Field Evaluation of Elliptical Steel Dowel Performance

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May 2008

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16. Abstract

Joints are always a concern in the construction and long-term performance of concrete pavements. Research has shown that we need some type of positive load transfer across transverse joints. The same research has directed pavement designers to use round dowels spaced at regular intervals across the transverse joint to distribute the vehicle loads both longitudinally and transversely across the joint. The goals are to reduce bearing stresses on the dowels and the two pavement slab edges and avoid erosion of the underlying surface, hence improving long-term joint and pavement structure performance.

Road salts cause metal corrosion in doweled joints, excessive bearing stresses hollow dowel ends, and construction processes are associated with cracked pavement at the end of dowels. Dowels are also a factor in the pavement costs when joint spacing is reduced to control curling and warping distress in pavements. Designers desire to place adequate numbers of dowels spaced at the proper locations to handle the anticipated loads and bearing stresses for the design life of the pavement.

This report is the third report on the evaluation of elliptical steel dowels. This report consists of a graphical analysis of the performance data regarding dowel material, shape, size, configuration, and location in the test pavement. These results provide the engineer with options in the use of the elliptical-shaped steel dowels at alternative spacings and configurations in the joints to provide equal or better performance than the traditional 1.5 in. (31.8 mm) diameter bars. The data indicates that the medium-sized elliptical steel dowels do provide the same or better performance than the standard 1.5 in. traditional round steel dowels in terms of ride, faulting, and load transfer values. With the elliptical shape, the spacing of the medium bars can be extended to 15 in. and possibly 18 inches in. Wheel path only elliptical bars at 12 inch in. spacings are an alternative.

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FIELD EVALUATION OF ELLIPTICAL STEEL DOWEL PERFORMANCE

Final Report
May 2008

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This research was made possible by Gordon Smith of Iowa Concrete Paving Association (ICPA) and the Fred Carson Company. The cooperation of Carlson's superintendent Charlie Davis III and foreman Don Grandstaff made the installation go smoothly and efficiently. C.J. Moyna & Sons Inc. aided in the instrumentation installation protection. This truly was a team effort that illustrated how much the construction industry participates in research.

1. INTRODUCTION

1.1 Problem Statement

Joints are always a concern in the construction and long-term performance of concrete pavements. Research has shown that we need some type of positive load transfer across transverse joints. The same research has directed pavement designers to use round dowels spaced at regular intervals across the transverse joint to distribute the vehicle loads both longitudinally and transversely across the joint. The goals are to reduce bearing stresses on the dowels and the two pavement slab edges and to reduce erosion of the underlying surface, hence improving long-term joint and pavement structure performance.

Other considerations include road salts which cause metal corrosion in doweled joints, excessive bearing stresses hollow dowel ends, and construction processes are associated with cracked pavement at the end of dowels. Dowels are also a factor in the pavement costs when joint spacing is reduced to control curling and warping distress in pavements. Designers desire to place adequate numbers of dowels spaced at the proper locations to handle the anticipated loads and bearing stresses for the design life of the pavement.

1.2 Background

This is the final report of three reports on the evaluation of elliptical steel dowels. This report consists of results of the testing and performance analysis of the various shapes and sizes of dowels. It also documents the results of the first series of performance surveys and draws conclusions about the performance of various bar shapes, sizes, spacings, and basket configurations.

The research project “Dowel Bar Optimization: Phases I and II,” sponsored by American Highway Technology, provided information in the laboratory on spacing and bearing stresses for installing conventional steel dowels and three types of elliptical dowels. Field evaluation of those bars and calibration of the results are important to the application of the results to the pavement design process. The field research tests a portion of the laboratory results of the “Dowel Bar Optimization: Phases I and II” study. The project is intended to yield results on the performance of elliptical dowels and the constructability of such devices in field situations.

A literature search was conducted in the preliminary stages as part of the “Dowel Bar Optimization: Phases I and II” project by Dr. Max L. Porter et al.at Iowa State University, and the findings were published in the final report prepared by the National Concrete Pavement Technology Center (CP Tech Center) at Iowa State University in October 2001. (The CP Tech Center was known as the Center for Portland Cement Concrete Pavement Technology, or PCC Center, at the time this project was initiated; the new name is used here throughout for consistency.) The report provided an average concrete bearing stress for each of the several types of dowels based on laboratory testing. A portion of the values is reproduced in Table 1 below (Porter et al. 2001).

Table 1. Dowel bar type and average concrete bearing stress

Dowel Bar Description	Concrete Bearing Stress
1.25 in. (35 mm) round steel	2,048 psi (594 kPa)
1.50 in. (38 mm) round steel	1,568 psi (10,811 kPa)
Large elliptical steel	1,147 psi (7,909 kPa)
Medium elliptical steel	1,611 psi (11,708 kPa)

The dowel bar arrangements chosen for field testing in the proposed project were based on the relationship of the elliptical bar spacing and bearing stresses to those of the 1.5 in.-diameter round bars used in the laboratory tests.

1.3 Objectives

The current field research was conducted to answer the following questions:

- What is the relative performance over time of medium- (major axis = 1.654 in. [42.01 mm], minor axis = 1.115 in. [28.32 mm], and area = 1.473 in. [37.41 mm]) and large- (major axis = 1.969 in. [50.01 mm], minor axis = 1.338 in. [33.99 mm], and area = 2.084 in. [52.93 mm]) sized elliptical steel dowels as compared to that of the conventional steel dowels (round, 1.50 in. [38.10 mm]diameter with a cross sectional area of 1.767 in.[44.88]) in terms of deflection, visual distress, joint faulting, and joint openings?
- What is the impact of dowel spacing on the relative performance of the elliptical and round dowels in field conditions?
- What is the impact on performance of the various dowel shapes when placed in cut or fill sections of the roadway?
- What constructability problems, if any, are associated with the installation of dowel shapes other than round?

1.4 Research Approach

The project period extended from May 2002 to September 2007. The first year, summarized in the previously submitted Construction Report, involves the installation of the dowel bars according to the spacing configurations outlined in the “Installation” section found later in this report. Years two through five include various tests and evaluations such as the tests described in the “Data Collection” section that follows.

The construction project chosen for the field research—Iowa 330 in Iowa’s Jasper, Story, and Marshall counties (Project NHSX-330-I(19)-3H-50)—provided all the variables needed for the research. Dowel test section length accounted for 3.5 mi (5.63 km) of the 11.47 mi (18.46 km) portland cement concrete (PCC) paving project that was used for this study. The typical cross section for this project can be found in Appendix A. The construction project’s contractor, Fred Carlson Company, Inc. of Decorah, Iowa, and materials suppliers, including American Highway Technology, provided the necessary support to implement the research.

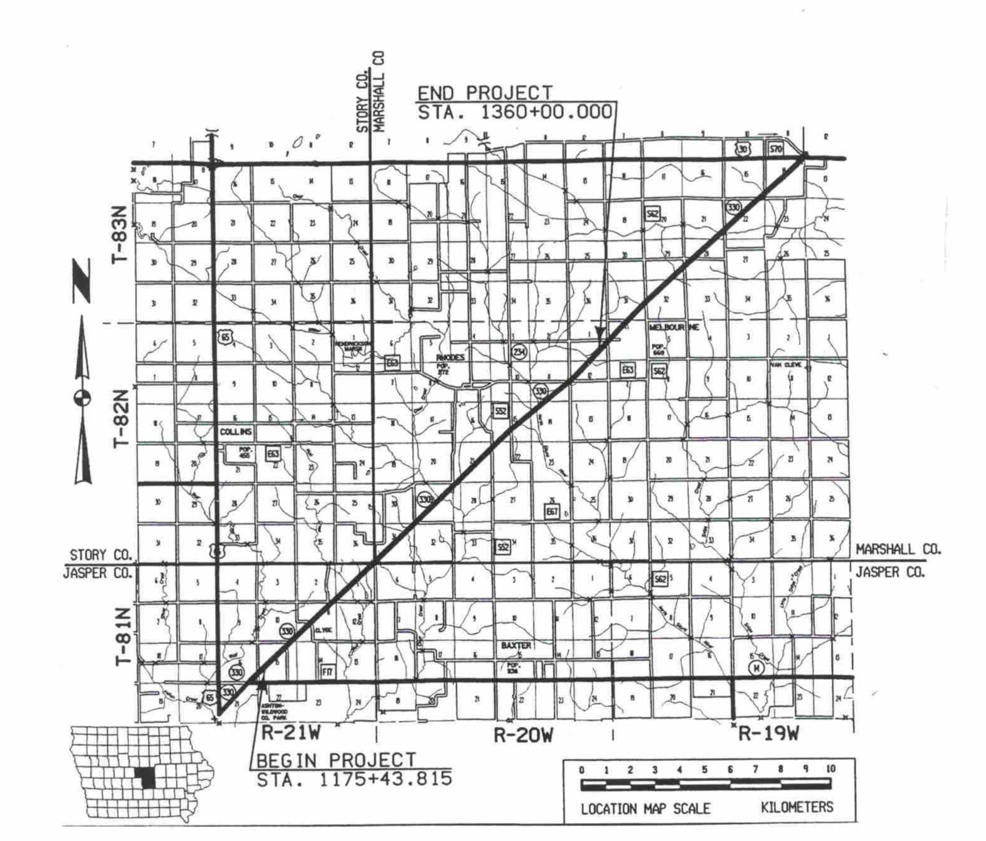


Figure 1. Site map

2. SPECIFICATIONS

Two types of elliptical steel dowels (medium and heavy) in addition to conventional 1.5 in. round steel dowels, each placed at three different conventional spacings across the transverse joints of the concrete pavement, were installed and monitored as part of the project. The variables and specifications are as follows:

- Dowel bar types
    - Heavy elliptical—major axis is 1.969 in. (50.013 mm), minor axis is 1.338 in. (33.985 mm), and area is 2.084 in. (1,344.513 square mm).
    - Medium elliptical—major axis is 1.654 in. (42.012 mm), minor axis is 1.115 in. (38.321 mm), and area is 1.473 in. (950.321 square mm).
    - Standard round—diameter is 1.5 in. (38 mm) and area is 1.767 in. (1,139.998 square mm).
- Uniform dowel bar spacing—12 in. (305 mm), 15 in. (380 mm), and 18 in. (460 mm) center to center.
- Three replicate sections of each dowel size and spacing were placed in cut, fill, and transition roadway sections.
- Dowel placement in wheel paths (tested medium elliptical and 1.5 in. [38 mm] and standard rounds at 12 in.[305 mm] spacing).

Each test section was developed to consist of 20 transverse joints of a particular combination of dowel shape and spacing separated from the next test section by a minimum of five conventional 1.5 in. (38 mm) standard round steel doweled joints.

The fourth layout was used to investigate the potential for placing dowels primarily in the wheel paths. The dowels had a spacing of four bars each at 12 in. (305 mm) center to center in each wheel path. The center of the first bar was located six inches (155 mm) from centerline for the inside wheel path and 30 in. (765 mm) from the edge of pavement for the outside wheel path. Hereafter, sections with dowels located in the wheel paths may be referred to as wheel path baskets or wheel baskets.

The field research involved the installation of full-width (26 ft, 7.93 m) transverse joint dowel baskets (12- and 14-ft lane, 3.66 and 4.27 m) of each bar type and configuration. Test baskets were only located on the mainline; turning lane joints located in test sections used the standard bar configurations. The project's test sections consisted of 390 joints with heavy elliptical dowels, 520 joints with medium elliptical dowels, and 390 joints with the conventional 1.5 in. (38 mm) round dowels. The joints, and ultimately the entire Iowa Department of Transportation (Iowa DOT) highway project were constructed rectangular or perpendicular to the centerline of the pavement rather than as skewed joints. The standard, heavy, and medium bars were coated with an epoxy meeting the ASTM-934 standard versus the Iowa DOT required ASTM-777 standard. The proposed epoxy was more resistant to abrasion and deicing chemicals than those presently required for highway work.

3. INSTALLATION

The cooperation of a capable and experienced contractor is very important to the successful implementation of any new technology or test in the field. Because the contractor's support is so important, the research staff made sure to plan for easy and efficient installation.

The experiment contained twenty-one different configurations of bar type, size, and spacing within the baskets. The configurations included a combination of heavy or medium elliptical, or 1.5 in. (38 mm) round bars and dowel spacings of 12 in. (305 mm), 15 in. (380 mm), or 18 in. (460 mm).

In order to measure actual strains within the bars during the curing process and various load conditions, six baskets in the outside lane were outfitted with strain gauges at multiple locations on one dowel in one basket assembly (see Figure B.1). Gauge wires were tied closely to the frame, routed to the outer end of the basket, and carried to the edge of the shoulder in capped PVC. The gauges were read by uncapping the end of the pipe at the edge of the shoulder.

The basket configurations chosen for instrumentation were

- medium elliptical with 12 in. (305 mm) spacing

- medium elliptical with 18 in.(460 mm) spacing
- heavy elliptical with 12 in.(305 mm) spacing
- heavy elliptical with 18 in.(460 mm) spacing
- heavy elliptical with 15 in.(380 mm) spacing
- standard 1.5 in.(38 mm) round with 12 in.(305 mm) spacing

The locations of each test and non-test section for the baskets fitted with gauged bars can be found in Appendix C. The subgrade properties pertaining to cut, fill, and transition areas were taken into account when deciding basket locations. A relatively equal number of test sections of cut and fill were chosen with some transition sections also included. Each test section consisted of twenty joints, separated from the adjacent test sections by a minimum of five joints, or roughly 100 ft (30 m) of non-test sections.

The test baskets were installed by setting baskets on the grade behind the trimmer a few days ahead of the slipform paver. Typically, baskets were offset from a centerline reference string so that the spacing between adjacent baskets was equal to the spacing of the dowels in the baskets themselves. Figure B.2 shows a typical dowel basket offset. A 20 ft (6 m) joint spacing was employed along the centerline offset to identify the location of each joint, thus basket, for the entire length of the project. Figure B.3 shows a typical roadbed section of placed dowel baskets.

Special sections were also used to test the theory of placing dowel baskets only in the wheel paths. The intention of testing these baskets was to see if wheel path baskets will perform significantly different than full baskets. Previous research in Iowa on local roads has indicated that satisfactory performance can be achieved from wheel path only dowel configurations. In many cases the earlier research indicated that the dowels between the wheel paths primarily only supported the handling of the basket during construction. Wheel path baskets were located such that the four-bar assembly would span the area of the normal wheel paths in each lane. The exact locations from the edge of pavement and from the centerline have already been noted in this report. The wheel path basket set-up can be seen in Figure B.4. The instrumented bar baskets were set in the same fashion as all other test baskets, but with a little more care for the wiring. The wires had to be protected during paving, shouldering, and drainage installation.

For the purpose of monitoring the transverse joint opening, surveyor mag-nails were placed in the concrete (flush with the surface) on either side of joints in the outside lane to serve as a point of reference for measuring. The 10 middle joints of every 20-joint test section were set with the joint opening nails. Nails were placed into the concrete within the first hour of paving 12 in. (305 mm) in from the edge of the slab with 10 in. (255 mm) between (5 in. [127 mm] offset either side of the joint). Initial measurements between the nails in the days after the paving served as a benchmark for future joint movement. Measurements from preliminary joint opening surveys can be found in Appendix D.

4. DATA COLLECTION

Each of the test sections in this project is comprised of 20 continuous and adjacent joints in the two southbound lanes. After installation, the following tests were performed in the field:

- Deflection (FWD) tests were conducted at three joints in each lane, in the outer wheel path only, in the spring and fall of each year (except for 2006 when FWD machine was broken down). The deflection test sites were located at joints 12–15 (as measured from the southern-most test section joint) of the 20 joints in the test section. Loads of 6, 9, and 12 k pounds were applied in each test. This method of data collection continued throughout the duration of the project.
- Visual distress surveys were conducted on each of the test sections twice per year (spring and fall) and continued through the duration of the project. Surveys were conducted in accordance with the practices developed by the Federal Highway Administration (FHWA) for the Long-Term Pavement Performance (LTPP) Project.
- Joint openings were measured along the outside edge of the pavement in the driving lane only in the spring and fall of each year. The center 10 joints of the test section were fitted with surveyor (PK) nails at construction on each side of the joint. The approximate distance between the nails was established at 10 in. An initial measurement was made of the distance between the centers of the two nails with a caliper. This assumes the base width of joint opening as sawed. The measurement serves as the base distance. All subsequent measurements are compared to this measurement to determine changes in the base joint opening. These measurements are documented in Appendix D.
- Faulting measurements were taken at the center 10 joints in each test section in the spring and fall of each year of the contract. The measurements were made at a distance of 18 in. from the outside edge of the driving area in each lane to represent the outer wheel path location in each case. Measurements were made with the LTPP standard digital reading fault meters at predetermined and marked locations in each lane. Two such devices were used simultaneously to advance the speed of data collection. The testing continued throughout the duration of the project. The results of testing to date are shown in Appendix E.
- Longitudinal profiles were measured in each of the four wheel paths (two per lane) twice per year (spring and fall). The data was gathered with the use of the Iowa DOT high-speed profiler. This data collection also continued through the end of the project.

FWD and profile testing are accomplished with the equipment and aid of the Office of Special Investigations of the Iowa DOT. The joint opening, visual distress, and faulting measurements are conducted by the research project staff. Testing is done at the same time of day for each testing period and within the same season of the year.

5. DATA ANALYSIS

5.1 Falling Weight Deflectometer (FWD)—Load Transfer

FWD normalized data were analyzed to determine the load transfer at each tested joint. The deflection-based load transfer is determined by dividing the deflection at sensor 3 (12 in. from load application) by the deflection at sensor 1 (over center of load application) and multiplying by 100 to get a percent of load transfer. This is then normalized by dividing 9000 pounds by the actual load applied by the machine. The formula can be seen below.

$$LTE = 100 * (D3/D1) * (9000\ \text{lb}/L_a)$$

Where, LTE = load transfer efficiency (%)
D3 = deflection reading 12 in. from the applied load (mm)
D1 = deflection reading 0 in. or at the center of the applied load (mm)
L_a = actual load applied (lb)

The load transfer for nine joints was averaged for each lane, for each test period, and over the test sections with the same characteristics. Using an Excel spreadsheet, the load transfer of each series of similar pavement characteristics was calculated. The data were broken down by their variable characteristics. First, the data were compared by different dowel shapes. Second, different dowel spacings were compared. Next, the data were compared by the difference in subgrade conditions, such as cut, fill, or transition sections. Then, the data were broken down into driving lane and passing lane faulting. Finally, the difference between full dowel baskets and dowel baskets placed in the wheel paths only was compared.

