

# Jointed Precast Concrete Pavement Systems (JPrCP)



**National Precast Concrete Association**

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## NATIONAL PRECAST CONCRETE ASSOCIATION

With nearly 1,000 member companies, NPCA serves as the voice of the precast concrete industry in the United States and Canada. The industry includes a diverse mix of companies, from small single-plant manufacturers to multi-national vertically integrated companies that operate in many sectors of the construction industry.

NPCA provides an array of services to these manufacturers that include technical engineering support, a certification program, safety programming, educational courses and a suite of print and online publications.

In addition to services to members, NPCA provides specialized technical information to owners, engineers and designers on precast concrete products. Most recently, NPCA member companies have emerged as the leaders in development and implantation of precast concrete pavement systems. This Technical Brief provides an overview of aspects of precast pavement systems that will prove invaluable when considering implementation of this technology.

For more information, please visit [precast.org](http://precast.org).



# Precast Concrete Pavement

## PRECAST VS. CAST-IN-PLACE PAVEMENT

Casting concrete pavement in place in fixed or slip forms is a suitable method of rehabilitating concrete pavements on projects where traffic can be detoured long enough to allow for adequate cure time. Recently introduced precast pavement is an important new alternative for rehabilitation projects where heavy traffic limits the curing time required for conventional cast-in-place construction.

## FASTER THAN CAST-IN-PLACE PAVEMENT

Precast pavement slabs require little, if any, additional on-site curing time since they are cast off-site, fully cured and ready for use upon arrival. All cast-in-place concrete pavement – even specialized fast-track concrete – requires on-site finishing and curing time. Precast pavement is especially beneficial for work windows of eight hours or less because slabs may be placed right up to the very end of the work shift.

## MORE DURABLE AND LONGER LASTING

Durability of precast pavement is enhanced because slabs are fabricated in a controlled plant environment free from adverse temperature and weather-related conditions. Precast concrete manufacturing plants stock a wider selection of admixtures and aggregates that may be used to enhance pavement life. Plant casting minimizes problems associated with job site curing and shrinkage problems associated with conventional

cast-in-place techniques. Anticipated pavement life that far exceeds life expectancies of fast-track concrete and asphalt patches.

## CONSISTENT AND THOROUGH INSPECTION

In states where NPCA certification is required, precast plants are inspected by an independent engineering firm, with approval based on their adherence to the extensive manufacturing and inspection procedures described in the NPCA Quality Control Manual for Precast and Prestressed Plants. Concrete is tested at frequent intervals in state-of-the-art concrete labs at each plant (Figure 1) with every



**Figure 2: Precast slabs installed in frigid conditions – see ice in foreground.**

slab thoroughly examined for defects and conformance to specifications. Quality control programs are specifically designed to prevent inferior concrete from reaching the job site, greatly enhancing the uniformity and quality of the finished pavement.

## LESS WEATHER DEPENDENT

Precast concrete slabs may be placed in weather that is not conducive to cast-in-place construction, such as rainy, hot or cold weather (Figure 2), since slabs are fully cured before they are delivered to the job site. This helps to extend work seasons in climates that may ordinarily restrict construction of conventional cast-in-place concrete pavement.

## KEEPS SITE CLEAN AND DEBRIS-FREE

Because it is manufactured off-site, precast concrete pavement minimizes job-site-generated waste, debris and noise related to construction operations. This is especially important in densely populated neighborhoods that are sensitive to environmental and social issues.



**Figure 1: Frequent testing enhances uniformity and quality.**



**Figure 3; Fast-setting grout is installed over dowels positioned in dowel slots.**

## WHY JOINTED PRECAST CONCRETE PAVEMENT?

### TYPES OF PRECAST PAVEMENT

Precast pavements may be designed as Precast Post-Tensioned Concrete Pavement (PPCP), where an assembly of smaller pre-tensioned slabs are post-tensioned together to create long slabs that are 150 to 250 feet long, or as Jointed Precast Concrete Pavement (JPrCP) made up of individual slabs that are 16 feet or less. Load transfer between slabs in JPrCP is accomplished by virtue of compression across tongue-and-groove joints and by standard doweled expansion joint devices between assemblies of slabs. Standard pavement dowels are used to assist load transfer in JPrCP. Expansion is achieved by insertion of expansion material at required locations. JPrCP is the simpler of the two types to design, fabricate and install and is applicable to almost every type of concrete pavement.

