May 2012
Volume 19 • Number 2

Interlocking CONCRETE PAVEMENT MAGAZINE

A publication of the Interlocking Concrete Pavement Institute

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Contents

May 2012 • Volume 19 Number 2

Editorial

Features

Industry News

Departments

Interlocking CONCRETE PAVEMENT MAGAZINE

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From the Editor

David R. Smith

Pain and Pleasure

While North Americans take pain at the pump, there might be a little pleasure in knowing that the price isn't $8/gallon ($2/L) like Europe. Filling a tank there thins the wallet by $125. Since it also requires crude oil, asphalt pavement is experiencing record prices here, bringing much pain to already stressed municipal street budgets. Mechanically installed concrete pavers, jointing and bedding sand could soon be competitive with 4 in. (100 mm) or thicker asphalt on an initial cost basis. Most parking lot and residential streets see 3 in. (75 mm) thick asphalt. The industry isn't cost competitive with these projects yet. Comparisons to more heavily used municipal pavements such as an urban collector street with at least 4 in. (100 mm) of asphalt present some possible game changing notions.

The game changer is that the interlocking concrete pavement (ICP) industry is positioned to reduce municipal fiscal pain, initially and in the long term. Like a lot of treatments and healings, it usually doesn't happen overnight. Given the right resources, it can happen. ICPI has them and they include ASCE 58-10 standard for structural design and an ASTM method for assessing pavement condition and maintenance needs (ASTM E2840). This magazine has written about these resources and supporting software issued by the Interlocking Concrete Pavement Institute. These are tools similar to those in use for asphalt.

The ICP industry challenge is delivering these resources to state DOTs and municipal governments, assisting with pain relief via accurate diagnoses. That process

Continued on p. 23

Asphalt Parking Lot Reloaded with Retrofit PICP

Two asphalt parking lots next to student housing at the University of Minnesota get retrofitted with PICP.

Stormwater from more than 60,000 sf (6,000 m²) at University of Minnesota parking lots are now being infiltrated into the ground instead of running directly into local waterways thanks to permeable interlocking concrete pavement (PICP). The projects took place over a three-year period at two student housing parking lots between Minneapolis and St. Paul campuses. The first lot was 30,000 sf (3,000 m²) and was finished in 2009; the second of the same size was completed in 2011.

According to Joel Severson, AIA, Senior Project Architect with HR Green, Inc., project designers from St. Paul, that the existing asphalt parking lots needed reconstruction due to their age and worn condition. The University of Minnesota's strict stormwater management guidelines required managing stormwater from "pre-settlement conditions" meaning prairie grass. In other words, additional runoff from any redevelopment required retention well beyond the much smaller volume released before development. The additional volume amounts to almost all of the rainfall and runoff from these sites.

Stan Lim, the project engineer at the time and formerly with HR Green, Inc. said that, "The existing site had an overburdened storm sewer system. When there was a big rain, people said you could see stormwater drain lids blown right off." The designers reviewed several options: combination or stand-alone detention ponds, rain gardens, underground storage tanks, pervious concrete, porous asphalt, and partial PICP with conventionally paved drive aisles.

Other design considerations included loss of parking stalls, children at the site (the facility houses University students with families), site space limitations, existing grading, long term maintenance, proximity to streets and buildings, aesthetics, and construction costs. While the cost for conventional pavement using a separate detention pond was slightly less than the PICP option, the University did not have space on the site for a pond. Purchasing an adjacent property for the pond would increase project costs significantly.

The PICP completely eliminated the need for a detention facility. There was sufficient water storage capacity below the pavers to store and infiltrate the design storm. This storm was a 24-hour, 100 year event at 5.9 in. (150 mm) depth. The PICP also captured the first flush or the first 1.25 in. (30 mm) of any rain event.

