

# **Best Practices for Concrete Pavements – Technical Briefs by Federal Highway Administration**

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## **Abstract**

The Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials routinely work to develop and deploy best practices for pavements. Technology transfer to the highway community has led to a better understanding of the multitude of factors that affect pavement performance and to a more accurate prediction of service life. One of the ways that FHWA addresses the need for technology transfer to highway engineers, consultants and contractors is through documentation of best practices in an accessible and easily readable format. This has resulted in the development and publication of “technical briefs” to address specific best-practices topics. These technical briefs are published online by FHWA and can be read and downloaded at no cost by anyone worldwide. This paper describes a series of recently published technical briefs that are focused on best practices for concrete pavements.

## **Introduction**

The life-cycle of concrete pavements begins with planning, design and construction followed by maintenance, rehabilitation, and reconstruction. With the advent of the interstate highway system in the US in the 1950s, a design life of twenty years was utilized by most highway agencies. Many of these pavements not only carried traffic volumes far in excess of design assumptions, but also remained in service, with varying levels of maintenance, for periods of forty to fifty years before rehabilitation or reconstruction were required.

A recent series of technical briefs published online by FHWA provide guidance concerning a variety of topics including concrete materials, concrete mixtures, bases and subbases, and several methods of construction that may be used advantageously by highway agencies to produce long-lasting concrete pavements. These topics are described in the following paragraphs, as follows:

- Materials-Related Distress – Aggregates (FHWA 2015-A)
- Materials-Related Distress – Hardened Cement Paste (FHWA 2015-B)
- Blended Aggregates for Concrete Mixture Optimization (FHWA 2015-C)
- Concrete Paving Mixtures with One or More Supplementary Cementitious Materials (FHWA 2016-A)
- Innovative Materials and Methods for Accelerated Construction and Maintenance of Concrete Pavements (FHWA 2016-B)
- Roller-Compacted Concrete Pavement (FHWA 2016-C)
- Permeable Concrete Pavements (FHWA 2016-D)
- Bases and Subbases for Concrete Pavements – European Practices (FHWA 2016-E)
- Internal Curing of Concrete Pavements (FHWA 2016-F)

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Each of these technical briefs is cited in the list of references at the end of this paper, where a weblink is provided following each of the references so readers can easily access the documents online to read and download the information provided as desired without cost.

***Materials-Related Distress – Aggregates.*** Materials-related distress (MRD) can substantially shorten the desired service life of concrete pavements. Aggregates comprise a significant volume in most concrete mixtures, which is generally desirable because aggregates are less expensive than components of the paste, they provide the load-carrying capacity of a concrete mixture, and they provide dimensional stability. However, some failure mechanisms in pavement concretes can be attributed to issues related to the quality of the aggregate. This technical brief provides pavement engineers with information to help them specify and choose materials that will last for the desired lifetime of the pavement.

The MRDs described in this technical brief include: alkali-silica reaction; D-cracking; contaminants; and coefficient of thermal expansion. Paste-related mechanisms are discussed in a separate parallel technical brief.

***Materials-Related Distress – Hardened Cement Paste.*** Concrete is a mixture of aggregates bound together by a cementitious matrix, or hardened cement paste (HCP). Both the aggregates and HCP need to be considered when discussing concrete durability or materials-related distress (MRD). The purpose of this technical brief is to provide pavement engineers with information to help them specify and choose materials that will last for the desired lifetime of the pavement. This technical brief focuses on considerations for distress mechanisms in the HCP.

The MRDs affected by the HCP include: freeze-thaw deterioration; deicer scaling; sulfate attack (external and internal); and corrosion of embedded steel. Alkali aggregate reactivity involves distress mechanisms in both the aggregate and the HCP. Strictly paste-related mechanisms are described in a separate parallel technical brief.

***Blended Aggregates for Concrete Mixture Optimization.*** Concrete mixtures that have well-graded combined aggregate are responsive to vibration and require less effort to consolidate and finish and are likely to last longer because less abuse has been applied to the surface to create the required finish. Another significant benefit of designing a well-graded aggregate system is that the paste content of the mixture can be managed and potentially reduced, thereby reducing heat of hydration, shrinkage, cracking, permeability, and cost.

