CONCRETE PAVEMENT
CPTP
TECHNOLOGY PROGRAM

Use of Magnetic Tomography Technology to Evaluate Dowel Bar Placement

TechBrief

The Concrete Pavement Technology Program (CPTP) is an integrated, national effort to improve the long-term performance and cost-effectiveness of concrete pavements. Managed by the Federal Highway Administration through partnerships with State highway agencies, industry, and academia, CPTP's primary goals are to reduce congestion, improve safety, lower costs, improve performance, and foster innovation. The program was designed to produce user-friendly software, procedures, methods, guidelines, and other tools for use in materials selection, mixture proportioning, and the design, construction, and rehabilitation of concrete pavements.

www.fhwa.dot.gov/pavement/concrete

U.S. Department of Transportation
Federal Highway Administration

The use of properly sized dowel bars has been a long-standing recommendation for jointed concrete pavements subject to heavy truck traffic to prevent roughness caused by faulting. Implicit in this recommendation is the assumption that the dowel bars will be placed in proper position and alignment. Misaligned dowel bars can cause joints to lock, which, in turn, can lead to spalling or cracking. Severe misalignment can also cause looseness around the dowel bars, greatly reducing their effectiveness. Proper centering of the dowel bars under the joint is important to provide adequate embedment length on either side of the joint. The types of dowel misalignment are illustrated in Figure 1, and their potential effects on pavement performance are summarized in Table 1.

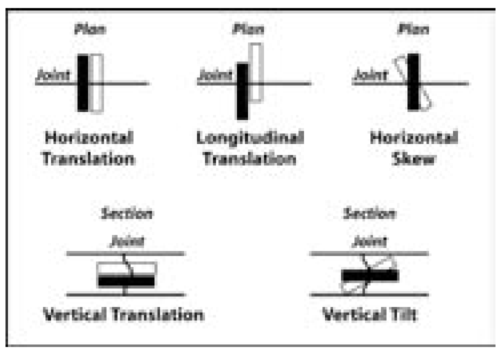

Figure 1. Types of dowel misalignment.

Table 1. Types of dowel misalignment and their effects on pavement performance.

Type of Misalignment	Effect on Spalling	Cracking	Load Transfer
Horizontal translation	no	no	yes
Longitudinal translation	no	no	yes
Vertical translation	yes	no	yes
Horizontal skew	yes	yes	yes
Vertical tilt	yes	yes	yes

The dowel placement accuracy needed to ensure good pavement performance has not been studied in depth. The effect of dowel alignment on pavement performance is the subject of a National Cooperative Highway Research Program (2005) study; and a report on dowel bar alignments of typi-

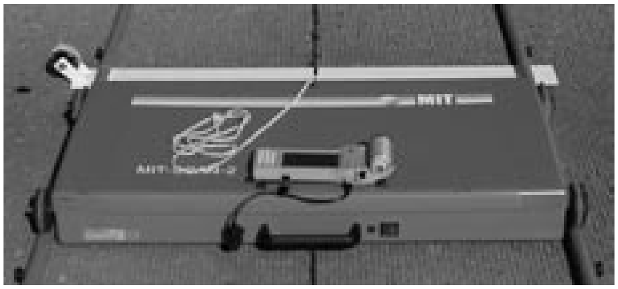

Figure 2. MIT Scan-2.

cal in-service pavements, based on data collected using the MIT Scan-2 device, is available from the Portland Cement Association (2005).

MIT SCAN-2

MIT Scan-2 is a state-of-the-art, nondestructive testing device for measuring the position of metal bars embedded in concrete. Developed by Magnetic Imaging Tools (MIT) GmbH (Dresden, Germany), MIT Scan-2 utilizes an array of sensitive detectors and sophisticated data analysis algorithms to produce very accurate results.

The device, shown in Figure 2, consists of the sensor unit, onboard computer, and plastic rail system. The onboard computer runs the testing, stores data, and performs field data analysis. The rail system guides the sensor unit precisely along the test joints at a constant elevation (see Figure 3).

Unlike other devices that have been used in the past, which are general-purpose instruments adapted to the dowel bar detection application, MIT Scan-2 was developed specifically for measuring dowel and tie bar alignments. As a result, the device is simple to operate, efficient, and able to produce real-time results in the field.

