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# Evaluation of Premature Cracking in Urban Concrete Pavement

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**16. Abstract**

This study investigated the causes for premature, transverse cracking on urban jointed plain concrete pavements in Illinois. A field survey of 67 sections throughout Illinois coupled with ultrasonic evaluation was completed to synthesize the extent of premature cracking on urban JPCP. The visual survey showed some transverse and longitudinal cracks were a result of improper slab geometry (excessive slab length and width). Ultrasonic tests over the contraction joints determined some notched joints had not activated and adjacent transverse cracks were likely formed as a result. Three-dimensional finite-element analyses confirmed that cracking would not develop as a result of normal environmental factors and slab-base frictional restraint. The concrete mixture also did not appear to be a contributing factor to the premature cracks. Finally, the lack of lubrication on dowel bars was determined to potentially be a primary mechanism that could restrain the transverse contraction joints, produce excessive tensile stresses in the slab, and cause premature transverse cracks to develop.

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# EXECUTIVE SUMMARY

The University of Illinois at Urbana-Champaign conducted a research investigation on the potential mechanisms causing premature cracking distresses in urban jointed plain concrete pavements (JPCP) in the state of Illinois. Premature transverse cracking has been periodically observed in relatively new urban concrete pavements. Figure S1 illustrates an example of a premature transverse crack in Champaign, Illinois.

**Figure S1. Photo. Urban concrete pavement section with a transverse crack.**

The objectives of this research were to define the likely mechanisms causing the premature cracks to develop in urban JPCP sections and provide recommendations to mitigate its occurrence. To achieve this, three research tasks were completed.

1. Literature Review of Premature Cracking on Urban JPCP: A literature review was conducted to identify studies related to premature deterioration of urban JPCP. The findings included a list of potential design, construction, and material-related deterioration mechanisms causing excessive local stresses and subsequent premature failures.

2. Field Surveys of Urban JPCP in Illinois: 67 JPCP sections encompassing most of Illinois Department of Transportation's (IDOT's) districts were surveyed. The field surveys included visual inspection and ultrasonic evaluation of the slab and joint details. For the visual inspection, the research team took photographic images and documented slab geometry and pavement distresses as well as any other relevant features. Nondestructive evaluation of the section was conducted using the MIRA ultrasonic tomography device,

which determined the slab thickness, joint reinforcement details (dowel and tie bar location as well as spacing), and contraction joint activation.

3. Analysis of Potential Premature Cracking Mechanisms: To explain the potential premature cracking mechanisms, several analyses were conducted: (a) 3D finite-element analysis to investigate frictional restraint provided by the base layer and adjacent slabs, curb and gutter section, and tie bars in longitudinal contraction and construction joints; (b) dowelled transverse joint restraint forces; (c) HIPERPAV evaluation of concrete mix design; and (d) evaluation of transverse contraction joint activation.

The field survey results and analysis did not result in any single factor being the mechanism causing premature cracking. A combination of factors was found to contribute to the observed cracking, including slab geometry, construction practices, and joint details.

The field surveys of existing concrete pavements revealed a variety of slab geometries (slab length and width). Based on the distressed sections and slab thicknesses between 8 and 10 in., long panels (e.g., greater than a length of 20 ft) and wide panels (e.g., greater than a width of 12 ft) were most susceptible to premature transverse and longitudinal cracking development. Premature cracking was also noted in panels near intersections, over utility lines, or emanating from drainage structures.

Several design and construction practices are contributing to premature cracking such as exceeding IDOT slab geometry standards, potential lack of lubrication of dowel bars, and saw-cutting details. Many slab geometries exceeded the currently recommended limits in the BLRS (2018) manual, i.e., maximum slab length of 12 ft for less than 10 in. slab thickness and 12 ft slab width. Tie bar spacings in longitudinal construction joints and longitudinal sawed joints were 24 in. and 30 in., respectively, before being changed to 36 in. in 2018. Analyses of pullout results of dowels with and without lubrication showed it was highly probable to lock up transverse joints when lubrication was not done.

Additionally, the MIRA ultrasonic device determined some transverse contraction joints were not activated, which could be a reason for some of the premature cracking. Finally, several sections also showed high reflection anomalies in the ultrasonic images that could be caused by poor concrete consolidation near the surface.

Based on the study's findings, the following recommendations were made to minimize premature cracking in urban JPCP sections:

1. Follow IDOT's current slab geometry recommendations: pavement sections with slab thicknesses less than 10 in. should have a maximum slab length of 12 ft, while sections with slab thicknesses greater than or equal to 10 in. should have a maximum slab length of 15 ft. Slab width should not exceed 12 ft for slab thicknesses less than 10 in.

2. Follow updated joint design details provided by IDOT on dowel and tie bar sizes and spacings: dowels spaced at 12 in. on center and dowel diameter equal to 1 in. for slab thicknesses ≤ 8 in., equal to 1.25 in. for thicknesses between 8 and 10 in., and 1.5 in. for thicknesses ≥ 10 in.

Tie bars for both longitudinal construction joints and longitudinal sawed joints are to be designed using #6 bars by 30 in. lengths and spaced at 36 in. on centers.

3. Specify the use of pre-lubricated dowel bars to avoid reliance on field personnel applying lubrication or drastically improve construction inspection education on necessity of dowel lubrication prior to paving.

4. Follow saw-cutting practices for notch depth to slab thickness ratio of 0.33 and timing of saw cut to ensure contraction joint activation. For example, use of a noncontact ultrasonic method to estimate saw-cut timing in the field.

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# CHAPTER 1: INTRODUCTION

Over the past 15 years, premature cracks have been occasionally observed on jointed plain concrete pavements (JPCP) in Illinois. Premature cracking was first observed in Champaign-Urbana on urban JPCP sections designed with a curb and gutter (C&G). The design life for a JPCP section in Illinois is 20 years, with an even longer expected service life. Some of these observed sections had developed mid-panel transverse cracks within the first few years after construction. Figure 1 shows several urban streets in Champaign, Illinois, that exhibited mid-panel transverse cracking within several years after construction (Figure 1).

(A) East Armory Avenue

(B) Green Street

**Figure 1. Photo. Premature transverse cracking on (a) East Armory Avenue and (b) Green Street in Champaign, Illinois.**

Premature distresses in concrete pavement significantly increase maintenance costs and decrease service life of the pavement section. Specifically, premature cracks may not maintain load transfer capabilities and can develop spalling and/or faulting, which can affect the ride quality of the road. Additionally, these cracks increase water ingress into the pavement structure, which can weaken the foundation layers and lead to more rapid deterioration of the localized area.

There are multiple reasons for premature transverse cracks such as excessive joint spacing, high slab-base friction, nonactivated transverse contraction joints, dowel misalignment, high slab curling (temperature/moisture), longitudinal/lateral restraint from adjacent slabs and structures, load-related distresses from trucks, and reflective cracks from utility and drainage structures. Because there are multiple mechanisms that could lead to premature transverse cracking on urban JPCP sections, a systematic field survey and evaluation is necessary to assist in defining the likely mechanisms. Once plausible mechanisms are determined, educating design and construction engineers on current policy that is not being followed as well as recommending any adjustments to existing design and construction policy and standards can be made to minimize future premature cracking distress.

## OBJECTIVES

The objectives of this project were to determine the extent of premature cracking on urban JPCP sections in Illinois and the plausible mechanisms causing premature cracking as well as recommend solutions to minimize its future occurrence.

## RESEARCH TASKS

The following tasks were conducted to meet the research objectives:

1. Review of past studies related to premature cracking in urban JPCP sections.
2. Field survey of urban JPCP throughout the state of Illinois.
3. Analysis of several potential mechanisms for premature cracking.

# CHAPTER 2: LITERATURE REVIEW

## PAST STUDIES

There have been numerous past studies by transportation agencies on the reasons for rapid deterioration of newly constructed JPCP, e.g., Harrington et al. (2018), Rangaraju (2002), and Shoukry et al. (2007). A recent study in Texas by Vickery (2019) demonstrated three main causes contributing to early failures in urban concrete pavements. The first is joint spacing and joint deficiencies, which include excessive transverse joint spacing, missing dowel bars with saw-cutting operation, and improper placement depths of the reinforcement. Second, settlement, particularly over utility trenches, can lead to premature cracks. Third, poor subgrade soils can heave and lead to cracking. Concrete slab curling can also be a source of premature deterioration if not considered in the design (Hansen et al. 2002). A study performed in India also assessed early failures in concrete pavements (Kumar et al. 2009). Their findings also concluded a number of contributing factors can cause early failures in concrete pavements such as saw-cut timing, saw-cut depth, excessive joint spacing relative to slab thickness, dowel misalignment, misplaced saw cuts at transverse joints (dowel misplacement), utility locations, and cracks initiating in monolithically cast curb. The results in these studies show different mechanisms can lead to premature cracking.

Pavement design, environmental factors, and construction methods are all impacted by specific location and site conditions. Overall, the deterioration mechanisms cannot be generalized without consideration of these specific site conditions. The physical-related cracking mechanisms are caused by the local truck traffic and environmental loading. Environmental loading includes thermal and moisture gradients as well as drops in temperature and permanent loss in moisture. JPCP cracking could be linked to concrete materials such as the concrete mixture design and the evolving concrete material properties with time. Table 1 summarizes the most common deterioration mechanisms for both categories.

The premature cracking in most urban JPCP sections does not appear to be related to fatigue cracking, given the insignificant levels of truck traffic and section age at the time of cracking. Therefore, different mechanisms or a combination of mechanisms already discussed could be the cause of the premature distress.

**Table 1. Potential Transverse Cracking Mechanisms for Urban JPCP Sections**

| Reason or Mechanism | Explanation or Result |
|---|---|
| Concrete fatigue | Repeated loading by trucks; can be top-down or bottom-up cracking |
| Slab curling | High moisture and temperature gradients can produce top-down or bottom-up tension cracks |
| Excessive slab length | Premature cracks may occur primarily because of friction or curling |
| Misaligned dowels | Develop localized high tensile stresses, which can cause localized cracking, spalling, or even transverse cracking |
| Late saw cutting at contraction joint | Joint is not activated and premature transverse or longitudinal cracks elsewhere |
| Insufficient saw-cut depth | Joint is not activated, and premature cracks develop elsewhere |

| Reason or Mechanism | Explanation or Result |
|---|---|
| Longitudinal restraint | Excessive restraint by adjacent lane or curb and gutter coupled with too high of contraction or construction joint reinforcement, e.g., tie bar size too large and spacing too small, may initiate transverse crack |
| Utility and drainage structures | Reflective cracks initiated when nonuniformity exists in the support |
| Heaving | Foundation layers heaving because of frost or expansive materials |
| High concrete shrinkage | Rapid contraction of concrete because thermal cooling or moisture loss can lead to premature cracks |
| Material related | Adverse chemical and physical reactions can deteriorate concrete but generally do not produce discrete transverse or longitudinal cracks |

## ULTRASONIC TOMOGRAPHY EVALUATION

To assess as-constructed features of field concrete pavements, this study employed MIRA, an ultrasonic tomography device, during the field surveys. MIRA is a portable commercial ultrasound equipment that contains an array of 4 × 12 transducers (Figures 2-A and 2-B). This arrangement can obtain tomographic information from a small section of the concrete pavement, about 12 in. in length. The equipment evaluates the small section of concrete pavement beneath the device, analyzes the ultrasonic response, and presents a tomographic image in seconds (Hoegh et al. 2011). A multi-array ultrasonic tomography device works by sending multiple ultrasonic shear waves through the concrete slab and recording the received direct, reflected, and diffracted signals. The received signals are interpreted as the distance from the surface to a change in the surveyed element, which includes voids, a different material, change in density, or any other component that reflects the ultrasound waves (Popovics et al. 2017).

(A) MIRA tomographic device

(B) MIRA transducers

**Figure 2. Photo. Ultrasonic tomography devices used during field surveys.**

The recorded ultrasonic image can be used to detect slab thickness, dowel and tie bar placement (depth and spacing), and whether a contraction joint is activated. Figure 3 shows an example of the tomographic image taken from a specific project and its interpretation.

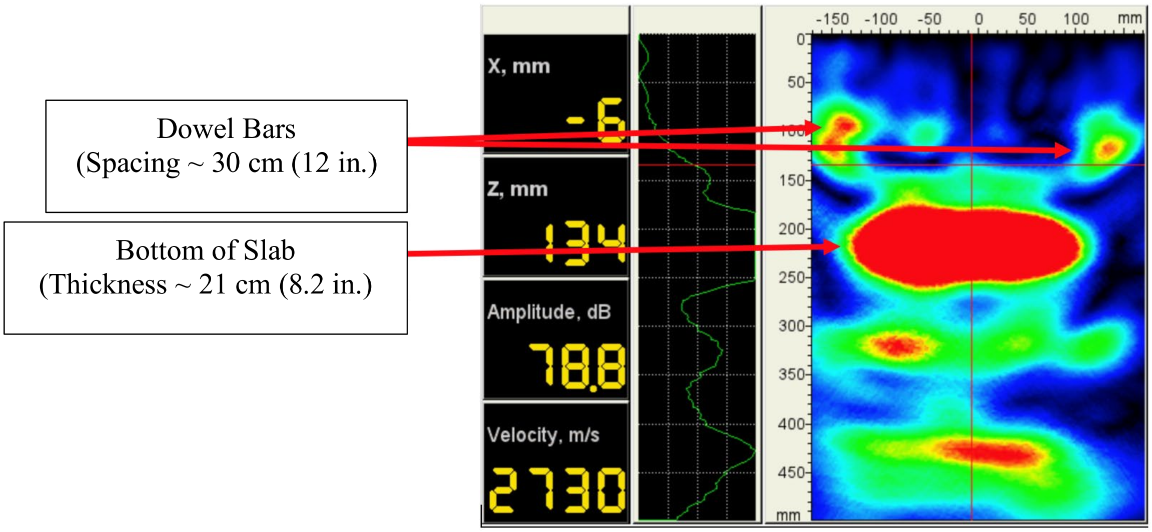



**Figure 3. Photo. Ultrasonic tomographic image from example concrete pavement section.**

# CHAPTER 3: EVALUATION AND ANALYSIS PROCESS OF CRACKING DISTRESS

The evaluation and analysis process consisted of a combination of field visual surveys and testing (Task 2: Field Surveying of Urban JPCP in Illinois) along with analyses to develop mathematical explanations for premature cracking (Task 3: Analysis of Different Mechanisms for Premature Cracking).

## FIELD EVALUATION

The field evaluation process consisted of identifying potential JPCP sections located throughout the state of Illinois, conducting a visual distress survey for each JPCP section, and performing an ultrasonic evaluation of the JPCP cross-section periodically. The following section outlines the process for each of the listed steps.

### Concrete Pavement Selection Process

One of the main challenges of this research was to find recently constructed urban JPCP sections within the state of Illinois. To locate these urban JPCP sections, three methods were used to find and select the pavement sections to survey.

1. IDOT's Transportation Bulletin Archive Database: This was used to find potential projects that met the following criteria: urban concrete pavement section with C&G, slab thickness of approximately 8 in., aggregate base, and constructed between 2012 and 2018. The database contains all lettings related to Illinois transportation but does not include all local roads projects. In most cases, the project information includes type of pavement, thickness, project length, and other relevant information. This database is open to anyone and can be accessed using the following link: http://www.idot.illinois.gov/home/resources/Archives/transportation-bulletin-archives.

2. Google Maps—Virtual Surveying of Project: This software offered a combination of real-life satellite images, street-view images, and, in some cases, 360° interactive panoramic views of the roadway. The process for detecting potential concrete roads with this software consisted of three steps:

   2.1 The first step consisted of conducting an aerial survey for potential project sections using satellite images. The purpose of this step is to detect recent construction developments, including industrial sites, highways, quarries, and other locations where concrete roads are common. Figure 4 shows an example of a satellite image from the city of Effingham. There appears to be pavement under construction (circled in Figure 4), and the new pavement is likely concrete based on the color of the constructed pavement.


**Figure 4. Photo. Effingham Google satellite image.**

2.2 The second step is to zoom-in on the satellite image and detect roads with evenly spaced transverse joints. These transverse joints can represent two alternatives: transverse contraction joints in JPCP or reflective cracking in asphalt pavements. Figure 5 shows a zoomed-in pavement section in Effingham. The picture shows clear rectangular joints that indicate a JPCP section.

**Figure 5. Photo. Effingham zoomed-in Google satellite image.**

2.3 The third step is to use the 360° tool in Google Maps to obtain panoramic views of the street. In these pictures it is possible to detect if the section is a concrete road and if it has any visible deterioration. In some cases, the image is not perfectly clear, and some joints appear discontinued, as shown in Figure 6.

**Figure 6. Photo. 360° sample image.**

3. Field Surveying Site Visits: The IDOT database and Google Maps were the main methods of locating concrete pavements throughout Illinois. Locating the JPCP sections using these two methods allowed for the third method of in-person surveying. During site survey visits, it was possible to detect recently constructed local concrete roads that did not appear within the IDOT Transportation Bulletin Archives and were constructed after the last aerial photography from Google Maps.

In the end, 67 pavement sections were identified and eventually surveyed.

## Visual Inspection of Field Sections

The visual evaluation process of the selected sections consisted of measuring the slab geometry (length and width throughout the section), documenting types of distresses, and recording additional observations that may have influenced the cracking (number of lanes, paving lane construction sequence, types of longitudinal joints). Table 2 was completed for all visited sections.

**Table 2. Visual Inspection Survey**

| Section | Address | Panel Length | Panel Width | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|
| | | | | | | |

## Ultrasonic Measurements

The MIRA portable ultrasonic equipment was used to conduct nondestructive testing and obtain as-constructed pavement information. The device was able to detect the thickness of the concrete, tie and dowel bar depths and spacing, delamination, and indicate potential poor concrete consolidation or honeycombing. Table 3 was completed for all visited sections.

**Table 3. Ultrasound Evaluation Survey**

| Section | Slab Thickness | Dowel Bar Spacing | Tie Bar Spacing | Additional Observations (i.e., depth to steel) |
|---|---|---|---|---|
| | | | | |

## ANALYSIS OF POTENTIAL CRACKING MECHANISMS

Several analysis types were performed to investigate different factors that could result in the premature distress observed with data collected from the field evaluations.

### Finite-Element Analysis

A finite-element analysis was conducted to estimate the tensile stresses that could be developing in the JPCP sections with similar geometry and cross-sectional features. The analysis was conducted in the general-purpose finite element software package, ABAQUS, and consisted of a three-layer system: concrete slab, base layer, and foundation. The computational model was developed to estimate the tensile stresses caused by frictional restraint from the base layer with consideration of the C&G section, dowelled transverse joints, and tie bars along the longitudinal contraction and construction joints. The tensile stresses at the bottom and top of the concrete slab caused by the frictional restraints were the primary output evaluated.

### Field Measurement of Transverse Joint Activation

The purpose of MIRA testing is to determine if a contraction joint between adjacent slabs has a propagated crack emanating from the saw-cut joint. If consecutive contraction joints have not activated, then it is very plausible that observed transverse cracking is the result of late sawing, insufficient notch depth or nonworking joint, and the crack is acting like a contraction joint. The testing protocol consists of straddling the MIRA device over a transverse contraction joint, as seen in Figure 7. Three consecutive measurements at the same location are collected. An algorithm was developed in MATLAB and published by Tran and Roesler (2020b) to analyze the wave transmission across the joint. An activated joint will transmit a very small amount of wave energy across the crack, whereas a joint that has not propagated will transmit a large amount of energy to the MIRA transducer on the opposite side of the joint.

**Figure 7. Photo. Transverse contraction joint activation testing with MIRA device.**

### Concrete Mix Design Evaluation

Some transverse cracks could be a result of early-age properties of the concrete coupled with the selected pavement design features for the urban road, e.g., tied curb and gutter and tied longitudinal joints. HIPERPAV software was run to evaluate the early-age cracking susceptibility of concrete pavements in Illinois for specific mix designs and constituents. The HIPERPAV software was developed by the Transtec Group, Inc. (Ruiz et al. 2004) and the Federal Highway Administration to assess the impact of pavement geometry, concrete mixture designs, curing methods, and local environmental conditions on the early-age performance of concrete pavements. Four concrete pavement sections from different IDOT districts were evaluated for early-age cracking susceptibility. Figure 8 shows a sample output from HIPERPAV, where the blue line represents the expected tensile strength for a concrete mixture over time and the red line represents the calculated maximum tensile stresses in the concrete pavement during the initial 72 hours.

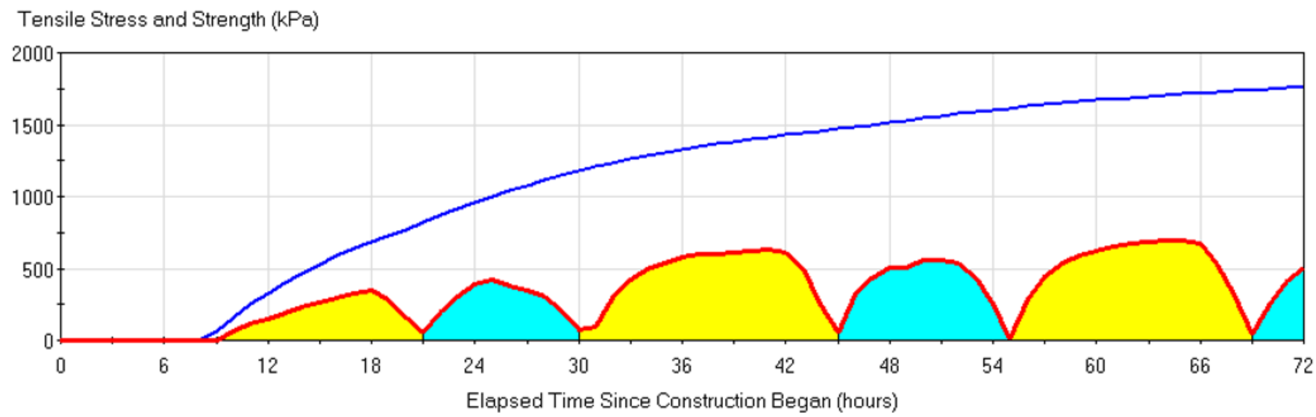



**Figure 8. Graph. HIPERPAV sample output.**

## Dowel Restraint and Slab Tensile Cracking Analysis

An analytical estimation of the forces required to produce a transverse crack in a concrete slab due to a dowel-restraining mechanism at a transverse joint was completed. The calculated restraining forces were compared to the measured forces from experimental dowel pullout tests conducted by Khazanovich et al (2009). The collective dowel restraint at the transverse contraction joint can develop as a function of dowel embedment length, horizontal and vertical misalignment (skew/tilt), and condition of the dowel-concrete interface, i.e., presence of lubrication or oil.

