal to 1 for rigid photovoltaic modules.

R_p – component response modification factor. Equal to 1.5 for rigid photovoltaic modules.

z – height of the base of the rigid photovoltaic module above ground, in feet. Equal to zero for a ground supported rigid photovoltaic module.

h – total height of the supporting structure measured from the ground, in feet.

$\bar{h}$ – height of the center of gravity (C.G.) of the rigid photovoltaic module from the base of the rigid photovoltaic modules, in ft

S_{MS} – 0.2 second (short period) 5% damped free surface spectral acceleration adjusted for site soil properties.

F_p – design base shear

W_p – weight (dead load) of the rigid photovoltaic module, in lbs.

M_p – design overturning moment. Calculated using $M_p = F_p \cdot \bar{h}$

3.6.3 Base Shear Coefficient

The seismic base shear coefficient shall be calculated as follows:

$$A_p = \frac{0.4a_p S_{DS}}{R_p} \left(1 + 2 \frac{z}{h} \right) \quad (1)$$

A_p shall not be less than 0.3 S_{DS} and need not be more than 1.6 S_{DS}

3.6.4 Short-period design spectral response acceleration (S_{DS})

For sites within the USA, the short-period design spectral response acceleration S_{DS} shall be calculated according to the ASCE 7 standard, as follows.

The MCE (maximum considered earthquake) value of the 5% damped 'firm' rock spectral acceleration at 0.2 second (S_s) is read from the maps in ASCE 7. This is multiplied by the NEHRP (National Earthquake Hazard Reduction Program) soil amplification factor F_a (2) to obtain the free-surface spectral accelerations S_{MS} :