# CONCRETE PAVING UNITS FOR ROOF APPLICATIONS

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## ABSTRACT

Interlocking concrete pavers and paving slabs are seeing increased use in pedestrian and vehicular roof deck applications. This paper provides an overview of design guidelines for these applications for the United States and Canada. Discussion includes ASTM and CSA paving product standards and applications guidelines. Setting materials and placement are covered. Design considerations are explained including paver thickness, resistance to wind uplift, slope for drainage, roof drains, and methods to create elevations for drainage for flat roof decks. The paper includes several detail drawings to explain the various assemblies for pedestrian and vehicular applications. A brief overview of construction techniques is provided for the various setting methods including mechanical installation.

## 1. INTRODUCTION

An increasing amount of new and rehabilitated roofs use segmental concrete paving units to support pedestrian and vehicular applications. Segmental concrete paving units protect roofing materials from damage due to foot traffic, equipment, hail, and vehicles. Concrete provides a heat sink that reduces the thermal stress and deterioration of waterproofing materials. Additionally, the units provide a slip-resistant surface and are especially attractive when viewed from adjacent buildings. When manufactured to product standards, they exhibit high durability under freeze-thaw and deicing salt conditions.

**Figure 1. Concrete pavers provide a durable and attractive roof surface. At left is the observation deck of the 86th floor of the Empire State Building in New York City. At right is a hotel plaza deck constructed with concrete paving slabs.**

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A primary role of segmental concrete units is ballast for low slope roofing materials to prevent uplift from high winds. The units provide superior performance compared to gravel ballast. When caught by high winds, gravel ballast on roofs can shift and distribute unevenly. This exposes part of the roof materials to winds, thereby increasing the risk of dislodged roofing materials. In some cases the gravel can be blown from roofs creating a hazard for glass, pedestrians, and vehicles. Concrete units are preferred over gravel ballast because they provide a consistent, evenly distributed weight for protection from wind uplift and damage. Furthermore, concrete unit paving is required by many building codes as roof ballast for high-rise buildings.

**Figure 2. Concrete pavers support vehicular traffic and parking over a concrete parking structure next to a residential development.**

## 2. PLAZA DECK COMPONENTS

2.1 Concrete pavers and slabs

There are two categories of segmental concrete surfacing materials for roofs, concrete *pavers* and *slabs*. In North America concrete pavers are units that can be lifted and placed with one hand and whose surface doesn't exceed 0.065 $m^2$. Their maximum length to thickness (or aspect) ratio is 4 to 1. They conform to the requirements of ASTM C 936 (ASTM, 2001) in the U.S. or CSA A231.2 (CSA, 1995) in Canada. These units can be used in pedestrian and vehicular applications. 60 mm thick concrete pavers are commonly used in pedestrian plaza or terrace applications. When structural capacity is limited to additional weight, units as thin as 40 mm have been used in pedestrian applications. 80 mm thick pavers are recommended for heavy vehicular applications.

Concrete paving slabs made in Canada should conform to CSA A213.1 (CSA, 1999). Unit dimensions are measured on samples and compared to the dimensions of the manufacturer's product drawings. Allowable tolerances for length and width are –1.0 to +2.0 mm from the manufacturer's product drawings. Height should not vary by more than ±3.0 mm. Units should not warp more than 2 mm on those up to 450 mm in length and/or width. For units over 450 mm, warping should not exceed 3 mm. At the time of this writing, a draft standard for precast concrete paving slabs made in the U.S. has been introduced by ICPI to ASTM for review and eventual approval.

2.2 Setting materials

2.2.1 Pedestals

Paving slabs for pedestrian plaza decks are often placed on plastic pedestals. Pedestal-set paving units install quickly and enable fast removal for repair of waterproofing materials and for maintenance of deck drains. The units can be reinstated after repair with no visible evidence of movement. Damaged paving units can also be easily removed and replaced.

Figure 3 shows a diagram of a pedestal system with paving slabs. Pedestals can be placed under smaller-sized concrete pavers, but this type of construction is not common.