# CHAPTER 4: FIELD SURVEY AND EVALUATION RESULTS

Jointed plain concrete pavements sections evaluated in Districts 1, 2, 3, 4, 5, 7, and 8 were selected based on the process described in Chapter 3. Districts 6 and 9 had a very low number of concrete pavement sections and were not included in this analysis. Figure 9 presents the corresponding locations of all surveyed sections throughout Illinois, which were located within 27 towns/cities. Appendix A contains summary tables of the 67 surveyed sections and evaluation data. All urban concrete pavement sections selected were expected to have dowelled joints, tied longitudinal joints, and tied curb and gutter. The sections surveyed followed the process in Chapter 3. Each pavement section is described in greater detail in the following sections, which are broken down by the respective IDOT district. Appendix A also includes a summary of each site visit, observations, and photos.


**Figure 9. Photo. Surveyed locations containing all 67 surveyed pavements.**

## DISTRICT 1

District 1 is in northeastern Illinois and includes the city of Chicago. The pavement sections evaluated had higher traffic volumes than the remaining district sections. Table 4 summarizes the surveyed sections in District 1. There were no recently constructed urban concrete pavement sections (< 10 years) exhibiting premature distresses. The two sections that did show distresses were constructed approximately 20 years ago. It is unknown if the observed distress for these two sections developed at early or later ages.

**Table 4. District 1 Field Survey and Evaluation Summary**

| Section | Thickness (in.) | Slab Width (ft) | Slab Length (ft) | Distress | Construction Year |
|---|---|---|---|---|---|
| IL 59 from 103rd St. to 95th St. (Naperville, IL) | 10 | 11 | 15 | Joint deterioration, longitudinal and transverse cracks (> 30%) | 1998 |
| IL 59 from US 30 to I-80 (Naperville, IL) | 10 | 11 | 15 | Transverse cracks (< 3%) | 2002 |
| IL 59 with I-88 (Naperville, IL) | 10 | 12 | 15 | 0 | 2010s |
| IL 62 from Penny Rd. to Eastings Way (Elgin, IL) | 10 | 12 | 15 | 0 | 2010s |
| Route 31 – 176 (Crystal Lake, IL) | 10 | 14 | 15 | 0 | 2010s |
| IL 19 and York (O'Hare Airport Area) | 10 | 12 | 13 | 0 | 2010s |
| IL 30 with SS 55 (Joliet, IL) | 10 | 11 | 15 | 0 | 2015 |
| Irving Park (O'Hare Airport Area) | 9 | 11 | 16 | 0 | 2019 |

In addition to the overall evaluation, the following section evaluation is representative of the pavement sections in District 1.

### Illinois Route 59 (IL 59)

Illinois Route 59 (IL 59) is an important principal arterial for the western suburbs of Chicago. This route was surveyed in both directions from IL 173 in Antioch to I-55 in Shorewood. The length of the road is approximately 71 mi. Three individual sections were selected and surveyed along this roadway based on different construction years: 1998, 2002, and 2010s. The ultrasonic evaluation conducted on the three sections showed a similar concrete pavement cross-section. Figure 10 presents one of the ultrasonic images from IL 59. In the image, the dowel bar spacing is approximately 300 mm (12 in.), the depth of the dowel bar is approximately 135 mm (5.25 in.), and the depth of the concrete pavement is 250 mm (10 in.). Table 5 presents a summary of the ultrasonic evaluation for IL 59.

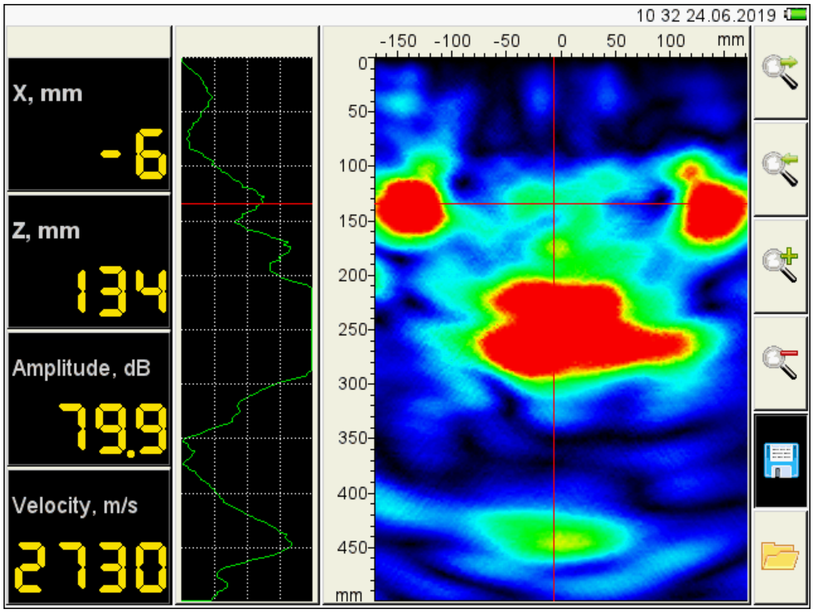



**Figure 10. Photo. Ultrasonic MIRA example image for IL 59.**

**Table 5. IL 59 Average Ultrasonic Results for One Slab Panel Evaluated**

| | |
|---|---|
| Pavement thickness (in.) | 10 |
| Dowel bar spacing at contraction joint (in.) | 12 |
| Tie bar spacing at construction joint (in.) | 27 |

The most recent sections constructed on IL 59 (see Figure 11) were well constructed JPCP and do not exhibit any distress. Figure 12-A presents a picture of another section constructed around 2002. This section was 17 years old at the time of the survey and has some mid-panel transverse cracks. Figure 12-B illustrates the 1998 section, which has a significant amount of cracking distress. It is unknown when the distress initiated and developed.

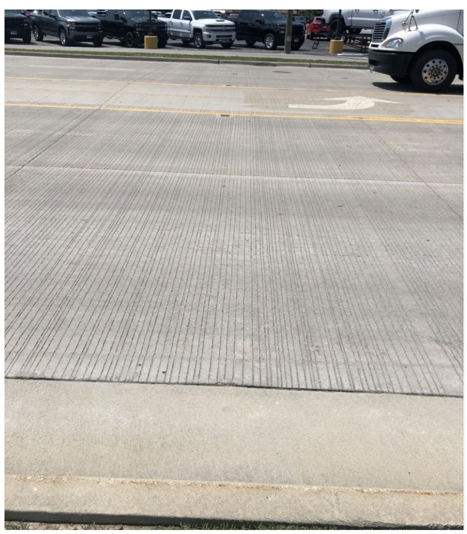


**Figure 11. Photo. IL 59 section constructed approximately in 2010 (no distress).**

(A) IL 59 section constructed in 2002 (some cracking).

(B) IL 59 section constructed in 1998 (significant cracking).

**Figure 12. Photo. IL 59 with cracking present.**

## DISTRICT 2

District 2 is in northwestern Illinois and includes the cities of Galena, Freeport, and Rockford. Table 6 summarizes the field survey and evaluations performed on the pavement sections in District 2.

**Table 6. District 2 Field Survey and Evaluation Summary**

| Section | Thickness (in.) | Slab Width (ft) | Slab Length (ft) | Distress | Construction Year |
|---|---|---|---|---|---|
| State St. with Bell School Rd. (Rockford, IL) | N/A[1] | 15 | 42 | Longitudinal and transverse cracks (>50%) | 2000s (Some panels replaced) |
| US 20 (Galena, IL) | 10 | 13 | 15 | Longitudinal and transverse cracks (>50%) | 2002 |
| Union St. with Blackhawk Blvd. (Rockford, IL) | 10 | 13 | 15 | Joint deterioration (<2%) | 2010s |

[1] Ultrasonic testing could not be performed due to high traffic volume.

In addition to the overall evaluation, the following section highlights a detailed evaluation of US 20 within District 2.

## US 20 (Galena, IL)

US 20 is a principal arterial highway that connects cities and towns across the United States. In 2002, a section of the highway near Galena underwent a full reconstruction. The constructed pavement consists of a JPCP with curb and gutter. The surveyed pavement section had one lane in each direction along with a two-way left turn lane. This section shows significant distress and deterioration. Figures 13 and 14 show longitudinal cracking and joint deterioration within the section.

**Figure 13. Photo. US 20 longitudinal cracking in a two-way left turn lane.**

**Figure 14. Photo. Transverse construction joint deterioration on US 20.**

Table 7 presents the ultrasonic evaluation results for slab thickness and joint reinforcement. The evaluation also showed near-surface reflections at about 50 mm (2 in.) below the surface (see Figure 15). These reflections could represent potential voids or poor consolidation within the top portion of the concrete, but coring would need to be taken to verify the image results.

**Table 7. Average of US 20 Ultrasonic Evaluation Conducted on Outer Slab Panel**

| | |
|---|---|
| Pavement thickness (in.) | 10 |
| Dowel bar spacing at contraction joint (in.) | 12 |
| Tie bar spacing at construction joint (in.) | 36 |

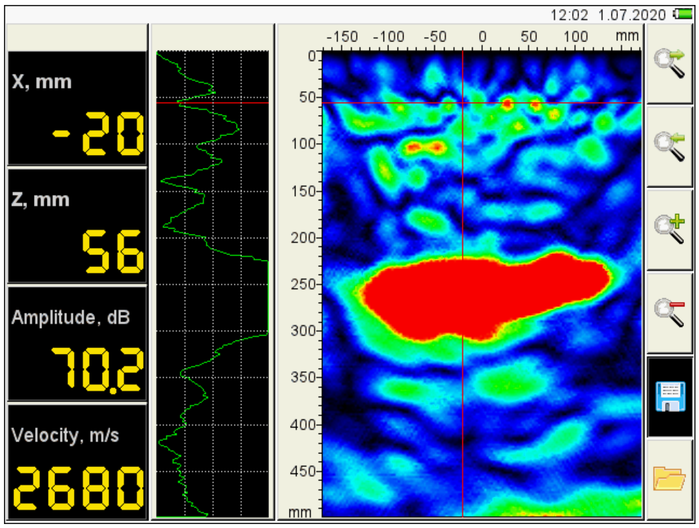



**Figure 15. Photo. Ultrasonic MIRA example image for US 20.**

## DISTRICT 3

District 3 is in northeastern Illinois, just south of District 1 and parts of District 2. Table 8 summarizes the field survey and evaluations performed in District 3.

**Table 8. District 3 Field Survey and Evaluation Summary**

| Section | Thickness (in.) | Slab Width (ft) | Slab Length (ft) | Distress | Construction Year |
|---|---|---|---|---|---|
| Marmont with Dwight St. (Dwight, IL) | 10 | 14 | 15 | 0 | 2010s |
| IL 47 (Morris, IL) | 10 | 12 | 13 | 0 | 2010s |
| IL 47 Veterans Parkway (IL 34) | 10 | 14 | 14 | 0 | 2010s |
| IL 71 with Franklin St. (Oswego, IL) | 10 | 12 | 15 | One full lane width transverse crack | 2010s |
| Eldamain Rd. (Yorkville, IL) | 9 | 12 | 15 | 0 | 2010s |
| Clark St. (Utica, IL) | 10 | 13 | 15 | 0 | 2010s |

For the sections surveyed in District 3, only one section developed distress since construction. The one transverse crack in IL 71 could have been a premature distress shortly after construction.

## Illinois Route 71 (IL 71)

IL 71 showed a mid-panel transverse crack, as seen in Figure 16, spanning the entire width of the pavement cross-section near the entrance to Oswego High School. The results of the ultrasonic evaluation are presented in Figure 17 and Table 9. The ultrasonic evaluation did not show anomalies in the dowel or tie bar construction and design. A plausible deterioration mechanism is an over-restriction caused by the intersection panels.

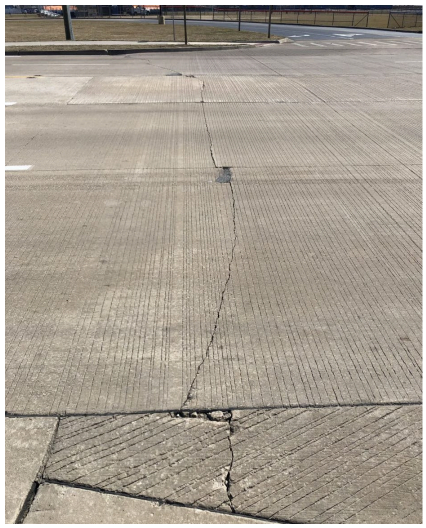


**Figure 16. Photo. IL 71 transverse cracking distress.**

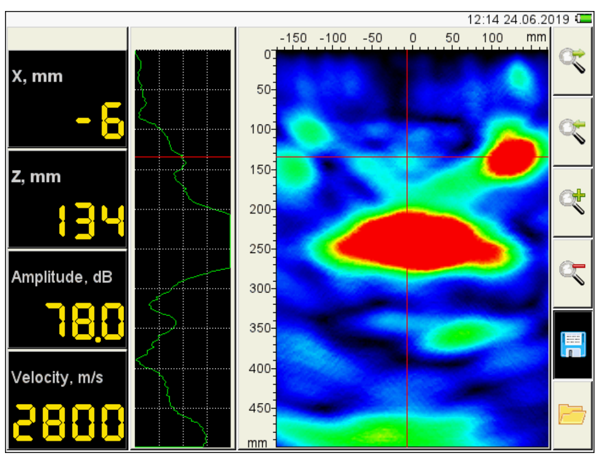



**Figure 17. Photo. IL 71 MIRA ultrasound evaluation.**

**Table 9. Average Ultrasonic Results for One Outer Slab Panel on IL 71**

| | |
|---|---|
| Pavement thickness (in.) | 10 |
| Dowel bar spacing at contraction joint (in.) | 12 |
| Tie bar spacing at construction joint (in.) | 24 |

## DISTRICT 4

District 4 is in western Illinois and includes the city of Peoria. District 4 has a large volume of concrete pavements. Table 10 summarizes the field survey results in District 4.

**Table 10. Summary of District 4 Field Survey and Evaluation Results**

| Section | Thickness (in.) | Slab Width (ft) | Slab Length (ft) | Distress | Construction Year |
|---|---|---|---|---|---|
| Route 8 from Farm to Sunrise (Peoria, IL) | 9 | 12 | 15 | 0 | 2011 |
| Route 8 from Summit to Region (Peoria, IL) | 10 | 12 | 15 | 0 | 2012 |
| N. Allen Rd. from Alta Lane to IL 6 (Alta, IL) | 9 | 12 | 14 | 0 | 2014–2015 |
| Jefferson St. with Jackson (Morton, IL) | 9 | 9 | 20 | Transverse cracks in less than 30% of panels | 2016 |
| Radnor Rd. with Alta Lane (Alta, IL) | 9 | 12 | 14 | 0 | 2017 |
| MacArthur Highway with Richland St. (Peoria, IL) | N/A[1] | 12 | 12 | Transverse cracks near utilities and manholes | 2018 |
| Old Galena Rd. (Mossville, IL) | 9 | 12 | 14 | 0 | 2018 |

[1] Ultrasonic testing could not be performed due to high traffic volume.

The only premature distresses observed in District 4 were seen on MacArthur Highway in the city of Peoria and Jefferson Avenue in the municipality of Morton.

### MacArthur Highway

The distress in MacArthur Highway consisted of a transverse crack spanning the entire width of the pavement section (Figure 18). The crack is extremely wide and is located by a utility manhole (seen in Figure 18 on the opposite side of the road). This is likely the cause of the premature distress.

**Figure 18. Photo. MacArthur Highway transverse distress near utility duct.**

## Jefferson Avenue

The distresses observed in Jefferson Avenue consisted of mid-panel transverse cracks (Figure 19). Table 11 presents the results of the ultrasonic evaluation. The observed transverse cracks are likely related to the excessive slab length of 20 ft for the given slab thickness of 9 in.

**Figure 19. Photo. Transverse crack on Jefferson Avenue near Jackson Street.**

**Table 11. Average Ultrasonic Results on One Outer Slab Panel on Jefferson Avenue**

| | |
|---|---|
| Pavement Thickness (in.) | 9 |
| Dowel Bar Spacing at contraction joint (in.) | 24 |
| Tie Bar Spacing at construction joint (in.) | 45 |

## DISTRICT 5

District 5 is in the east central part of Illinois and includes the cities of Champaign-Urbana, Mahomet, Rantoul, and Bloomington. District 5 contained a large number of low-volume JPCP sections, which were included within the surveys. For this reason, each city has been analyzed individually.

## Champaign-Urbana

The conducted physical evaluation on the city of Champaign-Urbana showed a large number of concrete pavement sections with premature distresses. Table 12 summarizes the physical evaluations performed.

**Table 12. Summary of Champaign-Urbana Field Surveys and Evaluation Results**

| Section | Thickness (in.) | Slab Width (ft) | Slab Length (ft) | Distress | Construction Year |
|---|---|---|---|---|---|
| Green St. from 4th St. to Wright St. (Champaign, IL) | 8 | 11 | 15 | Transverse cracking and joint deterioration (>50%) | 2005 |
| Legacy Ave. (Champaign, IL) | 8 | 10 | 15 | 0 | 2007 |
| John St. from Neil St. to Elm St. (Champaign, IL) | 8.5 | 7.5 | 15 | Transverse cracking (>30%) | 2008 |
| Stadium Dr. (Champaign, IL) | 10 | 9 | 15 | 0 | 2008 |
| Logan St. (Champaign, IL) | 8 | 11 | 15 | Transverse cracking (>50%) | 2010 |
| Healey St. from 4th St. to 5th St. (Champaign, IL) | 8 | 12 | 12.5 | Transverse cracking (>50%) | 2010s |
| Healey St. from 5th St. to 6th St. (Champaign, IL) | 8 | 12 | 12.5 | Transverse cracking (>30%) | 2010s |
| John St. from Prospect Ave. to New St. (Champaign, IL) | 8 | 13 | 13 | Transverse cracking (>30%) | 2010s |
| Gregory St. from 1st St. to 4th St. (Champaign, IL) | 7–8[1] | 12 | 17 | Transverse cracking (>50%) | 2010s |
| Curtis Rd. from Prospect Ave. to Duncan Rd. (Champaign IL) | 8 | 12 | 15 | Transverse cracking (>30%) | 2010s |
| Gregory St. from Oak St. to 1st St. (Champaign IL) | 8 | 18 | 15 | Transverse cracking (>50%) | 2013 |
| Gregory St. from 4th St. to 6th St. (Champaign, IL) | 8 | 10.5 | 15 | Transverse cracking (>50%) | 2013 |
| 1st St. (Champaign, IL) | 9 | 10 | 15 | 0 | 2016 |
| 4th St. from Florida to St. Mary's Rd. (Champaign, IL) | 10 | 11 | 14 | Post-construction full-depth repair | 2016 |
| White St. from 4th St. to Wright St. (Champaign, IL) | 10 | 13 | 15 | Distress over detention basin bridge area | 2018 |
| Prospect Ave. from Windsor Rd. to Curtis Rd. (Champaign IL) | 10 | 12.5 | 10 | 0 | 2019 |
| Lincoln Ave. from Saline Ct. to Olympia Dr. (Urbana, IL) | 9 | 12 | 12 | 0 | N/A |
| Peabody Dr. (Urbana, IL) | 8 | 8 | 10.5 | 0 | N/A |

The following sections are highlights from Champaign-Urbana field surveys and evaluations.

### *Green Street*

Green Street is in the heart of the University of Illinois at Urbana-Champaign. The road had a full reconstruction around 2005 and developed transverse cracking distresses within the first few years. Figure 20 shows an image of Green Street with the commonly observed transverse cracking.

**Figure 20. Photo. Transverse cracking on Green Street (Champaign, IL).**

The ultrasonic evaluation was performed in five different testing locations to have a better representation of the JPCP section. The ultrasonic evaluation showed inconsistencies between the thickness at the different locations, as well as the tie bar spacing. The obtained thickness measurements ranged from 8 in. to 10 in., and the tie bar spacing ranged from no tie bars detected to 36 in. Table 13 summarizes the ultrasonic evaluations for Green Street.

**Table 13. Summary of Green Street Ultrasonic Evaluation for Multiple Slab Locations**

| | Test Location | | | | |
|---|---|---|---|---|---|
| Properties | 1 | 2 | 3 | 4 | 5 |
| Pavement thickness (in.) | 8 | 10 | 10 | 8 | 9 |
| Dowel bar spacing (in.) | 12 | 12 | 12 | 12 | 12 |
| Tie bar spacing (in.) | 36 | 36 | No tie bars detected | 36 | 25 |

### *Healey Street*

Healey Street is a road that runs parallel to Green Street but is located one block north. Healey Street is a local street and has only car traffic. This recently reconstructed urban JPCP section is showing premature transverse cracks in about 30% of the slab panels (see Figure 21). The images from the ultrasonic evaluation showed significant distortion near the surface of the concrete (Figure 22). This may be related to poor consolidation of the concrete and may have contributed to premature cracking with another mechanism.

