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DEVELOPMENT OF A NORTH AMERICAN CERTIFICATE PROGRAM FOR INSTALLERS OF PERMEABLE INTERLOCKING CONCRETE PAVEMENT

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Summary

Due to national environmental regulations, permeable interlocking concrete pavement (PICP) is experiencing rapid growth in North America. Design and regulatory frameworks for awareness of sustainable design such as low impact development (LID) have embraced permeable pavement solutions. In 2006, PICP industry guidelines were updated and published by the Interlocking Concrete Pavement Institute (ICPI). These comprehensively address design, specifications, construction, and maintenance. As a fairly new stormwater management technology in North America, PICP designers and users have requested an industry education program to help ensure qualified installation contractors. In response, ICPI is developing a PICP certification course for contractors and to support this need as well as increase PICP exposure and technical credibility. This paper provides an overview of the program in development.

1. INTRODUCTION

The Interlocking Concrete Pavement Institute is developing and education program for the installation of permeable interlocking concrete pavements (PICP). The is in response to the rapid growth in the United States and Canada, especially as national, state/provincial and local regulations are mandating reduction of stormwater runoff and water pollution. The purpose of this paper is to highlight aspects of the course objectives and content that relate to PICP performance.

The course follows from the successful ICPI Level I Certified Concrete Paver Installer course. Since its inception in 1995, over 15 000 persons have taken the two-day course and exam. A rationale and summary of this course can be found in [Smith, 1998]. The course curriculum is found in *ICPI Level I Concrete Paver Installer Certification Program* [ICPI, 2008].

A PICP course certificate of completion is earned by individuals and is not ascribed to the company or employer. The course is expected to help meet demand for industry verification of contractor knowledge and experience. This is understood as an important marketing component in advancing PICPs nationally as well as in local markets.

2. COURSE PARTICIPANTS, OBJECTIVES AND USES

2.1 Communicate industry established guidelines for PICP installers

The course contents represent the industry consensus on best practices for PICP construction. This certificate is intended for experienced contractors and is aimed at contractors who are presently doing commercial segmental paving projects, or to those who wish to move into that market via PICP work. This two-day course is aimed at foreman and higher company personnel. In addition, the course may be of interest to design professionals and municipal stormwater management agency personnel.

2.2 Broaden, evaluate and recognize knowledge

Participants who successfully complete the course and pass a written exam receive a technician certificate of completion. This certificate affirms their commitment to gaining career recognition. The certificate is valid for five years and then is renewable annually with a fee. All those taking the PICP course must be certified as having taken the ICPI Level I Certified Concrete Paver Installer course and passed the exam. This perquisite course provides fundamental information on project planning, estimating and job costing, soils, compaction, base, and paver materials and installation.

2.3 Provide credible promotion by the individual contractor and by the ICPI

ICPI will be promoting PICP installer technician certificate of completion through its technical and marketing literature, guide specifications, and web site, as well as by ICPI producer members and installation companies with certified installers. The PICP installer technician certificate stays with the participating individual and is not bestowed on the company or the participant’s employer. Therefore, it is a portable credential that can move with the participating individual. Additional credibility can come from the number of years in the contracting business installing PICP.

2.4 Creating/contributing to a perception of value to PICP

A PICP installer technician certificate of completion can identify individuals who desire to excel in PICP construction. This is important to homeowners, architects, landscape architects, engineers, general contractors, and stormwater managers as they influence the selection of PICP contractors. By issuing a certificate of completion, the ICPI acknowledges that the person has taken the course and successfully passed the exam. The ICPI does not certify or guarantee the quality of the work by the person or the contracting company. The certificate demonstrates that the person has a basic level of knowledge in PICP construction. All participants agree to indemnify and hold harmless the ICPI, its officers, members and staff from any claims due to negligence, omission, faulty paving materials, or workmanship on the part of the applicant. The certificate of completion does not qualify an installer for membership in ICPI.

3. COURSE CONTENT

The following provides an outline of the course. Highlights from each section follow:

3.1 Section 1 – Introduction

- The Course: Objectives, Prerequisites, and Benefits.
- Registration and Course Procedures.
- A Brief Overview of Permeable Interlocking Concrete Pavement.
- Overview: Components of the System/Comparison to Other Pavements.
- Types of Designs/Installations.