The University decided to retrofit the asphalt entirely with PICP using subgrade infiltration and base/subbase storage. This option reduced runoff volumes while improving water quality. Small areas were paved with cast-in-

Continued on p. 8

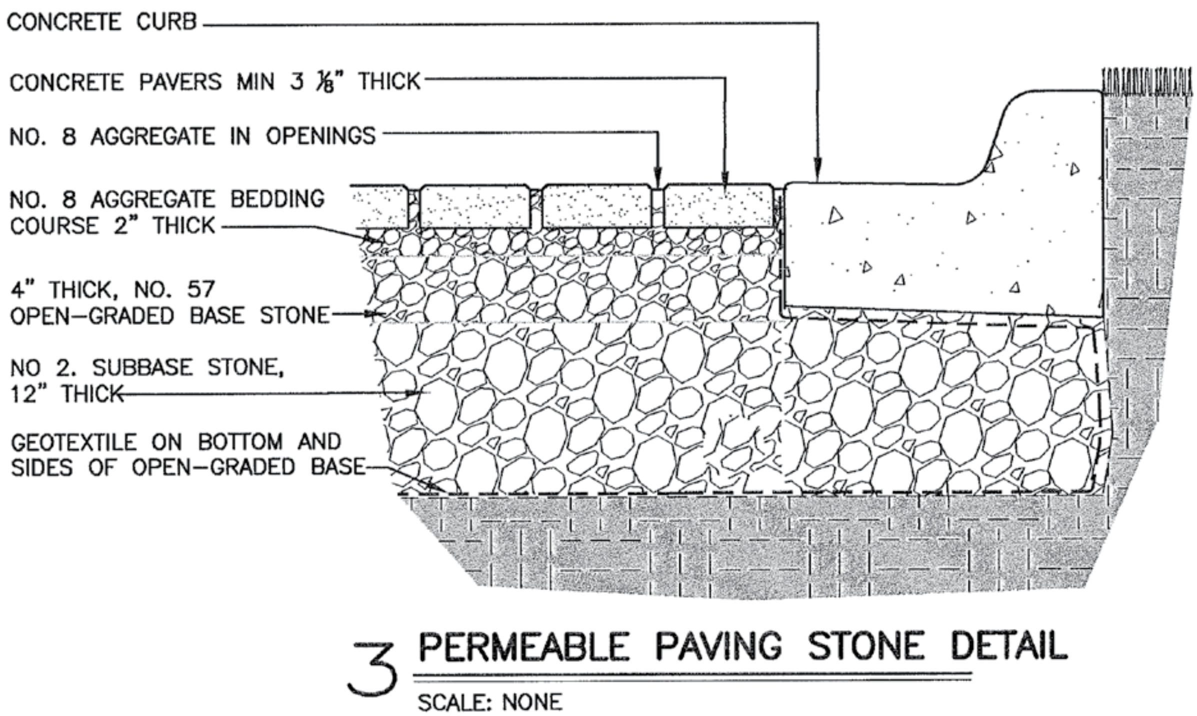

Figure 1. Typical PICP cross section for the retrofitted parking lots

place concrete to allow maneuvering places for trash trucks and dumpsters.

HR Green used ICPI recommendations for the pavement cross section. They also used ICPI guide specifications for PICP and edited them to suit the project. (Guide specs are available on www.icpi.org.) The engineers used 3$^{1}/_{8}$ in. (80 mm) thick pavers over a 2 in. (50 mm) layer of ASTM No. 8 stone. A 4 in. (100 mm) thick layer of No. 57 stone transitioned to a No. 2 stone subbase. This layer was designed at 12 in. (300 mm) thick to provide structural support and water storage for infiltration. Figure 1 illustrates a typical project cross section. The design includes underdrains placed near the top of the No. 2 stone subbase and connected to existing catch basins. The soil subgrade is SP or poorly graded sand, and the PICP hydrologic design used a NRCS Curve Number of 60 provided by the University's Geology and Geophysics Department.

The project was supplied and mechanically installed by ICPI producer and contractor members.

Figure 2 shows screeding the bedding layer and Figures 3 and 4 illustrate machine placement of the paver layers. The openings are filled with No. 8 stone, the surface cleaned and then the pavers are compacted. The surface is then ready for traffic.

