

An ***IPRF*** Research Report
Innovative Pavement Research Foundation
Airport Concrete Pavement Technology Program

Report IPRF-01-G-002-4.1

Evaluation of Dowel Bars Installed Using Plastic Sleeves



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Evaluation of Dowel Bars Installed Using Plastic Sleeves

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1. INTRODUCTION

The conventional procedure for inserting dowel bars at longitudinal construction joints involves drilling holes after the concrete has gained sufficient strength. A new, innovative dowel bar installation procedure has the potential to greatly facilitate concrete pavement construction by eliminating the drilling step. The procedure involves inserting plastic sleeves into plastic concrete (Figure 1). The plastic sleeves are later stripped (Figure 1c), and the dowels are installed in the holes left after the removal of the plastic sleeves. Plastic sleeves can be stripped without causing damage to concrete at a lower strength than for drilling. This early access to pavements can be important in time-critical projects.



(a)



(b)



(c)



(d)

Figure 1. (a) A plastic sleeve being inserted into plastic concrete; (b) Plastic sleeves after the insertion; (c) Stripping the plastic insert; (d) A hole left behind after stripping the plastic sleeve.

To demonstrate that the new technique for dowel bar installation is free of deleterious effects, the technique must produce dowel bar alignments that exceed or are comparable to the bars installed using conventional methods without causing other problems. Because the new technique involves inserting the sleeves into plastic concrete, the following factors are also of concern:

- Consolidation of concrete around the plastic sleeves.
- Bumps on the pavement surface (causing roughness) due to the concrete being displaced as the sleeves are inserted into plastic concrete.

The objective of this study is to evaluate the viability of the new technique. This was accomplished by evaluating the factors that determine the engineering characteristics of the dowels after the installation. The factors evaluated include the following:

- Dowel bar alignment.
- Consolidation of concrete around the plastic sleeves.
- The impact of the insertion techniques on pavement surface profile.

2. APPROACH

The feasibility of the new construction technique was evaluated by field testing. The testing was conducted at Hopkins International Airport in Cleveland, Ohio, with the cooperation of the city of Cleveland and Anthony Allega Cement Contractors, Inc., also of Cleveland, from May 19 through 21, 2004.

The test section was a short section of the outermost row of slabs in the Runway 6L-24R extension (Figure 2). The dowel bar alignment was evaluated by comparing the alignment of the dowel bars installed using plastic inserts and those installed by drilling (control section). The plastic sleeve section consisted of 20 joints, and the control section consisted of 2 replicates of 30 joints each. The length of the plastic sleeve section was limited to 20 joints because of logistical limitations.

The field testing included the following:

- Comparison of the alignment of the dowel bars installed using the plastic sleeves and those installed in conventionally drilled holes (control section). The dowel bar alignments were evaluated using MIT Scan-2, a state-of-the-art nondestructive testing (NDT) device for detecting the exact position and orientation of metal bars embedded in concrete.
- Evaluation of concrete consolidation around the plastic sleeves. Three cores each were taken from each section near the end of the dowel and a visual examination was accomplished to evaluate the quality of concrete consolidation around the dowel.
- The surface profile was measured using a Dipstick. The surface profile was measured along the ends of the dowels and along a line offset from the dowels. The two profiles were compared to determine if the profile along the ends of the dowel bars show any noticeable bumps due to the material displaced by the insertion of the plastic sleeves.

The results for the section where the plastic sleeves were used were compared with those for the control section.



Figure 2. Test section for plastic sleeve at Hopkins International Airport in Cleveland, OH.

3. DOWEL BAR ALIGNMENT

The dowel bar alignment for both the plastic sleeve and control sections was measured using MIT Scan-2 (Figure 3), an automated device that is designed specifically for measuring dowel bar alignment. MIT Scan-2 emits a weak electro-magnetic pulse and detects the transient magnetic response signal induced in metal bars using an array of sensitive detectors. The methods of magnetic tomography are then used to determine the position of the bars. An example of output from the fully automated data analysis program MagnoProof is shown in Figure 4. Because MIT Scan-2 was designed and optimized specifically for measuring dowel bar alignment, it produces very accurate results. The overall standard deviation of measurement error is less than 2 mm for horizontal and vertical alignment results.



Figure 3. MIT Scan-2, a magnetic imaging device for measuring dowel bar alignment.

