Asphalt Mix Overlay Alternative for Low Volume Roads on the Local Transportation System

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16. Abstract

This research project aimed to identify or develop a practical method for designing a well-performing hot mix asphalt (HMA) for use on low-volume local roads with severe cracking that can be produced in existing asphalt plants and can be placed using conventional paving equipment available in Ohio. This research project was conducted in two phases. In Phase 1, a comprehensive literature review was conducted to identify mix design procedures that have been used to produce an asphalt mixture that is resilient to cracking and can withstand prevailing environmental conditions in Ohio. In addition, state and local transportation agencies in the United States were surveyed to document their current state-of-the-practice with regard to pavement resurfacing for low-volume roads. Medina County Highway Department (MCHD) reported using a recipe mix (Medina County Specification (CS) 402) that is resilient to cracking and can be produced and placed using conventional HMA plants and paving equipment. This asphalt mixture consisted mainly of 90% No. 57 limestone aggregates mixed with 10% natural sand. A PG 58-28 asphalt binder was used in this mixture at a binder content of 4.3%. This asphalt mixture is installed as an intermediate asphalt course followed by aggregate choking using No. 9 aggregates and chip sealing. A laboratory testing plan was designed and executed in Phase 1 to optimize the mix design of Medina CS 402. Based on the outcome of these laboratory tests, several modifications were proposed to Medina CS 402 for consideration in the field evaluations in Phase 2. These modifications included reducing the amount of No. 57 aggregates to 80% and increasing the amount of natural sand to 20%. In addition, it was recommended to increase the asphalt binder content to 4.8% or 5.3%. To validate the proposed modifications and further optimize the mix design of Medina CS 402, several pavement test sections were constructed using different material combinations at two test sites in Medina County and Franklin County. Based on the laboratory test results for the plant-produced asphalt mixtures that were collected during production, it was recommended to use an asphalt binder content of 5.3% for Medina CS 402. The laboratory test results obtained for the field-produced asphalt mixture containing crushed gravel suggested that this type of aggregate can be used as an alternative to limestone in this asphalt mixture. Therefore, either No. 57 limestone or No. 57 crushed gravel can be used for Medina CS 402. It was recommended to continue to monitor the performance of the field sections for the next three years to five years to determine if any changes in the mix design of the asphalt mixture are needed.

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1. Problem Statement

Pavement resurfacing for low-volume roads with extensive fatigue cracking is an issue faced by many local public agencies (LPAs) in Ohio. Current options range from chip sealing, which is generally not effective if used on a pavement surface in a poor condition, to full-depth reclamation, where the existing asphalt surface and base materials are pulverized using a specialized machine called a reclaimer, mixed with other materials such as Portland cement, lime, fly ash, or asphalt emulsion and possibly virgin aggregate, before being compacted to produce a stabilized base course for either an asphalt or concrete surface. While the latter option might provide a more durable surface, it is prohibitively expensive for most LPAs especially for roads with very low traffic volumes.

Another resurfacing option used by some counties in Ohio is motor paving with cold mix asphalt followed by chip sealing. In this process, aggregates are mixed with an asphalt emulsion in a paver and applied to the road surface. The paved surface is then compacted with a roller and, after the emulsion has cured, the surface is chip sealed. The advantage of this option is that it provides a resilient mix that conforms to the surface of the existing pavement. While counties using this resurfacing option have reported positive results, the required motor paver equipment is not widely available in Ohio, making this option expensive for some LPAs. As a result, LPAs are interested in having a hot mix asphalt (HMA) – with comparable performance to cold-laid motor-paving mix – that can be produced in existing asphalt plants and placed using conventional paving equipment commonly available in Ohio.

The Ohio Department of Transportation (ODOT) has a supplemental specification that provides guidance for producing asphalt mixtures for use on roads with light traffic: Supplemental Specification (SS) 823 "Light Traffic Asphalt Mixture Composition Requirements" (ODOT 2014). For surface courses, ODOT SS 823 specifies a Type 1 asphalt mixture prepared using PG 64-22 asphalt binder with a nominal maximum aggregate size (NMAS) of 3/8 inch (9.5 mm). This asphalt mixture is designed using the Marshall mix design method with a design air voids of 3.5%, 35 blows per side for compaction (to simulate light traffic), target asphalt binder content ranging between 5.8% and 10.0%, maximum fines to effective asphalt (F/A) ratio of 1.2, minimum voids in mineral aggregates (VMA) of 16%, minimum stability of 750 lbs (3,336 N), and flow ranging between 8 to 18 (measured in 0.1-inch or 0.25-mm increments).

ODOT SS 823 defines a light traffic level as having fewer than 50 trucks per day. However, some of the roads maintained by LPAs have less than 50 trucks per year. Therefore, direct application of SS 823 Type 1 surface mix for pavement resurfacing on such roads may not be appropriate. Moreover, for county and township roads with very low traffic volumes, the impact of weather on pavement performance might be more of a factor than traffic loading. As indicated in the Request for Proposals (RFP) for this project, some county engineers have tried to develop in-house HMA mixes for this application with varying degrees of success. While some believe that the solution to this issue is in the application method, others question if the mix being used is more of a contributing factor.

Research is needed to identify or develop a mix design method for an HMA mix with adequate resistance to fatigue cracking and environmental conditions that can be used by LPAs throughout Ohio on local roads with very low traffic volumes. The recommended mix design method shall also result in an asphalt mixture that can be produced in a conventional HMA plant and be placed using readily available paving equipment.

2. Objectives of the Study

The primary objective in this study is to identify or develop a practical method for designing a well-performing asphalt mixture for use on low-volume local roads with severe cracking that has comparable performance to a cold-laid, motor paver mixture and can be produced in existing asphalt plants and can be placed using conventional paving equipment available in Ohio. The specific objectives of this study include:

- Assess the current-state-of-the-practice for pavement resurfacing alternatives currently used by LPAs in Ohio and other states.
- Recommend a cost-effective mix design for an asphalt mixture that is resilient to cracking and environmental conditions prevalent in Ohio.
- Validate the proposed mix design procedure through laboratory testing and in-field evaluations.

3. Preliminary Results from Phase 1

This research project was conducted in two phases. In Phase 1, a comprehensive literature review was conducted to identify mix design procedures that have been used to produce an asphalt mixture that is resilient to cracking and can withstand prevailing environmental conditions for use on low-volume roads with deteriorated surfaces. In addition, state and local transportation agencies in the United States were surveyed to document their current state-of-the-practice with regard to pavement resurfacing for low-volume roads. Medina County Highway Department (MCHD) reported using a recipe mix, referred to as Medina County Specification (CS) 402, that has a similar composition to a motor-paving mix but can be produced and placed using conventional HMA plants and paving equipment. This asphalt mixture consisted of 90% No. 57 coarse limestone aggregates mixed with 10% natural sand. A PG 58-28 asphalt binder was used in this mixture at a binder content of 4.3%.

A laboratory testing plan was designed and executed in Phase 1 to optimize the mix design of Medina CS 402. A performance-based approach was followed to ensure a satisfactory performance for the resulting asphalt mixtures. This approach consisted of limited testing for screening purposes as well as more extensive testing for thorough evaluation of these mixtures. The indirect tension asphalt cracking test (IDEAL-CT) was used to screen several asphalt mixtures in order to identify the mixtures to consider in the thorough evaluation (Zhou et al. 2017 and ASTM D8225-19). As part of the thorough evaluation, the asphalt mixtures were evaluated using the modified Lottman test (AASHTO T 283 and ODOT Supplement 1051), Texas overlay tester (according to Tex-248-F), asphalt binder cracking device (ACCD; Kim et al. 2015), semi-circular bend (SCB) test (AASHTO TP 124-16), and asphalt pavement analyzer (APA; AASHTO T 340 and ODOT Supplement 1057).

Based on the outcome of the screening and thorough evaluations that were conducted as part of the laboratory testing plan in Phase 1, several modifications were proposed to Medina CS 402 to be considered for the field evaluations in Phase 2:

- Aggregate gradation and asphalt binder content: An asphalt mixture consisting of 90% No. 57 limestone and 10% natural sand mixed with PG 58-28 at an asphalt content (AC) of 4.3% has previously been used by Medina County for Medina CS 402. However, this asphalt mixture failed the Texas overlay tester for the minimum number of cycles to failure of 100. To enhance the resistance of the asphalt mixture to cracking, several asphalt mixtures were evaluated that consisted of a lower amount of No. 57 coarse aggregates and a higher amount of natural sand (i.e., a finer aggregate gradation) mixed with asphalt binders at higher asphalt contents. The resulting asphalt mixtures showed an improvement in the resistance of the asphalt mixture to cracking as measured in the IDEAL-CT, SCB, and Texas overlay tester. Consequently, it was suggested to adjust the aggregate gradation of Medina CS 402, as outlined in Table 3, to reduce the amount of No. 57 coarse aggregates that can be incorporated into the asphalt mixture. In addition, it was suggested to increase the asphalt binder content in the asphalt mixture from 4.3% to 4.8% or 5.3%.

Table 1: Current and Proposed Aggregate Gradation Specification Limits for Medina CS 402.

