CNCA CALIFORNIA NEVADA CEMENT ASSOCIATION

January 11th, 2018

The Honorable Bob Blumenfield
Chair, Public Works and Gang Reduction Committee
200 N. Spring Street, Room 415
Los Angeles, California 90012

Re: Council File No. 16-0395-S1
City Streets/Reconstruction and Rehabilitation/Conditions D and F/Concrete Street Repair Pilot Projects/Cost Comparison Analysis

Dear Councilmember Blumenfield:

On August 8, 2017 Councilmember Ryu introduced Motion 16-0395-S1 aimed at addressing the poor condition of many of the city's streets. The California Nevada Cement Association (CNCA) supports this effort and stands ready to assist the City of Los Angeles with this effort. We are offering resources including national experts, design standards, specifications, and best practices to help the city with these analyses and the path forward.

The CNCA can introduce experts in the areas of realizing the long term benefits of concrete pavements including: (1) lower environmental impacts; (2) lower cost of long-term ownership; (3) reduced urban heat island effects; and (4) reduced fuel consumption of the vehicles using concrete pavements. We have specific recommendations to make regarding (5) bid practices for future pavement work; (6) the use of reinforcing steel in concrete pavements; and (7) properly handling utility cuts to ensure that these pavements deliver on their anticipated lifespan.

The CNCA has a long history of working with the Hancock Park Neighborhood Association to analyze and offer suggestions on pavement conditions and rehabilitation efforts, reviewing previous pavement work, and providing cost estimates for proposed work.

We are closely monitoring the current Hancock Park pilot projects; 4th Street (Highland to McCadden Place) and McCadden Place (Beverly to between 2nd/3rd Street) and are eager to share our observations of the work with Bureau of Engineering, Bureau of Street Services, and Bureau of Contract Administration as they prepare their reports as directed by Councilmember Ryu's motion.

Thank you for considering our recommendations, and we look forward to working with you to assure success in 2018.

Sincerely,

Tom Tietz
Executive Director

cc: Public Works & Gang Reduction Committee
Councilmember Joe Buscaino, 15th District (Vice Chair)
Councilmember Nury Martinez, 6th District (Member)
Councilmember David E. Ryu, 4th District (Member)
Councilmember Monica Rodriguez, 7th District (Member)
Michael Espinosa, Office of the City Clerk

Concrete Sustainability Hub@MIT – Special Research Brief – March 2011

Designing for Sustainable Pavements

Problem

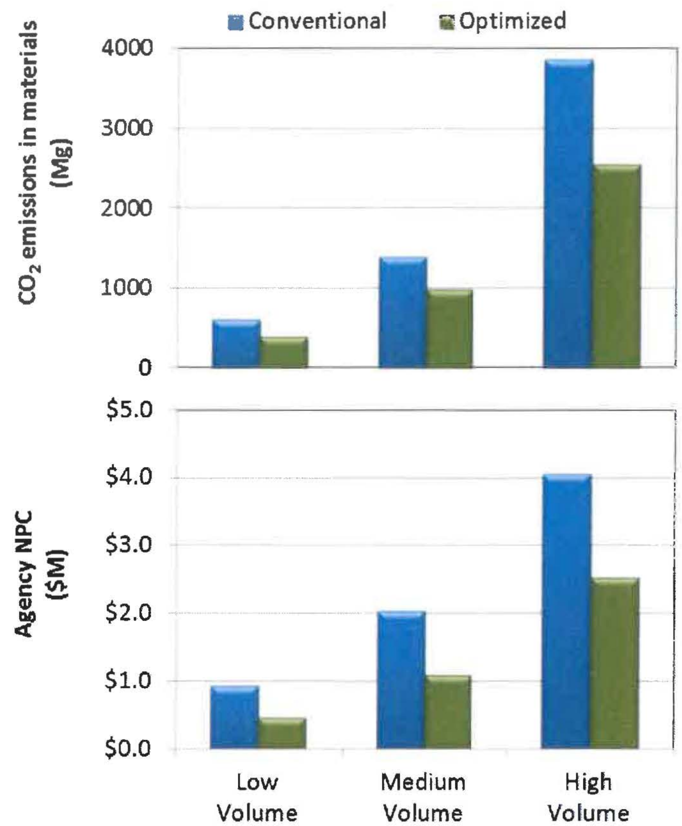
Increasing the sustainability of our infrastructure is accomplished in ways other than just developing better materials and more efficient processes: it is also about employing the right designs. For pavements, overdesign causes excess materials to be used during construction, leading to higher economic costs and environmental impacts. Optimizing design thicknesses for prescribed service lives, climates, and traffic conditions allows pavement engineers to create structures with minimal waste.

Approach

Advancements in design techniques allow for such optimizations. Pavement design tools, such as the National Cooperative Highway Research Program's *Mechanistic-Empirical Pavement Design Guide (MEPDG)*, use embedded models to forecast the propagation of various pavement distresses for combinations of materials properties and external parameters. MIT has developed three case studies to demonstrate the effect that design optimization can have on costs and CO_2 emissions. Conventional designs are compared against *MEPDG* designs for sample low-volume, medium-volume, and high-volume highways in California. The designs are evaluated over a 50-year analysis period using life-cycle assessment (LCA) and life-cycle cost analysis (LCCA) principles.

Findings

Optimized designs can provide significant economic and environmental benefits. For the three case studies, the optimized designs reduce agency net present cost (NPC) by roughly 40–50% and CO_2 emissions by roughly 30%. These are likely to be conservative estimates, as other life-cycle implications, such as shorter construction times and reduced transportation, are not considered in the current demonstrations studies. User costs due to traffic delay may also be reduced using optimized design thicknesses.



Using optimized designs helps reduce both embodied CO_2 emissions and net present value (NPC)

Impact

The use of optimized design thicknesses helps reduce costs and CO_2 emissions by minimizing the materials needed to construct a pavement. The economic and environmental benefits are significant and can help transportation agencies reduce their carbon footprint while working within tight budgetary constraints.

More

The research presented here is a part of an ongoing project by the pavements LCA team at the MIT Concrete Sustainability Hub. More information on the *MEPDG* model can be found at <http://www.trb.org/mepdg/>.

This research was carried out by the CSHub@MIT with sponsorship provided by the Portland Cement Association (PCA) and the Ready Mixed Concrete (RMC) Research & Education Foundation. The CSHub@MIT is solely responsible for content. For more information, write to CSHub@mit.edu.

Perspectives
ACPA Positions and Perspectives on Key Issues

Life Cycle Cost Analysis: Enhancing our Investment Decisions

The American Concrete Pavement Association supports the view that *"all possible and proper measures be taken to ensure the tax payers of this country that they are receiving full value of every highway dollar spent"*.[1] This view was expressed clearly by the American Association of State Highway Officials (AASHO) in the context of the early years of Interstate highway construction and full-value return on the investment remains a fundamental principle advocated by the concrete pavement industry to this day.

In the challenging economic climate, life cycle cost analysis (LCCA) can be a supportive measure to achieve this full-value return on investment, enhancing the prospect of increased investment levels in transportation infrastructure moving forward, through increasing fuel user fees or other highway-focused revenue streams.

What is LCCA?
When performed thoroughly and correctly, LCCA will identify a best value solution with the desired performance at the lowest cost over an economic analysis period, usually long-term:[2]

- LCCA is a proven economic analysis technique, based on well-founded economic principles that are taught in Economics and Civil Engineering programs at the University level in the U.S.
- LCCA is a tool for evaluating the long-term economic efficiency between competing alternate options, each providing equivalent or near-equivalent engineering designs. In the highway context, LCCA is typically used as a means to evaluate and then compare the cost to an owner/agency of any number of alternates, including options for pavements, bridges or other major infrastructure investments.

What LCCA is Not...
Equally important to knowing the history and fundamental importance of LCCA, is to understand that LCCA is not:

- About advantaging one industry over another.
- Another term for pavement type selection.
- A material specific technology – it is solely an economic evaluation technique that supports informed investment decisions.
- About selecting pavements or bridges at the Federal level.
- The same as life-cycle assessment (LCA); LCA is a cradle-to-grave accounting of a material's environmental impact.

[1] "An Informational Guide on Project Procedures," American Association of State Highway Officials (AASHO), Nov. 26, 1960.
[2] "Life Cycle Cost Analysis: Investment Tool for Better Pavement Investment and Engineering Decisions," EB011, American Concrete Pavement Association, 2012.

LCCA History Including Industry Support
LCCA has been applied in the context of highway decision-making for over half a century:

- AASHO, as early as 1960, supported the concept of life cycle cost analysis as a means of enhanced decision making to realize savings.[1]
- Federal Highway Administration affirmed the importance of LCCA in its 1981 policy statement on pavements,[3] and again in its 1996 Final Policy on LCCA.[4]
- Congress required the use on LCCA for projects on the National Highway System in the National Highway Designation Act of 1995. This requirement was rescinded in 1998 (section 1305 of TEA-21), as States pointed to a lack of guidance on how to conduct LCCA properly.
- In response, FHWA issued detailed guidance to the states in the 1998 Interim Technical Bulletin titled *"Life Cycle Cost Analysis in Pavement Design: In Search of Better Investment Decisions"*. FHWA has continued to develop guidance, and has developed and refined an LCCA software tool called RealCost that comprises the most recent and up-to-date FHWA guidance on LCCA.
- The Transportation Research Board through its National Cooperative Highway Research Program recommends the use of LCCA as an integral part of an agency's pavement type selection process in its 2011 Guide for Pavement-Type Selection.[5]
- The concrete and asphalt paving industries in the U.S. have supported use of LCCA for many years and have published volumes on the benefits of LCCA as well as LCCA best practices. Both the concrete and asphalt paving industries have developed LCCA software (StreetPave 12 and LCCAExpress, respectively) to accelerate and ease implementation. These guides strongly support the idea that determination of life-cycle costs of alternative pavement types is an important part of a rational means for decision making.[6]
- Currently, 38 states use LCCA in some form for guiding their pavement investments.
- Congress continues to recognize the value of LCCA, as the current transportation authorization, MAP-21, in the National Highway Performance Program (section 1106) requires a State asset management plan to include life-cycle cost analysis for pavement and bridge assets on the National Highway System.

