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Tech Brief

Precast Concrete Pavement Bedding Support Systems

INTRODUCTION

Precast concrete pavement (PCP) technology is gaining wider acceptance in the U.S. for rapid repair and rehabilitation of concrete pavements, as well as for reconstruction of heavily trafficked asphalt concrete intersections. Widespread use in the U.S. is fairly recent, with most projects in service less than about 14 years. Nonetheless, dozens of projects have been constructed, and advances continue to be made in all aspects of the technology, including panel design, fabrication, and installation. PCP technology is being used for intermittent repairs (both full-depth repairs and full panel replacement) and for continuous applications (longer-length/wider-area rehabilitation) with service life expectations of at least 20 years for repairs and at least 40 years for continuous applications, without significant future corrective treatment.

Available PCP systems include jointed PCP with reinforced or prestressed panels installed singly or in a continuous series, as well as PCP that typically incorporates thinner reinforced or prestressed panels installed and posttensioned in a continuous series, resulting in fewer joints. The use of PCP technology can significantly reduce the impacts that roadway repair and reconstruction projects have on traffic, particularly on heavily traveled routes. The technology is applicable to small segments, enabling flexibility in construction phasing, and for use in corridor-wide pavement rehabilitation/reconstruction. A review of projects constructed in the U.S. and field testing of selected projects has shown that sufficient advances have been made to reliably design and construct PCP systems to achieve five key attributes of successful pavements, as follows:

- Constructability – Techniques and equipment are available to ensure acceptable production rates for the installation of PCP systems.
- Concrete durability – Plant fabrication of precast panels results in excellent concrete strength and durability.
- Load transfer at joints – Reliable and economical techniques are available to provide effective load transfer at transverse joints in both jointed and prestressed PCP systems.
- Panel support – Techniques to provide adequate and uniform base support conditions are available and continue to be improved.
- Performance/efficiency – PCP panels can be thinner than equivalent cast-in-place concrete pavement slab and last longer because of prestressing and/or reinforcing elements in the PCP systems.

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The use of both jointed PCP and posttensioned PCP systems has advanced during the last decade due to a combination of work sponsored by the Federal Highway Administration (FHWA), projects constructed by highway agencies, and innovations by the highway agencies and the construction industry. One area of innovation relates to improvements in the bedding support under precast concrete panels. This Tech Brief describes the technical considerations for bedding support and current bedding support practices for PCP systems.

BACKGROUND

For new construction, as well as for repair applications, pavement support is critical to the long-term performance of PCP systems. The proper seating of the panels on the base is a critical design and construction element. The support under the panels needs to be firm (strong) and uniform. All PCP applications require an “interlayer” of material between the base and the bottom of the precast panels since these two surfaces will not match each other perfectly. In most cases, the existing base surface will not be accurate enough to provide the necessary grade control for the new panels. To compensate for this, a bedding layer (interlayer) must be used to serve as grade control and as void filler to ensure the panels are fully supported. Some interlayer materials are installed prior to the installation of the panels; however, in all cases, the completion of the interlayer will take place after panel installation.

For most PCP repair, rehabilitation, or reconstruction applications, the following support alternatives need to be considered:

- Use of existing base:
  - Existing granular bases.
    - Base may be graded and compacted.
    - Base may be trimmed, graded, and compacted.
    - Additional base material is used to achieve the desired base grade.
  - Existing stabilized bases (cement-treated bases or lean concrete bases [LCB]).
    - If not damaged in the existing slab removal process, the base may be used as is.
    - Base may be trimmed, as necessary, to accommodate the panel thickness.
- Use of new base:
  - A new base may be used if it is determined that the existing base will not serve the long-term needs of the new PCP. Because of time constraints, it is necessary that the new base material be of good quality and can be placed, graded, and compacted, if granular, fairly quickly within the same roadway closure that the panel installation takes place. This option is common when PCP is used to rehabilitate existing asphalt pavements. The new base type may include the following:
    - Dense-graded, free-draining granular base.
    - Rapid-setting LCB.
  - Cement-treated or asphalt-treated bases are not considered viable options for PCP installed during typical nighttime lane closures, but they may be considered if the duration of the lane closure is not a concern.

For lane replacement applications, the use of new base should not result in a “bathtub” detail. If adjacent lanes incorporate a free-draining granular base, use of an LCB in the repair lane may affect the subsurface drainage condition, possibly resulting in early failure of adjacent lanes.

The current practice when using an existing or a new granular base is to rework the granular material and compact it as is. Frequently, no attempt is made to ensure that the granular material is at an optimum moisture content to allow for maximum compaction density. This can be a serious limitation, as non-uniform settlement under traffic can result.

The requirements for bedding support systems for precast panels should be no less than the requirements for a cast-in-place concrete pavement. The best-constructed precast panels cannot perform well if they are placed on poor support.