	Percent Passing (%)	
Sieve	Current Specification Limits	Proposed Specification Limit
1”	100	100
¾”	85 – 100	85 – 100
⅜”	20 – 45	25 – 45
No. 4	15 – 30	18 – 30
No. 16	10 – 25	12 – 25
No. 50	3 – 15	3 – 15
No. 200	0 – 5	0 – 5

- Asphalt Type: Several asphalt mixtures prepared using different asphalt binders (PG 52-28, PG 58-28, and PG 64-22) were investigated in this study. The asphalt mixtures prepared using PG 58-28 showed the highest resistance to cracking. Therefore, it was suggested to continue to use PG 58-28 for Medina CS 402.
- Aggregate properties: Several asphalt mixtures prepared using No. 57 limestone, partially crushed gravel, and crushed gravel were investigated in the laboratory testing plan. The asphalt mixture prepared using No. 57 limestone and No. 57 crushed gravel showed better performance than the asphalt mixture prepared using No. 57 partially crushed gravel. Therefore, it was suggested to use either No. 57 limestone or No. 57 crushed gravel. In addition, it was suggested to limit the aggregate absorption to no more than 3%, as the use of highly absorptive aggregates might require a higher asphalt binder content.
- Use of PG 58-28 mixed with aromatic oil: This study explored the effect of using aromatic oil as a binder modifier (or extender) to improve the resistance of Medina CS 402 to cracking. Favorable results were obtained for the resulting asphalt mixtures. Therefore, it was suggested

to evaluate the performance of these mixtures in the field to determine if aromatic oil can be used in Medina CS 402 and at what percentage.

- Asphalt draindown: Increasing the asphalt binder content in an asphalt mixture such as Medina CS 402 may lead to draindown and/or bleeding. To ensure that the resulting asphalt mixture is not susceptible to significant draindown and/or bleeding, it was recommended to perform the asphalt draindown test according to AASHTO T 305 using a 1/4-inch mesh basket. A maximum allowable draindown of 0.3% was recommended for the evaluation.
- Asphalt mixture performance: For designing the asphalt mixtures used in the construction of the field test sections in Phase 2, it was recommended to include the IDEAL-CT and APA tests as part of the mix design process. It was suggested to use a minimum CT_{Index} value of 120 for the IDEAL-CT test and a maximum rut depth of 8 mm after 8,000 cycles in the APA test.

4. Research Approach

To validate the proposed modifications and further optimize the mix design of Medina CS 402, several pavement test sections were constructed in Phase 2 using different material combinations at two test sites, one in Medina County and one in Franklin County. Prior to construction, the research team coordinated with both counties regarding the construction specifications for the pavement test sections and provided the necessary information to be included in the project bid documents. Following the bidding process in both counties and the selection of an asphalt paving contractor, the research team met with county personnel and the contractor to coordinate the mix production and construction activities and discuss the field and laboratory sampling and testing plans. During construction, the research team monitored the placement and compaction of the asphalt mixtures and collected loose asphalt mixtures to evaluate the laboratory performance of the plant-produced material. Photographs were also taken to document the construction process.

Five pavement sections were constructed at the Franklin County test site, which is located on Kitzmiller Road in New Albany between Reynoldsburg-New Albany Rd and Morse Road, as shown in Figure 1. This test site has one lane per direction with an average daily traffic of 748 vehicles per day for both directions. The construction of the pavement sections at this site involved placing a 1.5-inch-thick intermediate asphalt course using Medina CS 402 (with milling) and choking using No. 9 limestone aggregate, followed by chip sealing. Figure 2 presents the layout of the five pavement sections at the Franklin County test site, and Table 2 presents the material combination used for the intermediate asphalt course in each pavement section. Additional information about the construction of the pavement sections at Franklin County is available in Appendix A.

Four pavement sections were constructed at the Medina County test site, which is located on the westernmost portion of Crow Road in Lichfield Township between Yost Road and the western border of Medina County, as shown in Figure 3. This test site has one lane per direction with an average daily traffic less than 500 vehicles per day for both directions. The construction of the pavement sections at this site involved placing a 2-inch-thick intermediate asphalt course using Medina CS 402 (without milling the existing pavement surface) and choking using No. 9 limestone aggregate, followed by chip sealing. Figure 4 presents the layout of the four pavement sections at the Medina County test site, and Table 3 shows the material combinations used for each intermediate asphalt course. Additional information about the construction of the pavement sections at Medina County is available in Appendix B. It is noted that crushed gravel is not readily available in the Medina County area; therefore, the fifth material combination that was used in Franklin County that included crushed gravel was not included in the evaluation at this site.

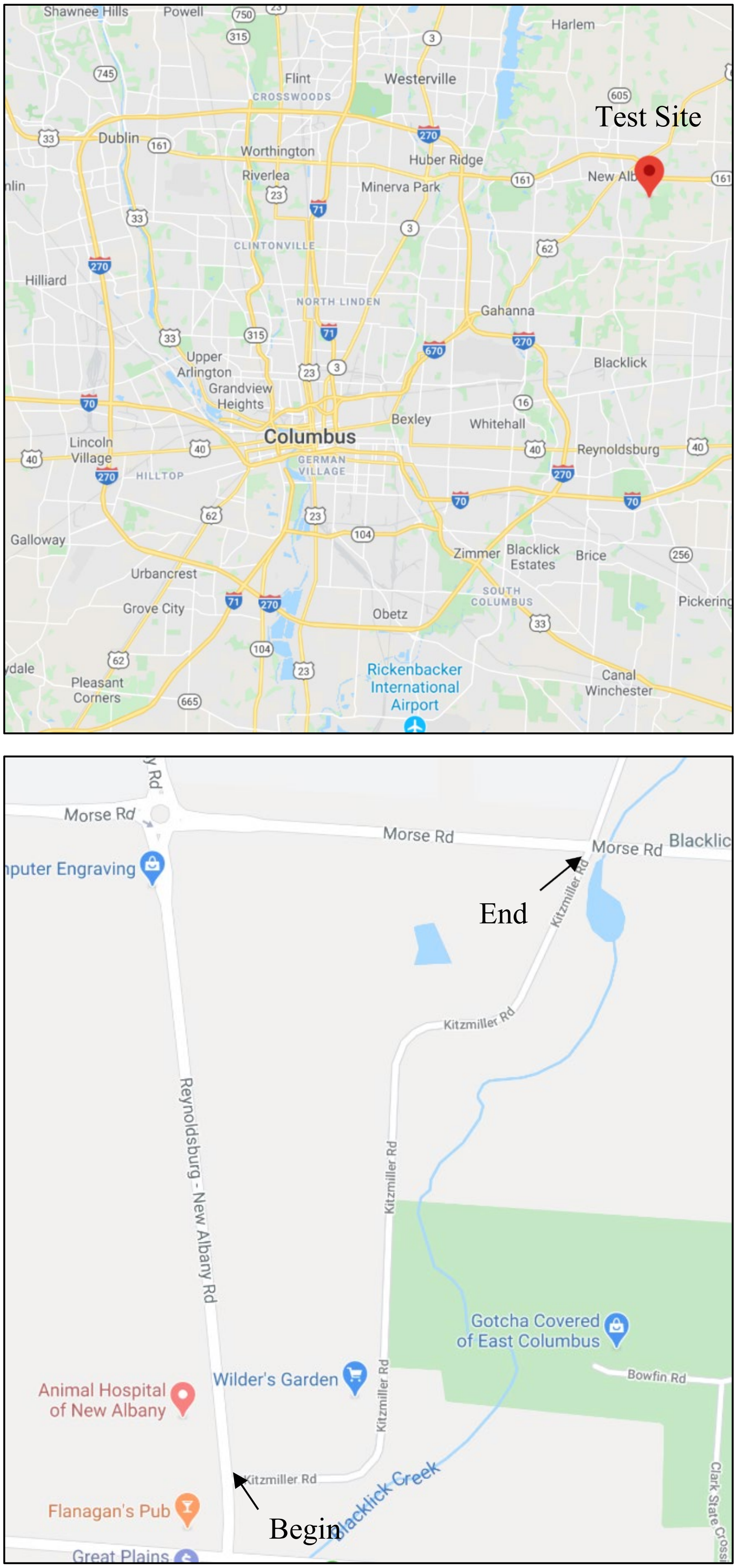

Figure 1: Location of the Franklin County Test Site (www.google.com/maps).

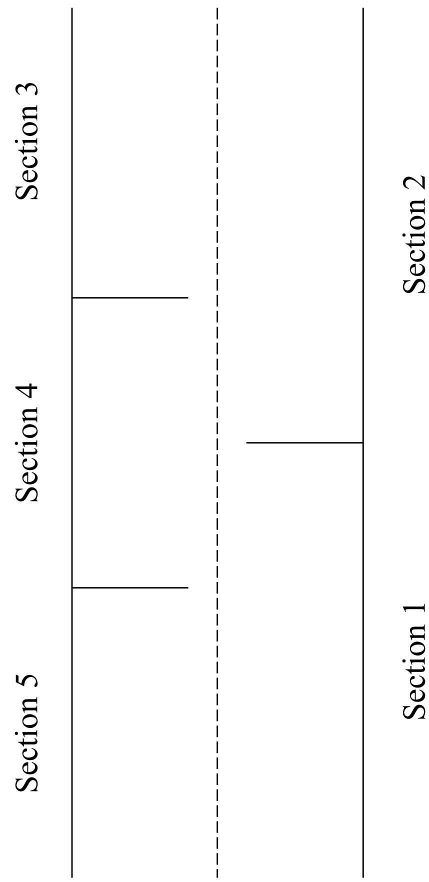

Figure 2: Layout of Pavement Sections at the Franklin County Test Site.

Table 2: Material Combinations used in Pavement Sections at the Franklin County Test Site.