A primary purpose of this section is to describe PICP components as shown in Figure 1.

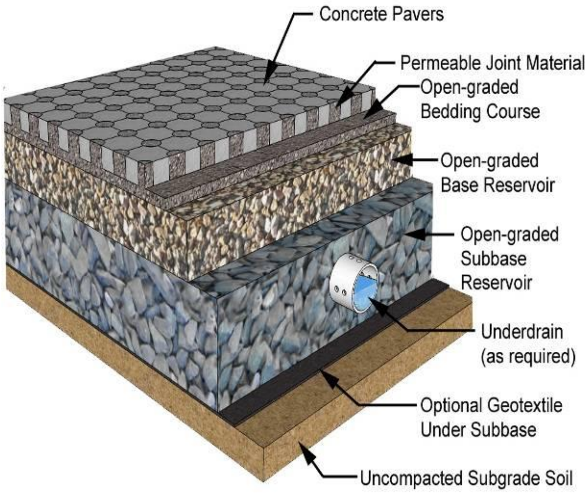

Figure 1. Typical PICP components.

Establishing uniform and consistent terms that refer to various PICP components is defined at the start of the course. In addition, the PICP cross section is compared to conventional, sand-set interlocking concrete pavement cross section so participants clearly understand the differences between these two types of paving. The three types of PICP base/subbase exfiltration design options are also presented. These include no exfiltration with no perforated drain pipes, partial exfiltration using perforated drain pipes to remove water that cannot be infiltrated into the soil subgrade, and no exfiltration that uses an impermeable liner (typically polyvinyl chloride, high density polyethylene or ethylene propylene diene monomer) under the base penetrated by drain pipes. Partial or no exfiltration designs combined with water harvesting systems for irrigation or building gray water use are briefly covered.

A key construction item for all PICP projects includes managing water that exceeds the base/subbase storage and soil infiltration capacity of the system. Excess water can exit through perforated pipes in the base, overflow from the surface in selected areas and drain into a grass swale/bioswale, or directly into a storm sewer inlet via surface runoff or drainpipes in the base. Figures 2, 3 and 4 illustrate these approaches. Drains are typically placed prior to subbase stone placement and compaction. The PICP contractor can be responsible for building or connecting to these overflow drainage methods.

Figures 2, 3 and 4. PICP construction typically includes methods to drain water from that cannot be stored in the base or infiltrated into the soil. These include drainpipes within the base, or managing surface overflow by directing water to a bioswales or storm sewer inlet.

3.2 <u>Section 2 – Job Planning and Documentation</u>

- Critical Factors for Successful Installations.
- Site Plans, Bid Documents, and Cost Recovery.
- Submittals.
- Method Statement.

Figure 2.

Figure 3.

Figure 4.

The purpose of this section is to present a checklist of site factors that affect project schedule and costs. This assists the contractor in planning job execution. Factors can include:

- Scope of work.
- Bonds and insurances.
- Wage requirements for publicly funded projects.
- Equipment accessibility.
- Erosion and sediment control.
- Site/material access and flow.
- Staging/lay down areas.
- Labor estimates by job function.
- Material packaging, paver layout and laying face delivery for manual or mechanical installation.
- Material delivery/timing.
- Grades/elevation benchmarks.
- Installation schedule and weather.
- Installation schedule.
- Mobilization costs.
- Test requirements for soils, subbase/base and bedding materials, concrete pavers, etc.

The section on submittals prepares the contractor for the types of materials, quantities, and test results that may be required in commercial project specifications, since many PICP projects are commercial in nature. The method statement is encouraged within project specifications and it provides an opportunity for the contractor to document how the project will be executed. The method statement can be supported by project plans showing materials locations and construction timing of each. It also includes expected productivity rates using manual or mechanical installation. The method statement is provided to the general contractor and project owner's representative via a preconstruction meeting. This meeting is considered essential establishing acceptance methods for excavation, geotextile (if used), subbase and base, bedding, pavers and jointing materials, and installation, as well as drainage and edge restraints.