**Figure 21. Photo. Healey Street premature mid-panel crack.**

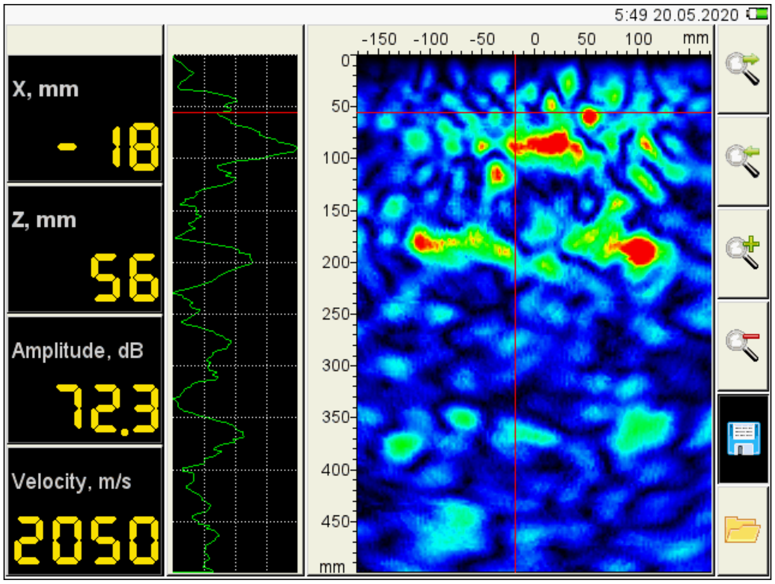



**Figure 22. Photo. Healey Street ultrasonic image.**

## Mahomet/Rantoul

Table 14 summarizes the field survey and evaluation results conducted in Mahomet and Rantoul, Illinois. Lake of the Woods Road was the only section with observed distress. A construction materials warehouse is located along this pavement section and is likely the contributor to transverse cracking.

**Table 14. Summary of Mahomet/Rantoul Field Survey and Evaluation Results**

| Section | Thickness (in.) | Slab Width (ft) | Slab Length (ft) | Distress | Construction Year |
|---|---|---|---|---|---|
| Lake of the Woods Rd. (Mahomet, IL) | 9 | 12 | 12 | Transverse cracking (<30%) | ~2014 |
| Veterans Parkway (Rantoul, IL) | 8 | 13 | 15 | No | 2014 |
| Forest View (Mahomet, IL) | 7 | 7 | 11 | No | N/A |
| Sprucer Dr. (Mahomet, IL) | 7 | 13 | 15 | No | N/A |

## Bloomington

Table 15 summarizes the field survey and evaluation results conducted in Bloomington, Illinois. Most slab panels are significantly longer than recommended, and, therefore, the excessive slab length has contributed to the premature cracks. IDOT requires slab lengths to be 12 ft or less when concrete slab thickness is less than 10 in.

**Table 15. Summary of Bloomington Field Survey and Evaluation Results**

| Section | Thickness (in.) | Slab Width (ft) | Slab Length (ft) | Distress | Construction Year |
|---|---|---|---|---|---|
| Raab St. (Bloomington, IL) | N.U.[1] | 12 | 17 | Longitudinal cracking. (>50%) | 2000s |
| Providence Dr. (Bloomington, IL) | N.U.[1] | 9 | 20 | Transverse cracking (>30%) | 2000s |
| Vladimir Dr. (Bloomington, IL) | N.U.[1] | 9 | 15 | Transverse cracking (>30%) | 2000s |
| Slaydon Dr. (Bloomington, IL) | N.U.[1] | 9 | 20 | Transverse cracking (>50%) | 2000s |
| Challis Dr. (Bloomington, IL) | N.U.[1] | 9 | 20 | Transverse cracking (>30%) | 2000s |
| Bancoft Dr. (Bloomington, IL) | N.U.[1] | 9 | 20 | Transverse cracking (>50%) | 2000s |
| Cadwell Dr. (Bloomington, IL) | N.U.[1] | 9 | 20 | Transverse cracking and potholes (>30%) | 2000s |
| Newcastle Dr. (Bloomington, IL) | N.U.[1] | 9 | 20 | Transverse cracking (>30%) | 2000s |
| Chantal Ln. (Bloomington, IL) | N.U.[1] | 9 | 20 | Transverse cracking (>30%) | 2000s |
| Virginia Ave. (Bloomington, IL) | 8 | 9 | 13 | 0 | 2012 |

[1] N.U.= No ultrasonic evaluations were conducted in these sections.

## DISTRICT 6

No JPCP sections were surveyed in District 6 because the IDOT Transportation Bulletin Archives showed very few recently constructed JPCP projects.

## DISTRICT 7

District 7 is located directly south of District 5 and includes the city of Effingham. Table 16 summarizes the field survey and evaluation results conducted in District 7. Most of the sections are close to or have exceeded 20 years of service life, and the mechanisms for cracking could be fatigue cracking from loading or premature cracking that occurred many years ago.

**Table 16. Summary of District 7 Field Surveys and Evaluation Results**

| Section | Thickness (in.) | Slab Width (ft) | Slab Length (ft) | Distress | Construction Year |
|---|---|---|---|---|---|
| Maple St. (Downtown) Effingham, IL | 8 | 12 | 15 | Longitudinal cracking (>50%) | 2000s |
| Maple St. (North) Effingham, IL | 8 | 12 | 15 | Transverse and longitudinal cracking (<30%) | 2000s |
| Ford St. Effingham, IL | 9 | 13 | 20 | Transverse cracking (~30%) | 2000s |
| Merchant St. Effingham, IL | 9 | 12 | 12 | No | 2010s |

## DISTRICT 8

District 8 is in southwestern Illinois and includes East St. Louis. Table 17 summarizes the field surveys and evaluation results conducted in District 8.

**Table 17. District 8 Summary of Field Surveys and Evaluation Results**

| Section | Thickness (in.) | Slab Width (ft) | Slab Length (ft) | Distress | Construction Year |
|---|---|---|---|---|---|
| Harrison with Wesley Dr. (Alton, IL) | 8 | 12 | 45 | Slabs have transverse cracking or joint deterioration | 2010s |
| Matter Ave. (Columbia, IL) | 8 | 11 | 15 | 0 | 2010s |
| Koepfli Ln. (Highland, IL) | 8 | 12 | 15 | 0 | 2010s |
| Bissel Rd. (East St. Louis, IL) | 10 to 12 | 12 | 15 | 0 | 2010s |
| Bissel Rd. Section 2 (East St. Louis, IL) | 7 | 12 | 18 | Transverse cracking (>50%) | 2010s |
| Central St. (East St. Louis, IL) | 8 | 14 | 30 | Transverse cracking (100%) and longitudinal cracks | 2010s |
| Troy Ave. (Troy, IL) | 10 | 13 | 15 | Longitudinal cracks (>50%) | N/A (old road) |

The following sections are important highlights from District 8.

## Harrison Street

Harrison Street is composed of long JPCP panels (up to ~45 ft) that are showing significant premature cracking distress and deterioration. Almost all the panels (98%) are showing a type of distress in the form of either a transverse crack (Figure 23) or joint deterioration (Figure 24). Excessive panel length with an 8 in. thickness is the main factor contributing to the transverse cracks. In addition, large joint spacing can cause large changes in magnitude of joint width and can lead to joint damage and deterioration.

**Figure 23. Photo. Harrison Street transverse crack.**

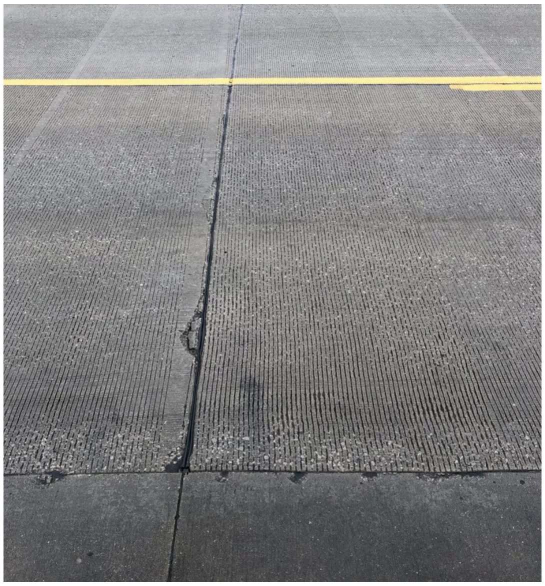


**Figure 24. Photo. Harrison Street transverse joint deterioration.**

## Central Street

Similar to Harrison Street, Central Street is composed of very long JPCP slab panels (~30 ft) that are exhibiting premature transverse cracks. These mid-panel cracks are likely due to excessive panel length relative to this slab's thickness (see Figure 25).

**Figure 25. Photo. Mid-panel transverse crack on Central Street (East St. Louis, IL).**

## DISTRICT 9

No JPCP sections were surveyed in District 9 because the IDOT Transportation Bulletin Archives showed very few recently constructed JPCP projects.

# CHAPTER 5: ANALYSES OF MECHANISMS FOR PREMATURE CRACKING ON JPCP

In addition to the field surveys and nondestructive evaluations, several types of analyses were performed to investigate potential mechanisms causing premature failure within urban JPCP sections. First, a finite-element analysis was performed to investigate the various frictional restraint restricting the movement of the urban JPCP section. Second, an ultrasonic investigation was performed using MIRA to examine joint activation of transverse contraction joints that were separated by a premature transverse crack. Third, an analysis was performed on the early-age behavior of the urban concrete pavement using the software HIPERPAV. Finally, an estimation of the likelihood of transverse cracking was performed by considering the restraining stresses induced as a result of nonlubricated dowel bars, embedment depth, and misalignment or skew of the dowels at the joint.

## FINITE ELEMENT

To better assess the premature failures occurring in the field, a 3D analysis was performed using the general-purpose finite-element modeling software ABAQUS (2013). A 3D pavement model was developed to examine potential cracking mechanisms that could be causing the premature failures and their interactions:

1. Restraint offered by longitudinal tie bars and dowels at transverse joints.
2. Frictional interaction between the concrete and aggregate base layer (low or high).
3. Shrinkage of the concrete from drying shrinkage (moisture) and thermal contraction.
4. Nonuniformity in restraint.

ABAQUS allowed for consideration of different pavement geometries, environmental factors, and restraint to assist in predicting the slab tensile stresses for similar slab geometries and joint configurations.

The 3D model consisted of either a two-lane or four-lane pavement section with a curb and gutter on both edges of the pavement. Figure 26 shows a representation of the two-lane model. The model assumptions included the slab geometry, curb and gutter, and steel reinforcement at the various joints. The model consisted of three elastic layers: concrete surface layer (8 in.), aggregate base layer (16 in.), and a soil foundation (semi-infinite layer). All steel reinforcement was represented by springs, and their corresponding stiffnesses were determined based on properties of the steel and are presented in Tables 18 and 19. For the initial analysis, discrete modeling of the dowel or tie bars was not considered necessary.

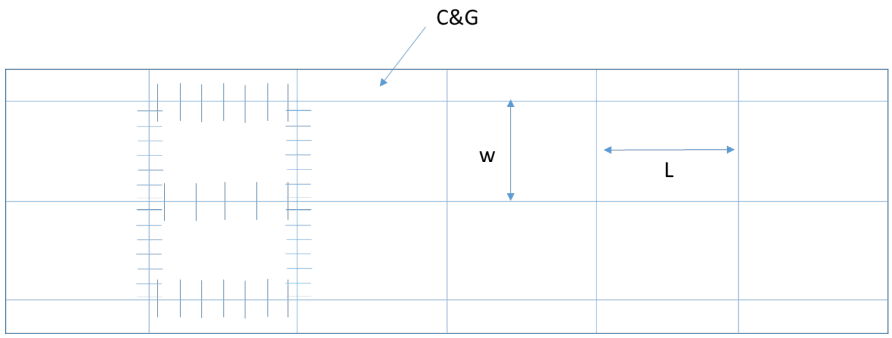



**Figure 26. Photo. Plan view of 3D ABAQUS model.**

**Table 18. Concrete Pavement Section Assumptions**

| | |
|---|---|
| Concrete Layer | |
| Geometry (L × W × D) | 15 ft × 11 ft × 8 in. |
| Elastic modulus (psi) | $4.4 \times 10^{6}$ |
| Poisson's ratio | 0.17 |
| Coefficient of thermal expansion (in/in/°F) | $5.5 \times 10^{-6}$ |
| Density (pcf) | 156 |
| Temperature differential (°F)[1] | 27 |
| C&G dimensions (L × W × D) | 15 ft × 2 ft × 8 in. |
| Aggregate Base Layer | |
| Thickness (inch) | 16 |
| Elastic modulus (psi) | $1.75 \times 10^{5}$ |
| Poisson's ratio | 0.25 |
| Foundation Layer | |
| Elastic modulus (psi) | $5.8 \times 10^{3}$ |
| Poisson's ratio | 0.35 |

[1] Temperature distribution is uniform temperature distribution through slab thickness.

**Table 19. Steel Reinforcement Assumptions and Spring Stiffnesses**

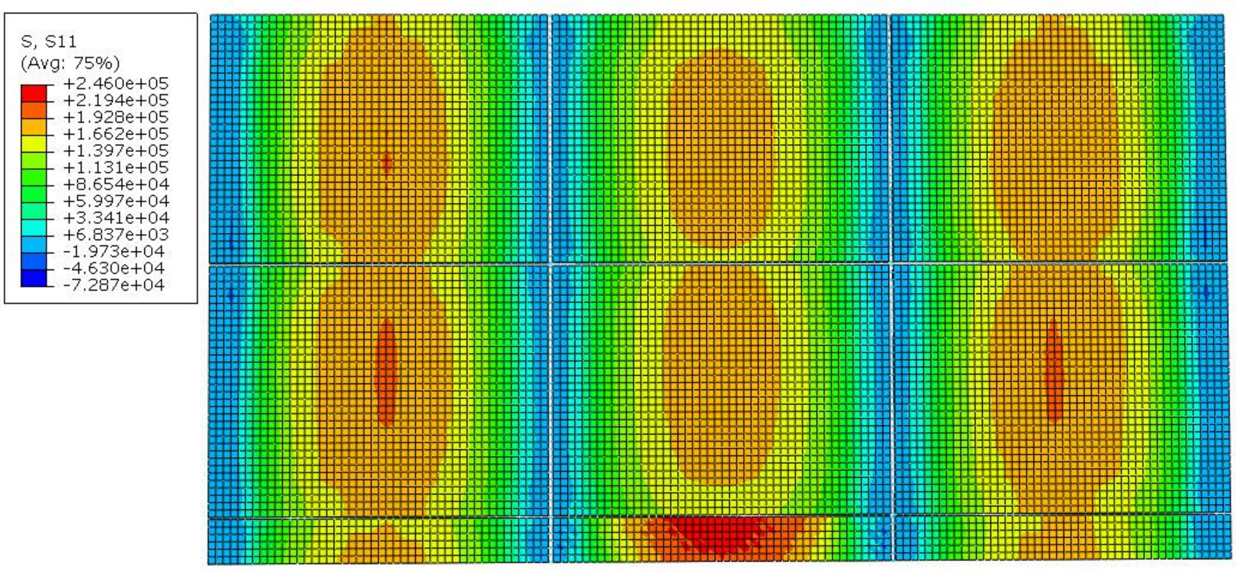
| | |
|---|---|
| Steel Properties | |
| Elastic modulus of steel (psi) | $30 \times 10^{6}$ |
| Poisson's ratio | 0.20 |
| Coefficient of thermal expansion (in./in./°F) | $5 \times 10^{-6}$ |
| Dowel Bars | |
| Diameter (in.) | 1.5 |
| Spacing (in.) | 12 |
| Embedment depth (in.) | 4 |
| Spring stiffness (lb/in.) | 173,760 |
| Tie Bars | |
| Diameter (in.) | 0.75 (#6 bars) |
| Spacing in longitudinal joints (in.) | 24 |
| Spacing in C&G (in.) | 30 |
| Embedment depth (in.) | 4 |
| Spring stiffness in longitudinal joints (lb/in.) | 47,850 |
| Spring stiffness in C&G (lb/in.) | 38,430 |

The 3D model consisted of two elements along the depth of each pavement layer to achieve mesh convergence. A frictional interface was assumed between the concrete, and the base layer was modeled in ABAQUS. This is a Mohr-Coulomb friction that uses a stiffness (penalty) method, which permits some relative movement of the surfaces (an "elastic slip") when the surfaces are in full contact with a maximum shear stress allowed at the interface (i.e., $\bar{\tau} < \bar{\tau}_{crit}$). A full bond assumption was between the base and soil foundation. Springs were used to simulate the shear load transfer (dowels and tie bars) between adjacent slabs. A gap or space was not considered between transverse and longitudinal joints.

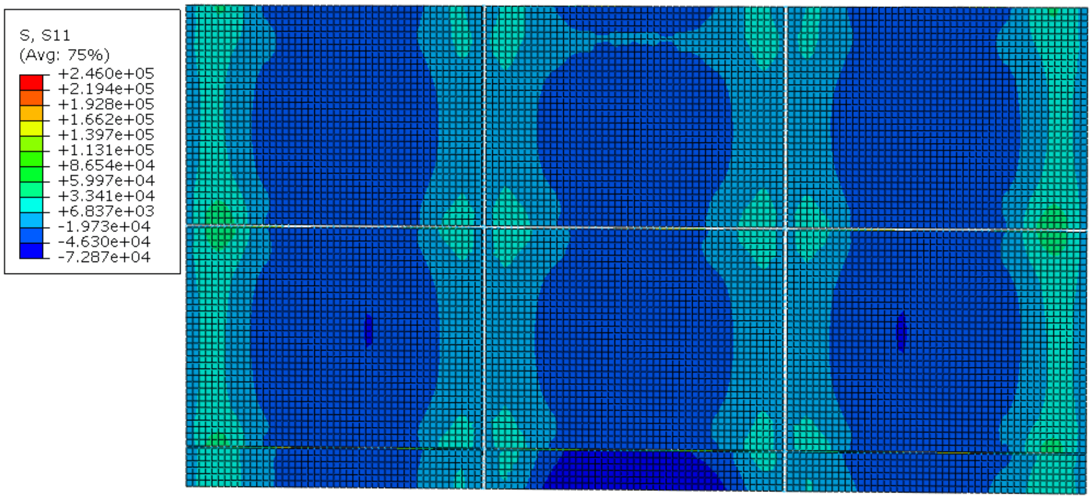
The maximum stress results at the bottom of the concrete can be seen in Table 20 and Figure 27 as a function of friction. From these results, the maximum tensile stress levels would not exceed the strength of the concrete (435 to 580 psi). Therefore, additional internal restraining forces must be occurring and significantly affecting the magnitude of tensile stress in the concrete pavement cross-section.

**Table 20. Maximum Slab Tensile Stresses (S11) as a Function of Friction**

| Friction coefficient | Max. S11 (psi) |
|---|---|
| 1 | 6.7 |
| 10 | 35.7 |
| 100 | 116 |
| infinite | 174 |




(A) Stress distribution along the bottom surface of the concrete layer (in Pa)




(B) Stress distribution along the top surface of the concrete layer (in Pa)

**Figure 17. Photo. Stress distribution of 3D model with friction coefficient of 10.**

## JOINT ACTIVATION

Saw-cut contraction joints must propagate a full-depth crack in order allow slabs to move independently of each other and reduce the likelihood of premature transverse or longitudinal cracking. When a contraction joint does not activate, this causes an increase in the effective slab length and an increase in the tensile stresses as a function of wheel loads and the environment. As these tensile stress levels approach and exceed the concrete strength, a crack will develop away from the intended joint location.

To assess the joint activation in the field, an algorithm was developed by Tran and Roesler (2020b) that uses the MIRA shear wave response across the theoretical plane of the contraction joint. The algorithm uses the received signal energy from specific transducer pairings and calculates a normalized transmission energy (NTE) quantity. From the energy analysis, sensor pairings 2–7 and 2–11 resulted in the best prediction of whether a joint was activated for concrete overlays. In addition to the optimal transducer pairings, a hyperplane model was determined for the final assessment. The hyperplane is the decision line that separates an activated joint with a crack (below the hyperplane) and a joint that has been sawed but is not activated (above the hyperplane).

An investigation was performed examining six streets in Champaign: Green Street, Healey Street, Gregory Avenue, Armory Drive, Curtis Road, and Logan Street. This comprehensive analysis consisted of 10 different sections tested from the six streets. Some portions of the JPCPs were constructed at different dates and/or had different designs and, therefore, a total of 10 sections were examined. The joint analysis was performed by examining adjacent transverse joints on either side of transverse cracks, as well as joints that did not have any slab cracking. Table 21 summarizes the results of the joint evaluation conducted on the 10 sections. The total number of activated joints, nonactivated joints, inconclusive joints, total number of joints tested, as well as the number of slabs with transverse cracking out of the total number of slabs is presented for each section. From this predictive analysis, 60% of the tested joints were activated, 12% were determined not activated, and the remaining 28% of the joints were inconclusive (ultrasonic results of NTE fall near the hyperplane). The NTE results for all sections are presented in Figure 28.

