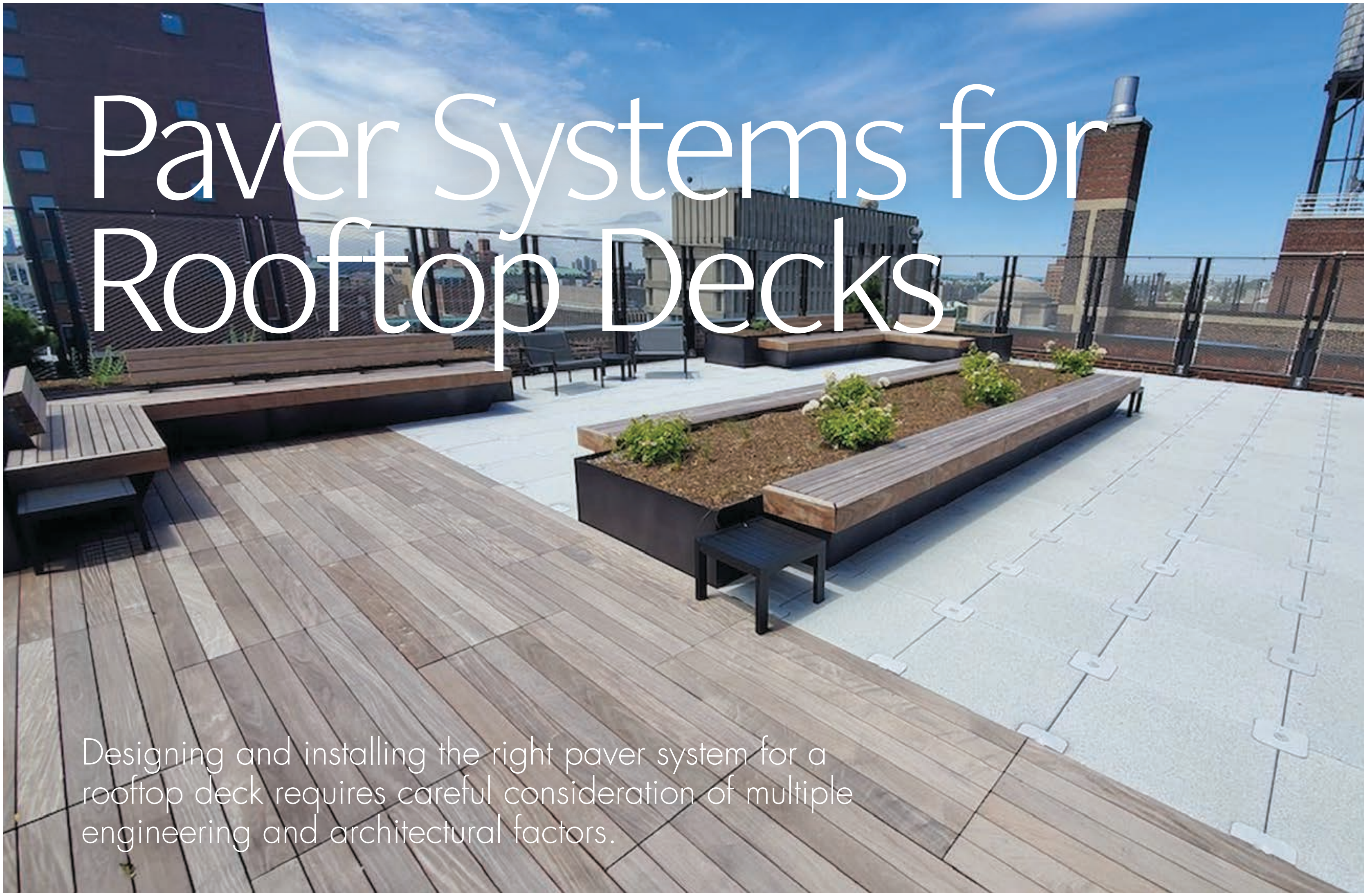
Paver Systems for Rooftop Decks



Designing and installing the right paver system for a rooftop deck requires careful consideration of multiple engineering and architectural factors.

At this university residence hall roof terrace, lockdown concrete pavers and interlocking ipe wood tiles secure against wind uplift, while providing an inviting blend of textures and hues.

BY TAI MAHMUTI, PE, HOFFMANN ARCHITECTS

The COVID-19 pandemic has laid bare the fact that access to outdoor spaces is not only an amenity, but a necessity, especially in our cities. An increase in accessibility to outdoor spaces has now been demonstrated to be a priority that will long outlast the current crisis.

Building owners should take advantage of this high demand and, where possible, consider retrofitting existing roofs and terraces to create attractive and lucrative design solutions for their tenants.

ROOFING ASSEMBLIES: GETTING TO THE BASICS

Most low-slope roofs are what is referred to as traditional assemblies. This means that the roofing membrane, which provides waterproofing, is visible and exposed as the topmost layer, with the insulation beneath. Leaving the roofing membrane exposed may allow for easier access and repairs, but it also leaves the roof vulnerable to debris, the cycle of precipitation and drying out, exposure to ultraviolet radiation, and foot traffic.

