NEW YORK'S EXPERIENCE WITH PLASTIC-COATED DOWELS

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Because of past difficulties with joint supports in concrete pavements, New York began an investigation of plastic-coated dowels in 1972. This paper describes the construction and early performance of 5 pavements built to satisfy 3 major objectives: first, to identify construction problems related to the dowels; second, to determine if uniform joint movements are maintained; and, third, to determine the long-range corrosion resistance of the dowels. The plastic-coated dowels evaluated have a 2-layer coating of 4 mils (0.1 mm) of asphalt covered by 17 mils (0.4 mm) of polyethylene; they were welded or clipped into basket assemblies and staked to the subbase before paving with a slipform paver. Construction evaluation consisted of observing installation, checking alignment and coating damage, and noting joint cracks after paving. Six dowel samples were removed from the completed pavement for laboratory testing. Joint movement and pavement cracking have been monitored for up to 2 years. Observations and measurements during construction indicate that assemblies of plastic-coated dowels were easy to install and provided satisfactory control of joint crack formation. Some problems with dowel misalignment, damaged coatings, and slippage of coatings off the dowel ends were observed, but these are not considered serious inasmuch as they can be corrected. Performance observations indicate that joints are moving uniformly in all 5 pavements, and no distress has appeared that can be related to the dowels. Based on these observations, plastic-coated dowels show promise as transverse joint load-transfer devices for heavy-duty portland cement concrete pavements.

•STEEL dowel bars have long been used as load-transfer devices in the transverse joints in portland cement concrete pavements. Considerable difficulties have been experienced, however, due to dowel misalignment during construction and dowel corrosion, either of which may lead to premature pavement distress, including midslab cracking, blowups, joint spalling, and faulting. To alleviate these problems, in 1964 the Ohio Department of Highways (1) installed a number of dowel bars coated with a 2-layer system consisting of yellow polyethylene plastic over an inner layer of asphalt mastic, developed by Republic Steel Corporation for gas lines. This coating was intended to provide corrosion protection at a considerably lower cost than the stainless-steel sleeves in use by some states (2) and at the same time to eliminate the need for a grease or oil bond-release agent. The load-transfer capability of these dowels was reported to be nearly as good as plain steel dowels for a total coating thickness of 21 mils (0.5 mm), although thicker coatings resulted in a loss of load transfer (3, 4). Since then, other plastic coatings have been introduced by other manufacturers. New York State has used both dowels and various proprietary load-transfer devices (mainly malleable-iron castings) over the years, experiencing difficulties with both (5, 6).

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Since the plastic-coated dowel seemed to offer an economically attractive means of overcoming the difficulties previously experienced, an investigation of this device was begun in 1972. Plastic-coated dowels were installed in part of one paving contract in 1972 and throughout 4 others in 1973.

This paper describes the construction and early performance of the 5 pavements. The research was intended to satisfy 3 major objectives: (a) to identify construction problems related to the dowels and basket assemblies; (b) to determine if plastic-coated dowels are capable of maintaining uniform joint movements; and (c) to determine the long-range corrosion resistance of plastic-coated dowels in service.

INVESTIGATION

Load-Transfer Devices

The 3 types of load-transfer device under study are shown in Figure 1. The malleable-iron sleeve had been the standard device used by New York from the late 1950s until 1972 and was included as a control in the first test pavement. Both plastic-coated dowels are of the same type, a steel dowel $1\frac{1}{8}$ in. (29 mm) in diameter coated with a 4-mil (0.1-mm) asphalt coating and a 17-mil (0.4-mm) polyethylene outer layer. However, the dowels were fabricated into one type of joint assembly by welding and into the other by means of metal clips. All 3 devices were assembled into 12-ft (3.66-m) units and staked to the subbase prior to paving.