Historically, aggregate gradation has been controlled by specifications that call out envelopes for individual fractions, typically the coarse aggregate and the fine aggregate. The shortcoming of this approach is that the gradation of the overall system is not addressed. While it is sensible to stockpile coarse and fine fractions separately to prevent segregation, it is the combined system that is critical in the final mixture. The measurement of what comprises a good combined gradation is the topic of this tech brief.

***Concrete Paving Mixtures with One or More Supplementary Cementitious Materials.*** Supplementary cementitious materials (SCMs) have become common ingredients in modern concrete practice, especially the blending of coal fly ash with Portland cement. Such blending

for paving applications can optimize durability, strength, and economics thereby providing owners, engineers, materials suppliers, and contractors with substantial advantages over mixtures containing only Portland cement. The availability of other SCMs, such as ground granulated blast furnace slag and silica fume, creates the need for specific guidance for users to assist them in defining the performance requirements for a concrete paving application and the selection of optimal proportions of the cementitious materials needed to satisfy those requirements.

The fact that blended cements currently are available in many regions increases the options for blended SCMs in concrete mixtures for paving and thus can complicate the selection process. This technical brief addresses the addition of SCMs as binary, ternary, or even more complex mixtures, which can alter concrete properties and impact the placement of the resulting concrete pavement.

***Innovative Materials and Methods for Accelerated Construction and Maintenance of Concrete Pavements.*** The need for accelerated construction most frequently is driven by high volumes of traffic on roadways where maintenance of traffic and related work zone and safety issues place strict limits on lane closures. The available times for maintaining such roadways frequently are limited to nighttime hours with requirements to restore traffic on all lanes prior to morning rush-hours. The use of asphalt patches on concrete roadways is an expedient but temporary method for restoring the roadway surface. Similarly, while the use of rapid-hardening concrete mixtures as a restorative method has gained wide use, it is recognized that such mixtures typically are prone to early thermal stresses and related cracking, which diminishes their durability and leads to repeated maintenance activities in fewer than ten years (NCHRP 2005).

FHWA published a recent state-of-technology report on advanced high-performance materials for highway applications (FHWA 2010). Information from this document and other sources are described in this technical brief as examples of innovative materials methods that could be useful for accelerating both construction and maintenance of concrete pavements in order to achieve longer-term satisfactory performance.

***Roller-Compacted Concrete Pavement.*** Roller-compacted concrete (RCC) has been used for a variety of pavement applications since the 1970s, and current guidance for its use is available (ACI 2015). The majority of RCC applications in the US have been for non-highway applications including container ports and industrial and military facilities where very heavy wheel loads are experienced. This technical brief describes the use of RCC for highway applications.

RCC differs from concrete typically used in slip-form paving operations in several ways, the most significant being that RCC: is stiffer than zero-slump concrete mixtures for slip-form paving; contains a higher percentage of fines, which facilitates its compaction; can be placed using asphalt-type vibrating screeds or with special heavy-duty screeds for the highest level of compaction; is compacted and finished using rollers; does not contain either dowels or reinforcing steel; has less drying shrinkage, so aggregate interlock provides adequate load transfer at the narrow cracks that occur; does not require joint-sawing, however, for appearance it may be desirable to saw transverse joints; is sufficiently smooth for low-speed urban traffic; needs either diamond grinding or an overlay of either asphalt or concrete for higher-speed traffic

on primary and interstate routes; and, resists freeze-thaw damage if high levels of compaction are achieved, even though entrained air contents in RCC are minimal.

***Permeable Concrete Pavements.*** Pavement managers employ design and maintenance strategies to move water away from paved surfaces as quickly and efficiently as possible. Such strategies include the use of permeable concrete, also referred to as pervious concrete. The American Concrete Institute (ACI) has a state-of-the-art report on cast-in-place pervious concrete as well as a specification for its use (ACI 2011). The American Society for Testing and Materials (ASTM), in its C09.49 subcommittee on pervious concrete, developed four test methods for pervious concrete, as follows: fresh density and void content; field infiltration rate; surface durability and abrasion resistance; and, hardened density and void content (ASTM 2014). The National Ready Mixed Concrete Association (NRMCA) has developed a program with three levels of certification for contractors that construct pervious concrete pavements (NRMCA 2015).