5.1.1 Dowel Type Analysis—Load Transfer

The summary of load transfer effects due to the change in dowel shape can be seen in Figures 2, 3, and 4. Figure 2 shows a comparison between standard round dowels and medium elliptical dowels. Figure 3 shows a comparison between standard round and heavy elliptical dowels. Figure 4 shows a comparison between medium elliptical dowels and heavy elliptical dowels. Each group of bars in the figures represents a section combination where all things are considered constant except for the dowel type used.

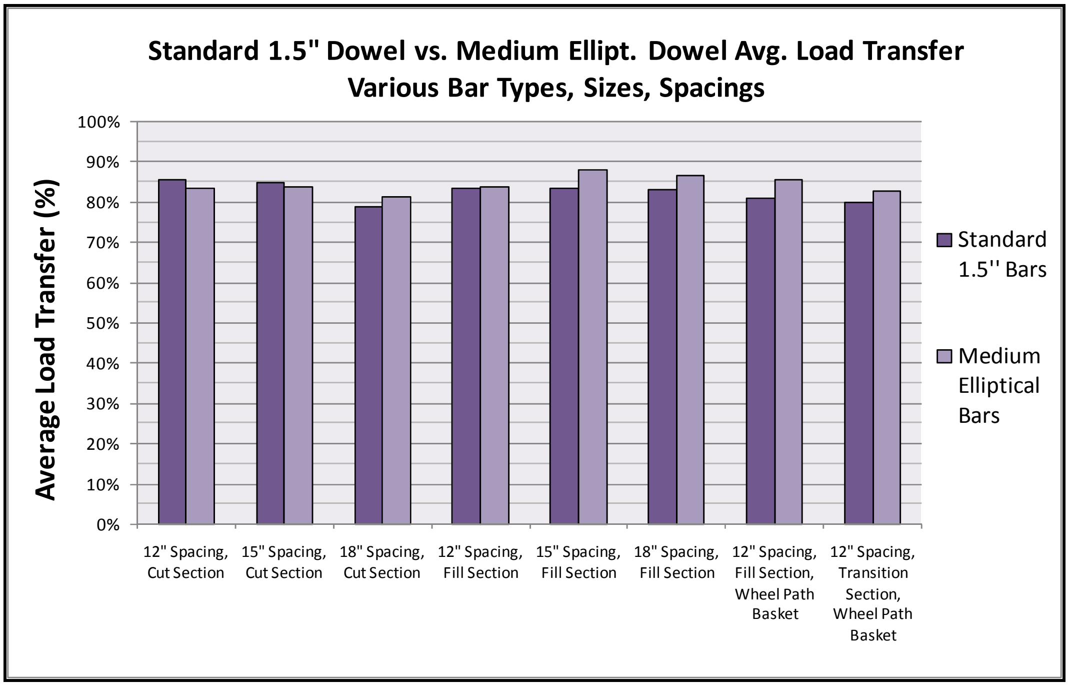


Figure 2. Standard 1.5 in. round vs. medium elliptical dowels load transfer

Figure 2 shows both standard 1.5 in. round dowels and medium elliptical dowels transferred about 80%–90% of the load across the transverse joints for the sections indicated. In many instances the medium elliptical dowels transferred more load than the standard round dowels. Figure 2 also indicates that medium elliptical bars transferred more load than the standard round bars in sections with wheel path dowel baskets.

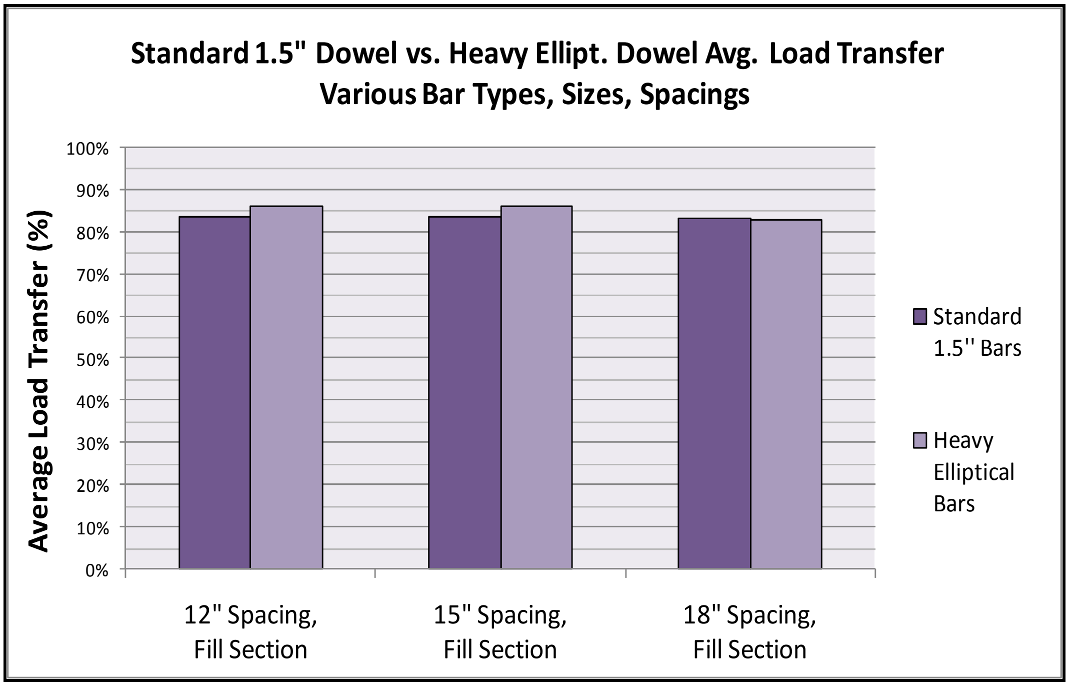


Figure 3. Standard 1.5 in. round vs. heavy elliptical dowels load transfer

Figure 3 shows both standard round dowels and heavy elliptical dowels transferred about 80%–85% of the load across the transverse joints in the sections noted. This figure indicates no significant difference in the performance of the two bars as they relate to load transfer.

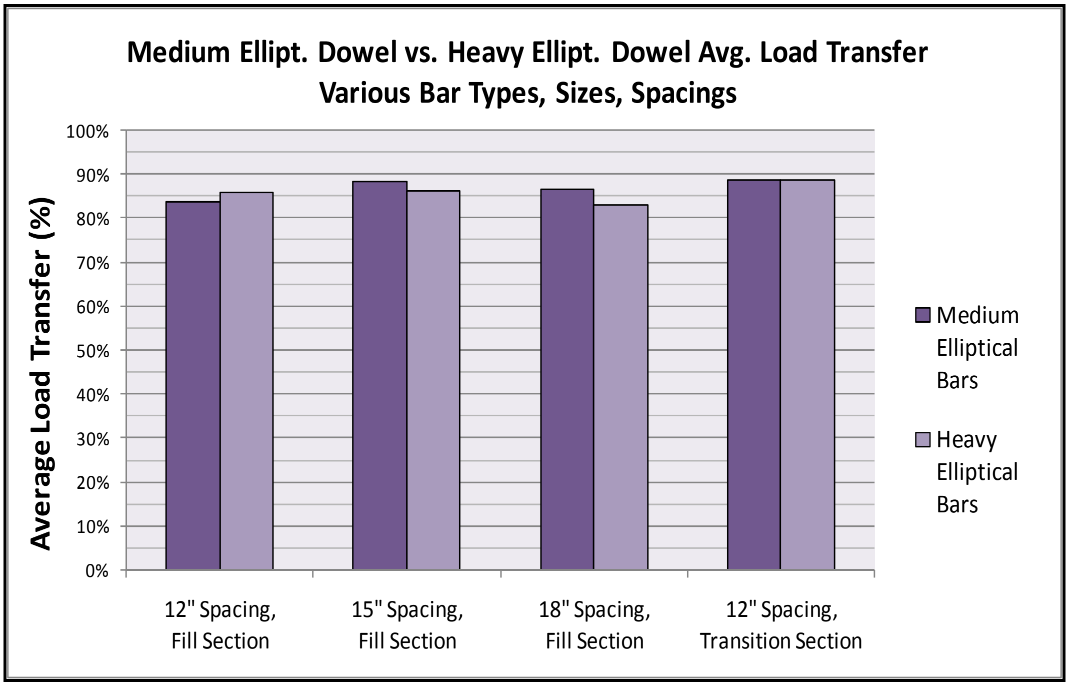


Figure 4. Medium elliptical vs. heavy elliptical dowels load transfer

Figure 4 shows both medium elliptical dowels and heavy elliptical dowels transferred about 80%–90% of the load across the transverse joints in the sections noted. The figure indicates no significant difference in the performance of the two bars as they relate to load transfer.

5.1.2 Dowel Spacing Analysis—Load Transfer

The summary of load transfer effects due to the change in dowel spacing can be seen in Figure 5 below. Figure 5 shows a comparison between 12 in., 15 in., and 18 in. spacing. Each group of bars in the figure represents a section combination where all things are considered constant except for the dowel spacing.

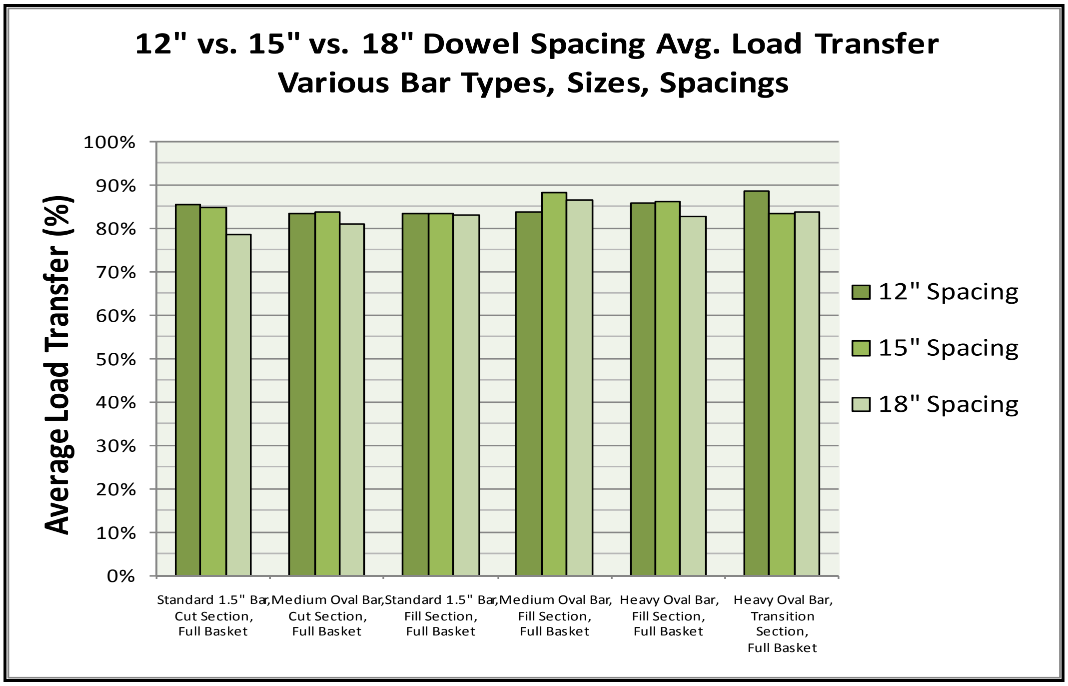


Figure 5. 12 in. vs. 15 in. vs. 18 in. spacing load transfer

Figure 5 shows the 12 in., 15 in., and 18 in. dowel bar spacing all transferred about 80%–90% of the load across the transverse joints in the sections noted. Figure 5 indicates that the 12 in. and 15 in. spaced dowels have very comparable results, with 18 in. spaced dowels coming in with slightly lower load transfer efficiency.

5.1.3 Cut, Fill, or Transition Analysis—Load Transfer

The summary of load transfer effects due to the change in subgrade location can be seen in Figures 6, 7, and 8. Figure 6 shows a comparison between cut and fill sections. Figure 7 shows a comparison between fill and transition sections. Figure 8 shows a comparison between cut and transition sections. Each group of bars in the figures represents a section combination where all things are considered constant except for the subgrade location.

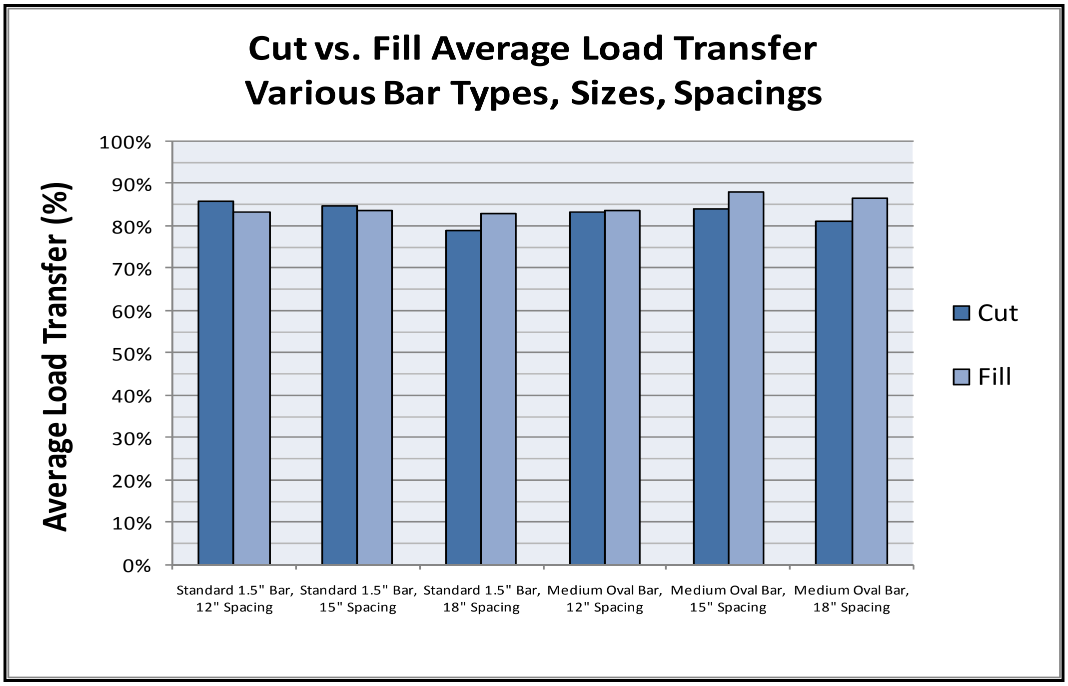


Figure 6. Cut vs. fill subgrade load transfer

Figure 6 shows both cut and fill sections transferred about 80%–90% of the load across the transverse joints in the sections noted. The average load transfer efficiency of all the cut and fill sections in Figure 6 are 83.0% and 84.7% respectively. This does not indicate a strong correlation of one subgrade location outperforming the other. The figure indicates no significant difference in the performance of the two bars as they relate to load transfer.

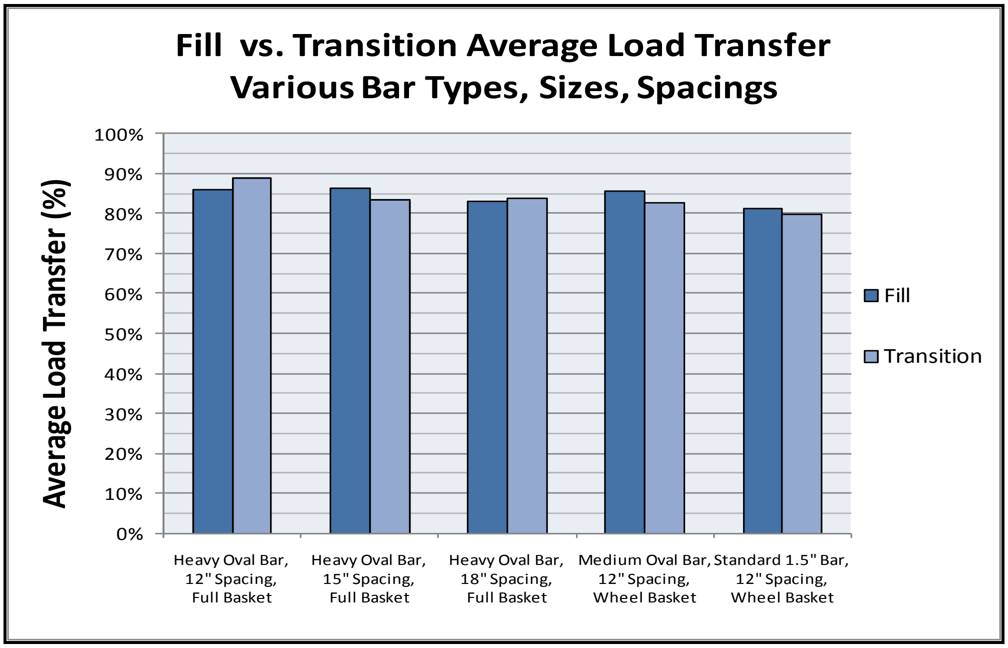


Figure 7. Fill vs. transition subgrade load transfer

Figure 7 shows both fill and transition sections transferred about 80%–90% of the load across the transverse joints in the sections noted. The average load transfer efficiency of all the fill and transition sections in Figure 7 are 84.3% and 83.6% respectively. This does not indicate a strong correlation of either subgrade location outperforming the other. Figure 7 indicates no significant difference in the performance of the two sections over the life of the study as they relate to load transfer.