The slope of the new parking lots stayed essentially the same as the previous ones. Existing catch basins were left in place to handle overflows which would likely not happen 90% of the time since infiltration and temporary storage accommodates the 24-hour, 100-year storm event. This resulted in practically no rainfall entering the city's storm sewer system. The University paid for temporarily moving student parking to other parking lots. Construction was expedited with mechanically placed PICP. As an extra touch, colored pavers delineate individual parking spaces to reduce maintenance costs for pavement striping. Figures 5 and 6 illustrate installation of the parking stalls and the final result.

Continued on p. 10

Figure 2. A wide screeding machine or screed "bucket" enables smoothing of the No. 8 stone bedding material prior to placing the concrete pavers. Note that one side rides on the existing concrete curb and the other on a metal screed rail.


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Asphalt Parking Lot Reloaded with Retrofit PICP *Continued from p. 8*

As existing asphalt parking lots wear out, compliance to national, provincial/state, and local stormwater management and low impact development regulations require retrofitting with permeable pavements. PICP is a particularly attractive retrofit option, especially in tight urban spaces where there is little or no space for a separate detention facility. Many sites with tight spaces do not easily accommodate repaving equipment. PICP surface placement requires small equipment and paving products that can operate in tight spaces. The University of Minnesota parking lots demonstrate the ability of PICP to work in such places and provide a cost-effective solution that meets local and state stormwater regulations. ❖

Figure 3. Lifting a layer of concrete pavers from the shipping pallet with an installation machine and clamp

Figure 4. Placing the pavers on the screeded No. 8 stone.

Figure 5. Prior to filling the joints with stone, pavers are removed and replaced with different color units to mark the parking stalls. This eliminates painting stripes.

Figure 6. The finished PICP surface with parking stalls marked with colored pavers

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PICP Maintenance

PICP is a best management practice for stormwater first and a pavement second. Therefore, it requires periodic surface cleaning for continued infiltration performance.

Like all permeable pavements, PICP surfaces can become clogged with sediment over time, thereby reducing its infiltration rate. The rate of sedimentation depends on the amount of traffic and other sources that wash sediment into the joints. Sediment sources can be eroding soil, leaves, mulch and debris deposited from vehicles. PICP streets and parking lots can be cleaned with vacuum-assisted, municipal street cleaning equipment and snow plows. Many municipal streets receive cleaning at least a few times annually and that can be sufficient to control the buildup of sediment in PICP joints. Vacuuming cost generally run about $1,000 per acre of parking if outsourced to a contractor.

Regular surface cleaning helps maintain a high surface infiltration rate and keeps out vegetation. The Interlocking Concrete Pavement Institute (ICPI) recommends inspection and cleaning once or twice in the first year of service and adjusting cleaning intervals as needed. Cleaning can be done with vacuum sweeping equipment such as regenerative air vacuum sweepers. Adjustments to the vacuum force likely are often required to minimize removal of stones from the openings. Sweeping alone is not as effective since vacuuming removes much of the sediment from the pavement surface. Sweeping only moves sediment from one place to another and does not reach into the joints between the pavers.

When monitoring PICP, there are two means to determining if the surface is infiltrating:

(1) Observe drainage immediately after a heavy rainstorm for standing water; or
(2) Conduct surface infiltration tests using ASTM C1701 *Standard Test Method for Infiltration Rate of In Place Pervious Concrete*.

ICPI recommends cleaning if the tested surface infiltration rate falls below 10 in./hr (250 mm/hr). Figure 1 illustrates C1701 and the inexpensive test apparatus for measuring PICP surface infiltration rate. A five gallon (20 l) bucket of water is slowly poured into a 12 in. (300 mm) ring secured to the pavers with plumber's putty. The putty creates a waterproof seal and is placed in the joints (upon removal of jointing stone) directly under the ring to direct water downward. The water inflow rate does not exceed a head of $^3/_8$ in. (10 mm) while being timed with a stopwatch. The surface infiltration rate is calculated using formulas in the test method.

Some PICP surfaces may not see any vacuum cleaning for years and this will result in a significant reduction in their infiltration rate. Restoring surface infiltration requires removal and replacement of the stones in the joints. This procedure is called restorative cleaning which generally removes top inch (25 mm) of stones and sediment (Figures 2 and 3). Stones are then spread and swept into the cleaned openings thereby refilling them to their original condition.