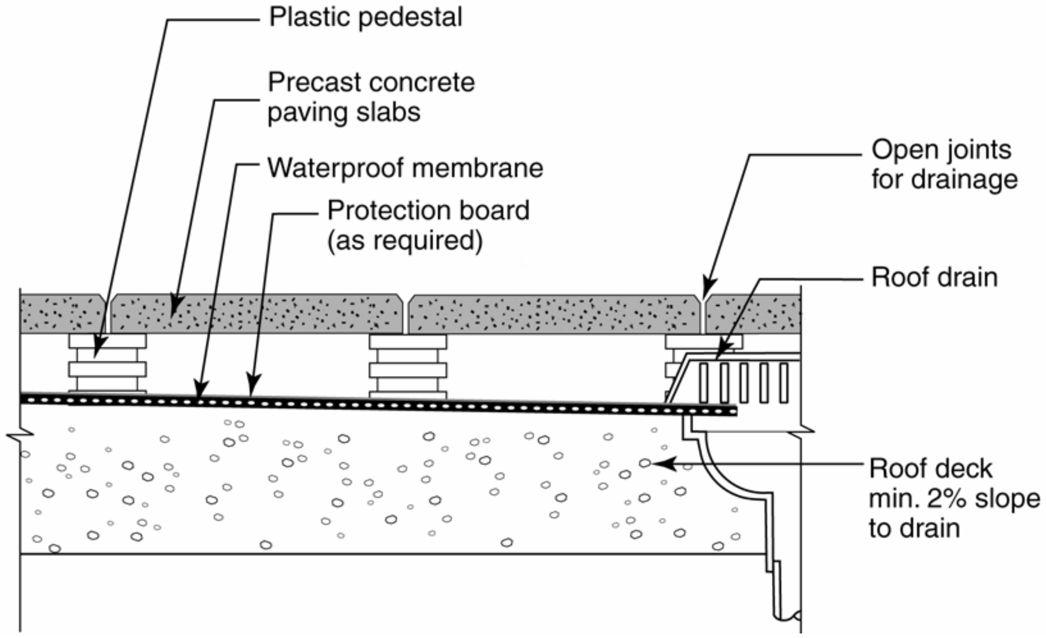


**Figure 3. Paving slabs on pedestals.**

In most applications, the corners of paving units rest on four pedestals with each pedestal sharing the load from one to four units. These units usually require shimming after placement. Shims are inserted under the corners of a nonaligned paving unit until its surface is even with adjacent units. Some plastic pedestals have a built-in leveling device to reduce the amount of labor involved with shimming. Some are telescoping cylinders whose length can be changed by rotating an adjustable sleeve within another. Other designs have a base that tilts slightly to compensate for the slope of the roof.

Vertical spacers are often molded in the plastic pedestals to ensure uniform joint widths among the paving units. The open joints allow runoff to pass through them onto the waterproof membrane and into roof drains. The joint created by the spacer should not exceed 5 mm and this will minimize the likelihood of tripping.

**Figure 4. Foam pedestal system.**

Another type of pedestal system consists of 200 mm square extruded polystyrene foam blocks 50 to 75 mm thick, glued together, spaced on a grid across the deck, and adhered to a polystyrene insulation board that rests on the waterproof membrane. The compressive strength rating of the foam is at least 0.4 MPa. A laser is used to set up and level a tracked guide holding a movable hot wire that cuts the tops of the pedestals to the required height. Shimming is not necessary except for the occasional paving unit that might be slightly out of dimension. This pedestal system supports units as small as 150 x 150 mm up to 910 x 910 mm paving slabs. The pedestals can extend as high as 0.6 m. Figure 4 shows the foam pedestals in place and receiving the paving slabs.

2.2.2 Bedding and Joint Sand for Pedestrian and Vehicular Applications

Sand-set pavers and slabs (up to 300 x 300 mm) are a common option for pedestrian applications. The typical sand thickness is 25 mm. Figure 5 illustrates a sand-set application for pedestrians.

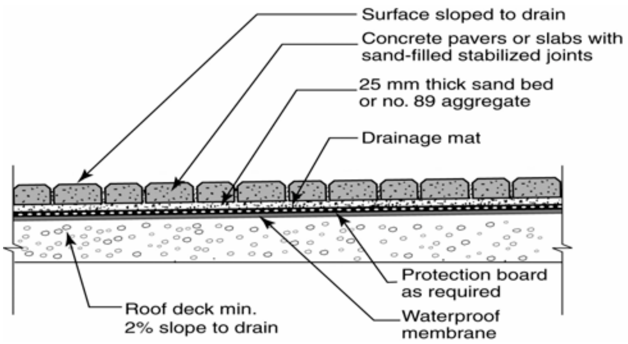


**Figure 5. Sand-set concrete pavers or slabs for a pedestrian roof plaza deck. Units no larger than 300 x 300 mm length and width are recommended for sand-set applications to avoid tipping.**

A key design consideration is not allowing the bedding sand to become saturated. Continually saturated sand and joints can support moss or vegetation that eventually clogs roof drains. Saturated sand can increase the potential for efflorescence that might exist in some concrete paving units. While not attractive, efflorescence will eventually disappear and it is not detrimental to structural performance.

The risk of saturated bedding sand is reduced by adequate slope of the roof deck, sand gradation, and use of a drainage mat with a geotextile wrapped around the perimeter of the bedding sand. The sand requires at least a minimum deck slope of 2% to drain adequately. Gradation of the bedding sand for pedestrian and vehicular applications should conform to ASTM C 33 (ASTM, 2002) or CSA A23.1 FA 1 (CSA, 2000). It is important that no material (fines) passes the 0.075 mm sieve, as the presence of this size of material will greatly slow the movement of water through the bedding sand. In addition, it may be useful to eliminate material passing the 0.150 and 0.300 mm sieves. This adds further protection from clogging near drains from accumulated fines that enter the bedding sand.