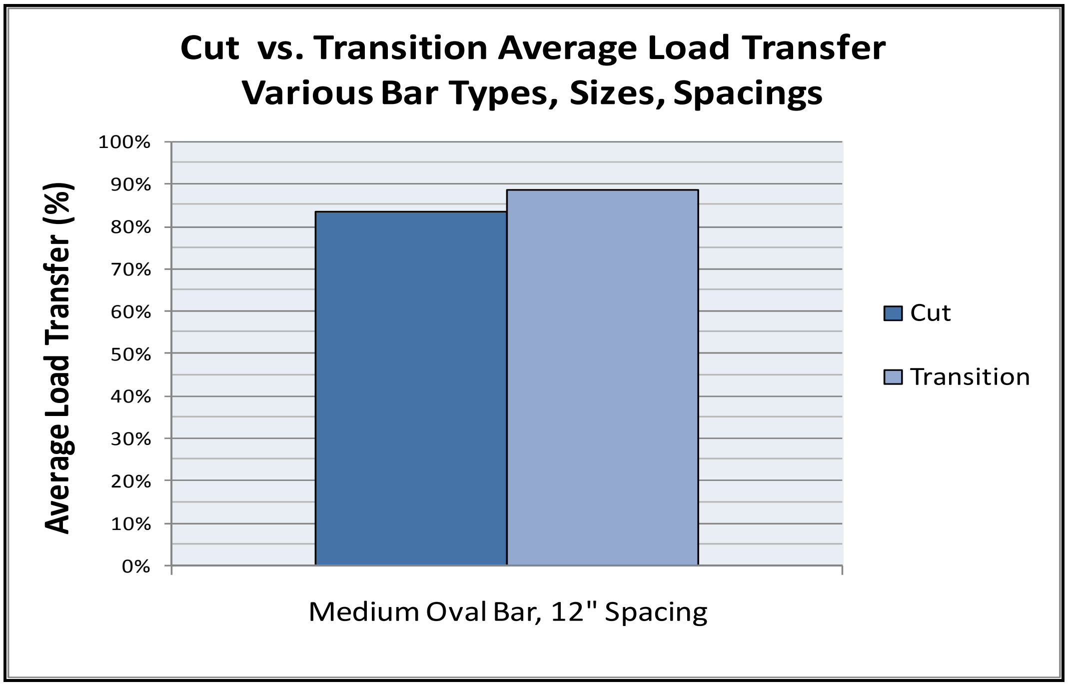


Figure 8. Cut vs. transition subgrade load transfer

Figure 8 shows the same results established in the other subgrade comparisons. The two sections did not indicate a significant difference in load transfer over the study period.

5.1.4 Full Basket and Wheel Path Basket Analysis—Load Transfer

The summary of load transfer effects due to using full dowel baskets or dowels only in the wheel paths can be seen in Figure 9. Each group of bars in the figure represents a section combination where all things are considered constant except for the dowel basket type across the transverse joint.

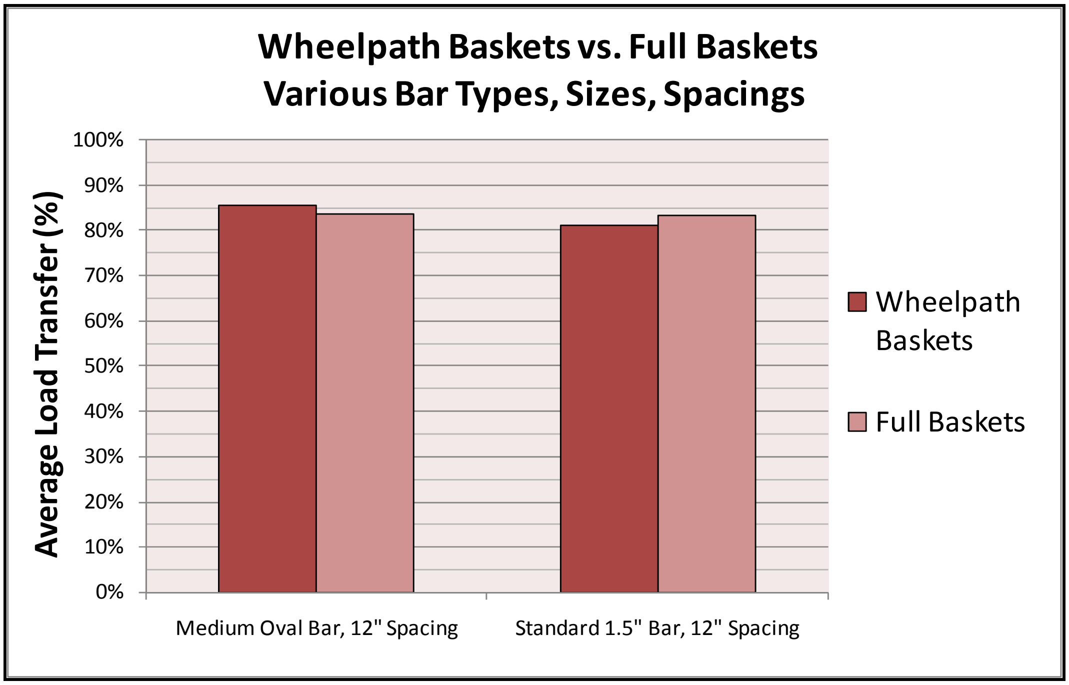


Figure 9. Wheelpath dowel baskets vs. full dowel baskets load transfer

Figure 9 shows the use of wheel path dowel baskets does not yield significantly different results than the full baskets over the five-year study period. The graph indicates medium oval dowels with wheel path baskets performed as well as the standard round bars with wheel path baskets.

5.2 Joint Faulting

Joint faulting data collected in the field were averaged over the ten joints in each test section. Ten joints in the driving lane and ten in the passing lane were tested individually and summarized as an average for each lane per test section. The average of the combined data from the passing lane and driving lane in each section group was used in the analysis. The fall 2007 faulting data was not used in the analysis due to an error in passing lane fault meter. The average faulting values obtained by the fault meters over the life of the data collection (0.5mm to 0.9 mm) were smaller than the accuracy of the fault meters (1.0 mm).

The data were broken down by their variable characteristics. First, the data were compared by different dowel shapes. Second, different dowel spacings were compared. Next, the data were compared by the difference in subgrade locations, such as cut, fill, or transition sections. Then, the data were broken down into driving lane and passing lane faulting. Finally, the difference between full dowel baskets and dowel baskets placed in the wheel paths only was compared.

5.2.1 Dowel Type Analysis—Faulting

The summary of faulting effects due to the change in dowel shape can be seen in Figures 10, 11, and 12. Figure 10 shows a comparison between standard round dowels and medium elliptical dowels. Figure 11 shows a comparison between standard round and heavy elliptical dowels. Figure 12 shows a comparison between medium elliptical dowels and heavy elliptical dowels. Each group of bars in the figures represents a section combination where all things are considered constant except for the dowel type used.

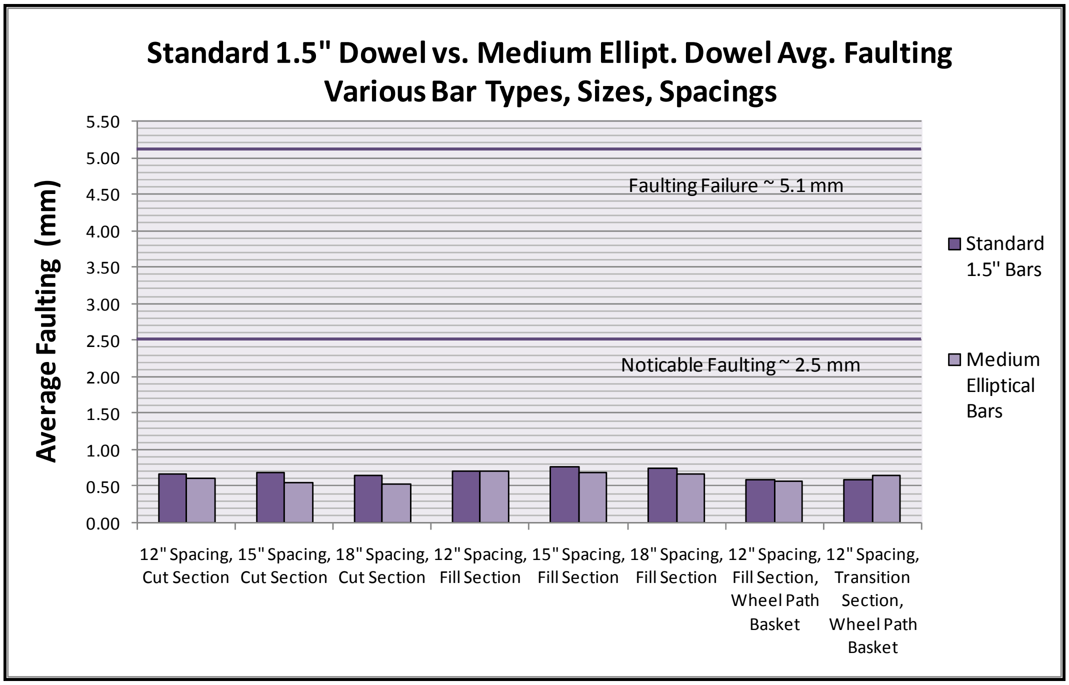


Figure 10. Standard 1.5 in. round vs. medium elliptical dowels—faulting

Figure 10 consistently shows an equal performance of medium elliptical bars compared to standard round bars in sections with full dowel baskets.

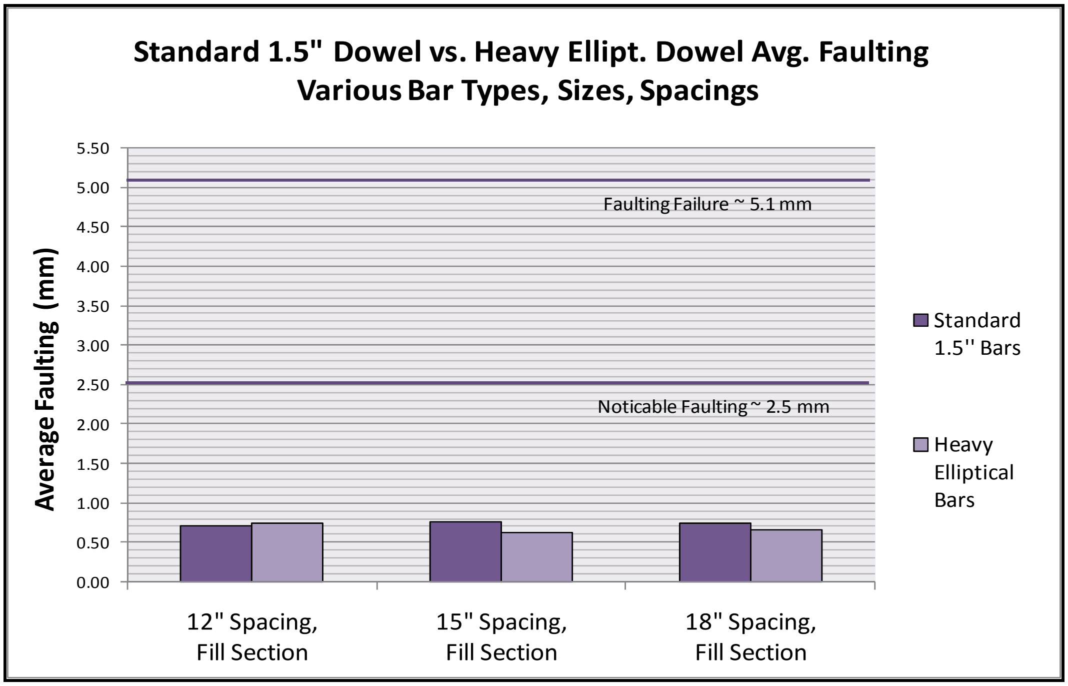


Figure 11. Standard 1.5” round vs. heavy elliptical dowels—faulting

Figure 11 indicates there may not be a strong relationship when comparing standard round dowel bars to heavy elliptical dowel bars. However, the heavy elliptical bars perform at least equal to, if not better than the standard bars in terms of faulting.

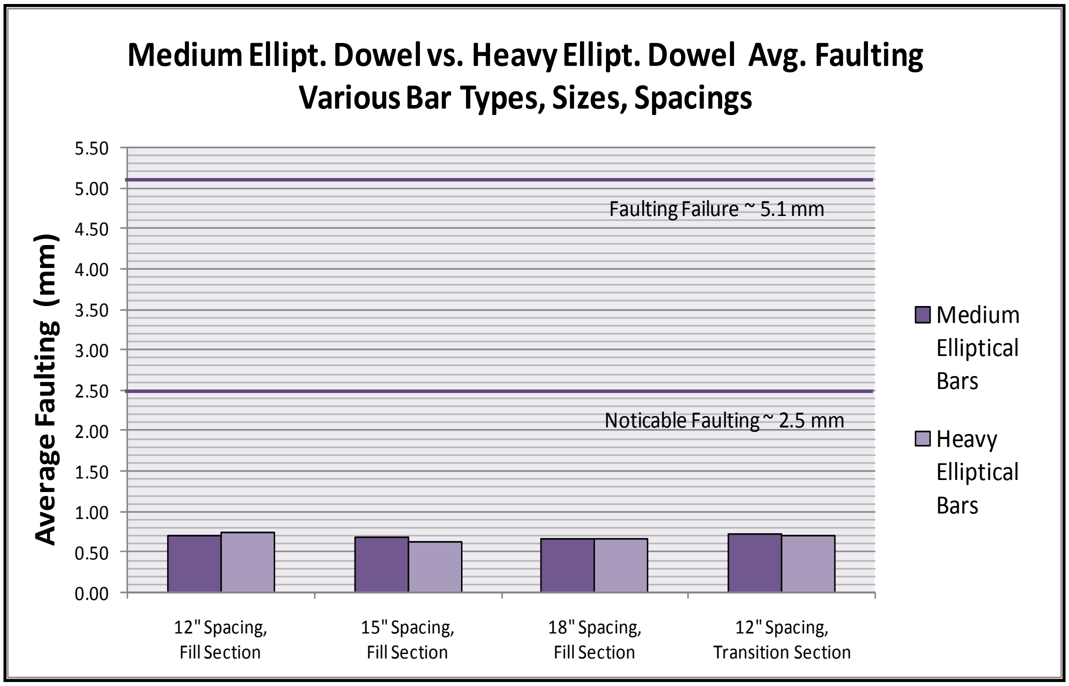


Figure 12. Medium elliptical vs. heavy elliptical dowels—faulting

Figure 12 indicates the medium and heavy elliptical bars are about equal in performance in terms of faulting.

5.2.2 Dowel Spacing Analysis—Faulting

The summary of faulting effects due to the change in dowel spacing can be seen in Figure 13 below. Figure 13 shows a comparison between 12 in., 15 in., and 18 in. spacing. Each group of bars in the figure represents a section combination where all things are considered constant except for the dowel spacing.

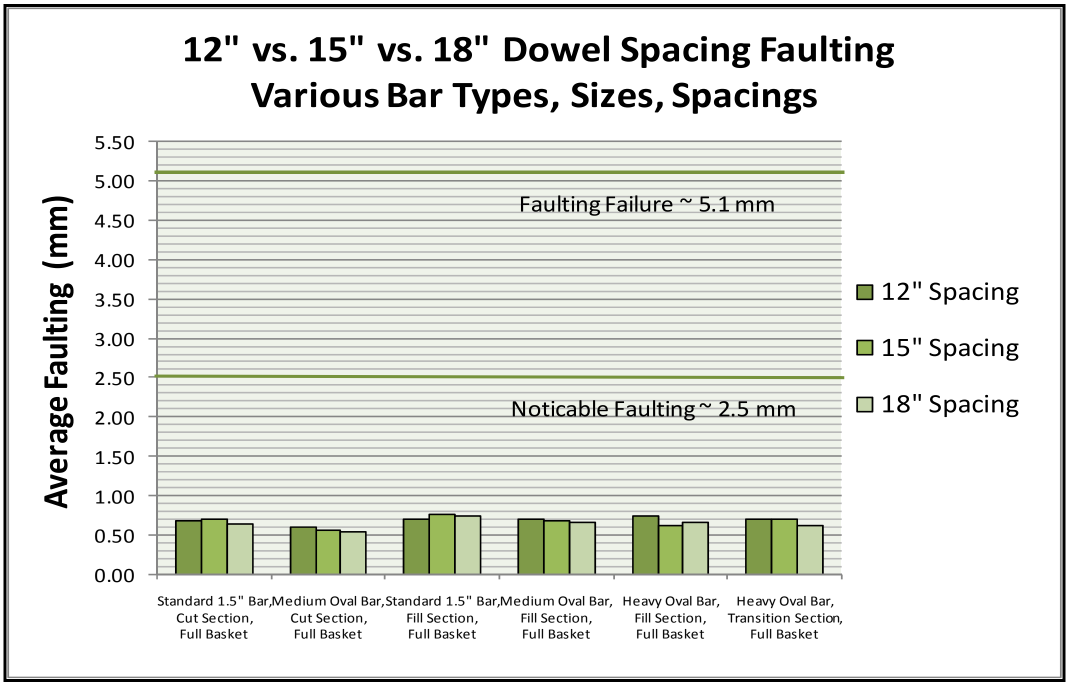


Figure 13. 12 in. vs. 15 in. vs. 18 in. spacing—faulting

Figure 13 shows the 12 in., 15 in., and 18 in. dowel bar spacing indicated no consistent patterns of performance in terms of faulting. One would expect the bars in each section to have an ascending pattern as the spacing is increased, indicating better performance when more bars are used. However, this was not the particular trend in any of the test sections. This hints at the possibility that 18 in. spaced dowel bars can produce similar faulting performance as 12 in. spaced dowel bars. Based on faultmeter accuracy, each of the bar locations and sizes provided equal faulting performance.

5.2.3 Cut, Fill, or Transition Analysis—Faulting

The summary of faulting effects due to the change in preconstruction subgrade condition can be seen in Figures 14, 15, and 16. Figure 14 shows a comparison between cut and fill sections. Figure 15 shows a comparison between fill and transition sections. Figure 16 shows a comparison between cut and transition sections. Each group of bars in the figures represents a section combination where all things are considered constant except for the subgrade location.