Figure 4 shows the joints prior to vacuuming and Figure 5 shows the cleaned joints filled with fresh stone. This procedure substantially increases the surface infiltration rate. A ballpark cost for this is $0.20 to $0.30/sf ($2.50 to $3.25/ m^2). Frequent, less aggressive surface cleaning is preferred to infrequent, more aggressive restorative cleaning from financial and performance perspectives. If surface cleaning is neglected, the annual costs accumulate and are eventually paid in later years when surface ponding and runoff are evident.

Winter Maintenance

Snow can be plowed from pavers as with any other pavement. Deicing salts infiltrate into the base and flow out with some remaining in the soil. The good news is

Continued on p. 16

Figure 1. Test apparatus on PICP for measuring surface infiltration rate per ASTM C1701.

that PICP requires less deicing materials than conventional pavement. Research by the Toronto and Region Conservation Authority indicated that PICPs require less deicing salt than asphalt pavements, since permeable pavement remains warmer throughout the winter. Sand for traction should not be applied on the PICP as it will accelerate surface clogging. If traction is required, ASTM No. 8, 89 or 9 stone (or similar) should be used. If sand is used, PICP surface should be vacuumed the following spring. Many years of experience and monitoring have demonstrated that PICP does not heave when frozen. This is evidenced by many PICP projects in Chicago, Minneapolis and Toronto remaining stable during freezing and thawing.

Another benefit of all permeable pavements is snow remaining after plowing can melt and infiltrate into the surface when temperatures rise, thereby reducing or eliminating re-freezing at night and ice hazards. This condition also reduces deicing salts and potential legal liability from injury claims resulting from falls. Cracked or damaged paving units, bedding and base can be removed and replaced, and such repairs can be done in the winter provided that aggregate materials are not frozen. This provides a maintenance advantage over site-formed paving materials that require above freezing temperatures for placement and supplies are often non-existent during the winter.

An advantage of PICP is that they can be removed for access to underground utilities. The following steps are recommended:

1. Pavers are removed, cleaned and stacked for reinstatement. If the PICP installation has some age to it, the pavers will require removal of dirt that typically accumulates in the stone filled openings at the surface. Undisturbed pavers can be secured with wood or metal frame as shown in Figure 6.
2. The bedding material (typically ASTM No. 8 stone) should be removed and disposed of, then replaced with fresh stones.
3. The ASTM No. 57 base layer (typically 4 in. or 100 mm thick) can be removed and stored for reinstatement as well as the ASTM No. 2 subbase material. Store in a place where the aggregates will remain clean. All dirty/contaminated aggregates should be replaced with clean stone.
4. Repairs can then be made to the utility pipe or box that is slightly above, on or in the soil subgrade. Temporary wood or metal edge around opening perimeter can keep pavers in place (Figure 6).
5. Flowable concrete fill (200 to 500 psi or 1.4 to 3.5 MPa) should be used to support repaired utilities. This material is also known as controlled low-strength material or CLSM. Flowable fill is needed because open-graded base cannot adequately fill under pipes or boxes, nor can it be compacted in these places. Many cities use flowable fill for utility repairs and have material and installation specifications.

   A minimum 4 in. (100 mm) layer of flowable concrete fill should cover the pipe or box. Then the subbase can


Figures 2 and 3. The vacuum machine removed the top inch (25 mm) of sediment and jointing stone.


Figures 4 and 5. Before and after cleaning with fresh stones swept into the joints