### PROVEN TRACK RECORD

The design of JPrCP emulates the design of cast-in-place concrete pavement that has been used successfully throughout the world. Modern jointed pavement design procedures that specify pavement thickness, joint spacing,

concrete materials, and the use of new corrosion-resistant dowels now enable engineers to think in terms of pavement life of 50 to 75 years.

### SIMPLE, LONG-LASTING LOAD TRANSFER MECHANISM

JPrCP doweled load transfer mechanisms are efficient and easy to design and install. Dowels are installed in slots cast or cut at either end of the precast slabs and anchored with fast-setting dowel grout in a simple one-step installation process (Figure 3). The life of this mechanism can be enhanced by using long-lasting epoxy-coated, zinc-coated, stainless steel or stainless steel-clad steel dowels, all of which are now readily available.

### JOINTED SLABS WORK BETTER TO REPAIR JOINTED PAVEMENT

The vast majority of concrete pavement in existence today is jointed. Jointed precast slabs installed in an existing jointed concrete pavement structure retain the expansion and contraction characteristics of the surrounding existing pavement, making it the logical choice of precast repair for existing jointed pavements.



**Figure 4: JPrCP installed intermittently in horizontal curves.**

### MORE VERSATILE

JPrCP can be designed for a myriad of applications such as for horizontal curves (Figure 4) three-dimensional surfaces, widening (Figure 5), changing crown lines, utility-intensive pavement, instrumented applications and heavily-skewed bridge approach slabs. Jointed slabs may be used singularly for isolated repairs or in multiples, to create a continuous surface of new pavement. Computer-aided survey, forming and grading equipment makes it possible to replace three-dimensional pavement encountered in intersections and super-elevations.



*Figure 5: JPrCP installed in a pavement widening during overnight work windows.*

## **ENVIRONMENTAL, SUSTAINABILITY AND SAFETY ASPECTS OF PCPS**

### **EXTENDING THE LIFE OF EXISTING CONCRETE PAVEMENT**

Before the emergence of precast concrete pavement systems, the choice of materials for rapid repair of concrete pavement was limited to asphalt or some type of rapid-setting concrete repair material, both of which are not considered to be long-term repair methods. Continued use of such materials on heavily traveled highways leads to progressive deterioration rather than preservation of a valuable asset that may last for many more years.

Precast pavement repair slabs extend the life of existing concrete pavements, delaying – perhaps for many years – investment in new energy-intensive total pavement replacement. This concept enhances sustainability of concrete pavements since it allows maximum recovery of all possible remaining service life of existing concrete pavement.

### **ENVIRONMENTAL & LEED ATTRIBUTES OF PRECAST CONCRETE PAVEMENT SLABS**

The use of precast concrete is a sensible choice for sustainable development. Precast plants reuse formwork, significantly reducing construction waste that would otherwise be generated at a job site. Because precast concrete components are modular and standardized, they are installed more rapidly which results in reduced construction

times and energy usage, less noise pollution and fewer emissions from on-site equipment.

The manufacture of cement has received scrutiny from environmentalists. While carbon emissions created by its production cannot be discounted, the cement industry has made significant progress in reducing emissions and energy usage in the last 30 years and is continually striving to make further reductions. When indexed against other materials, concrete has a lower carbon content.

In addition, cementitious material used in concrete often contains manufacturing byproducts such as fly ash and blast furnace slag that would otherwise find their way to a landfill. Waste water can be recycled for use in manufacturing. Steel used for concrete reinforcement is typically composed of 95 percent post-consumer recycled content. Aggregates used in the manufacturing of precast concrete are generally extracted and manufactured regionally.