Section	Material Combination
1	80% No. 57 Limestone + 20% Natural Sand @ 4.8% PG 58-28
2	80% No. 57 Limestone + 20% Natural Sand @ 5.3% PG 58-28
3	80% No. 57 Limestone + 20% Natural Sand @ 4.8% PG 58-28 with 4% Aromatic Oil
4	80% No. 57 Limestone + 20% Natural Sand @ 4.8% PG 58-28 with 2% Aromatic Oil
5	80% No. 57 Crushed Gravel + 20% Natural Sand @ 4.8% PG 58-28

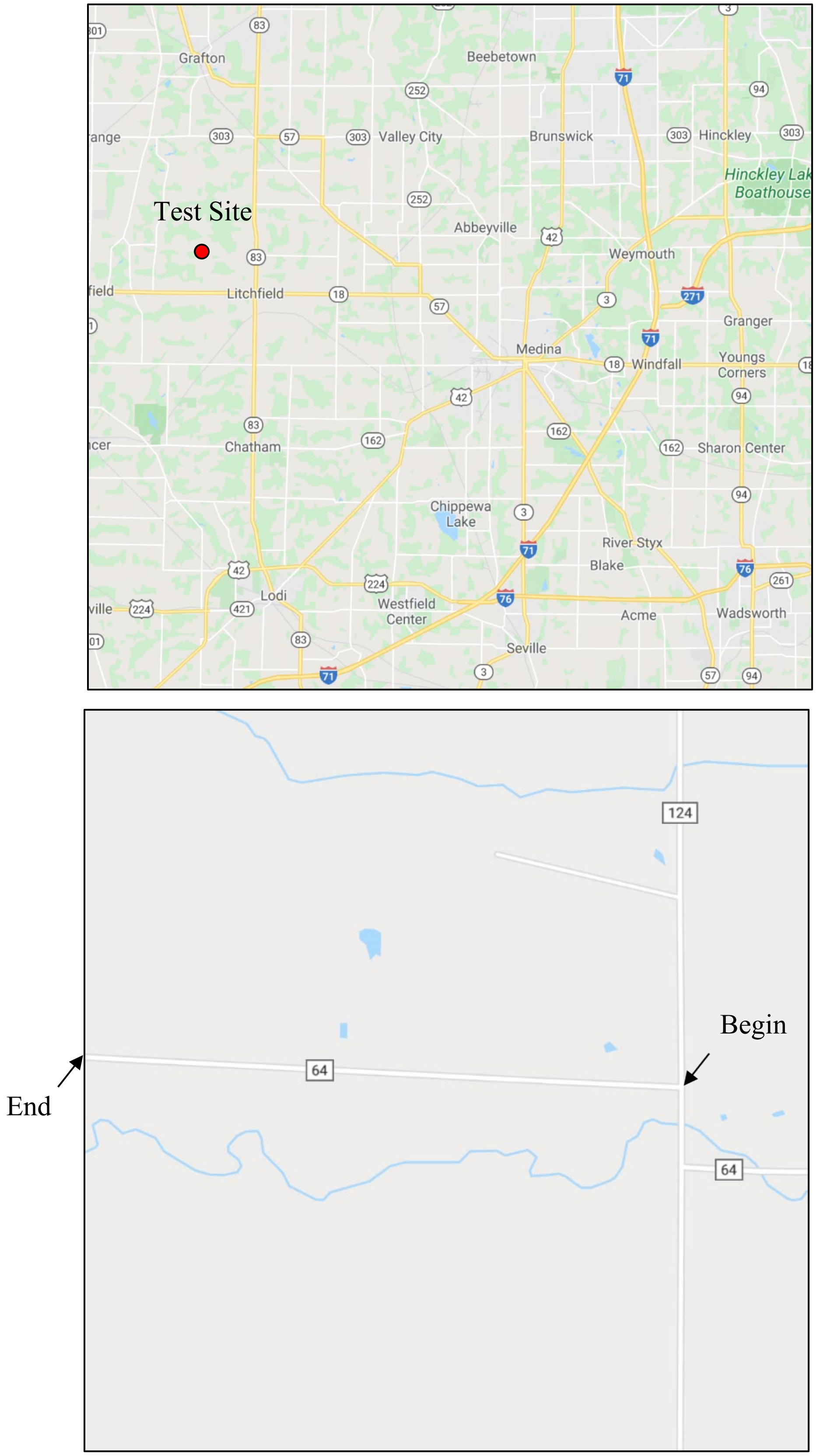

Figure 3: Location of the Medina County Test Site (www.google.com/maps).

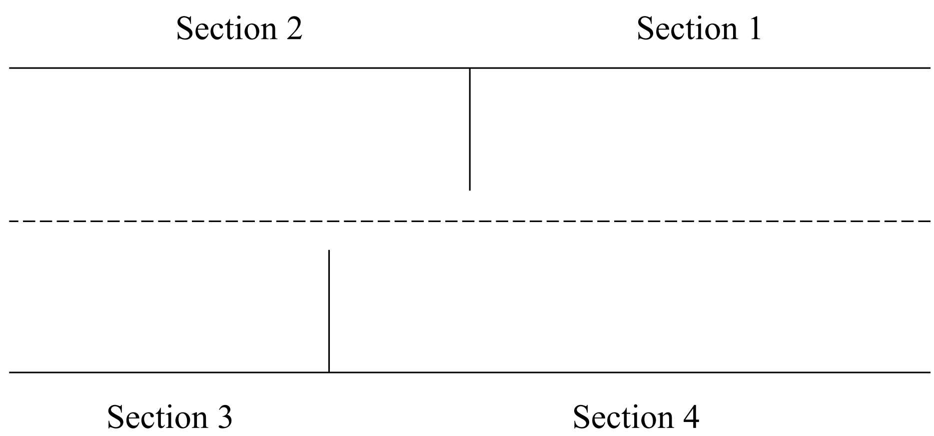

Figure 4: Layout of Pavement Sections at the Medina County Test Site.

Table 3: Material Combinations used in Pavement Sections at the Medina County Test Site.

Section	Material Combination
1	80% No. 57 Limestone + 20% Natural Sand @ 4.8% PG 58-28
2	80% No. 57 Limestone + 20% Natural Sand @ 4.8% PG 58-28 with 4% Aromatic Oil
3	80% No. 57 Limestone + 20% Natural Sand @ 4.8% PG 58-28 with 6% Aromatic Oil
4	80% No. 57 Limestone + 20% Natural Sand @ 5.3% PG 58-28

5. Research Findings and Conclusions

Laboratory testing was performed on the loose asphalt mixtures collected during construction in both Franklin and Medina counties. The performance of these materials was evaluated using the indirect tension asphalt cracking test (IDEAL-CT), semi-circular bend (SCB) test, Texas overlay tester, and asphalt pavement analyzer (APA). Appendix C presents the laboratory test results for the field-produced asphalt mixtures installed at the Franklin County and Medina County test sites.

Below is a summary of the observations that can be made from these test results:

- The material combination that included 80% No. 57 limestone and 20% natural sand mixed with PG 58-28 at an asphalt binder content of 5.3% showed better resistance to cracking (higher CT_{Index} in the IDEAL-CT test, higher FI in the SCB test, and higher number of cycles to failure in the Texas overlay tester) but higher susceptibility to rutting (higher rut depths in the APA test) than the material combination that included the same aggregate blend mixed with PG 58-28 at an asphalt binder content of 4.8%. Since this asphalt mixture is designed for use on roads with very low traffic volumes, where rutting is not a major concern, it might be advantageous to use the higher asphalt binder content for this asphalt mixture.
- The use of aromatic oil as a binder extender resulted in higher cracking indices (CT_{Index} and FI) and higher number of cycles to failure in the Texas overlay tester. These results suggest that aromatic oil may improve the cracking resistance of the asphalt mixture. However, it may result in a greater propensity for rutting as shown from the increase in rut depth in the APA test. Comparable results were obtained for asphalt mixtures containing aromatic oil regardless of the aromatic oil content. Since aromatic oil is typically used as a recycling agent for asphalt mixtures that contain a high amount of RAP and not as an asphalt binder modifier (or extender) as used in this study, it is recommended to monitor the field performance of the constructed test sections that contain aromatic oil in Franklin County and Medina County and compare it to the performance of the other test sections with regard to rutting, cracking, and surface disintegration before making a final decision regarding the use of aromatic oil as a binder extender in this asphalt mixture.
- The material combination that included 80% No. 57 crushed gravel and 20% natural sand mixed with PG 58-28 at an asphalt binder content of 4.8% showed better resistance to cracking but higher susceptibility to rutting than the material combination that included 80% No. 57 limestone and 20% natural sand mixed with PG 58-28 at an asphalt binder content of 4.8%. The No. 57 crushed gravel and the No. 57 limestone aggregates had comparable absorptions (~1.55%). Both aggregates also contained particles with a high percentage of fractured faces (100% for the limestone and

99.3% for the crushed gravel). However, the two aggregates did not have the same gradation, which might explain the variation in the test results. The main difference in gradation between the two aggregates was in the percentage passing the ¾" sieve, which was 97% for the No. 57 crushed gravel and 88% for the No. 57 limestone aggregates. The laboratory test results obtained for the field-produced asphalt mixture containing crushed gravel suggest that this type of aggregate can be used as an alternative for limestone in this asphalt mixture.

The performance of the pavement test sections in Franklin County and Medina County was evaluated every two months for the first six months after construction. The periodic field evaluations included an assessment of the pavement condition with regard to the various pavement distresses encountered during the evaluations and the corresponding extent and severity level for each distress. Photographs were also taken during the periodic field evaluations to document the presence, extent, and severity of the pavement distresses. A summary of the three performance evaluations conducted at each test site is presented in Appendix D.

6. Recommendations for Implementation

This section presents a summary of the recommended changes to Medina County Specification (CS) 402. As discussed previously, this application involves constructing an intermediate asphalt course followed by aggregate choking using No. 9 aggregates. A single layer of chip seal shall be installed within 21 days following the placement of CS 402 in order to prevent water penetration into the intermediate asphalt course. This section only covers the construction and material specifications for modified Medina CS 402. The local public agency (LPA) can use its own specification for the chip seal layer. As an alternative to using the single layer of chip seal, an agency may use an HMA surface course on top of the intermediate asphalt course. In this case, aggregate choking will not be required. However, tack coat shall be applied prior to the installation of the surface course.

