THE INTERNATIONAL TECHNOLOGY SCANNING PROGRAM

PRECAST CONCRETE PAVEMENT TECHNOLOGY

DESK SCAN

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DISCLAIMER

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This *Desk Scan* was conducted in cooperation with the members of the Scan Team and numerous individuals who served as resources for information on precast concrete pavement technology in the countries investigated.

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Summary

The use of precast concrete pavement is an emerging technology in the US for application to rapid repair and rehabilitation of existing pavements. The technology is currently being applied in high volume, congested urban/suburban roadways where lane closures are very difficult and work on the roadways can only be conducted at nighttime. Use of precast concrete pavement technologies must result in reduced lane closures or better managed lane closures that in turn result in less traffic disruptions and improved safety at construction zones. The precast concrete pavement technology is equally applicable to repair and rehabilitation of rural roadways where use of conventional repair/rehabilitation techniques may not be feasible because of ready access to the conventional techniques or cost.

Information for the desk scan was compiled based on published literature review, internet searches, and personal contacts with experts in the US and other countries. This work was facilitated by information collected previously as part of the Strategic Highway Research Program 2's Project R05 on Modular Pavement Technology.

Based on the result of the desk scan, it is recommended that the following countries be included in the international scan tour, in order of importance: Japan, Indonesia, and the Netherlands. If the scan tour itinerary can accommodate a stop in Russia, this would allow visiting with Russian experts and to evaluate the Russian precast pavement technology. Although France has implemented precast pavement technology, there is not much use currently of this technology for highway applications and would be of limited interest to US highway agencies.

Scope of Desk Scan

This desk scan was conducted to PCP technologies in other countries that show promise for implementation in the US or can support improvements in technologies currently in use in the US. The primary focus of the desk scan was to identify PCP technologies that support rapid renewal of existing pavements and result in longer lasting treatments. The durability of the pavement repair/rehabilitation is extremely important aspect when using precast concrete pavements.

The Scan Tour Panel has identified the need to examine the best international practices related to the following PCP related topics:

1. Criteria used to decide whether a project is a suitable candidate for use of precast concrete pavement systems (PCPS)
2. Design methods for PCPS
3. Construction techniques for PCPS

4. Performance related data on PCSP
5. Short-term and long-term ride quality of PCPS installations
6. Obstacles to deployment of PCPS
7. Strategies to advance wider use of PCPS
8. Technical information on PCPS in use
9. Technical information on advanced PCPS features (such as PCPS with a porous surface; “heated” PCPS; and prestressed PCPS)
10. PCPS concrete mixture design
11. PCPS joint load transfer mechanisms
12. Grout materials for PCPS joint hardware
13. Grout materials for PCPS bedding support and for under-sealing
14. steel reinforcement requirements
15. PCPS panel handling and shipping
16. PCPS standards to facilitate increased industry competition.

In relation to the emerging PCP technology, a topic of special interest is how new technologies, including proprietary technologies, are implemented in other countries.

Methodology Used

The desk scan information is based on literature review, internet searches, and information developed through personal contacts. In addition, information on PCP technology previously developed under the Strategic Highway Research Program 2 (SHRP2)’s Project R05 – Modular Pavement Technology was incorporated in the desk scan. Specific information is referenced as appropriate and specific websites are identified as appropriate. A limitation of the internet searches was that many of the websites that provided information on PCP use and PCPS were in the local languages. Based on discussions with US experts, the scan tour panel members, and personal understanding, the effort to obtain PCP technology information was directed at a few countries, principally, the Netherlands, France, Japan, Russia, and Indonesia.
It should be noted that, as discussed in Chapter 3, the US interest in the PCP technology is for rapid intermittent repairs (localized full-depth repairs or full slab replacements) and for rapid continuous applications (longer length or larger area rehabilitation). The use of the PCP technology in other countries (except Canada) is for rapid and/or longer lasting continuous applications. The use of the PCPS in the Netherlands also addresses installations over poor support conditions, a condition somewhat unique to the Netherlands.

Prior Study Tour

There have been no previous international scans that focused on PCP technology. An international scan on Long-Life Concrete Pavements that was conducted during 2006 did include discussion on the use of PCPS for rapid repair and rehabilitation by the Ministry of Transportation Ontario (MTO), Canada. The MTO was, at that time, evaluating US-developed PCPS for rapid repair and rehabilitation of concrete pavements in the Toronto area. The MTO has since then continued implementation of the PCP technology in Ontario.

Literature Review

A literature review was conducted to determine the status of PCP technology implementation in different countries. Most of this information was available primarily in the proceedings of international conferences held in the US or in Europe. Because of language constraints, literature in non-English languages was not reviewed. The literature review was facilitated by a previous literature review conducted under the SHRP2 Project R05. It should be noted that the PCP technology is an emerging technology in most countries, as it is in the US, and only a limited amount of published information is available. Some of the available information is of academic nature (theoretical analysis of PCPS, etc.) and is not incorporated in this report.

Internet Review

The internet review was conducted to seek information on specific PCPS in use in other countries and to access specific guidelines or national standards. Several sites of PCPS vendors were identified and are listed in Chapter 3. However, these sites are in the local language, but can be accessed using rudimentary internet webpage translators.

Personal Contacts with Experts

A significant amount of the desk scan information was developed using personal contacts in the US and in other countries. Information was readily available from sources in the Netherlands and from a US source for Indonesia. Some information was available for airfield PCPS use in Russia and discussions are continuing to obtain information on PCPS for roadway applications in Russia. Discussions are also continuing with contacts in France and Japan to obtain specific information on current PCPS use in these two countries.
Special thanks are extended to:

1. Mr. Tommy Nantung, Indiana Department of Transportation, for information on precast concrete pavements in Indonesia
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use in Japan.

5. Mr. Francois de Larrard, LCPC, Paris, France, for information on the removable hexagonal precast concrete pavement use in France.

CHAPTER TWO – DESK SCAN RESULTS

This chapter highlights the international activities in the areas of interest to the scan tour panel. A brief overview of the US experience with the PCP technology is presented first to establish a benchmark for the status of PCP technology in the US, identify perceived gaps in the technology, and review areas for refinements/innovations. This is followed by discussion of the current practice of the PCP technologies in the countries that have or are implementing these technologies.