**Table 21. MIRA Results of Transverse Joint Activation Surveys in Champaign, Illinois**

| Section | Activated Joints | Nonactivated Joints | Inconclusive Joints[1] | Total Joints Tested | Slabs with cracking/ Total slabs |
|---|---|---|---|---|---|
| Green St. from 4th St. to Wright St. | 11 | 0 | 0 | 11 | 5/10 |
| Logan St. | 1 | 0 | 5 | 6 | 3/5 |
| Healey St. from 4th St. to 5th St. | 4 | 0 | 3 | 7 | 4/6 |
| Healey St. from 5th St. to 6th St. | 6 | 0 | 0 | 6 | 1/5 |
| Curtis Rd. from Prospect Ave. to Duncan Rd. | 0 | 5 | 5 | 10 | 7/9 |
| Gregory St. from 1st St. to 4th St. | 9 | 0 | 0 | 9 | 3/8 |
| Gregory St. from Oak St. to 1st St. | 5 | 2 | 3 | 10 | 2/9 |
| Gregory St. from 4th St. to 6th St. | 5 | 0 | 1 | 6 | 3/5 |
| Green St. from 1st St. to 4th St. | 3 | 0 | 7 | 10 | 0/9 |
| E. Armory Ave. from 4th St. to Wright St. | 7 | 3 | 0 | 10 | 0/9 |
| **Totals** | **51** | **10** | **24** | **85** | **28/75** |
| **%/Total Joints** | **60%** | **12%** | **28%** | **-** | **37%** |

[1] Inconclusive results indicate ultrasonic joint evaluation falls on or near the hyperplane.

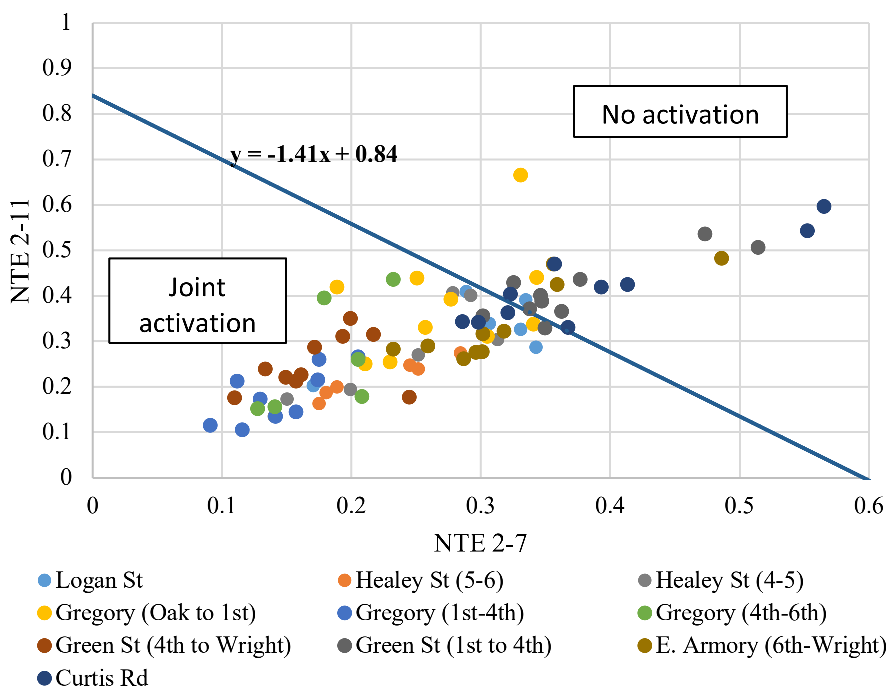



**Figure 28. Graph. Hyperplane joint activation results.**

This MIRA analysis shows that some joints may not be activated and could be contributing to premature cracking. Additionally, these joints were all tested a minimum of 5 years after construction. It is believed that if these joints have not activated by now, they will likely never become an activated joint. It is also possible that not all joints activated initially prior to the premature cracking, but have activated subsequently. It is important to ensure joint activation early in the service life (after saw-cutting has been performed) in order to prevent random cracks that develop prematurely as the internal stress exceeds the concrete strength. The MIRA sensor pairings and hyperplane equation are based primarily on NTE and observations from bonded concrete overlays of asphalt, where the concrete thickness was less than 6 in. and saw-cut notch depth was 25% to 33% of the slab thickness.

## CONCRETE MIX DESIGN EVALUATION

The early age of concrete properties has a significant influence on the long-term durability of the concrete (Ruiz et al. 2004). The HIPERPAV software was used to evaluate three concrete mixtures from three evaluated sections in District 1, 4, and 8. These selected sections have similar geometry and IDOT-approved concrete mix designs. The purpose of this analysis is to determine the early-age behavior of the concrete mix designs used and assess if they are contributing to excessive early stresses that could lead to premature cracks. Table 22 provides the concrete mix designs used in construction for the corresponding sections.

**Table 22. Concrete Mix Designs of Three Urban Concrete Pavement Sections**

| Pavement Section | River Rd. in Des Plaines, IL | Old Galena Rd. in Mossville, IL | Koepfli Ln. in Highland, IL |
|---|---|---|---|
| IDOT district | 1 | 4 | 8 |
| Coarse aggregate (pcy) | 1783 | 1829 | 1853 |
| Sand (pcy) | 1305 | 1214 | 1160 |
| Cement (pcy) | 435 | 405 | 435 |
| Fly ash (pcy) | 0 | 175 | 145 |
| Slag (pcy) | 145 | 0 | 0 |
| Water/cementitious ratio | 0.42 | 0.41 | 0.41 |
| Air content | 6.5% | 6.5% | 6.5% |
| Average slump | N/A | 2.6″ | 2.6″ |

The following location, geometry, and curing method were used for the analysis:

**Table 23. HIPERPAV Inputs**

| Location | Peoria, IL |
|---|---|
| Construction Date | July 28[1] |
| Slab Geometry | |
| Length (ft) | 15 |
| Width (ft) | 12 |
| Thickness (in.) | 8[2] |
| Curing Procedure | Single coating curing membrane |

[1] Warmest day in the year according to HIPERPAV database to be conservative for maximum stress levels.

[2] Koepfli Lane was also evaluated at 9 in. and 10 in.

HIPERPAV estimates the concrete mixture tensile strength and stress development based on the mixture components and environmental conditions. Figure 29 shows the tensile strength development for the first 72 hours of the concrete mixtures presented in Table 22. The hardening profile was similar for all the mixtures. However, the Des Plaines mixture design shows slightly faster strength development, but the lowest strength gain after 72 hours. The Old Galena mixture design showed the greatest strength gain at the end of the 72-hour evaluation.

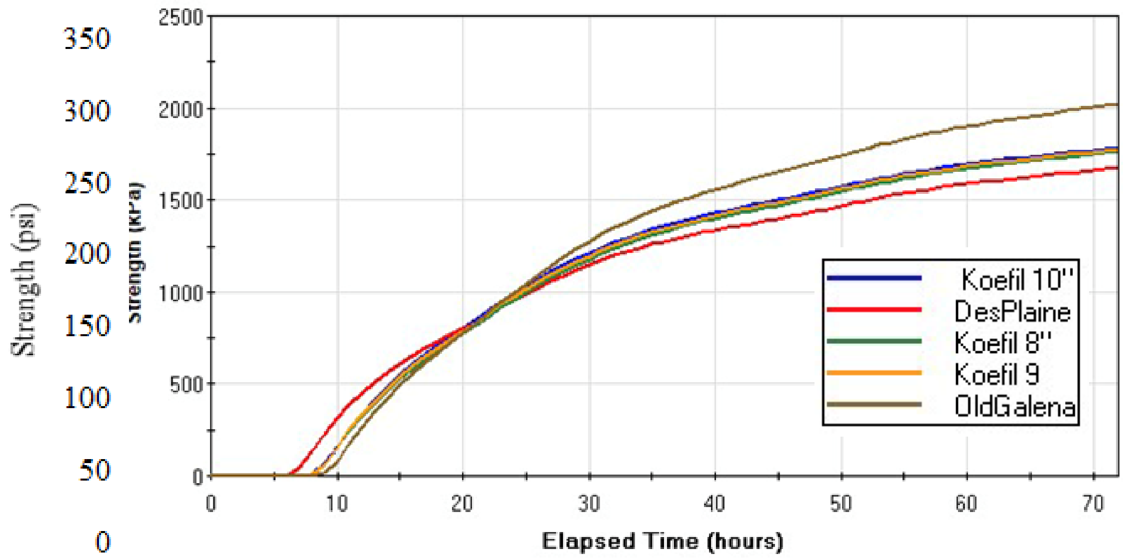



**Figure 29. Graph. Tensile strength development for three concrete mix designs.**

HIPERPAV compares the concrete strength development with the time-dependent environmental stresses developing in the slab with depth. Figure 30 presents the strength development versus stress demand of the three concrete mixtures. The stress demand curve shows fluctuations as a response to the high temperatures of daytime and cooler temperatures of nighttime. The stress demand did not surpass the strength gain in any cases.

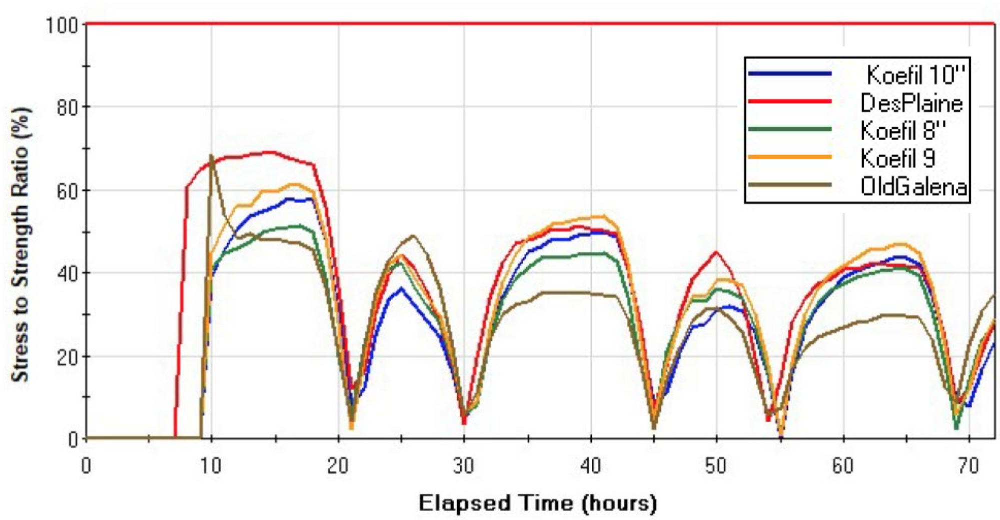



**Figure 30. Graph. Tensile strength/stress ratio for three concrete mixtures.**

Based on the HIPERPAV results, it appears that the strengths of the concrete mixtures are adequate, and the environmental tensile stresses are not sufficient enough to be a likely cause of premature cracking of urban concrete roads in Illinois.

## DOWEL BAR RESTRAINT FORCES

Another potential contributing factor to premature cracking is related to the additional restraint dowel bars can contribute at the transverse contraction joints. Dowel bars should be lubricated. Article 420.05(c)(2) of the Standard Specifications for Dowel Bars and Dowel Bar Assemblies states that "a light coating of oil shall be uniformly applied to the dowel bars" (IDOT, 2017). Dowel bars should also be placed parallel to the direction of travel to allow the concrete slab to expand and contract at the joint without restriction from the dowel bars. If the dowels at the transverse joints were misaligned horizontally or vertically and/or not lubricated, it is possible to generate enough restraining forces at the transverse joint to propagate a transverse crack even with full-depth contraction joint activation.

Khazanovich et al. (2009) performed laboratory pullout testing to examine the effect of lubricating or greasing dowels in addition to various degrees of dowel misalignment. The pullout testing examined 1.5 in. diameter dowels with a standard embedment depth of 6 in. As shown in Figure 31, an average pullout force of 11.6 kips is required for a 6 in. embedment without lubrication versus a required average pullout force of 3.5 kips for a 6 in. embedment with lubrication. The research demonstrated that the pullout force required for dowels moving relative to the concrete could be 3 to 4 times higher without lubricating dowels. This increased resistance to pullout may result in premature cracking.

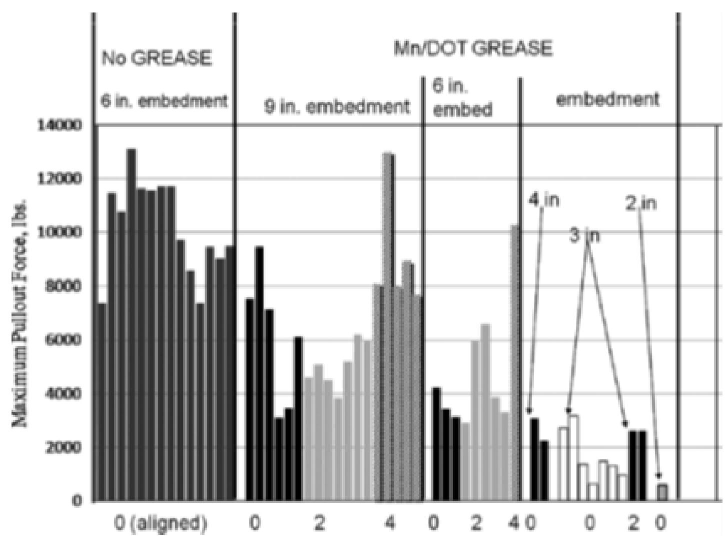



**Figure 31. Graph. Distribution of maximum pullout forces for greased and ungreased dowels.**

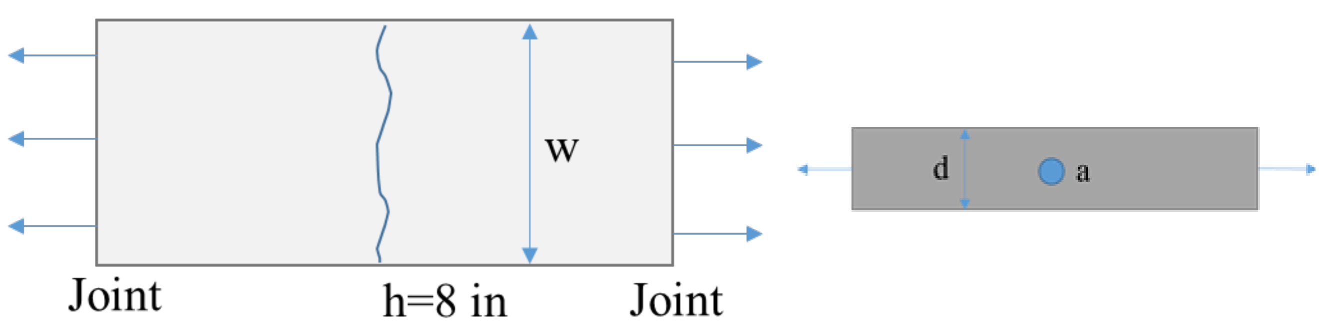
***(Khazanovich et al. 2009)***

To assess the findings presented by Khazanovich et al. (2009), the force required to generate a transverse crack mid-slab was calculated first. The equation to calculate force is as follows: Force (P) =

width (w) × thickness (h) × concrete tensile strength ($f_t$). This required force is the same force needed to restrain the transverse joints, i.e., lockup the joints from misalignment or nonlubricated dowels, or both. Examining a 15 ft × 11 ft × 8 in. thick slab with a concrete tensile strength of 400 psi results in a required force (P) of approximately 422.4 kips in order to crack the concrete (Figure 32-A) and restrain the joint from moving.

In addition to the concrete tensile strength, tie bars can add to longitudinal restraint as well as act as initiators of edge cracks, e.g., plate with a hole. Tie bars are located along the perimeter of the slab and act as a hole (stress concentration) within the concrete slab. The diameter of the tie bar is represented as the hole in Figure 32-B relative to the concrete slab thickness. The ratio between the diameter of the tie bars and the thickness of the pavement is used to determine the stress concentration factor which is approximately 3.0 for small a/d. For a small a/d (< 0.10), a stress concentration factor of 3.0 results in a slab transverse cracking force (P) of 141 kips. If this force is distributed over the 11 dowels at a transverse joint, the restraining force per dowel (locked-up joint) is 12.8 kips. Therefore, a doweled joint must resist more than 141 kips to generate a tensile crack in the slab or 12.8 kip dowel force if there are no other restraining elements.

These values per dowel are close to the results obtained by Khazanovich et al. (2009) for ungreased dowel bars (see Figure 31), which found the mean pullout force for ungreased dowels of 11.6 kips with 6 in. embedment. If dowel embedment is greater, for example, 9 in. (half of a standard dowel length of 18 in. in Illinois), then the pullout force could be 50% higher for ungreased dowels, e.g., 17.4 kips. In addition, any skew or tilt of the dowel will further increase the pullout force between 10%–20%. With these additional factors (skew/tilt and 9 in. embedment), a single dowel pullout force may require 20 kips, which is over 50% greater than the restraining force to create a transverse crack in the slab. This analysis suggests it is likely that some premature cracking is directly a result of lack of dowel lubrication and subsequent transverse joint restraint. For thicker slabs, e.g., 10 in., the force to crack the concrete is proportional to the thickness, and therefore it is more difficult for thicker sections. Some recent visual surveys of urban concrete construction by the lead author did not see evidence of dowel lubrication, and, thus, in some projects it appears dowel lubrication is not consistently occurring.




(A) Slab forces required to generate a crack

(B) Tie bars inclusion in slab force restraint calculation

**Figure 32. Schematic. Transverse joint restraint forces.**

# CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

Over the past decade, multiple urban concrete pavement sections (aggregate base, curb and gutter, dowelled transverse joints, and tied longitudinal sawed or construction joints) in Illinois have exhibited premature cracking. This research project reviewed past studies in the literature and investigated urban concrete pavement sections in Illinois through field surveys and nondestructive evaluation for characteristics that might explain the observed cracking. Multiple analyses of the potential mechanisms for the observed premature cracking were completed to explain the most probable explanations for the early failures.

In the literature, there were limited studies on mechanisms and explanations of premature transverse cracking in urban concrete pavement sections. Thus, University of Illinois researchers visited 67 urban jointed plain concrete pavement (JPCP) sections (in seven out of nine IDOT districts) to conduct visual surveys for the cracking distresses and document the as-built pavement geometry, slab thickness, and joint details. The goal was to primarily select sections that were 10 years old or less. The MIRA ultrasonic testing device was also employed to determine the slab thickness, presence of reinforcement, depth of reinforcement, and spacing of steel. Overall, the field surveys and MIRA evaluation did not point to a single mechanism for the observed cracking distresses seen on concrete pavements. MIRA outputs showed concrete thicknesses as well as dowel bar and tie bar spacing and depth were usually consistent with expectations. One clear observation from the field studies was some cracked sections had joint spacings of 20 ft or greater and slab widths greater than 12 ft, which exceeded IDOT's slab geometry limits. For the remaining cracked sections, multiple mechanisms were hypothesized to explain the cause of the premature cracking distresses.

A 3D finite-element analysis of typical urban JPCP section (8 in. slab and 12 ft × 15 ft slab geometry) was completed to assess the tensile stresses developing in the slab with a rapid drop in temperature. The analysis, which included slab-base friction, demonstrated that even high friction would not develop sufficient tensile stress in concrete slabs to crack it without other significant restraining factors.

An additional field evaluation was completed to determine if transverse contraction joint activation had occurred on projects exhibiting premature cracking. An algorithm developed recently was applied to nondestructively determine if the notch in contraction joints propagated full depth. There were some detected joints that did not activate, which were adjacent to transverse mid-panel cracks, but most joints had activated cracks and thus this late saw cutting or insufficient notch depth was not the primary mechanism causing the premature cracks.

A final analysis calculated the possibility that a lack of dowel lubrication could lead to joint lockup and a subsequent transverse crack. After a review of a NCHRP 637 report on dowel alignment in concrete joints, it was determined that 1.5 in. dowels embedded 6 in. or 9 in. could require a pullout force of 11.6 kips to 17.4 kips, respectively. Theoretically, the restraining force per dowel to produce a tensile crack in the concrete slab was found to be approximately 12.8 kips. Therefore, it was very probable that the primary premature cracking mechanism could be dowel bars not being lubricated prior to placement of the concrete.

To reduce premature cracking failures on urban JPCP sections in Illinois, the following pavement design and construction practice adjustments are recommended for future projects.

## PAVEMENT DESIGN

The following recommendations to the design of urban JPCP were developed based on results from the field surveys and analysis.

- Slab Geometry: District 4 and 8 showed sections with excessively long panels (greater than 20 ft) and slabs less than 10 in. developed transverse cracking. Longitudinal cracking was also more prevalent when slab widths exceeded 12 ft. Engineers should limit slab widths to 12 ft while slab lengths should be no greater than 12 ft when the slab thickness is less than 10 in. and 15 ft when the thickness is 10 in. or greater.

- Intersections and Utilities: Multiple sections over several IDOT districts showed pavement sections with cracked slabs near intersections and over or near utilities and drainage structures. It is important to review the design and construction details and specifications on these areas to avoid settlement cracking or restraint cracking.

- Concrete Mix Design and Selection: The concrete mix designs evaluated with the HIPERPAV software did not show any issues with early cracking potential for current IDOT mixtures.

## CONSTRUCTION PRACTICES

- Saw Cutting: The ultrasonic evaluation over transverse contraction joints showed some transverse cracks are likely associated with nonactivated joints, i.e., joint notch cracks do not propagate full depth. This lack of full-depth cracks can be attributed to late saw cutting or improper depth of saw cutting. To avoid nonactivated joints, monitoring the setting time of concrete is necessary to determine the earliest time to saw cut the joint without raveling. For example, Tran and Roesler (2020a) have developed a noncontact method to estimate the final setting time of the concrete and thus predict the optimal time for saw cutting.

- Tie Bar Design Details: Some sections showed variability in the tie and dowel bar spacing. This variability may have contributed to nonuniform restraint at certain locations of the panel and resulted in some premature cracking. The dowel and tie bar design should follow IDOT (2018) Standard 420001-09, which requires dowels spaced at 12 in. on center, dowel diameters equal to 1 in. for slabs ≤ 8 in., equal to 1.25 in. for slabs between 8 and 10 in., and 1.5 in. for slabs ≥ 10 in. Tie bars should be designed using #6 bars at 30 in. lengths, spaced at 36 in. on center for both longitudinal sawed and construction joints (IDOT, 2018).