XXX.01 Description. This work consists of constructing a 2-inch-thick intermediate asphalt course followed by aggregate choking using No. 9 aggregates. A compacted lift thickness of two inches is specified for the intermediate asphalt course in this application in order to ensure that the resulting asphalt layer will have a thickness that is at least two times the maximum aggregate size of one inch for the aggregate blend (as shown in the table below) to minimize aggregate crushing during compaction. This application is intended for use on low-volume roads with less than 1000 vehicles per day for both directions and an expected average daily truck traffic (ADTT) of 10 trucks per day.

XXX.02 Materials. The hot mix asphalt (HMA) material specified for the intermediate asphalt course shall be produced in a central plant, hauled to the site and spread with a full-size, self-propelled paver in a single course. The HMA shall meet the following requirements:

- Coarse and fine aggregates shall be combined such that the resulting blend is within the following limits (this can generally be achieved by combining 80% No. 57 aggregates with 20% natural sand):

Sieve	Total Percent Passing
1”	100
¾”	85 – 100
⅜”	25 – 45
No. 4	18 – 30
No. 16	12 – 25
No. 50	3 – 15
No. 200	0 – 5

- The coarse aggregates shall conform to ODOT CMS Item 703.05 with a maximum absorption of 3%.
- Limestone or “mechanically crushed” gravel, with a minimum of 90% fractured particles, shall be used for the coarse aggregates.
- The use of recycled aggregates or pavement grindings in the plant mix is prohibited.
- Use PG 58-28 asphalt binder conforming to the requirements of ODOT CMS Item 702.01.
- Combine asphalt binder with the aggregates in an amount equal to 5.3% percent by weight of the mix.

- The HMA shall not exceed a maximum asphalt draindown of 0.3% (using a 1/4-inch mesh basket) according to AASHTO T 305.

XXX.03 Preparation of Materials. Produce the HMA at the production temperature range established for the selected asphalt binder. Do not overheat the HMA to avoid damaging the asphalt binder.

XXX.04 Weather Limitations. Spread the HMA when the atmospheric temperature is above 50°F (10°C) and rising. Do not place the HMA when rain is imminent. If rain occurs during placement of the HMA, cease all operations.

XXX.05 Rollers. Use only tandem steel wheel rollers weighing 6 to 10 tons (5.5 to 9 metric tons) for compaction.

XXX.06 Spreading and Compacting. Ensure that the temperature of the mixture when delivered to the paver is a minimum of 250°F (120°C). Ensure that the temperature of the mixture is sufficient for the roller coverage to be effective in compacting the mixture. Spread the HMA in a method that produces a smooth, uniform layer before compaction. Do not overcompact the HMA to the extent that the aggregate particles are crushed or broken.

XXX.07 Aggregate Choking. Immediately following the initial rolling of the intermediate asphalt course, choke the placed HMA mixture using No. 9 aggregates at a rate of 10 lbs per square yard. Compact the aggregates into the placed HMA mixture.

Based on the cost analysis conducted in Phase 1, it was estimated that one ton of asphalt mixture for modified Medina CS 402 would cost approximately $80. However, it was understood that the cost per ton of asphalt mixture for the construction of the pavement sections at the Franklin County and Medina County test sites would be higher due to the small quantities used in each pavement section. According to the bid documents provided by Franklin and Medina counties, the unit cost for the five different asphalt mixtures used in Franklin County was $120 per ton and the unit cost for the four asphalt mixtures used in Medina County ranged between $170 and $186 per ton for the awarded bids. It is noted that the pavement sections in Franklin County were constructed as part of a countywide construction project, while the pavement sections in Medina County were constructed as a standalone project. If larger quantities of modified Medina CS 402 are used in a future rehabilitation project, the unit cost per ton of this mixture is expected to be lower than those in the two winning bids in the field study.

7. References

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Appendix A
Franklin County Test Site

A.1 Pavement Section Information

Five pavement sections were constructed at the Franklin County test site, which is located on Kitzmiller Road in New Albany between Reynoldsburg-New Albany Rd and Morse Road, as shown in Figure A.1. This test site has one lane per direction with an average daily traffic of 748 vehicles per day for both directions. The construction of the pavement sections at this site involved placing a 1.5-inch-thick intermediate asphalt course using Medina CS 402 (with milling) and choking using No. 9 limestone aggregate, followed by chip sealing. Figure A.2 presents the layout of the five pavement sections at the Franklin County test site, and Table A.1 presents the material combination used for the intermediate asphalt course in each pavement section.

The construction of the five pavement sections in Franklin County took place in early July 2020. Pavement Sections 1 and 2, which are located on the northbound direction of Kitzmiller Road, were constructed on Thursday July 9, 2020. Test Sections 3, 4, and 5, which are located on the southbound direction of Kitzmiller Road, were constructed on Saturday July 11, 2020. Loose asphalt mixtures were collected from the plant on the day of placement for laboratory testing. Chip sealing for all five pavement sections was performed on Monday July 13, 2020.

Photographs were taken to document the construction process. As can be noticed from Figure A.3, a hydraulic pump was used at the asphalt plant to introduce the aromatic oil into the asphalt line before being mixed with the aggregates during the hot mix asphalt production process. Tack coat was applied on the existing pavement surface prior to the placement of the intermediate asphalt course. Figures A.4 and A.5 show that conventional asphalt paving equipment was used for the placement and compaction of the intermediate asphalt course. It is noted that all asphalt mixtures used for the intermediate asphalt courses in the five pavement sections were produced at a temperature of 275°F (at the plant) and were compacted (in the field) at a temperature ranging between 210°F and 250°F. Figure A.6 shows the equipment that was used for choking the intermediate asphalt course with No. 9 limestone aggregates followed by rolling. The equipment used for chip sealing is presented in Figure A.7.

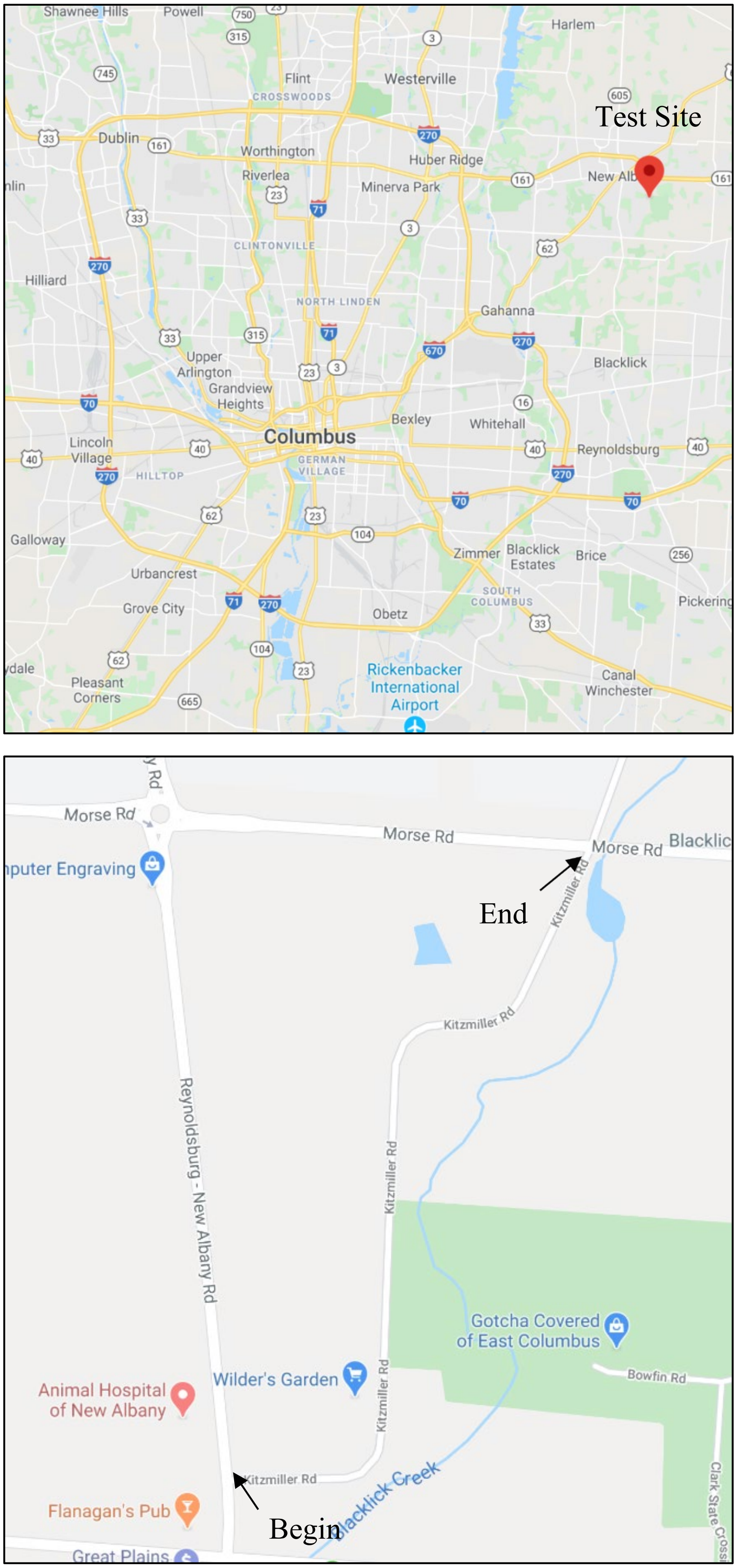

Figure A.1: Location of the Franklin County Test Site (www.google.com/maps).