Bedding for Repair Applications

The bedding system must be well designed and installed for repair applications. If there is any consolidation of the bedding material, the panel will exhibit the “bridge syndrome” and will be held in place only by the joint load-transfer mechanism. Such a repair will not last long. Also, the bedding provision should not lead to a “bathtub” detail; otherwise, the potential for pumping will be high.

For repair applications, the use of certain bedding materials may meet short-term needs, but these bedding types will not perform adequately over the long term under traffic loading if the base support is

not adequate. For existing concrete pavements with a granular base, it is important that damage to the base be minimized during the pavement removal process. As described above, when a granular bedding material is used over an existing granular base, the thickness of the bedding should be limited to 0.25 inches (6 mm). There is no benefit in providing thicker granular bedding material for repair applications, and the use of thicker, non-compactable granular material may be detrimental to long-term pavement performance. When a granular bedding material is used, the panels are undersealed using a flowable cementitious grout to fill in any voids/gaps under the panel.

The following methods of providing thicker non-granular bedding, up to 1 inch (25 mm), may be considered for repair applications:

- A rapid-setting cementitious grout is pumped beneath the precast panel while steel strong-backs bolted to the top of the panel span the repair area, holding the panel at the proper elevation.
- Threaded setting bolts are used to hold the panel at the proper elevation, and a rapid-setting cementitious grout is pumped beneath the panel.
- A rapid-setting flowable grout is placed in the repair area and is screeded to the desired elevation before the panel is installed. The panel is installed while the grout is still in a plastic state, allowing it to conform to the shape of the bottom of panel, thus providing full support to the panel.
- High-density polyurethane foam is injected under the panel after it is placed in the prepared repair area, about 1 inch (25 mm) below the desired roadway elevation. The foam expansion raises the panel to the desired elevation. The polyurethane foam becomes the permanent bedding for the panel.

For both subsealing and cementitious bedding materials, the compressive strength requirement typically is about 500 psi (3.4 MPa) at the time of opening to traffic. These materials also need to be non-erodible.

Bedding for Continuous Application

The support requirements for both jointed and posttensioned PCP systems are similar. For long-term performance, a good support condition is always necessary. The level of attention paid to ensuring good base support should be similar to that paid to panel fabrication. For continuous PCP applications, the following considerations for base support will be needed:

- Existing base:
  - Used as is or with shallow trimming to allow the placement of panels having about the same thickness as the existing pavement.
  - Trimmed to allow a panel thicker than the existing pavement to be installed.
  - Additional base material used to achieve the desired base grade.
- New base:
  - Granular base.
  - Rapid-setting LCB.

Existing granular base that is damaged during the removal of the existing pavement or that is trimmed needs to be reworked, regraded, and recompacted. As described earlier, granular bedding material 0.25 inches (6 mm) thick may be used to provide a uniform grade for panel placement. Placement of a new granular base should follow agency requirements, including those for compaction equipment, granular material moisture control, and compaction testing.

Rapid-setting LCB has not been widely used as a bedding support system for PCP applications, except in California. The strength and durability requirements for the rapid-setting LCB should be the same as for conventional LCB; however, the rapid-setting LCB needs to be workable for manual placement.

It should also be noted that several PCP systems incorporate a leveling system for panel installation for continuous applications. This feature requires the use of a rapid-setting high-strength cementitious grout material under the panels. The grout is injected using a series of ports while the panels are maintained at the desired elevation using the levelling lift system. Grout strength should be a minimum of 500 psi (3.5 MPa) at 1 hour and at least 2,500 psi (17 MPa) at 7 days, similar to the strength levels required for rapid-setting LCB. Caltrans specifications require the grout strength to be at least 2,500 psi (17 MPa) at 1 hour and 7,600 psi (52 MPa) at 7 days, both at 72 °F (22 °C).

Posttensioned PCP systems require the use of a stiff/strong base that ensures low deflections at the expansion joints under traffic loading. Also, for posttensioned PCP systems, the base needs to be smooth. A smooth base together with a friction-reducing treatment will minimize prestress loss at the panel–base interface. A rougher base will make

it difficult to connect the adjacent panels tightly, resulting in less residual prestress and possible misalignment of adjacent panels at the intermediate transverse joints.

Interface Treatment for Posttensioned PCP Systems

An interface treatment is necessary for posttensioned PCP systems to ensure a very low level of friction between the panels and the base. Typically, a friction-reducing membrane is used over the finished base. The membrane recommended is a 6-mil-thick (0.15-mm) polyethylene sheet. These sheets come in rolls and can be placed over the full width of the lane. Alternatively, a nonwoven geotextile fabric can be used. The geotextile fabric should be at least 0.1 inch (3 mm) thick.

For posttensioned PCP, the panel–base interface friction factor (coefficient of panel–base friction), incorporating the interface treatment, may range from 0.5 to 1.5 and may be assumed conservatively to be about 1.0. The friction factor is an important property of the posttensioned PCP system. It affects the level of effective prestress that develops in the posttensioned section and also affects the seasonal expansion joint width changes.