- Dowel Bars: The use of pre-lubricated dowel bars will prevent bonding between the concrete slab and dowel bars. Proper lubrication of the dowel bars will allow for expansion and contraction of the concrete slab at the transverse joints, while limiting the restraint stresses that could develop if bars are not properly aligned or lubricated. If dowels are not pre-lubricated, then quality checks are needed by inspectors to ensure dowels are aligned and lubricated prior to paving.

- Concrete Placement: The ultrasonic evaluations showed sections with significant image distortion throughout the depth of the concrete pavement. This is an undesired characteristic that will decrease the compressive and tensile strength of the hardened concrete. Low concrete workability, bad placing techniques, and/or poor compaction and consolidation are the main reasons that could create these potential voids. Regular maintenance of the concrete paving equipment, consistent material delivery and placement without stopping, evaluating the concrete slump prior to casting, and proper inspection and supervision are actions that will result in a better concrete pavement product.

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# APPENDIX A: FIELD SURVEYS AND EVALUATIONS

## DISTRICT 1

### Section 1: IL 30 with SS 55 (Joliet, IL)

**Table 24. Summary of IL 30 with SS 55 Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 15 | 11 | 12 | 27 | Two lanes per direction + central lane | No distress observed | Construction date ~2015 |

Ultrasonic Evaluation:

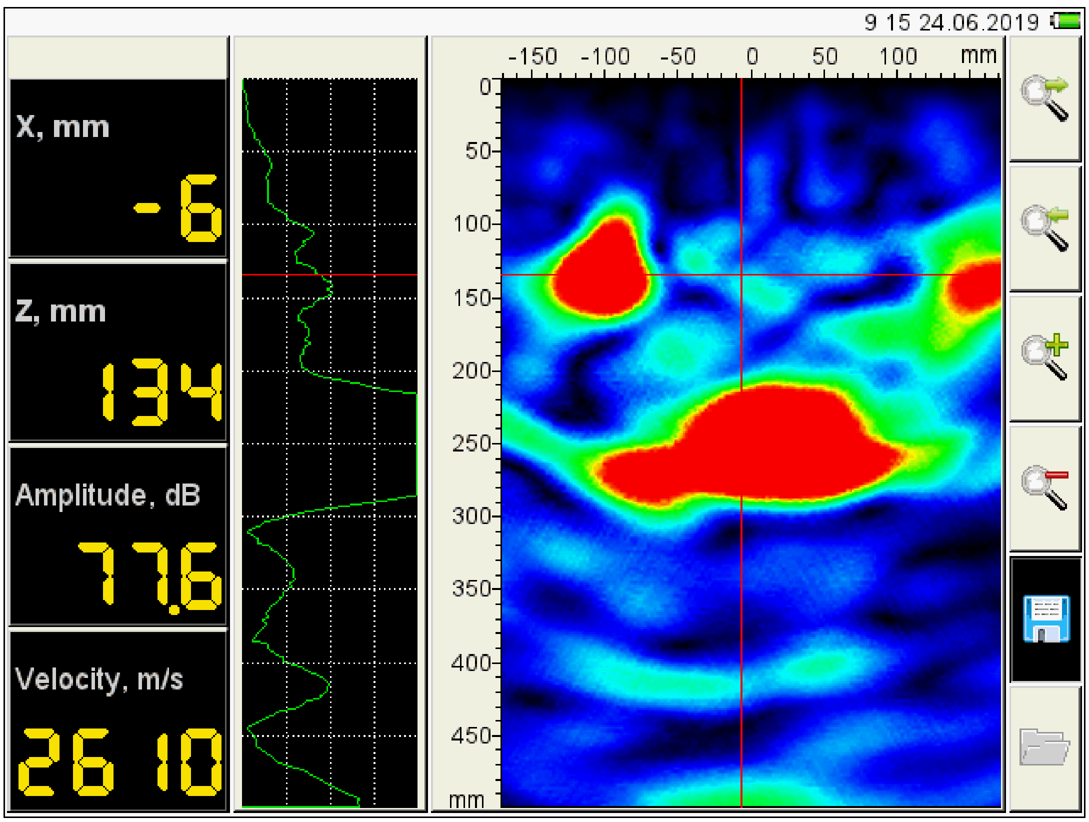



**Figure 33. Photo. Ultrasound image of IL 30 with SS 55.**


**Figure 34. Photos. IL 30 with SS 55.**

## Section 2: IL 59 from IL 30 to IL 80 (Naperville, IL)

**Table 25. Summary of IL 59 from IL 30 to IL 80 Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 15 | 11 | 12 | 27 | Two lanes per direction + central lane | About 3% of the panels showed deterioration in the form of cracks and joint spalling. | Construction date ~2002 |

Ultrasonic Evaluation:

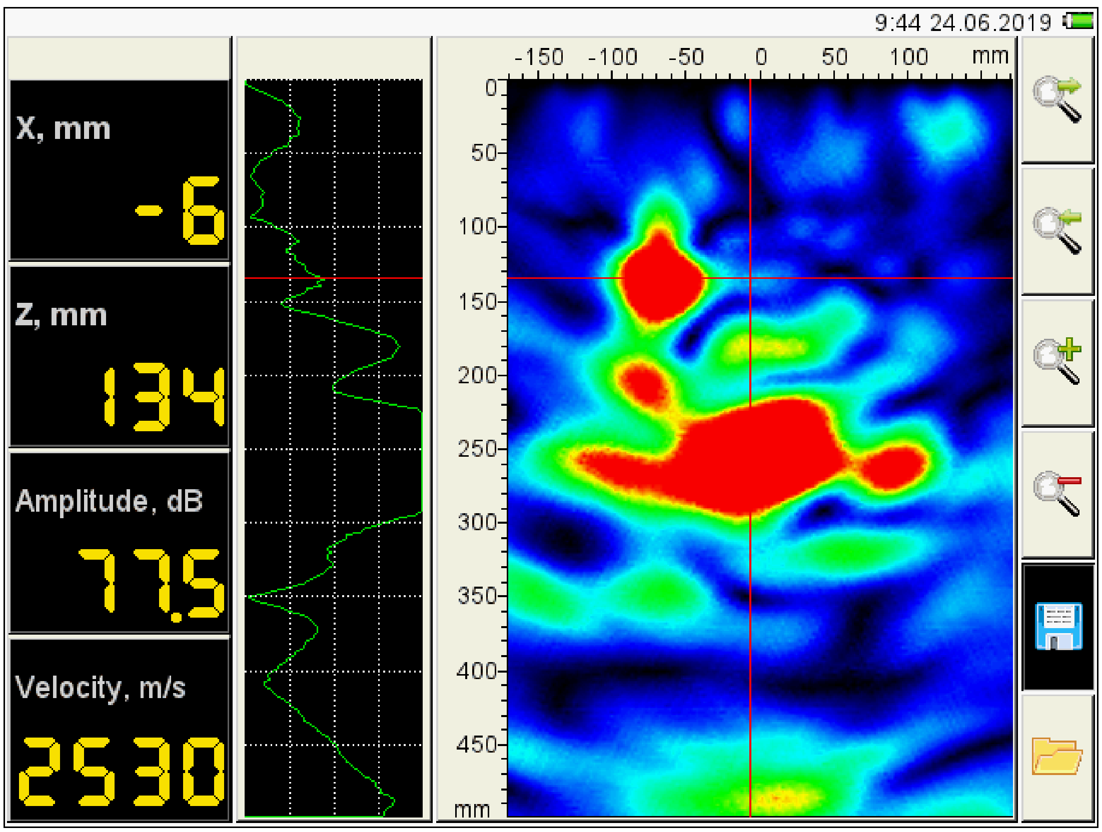



**Figure 35. Photo. Ultrasound image of IL 59 from IL 30 to IL 80.**

**Figure 36. Photo. IL 59 from IL 30 to IL 80.**

## Section 3: IL 59 from 103rd to 95th Streets (Naperville, IL)

**Table 26. Summary of IL 59 from 103rd to 95th Streets Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 15 | 11 | 12 | 27 | Two lanes per direction + central lane | More than 50% of the panels showed deterioration in the form of cracks and joint spalling. | Construction date ~1998 |

Ultrasonic evaluation was conducted but no files were saved.


**Figure 37. Photos. IL 59 from 103rd to 95th Streets.**

## Section 4: IL 59 with IL 88 (Naperville, IL)

**Table 27. Summary of IL 59 with IL 88 Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 15 | 12 | 12 | 27 | Three lanes per direction | No distress observed | Construction date ~2010s |

Ultrasonic Evaluation:

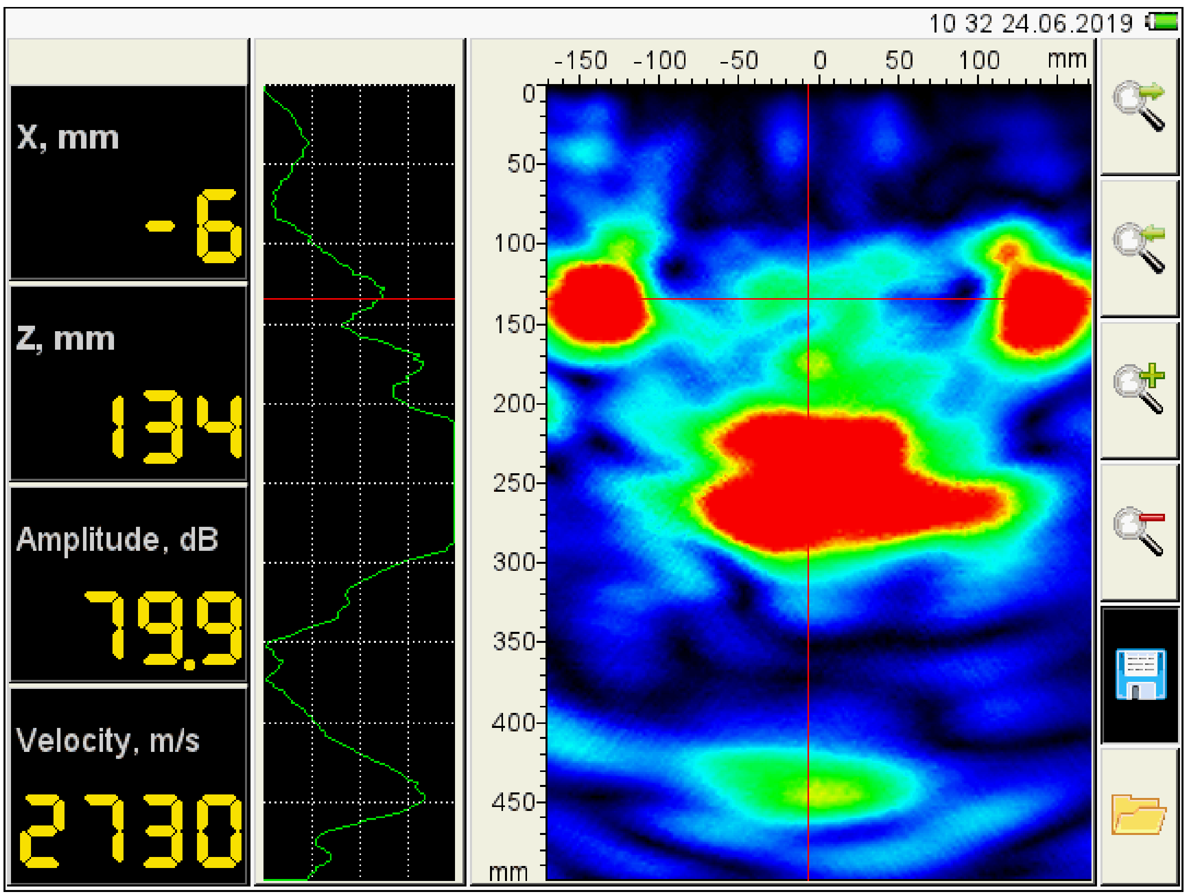



**Figure 38. Photo. Ultrasound image of IL 59 with IL 88.**

**Figure 39. Photos. IL 59 with IL 88.**

## Section 5: IL 62 from Penny Road to Eastings Way (Elgin, IL)

**Table 28. Summary of IL 62 from Penny Road to Eastings Way Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 15 | 12 | 12 | 27 | Two lanes per direction + central lane | No distress observed | Construction date ~2010s |

Ultrasound Evaluation:

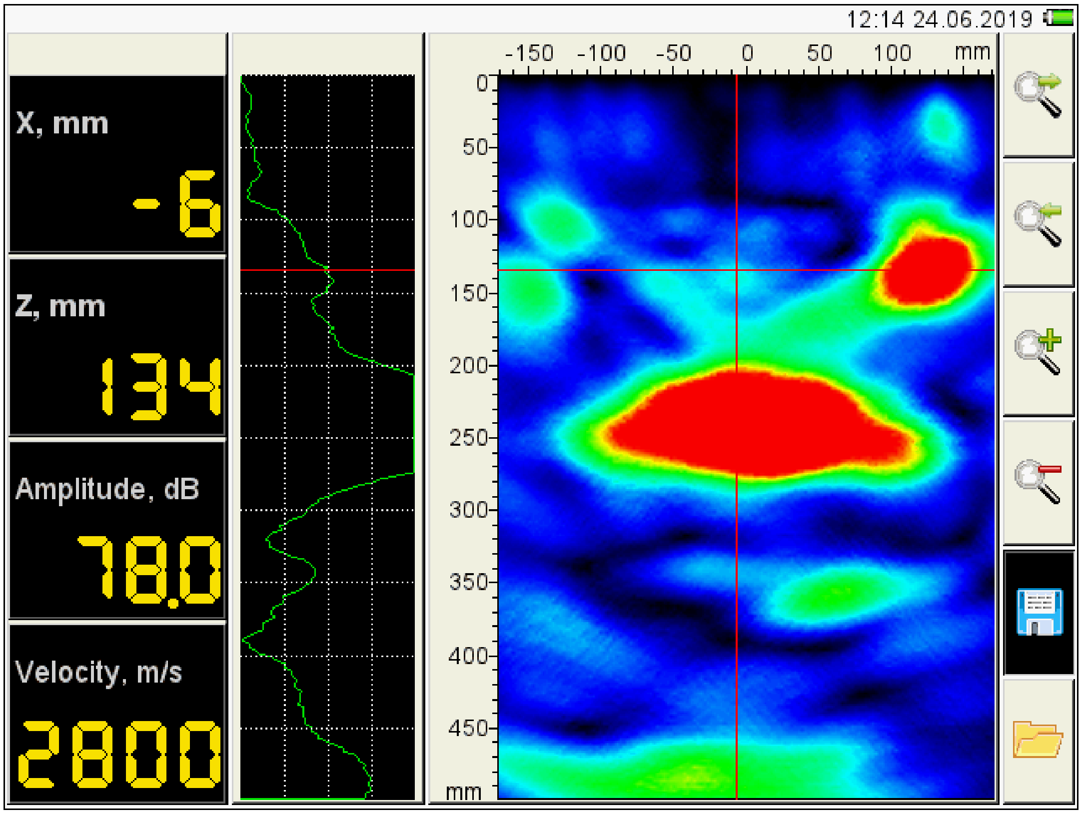



**Figure 40. Photo. Ultrasound image of IL 62 from Penny Road to Eastings Way.**

**Figure 41. Photos. IL 62 from Penny Road to Eastings Way.**

## Section 6: Illinois Route 31 at Illinois 176 (Crystal Lake)

**Table 29. Summary of Illinois Route 31 at Illinois 176 Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 15 | 14 | 12 | 27 | 2 lanes per direction + central lane | No distress observed | Construction date ~2010s |

Ultrasonic evaluation was conducted but no files were saved.

**Figure 42. Photos. Route 31–176.**

## Section 7: IL 19 and York Way (O'Hare Airport Area)

**Table 30. Summary of IL 19 and York Way Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 13 | 12 | 12 | 23 | Two lanes per direction + central lane | No distress observed | Construction date ~2010s |

Ultrasonic evaluation was conducted but no files saved.

**Figure 43. Photos. IL 19 and York Way.**

## Section 8: River Road (O'Hare Airport Area)

**Table 31. Summary of River Road Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 9 | 16 | 11 | 24 | 27 | 2 lanes per direction | No distress observed | Construction date ~2019<br>Survey conducted during construction. |

Ultrasonic evaluation was conducted but no files saved.


**Figure 44. Photos. River Road (under construction).**

## DISTRICT 2

## Section 9: State Street with Bell School Road (Rockford, IL)

**Table 32. Summary of State Street with Bell School Road Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| Not evaluated due to heavy traffic | 42 | 15 | Not evaluated due to heavy traffic | Not evaluated due to heavy traffic | 3 lanes per direction | Severe longitudinal and transverse cracks. (>50%) | Construction date ~2000s Some panels were renewed. |

Ultrasonic evaluation was conducted but no files saved.

**Figure 45. Photos. State Street with Bell School Road.**

## Section 10: Union Street with Blackhawk Boulevard (Rockford, IL)

**Table 33. Summary of Union Street with Blackhawk Boulevard Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 15 | 13 | 12 | 24 | One lane per direction + center turning lane | Minimal joint deterioration (<2%) | Construction date ~2010s |

Ultrasonic evaluation was conducted but no files saved.

**Figure 46. Photos. Union Street with Blackhawk Boulevard.**

## Section 11: US 20 (Galena, IL)

**Table 34. Summary of US 20 Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 15 | 13 | 12 | 36 | One lane per direction + center turning lane | Severe longitudinal and transverse cracks. (>50%) | Construction date ~2002<br>The ultrasonic evaluation showed a potential delamination. |

Ultrasound Evaluation:

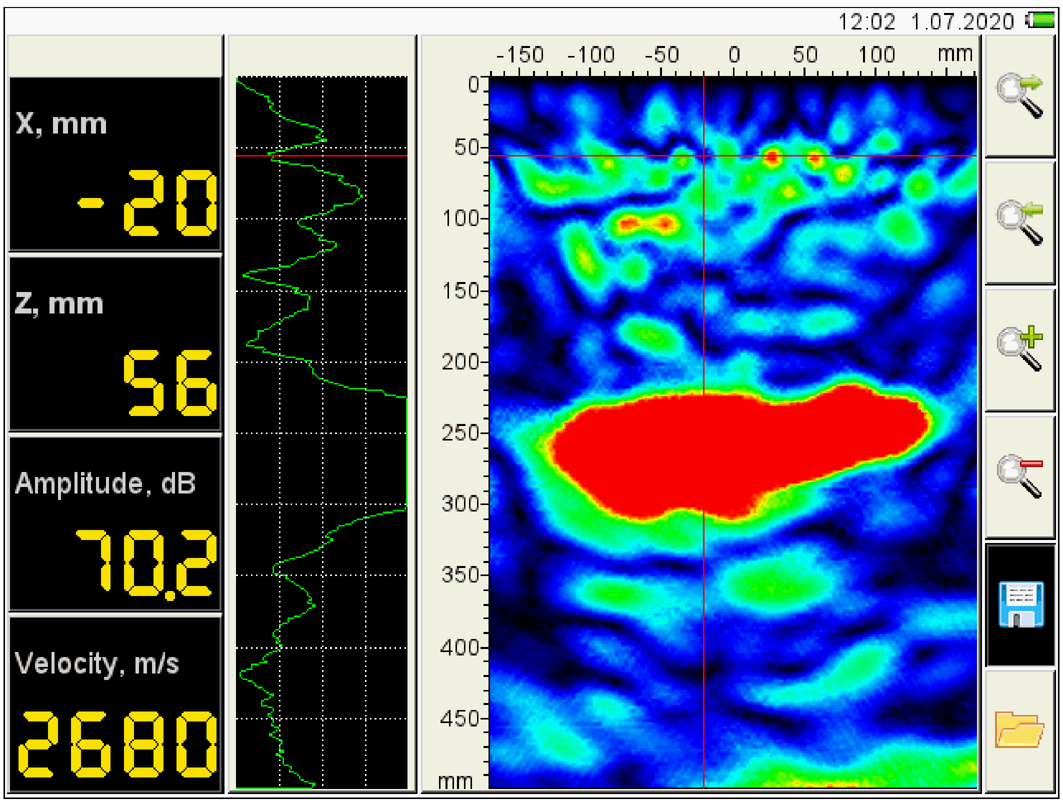



**Figure 47. Photo. Ultrasound image of US 20 at Galena, IL.**

**Figure 48. Photos. US 20 at Galena, IL.**

## DISTRICT 3

## Section 12: Marmont with Dwight Street (Dwight, IL)

**Table 35. Summary of Marmont with Dwight Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 15 | 14 | 12 | 36 | One lane per direction | No distress observed. | Construction date ~2010s |

Ultrasonic evaluation was conducted but no files saved.

**Figure 49. Photos. Marmont Street with Dwight Street.**

## Section 13: IL 47 (Morris, IL)

**Table 36. Summary of IL 47 Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 13 | 12 | 12 | 36 | 2 lanes per direction | No distress observed. | Construction date ~2010s |

Ultrasonic evaluation was conducted but no files saved.

**Figure 50. Photos. IL 47.**

## Section 14: IL 47 Veterans Parkway with IL 34 (Yorkville, IL)

**Table 37. Summary of IL 47 Veterans Parkway with IL 34 Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 14 | 14 | 12 | 24 | 2 lanes per direction | No distress observed. | Construction date ~2010s |

Ultrasonic evaluation was conducted but no files saved.

**Figure 51. Photos. IL 47 Veterans Parkway with IL 34.**

## Section 15: IL 71 with Franklin Street (Oswego, IL)

**Table 38. Summary of IL 71 with Franklin Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 15 | 12 | 12 | 24 | 2 lanes per direction + central turning lane | One full lane width transverse crack located at the intersection with a school entrance. | Construction date ~2010s |

Ultrasonic evaluation was conducted but no files saved.

**Figure 52. Photos. IL 71 with Franklin Street.**

## Section 16: Eldamain Road (Yorkville, IL)

**Table 39. Summary of Eldamain Road Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 9 | 15 | 12 | 12 | 24 | 1 lane per direction + central lane | No distress observed. | Construction date ~2010s |

Ultrasonic evaluation was conducted but no files saved.