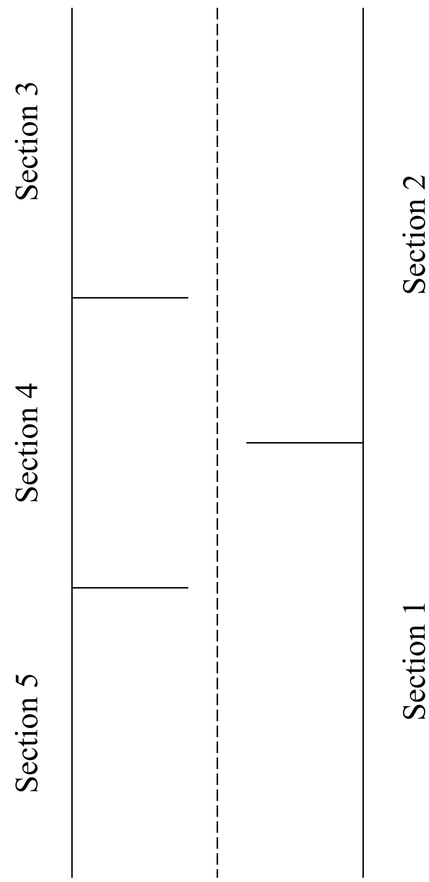

Figure A.2: Layout of Pavement Sections at the Franklin County Test Site.

Table A.1: Material Combinations used in Pavement Sections at the Franklin County Test Site.

Section	Material Combination
1	80% No. 57 Limestone + 20% Natural Sand @ 4.8% PG 58-28
2	80% No. 57 Limestone + 20% Natural Sand @ 5.3% PG 58-28
3	80% No. 57 Limestone + 20% Natural Sand @ 4.8% PG 58-28 with 4% Aromatic Oil
4	80% No. 57 Limestone + 20% Natural Sand @ 4.8% PG 58-28 with 2% Aromatic Oil
5	80% No. 57 Crushed Gravel + 20% Natural Sand @ 4.8% PG 58-28

Figure A.3: Introduction of Aromatic Oil into the
Asphalt Binder Line at the Asphalt Plant in Franklin County.

Figure A.4: Placement of Asphalt Mixture at the Franklin County Test Site.

Figure A.5: Compaction of Asphalt Mixture at the Franklin County Test Site.

Figure A.6: Choking with No. 9 Limestone at the Franklin County Test Site.

Figure A.6: Choking with No. 9 Limestone at the Franklin County Test Site (Continued).

Figure A.7: Chip Sealing at the Franklin County Test Site.

Figure A.7: Chip Sealing at the Franklin County Test Site (Continued).

Appendix B
Medina County Test Site

B.1 Pavement Section Information

Four pavement sections were constructed at the Medina County test site, which is located on the westernmost portion of Crow Road in Lichfield Township between Yost Road and the western border of Medina County, as shown in Figure B.1. This test site has one lane per direction with an average daily traffic less than 500 vehicles per day for both directions. The construction of the pavement sections at this site involved placing a 2-inch-thick intermediate asphalt course using Medina CS 402 (without milling the existing pavement surface) and choking using No. 9 limestone aggregate, followed by chip sealing. Figure B.2 presents the layout of the four pavement sections at the Medina County test site, and Table B.1 shows the material combinations used for each intermediate asphalt course. It is noted that crushed gravel is not readily available in the Medina County area; therefore, the fifth material combination that was used in Franklin County that included crushed gravel was not included in the evaluation at this site.

The construction of the four pavement sections in Medina County took place in early August 2020. Pavement Sections 1, 2, and 3 were constructed on Monday August 3, 2020, while Test Section 4 was constructed on Wednesday August 5, 2020. A heavy rainfall was encountered during the construction of the third pavement section. Therefore, constructed was terminated for that day, resulting in a shorter length for that pavement section than the other sections. Loose asphalt mixtures were collected from the plant on the day of placement for laboratory testing. Chip sealing for all four pavement sections was performed before the end of August 2020.

The method for introducing the aromatic oil into the asphalt line at the asphalt plant in Medina County was similar to that used in Franklin County, as shown in Figure B.3. Tack coat was applied on the existing pavement surface prior to the placement of the intermediate asphalt course. Figures B.4 and B.5 show the equipment that was used for the placement and compaction of the intermediate asphalt course. All asphalt mixtures used for the intermediate asphalt courses in the four pavement sections were produced at a temperature of 275°F (at the plant) and were compacted (in the field) at a temperature ranging between 210°F and 250°F. The intermediate asphalt course was choked using No. 9 limestone aggregates followed by final rolling.

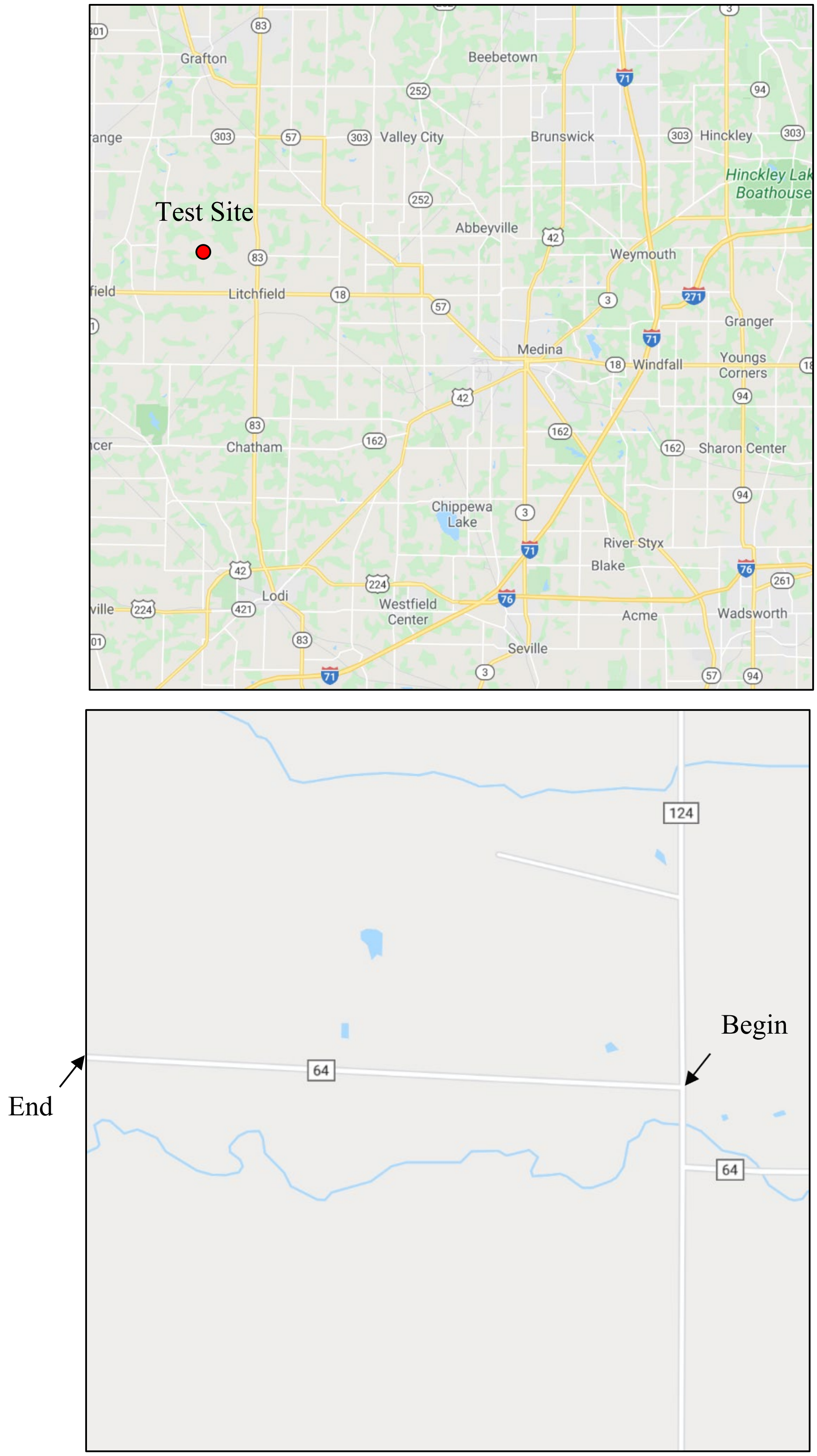

Figure B.1: Location of the Medina County Test Site (www.google.com/maps).

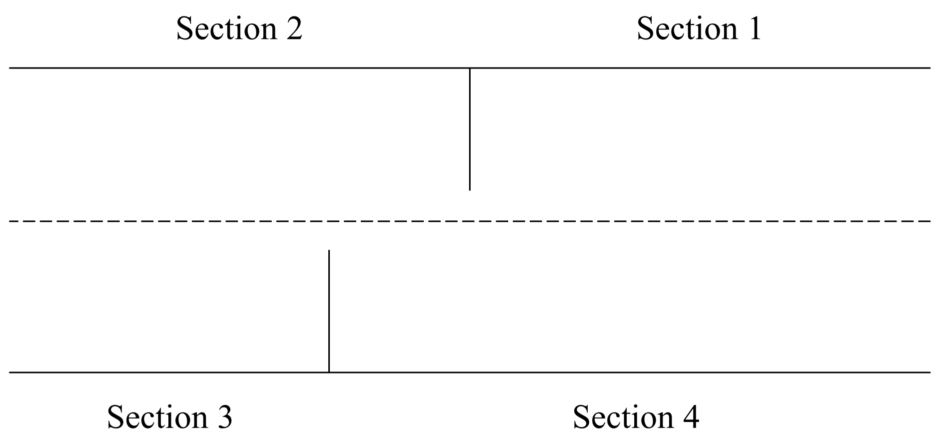

Figure B.2: Layout of Pavement Sections at the Medina County Test Site.