Concrete is a very strong and durable material, which is a significant sustainable attribute. It will not rust, rot or burn and has a service life of up to 100 years.

### **A SAFER REPAIR METHOD**

Precast slabs that last longer than alternative materials enhance jobsite safety since fewer repair projects are required over any given amount of time. Night work is dangerous at best and every night shift avoided significantly improves overall safety of highway maintenance.

# APPROPRIATE APPLICATIONS FOR JOINTED PRECAST CONCRETE PAVEMENT – **INTERMITTENT REPAIR**



## INTERMITTENT REPAIR

Distressed areas of existing pavement are saw-cut ahead of time to exact dimensions matching the sizes in the pre-determined menu. On replacement night, the existing pavement is removed and the new slabs are dropped in place in time for morning traffic. Repair areas may vary from a single drop-in slab in a single lane to multiple slabs used to replace longer areas of distress.



# APPROPRIATE APPLICATIONS FOR JOINTED PRECAST CONCRETE PAVEMENT – INTERSTATE MAINLINES

## INTERSTATE MAINLINES

Maintaining unimpeded travel on Interstate highways and on heavily traveled urban arterials is crucial to the economy and national safety. In some intensely trafficked areas only brief overnight work windows can be allowed for repair or replacement of existing pavement.

Precast slabs have been proven to be invaluable because they can be installed overnight and are expected to perform with an anticipated pavement life which far exceeds life expectancy of fast-track concrete and asphalt patches. The first JPrCP Interstate pavement, installed in 2001, was rated as being in excellent condition in one federal study nearly 10 years after installation on a road that averages 145,000 vehicles per day.



# APPROPRIATE APPLICATIONS FOR JOINTED PRECAST CONCRETE PAVEMENT – INTERSTATE RAMPS

## INTERSTATE RAMPS

Precast pavement is particularly appropriate to use for reconstruction of some interstate ramps for which there are no viable detour routes. The entire ramp may be replaced with precast pavement slabs in a series of overnight work windows or during 55-hour weekend closures. Two-lane ramps may even be replaced one lane at a time while traffic is maintained in the other lane.

Ramps are challenging to build with precast slabs because of the horizontal and vertical curvatures and associated super elevation transitions common to most ramps. The slabs in all three ramps shown in the accompanying photos were significantly three-dimensional requiring



# APPROPRIATE APPLICATIONS FOR JOINTED PRECAST CONCRETE PAVEMENT – INTERSECTIONS

## INTERSECTIONS

Intersection pavement takes a beating because vehicles are constantly stopping, starting and turning. This is a common problem on urban arterials that service a significant percentage of trucks. These intersections are often the most crucial part of a highway since local businesses depend upon uninterrupted flow of goods. Precast pavement slabs are ideal for such locations because they can be installed almost “invisibly,” yet are tough enough to stand up to abusive turning traffic for many years.



# APPROPRIATE APPLICATIONS FOR JOINTED PRECAST CONCRETE PAVEMENT – BRIDGE APPROACH SLABS

## BRIDGE APPROACH SLABS

Roadways at bridge approaches are frequently narrow with small shoulders, leaving little or no room for redirecting traffic around work areas. Precast pavement slabs are beneficial in these areas since they can be installed in very short work windows. They also work well to “span” effectively between the bridge seat and firm undisturbed subgrade beyond because they are fabricated to stringent design criteria. Jointed precast slabs are especially practical because they can be made to any shape or skew.



# INSTALLATION DETAILS AND CONSIDERATIONS

## INSTALLATION CRITERIA

Precast pavement slabs must be positioned at the correct surface elevation, fabricated to the correct surface contour, fully bedded or supported and structurally interlocked to emulate and perform the same as cast-in-place concrete pavement as shown in Figures 6 and 7. Various methods of achieving these criteria have been developed and used in North America.