Test Pavements

The 5 test pavements (Table 1) all have dual pavements 24 ft (7.32 m) wide. The first—a parkway—is 8 in. (203 mm) thick, whereas the others are 9 in. (229 mm) thick. All were paved with a CMI slipform paver, supplied with central-mixed concrete, over a 12-in. (305-mm) gravel subbase. Sections containing the sleeve devices have joints spaced at 61 ft, 6 in. (18.74 m); the others are spaced at 63 ft (19.20 m). Reinforcing mesh with No. 0 longitudinal wires at 6-in. (152-mm) spacings and No. 3 transverse wires at 12-in. (305-mm) spacings was used in all the pavements, with a clearance of 3 in. (76 mm) provided between the ends of the mesh and the load-transfer devices.

Test Procedures

The evaluation consisted of carefully inspecting the load-transfer devices before paving, observing their installation and the paving, installing pins at the joints to measure joint movements, inspecting the finished joints after paving, and measuring joint widths. Several test sections of 30 joints each have been selected for intensive study, but paving operations and subsequent pavement performance are being monitored for entire contracts. Weather conditions and concrete properties were documented during paving, since they ultimately may affect performance of the pavement. After paving was completed on the first contract, a total of 6 dowels were cut out of the pavement and subjected to laboratory pullout tests.

Semiannual inspections started after paving was completed and will continue for a number of years. These include joint-width measurements, crack surveys, and riding-quality measurements. Joint faulting will be measured if it develops.

Figure 1. Load-transfer devices (not to scale).

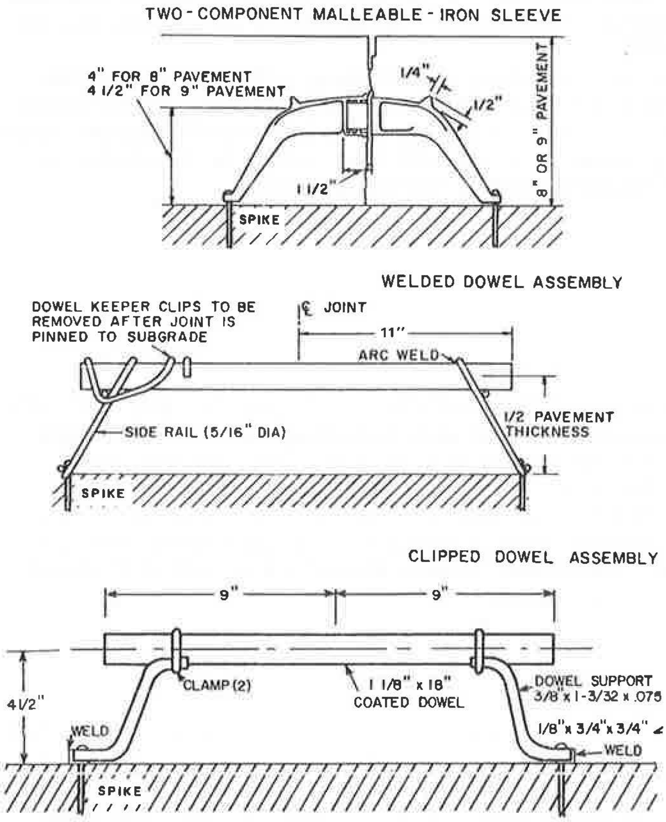


Table 1. Pavement details.

Location	Route	Year Paved	Section	Load Transfer (Figure 1)
Point Breeze	Lake Ontario State Parkway	1972	1	Sleeves
			2	Welded dowels
			3	Welded dowels
			4	Welded dowels
Avoca	Interchange, Southern Tier and Genesee Expressways	1973	–	Clipped dowels
Hornell	Southern Tier Expressway	1973	1	Welded dowels
			2	Welded dowels
Olean	Southern Tier Expressway	1973	1	Welded dowels
			2	Welded dowels
Oneonta	Susquehanna Expressway (I-88)	1973	1	Clipped dowels
			2	Clipped dowels