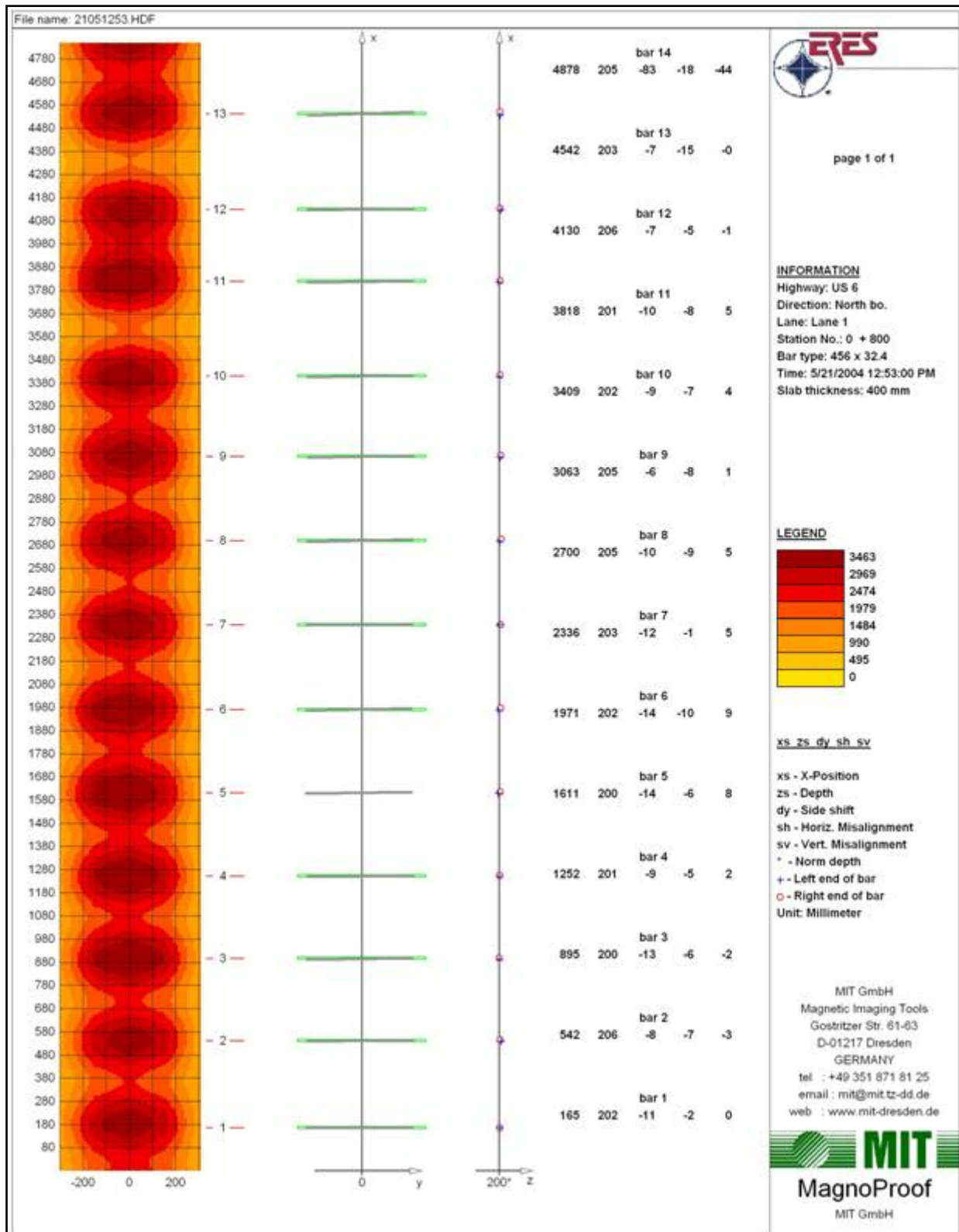


Figure 4. Example output of MIT Scan-2 showing the orientation of the detected bars.

The FAA standard for dowel bar placement accuracy is 0.25 in (6.4 mm) per foot (305 mm) of bar length for both horizontal and vertical alignment (FAA 1998). For the 20-in (508-mm) bars used in the test sections, the tolerance is 0.42 in (10.6 mm).

In general, the quality of dowel alignment was excellent. Figure 5 shows a comparison of the vertical alignment obtained in the plastic sleeve section as compared to the control section. The dowel bars installed using plastic sleeves have better vertical alignment than that observed for the drilled-in bars. About 2% of the bars installed using plastic sleeves are out of spec for vertical alignment, but this level of misalignment is not likely to cause any performance problems. The results are as good as can be achieved in the field by the conventional method of dowel placement.

Figure 5 shows that a significant percentage (8.9%) of the drilled-in dowel bars have vertical misalignment greater than 0.6 in. (15 mm). This is not a concern. The misalignment is uniform. The MIT Scan-2 data indicate that the gang-drill that was used to drill the control sections may have been set with a 0.35 in (9-mm) tilt with the hole at the joint face being lower than the interior end. A study by Khazanovich et al. (2001) showed that a uniform misalignment is not detrimental, and that a significant amount of uniform misalignment (up to as much as 2 in [50 mm]) can be tolerated.

The difference between uniform and nonuniform misalignment is illustrated in Figure 6. If the uniform misalignment is taken out of consideration (by subtracting the average misalignment), only about 0.2% of drilled-in bars are misaligned by more than 15 mm (0.6 in). Based on available information, the vertical misalignments of the dowel bars in the control sections are not likely to cause joint performance problems.

The results for horizontal alignment are shown in Figure 7. The control sections (drilled-in dowels) exhibited excellent horizontal dowel bar alignment. The results for the plastic sleeve section are not as good; however, the limitations of the prototype equipment used to insert the plastic sleeves, rather than the process itself, is responsible for the higher occurrences of more severe horizontal misalignments in the plastic sleeve section. The plastic sleeves are inserted in the free edge of newly paved lane using a mechanical inserter that is mounted on the side of the paver.