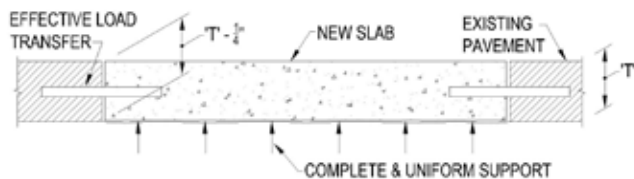


Figure 6: Installation criteria for JPrCP

## A SYSTEMS APPROACH

The process associated with designing, fabricating and installing precast slabs that meet all of the installation criteria listed above is detail oriented. Success is enhanced when all of the processes are proven and organized as a complete “system” prior to actual installation of any slabs.

The fewer the proven and detailed installation processes included in any particular system, the greater the risk of not achieving a successful installation. The most risky of systems are those that show only the finished product on the contract drawing, leaving all of the other key processes to be developed to the low-bid contractor.

## GRADE-SUPPORTED SYSTEMS

Grade-supported systems rely upon initial creation of a fully compacted precisely graded bedding interlayer to provide slab support and grade control for the precast slabs, and final injection of bedding grout to fill any remaining voids under the slabs. The graded surface must parallel that of the finished pavement and be sufficiently accurate to avoid large under-slab voids or crack-creating high spots. These systems include a method whereby voids under the slabs are filled with a bedding grout material to provide complete and full support to the slabs. The Super-Slab® System and the Illinois Tollway System are two well-known grade-supported systems in the U.S.



Figure 7: Precision grading for the Super-Slab® System.

## URETHANE AND GROUT SUPPORTED SYSTEMS

Urethane-supported systems utilize an expansive urethane grout, injected beneath the slab that expands, lifting the slab into the correct position (Figures 8 and 9). This one-step process eliminates a precision grading process. The Roman Road System® is one well-known urethane-supported system currently being used in the United States.



Figure 8: Urethane supported systems.



Figure 9: Urethane installation for the Roman Road system.

## GROUT-SUPPORTED SYSTEMS

Grout or concrete fill supported systems require a precisely-graded grout or concrete layer, finished to a surface parallel to the finished pavement surface, to provide grade control similar to the grade-supported systems. One grout-supported system alternatively utilizes leveling screws to support and position the slabs while grout is pumped under the slab to provide the complete bedding interlayer, similar to the interlayer shown in Figure 8.

## TOP SLOT LOAD TRANSFER

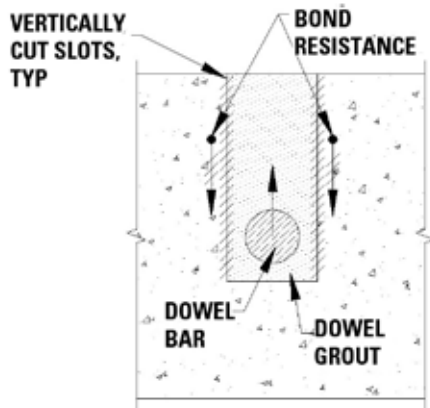


Figure 10: Generic top slot systems showing vertical sides.

## DOWELS FOR LOAD TRANSFER ACROSS TRANSVERSE JOINTS

To be equivalent to cast-in-place concrete pavement, dowels or other qualified load transfer devices must be embedded in two adjacent slabs, across transverse joints. Embedment is accomplished by encasing dowels, pre-placed in slots, with non-shrink structural grout.

## DOWELS FOR TOP SLOT SYSTEMS

Slots in generic top-slot systems (Figures 3 and 10) utilize top slots that are cut in the field or formed in the new precast slab. Dowels are either placed in the full slots prior to encasement or are cast in the new slab to match slots that are field-cut in the adjacent existing pavement. Load transfer is accomplished by bond strength between the new grout and the sandblasted sides of the slots, as shown in Figure 10. Open slots on the top of any slab must be filled with permanent grout or with temporary filler devices before the slabs can be opened to traffic.