Summary of ACPA's Position and Perspective
ACPA's number one priority for the next surface transportation authorization is increased federal investment. To this end, LCCA can be an important adjunct to discussions on better governance, enhanced fiscal accountability, and greater return on the taxpayer's investment.

ACPA supports implementation of LCCA at the state level for all federal-aid projects, as a means to enhance the credibility of the federal highway program.

LCCA is a sound economic analysis tool when applied properly and objectively, and guidance on how to properly conduct and interpret an LCCA has matured to the degree that broad implementation is easily accomplished.

The goal remains to: *"Ensure the tax payers of this country that they are receiving full value of every highway dollar spent."* [1]

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[3] FHWA Pavement Type Selection Policy Statement, Federal Register Vol.46, No.195, October 8, 1981.
[4] FHWA Life Cycle Cost Analysis Policy, Federal Register Vol. 61, No. 182, September 18, 1996.
[5] "Guide for Pavement Type Selection", Report 703, Transportation Research Board, Washington DC, 2011
[6] *Life Cycle Cost Analysis: A Position Paper*, IM-53, Asphalt pavement Alliance, September 2011

Quantifying the impact of pavement reflectivity on radiative forcing and building energy demand in neighborhoods

Research Brief, Volume 1, 2017

PROBLEM

Albedo is the measure of the fraction of solar energy reflected by the Earth's surface. High-albedo surfaces, which are lighter in color, absorb less sunlight energy and reflect more shortwave radiation. The change in radiative energy balance, which is called radiative forcing (RF), reduces nearby air temperatures and impacts the surrounding building energy demand (BED) including heating and cooling energy loads. The impact of reflective surfaces on RF and BED has been investigated by researchers through modeling and observational studies, however previous studies have not assessed RF and BED impacts under the same context and therefore cannot be directly compared. Here, we take a more comprehensive approach in assessing the net impacts of pavement albedo modification strategies in urban areas.

APPROACH

We apply an adapted analytical model for RF and, for BED, a hybrid model framework combining information from DIVA and Urban Weather Generator to estimate the impacts of increasing pavement albedo from 0.1 (typical for asphalt) to 0.3 (typical for concrete) for different urban neighborhoods in Phoenix. The 0.2 increase is also associated with changes of thermal properties. A universal and climate-based classification of urban neighborhoods is used to categorize different types of urban morphology into local climate zones (LCZs). For the purpose of illustration, we select two hypothetical LCZs (open high-rise and open low-rise, out of 10 LCZs) in Phoenix, representing a dense downtown area and a sparsely built residential neighborhood, respectively. See Figure 1, page 2.

FINDINGS

The impacts of RF and BED are translated into global warming potential (GWP) savings and normalized to kg CO_2 equivalent per square meter of pavement modified (see Fig. 1). Increasing pavement albedo results in temperature reductions and CO_2 savings from negative RF in both neighborhoods in Phoenix, but the impacts of changing pavement albedo on BED vary by urban morphology. The change often causes cooling energy to go up while leading to savings in heating load, but the magnitudes of burdens and savings depend on location of the urban neighborhood. In the densely-built high-rise neighborhood, reflective pavements can create net GWP burdens—this occurs because the tall buildings trap multiple reflections of radiation between them, thereby increasing BED—however, because high-rise and densely-built districts make up a small fraction of urban areas, the expected total savings from increasing pavement albedo at the urban scale is expected to be positive.

WHY DOES THIS RESEARCH MATTER?

This brief creates a foundation for future research taking into account various neighborhood characteristics. Making use of GIS data is necessary in order to demonstrate the impacts of reflective pavements accurately at urban scale. Results show:

- Evaluating the effectiveness of albedo modification strategies (changing surface reflectivity) involves quantifying the net impacts from both radiative forcing (RF) and building energy demand (BED).
- The relative magnitude of RF and BED depends on context, but usually RF is more significant.

This research was carried out by the CSHub@MIT with sponsorship provided by the Portland Cement Association and the Ready Mixed Concrete Research & Education Foundation. CSHub@MIT is solely responsible for content. Authors: Xin Xu, Jeremy Gregory, Randolph Kirchain

Quantifying the impact of pavement reflectivity on radiative forcing and building energy demand in neighborhoods

Research Brief, Volume 1, 2017

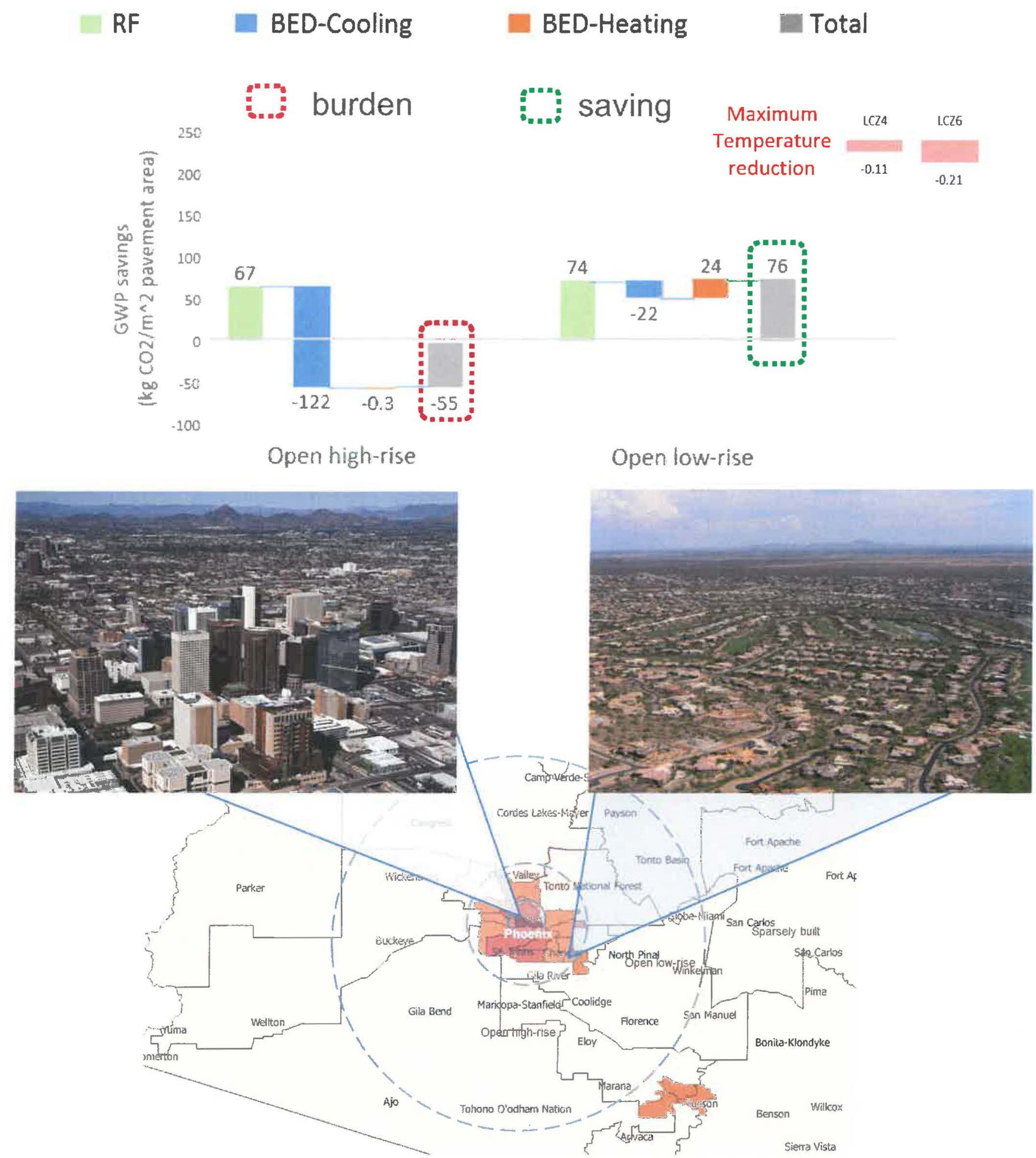

Figure 1. GWP savings from RF and BED due to 0.2 increase in 1 m^2 pavement albedo for two neighborhoods in two different LCZs over 50 years (positive indicates savings). Pictures in the middle show two example neighborhoods in Phoenix, representative of the two LCZs, and their locations in the map.

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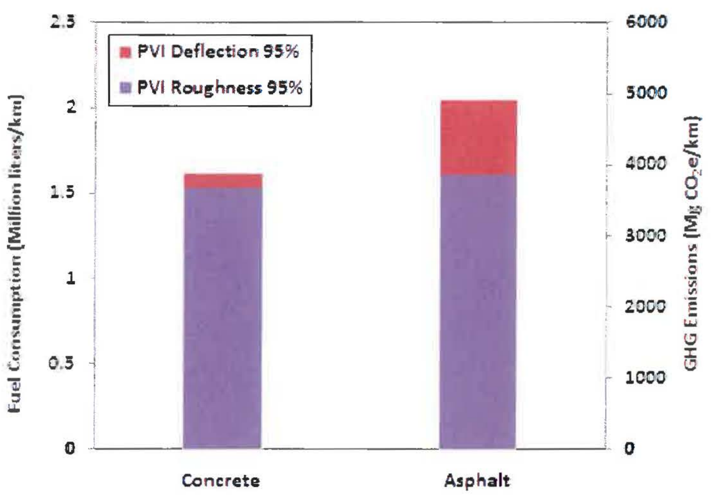
Concrete Sustainability Hub@MIT – Life Cycle Assessment Research Brief – 4/2012

Network, Pavements, and Fuel Consumption

Problem

Sustainability of the roadway transportation sector is highly dependent on passenger and commercial vehicle fuel consumption. The roadway system affects this fuel consumption via pavement-vehicle interaction (PVI) in two major ways: pavement deflection and roughness. Both sources of PVI are dependent on material and structural properties of the pavement. In addition, ineffectual application of maintenance and rehabilitation strategies throughout the pavement lifetime can significantly affect a pavement's environmental performance and durability. In order for the impacts of PVI to be captured within pavement design procedures and life cycle assessment models, the combined effect of the PVI elements (deflection and roughness) along with that of maintenance and rehabilitation scenarios must be understood and quantified. The impacts of PVI on fuel consumption are not constant and evolve over time, mainly due to pavement deterioration from loading and environmental factors. Calculation of the excess fuel consumption due to pavement conditions throughout their lifetime draws a perspective on the environmental benefits of reducing PVI, through better design, material, and maintenance schedules.