Table B.1: Material Combinations used in Pavement Sections at the Medina County Test Site.

Section	Material Combination
1	80% No. 57 Limestone + 20% Natural Sand @ 4.8% PG 58-28
2	80% No. 57 Limestone + 20% Natural Sand @ 4.8% PG 58-28 with 4% Aromatic Oil
3	80% No. 57 Limestone + 20% Natural Sand @ 4.8% PG 58-28 with 6% Aromatic Oil
4	80% No. 57 Limestone + 20% Natural Sand @ 5.3% PG 58-28

Figure B.3: Introduction of Aromatic Oil into the Asphalt Binder Line at the Asphalt Plant in Medina County.

Figure B.4: Placement of Asphalt Mixture at the Medina County Test Site.

Figure B.5: Compaction of Asphalt Mixture at the Medina County Test Site.

Appendix C
Laboratory Test Results for Field-Produced Asphalt Mixtures

C.1 Summary of Observations

Laboratory testing was performed on the loose asphalt mixtures collected during construction in both Franklin and Medina counties. The performance of these materials was evaluated using the indirect tension asphalt cracking test (IDEAL-CT), semi-circular bend (SCB) test, Texas overlay tester, and asphalt pavement analyzer (APA). Six replicates were used for the IDEAL-CT and SCB tests and three replicates were used for the Texas overlay tester and the APA test. Figures C.1 to C.4 present the laboratory test results for the field-produced asphalt mixtures installed at the Franklin County site, and Figures C.5 to C.8 present the laboratory test results for the field-produced asphalt mixtures installed at the Medina County site. The same threshold criteria used in Phase 1 were also used for comparing the performance of the various asphalt mixtures in this phase of the study ($CT_{Index} \geq 120$ for the IDEAL-CT, FT ≥ 6 for the SCB, number of cycles to failure ≥ 100 cycles for the Texas overlay tester, and rut depth < 7 mm (after 8,000 cycles) for the APA test.

Below is a summary of the observations that can be made from these figures:

- The material combination that included 80% No. 57 limestone and 20% natural sand mixed with PG 58-28 at an asphalt binder content of 5.3% showed better resistance to cracking (higher CT_{Index} in the IDEAL-CT test, higher FI in the SCB test, and higher number of cycles to failure in the Texas overlay tester) but higher susceptibility to rutting (higher rut depths in the APA test) than the material combination that included the same aggregate blend mixed with PG 58-28 at an asphalt binder content of 4.8%. Since this asphalt mixture is designed for use on roads with very low traffic volumes, where rutting is not a major concern, it will be advantageous to use the higher asphalt binder content for this asphalt mixture.
- The use of aromatic oil as a binder extender resulted in higher cracking indices (CT_{Index} and FI) and higher number of cycles to failure in the Texas overlay tester. These results suggest that aromatic oil may improve the cracking resistance of the asphalt mixture. However, it may result in a greater propensity for rutting as shown from the increase in rut depth in the APA test. Comparable results were obtained for asphalt mixtures containing aromatic oil regardless of the aromatic oil content. Since aromatic oil is typically used as a recycling agent for asphalt mixtures that contain a high amount of RAP and not as an asphalt binder modifier (or extender) as used in this study, it is recommended to monitor the field performance of the constructed test sections that contain

aromatic oil in Franklin County and Medina County and compare it to the performance of the other test sections with regard to rutting, cracking, and surface disintegration before making a final decision regarding the use of aromatic oil as a binder extender in this asphalt mixture.

- The material combination that included 80% No. 57 crushed gravel and 20% natural sand mixed with PG 58-28 at an asphalt binder content of 4.8% showed better resistance to cracking but higher susceptibility to rutting than the material combination that 80% No. 57 limestone and 20% natural sand mixed with PG 58-28 at an asphalt binder content of 4.8%. The No. 57 crushed gravel and the No. 57 limestone aggregates had comparable absorptions (~1.55%). Both aggregates also contained particles with a high percentage of fractured faces (100% for the limestone and 99.3% for the crushed gravel). However, the two aggregates did not have the same gradation, which might explain the variation in the test results. The laboratory test results obtained for the field-produced asphalt mixture containing crushed gravel suggest that this type of aggregate can be used as an alternative for limestone aggregates in this asphalt mixture.

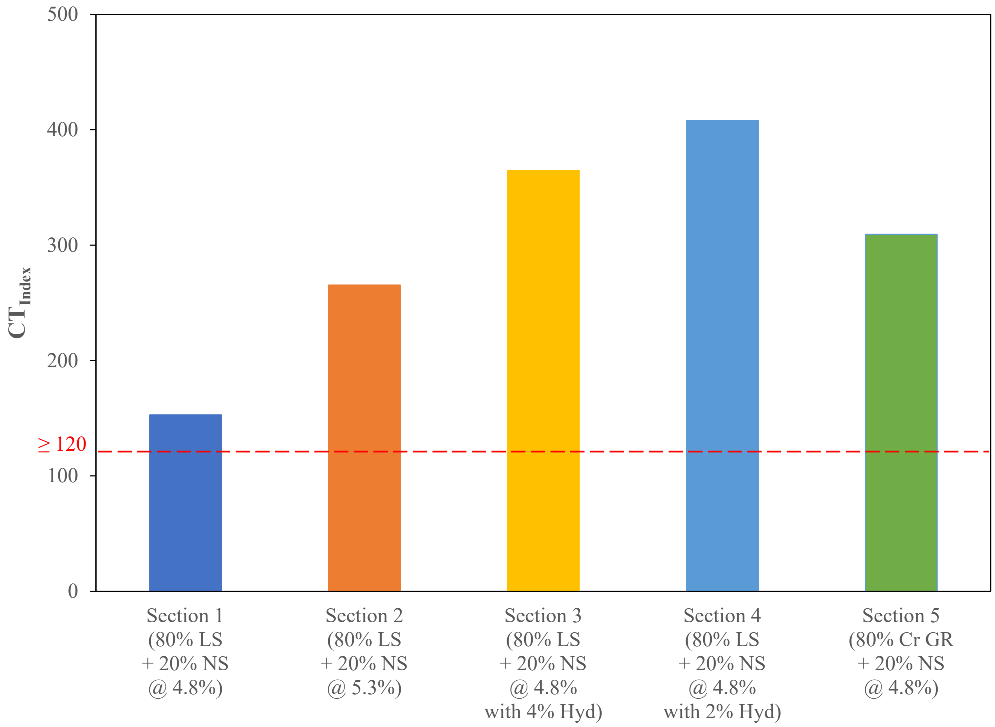

Figure C.1: CT_{Index} Results for Field Asphalt Mixtures

Placed at the Franklin County Test Site.

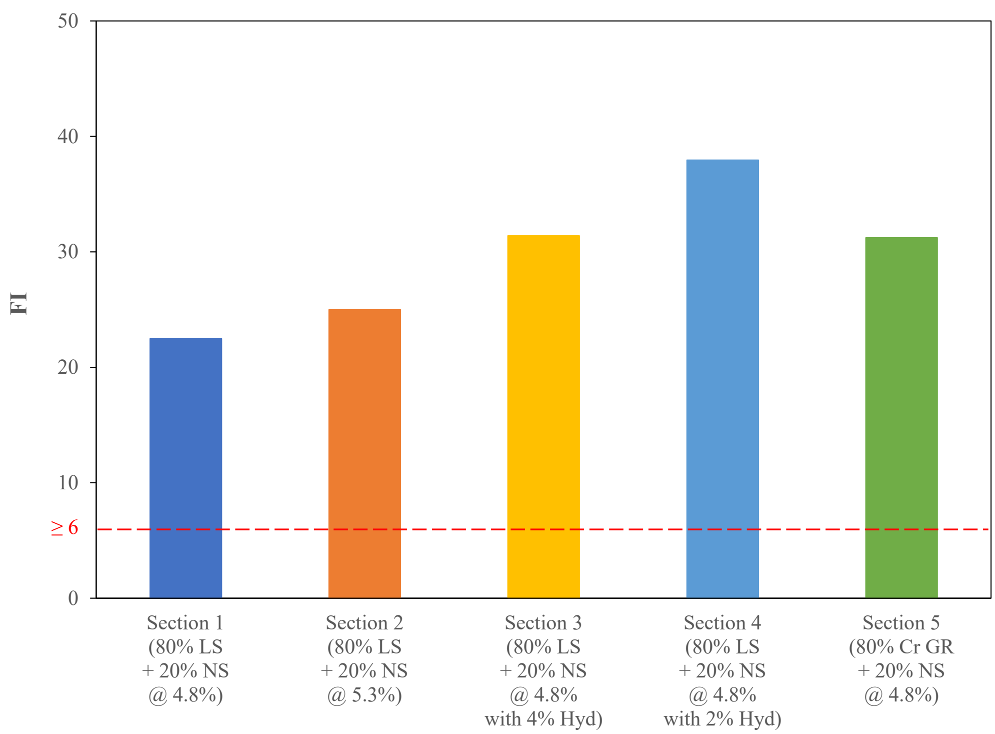

Figure C.2: FI Results for Field Asphalt Mixtures

Placed at the Franklin County Test Site.