## DOWEL CONNECTION FOR BOTTOM SLOT SYSTEMS

Slots in the proprietary system shown in Figure 11 are cast in the bottom of the slabs. The slots are cast in a dove-tail shape to provide a mechanical, as well as a bond resistance to dowel bar pull-out. Super-Slab panels may be opened to traffic before the slots are filled since they provide no impediment to traffic. The bottom slot detail shown in Figures 11 and 12 is proprietary to the Super-Slab System.

The bottom slots of the Super-Slab System are filled by

## BOTTOM SLOT LOAD TRANSFER (SUPER SLAB)

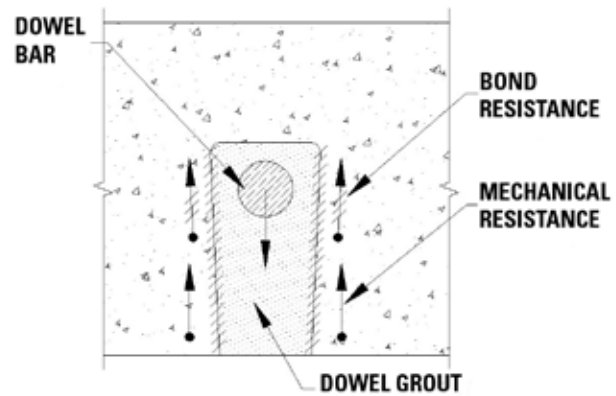


Figure 11: Proprietary dove-tail-shaped bottom slot system.

injecting a flowable non-shrink structural grout in grout ports. The grout must be of proper consistency to ensure the dowels are fully encased and the slots are completely filled.

## TIE BARS ACROSS LONGITUDINAL JOINTS

Tie bars for the Super-Slab system are embedded in the same fashion as the dowel bars. In the Illinois Tollway process, precast slabs are tied with standard pavement stitches that are standard in the pavement industry.



Figure 12: Installation of bottom slot Super Slab® system.

# THE CASE FOR LONG-LASTING JOINTED PRECAST CONCRETE PAVEMENT

## REQUIREMENTS FOR LONG-LASTING JP<sub>r</sub>CP

In order for any concrete pavement to provide decades of service it must be made of high quality concrete and be fully bedded (supported) with panels that are structurally interlocked to provide effective load transfer from panel to panel.

Long pavement life is assured with precast slabs since they are cast and cured under controlled conditions at the precast plant. The effectiveness of bedding techniques and load transfer mechanisms (as they pertain to extending pavement life) is best determined by performing appropriate testing.



**Figure 13: Falling weight deflectometer testing device**

## FALLING WEIGHT DEFLECTOMETER (FWD) TESTING

A falling weight deflectometer (Figure 13) is a testing device used to provide data that calculates the degree of subgrade support provided by bedding layers. The deflectometer test also determines the efficiency of load transfer mechanisms (steel dowels) in transmitting load from one slab to another.

FWD testing on precast pavement has been focused primarily on load transfer efficiencies across transverse joints. Numerous tests have indicated efficiencies similar to those recorded for cast-in-place pavements with values ranging from well over 90% to less than 80% in some cases.

## HEAVY VEHICLE SIMULATOR (HVS) TESTING

A heavy vehicle simulator (Figure 14) is a testing apparatus used for accelerated testing of concrete pavement by



**Figure 14: Heavy vehicle simulator testing device**

continuously loading it with heavy truck or aircraft tires. In 2005-2006 an assembly of 10 jointed Super-Slab® panels was subjected to more than 4.3 million cycles of overloaded truck tires at a test facility in Fontana, Calif. Researchers concluded the pavement life, from a structural point of view, for panels subjected to the test loading conditions, supported with that particular subgrade system could be assumed to be up to about 37 years. It should be pointed out that the test concluded before the panels ever failed.

This year-long test was the most comprehensive test ever performed on precast pavements of all types, and although it was just a test it provided convincing evidence that jointed pavements will perform well over many years.

## CONCLUSIONS

The many FWD tests and the HVS test conducted in California on precast pavement sections show promise that precast pavement will provide decades of service.