RESULTS

Installation of Joint Assemblies

Installation of joint supports was observed to determine the time and effort required to align them properly and stake them in place. At Point Breeze, a point was set on the pavement centerline to locate each joint longitudinally. A crew consisting of a foreman and 4 laborers unloaded the devices and set them in place. The 12-ft (3.66-m) sections of either device were handled easily by 2 men. Once set in place, they were aligned by eye to a right angle with the centerline and staked to the subbase. At first J-shaped hooks made from No. 4 (13-mm) reinforcing bars were used as pins, but they were difficult to drive into the compacted subbase, so 12-in. (305-mm) 60-d spikes were substituted. Although much easier to drive, the spikes were still not ideal because their small heads provided relatively little horizontal surface area to grip the transverse wire of the basket. In all, 7 or 8 spikes were used for each 12-ft (3.66-m) section of both joint support types. Considerable caution was necessary in staking the dowel assemblies to avoid hitting the wire basket and damaging it. While the 2-component devices were easier to stake (the base angles are provided with holes for this purpose), this advantage was far outweighed by the inherent instability of the assemblies. Great care had to be taken while handling them to avoid damage, and they had to be carefully aligned after being placed on the grade to ensure that each casting would open and close without binding. After the dowels were staked in place, nails were placed just outside the pavement edges at the center of the dowels to align the sawcut. For the sleeve device, a cotter key was attached to each end of the centerplate, and a wire attached to it ran to the outside of the pavement. After the paver passed, this wire was pulled out to locate the cotter key and thus the ends of the centerplate, marking the position for the sawcut. Although production varied from time to time, the stake-out crew could generally prepare about 25 dowel joints per hour but only 8 or 9 sleeve joints in the same period.

On the other 4 pavements, 3 points were set on the subbase to align each joint—one on the centerline and one outside each pavement edge, making alignment much easier. These devices were pinned to the subbase as on the first pavement. The clipped devices had holes through the base angles for this purpose, which made them the easiest of the three types to install.

Joint Alignment

The joint assemblies were checked carefully before paving for misalignment or other problems; the types of alignment checked are shown in Figure 2. Because the dowels were shop-fabricated into baskets, both transverse spacing and horizontal alignment were extremely consistent. No assemblies were found with any appreciable error in either respect. Vertical alignment, however, did present minor problems. A number of joints were checked on each job, with the results given in Table 2. Generally, no more than 1 or 2 dowels per joint were misaligned, although in a few cases there were several, generally near the ends of the assembly and probably due to rough handling during transportation and installation. The vertical alignment errors detected could have been prevented by more careful handling or corrected before paving, which was effectively accomplished on the 3 contracts having few vertical alignment errors.

At Point Breeze, longitudinal alignment of the dowels was poor. Variations of up to 2 in. (51 mm) were noted in a few instances, and errors of 1 in. (25 mm) occurred in nearly every assembly; this can be seen in Figure 3, which shows a typical joint assembly (one dowel near the center of this assembly is also vertically misaligned). Bowing of the basket assembly (Figure 4) was common at Oneonta and to a lesser degree at the other 3 locations. Both problems resulted in the same defect—decreased embedment length of some dowels.

The joint devices were watched closely during concrete placement for signs of

Figure 2. Dowel alignment errors.

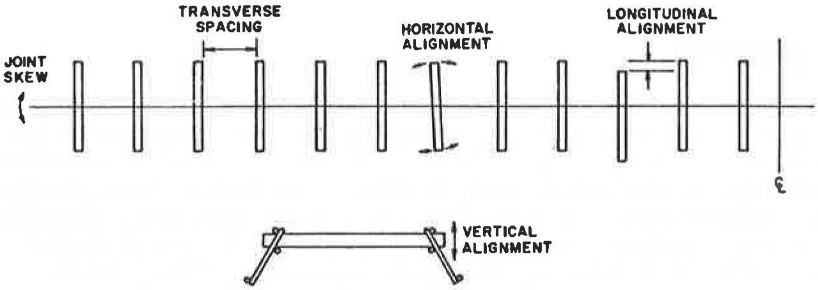


Table 2. Summary of vertical dowel alignment.