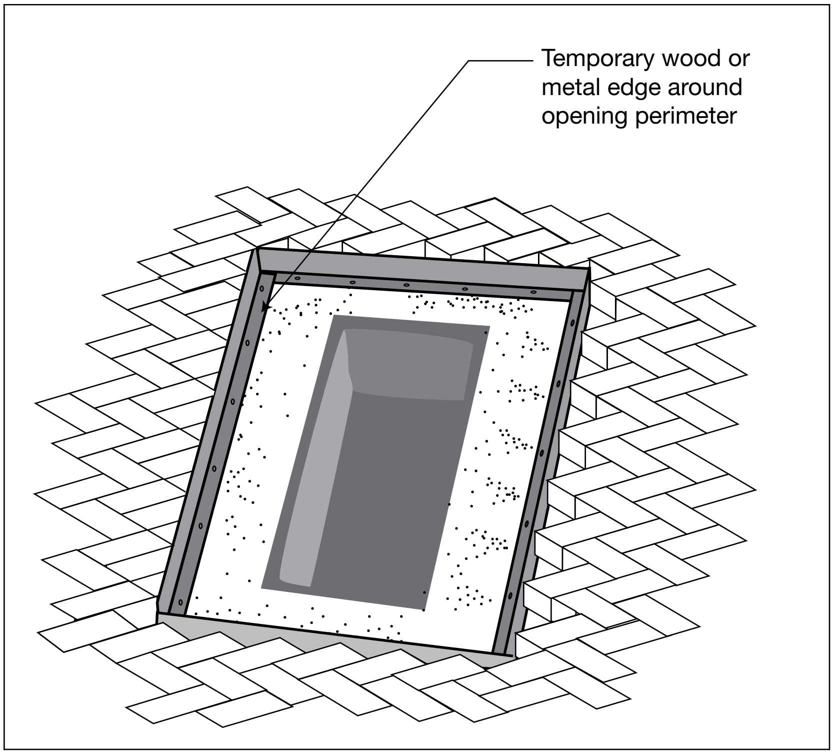

Figure 6. Restraining undisturbed pavers with a wood or metal frame can save time when reinstating concrete pavers.

be reinstated around it. Flowable fill will likely seep into the ASTM No. 2 stone, so there needs to be a barrier to stop it. The barrier can be plastic sheets or geotextile. Flowable fill takes a few hours to stiffen. After 24 hours, the ASTM No. 2 subbase stone should be reinstated and compacted. There should be at least 12 in. (300 mm) distance between the top of the flowable fill and the bottom of the plate compactor. The compactor force should be 13,500 lbf (60 kN).

6. The ASTM No. 57 base is reinstated and compacted.

7. New ASTM No. 8 stone is placed and screeded. Sometime it helps to remove a few courses of undisturbed pavers so the new and existing bedding layers can be screeded together.

8. Pavers are reinstated, joints filled and compacted. The pavers should be at least one inch (25 mm) above the surrounding undisturbed pavers prior to compaction. Test compact a small area to determine settlement. They will probably settle a bit after compaction as all flexible pavements. Likewise, the same units can be reinstated after repairs to the base, drain pipes, liners or underground utilities.

While not typically done, sealers can be applied to the pavers. Overflow onto the aggregates is avoided by using a roller. Such sealers can enhance appearance while making stains easier to remove if surface appearance is important to the facility owner.

PICP is sometimes constructed with an observation well. The well is typically a 4 to 6 in. (100 to 150 mm) diameter perforated pipe with a screw cap just slightly below the surface of the pavers that can be removed to observe the exfiltration rate. The cap should lock and be vandal-resistant. The depth to the soil subgrade should be marked inside the lid. The observation well is located in the furthest down-slope area within 3 ft (1 m) from the pavement edge.

Figure 7 shows an observation well as a parking lot at a U.S. Army base in Georgia. The top of the pipe can also be placed under the pavers. This hides the cap from vandals and a few pavers can be removed to access the well cap and reinstated.

Regarding pavement condition surveys, ASTM E2840 *Standard Practice for Pavement Condition Index Surveys for Interlocking Concrete Roads and Parking Lots* can be used to assess the structural condition of the PICP and indicate when maintenance might be required. This new ASTM standard was covered in the February 2012 issue as is available at http://www.astm.org/Standard/index.shtml. For infiltration assessments, C1701 is recommended as well as checking the observation well and outflow pipes. ❖

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Figure 7. A PVC pipe with a screw cap serves as an observation well on PICP parking lot at a U.S. Army base in Georgia.