EVALUATION UNDER CPTP

A comprehensive evaluation of MIT Scan-2 was conducted under the Concrete Pavement Technology Program (CPTP). That study concluded that MIT Scan-2 provides an accuracy of ±5 mm with 95 percent reliability on rotation (horizontal or vertical misalignment), as long as no foreign metal object is within about 1 m (3 ft) of the bars being scanned. The estimated overall standard deviation of measurement error is 3 mm (FHWA 2005).

TECHNOLOGY

MIT Scan-2's detectors and sophisticated data analysis algorithms produce very accurate results. The device emits a weak, pulsating magnetic signal and detects the transient magnetic response signal induced in metal bars. The methods of tomography are used to determine the position of the metal bars.

CALIBRATION REQUIREMENTS

The data analysis scheme for MIT Scan-2 includes the use of calibration data to produce very accurate results. Each unit of the MIT Scan-2 device is individually calibrated for each type of bar that will be tested using the device. A bar type is defined by material (e.g., steel vs. stainless steel), bar diameter, and bar length. The dowel baskets are calibrated by basket type, which is defined by the basket geometry, diameter of the basket wire, and dowel bar type. Although the correct calibration is required to obtain accurate results, the calibration information can be substituted at the time of data analysis. Testing can thus be conducted without having the actual calibration for the bar type (or basket type) being tested.

MIT Scan-2 is provided with calibrations for common U.S. bar types: #5 tie bars (750 mm [30 in.]) and 32-, 35-, and 38-mm (1.25-, 1.375-, and 1.5-in.) dowel bars. Additional calibration can be obtained by sending the bars to MIT GmbH. The cost of calibration is about $1,000 per bar or per basket.

Figure 3. Pulling MIT Scan-2 along the joint being scanned.

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Highway: US 90
Direction: E
Station No.: 1 + 00
Lane: Lane 1
Joint: 1
Bar type: 454 x 38mm
Bar spacing: 300 mm
Concrete thickness: 280 mm

Bar No.	x-Location mm	Depth mm	Side Shift mm	Misalignm. hor. mm	Misalignm. vert. mm	Bar Space mm
1	129	138	54	-19	8	129
2	455	146	25	-7	-6	326
3	766	148	-2	-3	-10	311
4	1071	143	27	0	-2	305
5	1379	151	-13	8	12	308
6	1690	151	-32	-1	4	311
7	1996	148	-19	-3	6	307
8	2302	137	10	2	2	305
9	2601	140	9	-2	-10	300
10	2908	137	-9	-3	0	307
11	3211	141	-17	8	-7	304
12	3516	144	-26	2	-2	304

Figure 4. Data output from a joint scan shows depth, horizontal and vertical alignment, and identifying information.