Sample Output: Excess fuel consumption and resulting CO_2e emissions for two high-volume pavement systems for a 50 year design life using a 95% confidence interval. (Two lane kilometer section design from Athena (2006); AADT=15,000; AADTT 1,500; AC maintenance at years: 17, 28, 38, 47; PCC maintenance at years 20, 40).

Approach

In order to calculate the impact of pavement deflection and roughness along with that of maintenance on the vehicle fuel consumption, an analysis on the current state of the roadway Network has been performed using the long term pavement performance program (LTPP) databases as a representation of the network. According to the theory of ergodicity, a dynamic system such as a road network has the same behavior averaged over time as averaged over space. Hence, we use structural and material properties of the LTPP sections as inputs for the PVI deflection model, and the roughness values through the international roughness index (IRI) for the roughness model. By applying these models to a high-volume pavement scenario we can calculate the extra fuel consumption due to these impacts throughout the lifetime of a pavement.

Findings

For the high-volume roadway analyzed, we find that the contribution of both pavement deflection and roughness to added fuel consumption are significant. Since a Network analysis is performed, the results represent the state of the pavement throughout its lifetime. Considering a 95% confidence interval of the available network data, the impact of pavement deflection is more pronounced on asphalt pavements, while the impact of roughness on PVI is almost identical for asphalt and concrete.

Impact

Quantifying the impacts of pavement properties and management strategies on vehicle fuel consumption can provide guidance to pavement design and maintenance schedules while reducing the footprint of these systems. Although the impact of pavement roughness is higher than that of deflection, both are highly important within the environmental analyses of pavement systems, and greatly influence the aggregated vehicle fuel consumption.

More

A comprehensive research report on model-based PVI simulation for LCA of pavement by M. Akbarian and F.-J. Ulm is available at http://web.mit.edu/cshub/.

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Research Brief
Issue 11 2015

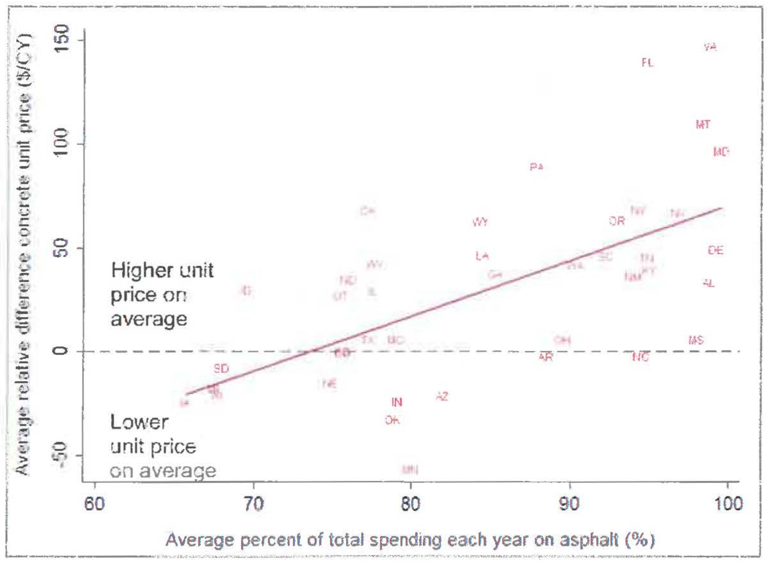
Estimating the impact of competition

PROBLEM

There is wide variation across states in the amount spent on concrete and asphalt, the two primary paving materials. These two materials can be considered substitutes because they perform a similar function for consumers. In many contexts, the existence of either inter-industry or intra-industry competitive substitutes drives down prices. This research brief explores the question: Does the presence of inter-industry competition within a state between paving material substitutes impact pavement material prices?

APPROACH

We gathered concrete and asphalt pay item and state-level DOT bid information. Pay items were screened in order to compare only activities that had legitimate concrete or asphalt alternatives (patching, grinding, curbs, and similar projects were removed). Jobs that had at least the equivalent of one mile of 5-lane pavement 6 inches thick in either material were included. To simultaneously compare unit prices over multiple years, we adjusted for year-to-year change. To do so, we found a relative difference unit price by subtracting a state's unit price each year from the national average that year.



Comparison between the average relative difference unit price of concrete and the 2005-2014 average percent of total spending on asphalt in the 44 states with concrete spending. Zero is the average unit price across all states, and higher average relative difference unit price indicates a higher unit price for a state.

We selected the percent of total spending on asphalt within a state each year to represent inter-industry competition. Comparisons were then made using ten-year averages from 2005 to 2014 for the 41 states that recorded spending on both materials during that period (New England states had insignificant concrete spending and AK, HI, and NJ do not report bid data). A regression analysis was then performed on the two sets of ten-year average data to compare average relative difference concrete unit price with the average percent of total spending on asphalt.

FINDINGS

Our analyses suggest that if a state were to sustain more competitive pavement spending for multiple years, they could expect to then pay a lower unit price for concrete paving. Results from a regression analysis show that the percent of total spending on concrete pavement explains approximately 36% of the variation in the unit price of concrete pavement. There is a negative trend in the asphalt case as well, but it explains little of the variation in asphalt unit price.

IMPACT

In 2014, state DOTs spent nearly $10 billion on paving materials. Given the need to expand and improve the road networks across the country and the enormous sums of taxpayer funds expended, it is vital that agencies obtain maximum benefit from the limited funds available. Leveraging competition between industries to reduce paving material prices appears to be one way to extend the impact of paving funds.

This research was carried out by CSHub@MIT with sponsorship provided by the Portland Cement Association and the Ready Mixed Concrete Research & Education Foundation. CSHub@MIT is solely responsible for content.
Authors: T. Reed Miller, in collaboration with Dr. J. Gregory, and Dr. R. Kirchain.

accommodate differential horizontal or vertical movement; however, use of dowels across the isolation joint will inhibit vertical displacement relative to the fixed objects. Isolation joints are used around light standard foundations, area drains, manholes, catch basins, curb inlets; between the pavement and sidewalks; and between the pavement and buildings.

Isolation joints are also used at asymmetrical intersections and ramps where joint grids are difficult to align. In these locations, load-transfer dowels should not be used so differential horizontal movements can occur without damaging the abutting pavement. Isolation joints (Fig. 4.6) are produced by inserting premolded joint fillers before or during the concreting operations. The joint filler should extend all the way to the subgrade and not protrude above the pavement. If vehicles are to pass over isolation joints along slab edges, consider using a thickened-edge joint. The pavement edge should be thickened by approximately 20% (at least 50 mm [2 in.] min.) and tapered to the required thickness over a distance of six to 10 times the pavement thickness, as shown in Fig. 4.6.[38]

4.4.2 *Expansion joints*—Studies of pavements in service have shown that expansion joints are not needed, except where a concrete slab is placed next to a bridge that is not subjected to the same temperature and moisture movements as the pavement. Pavements in slabs less than 200 mm (8 in.) thick with expansion joints should have thickened edges with no dowels, as discussed for isolation joints. Expansion joints in slabs 200 mm (8 in.) or thicker should be doweled.

In transverse expansion joints, at least one end of each dowel should be equipped with an expansion cap. The expansion cap allows the pavement to move freely as the joint expands and contracts. The cap should be long enough to cover at least 50 mm (2 in.) of the dowel and should provide a watertight fit. The cap should be equipped with a stop that prevents the cap from slipping off of the dowel during placement. A good stop location will provide a minimum dowel coverage by the cap equal to 6 mm (0.25 in.) more than the expansion joint width (typically 32 mm [1.25 in.]). The capped end of the dowel is also lubricated to prevent bond.

The same dowel placement and alignment requirements used for doweled contraction joints apply to doweled expansion joints. The dowels are typically placed at middepth, spaced 300 mm (12 in.) apart (on center), and have a diameter of 32 mm (1.25 in.) for 200 to 225 mm (8 to 9 in.) slabs and 38 mm (1.5 in.) for 250 mm (10 in.) or greater slabs. Epoxy coating for corrosion resistance is recommended for harsh climates when deicer salts are used. A bond breaker such as form oil is essential on the dowel bar.

An expansion basket supports and aligns the dowel bars while also supporting the preformed filler material. The filler should extend the entire width of the slab and fit snugly into the basket frame. Alignment of the dowel bar basket is important to allow for joint movement.

Transverse contraction joints within 20 to 30 m (65 to 100 ft) of transverse expansion joints should be thickened for pavements less than 200 mm (8 in.) thick and doweled for pavements 200 mm (8 in.) or thicker. The expansion joint may allow adjacent contraction joints to open more than other

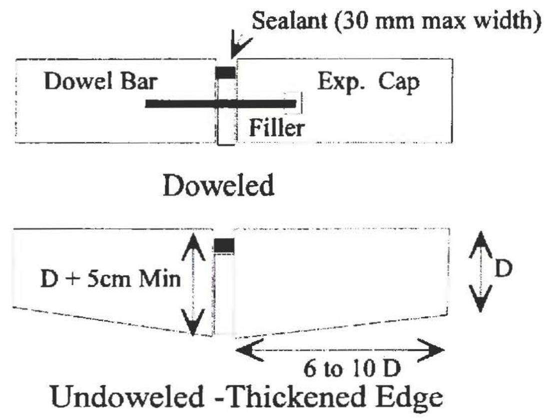


Fig. 4.6—Expansion and isolation joints (using a doweled or thickened-edge joint).

contraction joints. If not doweled, adjacent contraction joints would lose load transfer.[38]

4.5—Slab reinforcement

For most normal applications, distributed steel or wire mesh is not necessary in low-volume concrete pavements for roads and streets if joint spacings are kept short. The use of reinforcing steel will not add to the load-carrying capacity of the pavement nor compensate for poor subgrade preparation or poor construction practices. Embedded reinforcement may minimize deterioration of any cracking over the pavement service period if a possibility exists for cracking to occur due to poor soil support, settlement (from utility cuts, for example), frost heave, and swelling soils.