Overestimating the friction factor would result in a lower computed effective prestress level. This may require the use of a higher level of prestress application or shorter lengths of posttensioned sections. Overestimating the friction factor would also result in less change in the computed expansion joint width due to seasonal temperature changes and may result in under-designing the joint width.

Underestimating the friction factor would result in a higher computed effective prestress level. This may result in the use of a lower level of prestress application or longer lengths of posttensioned sections. Underestimating the friction factor would also result in more change in the computed expansion joint width due to seasonal temperature changes and may result in over-designing the joint width.

Granular Base Compaction Testing

On-site testing should be performed to ensure that the granular base used for PCP applications (repair or continuous) is adequately compacted. Poor compaction of the granular base or a fine-grained bedding layer can lead to excessive non-uniform settlement and early distress development in the PCP. As indicated previously, the support condition requirements for PCP systems should be as good as or better than those required for cast-in-place concrete pavements. Figure 1 shows an example of a poor support condition. At this project, a layer of manufactured sand 0.5 to 1 inch (13 to 25 mm) thick was used over a trimmed existing cement-treated base. As evidenced by the footprints in the photo, the bedding material was not stable and most likely does not provide good, uniform support under the precast panels. The use of non-compactible fine-grained bedding material in a layer thicker than 0.25 inches (6 mm) is not a good practice.

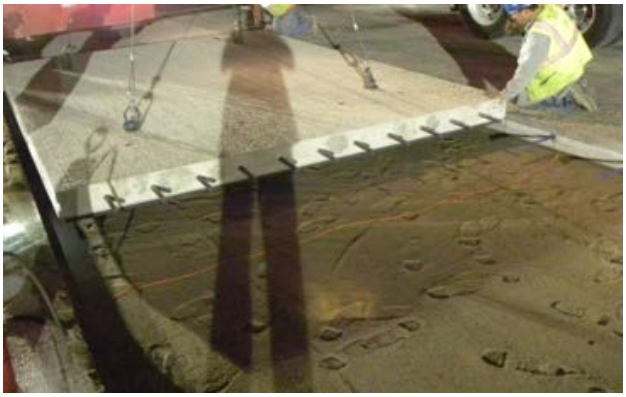

Figure 1. Photo. Non-uniform bedding material.

It is recommended that agencies specify quality control/quality assurance (QC/QA) testing of granular bases to monitor the level of compaction through use of the lightweight deflectometer (LWD) (ASTM E2835-11, Standard Test Method for Measuring Deflections using a Portable Impulse Plate Load Test Device). The LWD was introduced in the U.S. during the 1990s, and several agencies use it for acceptance testing of granular paving material (base, subbase, and subgrade). The LWD, shown in figure 2, is fairly simple to use and performs the testing rapidly and nondestructively.

LWD testing provides the stiffness of the unbound granular material by measuring the deflection of the compacted material in response to a repeatedly dropped weight. The test significantly reduces inspection time for determining the compaction of granular materials. LWD testing should be required for PCP projects to monitor the uniformity of compaction, especially when fine-grained bedding material is used.

Figure 2. Photo. Lightweight deflectometer testing on a base material.

The compaction of granular material depends on the moisture content, and maximum compaction is achieved only when the material is at optimum moisture content (determined using a maximum density test method, such as the Proctor methods). The use of the LWD is recommended for PCP installations if in-place density of compacted restored or new base material cannot be reliably determined.

SUMMARY

The support condition under the precast panels is a key requirement for successful performance of PCP systems. It is important to control the quality of the base and bedding materials to ensure that these materials provide the desired support over the long term and that the support is uniform along the length of each panel. It is important that testing of the granular base/bedding be performed to monitor the compaction level.

If a fine-grained, granular bedding material is used to ensure uniform support under panels, its thickness should be limited to 0.25 inches (6 mm). If a thicker bedding layer is needed, rapid-setting cementitious grout should be considered. As a rule of thumb, no base or bedding material should be allowed that would not be allowed during the construction of cast-in-place concrete pavements.

If the opportunity does not exist to improve the bedding system and the subgrade is of marginal quality, more attention should be paid to the structural design of the PCP system. The load transfer system at transverse joints must be adequate, and the panels may need to be prestressed if thicker nominally reinforced panels cannot be accommodated. One size (thickness) panel cannot be expected to meet all design needs, especially when a marginal support condition is encountered.

REFERENCES

For additional information on SHRP2 Project R05, see Tayabji, S., Ye, D., and Buch, N., “Modular Pavement Technology Final Report,” Project R05, Strategic Highway Research Program 2, Washington, DC, May 2012.

For additional information on PCP systems, applications, guidelines, and usage, refer to FHWA publication FHWA-HIF-15-022 (http://www.fhwa.dot.gov/pavement/concrete/pubs/hif15022.pdf). This publication summarizes the technical resources available to engineers and planners seeking an understanding of PCP technology. The Tech Brief includes weblinks that provide easy access to recent documents covering a range of PCP topics.

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