Covering the roof with an overburden, most often a thin layer of river stone loosely laid directly on the roofing membrane, is a common solution. However, loose aggregate surfacing may be prohibited by code, notably for buildings in hurricane-prone regions and for taller buildings in certain wind speed and exposure categories. Another solution is to place walkway pads on top of the membrane to allow maintenance staff to access equipment without treading directly on the roof; however, this does not alleviate the issue of the exposed membrane.

An inverted system, known as an IRMA (inverted roof membrane assembly) or PRMA (protected roof membrane assembly), can be installed in the reverse order of the traditional assembly. The roofing membrane is loose-laid, adhered, or anchored directly to the structural deck, with a drainage mat and insulation installed atop the

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membrane. Inverted systems were once capped with stone ballast, but because of the updated building code, they are now frequently covered by a paving system.

The IRMA system allows for greater protection of the roofing membrane, as it is not exposed to ultraviolet radiation, debris, or wear and tear, and insulation may be added without having to remove the membrane. Roof pavers are also a better walking surface than ballast.

ENGINEERING CONSIDERATIONS FOR PAVER SYSTEMS

Converting unoccupied roofs into occupied terraces requires consideration of amenities like furniture and greenery, but also structural capacity, access/egress and safety, wind uplift resistance, insulation and energy performance, and appropriate situation-specific detailing. In transforming a bare-bones roof covering into a usable space, building owners should be aware of the modifications that might be necessary before a roof designed to support little more than its own weight can safely bear plantings, furnishings, and people.

Load capacity. A licensed structural engineer must evaluate the structural capacity of the existing roof deck and compare roof load capacities with code requirements for occupied terraces. Roofs that were not originally designed as occupied terraces may not meet building code live load requirements, and structural reinforcement of the roofs may be necessary.

If the design of the occupied terraces includes dead loads such as planters, pergolas, and furniture, the existing roof structural deck must be able to withstand the additional load. Structural reinforcement to withstand required loads may vary from reinforcing the existing structural members, such as beams, columns, and deck, to providing additional beams, to replacing the entire structural deck and framing.

Occupancy and accessibility. Other factors to consider include determining maximum occupancy load, obtaining an occupancy permit from the governing agency, providing appropriate lighting and exit signage, and providing guardrails of appropriate height and load resistance.

Barrier-free accessibility to occupied roof terraces must also be considered during design, both accessibility from the interior as well as accessibility throughout the terrace. The slope of the terrace, position and height of handrails, turn radius, doorway clearance, threshold design, and automatic doors must all meet Americans with Disabilities Act (ADA) requirements.

Roof geometry. Too often, the design of paving systems for occupied terraces or roofs is overlooked. Concrete pavers of "typical" size and thickness are specified, often with little attention to the design significance of individual roof characteristics. The design parameters for each roof paving system are unique. Building height and location must be considered, because they have a direct impact on wind speeds and roof wind uplift pressures. Furthermore, parapet heights at roofs affect the overall wind uplift requirements and therefore also influence the selection of a suitable paving system.

Wind uplift is the primary engineering concern in the design the roof paving system. The New York City Building Code references the Single-Ply Roofing Industry RP-4 Wind Design Standard for Ballasted Single Ply Roofing Systems, which guides design professionals in selecting an appropriate paving system based on wind speed, building location, height, exposure, and parapet height. However, this standard is limited to a maximum building height of 150 feet. For taller structures, the building code relies on the expertise of design professionals for the design and engineering of the paving system, which must be approved by the authority having jurisdiction.

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For the installation of a paver-on-pedestal system, elevated paving units protect waterproofing and insulation with a level walking surface.

There are two methods for determining roof wind uplift for a specific building. The first, *wind tunnel testing,* involves constructing a scale model of the existing or proposed building and the surrounding structures on a turntable. The turntable is placed inside a wind tunnel, which simulates the characteristics of natural wind, and the turntable allows the scale model to be rotated through a range of wind directions. The test building is equipped with sensors that measure wind pressures on the building, including façade and roof uplift pressures.

The wind tunnel test provides more accurate design information than can be calculated based on the second method, calculations using the American Society of Civil Engineers' ASCE 7 Minimum Design Loads and Associated Criteria for Buildings and Other Structures. Not always, but often, wind tunnel testing yields reduced design pressures in comparison to calculated values, which in turn prevents overdesign of building systems. Since wind tunnel testing generally results in cost savings for the design of building systems, the expense for the testing

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Living walls and planters can be used to complement roof pavers, while improving air quality and stormwater management.

can be a good investment.