Precast Concrete Pavement Technology

Pavement rehabilitation and reconstruction, major activities for all U.S. highway agencies, have significant impact on agency resources and traffic disruptions because of extensive and extended lane closures. Traffic volumes on the primary highway system, especially in urban areas, have increased tremendously over the last 20 years, leading in many instances to an earlier-than-expected need to rehabilitate and reconstruct highway pavements. Pavement rehabilitation in urban areas is resulting in serious challenges for highway agencies because of construction-related traffic congestion and safety issues. Many agencies also continue to wrestle with the age-old problem: longer delays now and longer service life versus shorter delays now and shorter service life. In recent years, many agencies have started investigating alternative strategies for pavement rehabilitation and reconstruction that allow for faster and durable rehabilitation and reconstruction of pavements. A promising alternative strategy is the effective use of modular pavement technologies, principally PCPS, which provide for accelerated repair and rehabilitation of pavements and also result in durable, longer-lasting pavements. Accelerated construction techniques can significantly minimize the impact on the driving public, as lane closures and traffic congestion are kept to a minimum. Road user and worker safety is also improved by reducing users' and workers' exposure to construction traffic.

Precast concrete pavement systems are systems that are essentially fabricated or assembled off-site, transported to the project site and installed on a prepared foundation (existing pavement or re-graded foundation). These systems do not require field curing for the precast concrete panels and require only minimal time for system components to achieve strength before opening to traffic. Ideally, PCPS are installed rapidly, cause minimum disruption to traffic, and produce long life for the repaired or rehabilitated pavement areas. Shorter-life pavement rehabilitation cannot be accepted as the price of rapid repair and rehabilitation. The primary warrant for use of PCP technology is the ability to reduce construction time without sacrificing quality or longevity, thus reducing lane closure time in heavily congested traffic corridors. Off-site fabrication also has the potential to permit use of lighter, thinner, and more durable pavement sections through more stringent quality control and use of design details not feasible for in-place construction. Also, the use of multi-lift fabrication allows incorporation of a range of surfaces that can meet specific needs related to tire/pavement noise, surface drainage, and spray/splash considerations.

The precast concrete pavement technology is gaining wider acceptance by US highway agencies and contractors and precasters are beginning to seriously explore business opportunities related to precast concrete pavement applications. The US precast concrete pavement technology is generally based on sound technical/engineering considerations and field installation processes appear to be workable given the severe working conditions for many of these projects. Gaps in technology remain and need to be addressed before the use of precast pavement for rapid pavement renewal becomes an established and routine process.

Specific benefits of PCP use are summarized below:

1. Reduced and/or better managed lane closures
2. Better quality concrete (better control at plant)
3. Better concrete curing conditions – at fabrication plant,
4. Minimal weather restrictions during panel installation
5. Reduced delay prior to opening to traffic – no on-site curing of concrete and minimal curing time for other materials (fast-setting grouts, etc.).

Precast Pavement Concepts

The application of precast concrete pavement technology can be classified as follows:

1. Intermittent Repair of PCC Pavement: Under this approach, isolated pavement repairs are conducted using precast concrete slab panels. Two types of repairs are possible:
    a. Full-depth repairs, to repair deteriorated joints, corner cracking or cracking adjacent to the joint.
    b. Full-panel replacement, to replace cracked or shattered slab panels.

    The repairs are typically full-lane width. The process is similar for full-depth repairs and full-panel replacement, except for the length of the repair area.
2. Continuous Applications: Under this approach, full-scale project level rehabilitation (resurfacing or reconstruction) of asphalt and concrete pavements is performed using precast concrete panels.

US Precast Concrete Pavement Systems and Experience

Several recently developed techniques are available in the US, as follows:

1. Precast prestressed concrete pavement (PPCP) developed at the University of Texas

2. Jointed precast concrete pavement, proprietary and generic systems:
    a. Fort Miller Super-Slab system (proprietary)
    b. Kwik Slab system (proprietary)
    c. Roman Stone system (proprietary)
    d. Michigan system (generic)
    e. Illinois Tollway system (generic)
    f. La Guardia International Airport system (generic)

Discussion of these systems and techniques is given elsewhere (Tayabji et al., 2009; Hall and Tayabji, 2008; Merritt and Tayabji, 2009). Brief details for the more common systems are given below:

<u>Precast Prestressed Concrete Pavement (PPCP)</u>

The PPCP system was developed at the University of Texas at Austin, under the sponsorship of FHWA and Texas DOT. This precast concrete pavement technology is well suited for continuous paving. The basic PPCP concept consists of a series of individual precast panels that are post-tensioned together in the longitudinal direction after installation on site. Each panel is pretensioned in the transverse direction (typically, the (long axis of the panel) during fabrication and ducts for longitudinal post-tensioning are cast into each of the panels. A keyway system is used along the intermediate transverse joints to provide for load transfer at these joints and to facilitate panel to panel alignment during panel installation in the field.

<u>The Fort Miller Super-Slab System</u>

The Super-Slab system is a proprietary PCP technology suitable for both intermittent and continuous paving operations. This paving system consists of precast slabs placed on a precision-graded fine bedding material or placed over a graded existing granular base. This particular PCP technology lends itself to the construction and rehabilitation of freeway entry and exit ramps because the manufacturer can produce panels with varying cross-slopes. This system has the most production paving experience to date.

<u>Precast Concrete Panels for Full-Depth Repair (The Michigan Method)</u>

Referred to as the “Michigan" method, this is a nonproprietary precast concrete pavement technology, a doweled full-depth system suitable for isolated or intermittent repair of highway pavements. This system was refined at the Michigan State University under a project sponsored by FHWA and the Michigan DOT. The repair panels are typically 6 ft long and 12 ft wide, fitted with three or four dowel bars in each wheel-path. The Michigan method can be used for full-depth repair as well as full-panel replacement. This method utilizes a partial or full dowel bar retrofit technique to install dowel bars at the transverse joints formed by the precast panel.