Another strategy for utilizing permeable concrete has been the use of precast pavers, instead of cast-in-place concrete, for alleys, parking areas, and lightly trafficked roadways (Public Roads 2010). Permeable interlocking concrete pavement (PICP) consists of paving units with joints that are filled with permeable aggregates that allow water to freely enter the surface. The paving units are placed on a bedding layer of permeable aggregates which rests over a base and subbase of open-graded aggregates. The base and subbase store water and allow it to infiltrate into the soil subgrade. Perforated underdrains installed in the base or subbase are used to remove water that does not infiltrate within a given design period, typically 48 to 72 hours (FHWA 2015-D).

Maintenance activities associated with restoring infiltration rates for cast-in-place pervious concrete that was used in sites ranging in age from six to twenty years in Florida, Georgia, and South Carolina have been documented (Stormwater Management Academy 2007). Infiltration rates measured before and after pressure washing, vacuum sweeping, and a combination of the two methods, demonstrated that infiltration rates can be fully restored and that overall pavement performance can be satisfactory. Similar maintenance activities for PICP involve the use of a regenerative air vacuum, which does not evacuate jointing materials, to remove fine materials from the surface. A full- or true-vacuum machine is used to remove sediment trapped in the joints; however, it also removes some of the jointing materials, which must be replaced (Public Roads 2015).

***Bases and Subbases for Concrete Pavements - European Practices.*** An international scan of concrete pavements in Europe and Canada found the use of pavement design catalogs, the use of better-quality materials in pavement subbases, greater attention paid to cement and concrete mixture properties, and the use of a geotextile interlayer to prevent concrete slabs from bonding to cement-treated bases (FHWA 2007). The catalog design method is a simple procedure for selecting an initial pavement structure. Most of the European countries visited have routinely used design catalogs to select pavement thicknesses and some other pavement features. The countries using design catalogs recognize that simply extrapolating empirical trends is not reliable and often leads to overdesign of concrete pavements. The design features and thicknesses in the catalogs reflect long-term experience with the local climate, materials, and traffic levels. These experiences are validated through analysis by expert teams using

mechanistic principles. The expert teams employ laboratory testing and field observations to validate the cross-sections in the design catalogs. The designs are defined and refined about every five years.

The use of a catalog for selection of pavement thicknesses and other pavement design features offers advantages of consistency and simplicity. Catalog design is not itself a design procedure, but rather a medium for identifying appropriate pavement design features for use in pavement analysis. A quick way to develop a catalog design is simply to incorporate the standard designs that have shown good, consistent, long-term performance. A matrix of design features is another part of the catalog concept that identifies alternatives for features (e.g., base types) and provides information on such items as the cost, performance, and feasibility of constructing the feature to allow an agency to make an informed decision on whether to include it in a design.

***Internal Curing of Concrete Pavements.*** The only difference between a conventional concrete mixture and an internally cured concrete mixture is that a small volume of the normal-weight concrete sand is replaced with pre-wetted fine lightweight aggregate. Internal curing is a practical way to supply additional curing water without increasing the water to cementitious material ratio. Conventional surface curing remains an important activity.

The water absorbed in the inclusions of the pre-wetted lightweight aggregate is drawn out during the hydration process. This addition of a relatively small proportion of fine lightweight aggregate to a regular concrete mixture in a bridge deck has been found by the Expanded Shale, Clay and Slate Institute (ESCSI) to reduce dramatically the amount of plastic shrinkage cracking. Additional small but collectively significant changes to several key mixture properties have been found to include the following: reduction in unit weight; reduction in elastic modulus; increase in strength; reduction in coefficient of thermal expansion; reduction in shrinkage; and, reduction in permeability (ESCSI 2013). These same benefits can accrue to internally cured concrete used for the construction of pavements.

## **Conclusions**

This paper provides a summary of a recent series of technical briefs published online by FHWA to provide guidance to highway agencies, consultants and contractors concerning a variety of topics including concrete materials, concrete mixtures, bases and subbases, and some alternative methods of concrete pavement construction that may be used advantageously by highway agencies to produce long-lasting concrete pavements.

## **Notice**

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