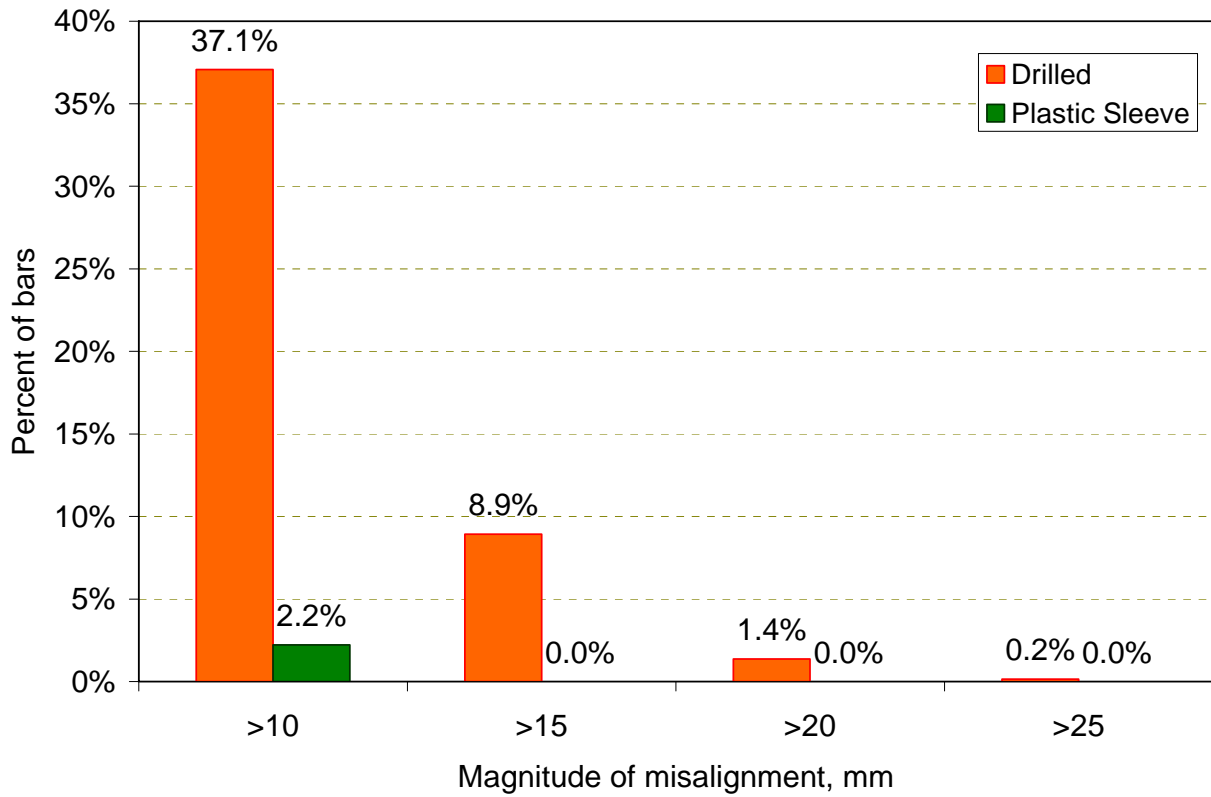


Figure 5. Comparison of vertical misalignment of dowel bars installed using the conventional method (drilled) and plastic sleeves.

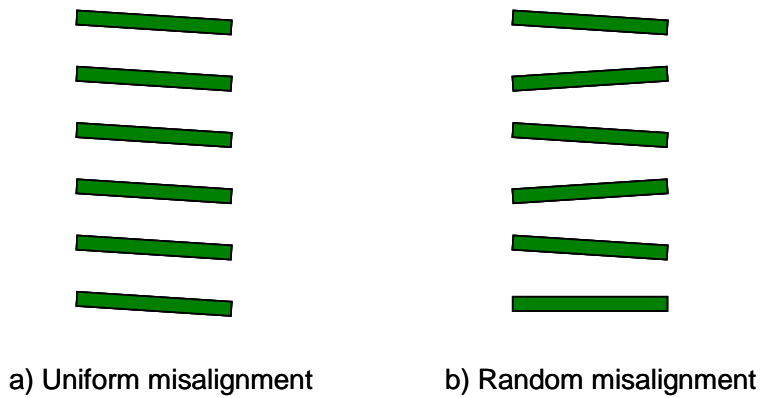


Figure 6. Uniform vs. random misalignment of dowel bars.