4.6—Irregular panels

In otherwise unreinforced city streets and low-volume roads, steel reinforcement should be considered for odd-shaped panels. An odd-shaped panel is considered to be one in which the slab tapers to a sharp angle, when the length-to-width ratio exceeds 1.70:1, or when a slab is neither square nor rectangular. At certain intersections where contraction joints are placed along radius lines to the edge of pavement, it can be difficult for a contractor to determine the precise location of odd-shaped panels before paving and sawing. Elimination of the reinforcement is acceptable in these circumstances.

Distributed steel is similar to joint reinforcement (in accordance with Section 4.3) in that it holds fracture faces together if cracks form. As pointed out previously for joint reinforcement, the quantity of steel varies depending on joint spacing, slab thickness, coefficient of subgrade resistance, and the tensile strength of the steel. A properly supported wire mesh should function adequately for most low-volume slab designs. Deformed wire mesh has performed significantly better than smooth wire mesh under greater traffic levels.

Because contraction joints should be free to open, distributed steel is interrupted at the joints. Because increased spacing between joints will increase joint openings and reduce aggregate interlock load transfer, thicker pavements with a wide joint spacing and carrying significant truck traffic may require load-transfer dowels. Distributed steel

CONCRETE PAVING Technology

ACPA AMERICAN CONCRETE PAVEMENT ASSOCIATION

Utility Cuts in Concrete Pavements

Concrete pavements have long been recognized as clean, smooth riding, strong, and durable, and properly designed and constructed concrete pavements should provide several decades of zero- to low-maintenance service. At times, it is necessary to cut trenches in some concrete pavements, particularly in urban areas, in order to repair or install utilities such as sewers, drainage structures, water mains, gas mains and service lines, telecommunication lines, and power conduits. Unless the cost of trenchless methods that do not disturb the pavement is justified, the pavement must be opened up, the utility installed or repaired, and the pavement restored using a utility cut restoration. If these operations are carried out properly (see Appendix 1 for the step-by-step process of making a utility cut in a concrete pavement), there will be minimal impact on the pavement's functional serviceability, ride quality, and lifespan.

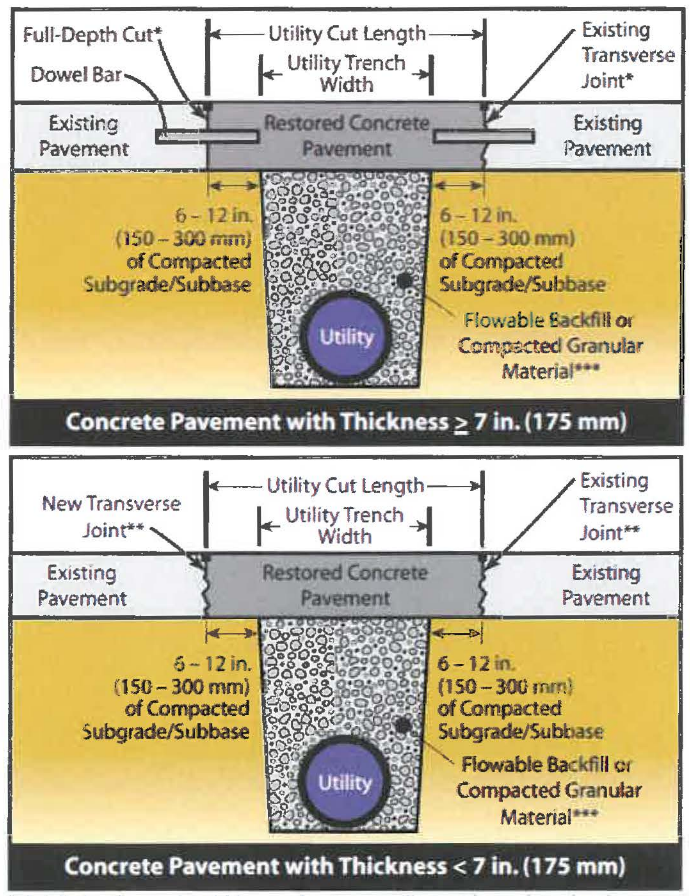
Experience has shown that it is best to repair or restore concrete pavements with concrete. Proper utility cut restorations, constructed even with the surrounding pavement, provide a smooth transition that can withstand traffic loads without future settlement. Flowable backfill, a material that solidifies in about four hours, and/or a fast-setting concrete mixture that can carry traffic in four hours or less can be specified; precast concrete panels might even be used to further expedite the most time-sensitive utility cut restorations.

The purpose of this publication is to provide guidance for the city engineer, public works supervisor, utility foreman, or contractor who must plan or carry out a utility cut and the subsequent utility cut restoration. This publication describes simple design and construction techniques, which usually do not involve any specialized equipment, contractors, or materials; these techniques apply primarily to utility cut restorations in light-truck-traffic roadways, such as residential and collector streets. Exceptions to these techniques for specialty situations, such as utility cuts in overlays, are included in the "Other Design Considerations" section.

Planning the Utility Cut Location, Size, and Shape

The first step is to plan the location, size, and shape of the utility cut after the location of the new or existing utility is identified.

Typically, the utility cut is made somewhat longer than the planned utility trench width, as shown in Figure 1. This will create a 6 to 12 in. (150 to 300 mm) wide shoulder of subbase/subgrade on each side of the excavation, which will help prevent the existing concrete from being undermined during the utility installation or repair. This subgrade/subbase shoulder also will help support the utility cut restoration patch.



* A full-depth cut should be made at any utility cut boundary that is not an existing joint for thicknesses of 7 in. (175 mm) and greater.

** For pavements thinner than 7 in. (175 mm), utility cut boundaries that are not at an existing joint should be cut to a depth of about one third of the slab thickness and the remainder of the depth removed with a jackhammer.

*** Some agencies have had success with up to a 2 ft (0.6 m) layer of natural soil above the backfill but below the restored concrete pavement surface course. This layer is used to mitigate differential frost heave or settlement between the utility patch and surrounding pavement (SUDAS 2005).

Figure 1. Detail of typical utility cuts.

Some engineers like to specify removal of a little more depth at the subbase/subgrade shoulders so that the concrete patch will be 1 to 2 in. (25 to 50 mm) thicker than the surrounding pavement, slightly enhancing the structural capacity of the restored concrete pavement section; such recommendations should be weighed against the anticipated remaining service life of the surrounding pavement because the utility cut should not be engineered to last longer than the existing pavement.

The layout of the section depends on the location of the new or existing utility relative to existing pavement edges and joints, and whether a square/rectangular or circular utility cut will be made. As mentioned, this publication focuses on utility cuts and the subsequent pavement restoration; more general details on managing utility cuts and their locations, permits, etc., are available elsewhere (AASHTO 2005; APWA 1997; FHWA 1993, 1996; Kansas LTAP 2007).

Any utility cut edge in a slab's interior should be located at least 2 ft (0.6 m) away from any joints or pavement edges. If it is determined that a cut would occur in this 2-ft (0.6-m) zone, extend the utility cut boundary to the joint or edge. This may require changing any circular utility cuts to square or rectangular cuts. This extension of the utility cut to nearby pavement joints or edges is done to avoid leaving small sections near joints or edges that may crack and break under traffic loads.

It is important that the edges of a utility cut line up as closely as possible with transverse and longitudinal joints in the existing pavement whenever possible. If this is not done, "sympathy cracking" may form, extending from the pre-existing joints. Also, if at least one edge of the utility cut can be located to coincide with an existing joint, the amount of saw cutting may be minimized.

If isolation or expansion joints are present in the existing pavement within the confines of the utility cut area, these joints should be re-constructed at the same location(s).

Creating the Utility Cut

Making the Necessary Cut(s) in the Concrete Slab

For utility cuts in concrete pavements thinner than 7 in. (175 mm), dowel bars can be excluded from the transverse joints as long as sufficient aggregate interlock is provided for load transfer. To create such a condition, the existing pavement should be cut with a concrete saw to a depth of about one-third of the slab thickness. The remainder of the slab depth will be chipped away during the section removal, resulting in a roughened, slightly-tapering-inward face (Figure 2). Any utility cut boundaries that are at existing joints might utilize any existing dowel bars or tiebars (noting that tiebars are only necessary in longitudinal joints in utility cut restorations longer than one panel), requiring the concrete around such embedded steel to be removed carefully. To easily accomplish this, buffer cuts may be made some distance away from the joint boundaries so that the bulk of the utility cut area can be removed using normal break energy and the sensitive boundary areas removed using reduced break energy (Figure 3).

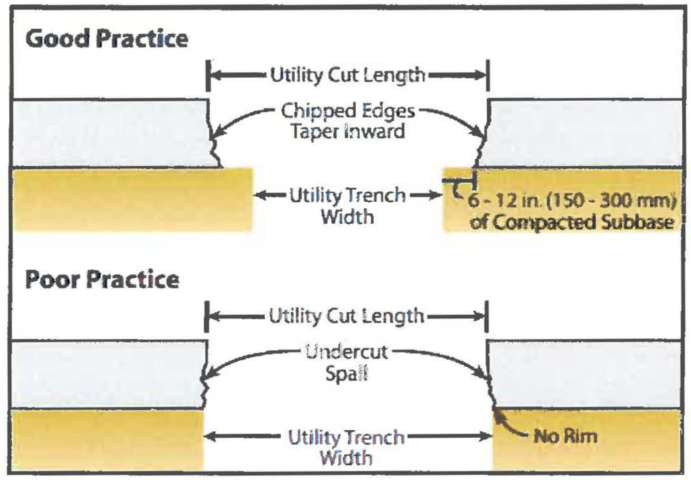


Figure 2. Examples of good and bad chipped faces and subgrade/subbase rims for a utility cut in a concrete pavement thinner than 7 in. (175 mm).