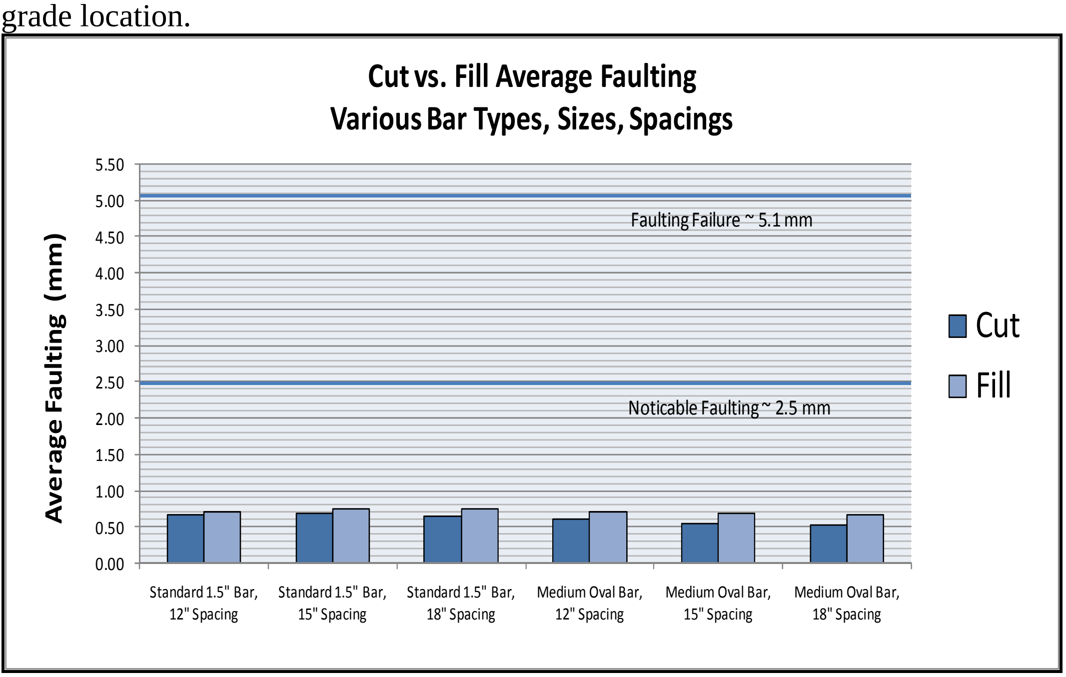


Figure 14. Cut vs. fill subgrade—faulting

Figure 14 shows the cut sections have consistently lower faulting values than the fill sections regardless of dowel bar type.

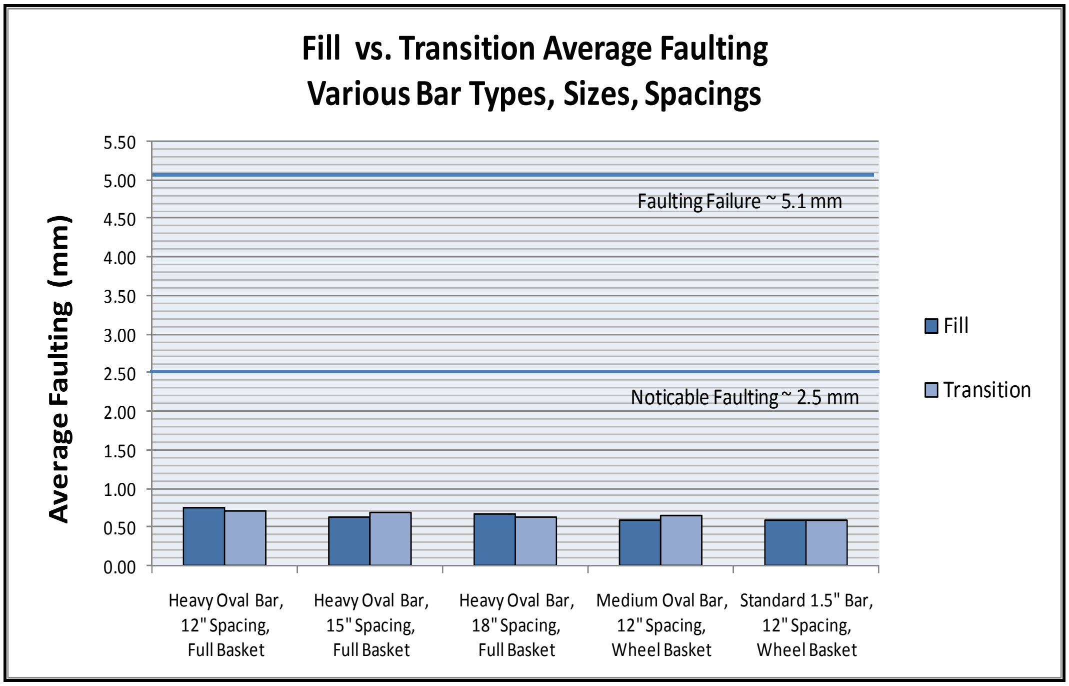


Figure 15. Fill vs. transition subgrade—faulting

Figure 15 shows the fill and transition sections have equal faulting. Over the life of the study, there were no strong correlations to show the sections were performing differently in fill sections as opposed to transition sections, in terms of faulting.

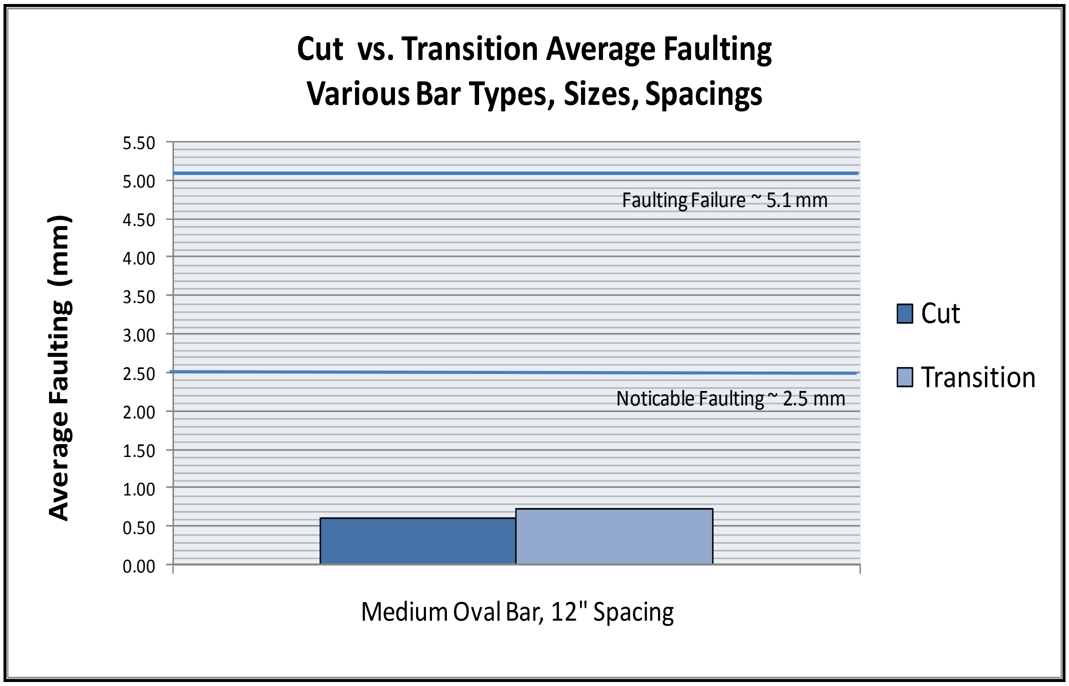


Figure 16. Cut vs. transition subgrade—faulting

Figure 16 shows the cut section has less faulting than the transition section. This coincides with Figures 14 and 15 which show cut sections have less faulting than fill and transition sections.

5.2.4 Driving Lane and Passing Lane Analysis—Faulting

The summary of faulting effects due to the change in driving or passing lanes can be seen in Figures 17 and 18 below. Figures 17 and 18 show equal faulting values (when faultmeter accuracy is considered) in the passing lane compared with the driving lane. This was the case for every test section in the project. Fault measurements in the passing lane for the last set of readings in 2007 are not included in the data due to an apparent error in the device used on that occasion.

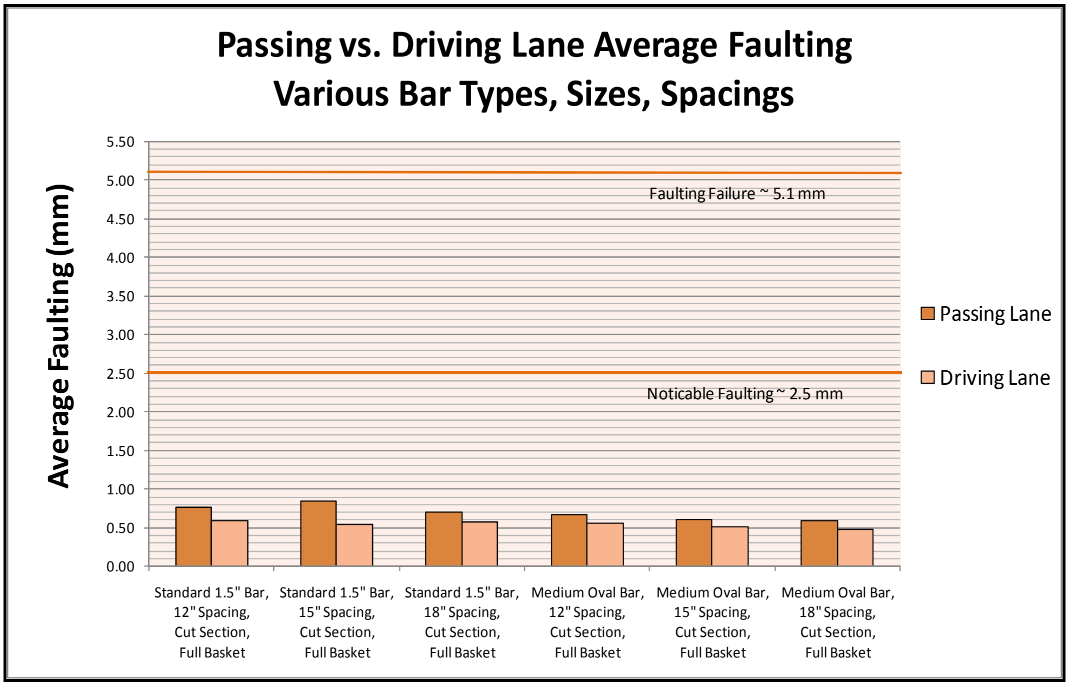


Figure 17. Driving vs. passing lane (1)—faulting

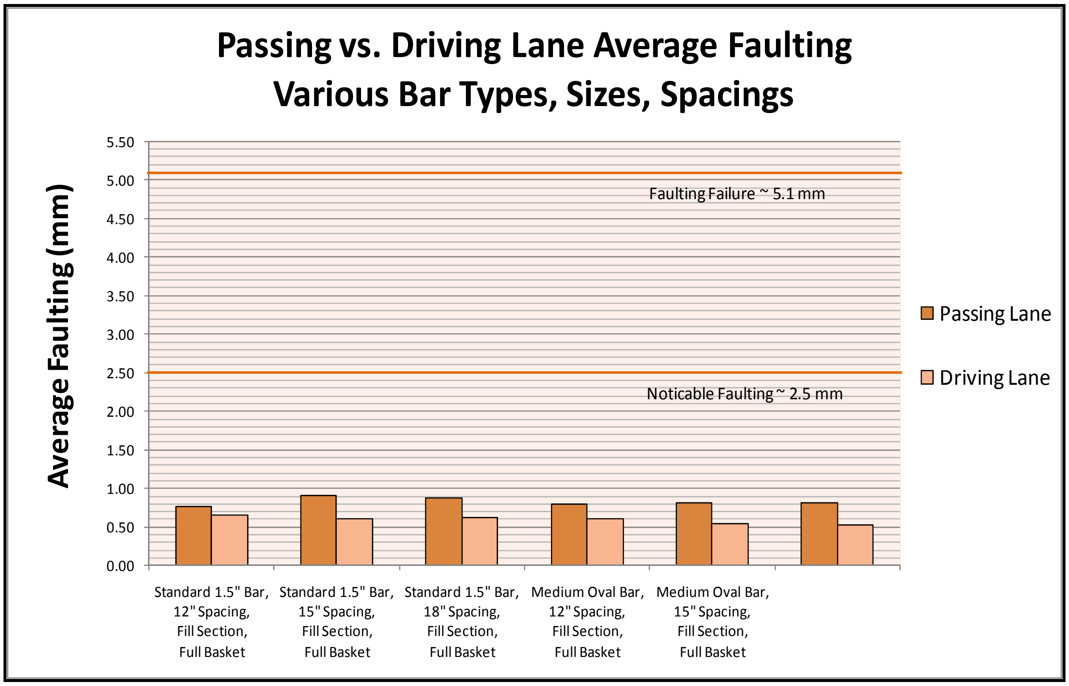


Figure 18. Driving vs. passing lane (2)—faulting

5.2.5 Full Basket and Wheel path Basket Analysis—Faulting

The summary of faulting effects due to using full dowel baskets or dowels only in the wheel paths can be seen in Figure 19. Each group of bars in the figures represents a section combination where all things are considered constant except for the dowel basket type across the transverse joint.

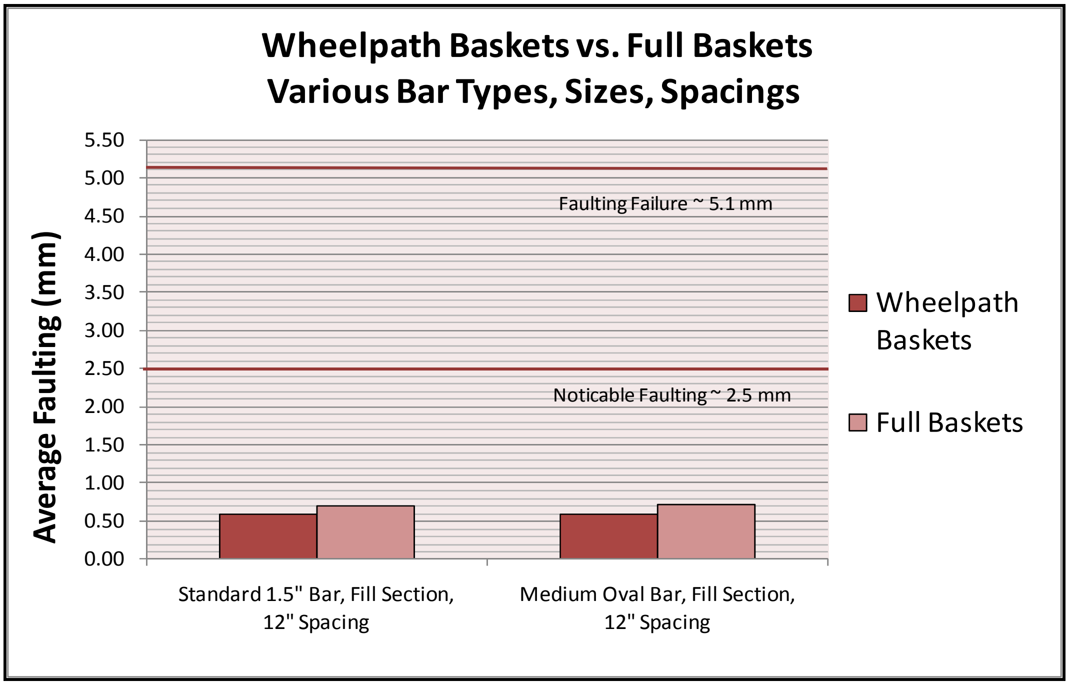


Figure 19. Wheel path dowel baskets vs. full dowel baskets—faulting

Figure 19 suggests sections with dowel baskets placed only in the wheel paths are performing as well for faulting as the sections with full dowel baskets over five years. The data suggest the possibility of using dowel bars only in the wheel path to maintain faulting minimums.

5.3 Joint Openings

Joint opening data collected in the field were analyzed in an Excel spreadsheet. As noted before, the joint opening changes were calculated by comparison of the measurement at construction to that at subsequent measurements. The values were obtained from the 10 joints in the driving lane only in the center of each test section. The absolute values of each joint opening were used in analysis. There were usually three test sections per treatment combination. This group of three sections will be referred to as a section group. This means that each collection period's average joint opening value is an average of about 30 different joints. The final values used in analysis were found by taking the average of all the collection periods for a particular section group. This means that each section group represented in the graphs to follow is a composition of as many as 300 data values. This large quantity of data is good for getting accurate results.

The data were graphed by their variable characteristics. First, the data were compared by different dowel shapes. Second, different dowel spacings were compared. Next, the data were compared by the difference in subgrade locations, such as cut, fill, or transition sections. Finally, the difference between full dowel baskets and dowel baskets placed in the wheel paths only was compared.

5.3.1 Dowel Type Analysis—Joint Opening

The summary of joint opening effects due to the change in dowel shape can be seen in Figures 20, 21, and 22. Figure 20 shows a comparison between standard round dowels and medium elliptical dowels. Figure 21 shows a comparison between standard round and heavy elliptical dowels. Figure 22 shows a comparison between medium elliptical dowels and heavy elliptical dowels. Each group of bars in the figures represents a section combination where all things are considered constant except for the dowel type used.

Figures 20–22 do not show any strong, consistent patterns of performance between the standard round dowel bars, medium elliptical dowel bars, or the heavy elliptical dowel bars in terms of joint opening.