Tiger Stone Machine Rolls Out Interlocking Pavement Construction and Rehabilitation Equipment

Leave it to the Dutch—for centuries the unchallenged masters of segmental concrete pavement roads—to develop a machine for installing and rehabilitating existing interlocking concrete pavement. Reminiscent of slip forming (but without wet concrete or the curing) the Tiger Stone machine places interlocking concrete pavers in a continuous sheet on the prepared bedding sand. Instead of bending over, crew members stand and move from side to side in the machine arranging pavers at waist level for machine placement. The Tiger Stone moves slowly on rubber tracks along the pavement at the rate at which the pavers are inserted into the machine. See Figure 1. As the machine moves along, the pavers slide down a grated chute onto the screeded bedding sand. After placement, the remaining operations of compacting pavers, filling the joints with sand, and final compaction are completed. When finished, the pavement is ready for traffic, thereby reducing user delays.

The machine moves along the roadway guided automatically by a sensor that follows curbs or a guide line. See Figure 2. Other than treads that propel it, the machine has no moving parts. A roof is available as an attachment for worker protection against the weather. Unlike asphalt and concrete, interlocking concrete pavements can be placed during wet weather conditions and below freezing as long as the bedding sand is not frozen or saturated. With two crew members, the machine can place about 3000 sf (300 m²) per day. Cutting edge pavers requires additional labor. Given today's high cost of labor, mechanizing any aspect of paver installation yields lower costs and faster installation times.

Tiger Stone rolls out a concrete carpet with their paver installation equipment.

This production rate is typically less than what can be achieved with wheeled machines using clamping devices. With experienced (seated) operators and additional crew working the laying face, such machines can facilitate placing about a square meter of pavers every 20 to 30 seconds. Tiger Stone's niche appears to be in rehabilitating existing interlocking concrete pavements. Existing pavers can be removed from the street by a front end loader and dumped into a hopper on the Tiger Stone machine (see Figure 3). The front end loader can ride on the freshly placed pavers

Figure 1. Rather than leaning over, workers stand on the machine while it moves on the bedding sand on treads.

Figure 2. The machine follows curbs or guide string lines to locate the pavers against curbs. Five-sided "bishop hats" are used as edge pavers to close 45° herringbone patterns.

Figure 3. Those aren't tumbled pavers. Sustainable paving is normal in The Netherlands meaning that concrete pavers get reused at every opportunity for low-speed vehicular pavements.

as part of the loading process (see Figure 4). After base or utility repairs are made and bedding sand is re-screeded, the crew can remove any broken units in the machine's hopper while arranging whole pavers into a herringbone pattern. Sand that normally sticks to the paver sides and bottoms is knocked off in the handling process.

Necessity is the Mother

A key consideration for using interlocking concrete pavement in the Netherlands is the ability of pavers to be removed, cleaned, and reinstated after repairs to the base. Much of the Netherlands is below sea level and an extensive canal system drains water from the soils. When that occurs, the soils settle and with them the pavements. During rehabilitation, additional pavement base and bedding are installed to restore initial elevations. The existing pavers are reinstated in most cases. The rate of settlement varies from a few inches to almost one foot (0.3 m) over ten years. The building foundations don't settle as much because most rest on pilings.

Following Dutch, German and U.S. experience and research, herringbone patterns are typically used in streets due to better interlock than other patterns. The Tiger Stone machine can accommodate herringbone patterns, plus edge pavers (called bishop's hats), and other laying patterns. The machine can negotiate road curves as well.

As a culture that does more with less, sustainable pavements are second nature to the Dutch. They have been reinstating segmental pavements for centuries. In today's economy, high asphalt prices require and the public demands interlocking concrete pavement as part of maintaining rural and urban neighborhood character (see Figure 5). Concrete paver streets aren't yet as common in the US and Canada, but the potential for projects is growing especially with rising asphalt prices that can make concrete pavers price competitive. There may be older street and parking lot projects in North America that could be rehabilitated using this machine or as well as for new construction. ❖

Figure 4. A loader rides on the newly paver concrete pavers to load more pavers into the machine's hopper.

Figure 5. Typical rural and urban roads in The Netherlands.