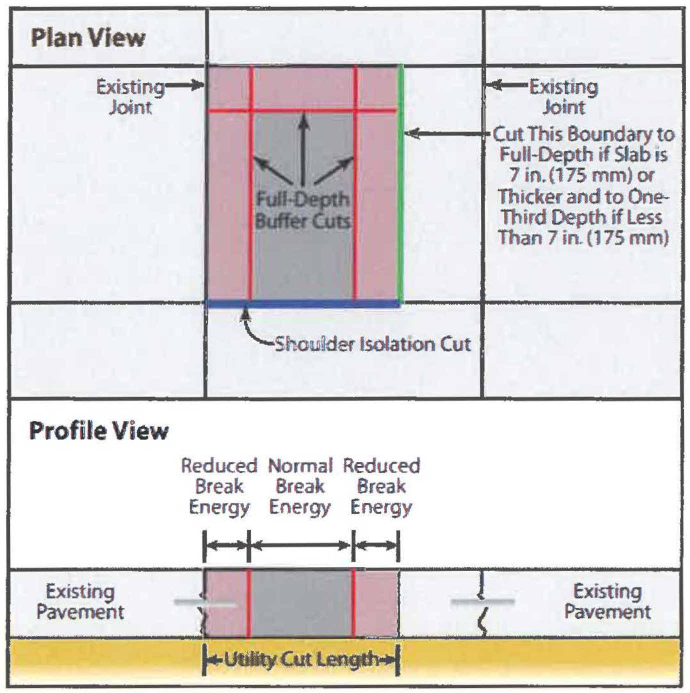


Figure 3. Buffer cuts for protecting the utility cut perimeter.

If the utility cut is to be made in a concrete pavement that is 7 in. (175 mm) or thicker, dowel bars are required for load transfer, rendering aggregate interlock unnecessary. As such, full-depth sawcuts can be made at any utility cut boundary that is not at an existing joint to ease removal. Depending on the concrete removal method and if any boundaries of the utility cut are at existing joints, buffer cuts might also be used to protect the utility cut perimeters from surface spalling and/or undercutting of the existing slab during removal of the section.

When making a rectangular or square utility cut, the cuts should be perpendicular, straight lines at the edge of the utility cut (Figure 4); round utility cuts are made through the full-depth of the concrete, similar to typical coring operation. Saw cuts are preferable to line drilling because they create a clean edge and will minimize the potential for long-term spalling around the utility cut boundaries.

Figure 4. Diamond-bladed saw making perpendicular, straight cuts around the perimeter of a utility cut.

Figure 5. A pressure relief cut made using a carbide toothed wheel saw (kerf saw) down the middle of a utility cut to aid in removal of the section.

During hot weather, the sawing equipment may bind during initial sawing, so it may be helpful to perform sawing at night when the temperatures are lower and the slabs are contracted (also when the traffic volume is lower). Another solution is to provide one or more transverse sawcuts in the area to be removed, similar to those made for buffer cuts (see Figure 3). If the saws continue to bind, yet another solution, if the contractor has the equipment readily available, is to use a carbide toothed wheel saw (or kerf saw) to provide a pressure relief cut within the patch area prior to boundary sawing (Figure 5). Such pressure relief cuts might also be used to ease breaking and removal of the concrete in the utility restoration area (Figure 6).

Removing the Concrete

Removal procedures should not spall or crack adjacent concrete slabs. If they do, the utility cut restoration area might need to be expanded to ensure that the boundary is free of major surface defects.

The concrete in the removal section typically is removed using the breakup and cleanout method. This is normally accomplished using a jackhammer or, for larger areas, a pavement breaker to break the slab(s), followed by removal of the pieces using a backhoe. Breakup should begin in the center of the removal area using normal break energy and, as the breakout operation nears the saw-cut boundary of the utility cut area, a reduced breaking energy, which might include switching to a lighter, hand-held jackhammer (see Figure 6).

If the pavement is thinner than 7 in. (175 mm), special care should be taken to obtain a slightly-tapering-inward cut for all transverse joints that are not at existing joints (see Figure 2). A rough, irregular face below the saw cut is desirable to promote load transfer across the transverse joints in these thin pavements.

Regardless, **the method of breaking the removal section should not damage the adjacent pavement or overbreak/undercut the slab bottom** resulting in a cone or pyramid-shaped patch with poor load transfer and an increased potential for punchout of the utility cut restoration section.

An alternate method of removing the concrete is the lift-out method, in which full or partial slabs are lifted out of place. After the area to be removed is isolated by full-depth saw cuts, holes are drilled through the slab and fitted with lift pins. The slab is then lifted and removed in one or more pieces by some type of heavy equipment (e.g., a backhoe or front-end loader) with a chain attached to the lift pins (Figure 7). Alternatively, a claw-like attachment that slides beneath the concrete slab and grabs it before lifting may be used (Figure 8). Regardless of which lift-out method is used, care should be taken to lift out the slab(s) as vertically as possible to prevent the slab from binding and spalling the adjacent pavement. Because both lift out methods require full-depth sawcuts around the perimeter of the utility cuts, it makes this method the ideal, quickest way to remove utility cut sections in pavements that are 7 in. (175 mm) or thicker. The lift-out method also is the preferred removal method for circular utility cuts because it often allows for the intact core to be retained and replaced as a pseudo-precast slab section.

If completed correctly, both lift-out operations leave a smooth, undamaged joint face. Although both lift-out methods typically are faster than the breakup and clean-out methods, the lift-out methods require some special equipment.

Figure 6. Breakup of a utility cut area in a concrete pavement thinner than 7 in. (175 mm) after sawing the perimeter to a depth of about one-third of the slab thickness and making two transverse full-depth kerf cuts several inches from the transverse boundaries (note the remaining slab with kerf cuts in the background) to further aid in removal of the section. Also note that the saw-cut area is being removed with light jackhammers to obtain a slightly-tapering-inward joint face on the transverse joints, without undercutting the slab.

Figure 7. Partial slab removal using a lift-pin and chain lift-out method with a front end loader.

Figure 8. Partial slab removal using a clawed hook lift-out method.

Excavating the Subbase and/or Subgrade

After the concrete has been broken and removed, the excavation is made to the utility or fixture that is to be replaced or repaired or to the depth necessary for the installation of the new utility. This may be done using a backhoe or skid steer loader, by hand, using a specialized vacuum, or by any other acceptable means.

The need for shoring to prevent cave-ins of the trench will depend upon the type of subgrade soil, its condition at the time of excavation, and the depth of the utility trench. The contractor must have a good knowledge of the soils under the pavement and make this determination based on the current local and federal specifications or regulations governing excavating techniques.

Repairing/Upgrading or Installing the Utility

The utility is repaired or upgraded upon excavation, or a new utility is installed, using the appropriate procedures.

Preparing the Utility Cut Area

Reconstructing a subgrade/subbase and the subsequent installation of any necessary dowel bars or tiebars are the two primary keys to proper preparation of the utility cut area. The subgrade/subbase might be backfilled and compacted with native or borrow material (possibly containing recycled concrete aggregate (RCA)), or the area might be filled with a flowable backfill (again potentially utilizing RCA). Dowel bars are not necessary for utility cut restorations in pavements thinner than 7 in. (175 mm). If the pavement thickness is 7 in. (175 mm) or greater, however, dowels must be drilled and installed into the existing adjacent pavement at transverse joints along the boundary of the utility cut and dowel baskets must be installed at any transverse joints in the utility cut if it is longer than one slab. Tiebars should be included in longitudinal joints that abut existing concrete pavements (and in interior longitudinal joints) in portions of the utility cut restoration area that are longer than one slab and a bond breaker might be used in such longitudinal joints in sections where the joint is less than one slab long.

As noted, it may be desirable to construct the utility cut concrete patch 1 to 2 in. (25 to 50 mm) thicker than the existing concrete for extra structural capacity of the restored concrete pavement structure, requiring slightly more subgrade/subbase to be removed between the perimeter of the utility cut trench and the utility cut; this should be done as part of the preparation of the utility cut area so that this lower elevation can be referenced when placing the backfill.

Some engineers recommend two additional cuts at the transverse boundaries of the utility cut area approximately 6 to 12 in. (150 to 300 mm) beyond the limits of the excavation after the utility cut trench has been backfilled/compacted (NCPTC 2008). This provides shouldering if sloughing of the trench has occurred during utility installation/repair. Such a precaution provides an even larger area of well-compacted subgrade/subbase to better ensure that the ends of the utility cut repair are supported. If done, the additional boundary cut(s) and the necessary hand-held jackhammer work should be performed prior to drilling any holes in the adjacent pavement for dowel bars. If a thickened slab is used in this scenario, removal of the top 1 to 2 in. (25 to 50 mm) of subgrade/subbase would be necessary prior to installation of dowel bars to ensure that the thickened slab is constructed to the boundaries of the utility cut area.

Backfilling with Granular Material and Compacting

Settlement of utility cut restorations in pavements is a prevalent problem that can be avoided by careful construction and inspection during backfilling operations. While concrete is more capable of bridging a slight settlement than other paving materials, it is, nonetheless, wise to pay particular attention to the backfill specifications and construction procedures.

When backfilling a utility trench, every attempt should be made to achieve adequate compaction of the backfill material so that it will not settle when in service. In the past, this often involved backfilling with previously removed material and tamping this material in 6-in. (150-mm) lifts at the proper moisture content and density. However, proper compaction of silt-clay soils in a utility cut trench is difficult, especially during wet weather.

Today, many public works engineers prefer removing all fine-grained soil at the time of excavation and replacing it with cement-treated sand/soil or a select granular material. If used, select granular material must be free of frozen lumps and rocks larger than 4 in. (100 mm) in diameter. As with any un- or partially-stabilized backfill material, adequate compaction (95% of density as determined by ASTM D698/AASHTO T99) is critical to prevent later settlement.

A cement-treated sand or soil will usually pay dividends to both the contractor and the municipality by ensuring higher, more uniform support, further preventing future settlement of the patch. The amount of cement used in such compacted mixtures should be only enough to "cake" the material rather than to produce a hardened soil-cement. Soils treated with lime or any other acceptable soil stabilizing material also may be used and should be compacted in layers at the proper moisture content.