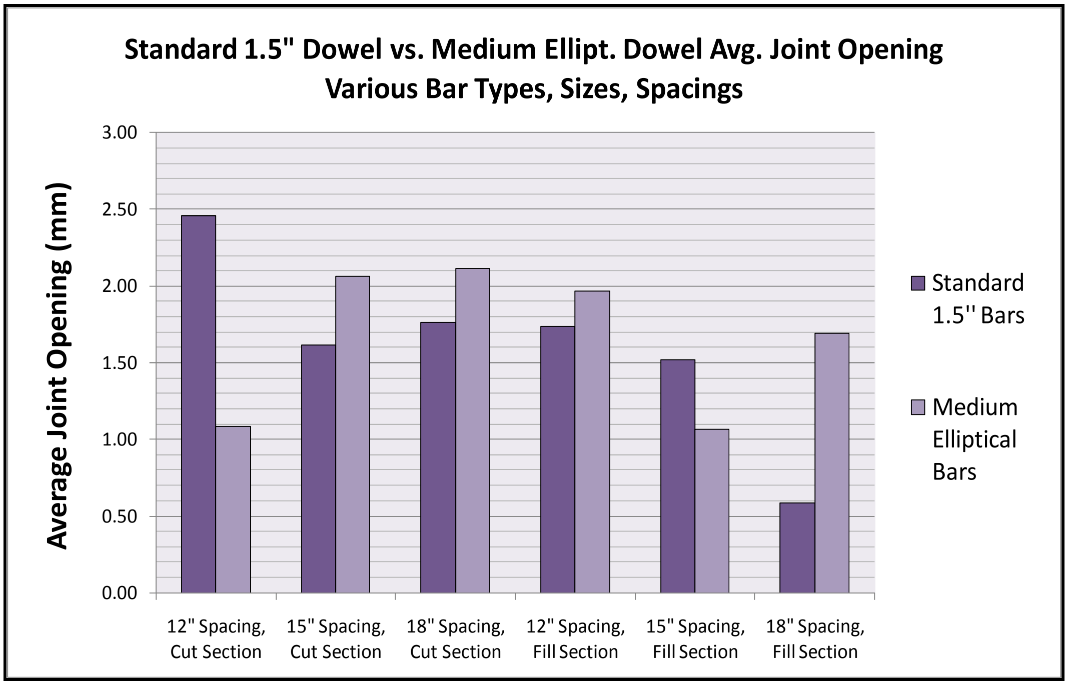


Figure 20. Standard 1.5 in. round vs. medium elliptical dowels—joint opening

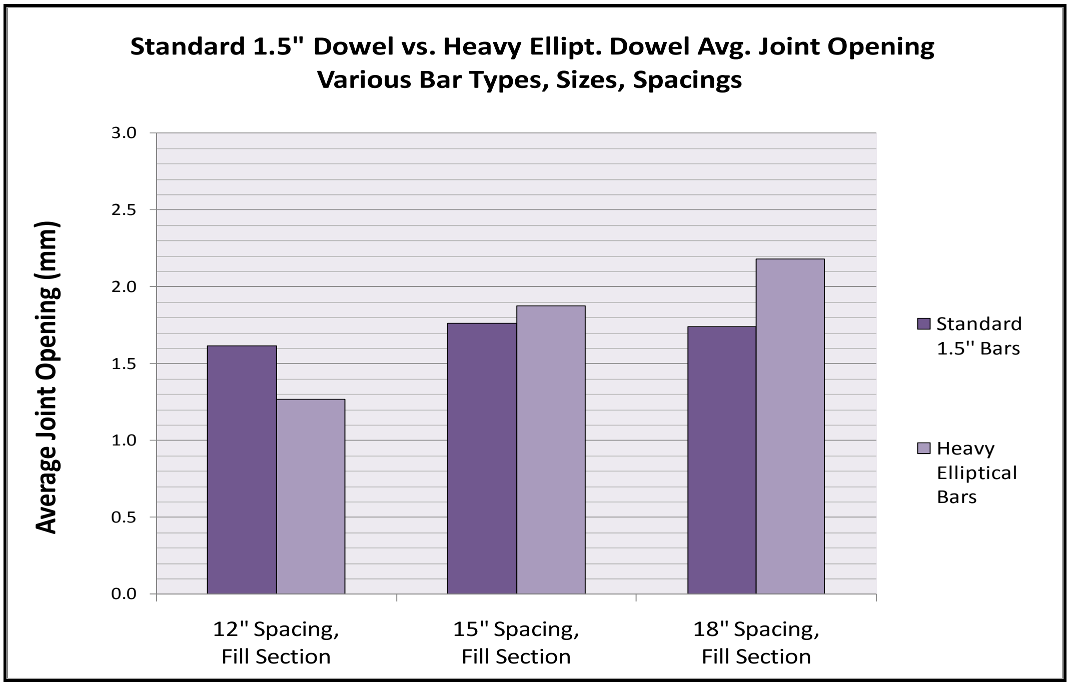


Figure 21. Standard 1.5” round vs. heavy elliptical dowels—joint opening

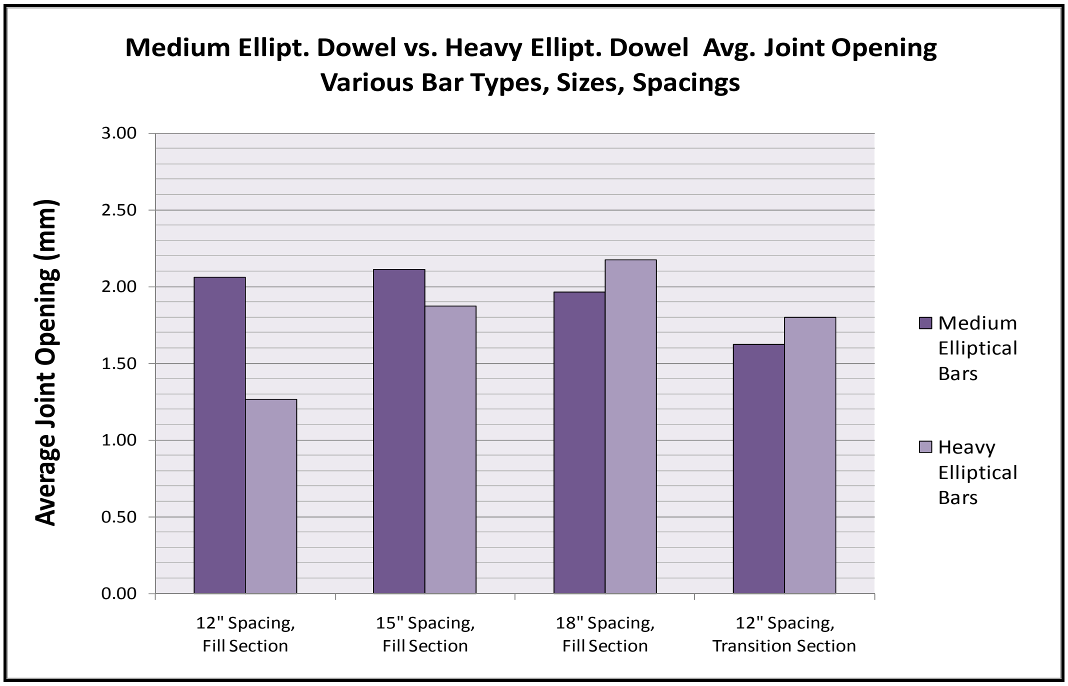


Figure 22. Medium elliptical vs. heavy elliptical dowels—joint opening

5.3.2 Dowel Spacing Analysis—Joint Opening

The summary of joint opening effects due to the change in dowel spacing can be seen in Figure 23. Figure 23 shows a comparison between 12 in., 15 in., and 18 in. spacing. Each group of bars in the figure represents a section combination where all things are considered constant except for the dowel spacing.

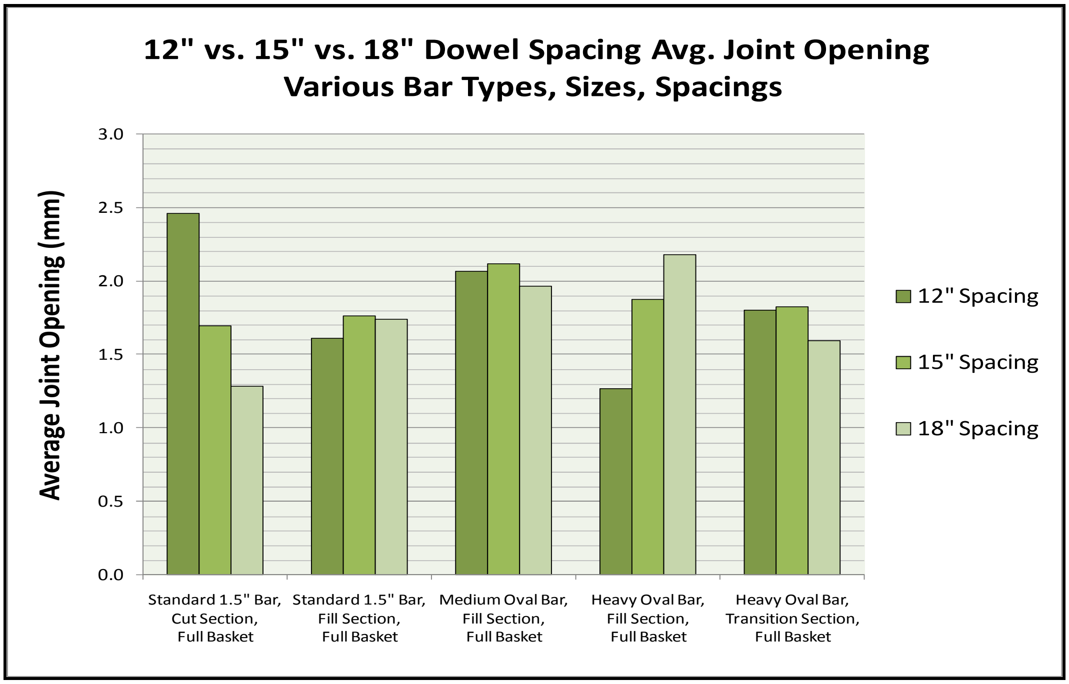


Figure 23. 12 in. vs. 15 in. vs. 18 in. spacing—joint opening

Figure 23 does not show any strong, consistent patterns of performance between the 12 in., 15 in., and 18 in. dowel bars in terms of joint openings.

5.3.3 Cut, Fill, or Transition Analysis—Joint Opening

The summary of joint opening effects due to the change in preconstruction subgrade location can be seen in Figures 24, 25, and 26. Figure 24 shows a comparison between cut and fill sections. Figure 25 shows a comparison between fill and transition sections. Figure 26 shows a comparison between cut and transition sections. Each group of bars in the figures represents a section combination where all things are considered constant except for the preconstruction subgrade location.

Figures 24–26 do not show any strong, consistent patterns of performance between the cut, fill, or transition sections in terms of joint opening.

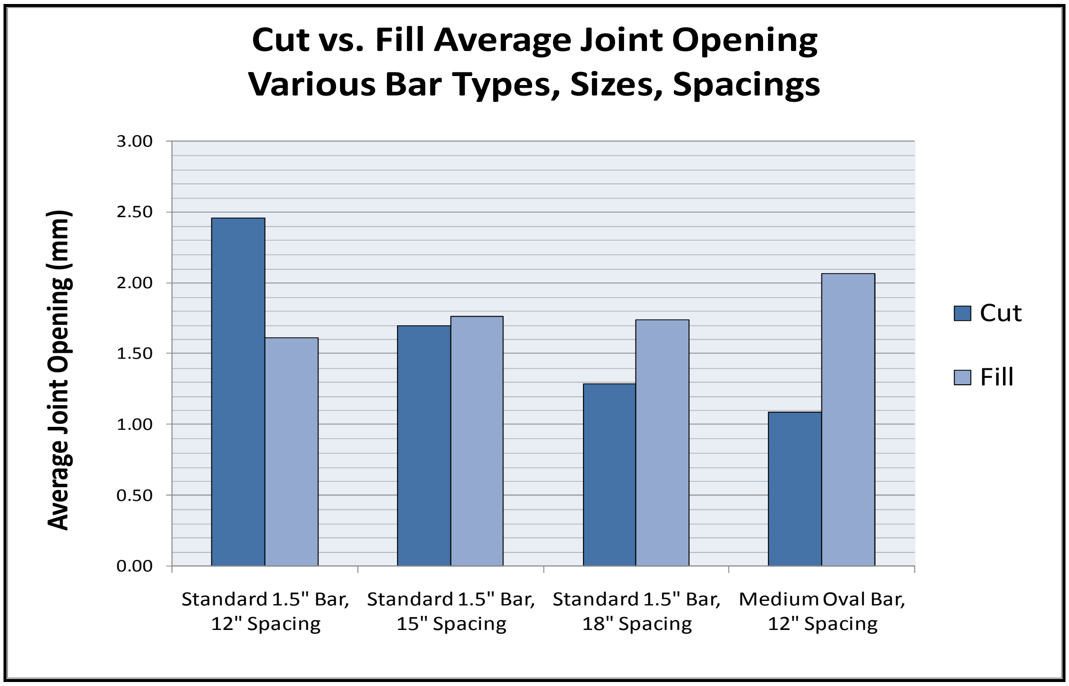


Figure 24. Cut vs. fill subgrade—joint opening

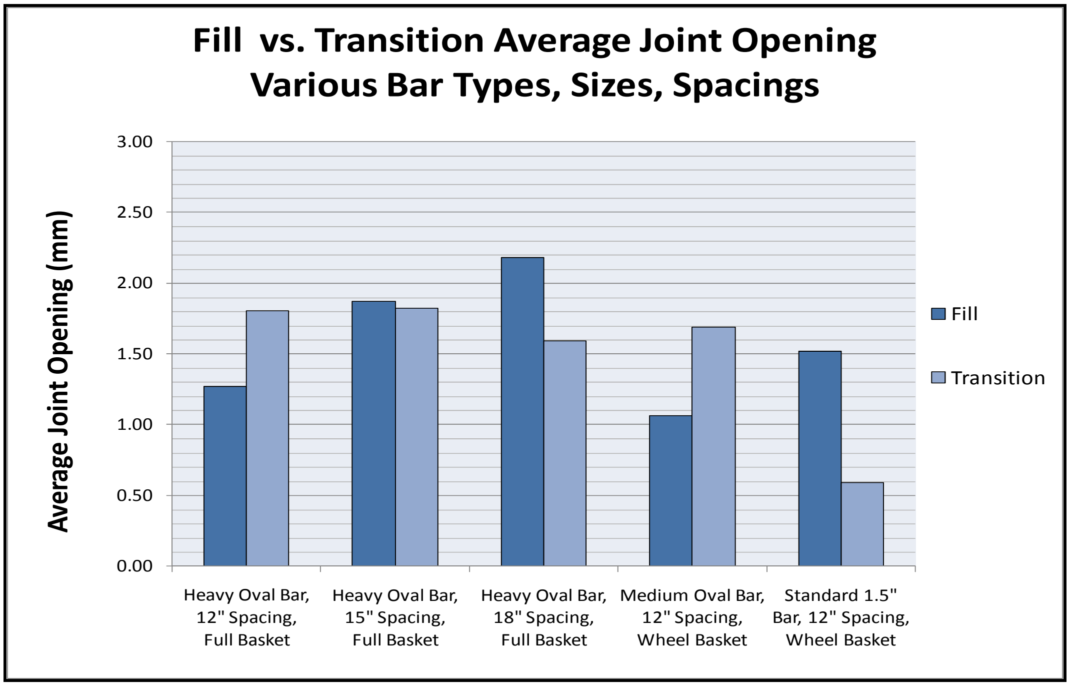


Figure 25. Fill vs. transition subgrade—joint opening

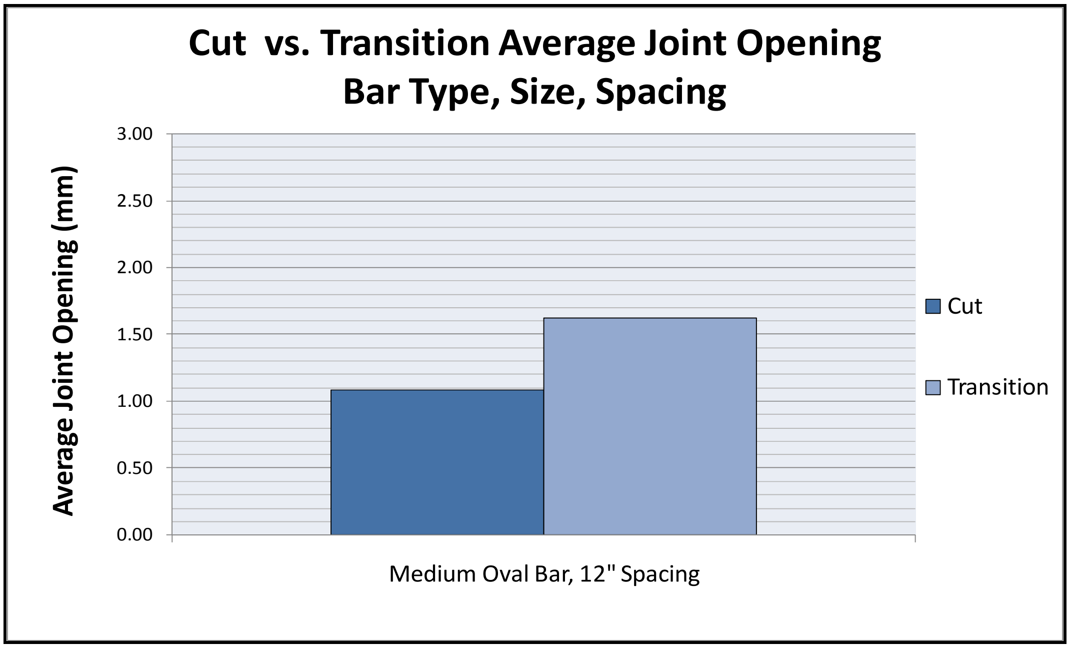


Figure 26. Cut vs. transition subgrade—joint opening

5.3.4 Full Basket and Wheel path Basket Analysis—Joint Opening

The summary of joint opening effects due to using full dowel baskets or dowels only in the wheel paths can be seen in Figure 27 below. Each group of bars in the figure represents a section combination where all things are considered constant except for the dowel basket type across the transverse joint.