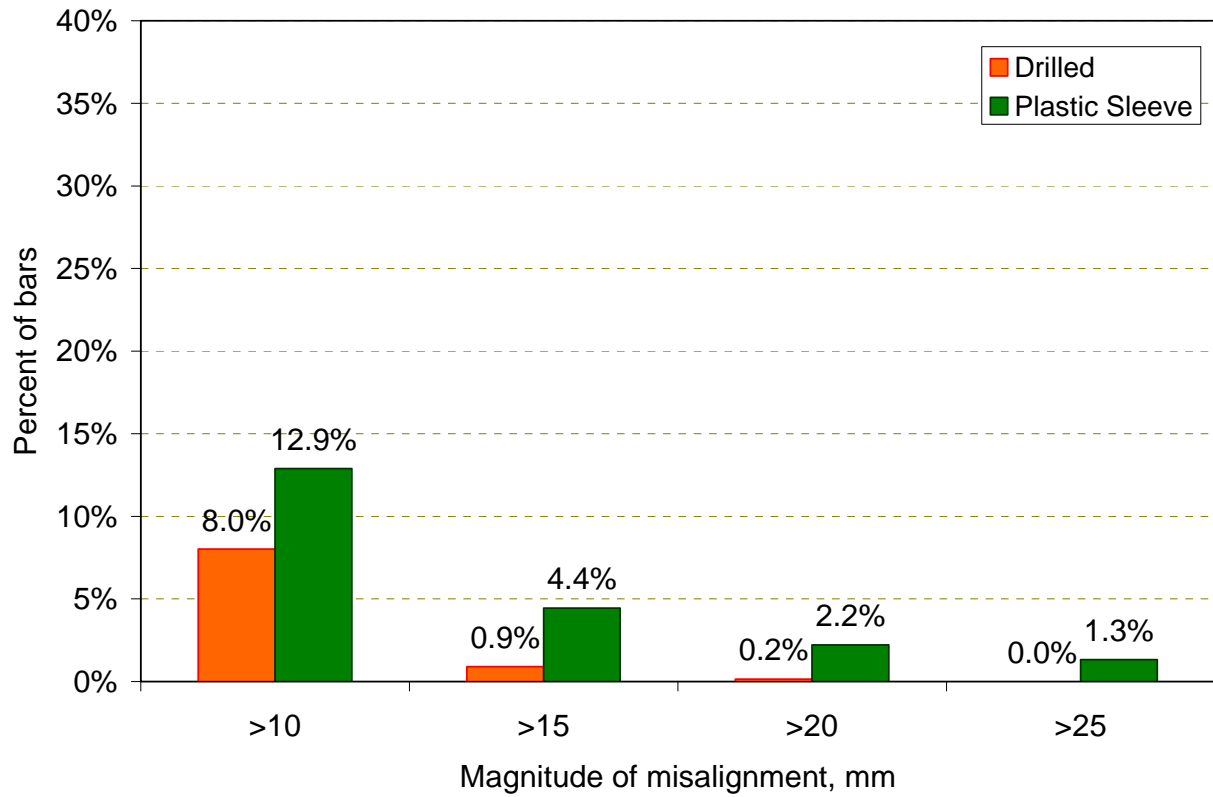


Figure 7. Comparison of horizontal misalignment of dowel bars installed using the conventional method (drilled) and plastic sleeves.

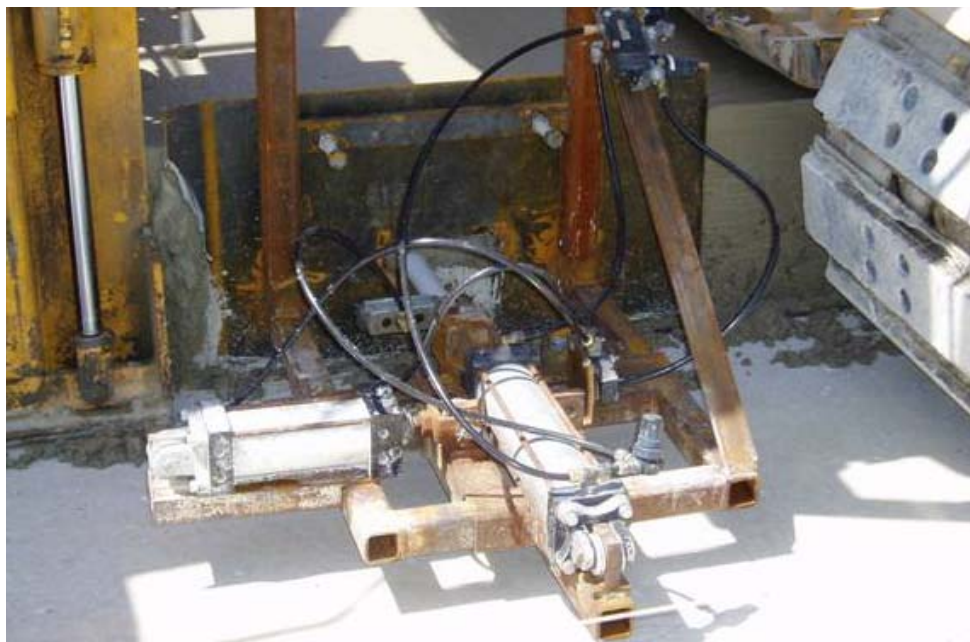


Figure 8. Plastic sleeve inserter attached to the paver.

To insert the plastic sleeve while the paver is moving, the inserter must remain stationary over the period that a plastic sleeve is being inserted. On the prototype equipment, this was accomplished using a simple hydraulic jack. A horizontal jack pushes the inserter within the inserter assembly, so that the inserter is stationary with respect to the concrete slab. The rate at which the inserter is pushed must match the advancing speed of the paver. On the prototype equipment, the rate at which the inserter was pushed was controlled by pneumatic pressure, rather than by a more sophisticated device with a positive control for matching the paver speed. Occasionally, the pneumatic jack was stuck, causing the plastic sleeve to drag. The results with and without the equipment problem are shown in Figure 9.



Figure 9. Dowel holes created using plastic sleeves: (a) result where the horizontal hydraulic jack snagged; (b) result where the equipment functioned properly.

The production equipment that would be used for plastic sleeve insertion should have positive controls for holding the inserter stationary during the insertion process and avoid the problems with horizontal alignment. As a proof of technology, the prototype device adequately demonstrated that the process works. The snagging occurred only a handful of times, and if the results from those incidences are taken out, the horizontal alignment results for the plastic sleeve section compares well with those of drilled-in bars (see Figure 10).

Figure 11 shows the distribution of the resultant misalignment, combining the vertical and horizontal misalignments (square root of the sum of the squares). The resultant misalignment reflects the overall quality of dowel bar alignment. Figure 11 includes all bars for the plastic sleeve section. As shown in Figure 11, even with the results for the bars that have a large horizontal misalignment due to the equipment problem, the results for the plastic sleeve section compare well with the drilled-in bars. Without the results for the sleeves that were affected by the equipment problem, the plastic sleeve section would have no bars in the higher-degree of misalignment categories (0.79 in [>20 mm]).

