# COST-EFFECTIVE LOAD TRANSFER RESTORATION OF JOINTED CONCRETE PAVEMENTS

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Much of the cost of portland cement concrete pavement (PCCP) is related to the construction, maintenance, and rehabilitation of joints or cracks. Various design strategies for building and maintaining the quality of the joints in PCCP have been tried. Yet most of the functional distress in PCCP is related to poor joint performance or transverse cracking. One of the design parameters in PCCP joint design is load transfer—the capacity of a joint or crack to distribute an approaching load by shear from one slab to the adjacent slab. Joint load transfer can be accomplished by providing strong slab support by means of aggregate interlock, mechanical load transfer devices such as steel dowels, or a combination of these.

## Problem

Much of the PCCP used for Interstate highways and major arterials was designed to rely on aggregate interlock for load transfer. The rapid growth of traffic, particularly heavy trucks, subjected the nation's pavements to unanticipated high stress levels. These stresses, combined with environmental factors, accelerated the erosion and fracture of the aggregate at the face of PCCP joints. Consequently, the aggregate interlock decreased, and with it the load transfer capacity of the joint or crack. This in turn allowed substantial pumping of subbase or subgrade material, causing loss of support for the pavement. The end result was faulting and rough ride, followed by deterioration of the pavement slabs.

In the mid-1970s, mechanical load transfer devices were incorporated in the joint design of most new concrete pavements to address the loss of load transfer across joints and the resulting distresses. Some state departments of transportation skewed the joints so the wheels of an axle strike the joints at different times. Of the various mechanical load transfer devices and joint design strategies used, round solid steel dowel bars provided the best performance in terms of load transfer capacity. This strategy, however, did not address the load transfer restoration of PCCP in service.

## Solution

In the late 1970s, the Federal Highway Administration contracted with Georgia DOT to evaluate alternative load transfer restoration devices and repair materials. In 1989 FHWA reported on the performance of 13 test sections whose construction involved load transfer restoration. Both evaluations revealed increases in the load transfer capacity across joints or cracks of PCCP with the use of mechanical devices. Again, while a variety of such devices were tried, the best performing was smooth, round solid steel dowels.

According to the American Association of State Highway and Transportation Officials' 1993 *AASHTO Guide for Design of Pavement Structures*, load transfer restoration should be considered for all transverse joints and cracks that exhibit measured load transfer of 60 percent or less. To restore the load transfer of a joint or crack, dowels are placed in slots cut in the pavement (see Figure 1), and portland cement concrete is used to backfill around the dowels.

Since 1980 the Puerto Rico Highway Authority has retrofitted dowels in more than 400 lane kilometers of highways subjected to heavy truck traffic. After as long as 18 years, the dowel bar retrofitting is performing well. Yet until recently, the use of dowel bar retrofitting has been infrequent in the continental United States, for two major reasons: the high cost of construction and the lack of equipment that can economically cut the slots needed for the dowel installation. The cost per dowel bar assembly installed in the continental United States was

$60–100, and the slots had to be cut individually, making the technique labor-intensive and time-consuming, with considerable disruption to traffic.

In the early 1990s the Washington State DOT investigated alternative ways of rehabilitating older concrete pavements. WSDOT was encouraged by FHWA to consider the use of dowels for restoring load transfer in existing concrete pavements. In 1992 WSDOT constructed short experimental sections to evaluate the technique, and achieved favorable results.

In 1992 an FHWA special project (SP 204) was undertaken to encourage industry to develop equipment for economically constructing slots for retrofit load transfer. A work order was issued to the Indiana DOT to demonstrate the feasibility of using carbide-milling technology for constructing the slots and reducing secondary cleaning, in turn necessitating fewer user delays by shortening the construction period. Tests conducted in 1993 and 1994 proved this technology successful.

The IDOT and WSDOT projects also provided the impetus for industry to develop improved diamond sawing equipment for use in constructing multiple slots in each wheelpath. This diamond sawing equipment and specially constructed milling heads have increased the accuracy and production rate of the procedure used to construct multiple slots for this promising technique.

## Application

As a result of the FHWA-sponsored evaluations, many states are now using dowel bar retrofit. Several state DOTs are also now routinely performing load transfer restoration using smooth dowel bars as part of their concrete pavement maintenance or rehabilitation programs. Diamond sawing equipment has been used on regular construction or maintenance projects in Kansas, Puerto Rico, Washington State, and North and South Dakota. The carbide-milling equipment has been used on regular construction projects in New Jersey, West Virginia, and Minnesota. Several other states have expressed interest in implementing this technique. Bid prices have ranged from a low of $22.50 per dowel in place to $50.00 or more, depending on the quantity of retrofit dowels, the hardness of the aggregate in the concrete, labor rates, and traffic control requirements.

## Benefits

The use of retrofit load transfer on jointed PCCP as a preventive maintenance technique or as part of a concrete pavement restoration or rehabilitation project will significantly extend the service life of the pavement. The technique is relatively rapid and involves minimum traffic disruption. Combined with other pavement restoration methods, this technique has the potential to extend the service life of pavements by 10–20 years, depending on the pavement condition at the time of the repair; the volume of heavy truck traffic; and the quality of the retrofitted load transfer design and construction.

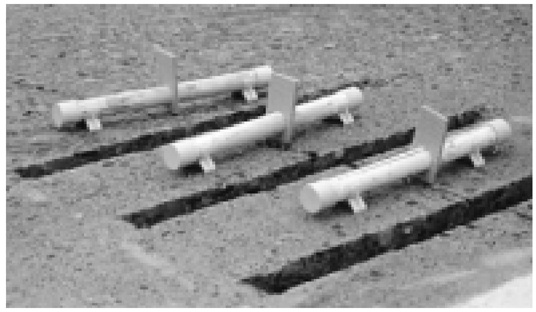

FIGURE 1 Three slots cut in pavement are ready for placement of load transfer dowel bar assemblies.

WSDOT estimates that the cost of this rehabilitation technique is $40,000 less per two-lane roadway kilometer than a conventional 90-mm asphalt concrete overlay, and the resulting pavement will last 10–15 years. Moreover, if an asphalt concrete overlay is placed without load transfer restoration, poor load transfer often leads to rapid development and deterioration of reflection cracks in the overlay. In the future, WSDOT expects to apply this technique to extend the service life of about 80 two-lane roadway kilometers of Interstate highway per biennium. The Kansas DOT estimated savings of $10 million for a 30-lane-kilometer project as compared with a total reconstruction cost, and expects a 10- to 20-year extension of the pavement's service life.

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