Other US Developed Systems

There has been increased interest shown by highway agencies to develop generic precast pavement systems and for precasters to develop their own precast pavement systems or to adopt a generic system, such as the Michigan system, for intermittent repair application. The Roman Stone Company, based in New York, is marketing such a system. In addition, the Illinois Tollway has also developed a generic PCP repair system based on the Michigan system and implemented this systems for full-depth, full-slab replacement projects beginning in 2009. During 2002, the PANY/NJ constructed two 200-ft jointed PCP test sections at a non-critical taxiway area at LaGuardia International Airport in New York City.

Precast Pavement Use in the US

Since about 2000, many highway agencies in North America have expressed interest in considering use of precast concrete for intermittent repair or continuous applications in heavily trafficked urban areas where extended lane closures are difficult.
The following U.S. and Canadian highway agencies have accepted the use of precast pavement for production work:

1. Caltrans
2. Illinois Tollway Authority
3. Iowa DOT (as an alternate for bridge approach slabs)
4. Ministry of Transport, Ontario
5. Ministry of Transport, Quebec
6. New Jersey DOT
7. New York State DOT
8. New York State Thruway Authority

The following U.S. agencies have investigated or are investigating use of precast pavement:

1. Colorado DOT
2. Delaware DOT
3. Florida DOT (demonstration project planned for construction, 2011)
4. Hawaiian Agencies
5. Indiana DOT
6. Michigan DOT
7. Minnesota DOT
8. Missouri DOT
9. Nevada DOT
10. Texas DOT
11. Virginia DOT
12. Airport Authorities
    a. Port Authority of New York and New Jersey

    b. Metropolitan Washington Airport Authority
13. US Air Force

US Current Activities

Production Use

In the last few years, several agencies have developed specifications that allow use of precast concrete pavement systems for repair applications. Also, several agencies have installed test sections to demonstrate the feasibility of using the precast concrete pavement systems. In addition, the Illinois Tollway has developed a generic precast concrete pavement system for intermittent repair applications. California has initiated several PCPS projects,

FHWA Initiatives

Recognizing the need to develop effective solutions for rapid rehabilitation of the nation's highway system, the Federal Highway Administration (FHWA) and the Michigan Department of Transportation (MDOT), as part of the FHWA's Concrete Pavement Technology Program (CPTP), sponsored a study during the late 1990s that investigated the feasibility of using precast concrete panels for full-depth repair of concrete pavements. This work was conducted at the Michigan State University and has resulted in several field trials of this technology. In addition, FHWA sponsored the development of the PPCP system at the University of Texas during the late 1990's and has continued support of that technology with demonstration projects and engineering support to agencies.

Industry Initiatives

Parallel to the FHWA sponsored efforts; several organizations in the US also initiated development activities to refine precast concrete pavement technologies, primarily for repair applications. Some of these technologies have certain proprietary features to the products and as such require licensing for use of the technologies. Privately developed technologies include the following:

1. The Fort Miller Super-Slab system
2. The Roman Stone system
3. The Kwik Slab system

The Fort Miller's Super Slab system has been used on several production projects (continuous and intermittent) for repair and rehabilitation applications. In continuous application, this system simulates conventional jointed plain concrete pavement sections.

AASHTO TIG Activities

Recognizing the increasing interest in PCP technologies by US highway agencies and to provide an effective platform for technology transfer activities, AASHTO established a Technology Implementation Group (TIG) during 2006 to support technology transfer activities related to PCPs. The mission of this AASHTO TIG was to promote the use of PCPs for pavement rehabilitation and pavement repairs to transportation agencies and owners nationwide and to present an unbiased representation to the transportation community on the technical and economic aspects of the current PCPS utilized in the marketplace. In June 2008, the AASHTO TIG completed work on the following documents:

1. Generic Specification for Precast Concrete Pavement System Approval.
2. Guidance and Considerations for the Design of Precast Concrete Pavement Systems.
3. Generic Specification for Fabricating and Constructing Precast Concrete Pavement Systems.

SHRP2 Project R05 – Modular Pavement Technology

The US Congress established SHRP 2 in 2006 to investigate the underlying causes of highway crashes and congestion in a short-term program of focused research. As part of this program, a highway renewal research plan was developed. The *Renewal* focus area emphasizes the need to complete highway pavement projects quickly, with minimal disruption to the users and local communities, and to produce pavements that are long-lasting. The goals of this focus area include applying new methods and materials for preserving, rehabilitating, and reconstructing roadways. The effective use of PCP technologies for rapid repair, rehabilitation and reconstruction of pavements addresses this goal.

The objective of the ongoing SHRP2 R05 project is to develop tools for use by highway agencies to design, construct, install, maintain, and evaluate modular pavement systems. These tools are to include the following:

1. Guidance on the potential uses of precast concrete pavement systems for specific rapid renewal applications
2. Generic design criteria for precast concrete pavement systems
3. Project selection criteria for precast concrete pavement systems
4. Guidelines and model specifications for construction, installation, acceptance, and maintenance
5. A long-term evaluation plan to assess the performance of precast concrete pavement systems and to refine these systems.

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By necessity, the primary focus of this study is on precast concrete pavements. The scope of Project R05 also includes field testing of selected precast concrete pavement

projects to assess the performance of these projects and to develop information to refine repair design, panel fabrication, and panel installation procedures.

A summary field test data collected to date from intermittent repair projects as well as from continuous application projects indicate that precast concrete repairs that are designed and installed well have the potential to provide long term service (Tayabji et al. 2010). Both the proprietary systems, such as the Fort Miller's Super Slab system, and generic systems, such as the Michigan system, appear to have the potential to provide service life ranging from 10 to 20 years. Overall, there does not appear to be any concern about the quality or the durability of the concrete used for the precast panels. For most of the precast applications, there is a requirement to grind the surface of the completed project and therefore any joint elevation differences during placement of the precast panels can be easily addressed.

International Experience with PCP Technologies

This section summarizes the use of PCPS in other countries and highlights specific innovations in the PCP technologies in these countries.