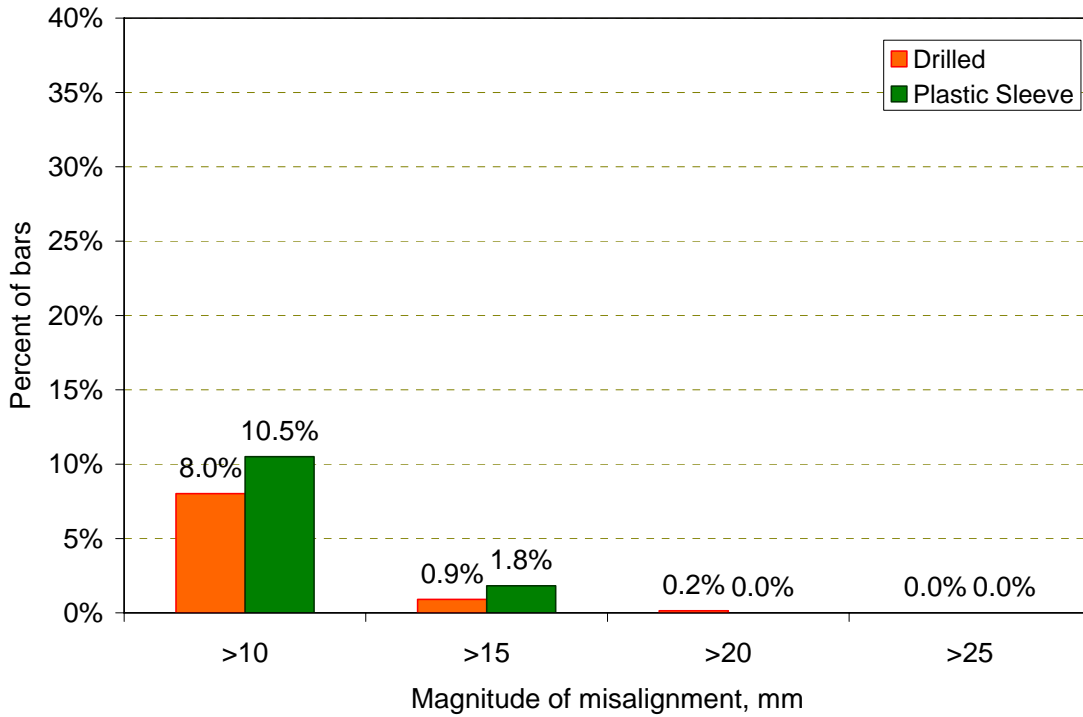


Figure 10. Comparison of horizontal misalignment, excluding the sleeves that experienced equipment problems.

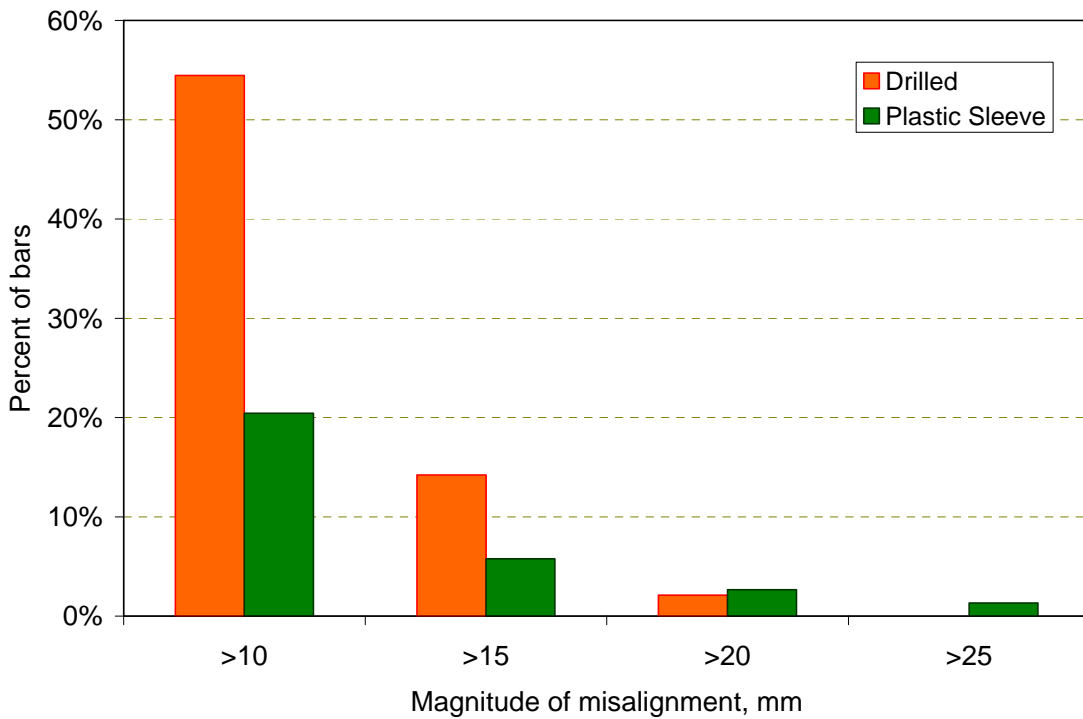


Figure 11. Comparison of resultant alignment.

4. EVALUATION OF PCC CONSOLIDATION

The consolidation around the dowels installed using plastic sleeves was evaluated by visual inspection of the cores retrieved from each section. Three cores each were taken from the plastic-sleeve and control sections from the ends of the dowels (Figure 12). The actual cores from the plastic sleeve section are shown in Figure 13, and those from the control section are shown in Figure 14.