3.3 Section 3 – Estimating Quantities, Job Layout and Flow

- Job layout for Excavation.
- Excavating Soil and Storm Water Prevention Plans.
- Estimating Geotextile, Subbase, Base, and Bedding Materials.
- Estimating Jointing and Paver Materials.
- Flow of Materials, Equipment, and Site Cleanliness.

Most of this section focuses on material quantity estimating for the subbase/base and bedding including the conversion of tons delivered to area/depth filled. Table 1 illustrates an example from the course of jointing materials required and indicates differences based on the percentage of open surface area within the paving units.

Table 1. Jointing material estimates for typical PICP joint widths for a 1 860 m^2 project.

MATERIAL	JOINT WIDTH	% OPENING (TYPICAL)	QUANTITY
ASTM Nos. 8, 89 or 9 stone	Up to 6 mm	< 9%	18.6 t
	6 mm to 12 mm	> 9%	37.2 t

A major difference in conventional interlocking concrete pavement and PICP is the need to maintain clean stone materials during PICP construction. Stone materials contaminated with dirt and sediment from handling, storage or vehicles can render such materials unusable and in need of replacement during construction. This can impose unwanted costs and schedule delays. This section covers how to manage the flow of materials, equipment and execute best practices for keeping equipment clean and handling aggregates to prevent contamination. For larger projects, this might include temporarily covering the installed base with geotextile and a thin layer stone to provide a riding surface for construction vehicles. Another approach may be to construct temporary roads for material delivery and subcontractor use. For large projects, the truck tire washing equipment may be beneficial at the project entrance.

3.4 Section 4 – Soil Characteristics

- Site Characteristics Beneficial to PICP.
- Soil Types and Infiltration Rates.
- Why the Soil Is Not Compacted.
- Geotextiles: Purpose and Uses.

The course reviews site characteristics beneficial to PICP. Many of these can be found in the ICPI manual, *Permeable Interlocking Concrete Pavements* [Smith, 2006]. While soils evaluation and infiltration testing are conducted by the design engineer, the course provides the contractor with information on this subject. As PICP project areas, loads and costs increase, and as soil infiltration rates decrease, the need for soil infiltration tests increases. The course reviews the importance of soil infiltration testing procedures and their results using a double-ring infiltrometer.

PICP is usually built over native, undisturbed soils. Native soils have some natural compaction and their natural, in-place density increases as the excavation depth increases. While some projects may require a compacted soil subgrade, the course warns against compacting soils under PICP other than grading and trimming for drainage. Compaction greatly reduces soil infiltration. There will be equipment passing over the soil subgrade surface and this will bring some compaction. However, compaction incidental to construction equipment is not near the same density or depth brought about by compacting soil uniformly with compaction equipment typical to parking lot or road construction.

A decrease in soil infiltration can be acceptable if the infiltration rate of the soil when compacted was initially considered during design and in drainage calculations. However, this should be verified at the pre-construction meeting with the design engineer. Compaction (or supplementary stabilization) of low CBR soils (< 4%) may be necessary to attain sufficient structural support and to minimize rutting from vehicular traffic. These soils should be compacted to at least 95% of standard Proctor density. Subsurface drains in the open-graded subbase will likely be required to remove water since compaction will greatly reduce the soil's permeability.

Specifications and minimum physical requirements for geotextiles for separation and drainage can be found in American Association of State Highway and Transportation Officials or AASHTO M-288, “Geotextile Specifications for Highway Applications” [AASHTO, 2004]. For vehicular applications, high-quality woven geotextile fabric should be specified that resists puncture from coarse, angular aggregate during compaction and from repeated wheel loads during its service life. If used, bases should have their sides and bottoms wrapped in geotextile. ICPI recommends a minimum of 0.3 m overlap in well-drained soils and 0.6 m overlap on poor-draining weaker soils (CBR< 4%).

PICP captures pollutants such as oils, total suspended solids, metals, and nutrients from the infiltrated runoff. Contractors may encounter PICP that incorporates a thermally bonded nonwoven geotextile to assist with filtering water that enters the system. These geotextiles are placed between the base and bedding layer of the system.

3.5 Section 5 – Subbase and Base Materials

- Gradation, Void Space and Other Aggregate Characteristics.
- Factors in Determining Subbase and Base Thicknesses.
- Subbase and Base Delivery, Installation and Compaction.
- Subbase and Base Density/Stiffness Testing and Verification.