Clogging risks can be greatly reduced by using small-sized aggregate for bedding rather than sand. Particle sizes generally range from 10 mm to 2 mm. Joint sand should not be used in these applications because it will move from the joints into the small spaces between the aggregate. Since joint sand is not effective, only pedestrian applications should use aggregate for bedding. The open joints can become unstable under vehicular traffic.

Joint sand for pedestrian and vehicular applications should conform to the gradation of ASTM C 144 (ASTM, 2000) or CSA A179 (CSA, 2000). These are gradations for sand used for mixing mortar. They are finer in particle size than bedding sand and generally have less than 10% passing the 0.075 mm sieve. They are finer to allow entry into joints and to help reduce infiltration of water through the joints. Joint sand should not be used for bedding pavers or slabs since it does not drain readily.

As with pedestrian plaza or terrace applications, bedding materials for vehicular applications need to freely drain water so that they do not become saturated. Again, an essential roof deck requirement is a 2% minimum slope. Parking decks with saturated bedding sand subjected to constant wheel loads will pump sand laterally or upward, and out of the paving assembly. Joint sand is pumped out as well, and loss of interlock follows. An unstable surface results where loose pavers are damaged (chipping and cracking) from continued wheel loads. Loss and lateral movement of bedding sand can result in damage to and leaks in the waterproof membrane from loose paving units.

2.2.3 Joint Sand Stabilization

Joint stabilization materials are recommended in sand-set roof applications for pedestrian and vehicular use. They are applied as a penetrating liquid polymer or mixed dry with the joint sand and activated by moistening the joints with water. These materials reduce infiltration of water and ingress of fines brought to the surface by vehicles, and they achieve early stabilization of joint sand. Stabilization can help prevent the joint sand from being washed out by rainfall or blown out by winds.

2.2.4 Neoprene adhesive with bitumen-sand bed

This setting method typically involves a 20 mm (25 mm maximum) thick asphalt-stabilized sand layer with an asphalt-neoprene adhesive applied to it. The sand asphalt mix is applied hot and compacted. After the asphalt cools, an asphalt-neoprene paste is applied to the sand-asphalt bed.

The units are pressed into the adhesive and the joints are filled with sand. Joint sand can be stabilized. Cement-stabilized joint sand is not recommended since the cement can stain the surface of the paving units. Figure 6 provides a schematic cross section. Drainage should be provided at roof drains as with sand-set assemblies. This includes holes in the sides of roof drains to remove water that collects below the paving units.

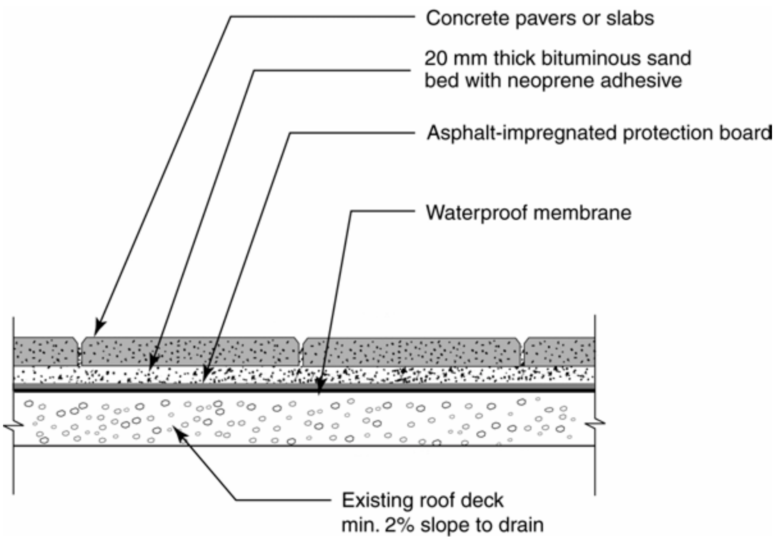


**Figure 6. Neoprene adhesive on a bituminous-sand setting bed.**

## 3. GEOTEXTILES, PROTECTION BOARD, INSULATION, AND DRAINAGE MATS

### 3.1 Geotextiles

Geotextile is needed to contain sand setting materials and keep them from migrating into deck drains or through scuppers (drains through parapets). In addition, sand requires geotextile under it to prevent loss into the protection board and insulation (if used). Geotextile manufacturers should be consulted on geotextile selection. The fabric should be turned up against drains, vents and other protrusions in the roof, along parapets or walls, and turned over and placed on top of a 300 mm perimeter of the bedding sand layer.

Geotextile should extend up the sides and placed over the top of bedding materials in order to contain them. The paving units hold down the edges of the geotextile around the roof perimeter, at penetrations (vents, pipes, etc.) and around drains. Figure 7 shows this detail that will help prevent loss of bedding materials from occasional gusts of wind or when there is a deluge of rainfall that causes temporary ponding around the drains. A separate piece of geotextile is wrapped around the roof drain to prevent loss of bedding sand.