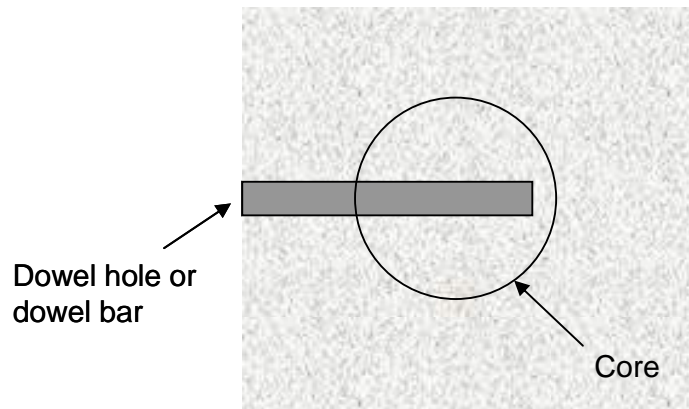


Figure 12. Illustration of coring location.



Figure 13a. Core 1 from the plastic sleeve section.

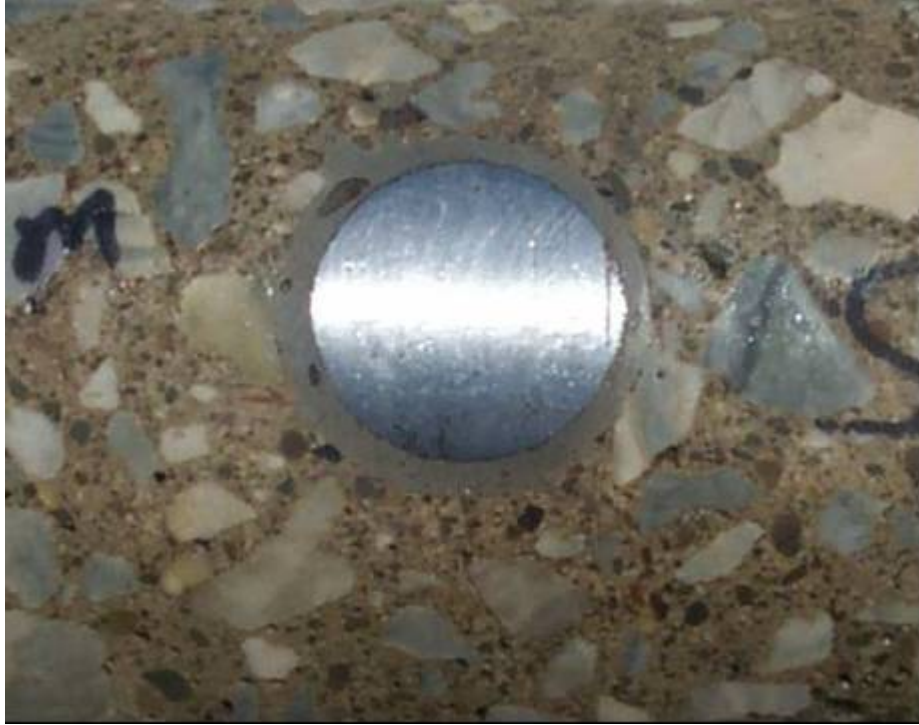


Figure 13b. Core 2 from the plastic sleeve section.



Figure 13c. Core 3 from the plastic sleeve section.



Figure 14a. Core 1 from the control section.



Figure 14b. Core 2 from the control section.

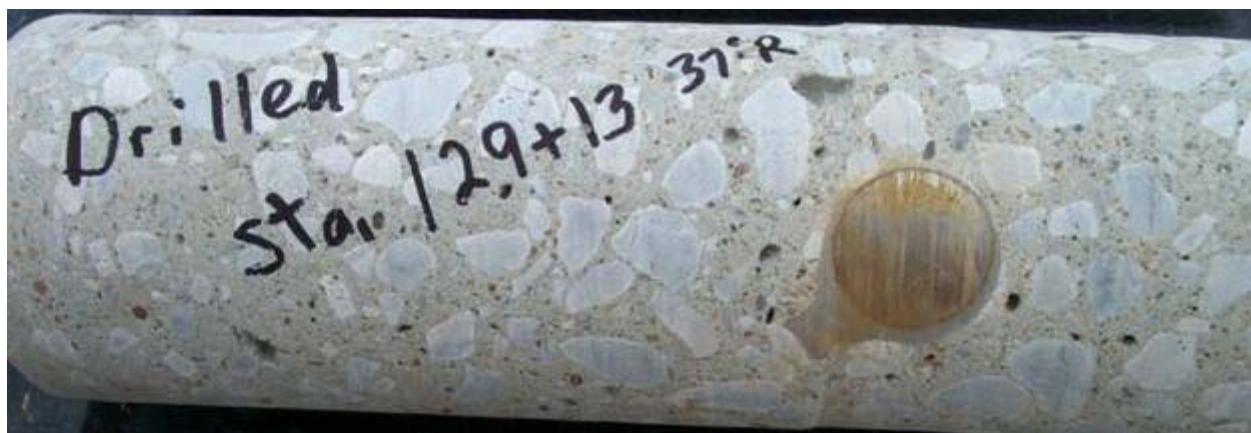


Figure 14c. Core 3 from the control section.