**Figure 53. Photos. Eldamain Road.**

## Section 17: Clark Street (Utica, IL)

**Table 40. Summary of Clark Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 15 | 13 | 12 | 24 | 1 lane per direction | No distress observed. | Construction date ~2010s |

Ultrasonic evaluation was conducted but no files saved.

**Figure 54. Photos. Clark Street.**

## DISTRICT 4

## Section 18: Old Galena Road (Mossville, IL)

**Table 41. Summary of Old Galena Road Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 9 | 14 | 12 | 24 | 35 | 2 lanes per direction + central lane | No distress observed. | Construction date ~2018 |

Ultrasonic evaluation was conducted but no files saved.

**Figure 55. Photos. Old Galena Road.**

## Sections 19 and 20: North Allen Road from Alta Lane to Route 6, and Radnor Road with Alta Lane (Alta, IL)

**Table 42. Summary of Alta Lane Sections Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 9 | 14 | 12 | 24 | 35 | 2 lanes per direction + central lane | No distress observed. | Construction date ~2015 |

Ultrasonic evaluation was conducted but no files saved.

**Figure 56. Photo. North Allen Road.**

## Section 21: MacArthur Highway with Richland Street (Peoria, IL)

**Table 43. Summary of MacArthur Highway with Richland Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| Not evaluated due to heavy traffic | 12 | 12 | Not evaluated due to heavy traffic | Not evaluated due to heavy traffic | 2 lanes per direction + central lane | Minimum transverse cracking around drainage area (<2%) | Construction date ~2011 |

Ultrasonic evaluation was conducted but no files saved.

**Figure 57. Photos. MacArthur Highway with Richland Street.**

## Section 22: Route 8 from Farm to Sunrise (Peoria, IL)

**Table 44. Summary of Route 8 from Farm to Sunrise Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 9 | 15 | 12 | variable | No Tie Bars were observed | 2 lanes per direction + central lane | No distress observed | Construction date ~2011 |

Ultrasonic evaluation was conducted but no files saved.

**Figure 58. Photo. Route 8 from Farm to Sunrise.**

## Section 23: Route 8 from Summit to Region (Peoria, IL)

**Table 45. Summary of Route 8 from Summit to Region Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 15 | 12 | Not evaluated due to heavy traffic | Not evaluated due to heavy traffic | 2 lanes per direction + central lane | No distress observed | Construction date ~2012 |

Ultrasonic evaluation was conducted but no files saved.

**Figure 59. Photos. Route 8 from Summit to Region.**

## Section 24: Jefferson Street with Jackson Street (Morton, IL)

**Table 46. Summary of Jefferson Street with Jackson Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 9 | 20 | 9 | Dowels present* | 45 | 2 lanes per direction | Minimum transverse cracks (<30%) | Construction date ~2016<br>* It has dowel bars, but no measurements due to heavy traffic. |

Ultrasonic evaluation was conducted but no files saved.

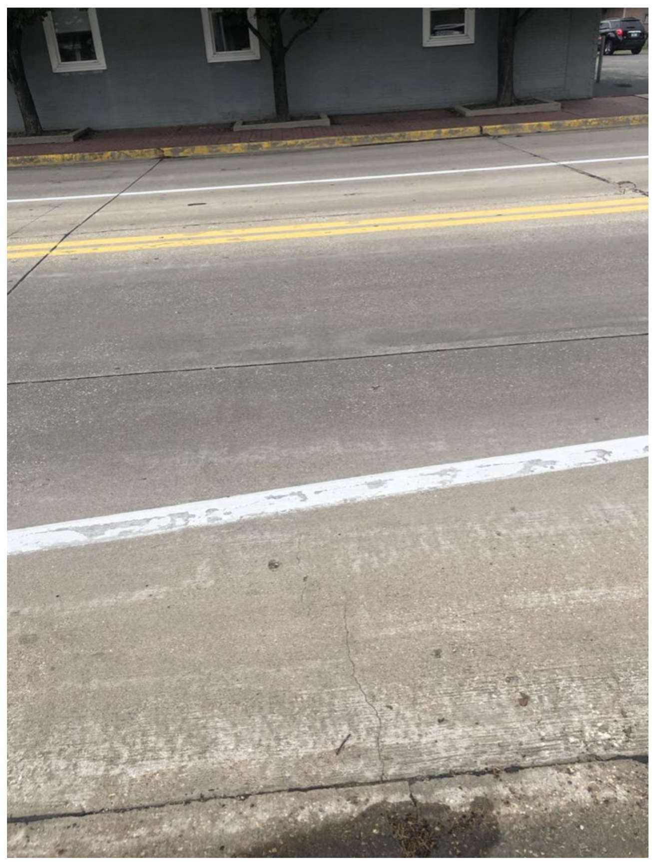


**Figure 60. Photos. Jefferson Street with Jackson Street.**

## DISTRICT 5

## Section 25: Legacy Avenue (Champaign, IL)

**Table 47. Summary of Legacy Avenue Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 15 | 10 | Not observed | Not observed | 2 lanes total | No distress observed | Construction date ~2007 *Very low traffic (new neighborhood)* |

Ultrasonic evaluation was conducted but no files saved.

**Figure 61. Photos. Legacy Avenue.**

## Section 26: White Street (Champaign, IL)

**Table 48. Summary of White Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 15 | 10 | 25 | 25 | One lane per direction | No distress observed. | Construction date 2019. High volume of buses. |

Ultrasound Evaluation:

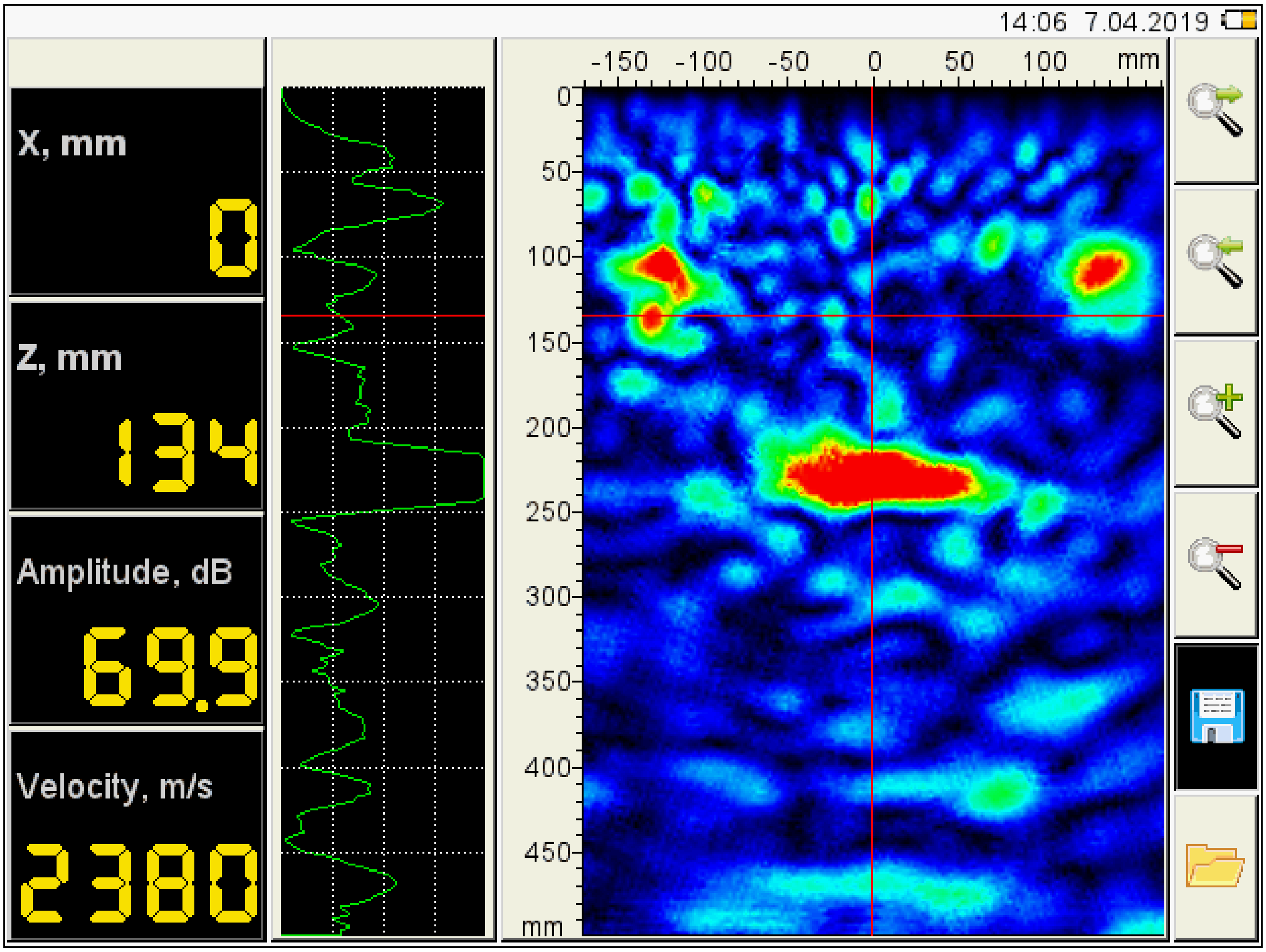



**Figure 62. Photo. Ultrasound image of White Street.**

**Figure 63. Photos. White Street.**

## Section 27: Healey Street from Fourth Street to Fifth Street (Champaign, IL)

**Table 49. Summary of Healey Street from Fourth Street to Fifth Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 12.5 | 12 | 24 | 26 | 1 lane per direction | mid-panel transverse cracks (>50%) | *Construction date ~2015* |

Ultrasound Evaluation:

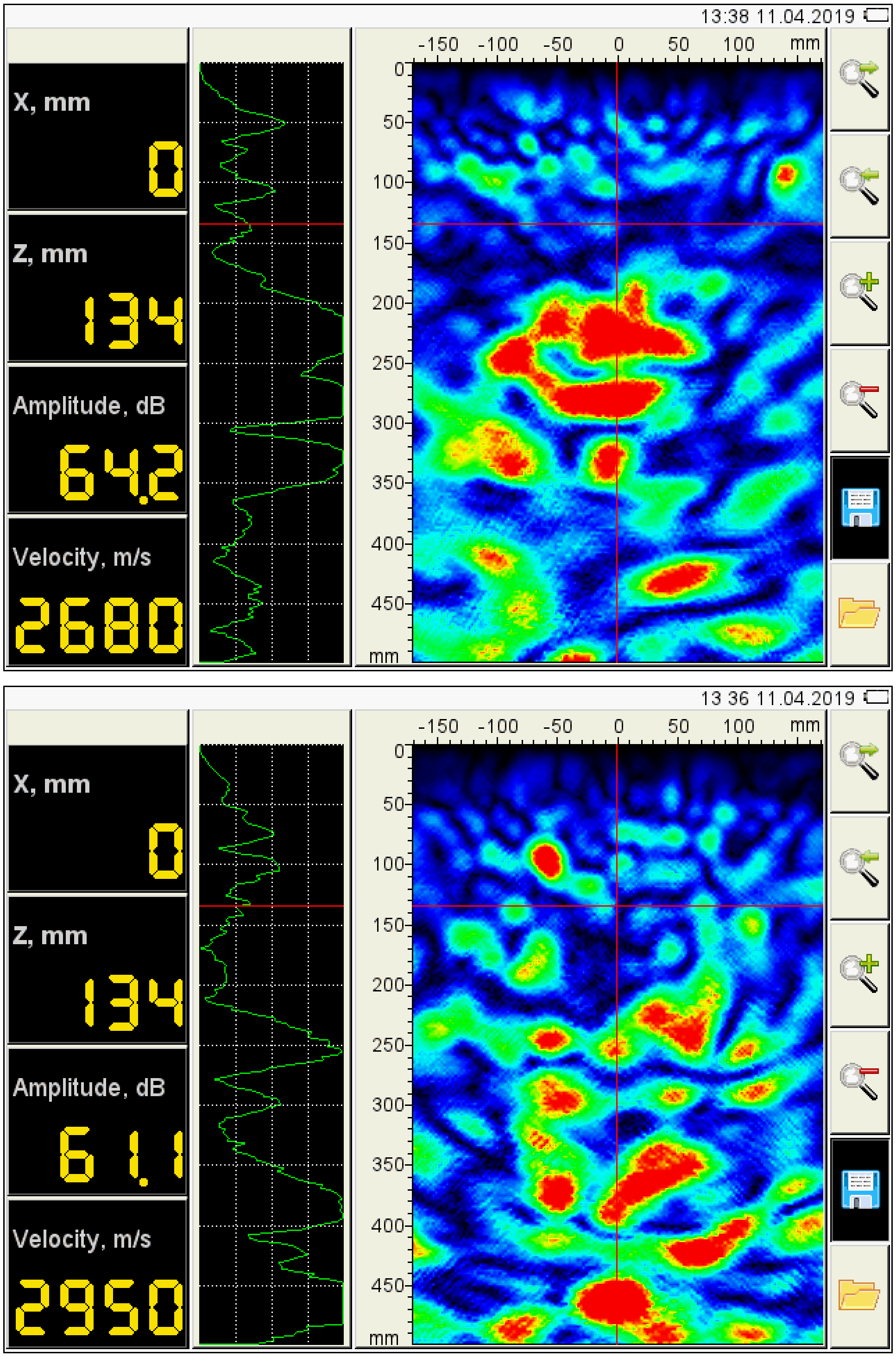



**Figure 64. Photo. Ultrasound images of Healey Street from Fourth Street to Fifth Street.**

**Figure 65. Photos. Healey Street from Fourth Street to Fifth Street.**

## Section 28: Healey Street from Fifth Street to Sixth Street (Champaign, IL)

**Table 50. Summary of Healey Street from Fifth Street to Sixth Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 12.5 | 12 | 16 | 26 | 1 lane per direction | mid-panel transverse cracks (>30%) | *Construction date ~2015* |

Ultrasound Evaluation:

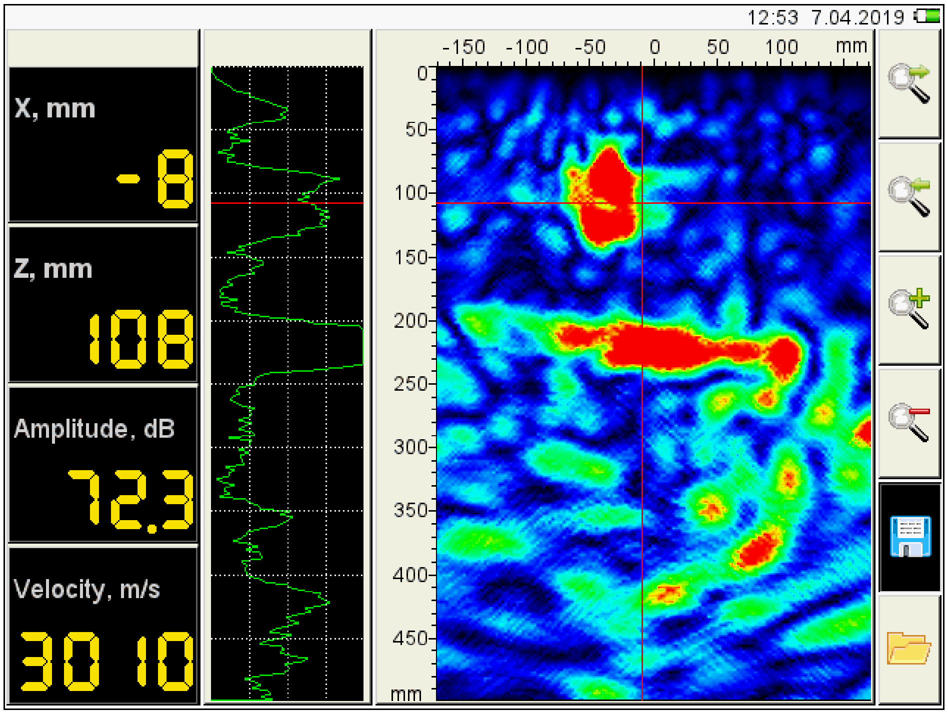



**Figure 66. Photo. Ultrasound images of Healey Street from Fifth Street to Sixth Street.**

**Figure 67. Photos. Healey Street from Fifth Street to Sixth Street.**

## Section 29: Gregory Drive from Fourth Street to Sixth Street (Champaign, IL)

**Table 51. Summary of Gregory Drive from Fourth Street to Sixth Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 15 | 10.5 | 23 | 39 | 1 lane per direction + 1 bicycle lane per side | mid-panel transverse cracks (>50%) | *Construction date ~2013* |

Ultrasonic Evaluation was conducted but no files saved.

**Figure 68. Photos. Gregory Drive from Fourth Street to Sixth Street.**

## Section 30: Gregory Drive from First Street to Fourth Street (Champaign, IL)

**Table 52. Summary of Gregory Drive from Fourth Street to Sixth Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 7–8* | 15 | 10.5 | Not observed | 36 | 1 lane per direction + 1 bicycle lane per side | Mid-panel transverse cracks (>50%) | Construction date ~2013 **Thickness was variable between slabs* |

Ultrasound Evaluation:

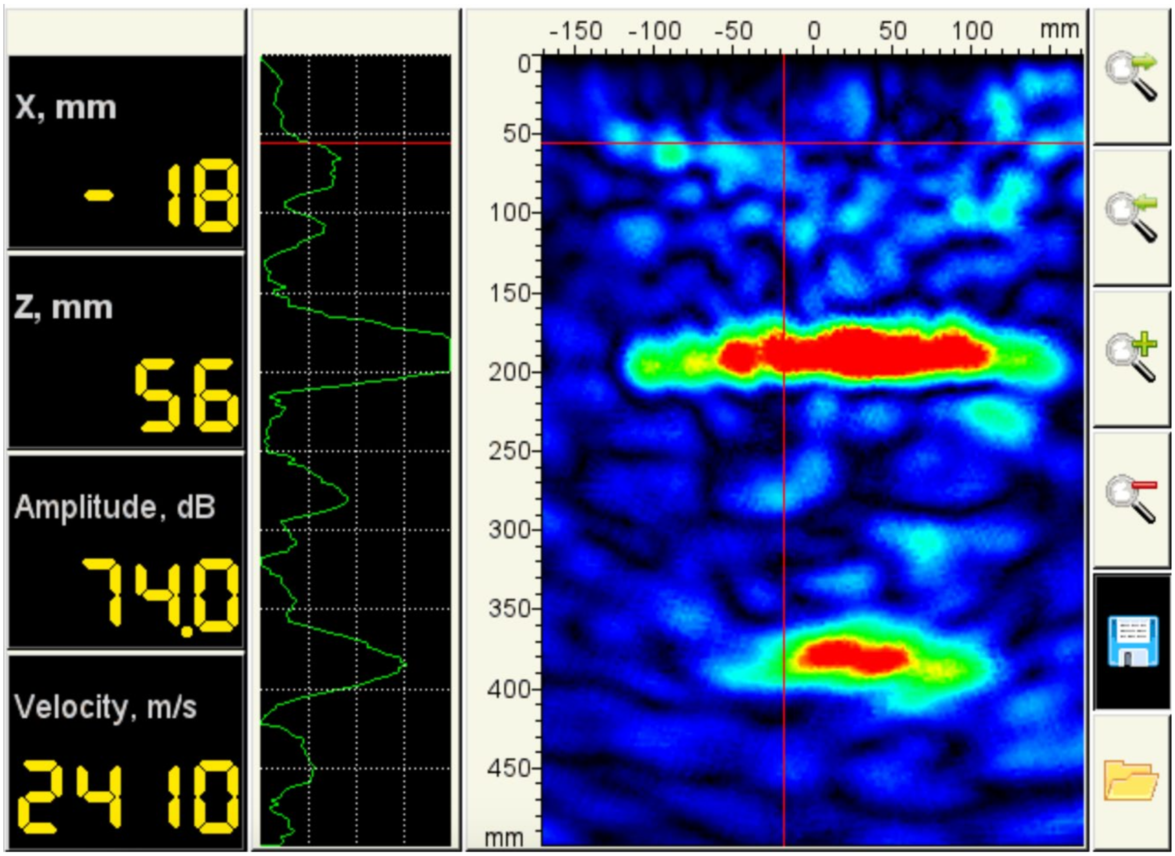



**Figure 69. Photos. Ultrasound images of Gregory Drive from First Street to Fourth Street.**

**Figure 70. Photos. Gregory Drive from First Street to Fourth Street.**

## Section 31: Gregory Drive from Oak Street to First Street (Champaign IL)

**Table 53. Summary of Gregory Drive from Oak Street to First Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 18 | 15 | 12 | 24 | 2 lane per side + | Mid-panel transverse cracks (>50%) | *Construction date ~2013* |

Ultrasound Evaluation:

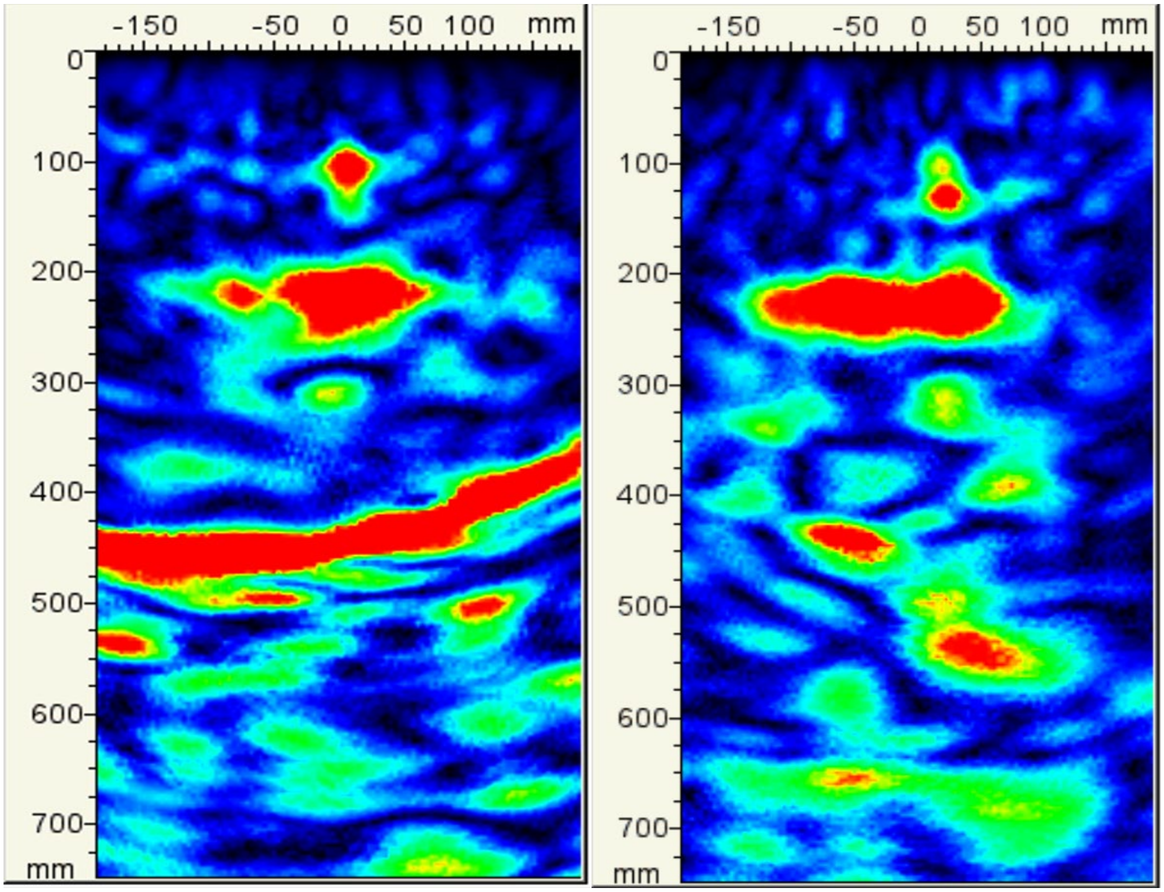



**Figure 71. Photos. Ultrasound images of Gregory Drive from Oak Street to First Street.**

**Figure 72. Photo. Gregory Drive from Oak Street to First Street.**

## Section 32: Peabody Drive (Champaign, IL)

**Table 54. Summary of Peabody Drive Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 10.5 | 8 | Not observed | 47 | 1 lane per direction with parking on both sides | No distress observed. | Construction date ~2010 |

Ultrasonic evaluation was conducted but no files were saved.