Canada

The PCP technology has been in use in the provinces of Ontario and Quebec. The PCPS practices are based on systems developed and in use in the US. In 2004, the Ministry of Transportation Ontario (MTO) carried out a trial project to evaluate construction techniques for precast concrete slab repairs in concrete pavement. The trial was carried out on Highway 427, in Toronto. The trial project included demonstrations of three precast concrete pavement full-depth repair methods: the Fort Miller Super-Slab Intermittent Repair Method, the Fort Miller Super-Slab Continuous Method, and the Michigan Method. Each method involves designing and fabricating precast concrete slabs to replace deteriorated concrete pavement. During 2008 and 2009, the MTO installed about 5,000 sy of PCP using the Fort Miller system at three projects in the Toronto area. There were no PCPS projects installed by the MTO during 2009 and 2010. The MTO has also developed a specification that details the requirements for repairing concrete pavement with PCP using either the Fort Miller Super-Slab Method or the Michigan Method. The specification is applicable to both continuous and intermittent slab repairs. The Ministry of Transport Quebec (MTQ) used the Fort Miller Super-Slab method for an approach slab project the Montreal area during 2008.

France

In France, in the pursuit for "removable urban pavements", researchers at the Pont et Chaussées laboratories (LCPC) developed a hexagonal shaped PCPS. Two projects were installed by LCPC in cooperation with other organizations, one in 2007 and a second one in 2008 and the technology was widely publicized to urban agencies in France. It is not clear if other local agencies (France has over 36,000 municipalities) did in fact implement this technology as no formal tracking of projects has been done by any organization. A unique advantage of the French PCPS is that the base course used is easy to place and grade and can be worked with light equipment available locally. A second type of the hexagonal PCPS has also been developed. The panels for this system are smaller in size and incorporate keyed joints to provide some level of load transfer at the joints. According to the LCPC experts, the size, base support and the optional keyway connections between panels allow the PCPS to carry heavy trucks loadings, up to 1.,500,000 cycles of truck loading. The system was tested successfully at an accelerated load testing facility. Views of the French hexagonal PCPS are shown in Figure 1.

Figure 1. Installation of keyed hexagonal slabs

Because of the removable requirements, the precast panels have to be mechanically independent in order to be easily lifted during maintenance operations. Therefore no load transfer mechanism is provided along joints and only a soft polymeric water-proof joint sealant is used. The slabs are installed over a granular bed. The base course has a structural function, so research continues to find an easy-to-dig material, yet strong enough to resist long-term traffic loadings. The slabs are typically 8 in. thick and have an equivalent diameter of about 5 ft. Accelerated pavement testing has been carried out successfully at LCPC. A guide for the use of the removable hexagonal-shaped PCPS has been developed. Some of the details contained in the guide are shown in Figure CC.

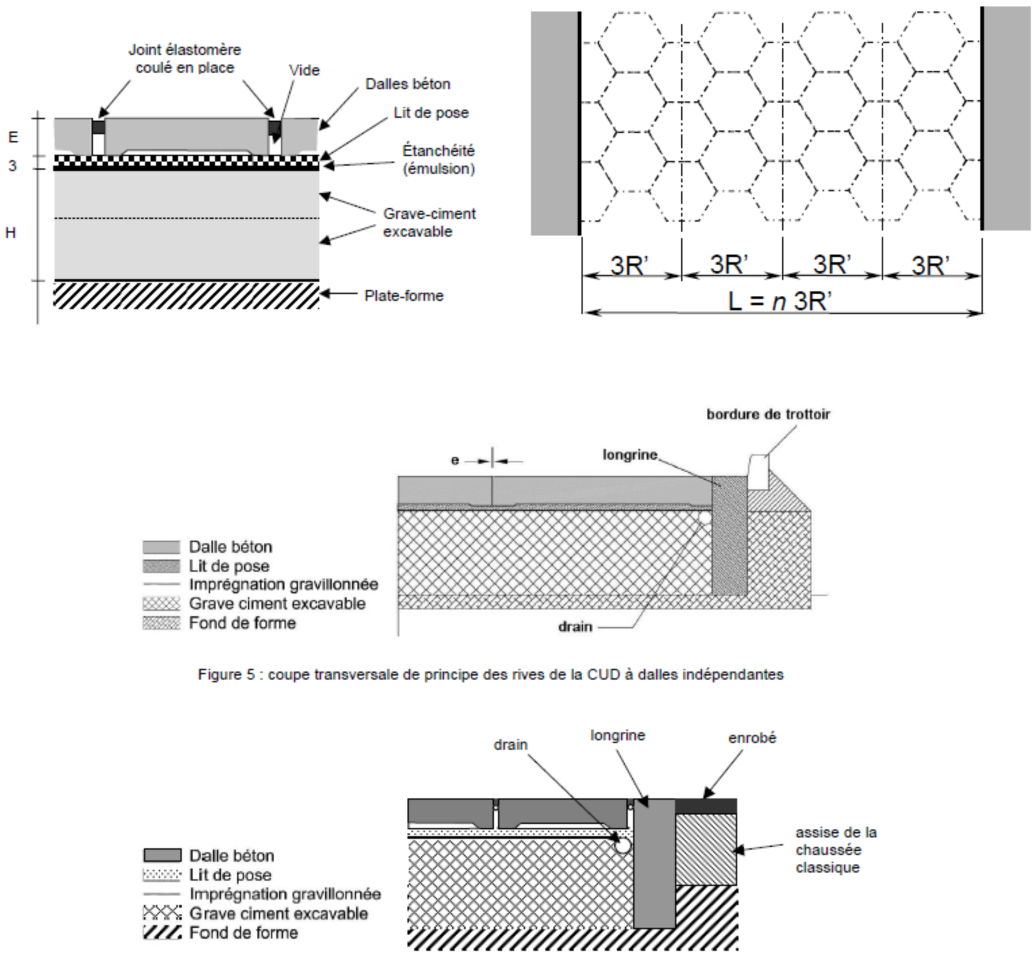


Figure 2. Details from the French hexagonal precast pavement guide

Indonesia

During 2008, a PPCP project was completed on a portion of the Kanci-Pejagan Toll Road near Cirebon on the island of Java in Indonesia. The four-lane project, which is about 22 miles in length, is located between the seaport city of Cirebon (a north coastal city of the West Java province) and Semarang (a north coastal city of the Central Java province). This particular toll road will become a section that connects the Trans-Jawa Toll Way System, which will have a total length of over 515 miles.