Depending on the duration between compaction of the subgrade/subbase and the time when the concrete is going to be placed, it might be necessary to recompact the subgrade/subbase immediately prior to placement of the new concrete surface course (Figure 9).

Placing Flowable Backfill

Flowable backfill is an ideal alternative to subgrade/subbase reconstruction for utility cuts. Flowable backfill is a low-strength, self leveling material made with cement, supplementary cementitious materials (SCMs; e.g., fly ash, slag cement, silica fume, etc.), sand (possibly fine RCA), and water that easily flows and fills the utility cut area, then hardens. Because it is designed not to become too hard, it is easy to remove later but, because it is so flowable, it requires some means of containment while it sets up.

In addition to its fast setup time—usually within a few hours—flowable backfill has many advantages over compacted soil and granular backfills. Flowable backfill, available from ready mixed concrete plants in most locations, hardens to a degree that precludes any future trench settlement.

Many terms are presently used to describe this type of backfill material: flowable fill, unshrinkable fill, controlled-density fill, flowable mortar, and various trade names. Controlled Low-Strength Materials (CLSM) is the technical general term that emerged through ACI Committee 229 (ACI 1999), although the term flowable backfill tends to still be more commonly used.

Flowable backfill has the advantage of being a standard, well-controlled material, mixed at a plant, transported to the site in a ready mix truck, or, on small jobs, delivered dry to a mobile mixer. In its application for backfill, the material is designed to have a very low strength compared to conventional concrete.

A typical flowable backfill mixture consists of about 60 lb/yd^3 (35 kg/m^3) of cementitious materials and fine and coarse aggregate, with a slump up to about 8 in. (200 mm). A minimum strength of 10 psi (0.07 MPa) at 24 hours typically is required and the 28-day compressive strength specification typically is in the range of 50 to 100 psi (0.35 to 0.70 MPa); this ensures that, if necessary, it can be easily removed later using normal excavation tools and equipment. As such, it is important not to use too much cement or SCMs so long-term strength gain does not become excessive.

Because flowable backfill is a self-leveling, flowable material, it can be poured into the utility trench, requiring no compaction, as shown in Figure 10. The trench is filled with the flowable material up to the level where the bottom of the new concrete surface course will be constructed. Typically, the material solidifies sufficiently to support loads or have the concrete surface course placed in about 4 hours.

If the utility is not filled with fluid or is not neutrally buoyant relative to the flowable fill, it might be necessary to either secure the utility against possible floating due to buoyancy of the empty pipe or place the flowable fill in two layers: the first layer filling the trench up to the bottom of the pipe and the second layer, placed only after the first has set up, filling the rest of the utility trench. Alternatively, the utility can be bedded in a granular material, rather than flowable fill, up to at least half of the pipe depth.

Figure 9. Recompaction of backfill immediately prior to placement of the new concrete surface course. Note that all other necessary preparation work has been completed, such as the dowel bars already having been drilled and installed.

Figure 10. Placement of flowable backfill in a utility cut. Note that the flowable material is self-leveling, with the top of the backfill being placed to the base of the existing adjacent concrete slab [Photo courtesy of the Cincinnati Ready-Mix Concrete Company].

Use of flowable backfill along with high early strength concrete patches or precast concrete panels—discussed later—becomes important where there is a need to restore the pavement quickly to minimize traffic disruption. The extra cost for the material, compared to compacted backfill, is offset by the fact that it eliminates the costs for compaction and labor, reduces the manpower required for close inspection of the backfill operation, requires less trench width, and reduces the time and cost for traffic control and public protection measures.

The performance of flowable backfill has generally exceeded that of compacted backfills with minimal problems due to settlement, frost action, or localized zones of increased stiffness. It has been used extensively in the U.S. and Canada since the 1970s.

Installing Necessary Embedded Steel (Dowel Bars and Tiebars)

It is crucial that all necessary subgrade/subbase and/or backfill compaction is completed prior to installing any dowel bars or tiebars because once the dowel bars and/or tiebars are installed it will be difficult to maneuver compaction equipment around them at the edges of the utility cut area.

Load transfer is the ability of a utility cut restoration section to transfer part of its load to the adjacent concrete. Re-establishing load transfer across any transverse joint on the perimeter of a utility cut is one of the most critical factors affecting long-term performance of the section. Good load transfer reduces the stresses on the patch and prevents it from rocking and moving.

For utility cut restorations in pavements thinner than 7 in. (175 mm), it is possible to obtain sufficient long-term load transfer with just aggregate interlock. Aggregate interlock load transfer is derived from the interlocking action between the roughened face of the in-place concrete and the face of the cast-in-place patch. As discussed, to create the roughened face, the crew removes the existing concrete along the transverse boundaries of the utility cut with a light pneumatic hammer to create a roughed, slightly-tapering-inward edge. If a concrete pavement thinner than 7 in. (175 mm) included dowels in the original design then dowels might be included as part of the utility cut repair but such recommendations should be weighed against the anticipated remaining service life of the surrounding pavement because the utility cut should not be engineered to last longer than the existing pavement.

For utility cut restorations in pavements 7 in. (175 mm) or thicker, load transfer typically is best achieved by a sufficient size and number of properly installed dowel bars. Dowel bars are smooth, round bars that extend from one side of a joint to the other, transferring the load across the joint. Dowels improve pavement performance by:

- Helping maintain the alignment of adjoining slabs.
- Providing load transfer across joints, while at the same time allowing the joint to open and close as the surrounding pavement expands and contracts in response to temperature and moisture changes.
- Limiting or reducing stresses that result from loads on the pavement.

The number of dowel bars required across the width of a full-depth repair such as a utility cut restoration may vary. Some specifications require three, four, or even five dowels per wheelpath while others might require dowel bars at 12 in. (300 mm) on-center across the entire lane width. Different sizes of dowels should be specified for different pavement thicknesses (Table 1). The necessary minimum length of a dowel for a utility cut restoration is 14 in. (350 mm), although stock bars sized in the 15 to 18 in. (375 to 450 mm) range typically are used.

Dowels in transverse borders of the utility cut are installed in holes drilled into the existing pavement. If possible, a gang drill should be used because of its ability to drill two or more holes simultaneously while maintaining proper alignment (Figure 11). The frame of a gang drill rig references the surface of the existing concrete pavement to hold the drills at the proper height and prevent the drill bits from wandering. If necessary, however, hand-held concrete drills might be used but special care should be taken to ensure that the drilled holes are within the acceptable tolerances. The depth of the holes should be approximately one-half the length of the dowel bar. Hole diameters exceeding the bar diameter are necessary to ease installation (see Table 1).

Table 1. Dowel Size Recommendations for Utility Cut Restorations in Jointed Concrete Pavements

Adjacent Pavement Thickness, in. (mm)	Dowel Diameter, in. (mm)	Drilled Hole Diameter, in. (mm)	
		Grout	Epoxy
≤ 7 (≤ 175)	No Dowel	-	-
7 to 8 (175 to 200)	1.0 (25)	1.2 (30)	1.08 (27)
8 to 9.5 (200 to 240)*	1.25 (32)	1.45 (37)	1.33 (34)
10+ (250+)	1.5 (38)	1.7 (43)	1.58 (40)

* 1.5 in. (38 mm) diameter dowel bars, with the appropriate drill hole diameter, might instead be used in 8 to 9.5 in. (200 to 240 mm) thick utility cut restorations if more cost effective.

Figure 11. A gang drill, used to drill multiple dowel bar or tiebar holes simultaneously.

The first step in installing dowel bars is to place grout (cementitious or epoxy) into the back of each hole (Figure 12). This ensures that the material flows out around each bar, fully encasing it. Do not coat one end of the bar with grout or epoxy and then insert the bar into the hole – the air pressure inside the hole will force the grouting material back out of the hole, leaving a void around the bar. The end of the bar that extends into the utility cut area should have a bond breaker applied to it to prevent bonding with the patch material. This bond breaker may be applied by the manufacturer or may be field-applied.

If the repair is large enough to require transverse joints in the interior of the repair area, a contraction joint with dowels is necessary in pavements that are 7 in. (175 mm) or thicker; these dowels are installed using dowel baskets.

Deformed tiebars have surface ridges that provide a locking anchorage when embedded in concrete. In contrast to dowel bars, tiebars are not designed to assist with load transfer but, rather, are designed to prevent opening of longitudinal joints at the utility cut/existing pavement interface or within the utility cut. Sections of a utility cut restoration that are longer than one slab, or utility cuts in pavements that have tiebars, should include tiebars of a diameter and spacing that complies with local requirements; utility cut restorations that are not as long as one slab may be isolated from the adjacent pavement by the inclusion of a bond breaker in the longitudinal joint. Tiebars are installed in much the same manner as dowel bars, with holes being drilled in the longitudinal joint of the existing pavement at a prescribed spacing, diameter and depth, and tiebars being epoxied or grouted into the holes. A bond breaker is not applied to tiebars because a bond with the concrete is desirable.

Be sure that all dowel bars and/or tiebars are clean, free of flaking rust, and are epoxy-coated or otherwise non-corrosive prior to their installation.

Utility cuts in continuously reinforced concrete pavement (CRCP) are rare because CRCP typically is only used on highways. Should a utility cut be necessary in a CRCP, the procedure to re-establish load transfer (and the continuous reinforcement) is similar to CRCP patching. Guidelines for the necessary lap distance for various splicing techniques to reestablish the continuous reinforcing in full-depth CRCP repairs are available elsewhere (ACPA 1995).

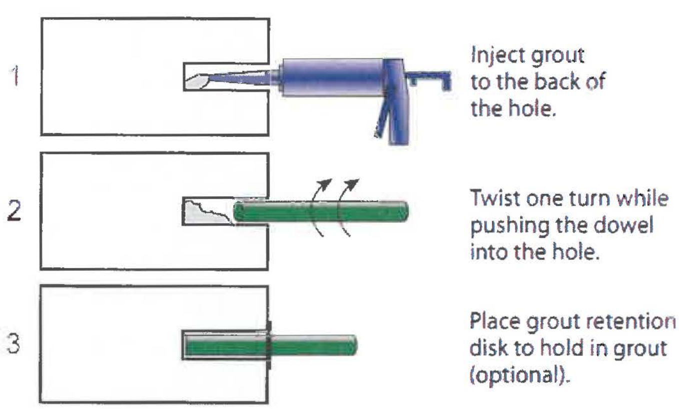


Figure 12. Steps for installing dowels in drilled holes in an existing concrete pavement.