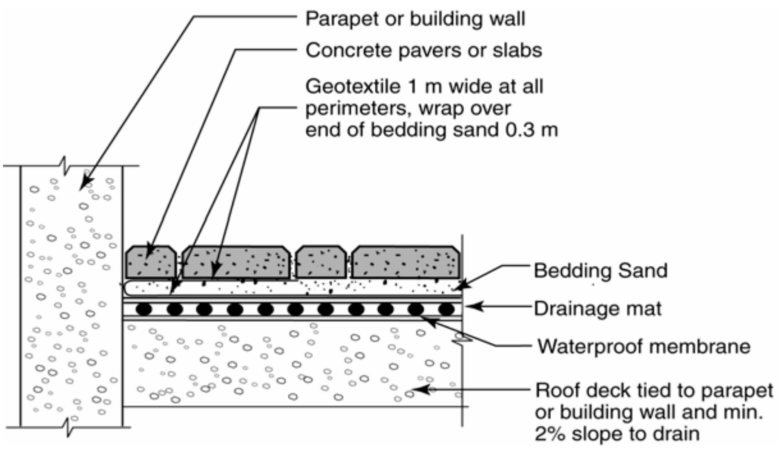


**Figure 7. Detail showing geotextile at all edges of sand bedding courses for a pedestrian application.**

### 3.2 Protection board

Some waterproofing systems require a protection board over them to prevent damage to the waterproofing from paving units and reduce thermal stresses from temperature changes. This can be high-density polystyrene, an asphaltic protection board or other materials. The manufacturers of waterproofing systems can provide guidance on the use of protection layers, and they can recommend specific materials when this option is required. Protection board is generally not used in vehicular applications.

### 3.3 Insulation

If the roof plaza deck covers an inhabited space, insulation should be required. Insulation typically consists of foam or fiber boards placed over the waterproofing. Sometimes they are adhered directly to the waterproofing. Insulation is generally placed under protection boards to preserve it from damage and to minimize exposure to water. Insulation may be tapered to roof drains to facilitate movement of water into the drains. Polystyrene insulation board should have minimum compressive strength of 0.4 MPa, and have drainage channels (grooves) at the bottom to facilitate drainage of water under them.

Insulation is generally not used under pavers or slabs in vehicular applications. The preferred location for insulation is sandwiched within or directly under the concrete deck where it does not interfere with the performance of concrete pavers under vehicles.

3.4 Drainage mats

Drainage mats are generally placed under bedding sand and over waterproof membranes to accelerate drainage of water from the sand. Drainage mats are typically 6 to 10 mm thick. They consist of a plastic structure covered by geotextile. The structure and geotextile support and contain the bedding sand under the paving units while allowing water to move into it and laterally to roof drains. They are recommended in pedestrian applications under a sand setting bed. They should be placed at a minimum of 2% slope.

Installation of drainage mats for pedestrian applications should start at the lowest slope on the roof with the work proceeding upslope. Flaps on the ends of each section of mat should go under the next (in a manner similar to placing roof shingles) so that the water drains from one section to the next. This helps prevent water from leaking under the mats. While mats reduce the amount of water reaching the waterproof membrane, they are not a substitute for deck waterproofing.

Drainage mats should be avoided under vehicles. Most mats deflect under wheel loads, eventually fatiguing, compressing and deforming. Repeated deflection tends to shift the pavers, bedding and joint sand, making interlock difficult to achieve. The deflection causes the joint sand to work its way into the bedding sand, and the bedding sand shifts under loads, especially when saturated. The movement, loss of joint and bedding sand, and possible eventual crushing of the mat retains water, and can saturate the bedding sand

## 4. DESIGN CONSIDERATIONS

4.1 Detailing for movement for pedestrian applications

Roof joints should be located when there is a change in roof direction, dimension, height, material, or when there are extreme differences in humidity or temperature within a building. Most roof structures have control joints that allow each part of the structure to move independently due to settlement, seismic activity, and thermal expansion/contraction. There is usually a flexible sealant in the joint to prevent water from entering and leaking into the space below. The sealant can be a compression seal squeezed into the joint, or a more expensive and durable strip seal. A strip seal is a length of flexible material fastened to metal clips secured to the concrete deck. The strip seal flexes with the movement of the adjacent structures.