Aggregate characteristics are presented as provided in the ICPI manual [Smith, 2006] and gradations are provided in ASTM D448, *Standard Classification for Sizes of Aggregate for Road and Bridge Construction* [ASTM, 2008]. Visual identification and comparison of aggregate sizes is important to contractors operating in the field. Figures 5, 6 and 7 illustrate ASTM stone sizes typically used in PICP construction. For construction expediency, the ASTM No. 57 layer is no greater than 100 mm thick and provides a transition between the ASTM No. 8 stone bedding layer and the ASTM No. 2 stone. ASTM No. 2 stone is not as found in all parts of North America and it is sometimes substituted with smaller sized ASTM No. 3 or 4 stone provided that each has a confirmed minimum void ratio of 32%.

Figure 5. ASTM No. 8 stone for bedding and joints.

Figure 6. ASTM No. 57 stone for the base.

Figure 7. ASTM No. 2 stone for the subbase.

The course includes a brief overview of factors influencing base and subbase thicknesses such as the amount water storage required and anticipated traffic loads. Information is provided on cross sections on various soils in non-frost and frost climates for loads up to 600 000, 80 kN equivalent single axle loads (ESALs). While the contractor typically does not get involved in structural base design, a general understanding of these relationships can put the contractor on alert for designs that might be insufficient from a structural perspective and possibly raise this concern with the project owner or designer.

A key requirement for water storage and infiltration is that open-graded base and subbase aggregates have minimum void space of 32% for water storage. Another is that the bedding, base and subbase layers choke or mesh into each other thereby enhancing the stability of the entire pavement section. Choking criteria for each layer is covered in the course. These can be verified by the contractor with sieve analysis reports from the aggregate supplier.

Concerning base and subbase compaction, the course recommends a minimum of four passes with a minimum single or dual smooth 10 T steel drum roller or a 60 kN reversible vibratory plate compactor. The ASTM No. 2 stone layer is typically compacted in 150 mm thick lifts. The ASTM No. 57 base layer can be compacted as one 100 mm thick lift using the same types of compactors.

While many PICP projects have performed well without measuring open-graded base density, an increasing number of projects will likely require base density testing for quality assurance. The course reviews a new test method developed by ICPI that determines a "target density" using nuclear density gauge on a control strip. The test method is for the ASTM No. 57 layer (or equivalent) only. No method yet has been established to evaluate the ASTM No.2 subbase density. The test method uses ASTM D 2922 *Standard Test Methods for Density of Soil and Soil-Aggregate In-Place by Nuclear Methods (shallow Depth)* [ASTM, 2004] with the gauge in backscatter mode rather than extending the probe into the base material. The testing company works with the contractor who constructs a control strip for determining of a target density. This consists of a single uniform lift as specified in the contract documents, but not more than 100 mm in depth and covering approximately 500 m^2. No testing is performed within 3 m from any outside edge of the work area. The control strip may be incorporated into the project upon acceptance of density measurements by the testing company.

During construction of the control strip, the aggregate is maintained in a moist condition during compaction. The aggregate surface should be visibly moist and maintained as such throughout construction and compaction. After initial placement of the aggregate material, the compaction equipment makes two passes over the entire surface of the control strip. Using the backscatter/indirect test method, densities and moisture contents are determined at five randomly selected locations at least 5 m apart. The dry density and moisture contents are calculated for each of these locations and the averages are used as initial values.

If the new average dry density exceeds the previous value by more than 20 kg/m^3 then two additional passes of the equipment are carried out as described above. If the new average dry density does not exceed the previous value by more than 20 kg/m^3, then compaction of the control strip will be considered acceptable. Seven additional field density and moisture tests are taken at random locations and the dry density and moisture content values determined. The final dry density and moisture content of the control strip should be equal to the average of these seven values plus the three most recent values obtained upon completion. This procedure should assist in providing more consistent densities across the open-graded base.

3.6 Section 6 – Edge Restraints

- Concrete Curbs and Placement.