**Figure 73. Photos. Peabody Drive.**

## Section 33: John Street from Prospect Avenue to New Street (Champaign, IL)

**Table 55. Summary of John Street from Prospect Avenue to New Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 13* | 13 | 12 | 24 | 1 lane per direction. | Transverse Cracking (>30%) | *The section showed variability in the panel length, long panels (20 ft) showed premature distress.* |

Ultrasound Evaluation:

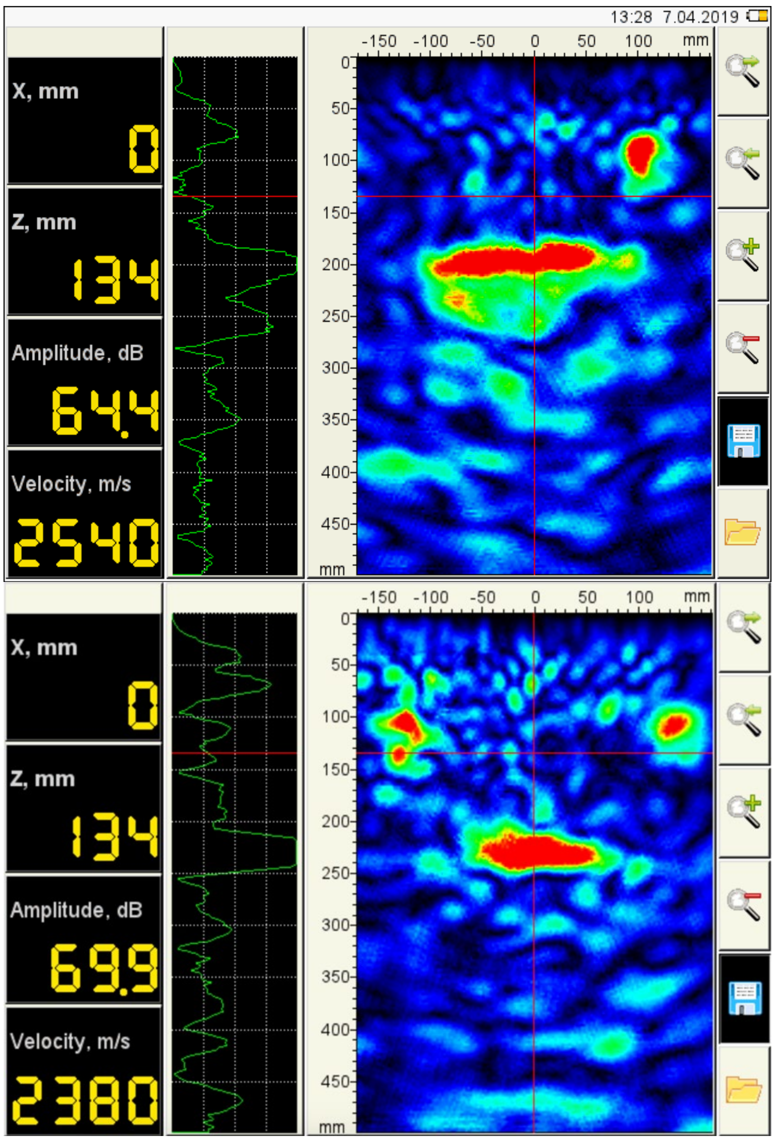



**Figure 74. Photos. Ultrasound images of John Street from Prospect Avenue to New Street.**

**Figure 75. Photos. John Street from Prospect Avenue to New Street.**

## Section 34: John Street from Neil Street to Elm Street (Champaign, IL)

**Table 56. Summary of John Street from Neil Street to Elm Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8.5 | Variable (10–15) | 7.5 | 12 | 24 | 1 lane per direction | Transverse cracking (>30%) and minimum joint deterioration | Construction date ~2008 |

Ultrasonic evaluation was conducted but no files saved.

**Figure 76. Photo. John Street from Neil Street to Elm Street.**

## Section 35: Green Street from First Street to Wright Street (Champaign, IL)

**Table 57. Summary of Green Street from First Street to Wright Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8-10* | 15 | 11 | 12 | 24 | 1 lane per direction + central lane | Transverse Cracking (>50%) | Construction date ~2011 **Slab thickness varies from 8" to 10".* |

Ultrasound Evaluation:

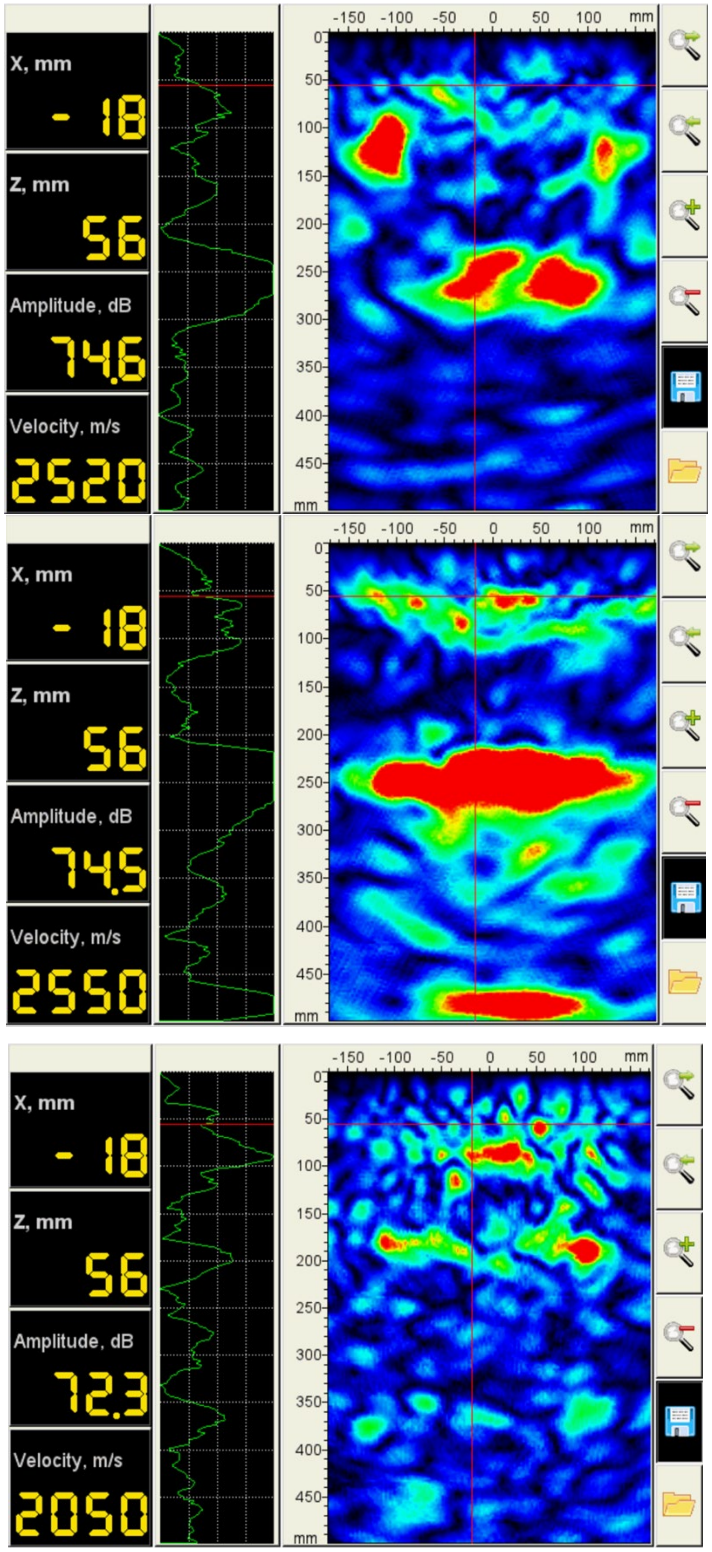



**Figure 77. Photos. Ultrasound images of Green Street from First Street to Wright Street.**

**Figure 78. Photos. Green Street from First Street to Wright Street.**

## Section 36: Stadium Drive (Champaign, IL)

**Table 58. Summary of Stadium Drive Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 15 | 9 | Not observed | 24 | 2 lanes per direction + 1 bicycle lane | Transverse Cracking (>50%) | *Construction date ~2016* |

Ultrasound Evaluation:

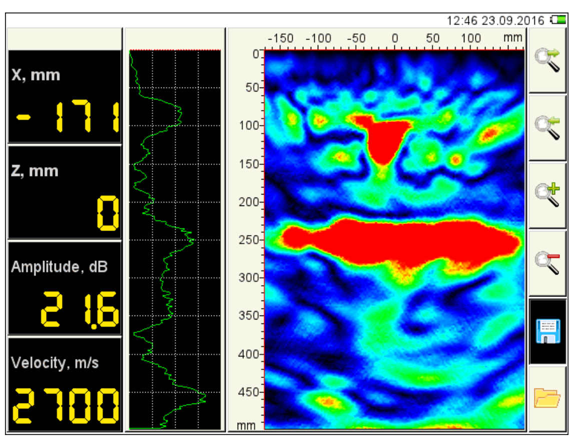



**Figure 79. Photo. Ultrasound image of Stadium Drive.**

**Figure 80. Photos. Stadium Drive.**

## Section 37: First Street (Champaign, IL)

**Table 59. Summary of First Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 9 | 15 | 10 | Not observed | 23 | 2 lanes per direction + 1 central lane | No distress observed. | *Construction date ~2016* |

Ultrasound Evaluation:

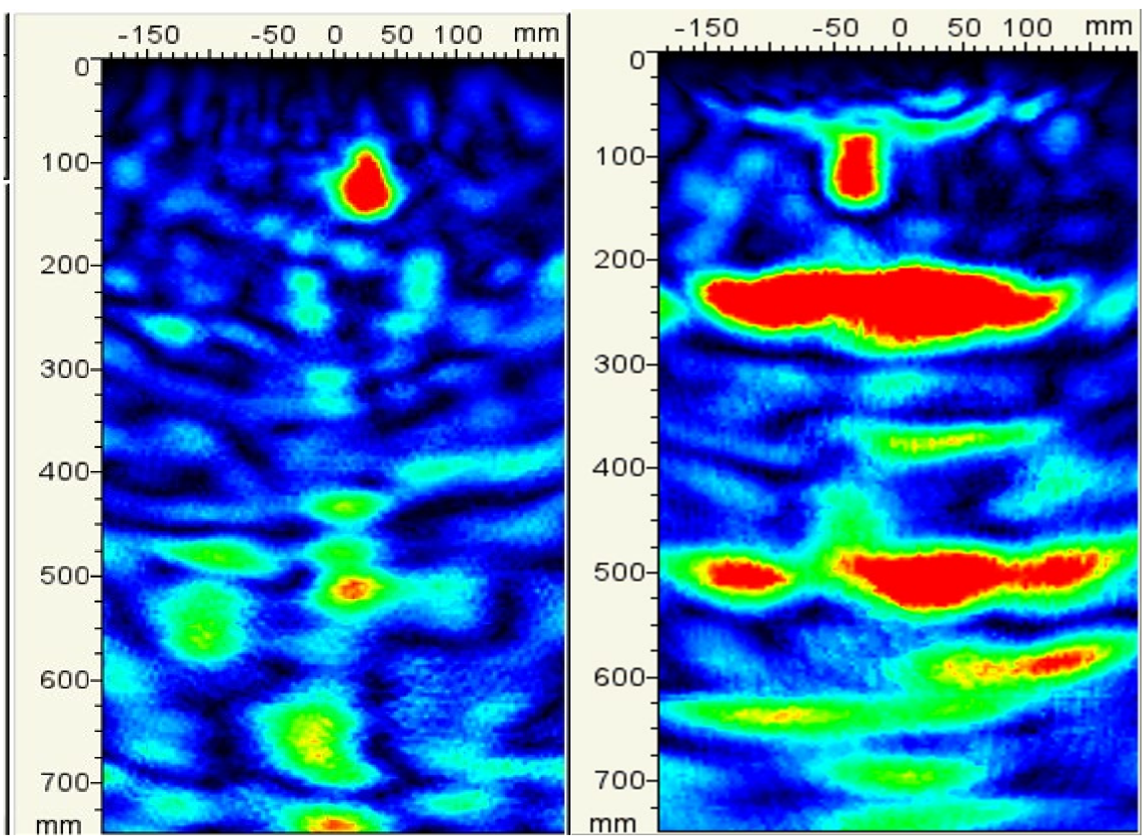



**Figure 81. Photos. Ultrasound images of First Street.**


**Figure 82. Photos. First Street.**

## Section 38: Fourth Street from West Kirby to St. Mary's Road (Champaign, IL)

**Table 60. Summary of Fourth Street from West Kirby to St. Mary's Road Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 14 | 11 | 12 | 26 | 2 lanes per direction | No distress observed. | Construction date ~2016. *Scattering* on ultrasound. |

Ultrasound Evaluation:

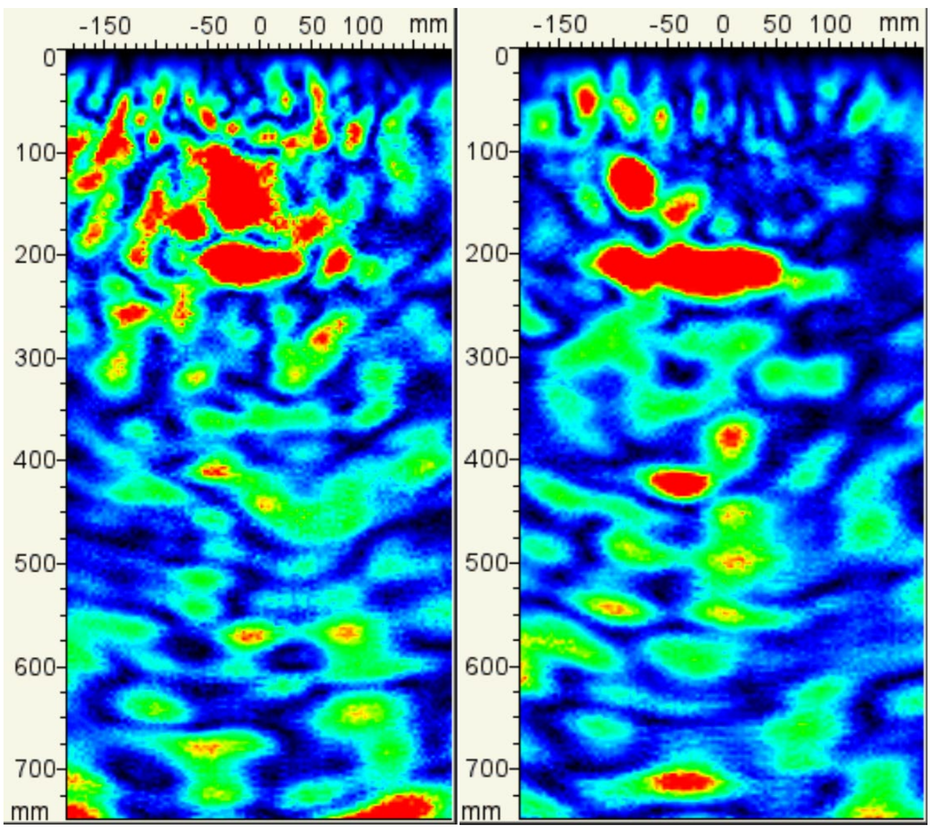



**Figure 83. Photos. Ultrasound images of Fourth Street from West Kirby to St. Mary's Road.**

## Section 39: Logan Street (Champaign, IL)

**Table 61. Summary of Logan Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 15 | 11 | 12 | 23 | 1 lane per direction | Transverse Cracking (>50%) | *Construction date ~2010* |

Ultrasonic evaluation was conducted but no files saved.

**Figure 84. Photos. Logan Street.**

## Section 40: Curtis Road from Prospect Avenue to Duncan Road (Champaign IL)

**Table 62. Summary of Curtis Road from Prospect Avenue to Duncan Road Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 15 | 12 | 12 | 36 | 2 lanes per direction | Transverse cracking (>30%) | *Construction date ~2010* |

Ultrasound Evaluation:

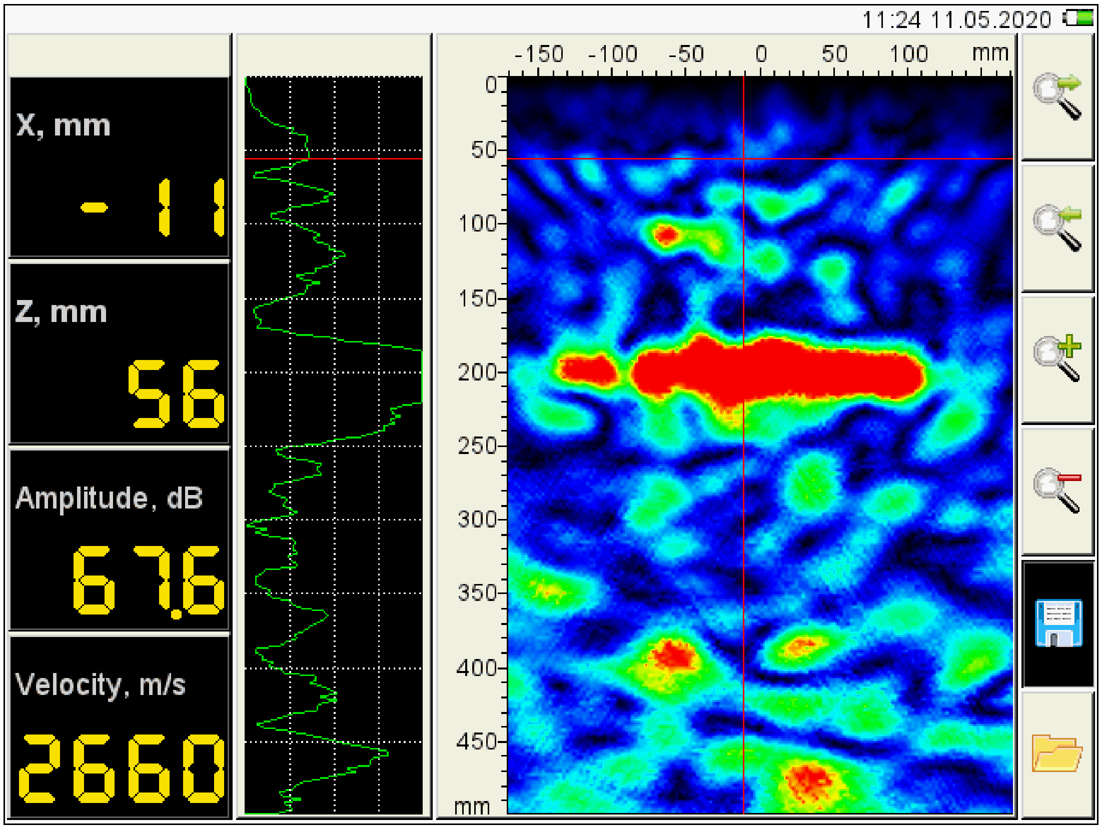



**Figure 85. Photos. Ultrasound images of Curtis Road from Prospect Avenue to Duncan Road.**

**Figure 86. Photos. Curtis Road from Prospect Avenue to Duncan Road.**

## Section 41: Prospect Avenue from Windsor Road to Curtis Road (Champaign IL)

**Table 63. Summary of Prospect Avenue from Windsor Road to Curtis Road Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 12.5 | 10 | 12 | 60 | 1 lane per direction + center turning lane | No distress observed | *Construction date 2019* |

Ultrasonic evaluation was conducted but no files saved.