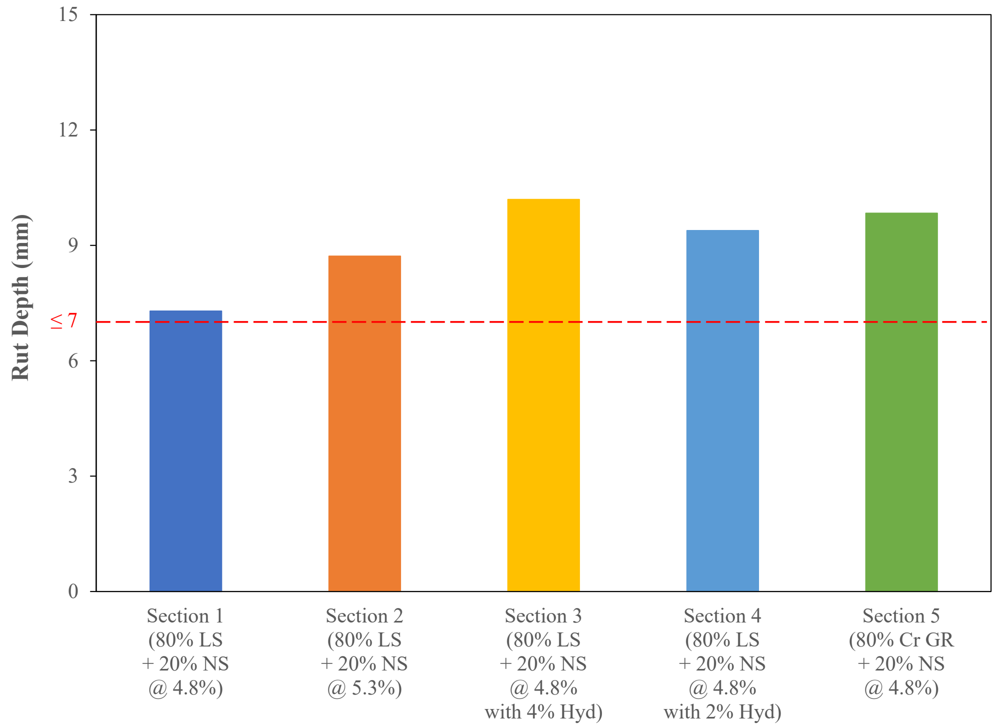

Figure C.3: APA Results for Field Asphalt Mixtures
Placed at the Franklin County Test Site.

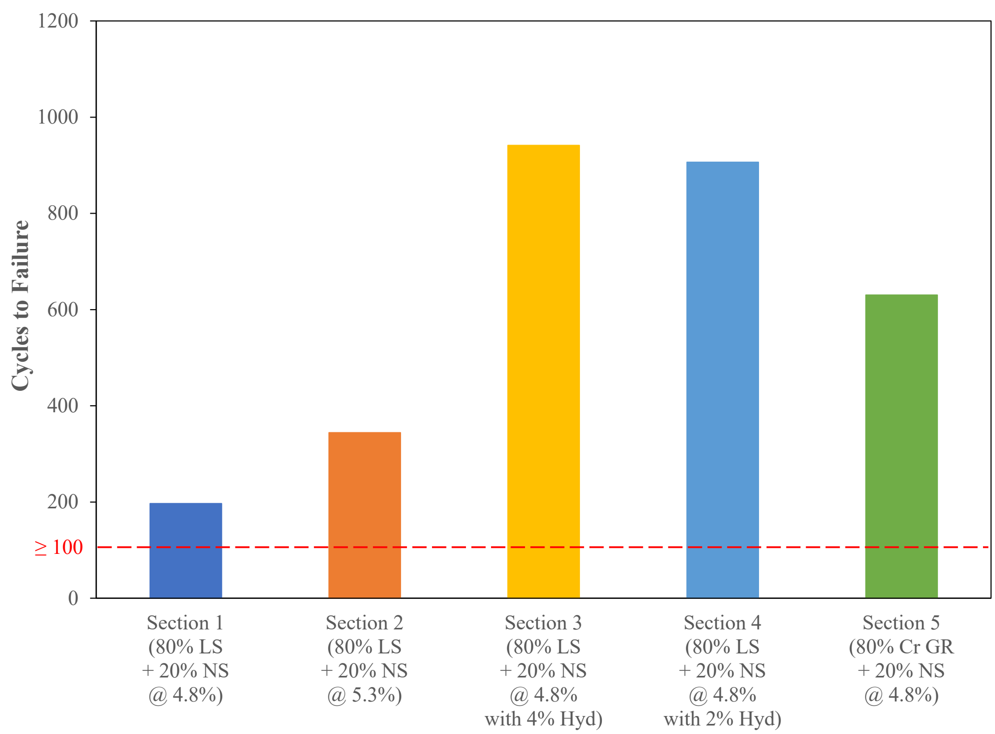

Figure C.4: Texas Overlay Results for Field Asphalt Mixtures
Placed at the Franklin County Test Site.

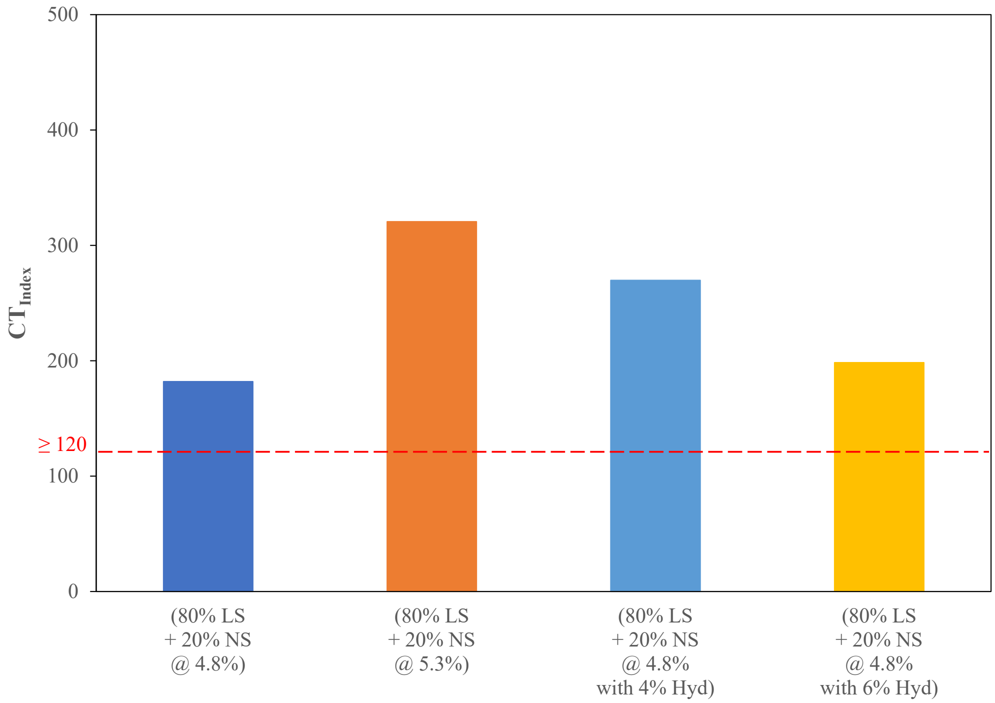

Figure C.5: CT_{Index} Results for Field Asphalt Mixtures
Placed at the Medina County Test Site.

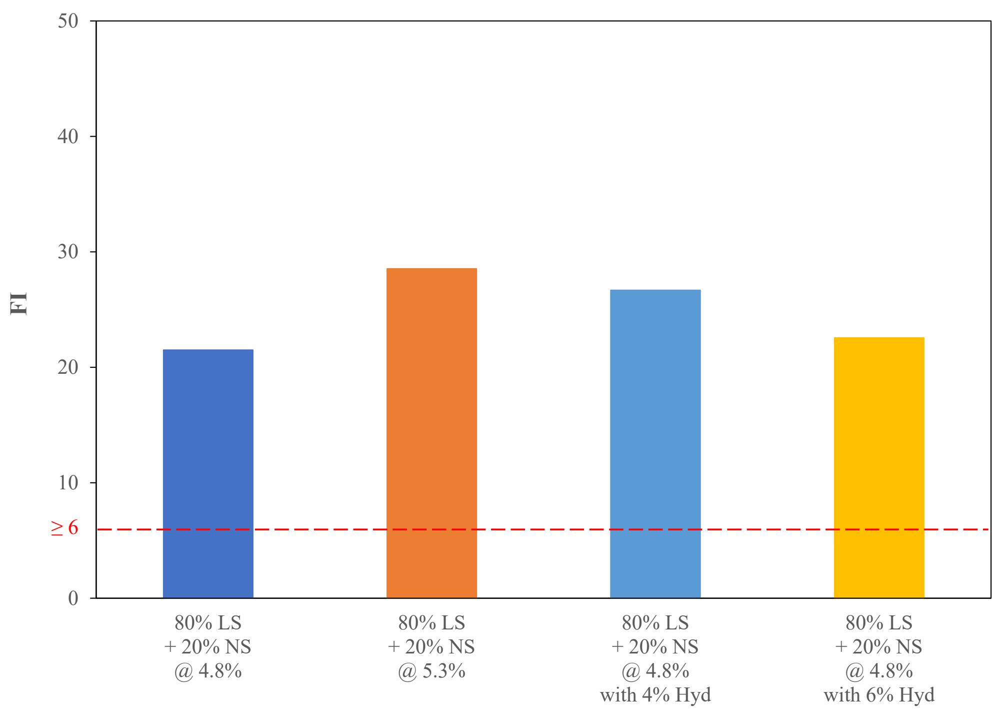

Figure C.6: FI Results for Field Asphalt Mixtures
Placed at the Medina County Test Site.