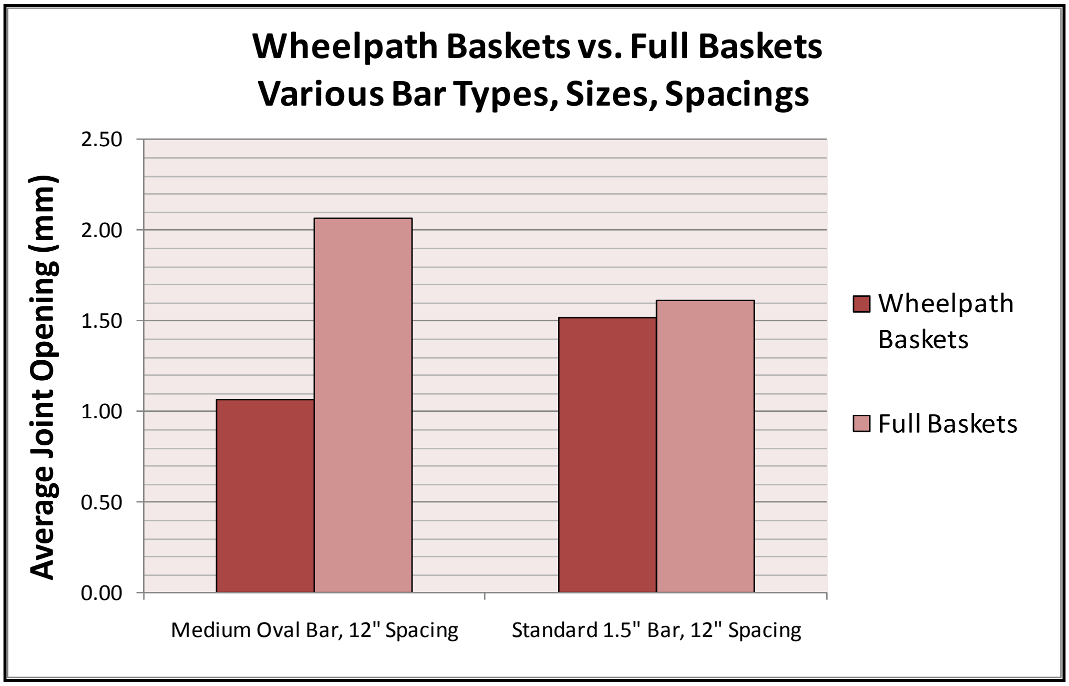


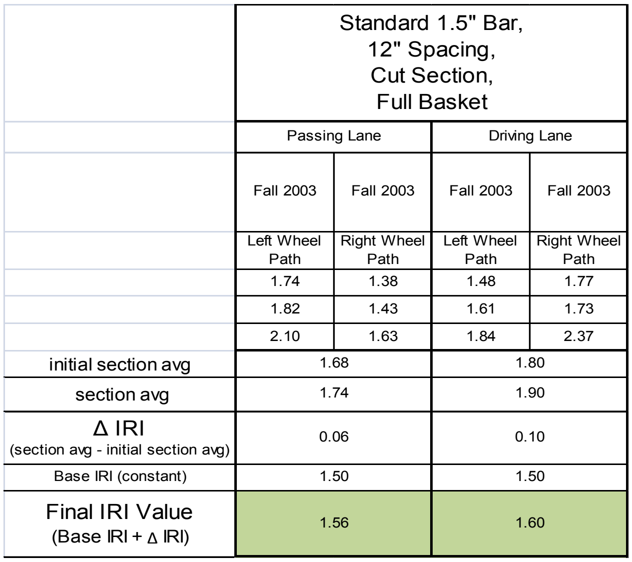
Figure 27. Wheelpath dowel baskets vs. full dowel baskets—joint opening

Figure 27 does show the possibility that wheel path dowel baskets had larger joint opening issues than full dowels baskets. However, with all the other erratic joint opening results, it is assumed that no conclusions can be reached for wheel path baskets versus full dowel baskets.

5.4 Profile

The data, normalized for temperature at collection time, were analyzed using the software ProVal, version 2.6. The length of the roadway profile was subdivided in sections that represent each of the test sections for the analysis. The software was used to calculate the International Roughness Index (IRI) of each test section in the left and right wheel paths of the driving and passing lanes. Just like before, the data were broken down by their variable characteristics. First, the data were compared by different dowel shapes. Second, different dowel spacings were compared. Next, the data were compared by the difference in subgrade location, such as cut, fill, or transition sections. Then, the data were broken down into driving lane and passing lane roughness. Finally, the difference between full dowel baskets and dowel baskets placed in the wheel paths only was compared. The initial IRIs for all the sections were not the same. This is attributed to construction irregularities, not the combination of dowel type, spacing, etc. Therefore, to account for this difference in initial IRI, the change in IRI was used to compare the different variables. The profile graphs in this section were created by using the base IRI, or the overall average initial IRI from the driving and passing lanes in all sections. This number turned out to be 1.50 m/km. This is noted on all the graphs. Then the initial IRI for a particular section (e.g. standard 1.5 in. bars, 12 in. spacing, cut section, full basket) was found and subtracted from the average of that particular section over the study period. This essentially gives a change in IRI that can be compared across sections. Then this change in IRI was added back on to the base IRI value so the numbers can be compared against one another at the appropriate scale. Table 2 below shows examples of how these numbers were calculated using the raw data.

Table 2. Example: Final IRI comparison determination



	Standard 1.5" Bar, 12" Spacing, Cut Section, Full Basket			
	Passing Lane		Driving Lane	
	Fall 2003	Fall 2003	Fall 2003	Fall 2003
	Left Wheel Path	Right Wheel Path	Left Wheel Path	Right Wheel Path
	1.74	1.38	1.48	1.77
	1.82	1.43	1.61	1.73
	2.10	1.63	1.84	2.37
initial section avg	1.68		1.80	
section avg	1.74		1.90	
Δ IRI (section avg - initial section avg)	0.06		0.10	
Base IRI (constant)	1.50		1.50	
Final IRI Value (Base IRI + Δ IRI)	1.56		1.60	

5.4.1 Dowel Type Analysis—Profile/Roughness

The summary of profile/roughness effects due to the change in dowel shape can be seen in Figures 28, 29, and 30. Figure 28 shows a comparison between standard round dowels and medium elliptical dowels. Figure 29 shows a comparison between standard round and heavy elliptical dowels. Figure 30 shows a comparison between medium elliptical dowels and heavy elliptical dowels. Each group of bars in the figures represents a section combination where all things are considered constant except for the dowel type used.

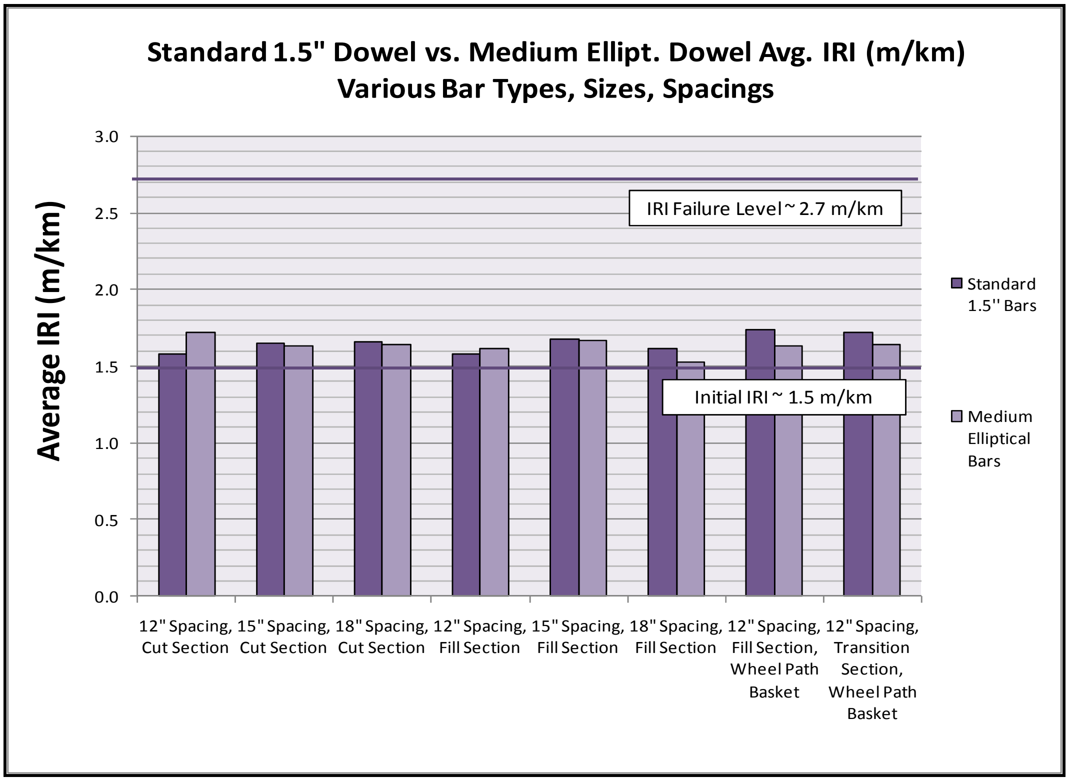


Figure 28. Standard 1.5 in. round vs. medium elliptical dowels—profile/roughness

Figure 28 shows medium elliptical dowel bars have profile values equal to the standard round dowel bars. The overall average IRI (m/km) of the standard 1.5 in. dowel bars in Figure 28 was 1.63 m/km verses an IRI of 1.61 m/km for the medium elliptical dowel bars. This indicates the medium elliptical dowel bars are performing just as well, if not better than the standard round dowel bars in terms of profile/roughness. Figure 28 also shows that medium elliptical dowel bars have lower profile values than standard round dowel bars when wheel path baskets are used. Data was collected with a single point high speed profiler. The differences shown in the data can be the result of the laser entering and exiting the longitudinal surface tining.

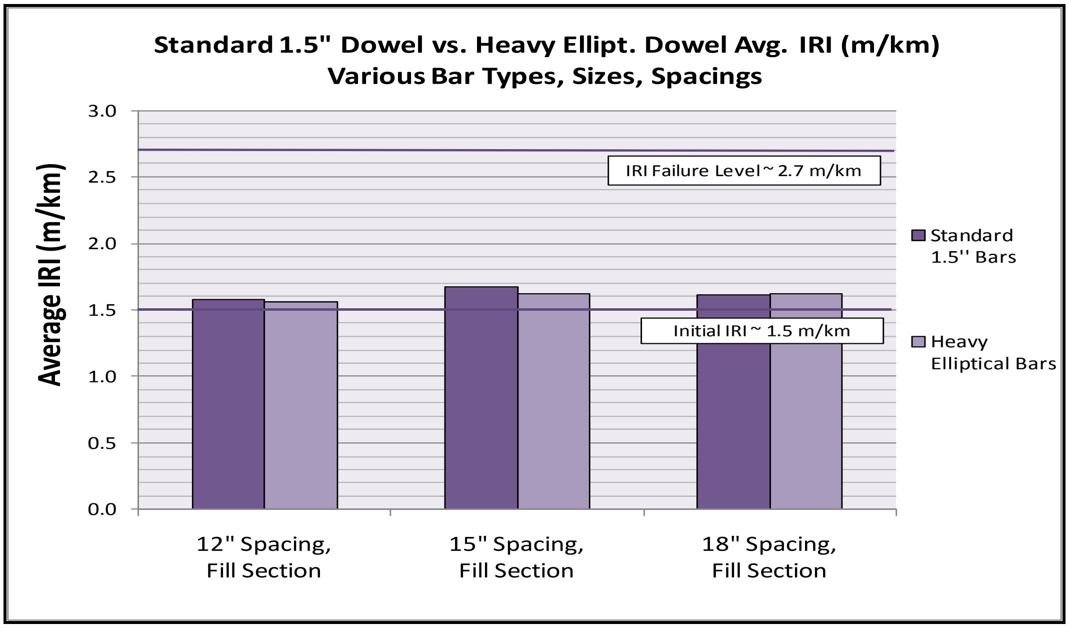


Figure 29. Standard 1.5" round vs. heavy elliptical dowels—profile/roughness

Figure 29 does not show any strong patterns of superior performance between the standard round dowel bars and the heavy elliptical dowel bars. The figure essentially shows equal IRI performance between standard round dowels and heavy elliptical dowels after five years of use.

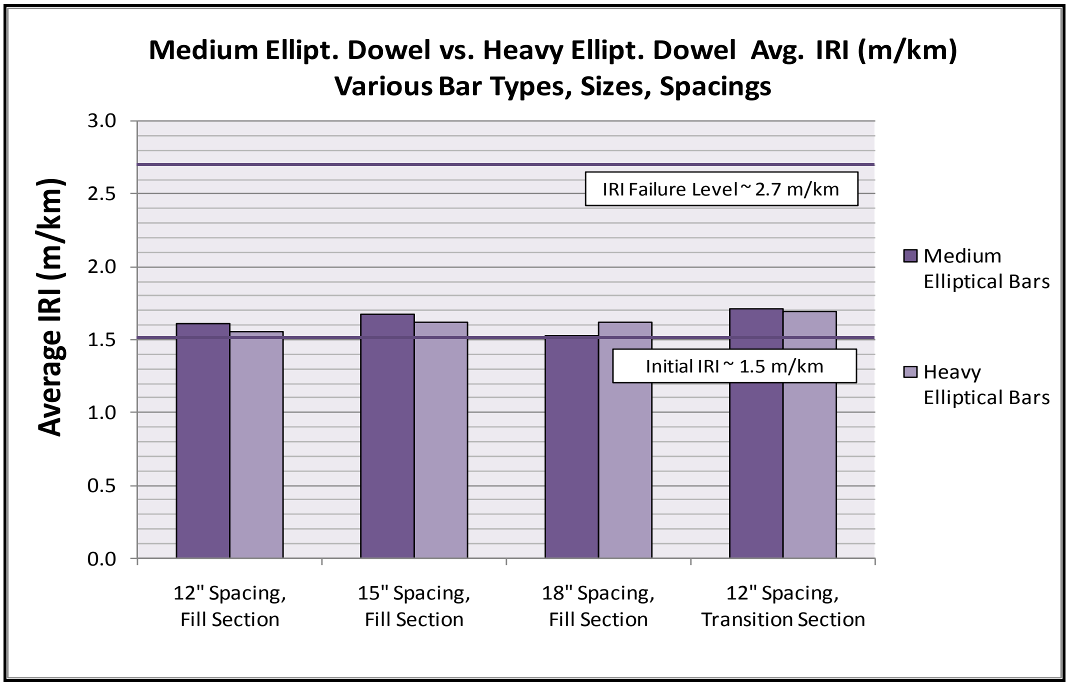


Figure 30. Medium elliptical vs. heavy elliptical dowels—profile/roughness

Overall, Figure 30 shows heavy elliptical may slightly outperform medium elliptical in terms of IRI over the five-year study. However, the slightly better performance of the heavy elliptical bars does not seem significant enough to justify spending extra money for the heavy elliptical bars. Therefore, it seems to be a better option to use medium elliptical bars instead of heavy elliptical bars in terms of IRI performance.

5.4.2 Dowel Spacing Analysis—Profile/Roughness

The summary of profile/roughness effects due to the change in dowel spacing can be seen in Figure 31 below. Figure 31 shows a comparison between 12 in., 15 in., and 18 in. spacing. Each group of bars in the figure represents a section combination where all things are considered constant except for the dowel spacing.

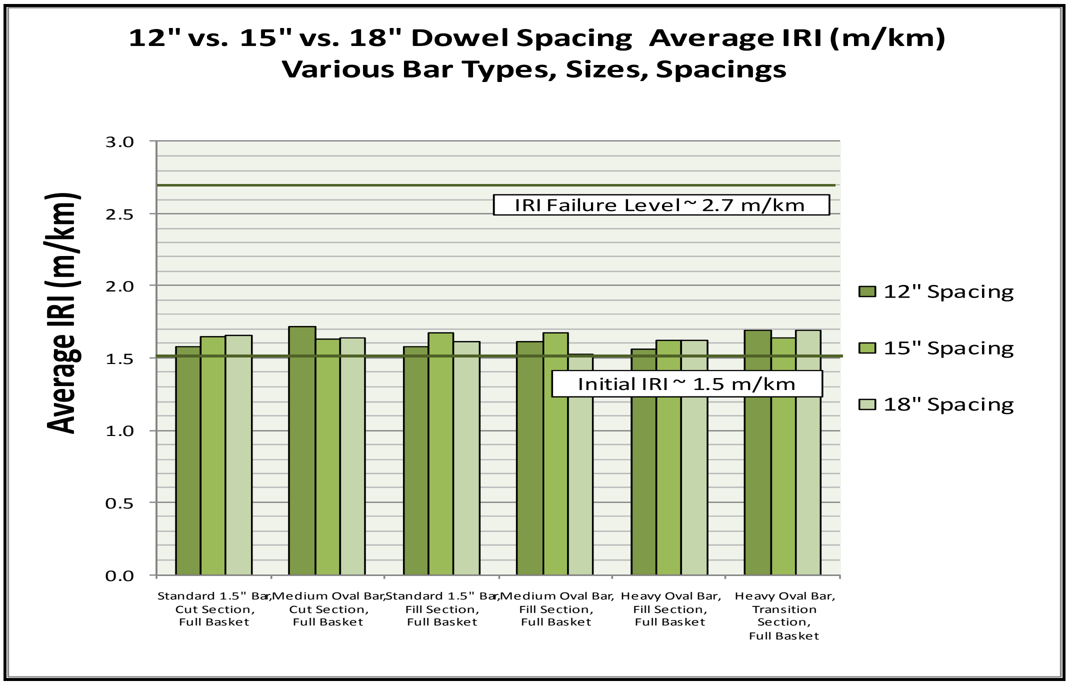


Figure 31. 12 in. vs. 15 in. vs. 18 in. spacing—profile/roughness

Figure 31 does not show any strong, consistent patterns of performance between the 12 in., 15 in., and 18 in. dowel bars. One would expect an increasing IRI as the spacing increased, as there would not be as many dowel bars. The overall average IRIs (m/km) for the 12 in., 15 in., and 18 in. spaced bars shown in Figure 31 were 1.60, 1.63, and 1.60 m/km respectively. This indicates little to no difference in IRI performance between 12 in., 15 in., and 18 in. spaced dowel bars.

5.4.3 Cut, Fill, or Transition Analysis—Profile/Roughness

The summary of profile/roughness effects due to the change in subgrade location can be seen in Figures 32, 33, and 34. Figure 32 shows a comparison between cut and fill sections. Figure 33 shows a comparison between fill and transition sections. Figure 34 shows a comparison between cut and transition sections. Each group of bars in the figures represents a section combination where all things are considered constant except for the subgrade location.

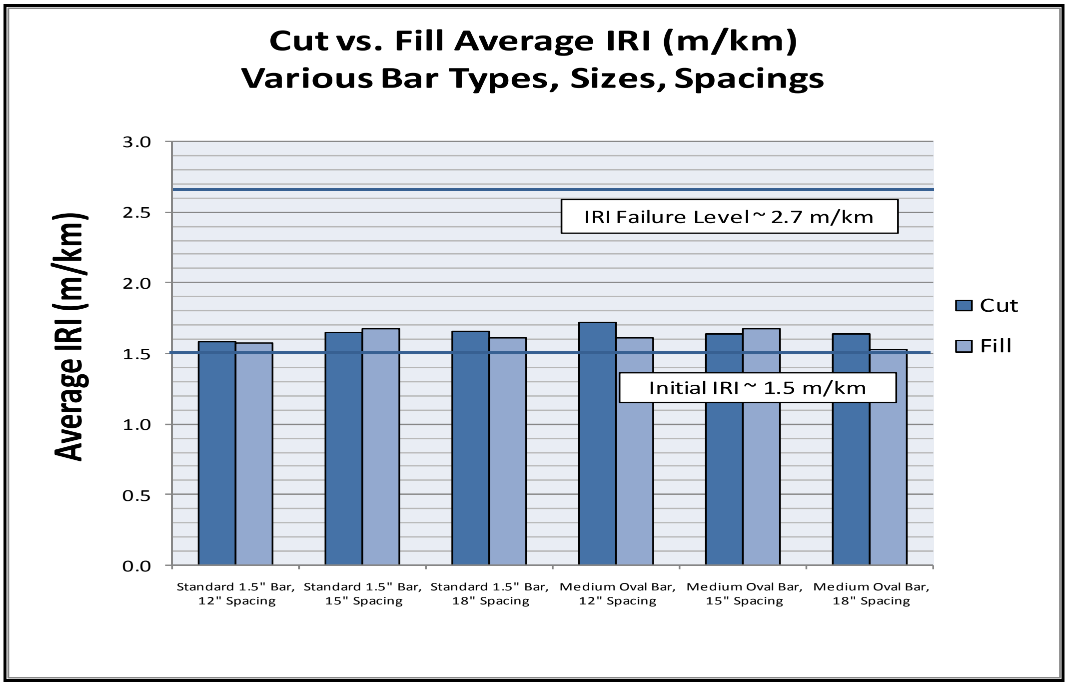


Figure 32. Cut vs. fill subgrade—profile/roughness

Figure 32 shows the fill sections had lower profile values than the cut sections. The overall average IRIs (m/km) for the cut and fill sections in Figure 32 were 1.63 and 1.59 m/km respectively.