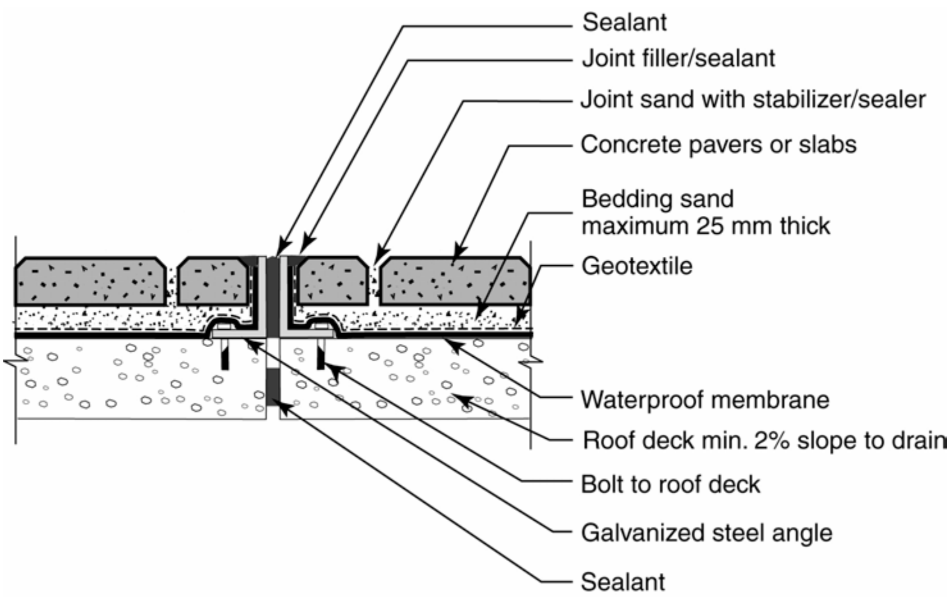


**Figure 8. Edge restraint detail at a roof control joint for pedestrian roof applications (Cairns, 2000).**

Figure 8 illustrates a control joint in a concrete structure and with sand-set paving units over it. Control joints should be treated as pavement edges. As with all segmental pavement construction, an edge restraint is required to hold the units together. Figure 8 shows steel angle restraint on both sides of the joint and secured to the concrete deck. There is a compression seal at the top against the steel edge restraints, as well as one between the concrete decks. This detail is preferred at roof expansion joints for pedestrian applications.

Figure 8 shows the paving pattern stopping at a control joint in the deck and resuming on the opposite side. The sealant is joined to the edge restraint and not to the sides of the paving units. The use of a sailor or soldier course of pavers on both sides of the joint will present a clean visual break in the paving pattern. Figure 9 below shows the consequences of not stopping the pattern with an edge restraint at an expansion joint. The pavers separated and exposed the bedding sand and waterproof membrane.

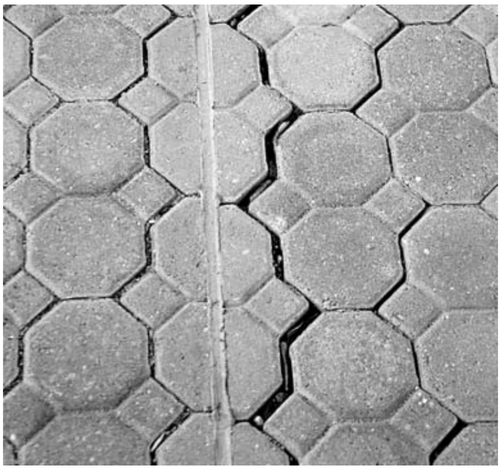

**Figure 9. An absence of edge restraints and use of a sealant in the construction joint caused the pavers to shift and open their joints on both sides of the sealant.**

Parapets or building walls can typically serve as edge restraints. For sand-set paving assemblies, expansion material should be placed between the outside edge of the pavers and vertical walls of buildings when functioning as separate structures from the deck on which the paving units rest.

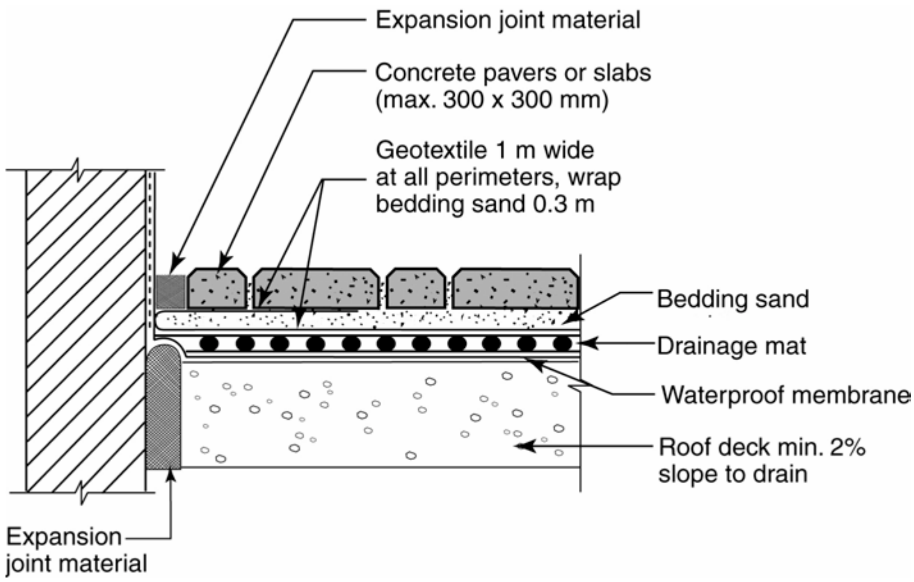


**Figure 10. Detail at parapet or building wall not joined to decking using paving units and bedding sand with a drainage mat.**

Figure 10 shows the condition where the expansion joint material is not adhered to the paving units or the wall. Rather, it independently expands and contracts with movement. Expansion joint materials between the perimeter of the pavers and parapets/wall when the wall and deck are joined, i.e., they are the same structure and will move together. Figure 7 illustrates this condition.