Paver Association Updates Technical Bulletins, Detail Drawings and Guide Specs

The Interlocking Concrete Pavement Institute announced updates of popular design resources including Tech Spec technical bulletins, detail drawings, and guide construction specifications. All of these are available to view at www.icpi.org. Click on Design Tools on the ICPI home page for links to these publications.

Tech Spec updates include:

Tech Spec 2—Construction of Interlocking Concrete Pavements: AASHTO references for geotextiles.

Tech Spec 5—Cleaning, Sealing and Joint Sand Stabilization of Interlocking Concrete Pavement: updated joint sand stabilizers information.

Tech Spec 11—Mechanical Installation of Interlocking Concrete Pavements: updated installation patterns.

Tech Spec 13—Slip and Skid Resistance of Interlocking Concrete Pavements: new information on slip resistance testing resources and removal of U.S. Access Board recommendations (since they removed them from their website) on coefficient of friction.

Updates to detail drawings include new ones on permeable interlocking concrete pavement (PICP) for patios, driveways, slopes, and on structural soils with street trees. Existing concrete grid pavement drawings are updated with geotextiles. Besides PICP and grid applications, there are numerous drawings on interlocking concrete pavements and precast concrete paving slabs. All drawings can be downloaded as PDF or DWG files for use in CAD programs. The additional drawings expand the library from 75 to 83.

There are 16 guide specifications each for use in U.S. and Canadian projects. The U.S. specs have English and metric dimensions with ASTM references and Canadian specs are in metric only with CSA references to paving products and materials. All guide specifications are written in the three-part MasterFormat published by the Construction Specifications Institute and the sister organization Construction Specifications Canada. The guide specifications cover interlocking concrete pavements, paving slab, grid pavements and PICP applications. Sand, bitumen, and mortar setting bed methods are included. All documents are in Word and include many notes to guide specifiers in editing the specifications to project conditions. ❖

HNA Registration Opens June 1st

2012 HARDSCAPE North America

Online registration for Hardscape North America (HNA) opens June 1 at www.HardscapeNA.com. Attended by thousands of contractors, the trade show is scheduled for Wednesday through Friday, October 24-26, at the Kentucky Exposition Center in Louisville.

HNA is produced by the Interlocking Concrete Pavement Institute and endorsed by the Brick Industry Association and the National Concrete Masonry Association. The show is co-located with GIE+EXPO, the Green Industry & Equipment Expo, to comprise the 9th largest tradeshow in the United States. The combined show includes 750 exhibitors indoors and outside in a 19 acre (7.7 ha) demonstration area.

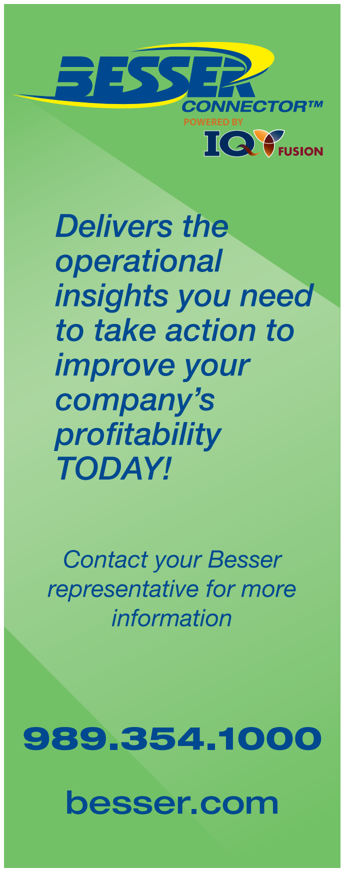
Early-bird registration fees for hardscape contractors and distributors start at $35 until September 12. This includes admission to both shows as well as demonstrations at the HNA Outdoor Arena, mechanical paver installation demos and all networking and entertainment activities. Rates for educational sessions will be available online. ❖