Location	Dowels Inspected	Dowel Misalignment, in.			
		½	¾	1	1¼
Point Breeze	15,720	60	12	1	0
Avoca	720	0	0	0	0
Hornell	1,440	8	1	1	1
Olean	1,440	2	0	0	0
Oneonta	1,334	3	0	0	0

Note: 1 in. = 2.54 cm.

Figure 3. Dowel assembly installed on grade at Point Breeze.

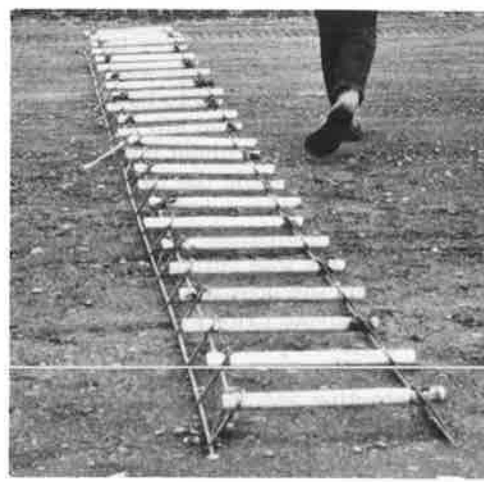
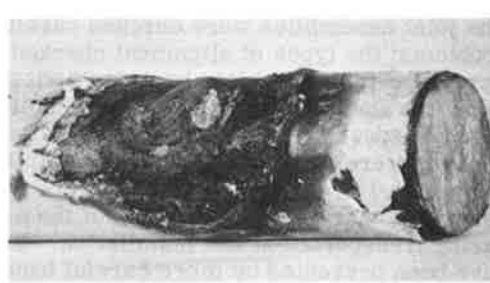


Figure 4. Bowed dowel assembly at Oneonta.

Figure 5. Coating damaged by welding.



pushing or shoving as a result of concrete pressure against the dowels or sleeve devices. At no time was any appreciable movement detected.

Finally, the joints were checked after paving to detect any deviation from a right angle with the pavement centerline. On the 4 pavements where 3 points were used to set the joint alignment, no errors were found. However, at Point Breeze, where only one point was set, alignment errors as great as 13 in. (330 mm) were found. Of 120 joints checked, 33 were skewed less than 1 in. (25 mm), 36 between 1 and 4 in. (25 and 102 mm), 34 between 4 and 7 in. (102 and 178 mm), 12 between 7 and 10 in. (178 and 254 mm), and 6 between 10 and 13 in. (254 and 330 mm). Joints containing sleeves and those containing dowels both were affected.

Since the ends of the centerplate and centers of the dowels were positively located to mark the sawcuts, their alignment corresponds closely to that of the joint support. Therefore, the 13-in. (330-mm) misalignment in a pavement 24 ft (7.32 m) wide is equivalent to a horizontal misalignment of ¾ in. (19 mm) in the 18-in. (457-mm) length of the dowels. However, all dowels in a joint would be parallel.

Coating Damage

A second type of deficiency was damage to the plastic coating, which was most severe on the welded baskets. The weld was designed to be placed approximately 1 in. (25 mm) from one end of each dowel so, when placed properly, only 1½ to 2 in. (38 to 51 mm) of plastic on the end of the dowel was damaged by the weld. However, if the dowel was misaligned in the basket, as was the case at Point Breeze, the damaged coating extended as much as 3 or 4 in. (76 or 102 mm) into the length of the dowel. While most welds were properly placed, a few dowels in each basket at Point Breeze generally approached this extreme. Figure 5 shows a badly burned dowel. While the plastic coating on the clipped dowels was generally in very good condition, a few dowels in most assemblies had approximately 1 in. (25 mm) of coating missing from one end. The dowel bar stock was coated in 21-ft (6.40-m) lengths and the coating shrank about 1 in. (25 mm) on each end. When cut to 18-in. (457-mm) lengths, two dowels were left with short coatings and were painted with red lead primer to inhibit corrosion (Figure 6).