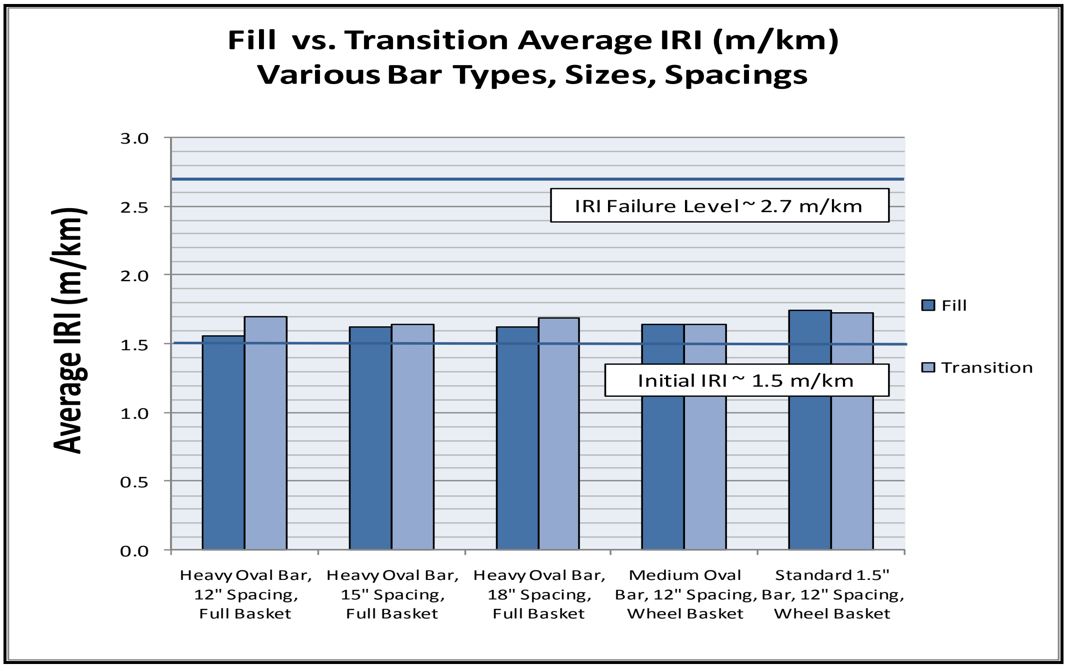


Figure 33. Fill vs. transition subgrade—profile/roughness

Figure 33 shows fill sections had lower profile values than transition sections over the five-year study. This indicates that fill sections had lower profile values than the cut and transition sections.

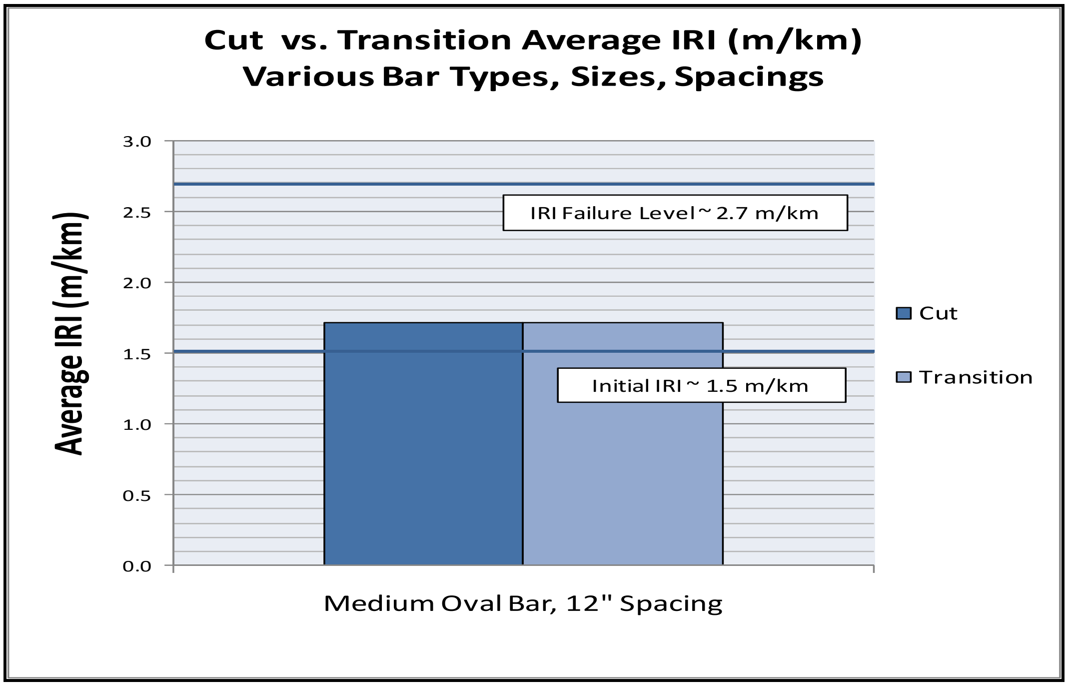


Figure 34. Cut vs. transition subgrade—profile/roughness

Figure 34 shows the cut and transition sections performing equally in terms of IRI. More test sections for this comparison would have been optimal; however, there is no evidence to conclude that either cut or transition sections performed differently than the other.

5.4.3 Driving Lane and Passing Lane Analysis—Profile/Roughness

The summary of IRI effects due to the change in driving or passing lanes can be seen in Figures 35, 36, 37, and 38. Figures 35–38 show the consistently higher IRI values in the driving lane compared with the passing lane. This was the case for most test sections in the study. The small magnitude of differences can be attributed to the single point laser and longitudinal tining of the surface.

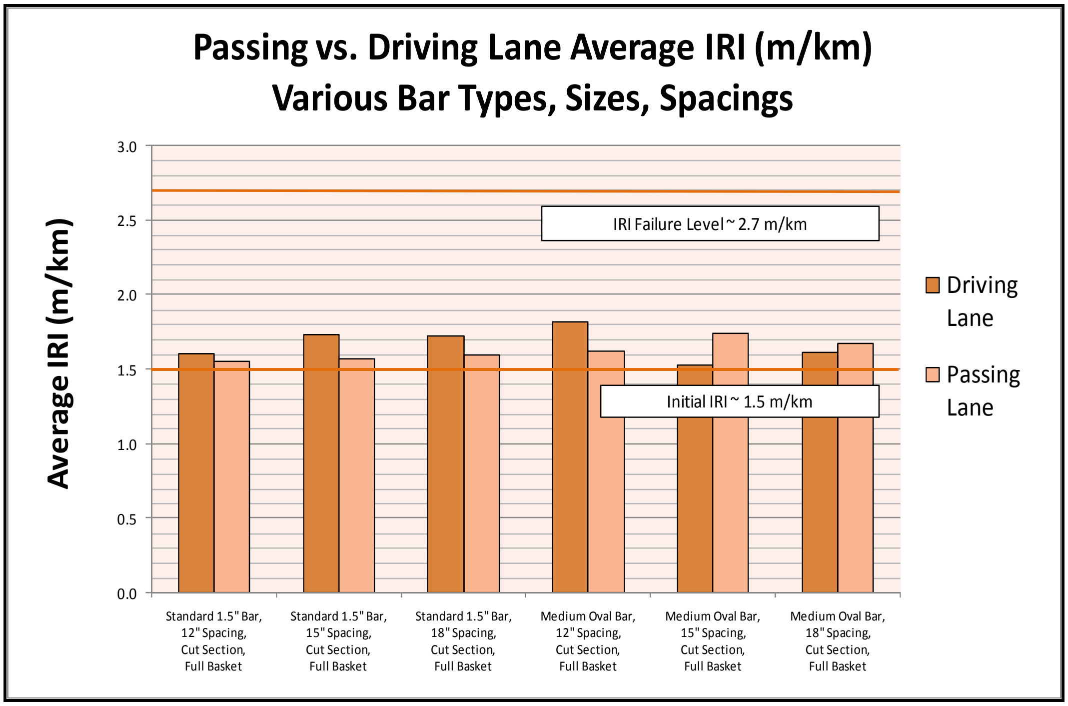


Figure 35. Driving vs. passing lane (1)—profile/roughness

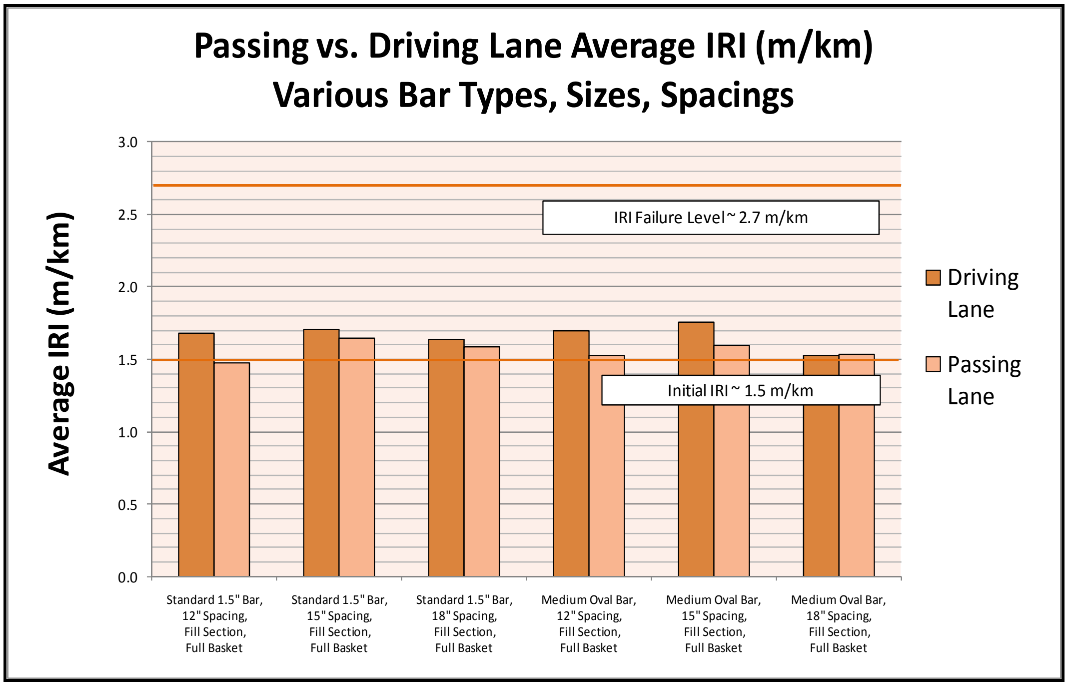


Figure 36. Driving vs. passing lane (2)—profile/roughness

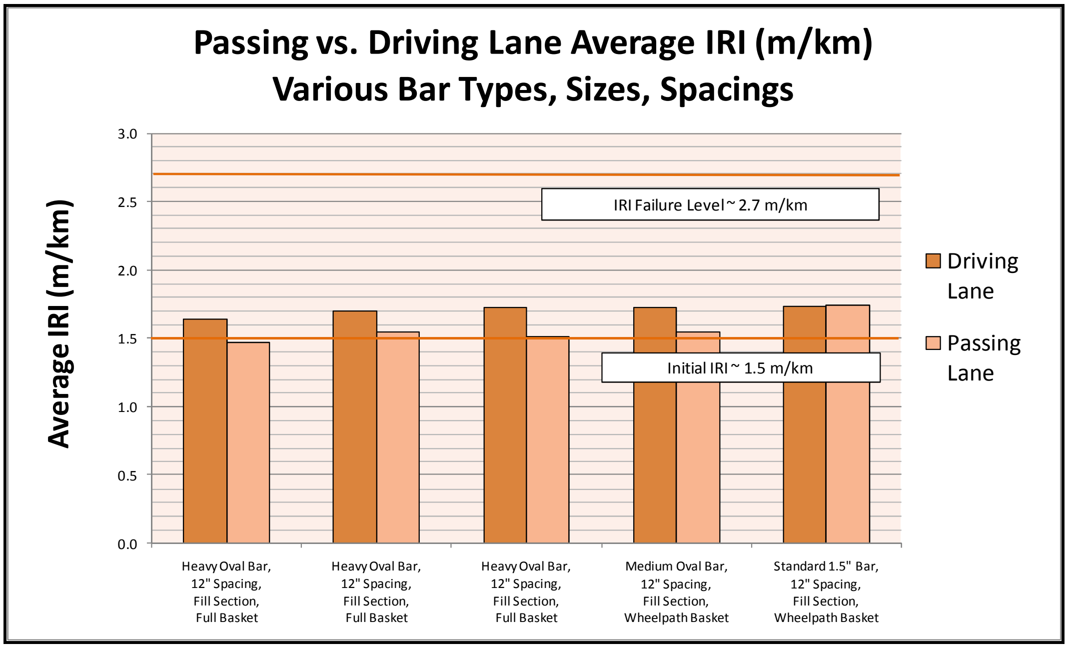


Figure 37. Driving vs. passing lane (3)—profile/roughness

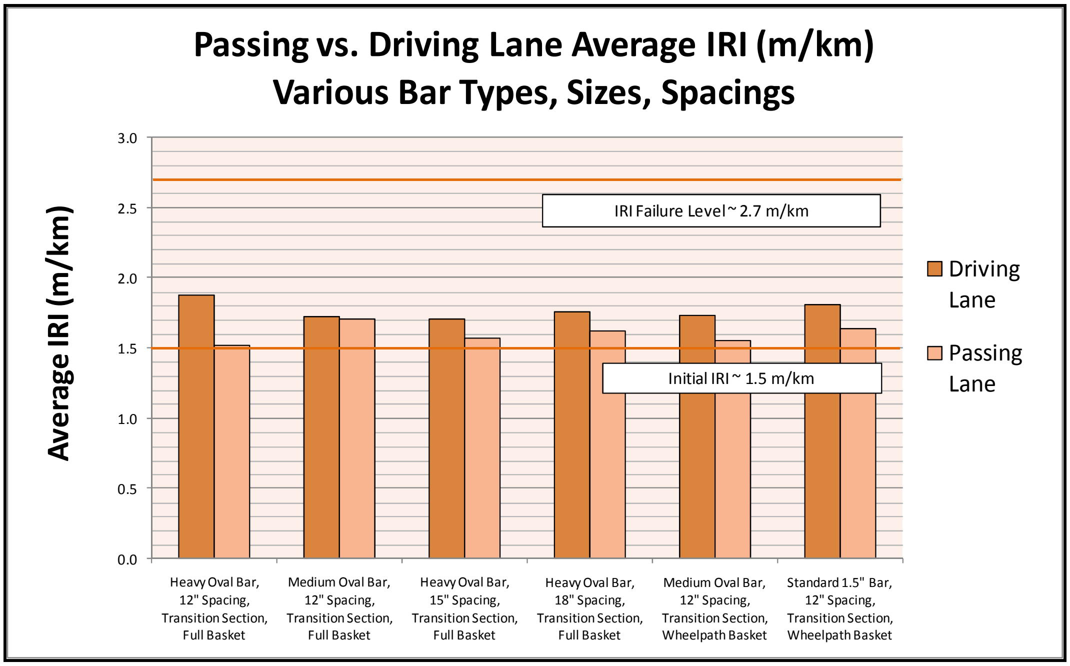


Figure 38. Driving vs. passing lane (4)—profile/roughness

5.4.4 Full Basket and Wheel path Basket Analysis—Profile/Roughness

The summary of profile/roughness effects due to using full dowel baskets or dowels only in the wheel paths can be seen in Figure 39 below. Each group of bars in the figure represents a section combination where all things are considered constant except for the dowel basket type across the transverse joint.

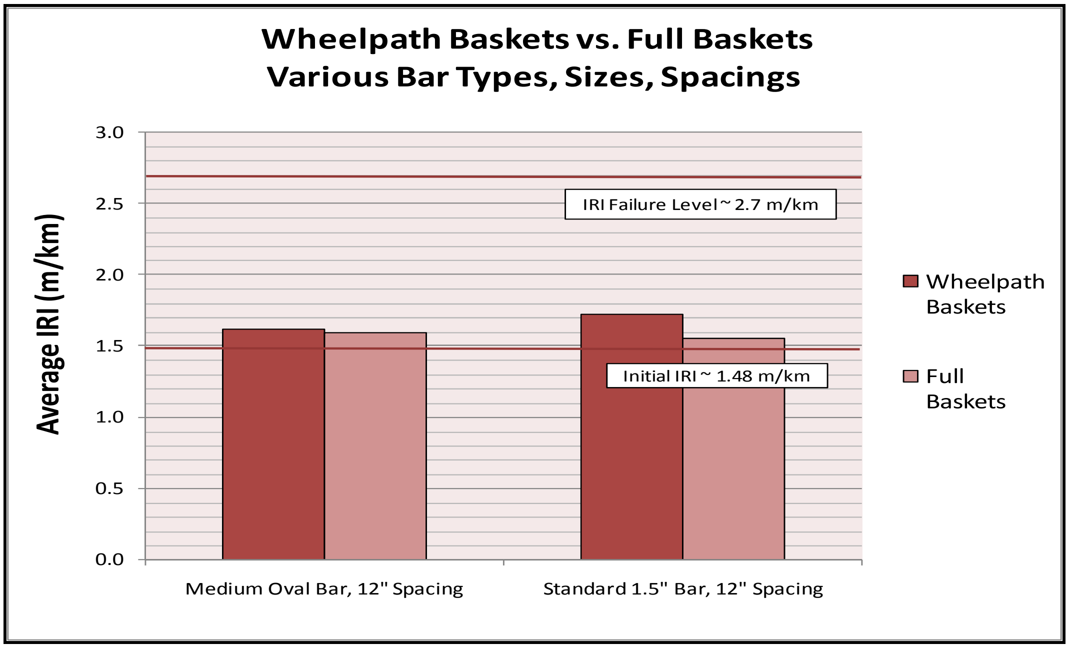


Figure 39. Wheel path dowel baskets vs. full dowel baskets—profile/roughness

Figure 39 suggests sections with medium elliptical dowel baskets placed only in the wheel paths provide equal IRI values with full medium elliptical dowel baskets. Figure 39 also suggests sections with standard round dowel baskets placed only in the wheel paths provide higher IRI values than full standard round dowel baskets. Further monitoring of this effect may be warranted.