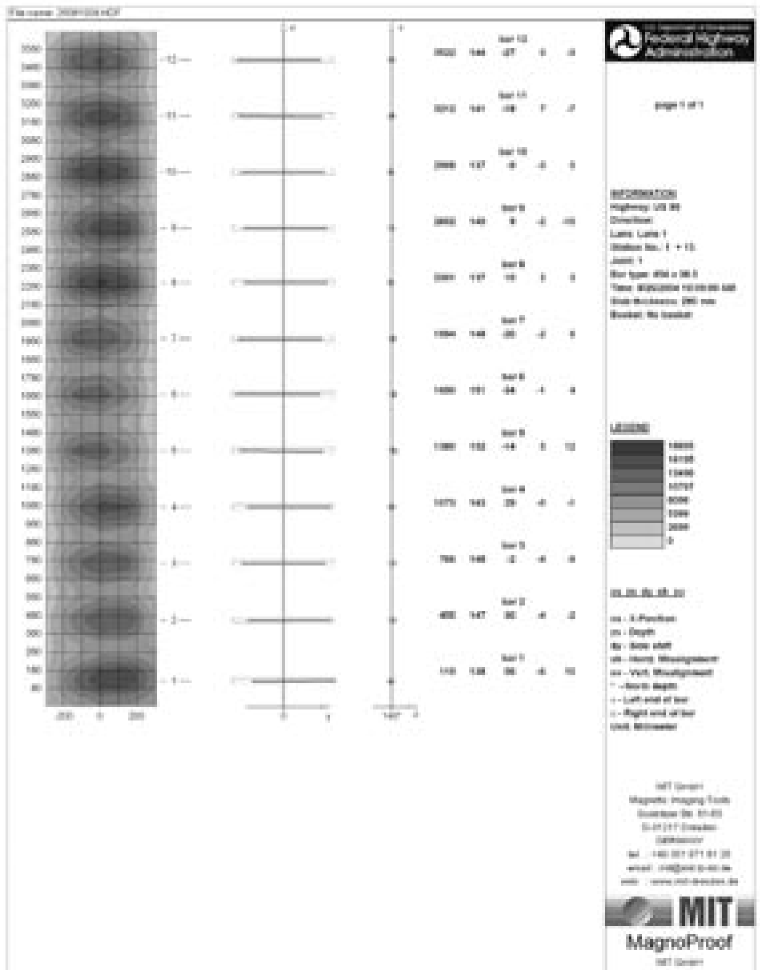

Figure 5. Graphical output displays signal strength and bar position.

OPERATION

The measuring process involves setting the rails alongside the joint to be scanned, entering the pavement information (bar diameter and length, slab thickness, joint length, and project information for reference) into the onboard computer, and then pulling the unit across the joint, as shown in Figure 3. The field data analysis is fully automated, and the results can be printed on the onboard computer.

For dowel bars, the field results produced by the system software are accurate for the following conditions:

- Mean dowel depth 150±40 mm (4.3 to 7.5 in.)
- Horizontal or vertical skew misalignment ±40 mm (1.6 in.)
- Lateral position error ≤80 mm (3.2 in.)

For other conditions, the system software can be used to conduct a more comprehensive analysis.

OUTPUT

Analysis results appear on the screen display and can be printed. A sample data report is shown in Figure 4. Figure 5 shows the graphical output, which is displayed in color. The contour map on the left displays the signal strength for each bar, and the diagram shows side and end views of the bar's actual position (gray bar) relative to its specified location (rectangle).

EFFECTIVENESS AND LIMITATIONS

MIT Scan-2 provides very accurate results, especially for dowel bars placed using a dowel bar inserter. However, the presence of foreign metallic objects within about 1 m (3 ft) of the bars being scanned essentially invalidates the results.

The dowel basket also interferes with the measurement results; however, approximate results can be obtained if two conditions are met: the dowel bars are epoxy coated, and the transport ties on the basket are either cut or removed. Under these conditions, the results for horizontal or vertical misalignment are very good, almost as good as the results for inserted bars. The reported bar depth, however, will be shallower than the actual because of the additional signal from the basket metal. The accuracy can be improved to a level comparable to that for the inserted bars by developing basket-type-specific calibration.

Even without specific calibration, the device is a useful screening tool for identifying problem areas. Any major problems in the bar placement or sawcut locations can be easily identified visually on the MIT Scan-2 images.

REFERENCES

Federal Highway Administration. 2005. *Use of Magnetic Tomography Technology to Evaluate Dowel Placement.* FHWA-IF-06-006. FHWA, Washington, DC.

National Cooperative Highway Research Program. 2005. *Guidelines for Dowel Bar Alignment.* NCHRP Project 10-69.

Portland Cement Association. 2005. *Dowel Bar Alignments of Typical In-Service Pavements.* PCA R&D Serial No. 2894. PCA, Skokie, IL.

Contact—The MIT Scan-2 device is available on loan to State highway agencies through FHWA's Mobile Concrete Laboratory. For more information, contact the following:

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Distribution—This TechBrief is being distributed according to a standard distribution. Direct distribution is being made to FHWA's field offices.

Availability—The publication from which this TechBrief was developed, *Use of Magnetic Tomography Technology to Evaluate Dowel Placement* (FHWA-IF-06-006), is available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (www.ntis.gov). A limited number of copies are available from the Research and Technology Product Distribution Center, HRTS-03, FHWA, 9701 Philadelphia Court, Unit Q, Lanham, MD 20706 (phone: 301-577-0818; fax: 301-577-1421).

Key Words—Concrete pavement, dowel bars, dowel bar alignment, pavement construction, pavement joints, quality assurance, quality control