For existing buildings, and when only the roof wind uplift pressures are required, the expense for the wind tunnel testing is generally not justifiable, and calculating wind uplift pressures based on ASCE 7 is a better alternative. ASCE 7 calculations take into account the general footprint of the building (in rectangular form), as well as its height and location. Since the formula is designed to encompass a simplified structure and does not precisely model surrounding buildings and geographic features, nor the exact geometry of the building, the wind uplift pressures are generally overdesigned. Still, if only the roof or roof finishes are being replaced, calculating wind uplift using ASCE 7 is generally the more cost-efficient option.

For high wind uplift pressures, several design solutions for the roof paving system are available, such as an interlocking system, where all the pavers on the roof are tied together and restrained at the edge. Considering that wind uplift pressures are generally highest at the perimeter and corners of the roof, the architect or engineer may design a system that straps together the paving systems at those locations and provides an edge restraint, generally anchored to the parapet wall.

Energy code compliance. Another aspect to consider is the likely potential for adding insulation. Energy codes are becoming more stringent, requiring greater insulating values of the roof assembly. Unless the building is a designated landmark structure, adhering to the new energy code requirements is a must. Even if the building is not required to comply with the current energy code, it is good practice to follow new code requirements where practicable. Be aware that an increase in insulation generally raises the finished roof height and therefore can impact the height of door thresholds, roof guardrails, and flashings.

The building code also specifies solar reflectance index (SRI) minimum requirements for roof coverings to reduce the urban heat island effect, whereby building materials, especially dark-colored roofs, absorb and retain heat, warming up the environment. Therefore, the roof coverings/overburden system must meet SRI minimums that are generally related to roof slopes.

ARCHITECTURAL AND AESTHETIC CONSIDERATIONS

The building owner and project team can now turn their attention to matters of aesthetics and durability. Selecting a paving system demands consideration of maintenance requirements, longevity, and intended use, as well as integration with vegetative assemblies and site amenities such as furnishings and entertainment features.

Paver material options. After the engineering component of converting unoccupied roofs to occupied terraces is achieved, the overburden system, which is the most visible aspect of the conversion, must be designed. Overburden, in the form of paver systems, comes in many materials, each with distinct properties, benefits, and installation methods. Available in various sizes and geometries, the wide range of pavers on the market allows for unique designs.

The most common paver material is *concrete.* Typically around two inches thick, concrete pavers come in a variety of shapes and sizes. Depending on the building height and wind uplift constraints, pavers can be loose-laid, integrated into an interlocking system, installed on a pedestal assembly, or some combination of methods. Concrete pavers are durable, relatively inexpensive, and widely available. Exposure and wear may cause pavers to crack, so planning for isolated paver replacement should be considered as part of long-term maintenance.

Porcelain tiles are an increasingly popular choice for finished roofs due to their aesthetic appeal and long-term performance. Manufactured in a slim profile (around ¾-inch thickness), porcelain pavers are lighter than concrete pavers and therefore easier to transport and install. However, because of their light weight, porcelain pavers have more limitations in terms of the assembly and are best used in a pedestal or tray system.

Porcelain is also completely nonporous, and therefore will not stain, will not require sealing, and will not fade over time. While the porcelain itself is extremely durable, the installation method, which involves setting the pavers in an adhesive around the perimeter of each tray, is subject to ongoing maintenance. The tiles can potentially debond from the trays and will require resetting to ensure a safe and secure finish surface.

Wood tiles offer a warm and modern finished roof. Typically constructed of ipe, the tiles are durable and aesthetically pleasing. The wood can be finished in a variety of ways, including smooth surfacing or grooved surfacing, and either sealed to preserve the natural brown color or left untreated to weather, resulting in a gray hue

Wood tiles are best used in an interlocked pedestal system or secured to a subframing system to meet wind uplift requirements. Because of the nature of the material, the tiles have the potential for splintering, splitting, warping, and separation over time. Wood naturally varies in color and will not provide as uniform an appearance as concrete or porcelain. Even so, ipe is far more resistant to humidity and temperature fluctuations than most hardwoods.

Furniture. Paver materials used in conjunction with a pedestal system also provide a level and resilient surface upon which to place outdoor seating, tables, lighting, and other fixtures. Pedestal systems allow for a sloped roof to facilitate water drainage underneath the pavers, while maintaining a level finished surface. In a traditional roof assembly that does not have a paving system, either the slope of the deck itself or the slope of tapered insulation causes the finished roof level to be uneven, creating complications with the installation of fixtures and finishes. For pedestrians, a sloped surface can be a fall hazard, and it can make navigating the roof difficult or impossible for those with impaired mobility.

Paving systems also create a barrier between the rooftop furniture and the roof membrane, which, when left exposed, can be vulnerable to scratches and tears that can compromise the integrity of the waterproofing.

SMALL SPACE, BIG BENEFITS FROM PAVED ROOF DECKS

With demand for outdoor recreation areas growing, along with the growing impetus toward responsible design that minimizes climate impact, building owners would do well to maximize available space by converting untapped rooftops into building amenities. With appropriate consideration of structural capacity, occupant safety, roof maintenance and lifespan, accessibility, and aesthetics, an ordinary roof deck can become an attractive and desirable asset. |**M**|

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