The PPCP design was based on the PPCP practices in the US, principally the pilot PPCP project constructed in Georgetown, Texas, during the fall of 2001. The final design selected for this project required use of 8 in. thick panels placed over a 2 in. lean concrete base. The design was based on maintaining a certain level of prestress in the panels (after post-tensioning) that would make the PPCP equivalent to a thicker conventionally designed jointed concrete pavement. The design was based on an Annual Average Daily Traffic (AADT) count of 76,302 vehicles and a total Equivalent

Single Axle Load (ESAL) of 43 million over a 30-year period. For the traffic, locally available materials, and climate, a jointed concrete pavement design would have required a thickness of 13.5 in. The panels as fabricated were 8.2 ft long and 27 ft wide. Thirty seven panels were post-tensioned together to result in 320 ft segments. The panels were installed in the following sequence: 1 joint panel, 18 base panels, 1 center panel, 18 base panels, and 1 joint panel. Each panel was also pre-tensioned in the transverse direction. The panels were placed on the lean concrete base that had been covered with a polyethylene sheet to reduce the slab/base interface friction during the post-tensioning.

This project was the first large scale use of the PPCP system and was the first PPCP project to be constructed in a remote area. The demonstrated the advantages that PPCP can offer in overcoming the challenges of building toll roads in developing countries. Local contractors were able to easily design and construct this project without a large initial capital investment. The quality of the PPCP concrete is considered superior to the quality of cast-in-place concrete for such remote area applications. Other advantages cited by the Toll agency include:

1. Less cost for mobilization for investment in heavy equipment
2. Better controlled construction process for the PPCP panels at one site
3. Higher strength concrete, better concrete curing process, and improved quality control
4. No construction delays as installation was possible 24 hours a day
5. PPCP panels are thinner and use less concrete than conventional jointed concrete pavements due to inclusion of relatively inexpensive prestressing tendon
6. PPCP is considered long-lasting and durable.

For this project, a panel fabrication facility, shown in Figure 3, was constructed in an isolated farming area that was located near the middle of the project to optimize transport time and costs.

Figure 3. Indonesia precast panel fabrication facility

The precast facility had three covered bays with four production lines in each bay. The 12 fabrication lines could manufacture 120 panels in one casting cycle. The main contractor used local laborers as helpers in the labor-intensive fabrication process as an ample supply of workers were readily available from nearby villages and their employment stimulated the local economy. Concrete was mixed on-site according to Indonesian standard K-400 (design compressive strength of about 4,850 psi). Trucks delivered the concrete to the fabrication lines where it was placed by hand, consolidated by spud vibrators, and finished by hand. Surface tining was done during production so the placed panels would have longitudinal tining. After tining, the panels were steam cured with elevated temperatures overnight. The following adjustments were made in the fabrication process:

1. To ensure consistent panel dimensions, adjustments had to be made to the framework
2. Adjustments had to be made to the anchoring of the steel formwork so the steel could move to compensate for the expansion of the concrete during steam curing
3. The location of the dowel bars in the joint panels had to be revised to accommodate the block-out spacing used for post-tensioning
4. To minimize patching in the field, grout ports were located at the lifting handle sites

Typically, 40 panels were placed each day. Panel installation views are shown in Figure 4.

Figure 4. Indonesia PPCP installation

To prevent damage to the lean concrete base, the soil subbase in one direction was used as an access road while the two lanes in the other direction were being constructed. The contractor made a few adjustments to initially match the panel keyways before modifications were made to the formwork. Some base panels were produced with modified dimensions so the panels would be in alignment. Keyway issues occurred while joining the panels to form the post-tensioned segments. These issues were resolved by refining the formwork and adjusting the keyways. The PPCP smoothness was measured to be about 145 inches/mile. A view of a completed PPCP section is shown in Figure 5.

Figure 5. View of the completed PPCP project

The Toll agency is planning to use the PPCP system additional lengths of new toll roadway. In addition, several Indonesian agencies are investigating use of PPCP to rehabilitate existing pavements, typically asphalt pavements, in congested urban areas. A one-mile experimental project, illustrated in Figure 6, is under construction to refine some of the PPCP design and construction features.

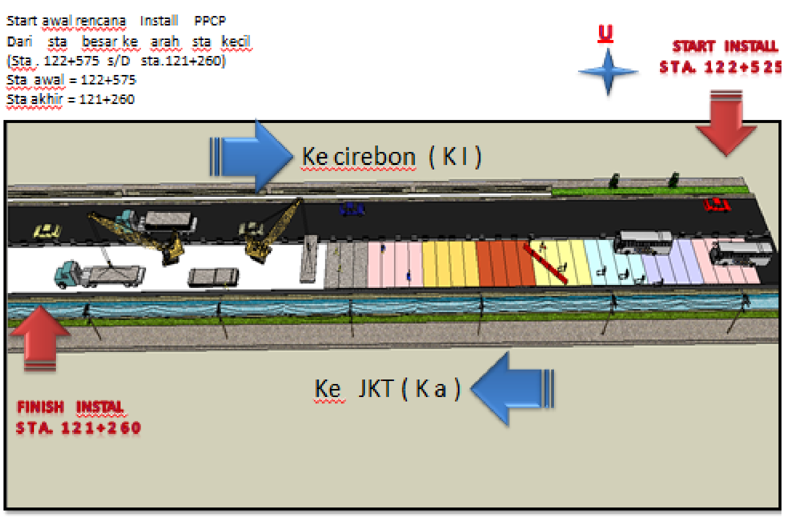


Figure 6 – Planned experimental PPCP project

Some of the new features being investigated include the use of a reinforced cast-in-place slab between the post-tensioned segments, as shown in Figure 7, and use of an AC surface layer over the PPCP, as illustrated in Figure 8.