5.5 Strain

All data from the strain measurements taken are summarized in the 2005 report “Field Evaluation of Elliptical Fiber Reinforced Polymer Dowel Performance” by Dr. Max Porter and Dr. James Cable. Strain gauge testing was terminated in fall 2005 due to strain gauge failures.

6. CONCLUSIONS

Using the graphs included in the data analysis section, a visual review of the data was conducted to determine conclusions about the study.

6.1 Load Transfer (FWD data)

- All dowel types transferred 80%–90% of the load across the joints.
- Medium elliptical steel dowel bars were equally adequate, if not better than standard round dowel bars at transferring load across the transverse joints.
- Medium elliptical steel dowel bars performed equally to standard round dowel bars when wheel path baskets were used.
- Dowel spacing of 12 in. (304.8 mm) and 15 in. (381 mm) indicated equal performance for elliptical medium, large, and round dowels, while 18 in. (457.2 mm) spacing provided a lower level of load transfer.
- Load transfer values were essentially equal for all bar materials and sizes, between cut, fill, and transition sections.
- Wheel path dowel baskets performed equal to full dowel baskets when the medium elliptical and standard rounds are compared.

6.2 Joint Faulting

- Elliptically shaped steel dowels show equal levels of faulting than standard round bars.
- Dowel spacing changes indicate no consistent faulting trends for any of the dowel bar sizes and shapes.
- Cut sections are showing more resistance to faulting while fill and transition sections are faulting equally at a higher faulting level for all dowel bar sizes and shapes.
- Passing lane faulting values are consistently higher than those in the driving lane for all dowel bar sizes and shapes.
- Wheel path dowel baskets are exhibiting faulting levels equal to that of full dowel baskets.

6.3 Joint Openings

- Bar size or shape shows no consistent performance trends in joint openings over the study period.
- Bar spacing shows no consistent performance trends in joint opening over the study period.
- Cut, fill, and transition sections indicate no consistent joint opening trends over the study period.

6.4 Profile

- Medium elliptical steel dowel bars are providing profile values equal to or lower than standard round dowel bars.
- Medium elliptical steel dowel bars provided equal profile values to standard round dowel bars when wheel path baskets were used.
- IRI values for 12 in. (304.8 mm), 15 in. (381 mm), and 18 in. (457.2 mm) spacings for each of the bar types and sizes provided equal levels of profile values.
- Fill sections are showing lower profile data than cut and transition sections for all dowel bar shapes and sizes. Cut and transition sections have equal profiling data.
- The passing lane provided lower profile values equal to that of the driving lane for all dowel bar shapes and sizes, when profiler capabilities are considered.
- Wheel path dowel baskets profile values were equal to those of the full dowel baskets when medium elliptical dowels were used.
- Wheel path dowel baskets have higher profile values than full dowel baskets when standard dowel bars were used.

Medium elliptical dowels bars are performing equal to or better than the traditional circular dowels.

7. GENERAL CONCLUSIONS

- The medium elliptical steel dowel (major axis = 1.654 in. [42.01 mm), minor axis = 1.115 in.[28.32 mm], and area = 1.473 in.[37.41 mm]) and large elliptical steel dowel (major axis = 1.969 in., [50.01 mm] minor axis = 1.338 in.[33.99 mm], and area = 2.084 in.[52.93 mm]) performed equal to or better than the conventional steel dowels (round, 1.50 in. [38.10 mm] diameter with a cross sectional area of 1.767 in.[44.88 mm]) in terms of deflection, visual distress, and joint faulting. No conclusions could be reached on the relative performance in terms of joint openings.
- The medium-sized elliptical steel dowels can be spaced up to 15 in. (381 mm) center to center and perform equal to or better than the conventional round bar. The use of 18 in.(457.2 mm) spacings cannot be substantiated with only five years of data.

- The impact of subgrade location (cut, fill, and transition) provided offsetting results in terms of faulting, load transfer, and profile, but not in terms of the differences between the performance of the various dowel shapes.
- The elliptical steel dowels, when used in standard baskets, can be placed as easily as the standard round bars in basket assemblies. The weight differences can be mitigated with the increased spacing of the elliptical bars to the 15 in. between round standard dowels and medium elliptical dowels.

8. RECOMMENDATIONS

- Make changes in the Iowa DOT specifications to allow for the use of elliptical-shaped steel dowels in the medium or large sizes (tested in this report) as an alternative to the standard round steel bars (1.5 in. [38.10 mm] diameter) currently in use.
- Employ the medium elliptical bars shown in this report for future construction at the 12 in. (304.8 mm) or 15 in. (381 mm) spacings.
- Consider further testing or monitoring of medium elliptical wheel path dowel bars to evaluate the long term performance.

9. REFERENCES

Porter, M. L., R. Guinn, A. Lundy. 2001. *Dowel Bar Optimization: Phases I and II*. Final Report. Ames, IA: Center for Portland Cement Concrete Pavement Technology.

Porter, M.L., J. K.Cable, J. F. Harrington, N. J. Pierson, A. W. Post. 2005. *Field Evaluation of Elliptical Fiber Reinforced Polymer Dowel Performance*. Final Report. Ames, IA: Center for Portland Cement Concrete Pavement Technology.

APPENDIX A: TYPICAL PROJECT CROSS SECTION

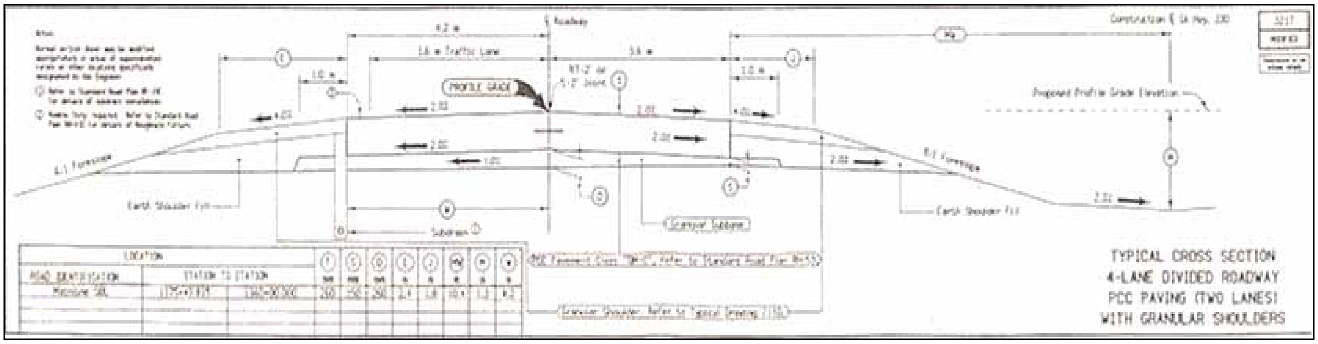


Figure A.1. Project cross section

APPENDIX B: INSTALLATION

Figure B.1 Gauge wires connected to frame

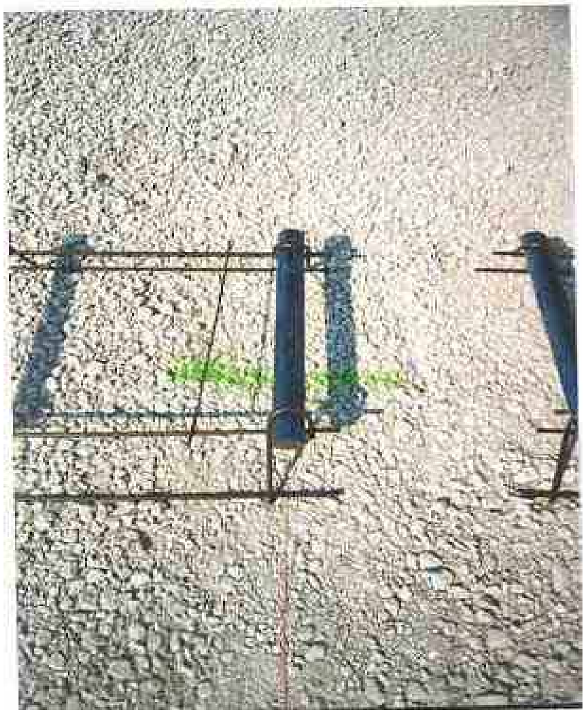


Figure B.2 Inner dowel bar over offset line

Figure B.3 Placed baskets

Figure B.4 Baskets placed at wheel paths

APPENDIX C: DOWEL BASKET LOCATIONS

Table C.1. Dowel basket locations

Field Evaluation of Elliptical Steel Dowel Performance—Iowa 330
Test and Non-test Dowel Basket Locations
As constructed July 16,2002 through September 30,2002

Test Section	Cut/Fill	Station		Station	Bar Type	Size	Spacing (Inches)
		Proposed	**Actual**				
1T	BOP	1175+44		1176+00	standard	35 mm	12
2	fill	1176+00	1176+00	1177+20	standard	1.5 in	12
3T		1177+20		1177+50	standard	35 mm	12
4	fill	1177+50	1177+51	1178+70	standard	1.5 in	12
5T		1178+70		1179+00	standard	35 mm	12
6	fill	1179+00	1179+03	1178+20	standard	1.5 in	12
7T		1178+20		1180+50	standard	35 mm	12
8	fill	1180+50	1180+55	1181+70	standard	1.5 in	15
9T		1181+70		1182+00	standard	35 mm	12
10	fill	1182+00	1182+00	1183+20	standard	1.5 in	15
11	fill	1183+50	1183+53	1184+70	standard	1.5 in	15
12T		1184+70		1187+00	standard	35 mm	12
13	fill	1187+00	1187+01	1188+20	standard	1.5 in	18
14T		1188+20		1188+50	standard	35 mm	12
15	fill	1188+50	1188+55	1189+70	standard	1.5 in	18
16T		1189+70		1190+00	standard	35 mm	12
17	fill	1190+00	1190+00	1191+20	standard	1.5 in	18
18T		1191+20		1191+50	standard	35 mm	12
19	fill	1191+50	1191+51	1192+70	medium	oval	12
20T		1192+70		1193+00	standard	35 mm	12
21	transition	1193+00	1193+00	1194+20	heavy	oval	12
22T		1194+20		1194+50	standard	35 mm	12
23	fill	1194+50	1194+50	1195+70	medium	oval	12
24T		1195+70		1197+00	standard	35 mm	12
25	transition	1197+00	1197+03	1198+20	heavy	oval	12
26T		1198+20		1198+50	standard	35 mm	12
27	transition	1198+50	1198+52	1199+70	heavy	oval	12
28T		1199+70		1201+50	standard	35 mm	12
29	transition	1201+50	1201+55	1202+70	medium	oval	12
30T		1202+70		1204+50	standard	35 mm	12
31	transition	1204+50	1204+55	1205+70	heavy	oval	15
32T		1205+70		1206+00	standard	35 mm	12
33	fill	1206+00	1206+01	1207+20	medium	oval	15
34T		1207+20		1209+00	standard	35 mm	12
35	fill	1209+00	1209+02	1210+20	medium	oval	15
36T		1210+20		1210+50	standard	35 mm	12
37	transition	1210+50	1210+55	1211+70	heavy	oval	15
38T		1211+70		1213+00	standard	35 mm	12
39	fill	1213+00	1213+05	1214+20	medium	oval	15
40T		1214+20		1214+50	standard	35 mm	12

Test Section	Cut/Fill	Station		Station	Bar Type	Size	Spacing (Inches)
		Proposed	Actual				
41	fill	1214+50	1214+56	1215+70	medium	oval	18
42T		1215+70		1216+00	standard	35 mm	12
43RG	fill	1216+00	1216+01	1217+20	medium	oval	18
44T		1217+20		1217+50	standard	35 mm	12
45RG	fill	1217+50	1217+50	1218+70	medium	oval	18
46T		1218+70		1219+00	standard	35 mm	12
47RG	fill	1219+00	1219+00	1220+20	heavy	oval	12
48T		1220+20		1222+00	standard	35 mm	12
49	transition	1222+00	1222+01	1223+20	heavy	oval	15
50T		1223+20		1223+50	standard	35 mm	12
51	fill	1223+50	1123+51	1224+70	heavy	oval	12
52T		1224+70		1225+00	standard	35 mm	12
53	transition	1225+00	1125+01	1226+20	heavy	oval	18
54T		1226+20		1226+50	standard	35 mm	12
55	fill	1226+50	1226+51	1227+70	heavy	oval	12
56T		1227+70		1228+00	standard	35 mm	12
57	transition	1228+00	1228+01	1229+20	heavy	oval	18
58T		1229+20		1229+50	standard	35 mm	12
59	fill	1229+50	1229+52	1230+70	heavy	oval	15
60T		1230+70		1231+00	standard	35 mm	12
61	fill	1231+00	1231+03	1232+20	heavy	oval	15
62T		1232+20		1232+50	standard	35 mm	12
63	fill	1232+50	1232+53	1233+70	heavy	oval	15
64T		1233+70		1237+00	standard	35 mm	12
65	fill	1237+00	1237+00	1238+20	heavy	oval	18
66T		1238+20		1238+50	standard	35 mm	12
67	transition	1238+50	1238+54	1239+70	heavy	oval	18
68T		1239+70		1240+00	standard	35 mm	12
69	cut	1240+00	1240+05	1241+20	standard	1.5 in	12
70T		1241+20		1241+50	standard	35 mm	12
71	cut	1241+50	1241+55	1242+70	standard	1.5 in	12
72T		1242+70		1243+00	standard	35 mm	12
73	cut	1243+00	1243+03	1244+20	standard	1.5 in	12
74T		1244+20		1244+50	standard	35 mm	12
75	fill	1244+50	1244+52	1245+70	heavy	oval	18
76T		1245+70		1246+50	standard	35 mm	12
77	cut	1246+50	1246+51	1247+70	standard	1.5 in	15
78T		1247+70		1248+50	standard	35 mm	12
79	cut	1248+50	1248+50	1249+70	standard	1.5 in	15
80T		1249+70		1250+00	standard	35 mm	12
81	transition	1250+00	1250+00	1251+20	spec. medium	oval	12
82T		1251+20		1251+50	standard	35 mm	12
83	fill	1251+50	1251+50	1252+70	heavy	oval	18
84T		1252+70		1253+00	standard	35 mm	12

Test	Cut/Fill	Station		Station	Bar Type	Size	Spacing
Section		Proposed	Actual				(Inches)
85	fill	1253+00	1253+00	1254+20	spec. medium	oval	12
86T		1254+20		1254+50	standard	35 mm	12
87	fill	1254+50	1254+50	1255+70	spec. medium	oval	12
88T		1255+70		1256+00	standard	35 mm	12
89	fill	1256+00	1256+06	1257+20	spec. medium	oval	12
90T		1257+20		1259+00	standard	35 mm	12
91	fill	1259+00	1259+03	1260+20	spec. standard	1.5 in	12
92T		1260+20		1260+30	standard	35 mm	12
93	transition	1260+30	1260+35	1261+50	spec. medium	oval	12
94T		1261+50		1261+60	standard	35 mm	12
95	cut	1261+60	1261+60	1262+80	standard	1.5 in	15
96T		1262+80		1262+90	standard	35 mm	12
97	cut	1262+90	1262+85	1263+70	standard	1.5 in	18
98	transition	1264+00	1264+06	1265+20	spec. medium	oval	12
99T		1265+20		1265+30	standard	35 mm	12
100	fill	1265+30	1265+32	1266+50	spec. standard	1.5 in	12
101	fill	1266+50	1266+53	1267+70	spec. standard	1.5 in	12
102T		1267+70		1275+80	standard	35 mm	12
103	transition	1275+80	1275+81	1277+00	spec. standard	1.5 in	12
104	cut	1277+00	1277+05	1278+20	standard	1.5 in	18
105T		1278+20		1278+50	standard	35 mm	12
106	cut	1278+50	1278+54	1279+70	standard	1.5 in	18
107T		1279+70		1280+00	standard	35 mm	12
108	cut	1280+00	1280+03	1281+20	medium	oval	12
109T		1281+20		1301+00	standard	35 mm	12
110	transition	1301+00	1301+01	1302+20	spec. standard	1.5 in	12
111T		1302+20		1317+00	standard	35 mm	12
112	cut	1317+00	1317+03	1318+20	medium	oval	12
113T		1318+20		1318+50	standard	35 mm	12
114	cut	1318+50	1318+54	1319+70	medium	oval	12
115T		1319+70		1320+00	standard	35 mm	12
116	cut	1320+00	1320+05	1321+20	medium	oval	15
117T		1321+20		1327+00	standard	35 mm	12
118	transition	1327+00	1327+06	1328+20	spec. standard	1.5 in	12
119T		1328+20		1331+00	standard	35 mm	12
120	cut	1331+00	1331+00	1332+20	medium	oval	15
121T		1332+20		1332+50	standard	35 mm	12
122	cut	1332+50	1332+52	1333+70	medium	oval	15
123T		1333+70		1339+00	standard	35 mm	12
124	cut	1339+00	1339+06	1340+20	medium	oval	18
125T		1340+20		1343+50	standard	35 mm	12
126	cut	1343+50	1343+56	1344+70	medium	oval	18
127T		1344+70		1345+00	standard	35 mm	12
128	cut	1345+00	1345+05	1346+20	medium	oval	18
129T	EOP	1346+20		1360+00	standard	35 mm	12

Note: Sections designated with a “T” are non-test sections
Test sections designated with a “RG” are located in the rebuilt gr