Restoration of the Utility Cut

Design of Concrete Mixtures for Utility Cuts

The concrete mixture requirements for a utility cut primarily depend on the required strength before opening of the area to traffic (see the section titled "Opening to Traffic" for minimum opening strength recommendations). Local ready mixed concrete producers should be able to recommend concrete mixtures that will be suitable to match the project requirements. Both coarse and fine RCA can be utilized in concrete mixtures for utility cuts.

If it is acceptable for the concrete to cure for several days (similar to new construction), standard concrete mixtures with a Type I cement will be sufficient. If an accelerated opening is required, a high early strength cement (Type III or Type HE) can be used or the cement content (not the same as the cementitious materials content) may be increased to as much as 650 to 850 lb/yd^3 (380 to 500 kg/m^3) of Type I or Type GU cement. Proprietary, rapid-set cementitious materials and blended cements also are available; some can reach sufficient strength for traffic in as little as four hours. These materials should be used in compliance with the manufacturer's recommendations for bonding, placing, curing, opening to traffic requirements, and placement temperature ranges. An accelerating admixture also is frequently added to utility cut restoration mixtures to achieve strengths earlier. Extra care may be necessary, however, to properly cure the utility cut restoration when using an accelerating admixtures and/or high early strength cement.

All concrete placement techniques should follow standard procedures. Where opening to traffic is critical, concrete mixtures should be tested for strength and strength gain properties at the approximate temperature in which it will be placed. A maturity curve may be developed before placing the concrete to help determine the earliest time for opening the utility repair area. (See the section titled "Opening to Traffic" for more details on the maturity method for early estimation of in-place strength).

In freeze-thaw climatic areas where deicing compounds are applied to pavements to melt snow and ice, it is imperative that air-entrained concrete be used. Failure to do so will frequently result in slab scaling. The amount of entrained air necessary depends on the maximum size of the aggregate in the concrete (Table 2). In addition to providing resistance to freezing and thawing and the action of deicer salts, entrained air improves the workability and ease of consolidation of the concrete utility cut restoration material. More general details on designing concrete paving mixtures that are resistant to freeze-thaw damage are available elsewhere (PCA 2002, FHWA 2006).

Table 2. Recommendations for Percent Entrained Air Based on Maximum Aggregate Size

Maximum aggregate size, in. (mm)	Entrained air, %
1 ½ (38)	5 ½ ± 1
¾ (19) or 1 (25)	6 ± 1
½ (13)	7 ± 1
⅜ (9.5)	7 ½ ± 1

Normal strength concrete, high early strength concrete, and proprietary materials all have been used successfully as materials for utility cut restorations; asphalt concrete is not a good material for utility cut restorations in concrete pavements. Asphalt has different thermal properties than concrete, and it is not as durable. Using asphalt in a utility repair area in a concrete pavement can lead to roughness from heaving or settling, and can compromise the utility.

Placing, Finishing, Texturing, and Curing the New Concrete Surface Course

Before placing concrete into the utility cut area, any loose subgrade/subbase material should be firmly compacted with hand or pneumatic tools. The exposed faces of existing joints that will still serve as working joints should be coated with form oil or a curing compound to prevent bonding to the new concrete. Also, a fiber-board bond breaker might need to be installed between the longitudinal joints of the existing concrete and the repair when the joint is not longer than one slab (Figure 13).

Concrete placed in the utility cut restoration area should be well consolidated using hand tools or internal vibrators to ensure that there are no voids under or adjacent to the existing pavement (proper mixture design is a critical variable in ensuring adequate consolidation along the perimeter of the utility cut) or beneath any embedded steel (Figure 14). Ambient temperatures should be between 40° and 90°F (4° and 32°C) for any concrete placement, otherwise the appropriate hot or cold weather concreting practices should be employed. The slump of concrete for utility cut restoration mixtures should be in the range of 3 to 5 in. (75 to 125 mm) to ensure proper consolidation and to permit manual finishing with a manual or vibrating screed.

After placing the concrete, screed and finish the patch to match the existing concrete using normal finishing equipment and procedures (Figure 15). For utility cuts less than 10 ft (3.0 m) long, the surface of the concrete should be struck off with a screed perpendicular to the centerline of the pavement (e.g., against the direction of traffic) and for utility cuts more than 10 ft (3.0 m) long, the surface should be struck off with the screed parallel to the centerline of the pavement (e.g., in the direction of traffic), as shown in Figure 16.

Figure 13. Fiber-board bond breaker placed along the longitudinal joint between the existing pavement and the utility cut section because the utility cut section is not longer than one slab.

Figure 14. Proper concrete placement operations, with the concrete being discharged directly onto the subgrade/subbase inside the utility cut restoration area and a hand vibrator being used to ensure proper consolidation in the repair area and, especially, around embedded steel.

Figure 15. The new concrete surface course of a utility cut restoration being finished by a vibrating screed. Note that the surface is being finished perpendicular to the centerline because the utility cut length is less than 10 ft (3.0 m).

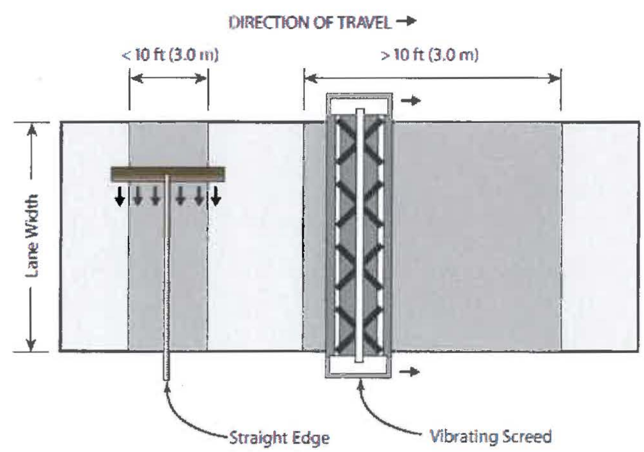


Figure 16. Finishing direction depends on the size of the utility cut.

Figure 17. Texturing of a utility cut surface using a broom. Note that the curing compound is sitting nearby so that it can be applied as soon as possible.

The final texturing of the surface should match the existing surrounding pavement as closely as possible. Usually, a light brooming or burlap drag will be satisfactory, typically applied once the surface sheen has disappeared (Figure 17). To avoid slippery surfaces, smooth-steel trowels should not be used.

As with the placement of any fresh concrete, proper curing of the new concrete surface course is important. The patch should be cured to ensure that the concrete achieves its potential strength and durability. It is best to begin curing operations as soon as possible after completing the finishing operations and/or as soon as the bleed water has disappeared from the surface of the concrete (typically within ½ hour after placement of the concrete for most paving and repair mixtures). While polyethylene, wet burlap, impervious paper, ponding, or constant spraying may be used for curing, a membrane-forming compound is the most common curing method. Unlike methods such as covering with wet burlap or a polyethylene, the application of a curing compound requires no uncovering at a later time, and traffic can be reinstated on the pavement soon after placement.

To ensure the area is thoroughly coated, curing compounds should be either white-pigmented or tinted for visibility. A useful rule of thumb is that proper application of a white-pigmented curing compound has occurred when the concrete surface is as white as a sheet of paper (Figure 18); any gray areas, streaks or blotches are an indication of under-application. A double application of curing compound is a good practice for repairs such as utility cut restorations. In all curing operations, make sure the entire utility cut surface and any exposed edges are covered.

For utility cuts utilizing high early strength materials that will open quickly to traffic, insulation boards/mats will hold in heat while the concrete is curing. The insulating material should be placed over a polyethylene sheet (Figure 19). In extremely cold ambient conditions, care should be taken to ensure that strength requirements are met prior to removal of any insulation boards/mats to prevent thermal shock.

Circular utility cuts oftentimes can use the intact, removed core as a repair, similar to a pre-cast slab. If this is done, the core should is oriented it in its original direction and grout used to level it up and bond it to the surrounding pavement (APWA 2004). Specialty non-shrink grout mixtures and epoxies also have been used successfully to set circular utility cut cores.

Figure 18. Proper application of white-pigmented membrane-forming curing compound. Note that the surface of the repair area is as white as a sheet of paper.

Figure 19. Insulation mats placed on top of polyethylene sheets to encourage a relatively quick strength gain.

Jointing and Joint Sealing

Joints may be formed by use of an edging tool or parting strips or cut later with a saw; the depth of any saw cuts should be one-fourth the slab thickness for any joints in the interior of the utility cut restoration and the minimum depth necessary for creation of the sealant joint reservoir for joints on the perimeter of the utility cut restoration. Or, if the joint(s) are not to be sawed and sealed, the patch edges may be finished with a one-eighth-inch (3 mm) radius edging tool for a neat appearance.

Any transverse or longitudinal construction/contraction or isolation/expansion joints in the adjacent pavement should be continued through the utility cut to prevent sympathy cracking.

If necessary, transverse and longitudinal joints within the utility cut may be sawed while the concrete is green to control cracking. If the concrete cracks before initial sawing, the resulting crack should be prepared and sealed.

Longitudinal and transverse joints typically are sealed, particularly if the original pavement had sealed joints. Jointing details such as commonly used sealant types and typical sealant reservoir dimensions for the various sealant types are available elsewhere (ACPA 1991, 2008b).

Opening to Traffic

It is preferred to require a minimum concrete strength prior to opening the utility cut restoration to traffic. Thanks to modern concrete mixture technologies, a mixture can be designed and proportioned to obtain a desired strength in the time required. In most cases, the opening strengths listed in Table 3 are sufficient for opening to public traffic. The use of maturity methods to estimate opening strength is recommended.