4.2 Detailing for movement for vehicular applications

Figure 11 details an control joint in a roof application subject to vehicles such as a parking structure. Although compression seals can be used, this assembly uses a strip seal for bridging the joint. The ends of the concrete deck are formed as edge restraints to hold the concrete pavers in place.

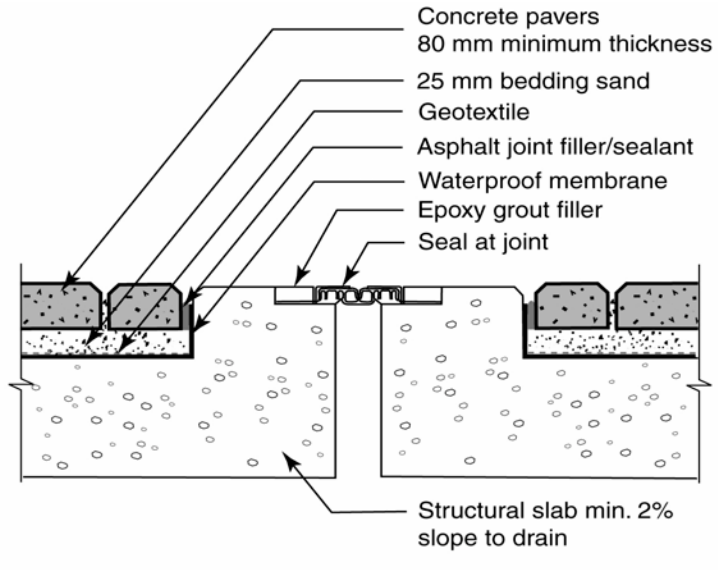


**Figure 11. Edge restraint detail at a roof control joint for vehicular applications.**

4.3 60 mm vs. 80 mm thick pavers for vehicular applications

Most vehicular applications with pavers are supported by a concrete structure. The support from such a structure is often used as rationale for using pavers that are less than 80 mm thick. Thicker units render greater vertical and rotational interlock. Using concrete pavers less than 80 mm thick in vehicular of applications can increase the risk of reduced surface stability by reducing vertical and rotational interlock under turning and braking vehicles.

4.4 Weight

Concrete pavers, slabs, and bedding materials exert substantial weight on roof structures.
The structure supporting these materials should withstand dead and live loads. The advice of a structural engineer should be sought to assess the capacity of the roof and tolerable deflections from paving-related loads especially when units are added to an existing roof deck structure. The weight of paving units can be obtained from manufacturers for the purposes of calculating loads. Bedding sand (25 mm thick) weighs approximately 50 kg/m$^2$.

4.5 Resistance to wind uplift

The designer in North America should consult *Loss Prevention Data for Roofing Contractors* Data Sheets published by Factory Mutual (FM) Engineering Corporation (Factory Mutual, 2000). Sheets 1-28 and 1-29 provide design data including the minimum kg/m$^2$ of paving unit weight required for resistance to wind uplift. The FM charts consider wind velocity pressure on roofs at various heights in different geographic locations. Design pressures are then compared to the type of roof construction, parapet height, and whether the paving units have tongue-and-groove, beveled joints, or are strapped together. Some high wind regions may have local building codes with additional weight requirements for paving units, especially on high-rise buildings.

4.6 Slope for drainage

A flat or "dead level" roof, i.e., one with no pitch, should never be designed. A dead level roof does not drain, creating a high risk of leaks in the waterproofing, as well a potential saturation of bedding sand (when used). The membrane will be exposed to continual standing water and ice that accelerates its deterioration and increases the potential for leaks. Likewise, paving units and bedding materials in constantly standing water subject to many freeze and thaw cycles will experience a decrease in their useful life.

4.7 Maximum slopes for pedestrians and vehicles

The maximum slope is constrained by the need for a comfortable walking surface and the maximum percentage is typically 8% (4.5°). For driving surfaces, the maximum recommended slope should not exceed 20% (11°) and ideally should not exceed 8%, as such surfaces will often have pedestrian use. For slopes exceeding 4% with exposure to vehicles, consideration should be given to using bituminous-set rather than sand-set systems.

4.8 Roof drains

Depending on the design, roofs are drained at their edges and/or from the interior with roof drains. When roof decks are loaded with dead and live loads, they will deflect. Continual deflection over time results in deformation of the roof. This movement can make drain inlets or scuppers adjacent to columns or on frame lines at the perimeter the highest points of the roof. Therefore, sufficient pitch to the roof that accounts for such deflections is essential for continual drainage. In addition, the surface of the paving should be a minimum of 5 mm above the inlet of roof drains.

When sand or aggregate is used for bedding or fill, it is essential that holes exist in the sides of drains to allow water to escape from the bedding sand. The bottom of the holes should be at the same elevation as the top of the waterproof membrane. As previously noted, drains should be wrapped in geotextile to prevent loss of bedding material through the drain holes.