A visual inspection of the cores did not show any significant difference in the quality of consolidation around the dowel bars. At the joint face, the dowel holes created using the plastic sleeves can offer better support than the drilled holes. The drilling causes some spalling around the holes at the joint face, whereas the plastic sleeves can produce smooth, formed holes (Figure 15). Proper functioning of the plastic sleeve inserter is essential to obtaining the smooth finish around the dowel holes at the joint face. Some snagging of the plastic sleeves occurred during paving with the prototype inserter, but such problems could be easily eliminated by the use of a production-grade inserter.



Figure 15. Quality of dowel support at the joint face: (a) typical spalling at the joint face of drilled holes; (b) smooth, formed hole produced by plastic sleeve.

5. EVALUATION OF SURFACE PROFILE

The possible presence of bumps on the pavement surface is a concern for the plastic sleeves because the plastic sleeves displace concrete as they are inserted. The presence of bumps over the dowel bars (plastic sleeves) was evaluated by measuring the elevation differences between a line away from the dowel bars and ends of the dowel bars using a Dipstick (Figure 16). The lines over which the Dipstick measurements were taken were selected such that the end of every dowel is hit as the Dipstick is “walked” between the two lines. The dowel locations were identified using MIT Scan-2 (Figure 17).

The measurements were taken from two slabs where plastic inserts were used and from one slab in the control section near the former sample location. If bumps were present, there would be a general increase in elevation, going from the points along the line away from the dowel bars to the ends of the dowel bars (the point along Line B to Line A in Figure 16). The presence of any bumps over the dowel bars would be indicated by the average difference in elevation between the points along Line A and Line B; however, the average difference in elevation also includes the effects of the pavement cross slope. So, the results for the plastic sleeve slab were compared with those of a control slab located in the same area with the same cross slope. The results did not indicate the presence of bumps in the slabs where the plastic inserts were used.

Figure 18 shows that the elevation difference for the control section is between that for the two slabs where plastic inserts were used. This is a clear indication that any effect of plastic sleeves on pavement surface profile is insignificant compared to the effects of the pavement surface texture. The random variations in the pavement surface profile due to surface texture are shown in Figure 19. The slab-to-slab variation in the mean elevation difference shown in Figure 18 is very small relative to the standard deviation of the individual data points for each slab. An analysis of variance showed that the small differences in the mean elevation difference for the three test slabs shown in Figure 18 are statistically insignificant. Since the elevation difference in the control slab is due only to the pavement cross slope, the common value of the mean elevation differences for the three test locations means that the plastic sleeve inserts did not cause bumps on the pavement surface.

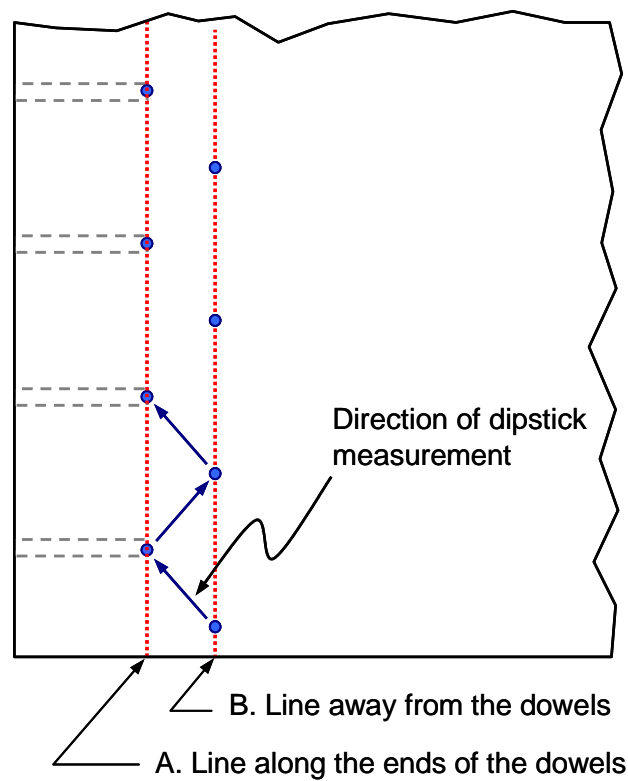


Figure 16. Measurement of elevation difference between points away from the dowels and over dowels using a Dipstick.



Figure 17. Identification of dowel location using MIT Scan-2.