Figure 7. Use of cast-in-place reinforced end slabs

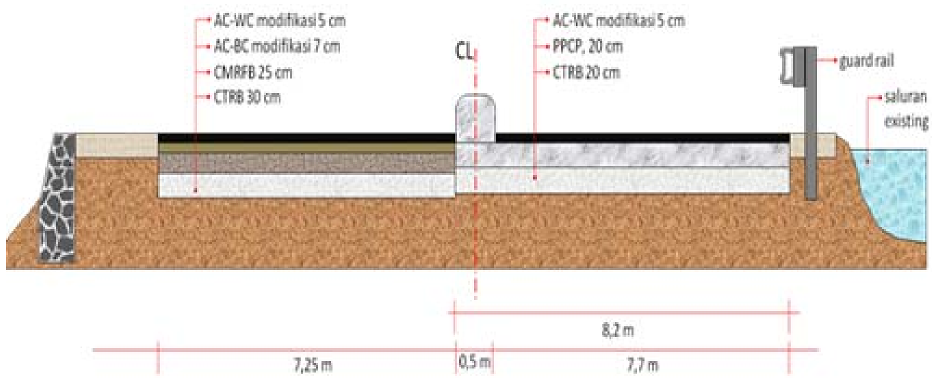


Figure 8. New PPCP feature – Use of an AC surface layer

The production use of the PPCP in Indonesia illustrates how innovative pavement technologies can be readily and cost-effectively applied in developing/emerging countries for new roadway construction as well as for rehabilitation of existing roadways in congested urban areas.

Japan

Precast concrete pavements were used in Japan for production paving at container yards and airports in the early 1970's, and by the early 1990's researchers began examining the use of PCP for roadway applications. Early projects were constructed using reinforced concrete panels on stabilized bases, but without load transfer at joints. Later projects incorporated the prestressing technology. The use of precast concrete pavement increased in Japan when a special load transfer system called the "horn device," shown in Figure 8, was developed. Typically, for roadway applications, the precast reinforced concrete (PRC) slabs are placed on an asphalt interlayer to prevent pumping in the granular base course underneath. Gaps between the slabs and interlayer are filled with a grouting material. The standard dimension of the slab is 4.9 ft in width and 18.0 ft in length. The thickness varies from about 8 to about 10 in.

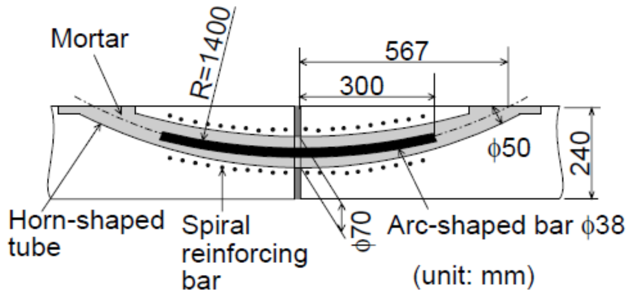


Figure 9. The "horn" load transfer device

Some examples of the PCP projects are shown in Figures 10 to 12. For tunnel applications, it has been reported that the precast panel surface is worn, the panels are turned over and re-used.

Figure 10. Intersection application (Kanazawa City, 2002) and roadway application (Kasugai City, 1998)

Figure 11. Airport applications (Osaka airport, 1998; Fukuoka airport, 2003)

Figure 12. Typical tunnel and port applications

For airport applications, the precast panels are about 8 ft wide, 47 ft long, and about 10 in. thick. The panels are prestressed (pre-tensioned) in the long direction. Also, the jointing for airfield pavements may incorporate both the horn device and a compression joint device as shown in Figure 13. For the compression joint device, stressing tendons (unbonded) are installed through the joint, tensioned to a pre-determined force, and fixed at both of its ends to the slabs. The compression joint devise is considered to be more efficient in transferring the load across the joint and allows easier replacement of damaged panels. However, because of the higher cost of installing the compression joint device, this system is used in combination with the horn device. The two devices are typically placed alternatively at about 18 in. An installation of the PCP using both joint load transfer devices is shown in Figure 14.

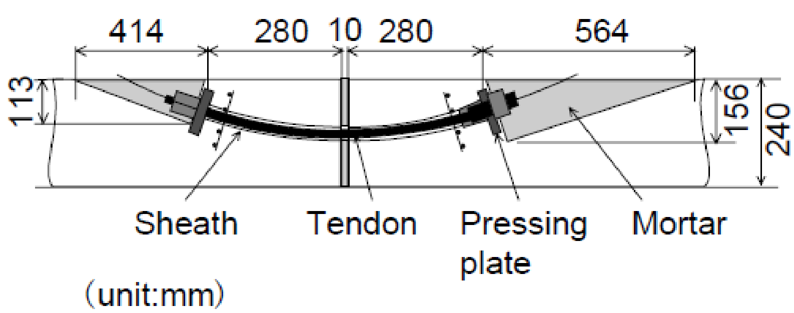


Figure 13. Compression joint unit

Figure 14. Constructed PCP at Sendai Airport

Another innovation introduced in Japan is the sliding dowel bar joint concept, as shown in Figure 15. This joint system is also widely used.

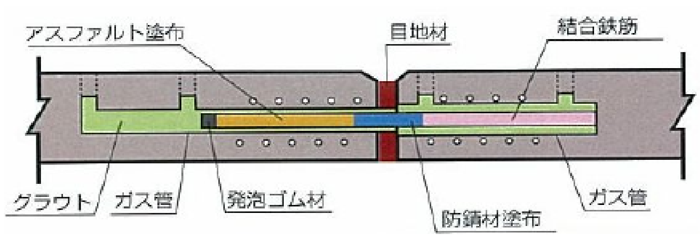


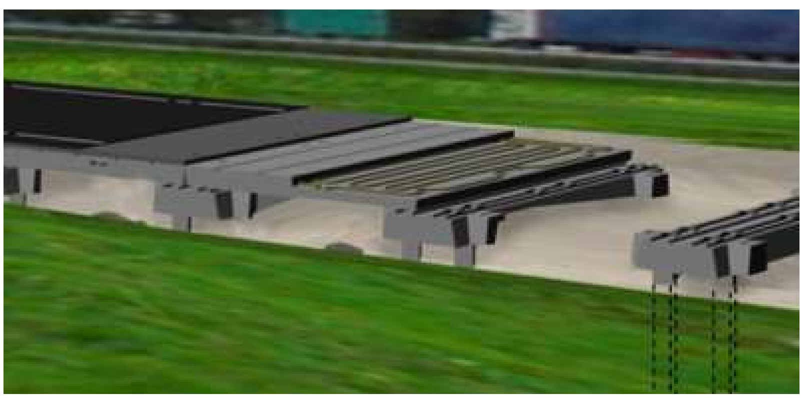
Figure 15. Sliding dowel bar joint

The use of precast panels with heating tubes has also been developed in Japan. Figure 16 shows a panel with heating tubes being fabricated and an installed project showing ice-free/snow-free pavement condition.