A 2011 Report prepared for The Strategic Highway Research Program 2, Project R05, provides a comprehensive overview of Precast Concrete Pavement Technology developed as of 2010. The Report indicates that precast pavements that have been installed since 2001 are performing well under an Average Daily Traffic (ADT) of 145,000 vehicles per day.

One of the most compelling reasons to expect long pavement life is that precast pavement installations have now been in place a significant number of years. The Tappan Zee Bridge Toll Plaza in Tarrytown, N.Y., for example, was still performing well after 11 years of service. The report indicates precast pavements that have been installed since 2001 are performing well with only minor identifiable issues.

# COST AND PRODUCTION RATE CONSIDERATIONS

## COST CONSIDERATIONS

The designer will ultimately need to compare the cost of precast pavement to the cost of comparable pavement alternatives that can be installed in the same amount of time and still provide similar life expectancy.

## COMPARE "TIME-SIMILAR" MATERIALS

Comparing the cost of precast pavement with that of conventionally cast concrete pavement can be seen as an inaccurate comparison if the times required to install the two materials are not factored into the equation. Comparison of the cost of precast pavement with that of rapid-setting cast-in-place concrete pavement is appropriate, however, since both can be installed in the same overnight work window.

## COMPARING LIFE CYCLE COST OF ALTERNATIVE MATERIALS

The usable life of fast-track cast-in-place concretes is as variable as the types of concretes used for that purpose. Some fast-track formulations last only five years or less while others provide 10 years or more of service, depending upon mix design, the rate of placement, weather conditions when finishing and curing, and the climate in which they are used. When comparing these materials to precast concrete pavement, which has a life expectancy of 40 years or more, it is important to compare life cycle, rather than comparing only the initial cost.

A detailed life cycle cost analysis takes into account initial, periodic maintenance and Maintenance and Protection of Traffic costs over a 20 or 30-year period. Such a comparison must also include all costs associated with any replacement of the fast-track concrete in that time period. One recent 20-year life cycle cost comparison of the two materials, made on a project where both materials were installed side-by-side, indicates precast concrete pavement is 11% more cost effective than fast-track concrete pavement.

## ALL ITEMS MUST BE INCLUDED IN THE COMPARISON

Unit bid prices for precast concrete pavement on a number of projects is now available for comparison purposes. Since precast pavement specifications are relatively new, it is important to look at the specification associated with each of these prices to determine exactly what each price includes.

Many of the more recent precast specifications have included all the work associated with the repair.

Specifications for fast-track cast-in-place concrete repairs, on the other hand are typically of the "à la carte" style in which items such as concrete, removal, drilling and anchoring of dowel and tie bars, fine grading and saw cutting are paid for under separate items. An accurate comparison between precast concrete and fast-track concrete repairs should include all items associated with each type of repair.

**TABLE 1: PRODUCTION RATES**

Work Window	Type Installation	No. Panels	No. Sq.Ft.
5 hrs.	Intermittent	7-10	800-1200
8 hrs.	Intermittent	12-15	1400-1800
8 hrs.	Continuous	20-30	3000-5000

## PRODUCTION RATES

The designer will also need to consider the rate of production or the amount of pavement that can be replaced in a given work window as that affects the overall cost and time duration of the project.

Production rates averaged over 50 projects, shown in Table 1, vary with the length of the work window and whether the panels are placed intermittently or continuously.

**TABLE 2: INSTALLED COSTS**

Repair Type	Bid Price Per Sq.Yd.
Intermittent	\$244-\$585
Continuous	\$350-401

## ACTUAL INSTALLED COSTS FOR PRECAST PAVEMENT

Nationwide installed cost data (bid prices) for precast concrete pavement is limited, but costs can vary widely depending on location (as it affects labor and material costs), the length of the work window and jobsite work area conditions. More specific cost data may be available from precast pavement suppliers in specific areas.

It is important to note that the cost for installed precast pavement approaches or equals the installed cost for rapid-set concrete repairs in a number of states. This is important information to include in any detailed life cycle cost comparison.