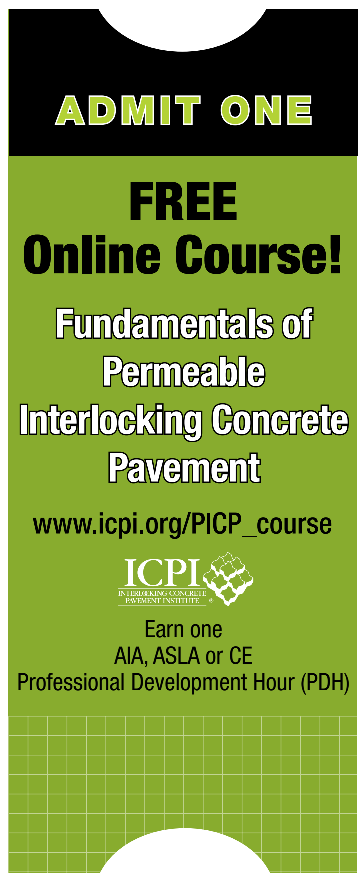
ICPI Offers Free Design Manuals for Port and Airport Pavement Applications

Since the early 1980s, interlocking concrete pavements have supported port and industrial operations in the U.S. and Canada. These pavements were introduced to airfields in the 1990s. The Interlocking Concrete Pavement Institute recently updated three design manuals for these applications. They are Port and Industrial Pavement Design with Concrete Pavers, and the U.S. and Canadian versions of Airfield Pavement Design with Concrete Pavers. The port pavement manual covers structural design using a method developed by The British Ports Association and used on many ports in that country and elsewhere. The U.S. and Canadian airfield manuals apply the U.S. Federal Aviation Administration flexible pavement design method and Public Works Canada design methods, respectively. All of the manuals include guide construction specifications and commentary on construction and maintenance.

The manuals are available at no charge for downloading as PDF files from www.icpi.org under "Design Tools." There are about 12 million sf (1.2 million m²) of interlocking concrete pavement in U.S. and Canadian ports, and millions more in overseas port and industrial uses. Such applications receive wheel loads as high as 10 times greater than truck wheel loads typical to highway pavements. For airfield pavement, there is about the same area in use worldwide, mostly in apron parking areas at commercial air carrier airports, as well as in military and NATO airfields. Again, the heaviest aircraft wheel loads are similar to that found on port and industrial pavements.❖

HARDSCAPE MARKETPLACE





Pain and Pleasure

Continued from p. 4

requires connecting with key agency people experiencing the pain of limited resources and then having them take ownership of ICP technology based on documented performance in other cities (of which there are several examples). When there's interest, agency gatekeepers then transform these tools into design guidelines, specifications, and maintenance procedures in formats familiar to the agency.

But that often takes a champion within the agency. Otherwise, why should a municipal government adopt standards and maintenance of another pavement? The industry finds such champions and assists technology transformation through education and not sales; integration into agency culture rather than imposition. That culture shift takes time and steady commitment by industry and agencies to review, test, and evaluate ICP performance. In some cases, agencies look to selected universities for ICP assessments as well.

In the past, a reason why a city occasionally used ICPs in streets was lower maintenance costs compared to asphalt. That wasn't an easy argument to win with some agencies when asphalt's initial price tag was lower than ICP, including downstream shave-and-pave maintenance. Now there is a crying need for pain relief in municipal pavement budgets. There is limited agency money available for new and rehabilitated urban pavement programs. ICP can be at the price starting gate with other pavements in certain street applications.

The pleasure of ICPs competitive pricing also requires a shift in agency maintenance practices. That might be viewed by some agencies as more pain than pleasure. Change will occur when the pain of not changing is greater than the pain of maintaining the status quo. Such change may need to come from the top down, i.e. from elected officials. In any case, there will be the municipal innovators, early adopters, early/late majority, and the laggards.

There is no instant fix for infrastructure pain relief using different and new pavement technologies. Agency culture and behavior shifts will eventually lead to more pleasure from reduced maintenance costs from ICP. And yes, there will be better looking, safer urban streets. Definitely more pleasure for taxpayers. ❖

Concrete Paver Industry Calendar of Events

August 22-25, 2012
ICPI Summer Meeting
Grand Traverse Resort
Traverse City, Michigan
www.icpi.org

October 24-26, 2012
Hardscape North America
Louisville, Kentucky
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