Figure 16. Heated precast panel fabrication and installed project

The Netherlands

The PCP technology, referred to as the ModieSlab, was developed in 2001 in the Netherlands as a response to the “Roads to the Future” program challenge sponsored by the Dutch Ministry of Transport. The challenge required that any innovative roadway design solutions result in a noise reduction of at least 5 db(A). The ModieSlab development was carried out by a joint venture team of of Arcadis, Betonson and Heijmans. ModieSlab is a proprietary technology. As initially conceived, the ModieSlab system was designed as a bridge system with a design life of 100 years. The system incorporates short length panels (11.8 ft) supported by precast concrete beams placed over precast foundation piles, as illustrated in Figure 17. The first pilot project was installed in 2001 at an access road to a rest area along the motorway A50 near Apeldoorn in the Netherlands. During the next 1½ years, the slabs were tested extensively on site with good performance results. The ModieSlab concept has evolved since then with several desk studies and additional demonstration projects along sections of motorway A12 near Utrecht (RWS-DVS, 2008) and a bus/tramway in Blankenberge, Belgium), and on-grade applications. For on-grade applications, a load transfer feature was developed to accommodate load transfer across joints.



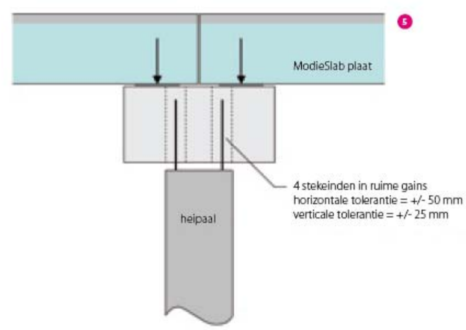


Figure 17. The ModieSlab concept

For the bridge-type applications, for use over poor soil conditions, the panels are 15 in. thick and consist of 2.75 in. thick two-layer porous concrete, as shown in Figure 18, and a 12.25 in. high quality base concrete (grade C65 with a characteristic compressive strength after 28 days of least 9,400 psi) with two-layer reinforcement. A fine grained top porous layer is used because a fine texture reduces the amount of tire/pavement noise. A high void content (> 20%) is needed for noise absorption. Coarser aggregates are used for the second porous layer in order to obtain larger pores resulting in an easy drainage of water coming through the porous top layer and preventing in that way any clogging of the top layer. The slabs are manufactured upside down which ensures a very even surface for each slab. Views of the ModieSlab installation are shown in Figure 19. ModieSlab has been tested under the accelerated load testing facility, LINTRACK, at the Delft University to investigate the structural integrity of the system. In general, the researchers reported a positive experience with this technology from both a technical and economic view point.

Figure 18. The two-layer porous surface

Figure 19. ModieSlab installation

The following ModieSlab projects have been completed:

1. ModieSlab Hengelo. Construction of 4 road crossings completed in August 2009 (phase 1) and September 2010 (Phase 2). A total of 600 slabs on grade were placed.
2. ModieSlab Haarlem. Reconstruction of pavements near a train station. 60 (large) slabs were placed.
3. ModieSlab bypass Oudenrijn (Bypass of Motorway A12). Slab on pile system constructed in 2006.
4. Modieslab Trambaan Blankenberge (Belgium). A total of 16 ModieSlab panels were installed to renovate a tram system. Constructed in November 2008 to January 2009. Part of larger project ‘Quiet City’. Goad is to design integrated infrastructure to control road and rail noise. Rails were embedded in the panels with porous concrete layer used at the surface.
5. ModieSlab De Somp. Constructed 2001. First project of ModieSlab system on piles. Still in service. However, several improvements were made to ModieSlab based on lessons learned at this project.

Another innovative pavement rehabilitation technique developed in the Netherlands is the RollPave system. Roll Pave was an initiative of a consortium of INTRON and Dura Vermeer Infrastructure. The product won a price in a contest of IPG (Innovation Program for Noise Reduction) of Rijkswaterstaat. RollPave is a thin, rollable surface of porous asphalt with a thickness of approximately 1.2 in. (30 mm). Using induction, the surface can be adhered in place and removed from the bottom layer very quickly. RollPave is intended for quick maintenance, replacement, or overlaying of existing asphalt pavements that have adequate structural capacity. Accelerated load testing of RollPave has been conducted at the Delft University in the Netherlands. The typical features of the RollPave system are illustrated in Figure 20.

Figure 20. RollPave features and installation

In 2001, the first test sections were laid on the parallel road to De Brink beside the A50. Since then, a few more sections have been constructed. In 2010 a new project was executed giving a noise reduction of 7 - 9 dB(A).

A scan tour visit to the Netherlands will provide an opportunity to visit with experts to discuss the RollPave modular pavement technology and to visit the plant and installed projects.