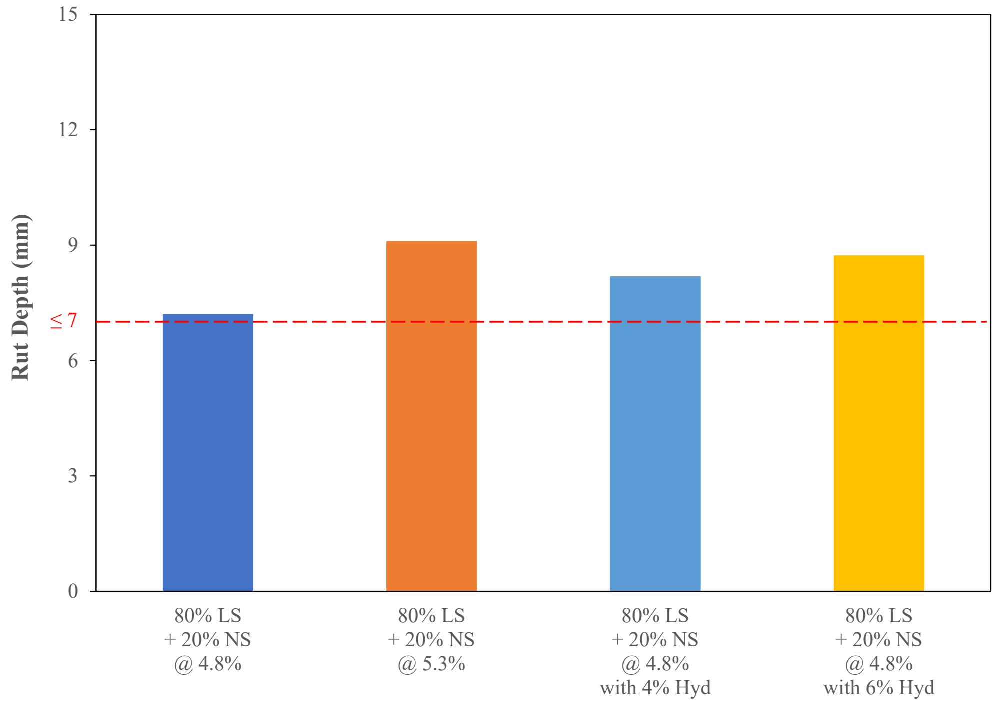

Figure C.7: Rut Depth Results for Field Asphalt Mixtures
Placed at the Medina County Test Site.

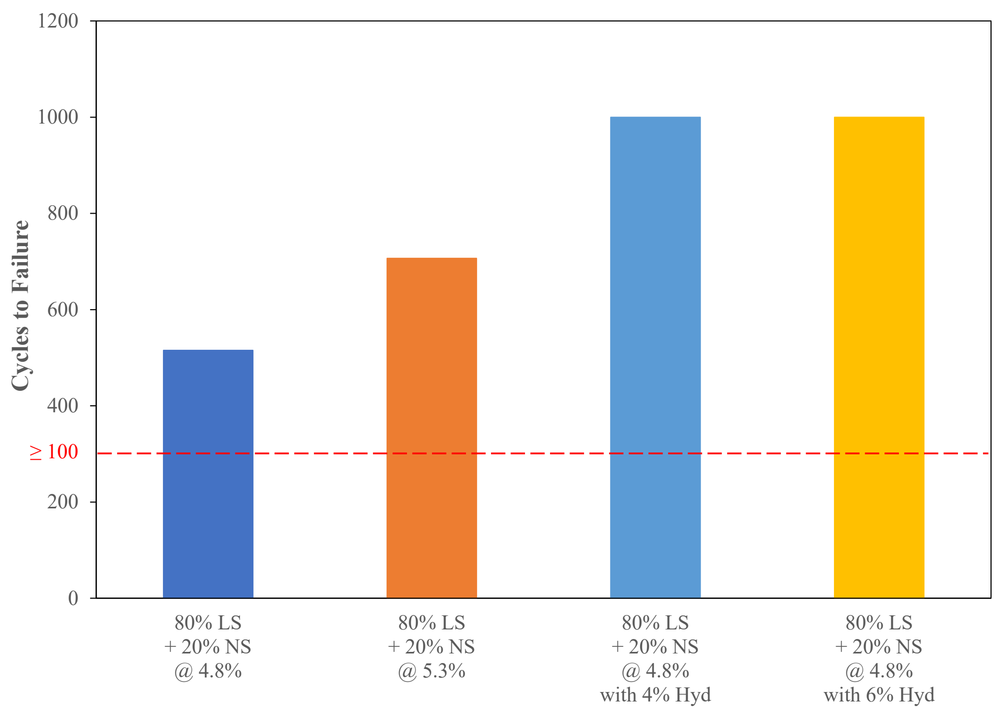

Figure C.8: Texas Overlay Results for Field Asphalt Mixtures
Placed at the Medina County Test Site.

Appendix D
Performance Evaluation of Test Sections

D.1 Introduction

The performance of the pavement test sections in Franklin County and Medina County was evaluated every two months for the first six months after construction. The periodic field evaluations included an assessment of the pavement condition with regard to the various pavement distresses encountered during the evaluations and the corresponding extent and severity level for each distress. Photographs were also taken during the periodic field evaluations to document the presence, extent, and severity of the pavement distresses.

D.2 Performance Evaluation in Franklin County

Three performance evaluations were conducted for the Franklin County test sections after construction. These evaluations were conducted on September 19, 2020, November 14, 2020, and January 26, 2021. Shortly after the end of construction of the pavement test sections on Kitzmiller Rd., major construction took place to convert the intersection of Reynoldsburg-New Albany Rd. and Clark State Rd. from a signalized intersection to a roundabout. An empty lot on the right-hand side of the southernmost segment of the test site was used as a staging area for the construction of the roundabout. This resulted in significant construction traffic, especially at the southern end of the test site where Pavement Sections 1 and 5 are located. Figure D.1 shows some photos taken during the first pavement performance evaluation that was conducted on September 19, 2020 to show the effect of the construction on the southern part of the test site.

Aside from the effect of the construction of the nearby roundabout on the pavement test sections, a short stretch of bleeding was observed in the first evaluation at the transition between Pavement Sections 1 and 2 where the asphalt binder in the asphalt mixture was increased from 4.8% to 5.3% (Figure D.2). No bleeding was observed at any other locations at this site in this evaluation. In the subsequent evaluations conducted in November and January, no changes were observed in the extent and severity of the bleeding at this site. Since bleeding was only encountered at the transition between Pavement Sections 1 and 2, it could be the result of switching between mixes at the plant. It is also likely that during the construction of the nearby roundabout, construction traffic had to use Kitzmiller Rd. when Reynoldsburg-New Albany Rd. was completely closed to traffic. Therefore, the asphalt mixtures at this site may have been subjected to higher traffic and load levels than expected for this location. In addition to bleeding, limited aggregate loss from the chip seal layer was observed at this site in the three performance evaluations, as shown in Figure D.3.

Figure D.1: Effect of Nearby Construction
on the Southern Part of the Franklin County Test Site.

Figure D.1: Effect of Nearby Construction
on the Southern Part of the Franklin County Test Site (Continued).

Figure D.2: Bleeding at the Transition between
Pavement Sections 1 and 2 at the Franklin County Test Site.

Figure D.3: Limited Aggregate Loss from
the Chip Seal Layer at the Franklin County Test Site.

D.5.1 Performance Evaluation in Medina County

Three performance evaluations were conducted for the Medina County test sections after construction. These evaluations were conducted on October 18, 2020, December 20, 2020, and February 26, 2021. Aside from very limited loss of aggregates from the chip seal layer (Figure D.4), no distresses were observed at this site in the three performance evaluations. However, the research team noticed some transverse marks at the transition points between the test sections or at locations where paving was interrupted due to rain, as shown in Figure D.5. The locations of these transverse marks were recorded (Figure D.6) to establish a possible cause of any future pavement distresses that may develop at these locations.

Figure D.4: Limited Aggregate Loss from the Chip Seal Layer at the Medina County Test Site.

Figure D.5: Transverse Marks at the Medina County Test Site
at the Transition between Pavement Sections or Interruption in Paving due to Rain.

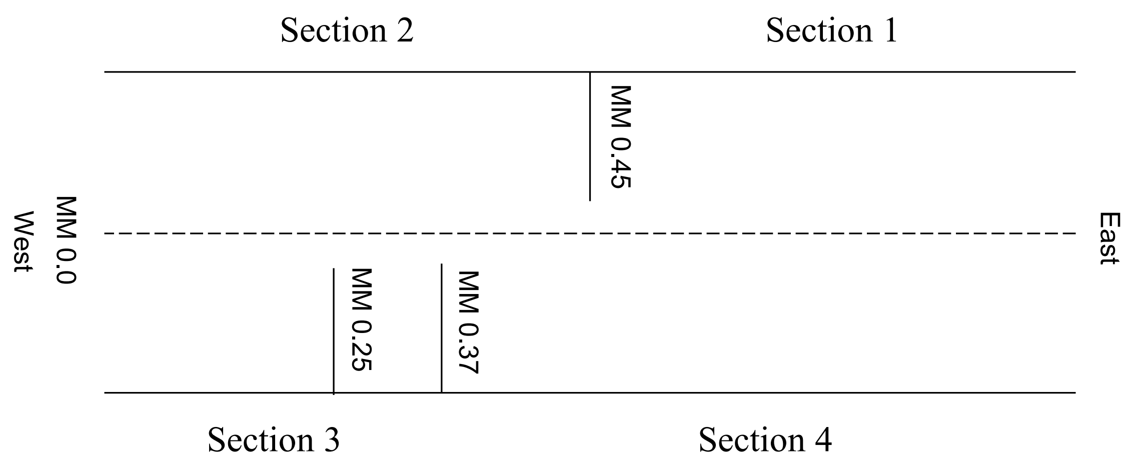

Figure D.6: Location of Transverse Marks in Transition Zones at the Medina County Test Site.