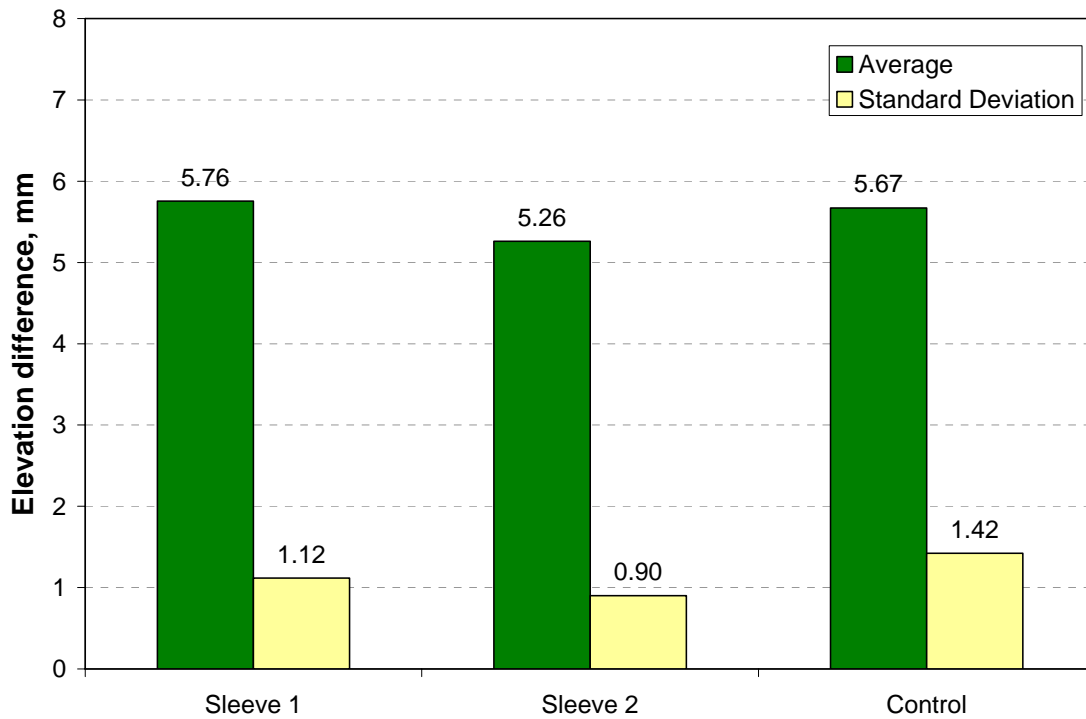


Figure 18. Elevation difference between Lines A and B shown in Figure 16.

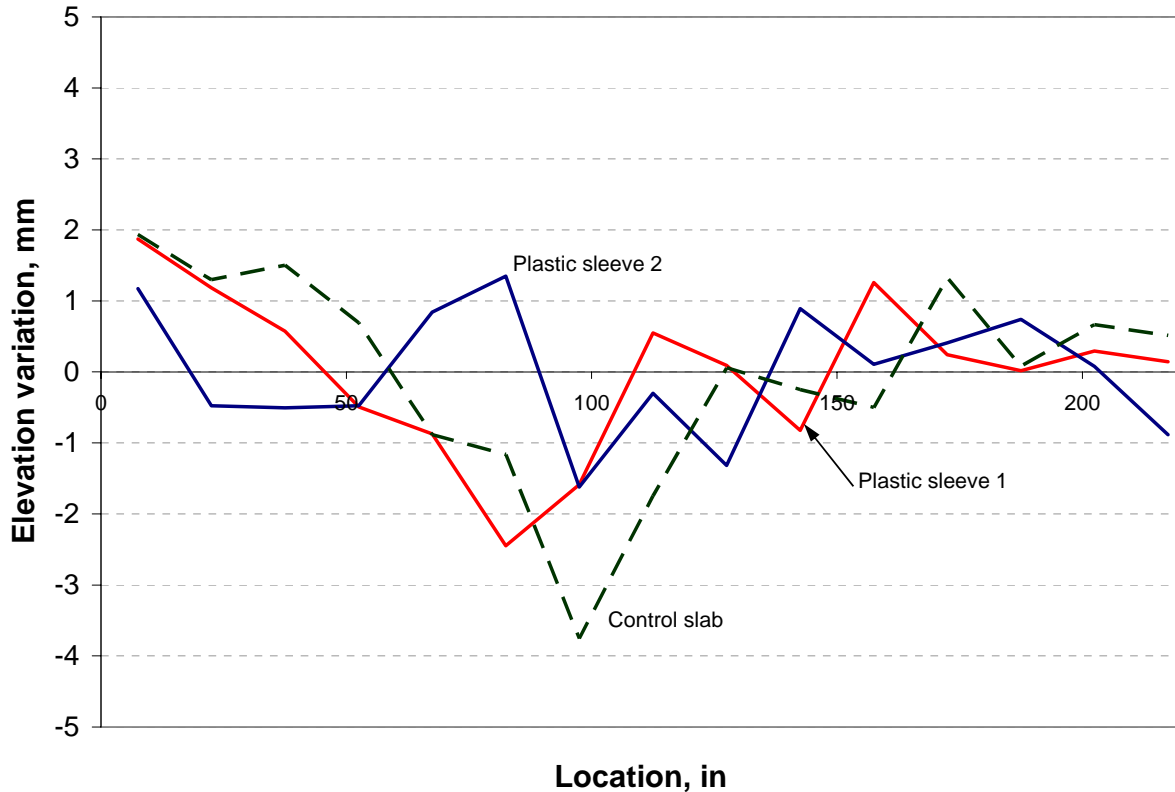


Figure 19. Variation of elevation differences between Lines A and B shown in Figure 16.

6. CONCLUSIONS

The objective of this study was to evaluate a new technique for installing dowel bars in construction joints using plastic sleeves, which are mechanically inserted into plastic concrete. The evaluation is based on the key factors that determine the engineering characteristics, which consist of the following:

- Dowel bar alignment.
- Consolidation of concrete around the plastic sleeves.
- The impact of the insertion techniques on pavement surface profile.

The consistency of the results is adequate to represent the typical quality of construction that can be achieved using plastic sleeve inserts. The evaluation shows that the new technique can produce results that are equal to or better than those produced using conventional methods. The dowel bars installed using plastic sleeves had better vertical alignment than those installed by drilling. The horizontal alignment was also good, but about 3% of the dowel bars installed using plastic sleeves had a significant horizontal misalignment. However, the horizontal misalignment was due entirely to the limitations of the prototype device for inserting plastic sleeves. As a proof of technology, the prototype device amply demonstrated that the process works and can produce acceptable dowel bar alignment. The concrete consolidation around the plastic sleeves was not different than that around the drilled bars, and the insertion of the plastic sleeves did not cause bumps on the pavement surface.

7. REFERENCES

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