Concrete curbs around PICP typically rest on top of the subbase layer. The curbs are usually cast-in-place concrete. If the curb separates PICP from conventional paving (see Figures 8 and 9), the depth of the curb should extend to the depth of the dense-graded base to protect it from becoming saturated. Figure 10 illustrates cast-in-place concrete curbs with indentations for overflow drainage into the parking lot island. Water flowing from extreme storms can drain into a bioswale providing further storage and pollutant reduction.

Plastic edge restraints are extensively used in residential and commercial interlocking concrete pavements throughout North America. These restraints typically are not used in vehicular PICP applications, as the stakes do not anchor securely into the open-graded base. Plastic edge restraints that utilize spikes are not recommended for commercial and municipal applications. In residential applications, some contractors have successfully installed a 1 m wide band of compacted, dense-graded aggregate at the perimeter of the pavement. The interior is filled with open-graded aggregate. Plastic edge restraints are then spiked to the perimeter band containing the bedding material and pavers.

Figures 8 and 9. The depth of the concrete curb separating PICP from conventional pavement should extend the depth of the conventional pavement. Note the PICP in travel lanes in Figure 6 and PICP in parking spaces in Figure 7.

Figure 10. Cast-in-place concrete curbs with indentations for PICP overflow drainage.

3.7 <u>Section 7 – Bedding and Jointing Materials</u>

- Gradation and Base Compatibility.
- Placing Bedding Material.

Bedding layer gradation and base compatibility concerns the ability of each layer to choke or mesh into each other. Acceptance criteria are provided in the course. Greater emphasis is placed on various methods of manually and mechanically screeding the bedding layer for larger projects. Mechanical screeds can rely on curbs or guide bars placed on the base and with adjustments to the screed for small changes in slope, or are guided with a laser. Figures 11 and 12 illustrate these types of mechanical screeds.

Figure 11. A mechanical screed relies on curbs or metal guide bars for creating a consistently thick PICP bedding layer.

Figure 12. Laser guided screeding equipment adapted from the asphalt pavement industry can accelerate screeding of large PICP areas.

3.8 Section 8 – Selection and Installation of Permeable Interlocking Concrete Pavers

- Paver Product Standards.
- Paver Types and Applications.

ASTM and CSA paver product standards are only briefly mentioned in the course since they are previously covered in detail in the perquisite Level I course. There are many PICP paver shapes and course participants are encouraged to evaluate each shape and related costs for joint/opening filling materials and labor, as well as manual or mechanical installation efficiencies. The course illustrates various PICP paver types that conform to ASTM and CSA national paver material standards.

PICP paving units are placed on the screeded bedding layer, joints filled, surfaces swept clean and compacted with only once with a plate compactor. This is different than conventional interlocking concrete pavement as it receives compaction before and after jointing sand is installed. In contrast, PICP has larger joint openings that cause bond lines to move if compacted without jointing material in the openings. Efficient joint material spreading/sweeping techniques and equipment are covered in the course as well as efficient compaction methods. Cutting pavers is not covered since it is discussed in the Level I certification course.

3.9 Section 9 – Maintenance

This section includes a maintenance checklist and recommends a minimum vacuum sweeping bi-annually. ICPI is currently investigating various surface cleaning techniques and the results will likely be included in future course editions. The installation of a vertical pipe with a cap at the paver surface (or just under it) is encouraged for monitoring drainage.

Winter maintenance includes snow plowing and less de-icing salt use than conventional interlocking concrete pavements. Sand is not recommended on PICP. However, if tire traction is needed, then jointing stone should be spread on the surface. Standard methods for measuring surface infiltration rates have yet to be developed and included in the course.

3.10 Section 10 – Class Review and Exam

The review consists of recapping the main points within each course section. For the exam, a passing grade is 75% or higher. Participants who do not achieve this grade can repeat the course and exam at a later date. Those who achieve this grade receive a certificate of completion.

3.11 Section 11 – Appendix

The appendix consists of references and glossary of terms, a list of specialty tools for PICP construction beyond that typically required for interlocking concrete pavement projects. The Appendix also includes a guide construction specification.

4. CONCLUSION

The PICP technician certificate course is under development and includes an instructor's manual and course. Instructors will consist of experienced PICP contractors. Instructor training is expected in late 2009 with the first installer course in early 2010. The course will help satisfy the demand for contractor education and assist contractors in expanding their knowledge and use of PICP.

5. REFERENCES

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