Figure 12 illustrates ponding around a parking deck roof drain that didn't have drain holes in its sides to drain subsurface water. Figures 13 and 14 illustrate a possible drain solution with holes for a pedestrian roof deck and vehicular parking. For paving slabs with pedestals, the slabs generally are located over roof drains, or are cut to fit around drains (see Figure 3). Bitumen-set assemblies require holes in the sides of the drains to remove water that may collect below the paving units. Bitumen and neoprene must not be allowed to clog roof drains or holes in their sides during installation.

**Figure 12. An absence of holes in the sides of this roof drain led to ponding.**

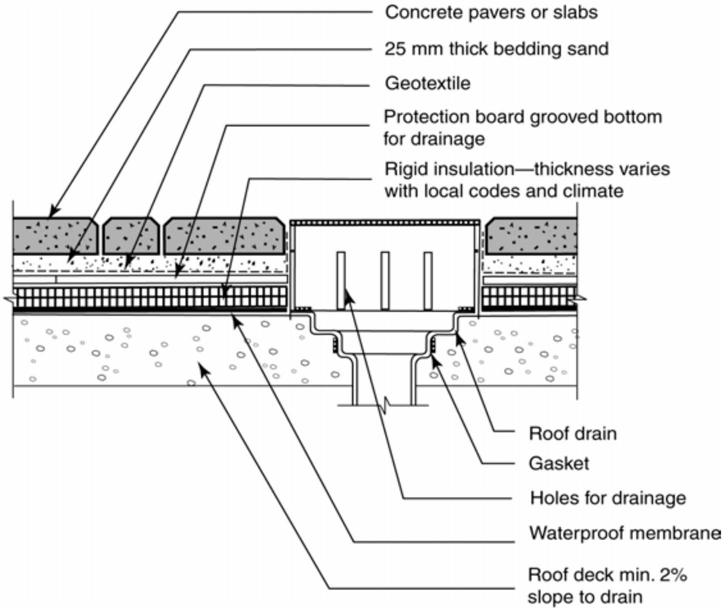


**Figure 13. A drain detail for a pedestrian plaza deck over habitable space.**

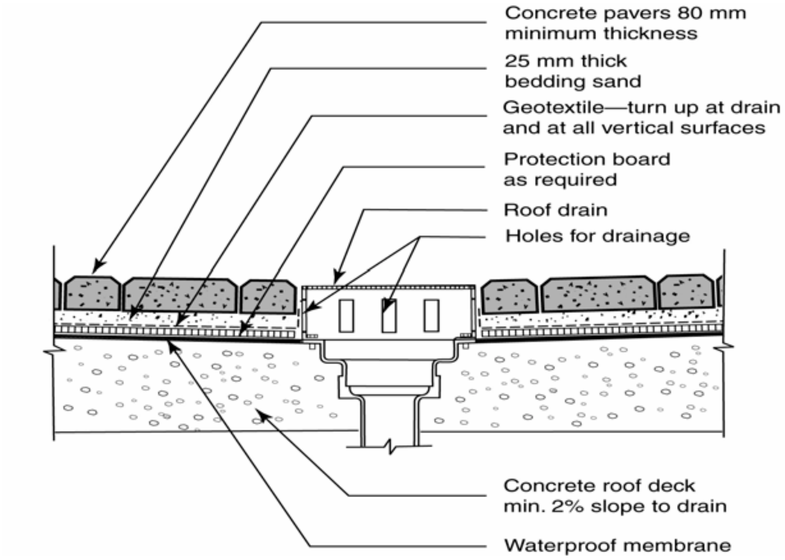


**Figure 14. A drain detail on a vehicular roof application.**

## 5. CONSTRUCTION CONSIDERATIONS

A specialty roofing subcontractor generally installs low slope roofs and waterproofing systems. A second subcontractor specializing in the installation of segmental paving is often used to supply and install drainage mat, bedding materials, pedestals, pavers or slabs after the waterproofing (insulation and protection board) is placed by the roofing contractor. Testing of the waterproofing for leaks and any repairs should be completed prior to starting the paving.

5.1 Job Planning

Roof jobs are typically built in a very limited space. There will be the additional expense of moving the paving units from the ground to the roof. Most roofs may not have the space to store cubes of pavers and stockpiled sand, and if they did, they most likely do not have the structural capacity to withstand their concentrated weight. The advice of a structural engineer should be sought on assessing the maximum load capacity of the roof to safely support the weight, packaging, and distribution of all materials delivered to the roof.

Forecasting delivery time for moving pavers to the roof, as well as sand, pedestals, saws, tools, geotextile, and crew to the roof is critical for accurately estimating roof projects. Labor functions and costs must be tracked on each project for use in future bids. For example, additional time and expense may arise from the need for the paving contractor to place temporary protection on the waterproof membrane to prevent damage during construction. A one level parking garage may allow all materials to be driven onto and delivered quickly to the roof. A multi-story parking garage with pavers on the top floor may have a 2 m ceiling height that will not allow delivery of pavers and sand in large trucks. Trucks with a low clearance will be needed to move materials through the structure and to the roof. The packaging of most concrete pavers and slabs allows their transport to the roof via elevator or crane during construction.