Joint Crack Formation

Since the dowel assemblies did not contain centerplates to control the location and shape of the joint crack, there was some concern that the cracks would not form properly, although each joint was sawed to approximately one-third the pavement depth the night after paving with a diamond-blade concrete saw. Therefore, the time of crack formation and condition of the joint cracks were noted. Because most of these projects were located several hundred miles from the Department's main office, research personnel were not at the job sites on weekends and holidays to check the previous day's placement of concrete for crack development, so only part of the joints were checked. In addition, widths of the shrinkage cracks were determined on three projects by measuring the distances between the joint pins before and after cracking. The results are given in Table 3.

The number of cracks occurring the first night varied from section to section because the weather during paving varied considerably. Sections paved during hot weather, however, cracked completely by the second or third night after paving; in those sections paved in cooler weather a substantial number of cracks appeared by the second day after paving. The time cracks occurred had no apparent effect on initial crack width. Six of the 7 test sections measured had nearly identical widths, between 0.052 and 0.071 in. (1.32 and 1.80 mm), and all 7 were uniform (low standard deviation). Even in those sections where the cracks developed a few at a time over several days, all the joints developed about the same initial width.

None of the pavements experienced problems with cracks occurring before sawing nor with spalling due to early sawing. The lack of a centerplate seemed to be no

Figure 6. Bare dowel ends painted with red lead.

Table 3. Widths of initial joint cracks.

Location	Section	Width, in. $\overline{X}$	Width, in. σ	Percent Cracked First Night	Percent Cracked Second Night	Percent Cracked Third Night
Point Breeze	1	NA	NA	53	NA	100
	2, 3, 4	NA	NA	51	NA	100
Hornell	1	0.062	0.024	80	100	–
	2	0.052	0.016	100	–	–
Olean	1	0.059	0.006	0	100	–
	2	0.037	0.010	70	80	NA
Oneonta	1	0.055	0.017	50	63	NA
	2	0.071	0.015	0	NA	NA

Note: NA = data not available (no Avoca data available).

Figure 7. Pavement sample pullout test.

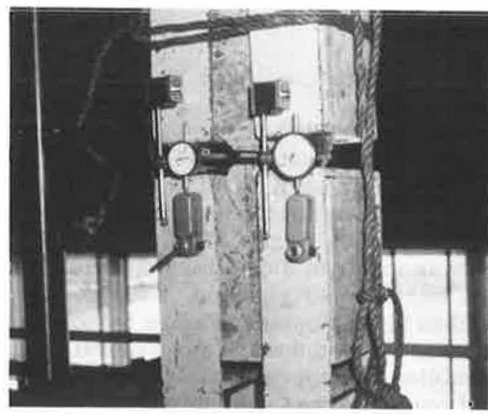


Table 4. Summary of joint movement.

Location[a]	Section	n	Summer to Oct. 1972 $\overline{X}$, in.	σ, in.	ΔT, deg F	Oct. 1972 to Jan. 1973 $\overline{X}$, in.	σ, in.	ΔT, deg F	Jan. to June 1973 $\overline{X}$, in.	σ, in.	ΔT, deg F	June 1973 to Jan. 1974 $\overline{X}$, in.	σ, in.	ΔT, deg F
Point Breeze	1	30	0.118	0.0059	40	0.007	0.0058	2	0.120	0.0106	31	0.165	0.0123	53
	2	30	0.127	0.0059	50	0.016	0.0076	2	0.146	0.0120	31	0.175	0.0124	53
	3	30	0.104	0.0059	45	0.018	0.0062	2	0.112	0.0103	27	0.171	0.0192	49
	4	30	0.137	0.0104	45	0.016	0.0098	2	0.142	0.0131	24	0.177	0.0105	46
Hornell[b]	1	30	–	–	–	–	–	–	–	–	–	0.136	0.0412	37
	2	30	–	–	–	–	–	–	–	–	–	0.117	0.0208	37
Olean[c]	1	30	–	–	–	–	–	–	–	–	–	0.159	0.0162	27
	2	21	–	–	–	–	–	–	–	–	–	0.191	0.0148	27
Oneonta[c]	1	30	–	–	–	–	–	–	–	–	–	0.110	0.0314	44
	2	26	–	–	–	–	–	–	–	–	–	0.085	0.0329	44

Note: 1 in. = 2.54 cm, 1 deg F = 0.55 deg C.