Russia

Soviet technical literature of the 1960's and 1970's includes a number of generally favorable descriptions of PCP use for temporary road construction, under heavy industrial traffic in the Donbass, on the Kiev-Odessa highway, under urban traffic in Moscow, and elsewhere. By 1962, standardized precast panel designs had been approved for airfields. By 1970, the PAG XIV slab system had been approved as a standard panel for airfields and a number of precast plants were capable of producing this system. Precast prestressed concrete was thought to be particularly efficient in use of materials, its plant manufacture offered the potential for high quality products, construction could proceed under adverse environmental or site conditions, and precasting allowed rapid repair of damaged pavements. Currently, the PCP is used primarily for airfield applications and as temporary pavement at construction sites. The precast panel dimensions, as used in the 1960's were as follows:

Soviet precast airfield slabs identified by Gerberg and Osipon in 1962

Designation	Size (ft x ft x in.	Weight (tons)	1b reinforcing/ft^2 of slab
PAG III	6.6 x 13.1 x 5.5	3.1	2.43
PAG IV	6.6 x 13.1 x 5.5	3.1	1.74
PAG IX	10.5 x 19.7 x 5.5	7.4	1.09
PAG XIV	6.6 x 19.7 x 5.5	4.6	2.37
PAG XV	6.4 x 19.2 x 5.5	4.6	1.55
PAG XV-1	6.4 x 19.2 x 5.5	4.4	1.73

Notes: PAG IX biaxially prestressed with 400 psi longitudinally and 300 psi transversely. All others prestressed only longitudinally. Based on Table 35 in

The panels are prestressed (pre-tensioned) using an electro-thermic process. The precast panel use has been standardized in Russia, the last set of standards published during 1992. A view of a recently fabricated standard panel is shown in Figure 21.

Figure 21. Russian standard design precast panel

Views of the stored panels for use at an airfield site during the Soviet era and a completed project are shown in Figure 22.

Figure 22. Soviet era precast panels – storage and installed site

A unique aspect of the Russian system is the use of the lifting loops, positioned along the long edge of the panels. These lifting loops are welded together. Good welding technique is mandatory. If the spacing between the adjacent loops is 0.15 in. or less, the loops are welded together in a single weld. If the spacing is greater than 0.15 in., a reinforcing bar whose diameter was three to four times greater than the gap is placed on the lifting loops and two welds are made, as shown in Figure 23. The welded connections are then trafficked with two to three passes of a fully loaded truck. Any broken welds are re-welded. The gap where the loops have been welded are cleaned and then filled with mastic.

Figure 23. Welded lift loop connection

The US Air Force has encountered this system at several military airfields constructed during the Soviet era in countries adjacent to Afghanistan and in Afghanistan. The US Air Force has been testing this system in the US, as shown in Figure 24, to determine the failure mechanisms and the methods to repair airfields using this system.

Figure 24. US Air Force test section

Summary

A review of the PCPS practices is summarized in this section. This review, conducted as part of the desk scan, indicates that US highway agencies are beginning to implement or are investigating use of PCP technologies to allow for rapid repair and rehabilitation of existing highway agencies. The US PCP technology is a developing technology and needs further refinements to reduce costs, to increase product rates, and to increase reliability with respect to performance. The desk scan indicates that innovative PCP technologies have been implemented in several countries and these technologies have support refinements in the US-based technologies or can be imported to provide alternate systems for implementation in the US.

CHAPTER THREE – REPORTER'S ASSESSMENTS

As discussed in previous sections, the PCP technology is an emerging technology in the US. Russia and Japan have a longer experience with the use of this technology. Japan still has an active program to use the PCPS for specific needs. However, in Russia, the PCPS is used primarily for airport applications. The Netherlands, France, and Japan are recent users of the technology. The approaches used for developing the PCP systems are unique to each country and within each country, the PCPS continue to evolve and continue to be refined and continue to be applied to new applications. The recommendations for visiting or for not visiting a country are presented below.

Recommended Scan Tour Locations

Based on the information provided in Chapter 2, visits to the following countries are recommended as part of the Precast Concrete Pavement technology Scan:

The Netherlands

A completely new PCPS, the ModieSlab system, has been developed in the Netherlands. This system can be used for soft foundations using pier supports and for conventional application placed directly on prepared grade (with base/subbase). The system incorporates a multi-layer surface to meet specific needs, such as, noise reductions, surface drainage, and spray/splash reduction. This technology and its variations would be of considerable interest for US applications. A visit to the Netherlands will also provide an opportunity to evaluate the RollPave technology.

Japan

The PCP technology has been used for many years in Japan for a range of applications – roadways, urban streets/intersections, tunnels, airfields, and ports. The PCPS used in Japan incorporate many technical innovations including innovative joint load transfer systems, refined structural design procedures, and prestressing techniques. This technology and its variations would be of considerable interest for US applications.

Indonesia

Indonesia has implemented the US-developed PPCP system for production use. The first implementation was for a new 22 mile project. Although the primary reason for the use of the PCP technology was to construct a longer lasting concrete pavements and not necessarily rapid installation under traffic, several refinements were made to the technology to allow for production use on a large scale. The US experience with PPCP is still limited to a few short length experimental projects. Thus, there is much to learn from the Indonesian experience with PPCP.

Russia

The PCPS technology was developed in Russia in the 1960's during the Soviet Union era. This technology, although simple in concept, incorporates several unique features, such as, electro-thermic prestressing, use of thinner panels, and a unique method for tying panels together. The technology has been standardized at the national level and is available for use at no cost. This technology, with some refinements for application in the US, has the potential to provide a cost-competitive alternative to current US developed PCPS.

Not Recommended

The country not recommended for inclusion in the scan tour is France. France has had only a limited involvement with PCP technology and only a few PCP projects have been constructed that utilize removable hexagonal panels. This technology is considered of limited interest to US highway stakeholders and a site visit is not warranted.

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Business management and monitoring of toll road enterprises (BPJT (Badan Pengatur Jalan Tol):
Chairman : Mr. Achmad Gani
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Phone: (021) 7257067,7258063. Fax: (021) 7257126.
Website : www. bpjt . net

(Current project: Pantura 4 lane public road, 1 kilometer (experimental road, on-going as of November 2010)
Past project: Kanci-Pejagan, 4 lane toll road, 35 kilometers (finished 2009)

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It is also possible to visit some precast concrete pavement plants such as:

1. BV De Meteaaor (market leader in NL). Visit: http://www.meteoor.nl/

2. BFBN represents the prefab concrete product range. Their prefab department is BeSt (Visit http://www.straategie.nl/projecten and http://www.bfbn.nl/#pagina=1000 for contact details).

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REFERENCES

References

Information Sources