Roof access, construction scheduling, the capacity of the roof to withstand loads from packaged materials, and reduction of labor costs will dictate the economics of using a crane to transport materials to the roof. The roofing contractor often handles this. In some cases, an elevator may be the only means of transport. An example of using only an elevator to move crews, tools, and materials was to the observation deck on the 86th floor of the Empire State Building in New York City where the deck was being rehabilitated with concrete pavers.

The layout of paving slabs can be more demanding than the layout of interlocking concrete pavers. Some designers prefer joint lines to be located in particular places such as centered at columns or staircases. Careful planning of the layout will spare wasted cuts and adjusting the pattern on site to conform to the drawings and design intent. Sometimes railings along the perimeter of a roof may require cutting or drilling holes in paving slabs to fit around them. In addition, paving units may need to be cut to fit against moldings and other protrusions from parapets. The location of the pattern and cutting should be anticipated in advance of the construction.

An additional expense to include in the construction estimate may be workers compensation insurance.

Unlike most segmental paving, working on roofs means an increased risk from falls. Increased risk means higher insurance premiums paid to cover injuries in case of a fall. All federal, provincial, state, and local worker safety codes should be followed for fall protection of crews working on roofs.

5.2 Installation on bedding sand

After placing the geotextile, the bedding sand is screeded using screed bars and a strike board to a 25 mm thickness. Mechanical screeders may be used on large deck jobs as shown in Figure 15. Once the bedding sand is screeded, the pavers are compacted into the bedding sand. Sand is spread, swept and vibrated into the joints with at least two passes of a plate compactor. Excess sand is removed upon completion of compacting.

For larger than 300 mm x 300 mm slabs, pedestals are recommended as the preferred setting method rather than a sand bed. If placed on bedding sand, larger slabs tend to tip and tilt when loads are placed on their corners. Pedestals are a more stable assembly for slabs in pedestrian applications. Some jobs may require slabs to completely cover the roof right up to the parapets and protruding vents. If full slabs do not fit next to vents and parapets, the slabs are saw cut and placed on pedestals next to them. When slabs or pavers are cut, careful consideration is needed on the location of the saw(s). The dust should not blow onto adjacent property and sediment from cut pavers should not to drain onto the roof. A dust removal system is typically required by safety agencies and is effective in keeping dust from surfaces.

**Figure 15. A mechanical screed used to level bedding sand on a roof parking deck project.**

5.3 Mechanical Installation

Concrete pavers and slabs can be mechanically placed on some roofs. Figure 16 shows a parking deck being installed with mechanical equipment. Slabs can be installed with vacuum equipment that relies on suction to grab and place each unit as shown in Figure 17. For most jobs, these kinds of equipment cannot run directly on the waterproofing. They must run over installed paving units. Therefore, a starting area of pavers may need to be placed by hand and the equipment placed on it to continue the paving. Further information on mechanical installation is found in ICPI *Tech Spec 11—Mechanical Installation of Interlocking Concrete Pavements* (ICPI, 1998).

**Figure 16. Mechanical equipment used to install concrete pavers on a roof deck.**

**Figure 17. Vacuum assisted mechanical equipment for installing paving slabs.**

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**Biography**

David R. Smith, MUPRL, ASCE, CSI, ASLA

With an architecture, engineering, and environmental planning background, David R. Smith has been involved with segmental concrete pavement since 1977. He has been working in the industry and for institutionalization of segmental concrete paving in North America since 1987. With many companies, he launched the Interlocking Concrete Pavement Institute (ICPI) in 1993. He has authored scores of magazine articles, brochures, and technical bulletins, technical papers, and promotional brochures for the ICPI.

His work includes co-authorship of ICPI technical manuals, *Port and Industrial Pavement Design with Concrete Pavements* and *Airfield Pavement Design with Concrete Pavers*. He has authored the *ICPI Concrete Paver Installation Contractor Certification Course* and *Permeable Interlocking Concrete Pavements*. David R. Smith is editor of *the Interlocking Concrete Pavement Magazine*, a quarterly publication featuring unique projects that circulates to thousands of designers and contractors. He also authored the design idea book, *Patio, Driveway and Plazas—The Pattern Language of Concrete Pavers*.

As a leading authority in North America on concrete segmental paving, Mr. Smith regularly speaks at national and international conferences. He is secretary-treasurer of the Small Element Paving Technologists. He is an active member of ASTM Committee C 27.20 on Architectural Precast Products, having written and revised product several standards on segmental concrete paving products for that organization. He is participates as a member in the American Society of Civil Engineers, American Public Works Association, Construction Specifications Institute, and the American Society of Landscape Architects. Mr. Smith has contributed continuing education programs to the American Society of Landscape Architects and to the American Institute of Architects.

His education includes a bachelor of Architecture and a masters of Urban and Regional Planning (environmental concentration) from Virginia Tech in Blacksburg, Virginia. As ICPI's Technical Director, he works daily with design professionals, contractors, and homeowners on the design, specification, construction, and maintenance of segmental concrete pavements.