[a]No Avoca data available. [b]Initial reading July 1973. [c]Initial reading August 1973.

Table 5. Pullout test results for Point Breeze dowels.

Sample	Maximum Load, lb	Joint Opening at Maximum Load, in.	Load at ½-in. Joint Opening, lb
2A	740	0.157	560
2B	260	–	220
3A	600	0.065	460
3B	1,000	0.141	640
4A	600	0.147	180
4B	440	0.100	440

Note: 1 in. = 2.54 cm; 1 lbf = 4.448 N.

Table 6. Point Breeze dowel positions.

Sample	Distance From Joint to Fixed End, in.	Depth to Welded End, in.	Depth to Free End, in.
2A	8	4¼	4
2B	7½	4	4½
3A	10	4$^{3}/_{16}$	–
3B	8	4½	4½
4A	9½	6	5½
4B	8	3½[a]	3¾[a]

[a]Distance from slab bottom.

disadvantage in crack control, since no cases were found where the crack deviated appreciably from the vertical or from a straight line.

Joint Movement

Widths of transverse joints in the test sections have been measured semiannually since the completion of paving; these results are summarized in Table 4 for all but one pavement, where no summer reading was obtained in 1973. The amount of movement varies somewhat among test sections over similar temperature ranges, but since joint width depends on temperature history before each measurement as well as on exact temperature at the time of measurement, these differences are not surprising. Width changes within each test section are very uniform, as evidenced by the low standard deviations. In comparing the uniformity of width change between test sections, some differences are seen, but they are small and show no advantage for any test section or joint type.

Joint Pullout Tests

At the conclusion of paving at Point Breeze, joint samples were removed from the end of each of the 3 sections containing dowels for testing in the laboratory. The pavement was sawed full-depth with a diamond-blade concrete saw to form a block 2 ft (0.6 m) square along the edge of the pavement. These blocks, containing 2 dowels each, were bolted rigidly across the joint to prevent any movement during removal and shipping. In the laboratory, each sample was cut in half (each half containing 1 dowel) and prepared so the sample could be fitted into jigs for the pullout test (Figure 7).

As the pullout load was applied, joint opening was recorded from dial indicators. The maximum load and joint opening at which it occurred were recorded, as well as the load at the ½-in. (13-mm) joint opening; these are given in Table 5. The loads required to open the joints ½ in. (13 mm) are very low compared to earlier results (5) where loads ranged from 4,100 to 14,000 lb (18 237 to 62 272 N) to open joints containing plain steel and stainless-steel-clad dowels that had been in service several years. After the pullout tests were completed, the concrete was carefully broken apart to examine dowel condition and position. In spite of low pullout loads, the plastic coating was not an entirely effective bond-release agent. The dowels apparently slid inside the plastic sleeve, and the plastic had slipped approximately ¼ in. (6 mm)—half the joint movement—off the free end of the dowel. In addition, concrete around the dowels was stained yellow—further evidence that the plastic had bonded to the concrete. Ohio had reported a similar problem (1) for plastic-coated dowels installed there. Otherwise, the plastic coating was in good condition and showed no signs of abrasion or other deterioration. The distance from the joint face to the fixed end of each dowel and the depth from the pavement surface to the center of the dowel on each end are both given in Table 6.