Table 3. Minimum Opening Strength for Utility Cuts of Various Thicknesses and Lengths

Utility Cut Thickness, in (mm)	Compressive Strength for Opening to Traffic, psi (MPa)	
	Utility Cut Length < 10 ft (3.0 m)	Utility Cut Length > 10 ft (3.0 m)
6 (150)	3,000 (20.7)	3,600 (24.8)
7 (175)	2,400 (16.5)	2,700 (18.6)
8 (200)	2,150 (14.8)	2,150 (14.8)
9+ (225+)	2,000 (13.8)	2,000 (13.8)

In any case, the concrete should have at least 4,000 psi (27.6 MPa) compressive strength in 28 days. Most normal paving and repair concrete mixtures will obtain strengths of the magnitude shown in Table 3 within 24 to 72 hours and some high early strength and proprietary mixtures reach such strengths in as little as 3 to 4 hours.

Maturity testing is one of the most useful methods to estimate early-age strength, particularly when early opening is required. It employs small thermocouples or maturity probes that can be monitored periodically or even continuously from placement in the field, whereas compressive (or flexural) strength testing requires testing specimens at a laboratory, making some delay inherent to such testing methods. More general details on the estimation of in-place strength using the maturity method and the construction of a maturity curve are available elsewhere (ACPA 2008a; FHWA 2005).

Other Design Considerations

Precast Panels

In areas where very short work windows are available, such as for a highly trafficked roadway in an urban area, precast panels have been used successfully as part of full-depth full- or partial-panel replacements (FHWA 2007) and, as such, they also may be used for utility cuts that also require very expedited opening to traffic (Figures 20). In some cases, cracked and damaged pavement panels have been removed and replaced with precast panels in as little as four hours. Although the window of time for the repair would necessarily be longer for a utility cut due to the need to unearth and repair/replace the underlying utility, some time might be saved by eliminating the placing, finishing, texturing, and curing of the concrete surface course because a precast panel is formed, finished, textured, and cured prior to placement. Precast panels also can be used temporarily and repetitively to accomplish utility work that might take more than one night.

There are a variety of precast panel approaches available. The differences between the available approaches relate to a variety of aspects, including:

Load transfer mechanism

Bedding material/subgrade preparation

Slab reinforcement

Slab geometry (flat panel, warped panel)

All approaches offer potential benefits, including faster construction, reduced user cost, reduced section thickness, controlled concrete fabrication conditions, and the potential for improved performance.

Successful use of precast pavement panel technology is contingent on the dimensions (thickness, width and length) of the pavement slabs in the utility cut(s) being clearly defined. In addition, subgrade conditions must be considered because the subgrade/subbase will require reconstruction during the unearthing of the utility.

Figure 20. Positioning of a precast panel during a utility-related repair in a nighttime closure [Photo courtesy of The Fort Miller Co., Inc.].

Emergency Patching

When an emergency develops such as a break of a major water, sewer, or gas main, particularly in an area of heavy traffic and major congestion, some of the precautions in this document may have to be ignored. Pavement cutting by sawing may not be practical and the use of heavy pavement breakers may be necessary. While this type of pavement breaking is not as free from later spalls and does not present as nice an appearance, expediting the utility cut and pavement restoration may be of more importance. Backfill compaction is still important, however, and should not be neglected. Granular or flowable backfill usually can be obtained on short notice.

Also, a temporary pavement patch of flowable backfill or granular material, or even a precast panel, may suffice to carry traffic temporarily, until a proper utility cut restoration can be constructed.

Utility Cuts in Heavy-Duty Concrete Pavements

During recent decades, many state highway departments have embarked on extensive programs to repair or restore existing interstate and primary highways. From this experience, successful best practice techniques for the rehabilitation of heavy-duty pavements have evolved. Concerning full-depth concrete pavement restorations, it has been found that more stringent measures than those described in this publication are necessary to ensure good performance of the patches under the pounding delivered by many heavy trucks. These measures involve different methods of pavement removal, use of fairly large-size patches (4 to 8 ft [1.2 to 2.4 m] or more) and extensive use of tiebars and dowel bars. More general information about full-depth repairs/restorations in major pavements, such as highways and airfields, is available elsewhere (ACPA 1995, 2003, 2008b).

Utility Cuts in Concrete Overlays

Bonded Concrete Overlay Over Concrete – Use a minimum utility cut restoration length of 6 ft (1.8m). Omit longitudinal tiebars on all partial length panel replacements. Place dowel bars in the underlying concrete, when required, and not the overlay. Replace the concrete overlay with a full-depth pavement, matching the existing joints in the adjacent pavement.

Bonded Concrete Overlay Over Asphalt or Composite – Do not tie the utility cut restoration to the existing bonded overlay. If there are dowel bars in a concrete course in an underlying composite pavement, they might be included at the same depth in the utility cut restoration. Although highly unlikely, if dowel bars were used in the overlay, they might also be used in the utility cut restoration. Replace the concrete overlay with a full-depth pavement, matching the existing joints in the adjacent pavement.

Unbonded Concrete Overlay Over Concrete, Asphalt or Composite – Do not tie the utility cut restoration to the existing unbonded overlay. Replace the concrete overlay with a full-depth pavement, matching the existing joints in the adjacent pavement and doweling the utility cut restoration to match the underlying pavement. If the utility cut restoration is approaching 20 ft (6 m) in length to match the existing joint pattern, saw a mid-panel transverse joint.

Utility Cuts in Pervious Concrete Pavements

If at all possible, it is best to prevent utilities from being installed or retrofitted under pervious concrete pavements through careful, foresightful planning of the original design of an area surrounding and beneath a pervious concrete pavement because any utility beneath a pervious concrete pavement might interfere with the percolation of water through the depth of the pervious concrete pavement structure. Pervious concrete pavements also might allow for deeper penetration of the frost line, requiring many utilities to be installed at deeper-than-typical depths.

If utilities are installed or retrofitted under a pervious concrete pavement and its drainage layers, precautions must be made to allow water to percolate properly through the layers and around the utility and, at the same time, to protect the utility. Any utility cut made in a previous concrete pavement will require that the backfill and restored surface course be replaced with the appropriate materials so that the pervious utility cut section can perform as intended. As such, construction of a utility cut restoration in a pervious concrete pavement is required to be performed by a National Ready Mixed Concrete Association (NRMCA) Pervious Concrete Contractor Certified Installer or Craftsman.

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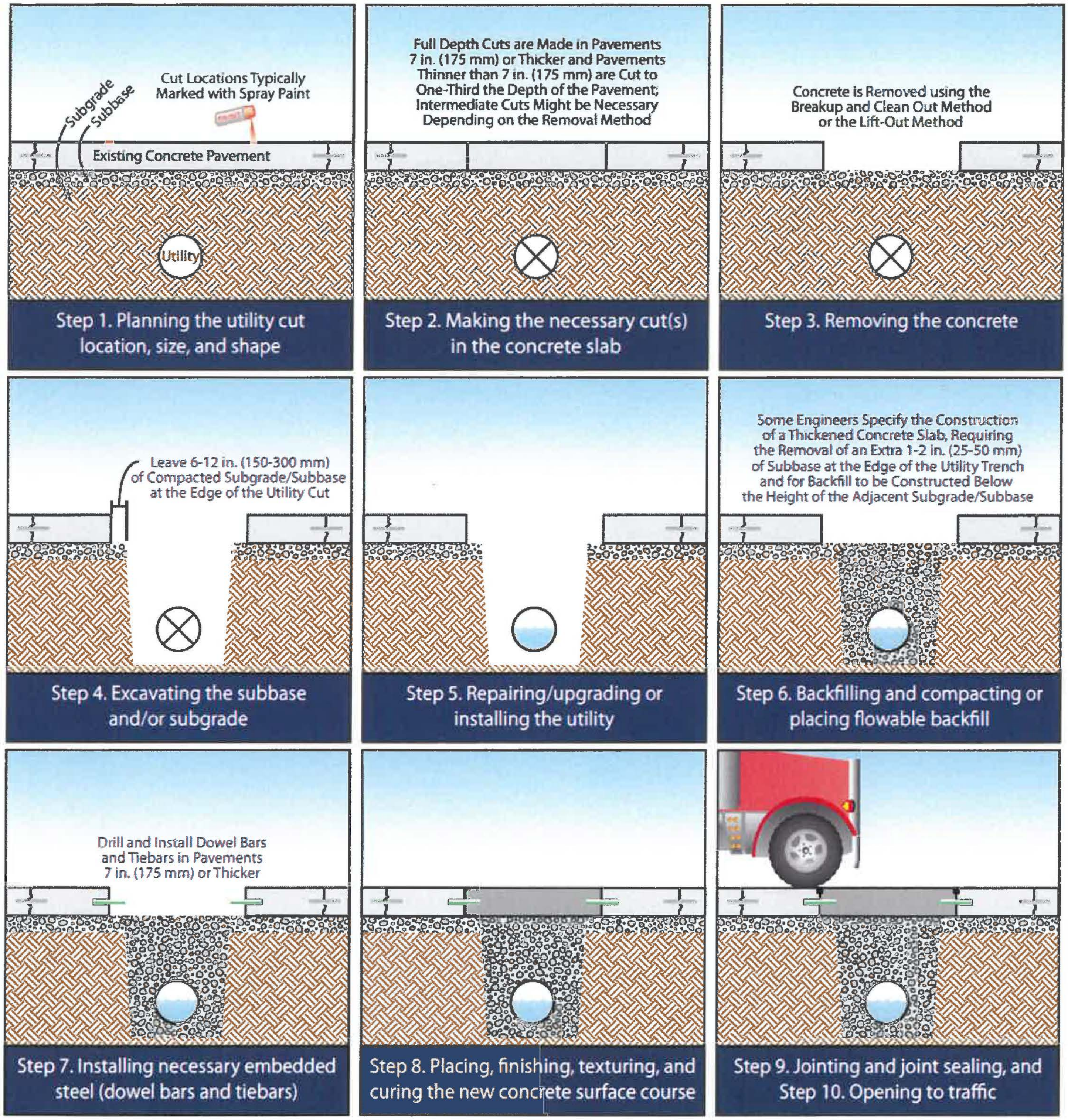

Appendix 1. The step-by-step process of a proper utility cut and the subsequent concrete pavement restoration.

ACPA

American Concrete Pavement Association
5420 Old Orchard Rd., Suite A100
Skokie, IL 60077-1059
(847) 966-ACPA
www.acpa.org

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