The design thickness of the Point Breeze pavement is 8 in. (203 mm), and thus the depth to the centerline of the dowels should be 4 in. (102 mm). The depth from the base of the slab is also set at 4 in. (102 mm) by the basket assembly. However, if the pavement thickness varies, more than 4 in. (102 mm) of concrete will be above the dowels, as was the case for sample 4A. Concrete depth above the dowel for sample 4B (from the same joint as 4A) was also considerably greater than 4 in. (102 mm), but the concrete broke in such a manner that it was impossible to obtain an accurate measurement; instead, depth to the bottom of the pavement is reported. Table 6 shows that some of these dowels were poorly aligned—2 by ½ in. (13 mm) and 2 others by ¼ in. (6 mm). This is considerable and surprising, since the dowels displayed good alignment before paving. Large variations from the joint to the fixed end, however, are not surprising, considering the fabrication deficiencies mentioned earlier. For the 18-in. (457-mm) dowels, the joint should have been 9 in. (229 mm) from each end, but instead it was as low as 7½ in. (190 mm).

Pavement Cracking

Since the completion of paving, the test roads have been observed semiannually for signs of pavement cracking or deterioration. Through January 1974, no deterioration other than a few small isolated spalls was noted at any of the transverse joints, and, except at Point Breeze, no midslab cracks have appeared. The first transverse crack at the latter site (paved in July 1972) was noted during the October 1972 survey, appearing as a hairline across both lanes at approximately the one-third point of a slab with doweled joints. By the June 1973 survey, 36 had occurred, all very tight hairline cracks perpendicular to the centerline. Of 101 slabs with sleeve joint supports, 10 had a total of 11 transverse cracks across the driving lane; 2 extended on across the passing lane. Of 1,120 slabs with doweled joints, 25 cracks had formed in 25 slabs, with 15 extending across the passing lane. None of the cracks observed showed signs of movement or broken mesh, and none were faulted.

By January 1974, 760 midslab cracks had developed; all were very tight hairline cracks, usually near either the third point or the center of the slab. In some cases, 2 or 3 were noted in a single slab, although there was generally only 1. None were major structural cracks, and they are attributed to high temperatures during paving. Similar cracking has been noted on a few other pavements in New York, and thus these were not attributed to the use of dowels. Further, pavement sections with sleeve-type joint devices have developed as much cracking as those with dowels.

DISCUSSION AND SUMMARY OF FINDINGS

Based on the information gained from the field test installations, plastic-coated dowel assemblies may prove to be satisfactory load-transfer devices for transverse joints in heavy-duty concrete pavements. Construction problems are minimal and installation proceeds rapidly. Even without a centerplate, sawing the pavement to about one-third its depth has provided excellent control of joint crack formation. In most cases, joint cracks have appeared within 3 days after paving and have been straight and vertical with no spalling or secondary cracking. In addition, initial crack widths have been very uniform, even where all did not occur the same day.

While a few alignment deficiencies have been noted in the dowel assemblies, they generally affected only a small percentage of the dowels, and these could be prevented or corrected. Longitudinal misalignment, however, is an exception, since bowed assemblies and staggered dowels were quite common. This condition, which results in a reduced embedment length, was most severe when combined with weld damage to the plastic coating and could lead to corrosion of the unprotected dowel ends. Careful alignment of the assemblies and careful inspection before paving, combined with improved fabrication techniques, are essential to eliminate these deficiencies. Another potential problem is slippage of the plastic coating on the dowels, as discovered on specimens removed from one test pavement. This slippage could lead to failure of the coating and provide a potential starting place for corrosion.

In conclusion, plastic-coated dowels show promise as a transverse-joint load-transfer device. However, adequate care must be taken to ensure that the dowels are properly aligned before paving. Furthermore, improved fabrication techniques are needed to lessen damage to the plastic coating due to welding, and steps are necessary to lessen slippage of the plastic coating on the dowel. Several years of performance under traffic will be necessary to determine the overall suitability of these devices, but, except for a few correctable deficiencies, it now can be concluded that these devices are satisfactory from a construction standpoint.

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