**Figure 87. Photos. Prospect Avenue from Windsor Road to Curtis Road.**

## Section 42: Lincoln Avenue (Urbana, IL)

**Table 64. Summary of Lincoln Avenue Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 9 | 12 | 12 | 24 | Not observed | 2 lanes per direction | No distress observed | *Construction date not available.* |

Ultrasound Evaluation:

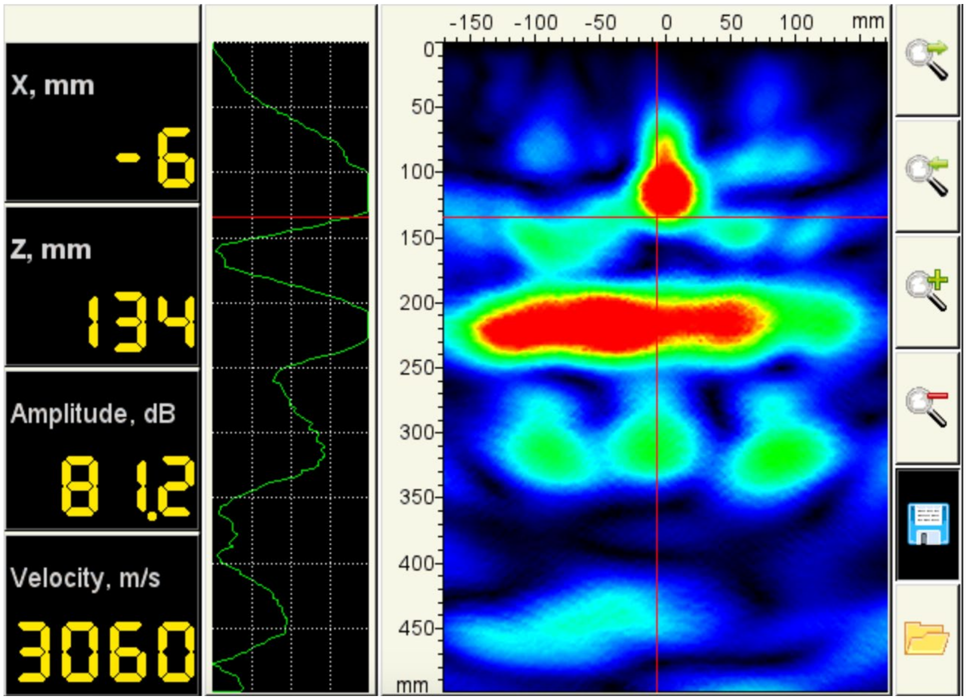



**Figure 88. Photos. Ultrasound images of Lincoln Avenue.**

**Figure 89. Photos. Lincoln Avenue.**

## Section 43: Forest View Drive (Mahomet, IL)

**Table 65. Summary of Forest View Drive Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 7 | 11 | 7 | Not founded | Not founded | 1 lane per direction | No distress observed. | *Construction date not available.* Low traffic road |

Ultrasound Evaluation:

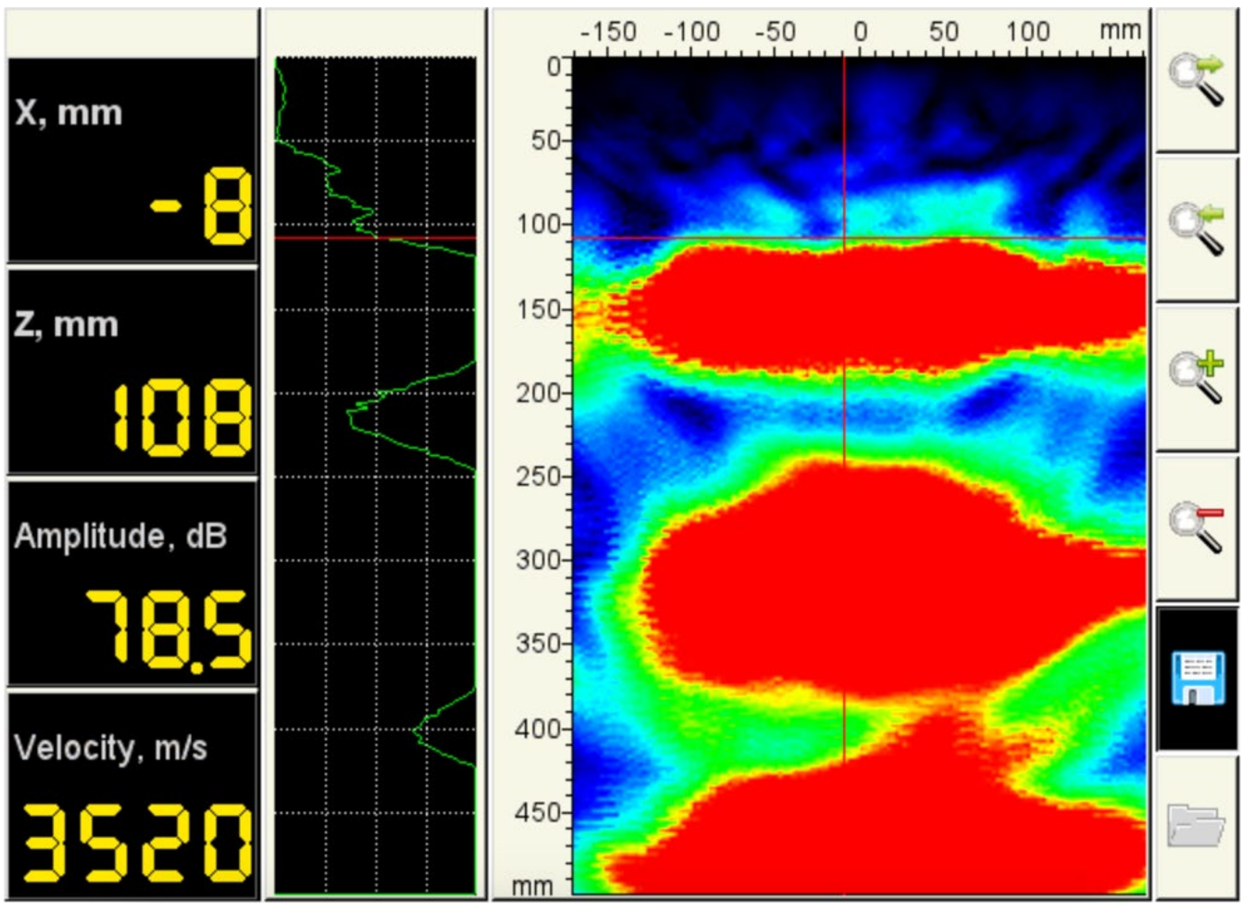



**Figure 90. Photos. Ultrasound images of Forest View Drive.**

**Figure 91. Photos. Forest View Drive.**

## Section 44: Sprucer Drive (Mahomet, IL)

**Table 66. Summary of Sprucer Drive Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 7 | 15 | 13 | 24 | Not observed | 1 lane per direction | Joint spalling and slab scaling | *Construction date not available.* |

Ultrasonic evaluation was conducted but no files saved.

**Figure 92. Photos. Sprucer Drive.**

## Section 45: Lake of the Woods Road (Mahomet, IL)

**Table 67. Summary of Lake of the Woods Road Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 9 | 12 | 13 | 30 | 22 | 1 lane per direction + central lane | Transverse cracking (<30%) | *Construction date ~ 2014.* |

Ultrasound Evaluation:

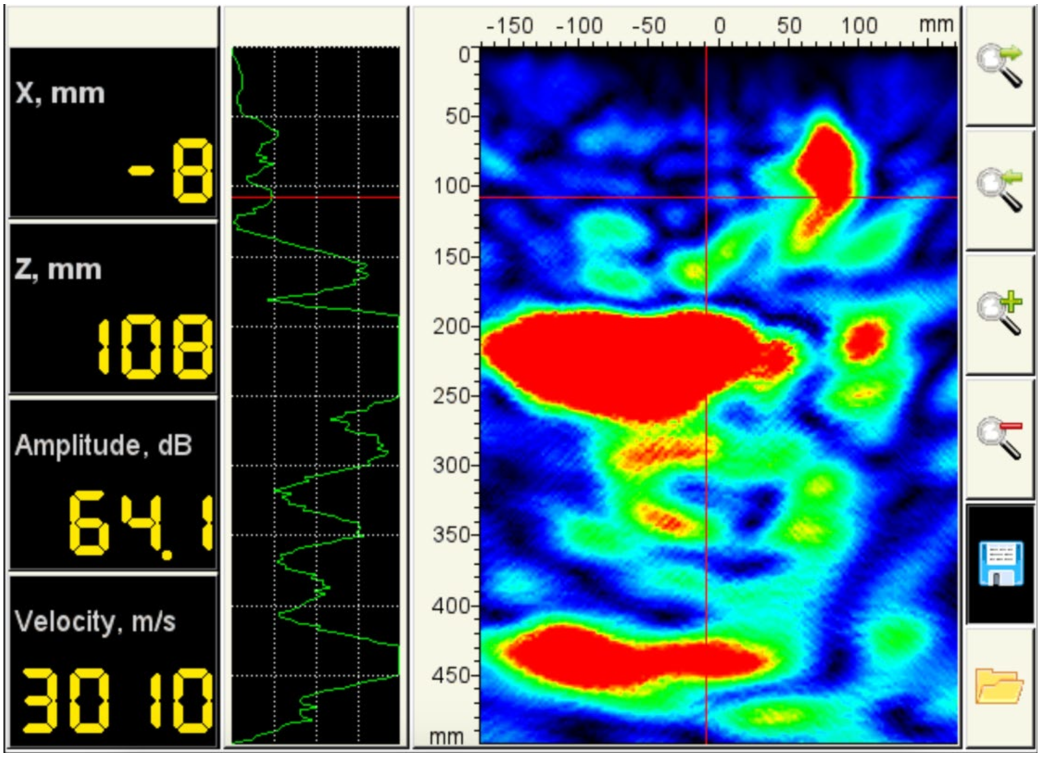



**Figure 93. Photos. Ultrasound images of Lake of the Woods Road.**

**Figure 94. Photos. Lake of the Woods Road.**

## Section 46: Veterans Parkway (Rantoul, IL)

**Table 68. Summary of Veterans Parkway Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 15 | 13 | 26 | Not observed | 1 lane per direction + central lane | Minimum surface cracks parallel to joint | *Construction date ~2014* |

Ultrasound Evaluation:

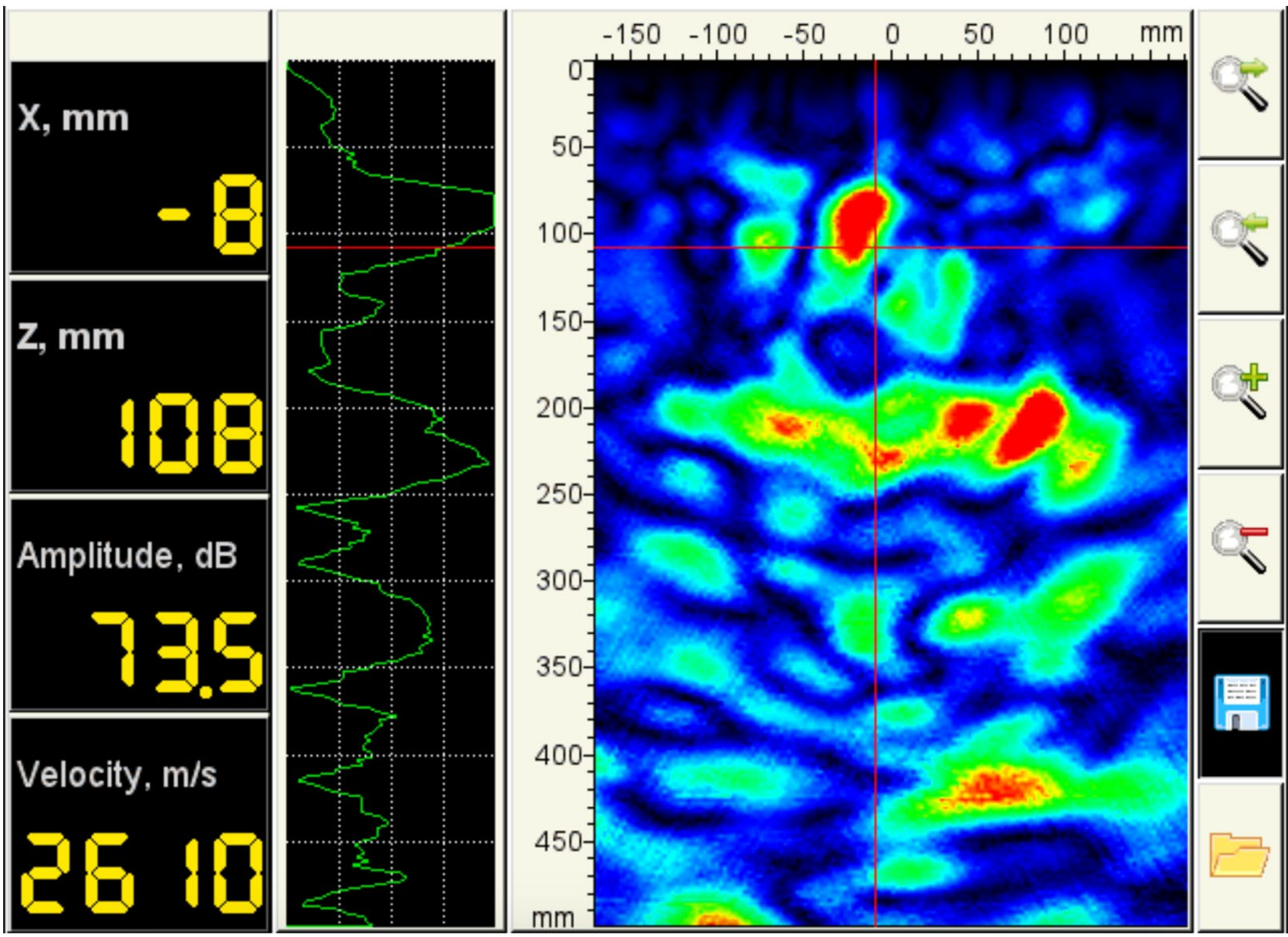



**Figure 95. Photos. Ultrasound images of Veterans Parkway.**

**Figure 96. Photos. Veterans Parkway.**

## Section 47: Virginia Avenue (Bloomington, IL)

**Table 69. Summary of Virginia Avenue Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 13 | 9 | Not observed | Not observed | 1 lane per side + central lane | No distress observed | *Construction date ~ 2015s* |

Ultrasound Evaluation:

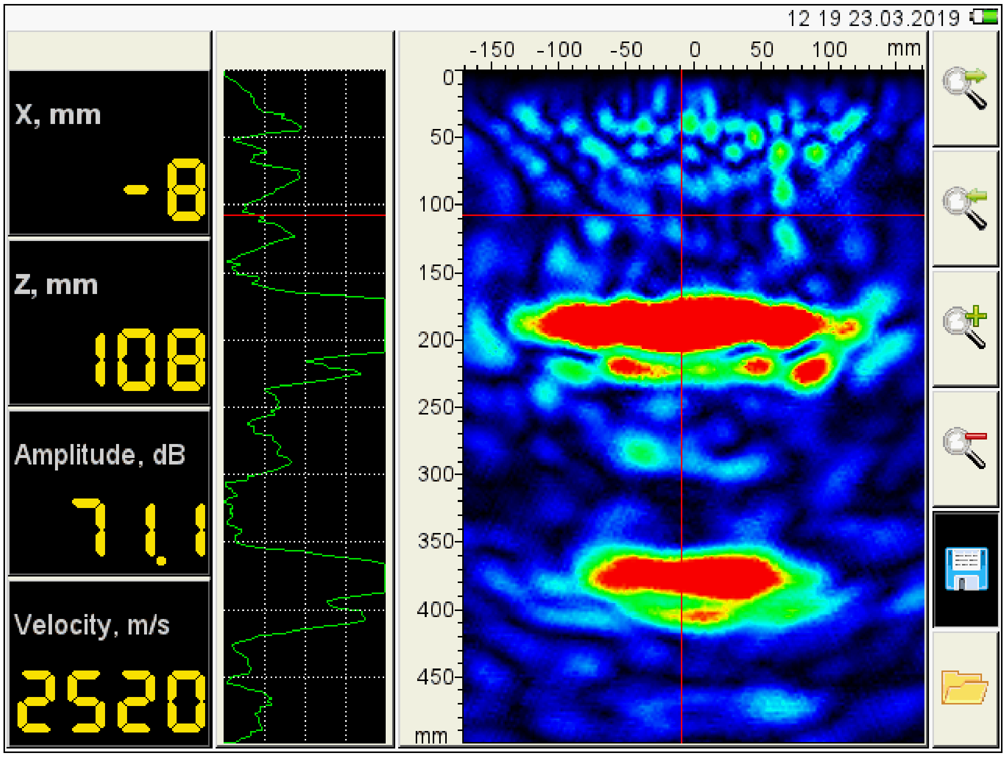



Figure 97. Photos. Ultrasound images of Virginia Avenue.


Figure 98. Photos. Virginia Avenue.

## Section 48: Raab Street (Bloomington, IL)

**Table 70. Summary of Raab Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| Not evaluated. | 17 | 12 | Not evaluated. | Not evaluated. | 2 lanes per direction | Continuous longitudinal cracking. (>50%) | Construction date ~ 2000s |

Ultrasound Evaluation was not conducted.

**Figure 99. Photos. Raab Street.**

## Section 49: Providence Drive (Bloomington, IL)

**Table 71. Summary of Providence Drive Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| Not evaluated | 20 | 9 | Not evaluated | Not evaluated | 1 lane per direction + central lane | Medium transverse cracking (>30%) | Construction date ~ 2000s |

Ultrasound Evaluation was not conducted.

**Figure 100. Photos. Providence Drive.**

## Section 50: Vladimir Drive (Bloomington, IL)

**Table 72. Summary of Vladimir Drive Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| Not evaluated | 15 | 9 | Not evaluated | Not evaluated | 1 lane per direction + central lane | Transverse cracking (>30%) | *Construction date ~2000s* |

Ultrasound Evaluation was not conducted.

**Figure 101. Photos. Vladimir Drive.**

## Section 51: Slaydon Drive (Bloomington, IL)

**Table 73. Summary of Slaydon Drive Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| Not evaluated | 20 | 9 | Not evaluated | Not evaluated | 1 lane per direction + central lane | Transverse cracking (>50%) | *Construction date ~2000s* |

Ultrasound Evaluation was not conducted.

**Figure 102. Photos. Slaydon Drive.**

## Section 52: Challis Drive (Bloomington, IL)

**Table 74. Summary of Challis Drive Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| Not evaluated | 20 | 9 | Not evaluated | Not evaluated | 1 lane per direction + central lane | Transverse cracking (>30%) | *Construction date ~2000s* |

Ultrasound Evaluation was not conducted.


**Figure 103. Photos. Challis Drive.**

## Section 53: Bancoft Drive (Bloomington, IL)

**Table 75. Summary of Bancoft Drive Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| Not evaluated | 20 | 9 | Not evaluated | Not evaluated | 1 lane per direction + central lane | Medium transverse cracking (>50%) | *Construction date ~2000s* |

Ultrasound Evaluation was not conducted.


**Figure 104. Photos. Bancoft Drive.**

## Section 54: Cadwell Drive (Bloomington, IL)

**Table 76. Summary of Cadwell Drive Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| Not evaluated | 20 | 9 | Not evaluated | Not evaluated | 1 lane per direction + central lane | Transverse cracking (>30%) | *Construction date ~2000s* |

Ultrasound Evaluation was not conducted.

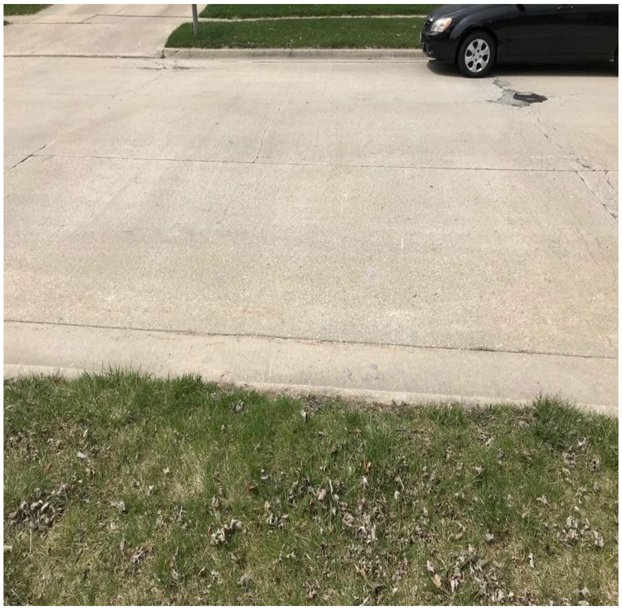


**Figure 105. Photos. Cadwell Drive.**

## Section 55: Newcastle Drive (Bloomington, IL)

**Table 77. Summary of Newcastle Drive Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| Not evaluated | 20 | 9 | Not evaluated | Not evaluated | 1 lane per side + central lane | Transverse cracking (>30%) | *Construction date ~2000s* |

Ultrasound Evaluation was not conducted.

**Figure 106. Photos. Newcastle Drive.**

## Section 56: Chantal Lane (Bloomington, IL)

**Table 78. Summary of Chantal Lane Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| Not evaluated | 20 | 9 | Not evaluated | Not evaluated | 1 lane per direction + central lane | Transverse cracking (>30%) | *Construction date ~2000s* |

Ultrasound Evaluation was not conducted.

**Figure 107. Photos. Chantal Lane.**

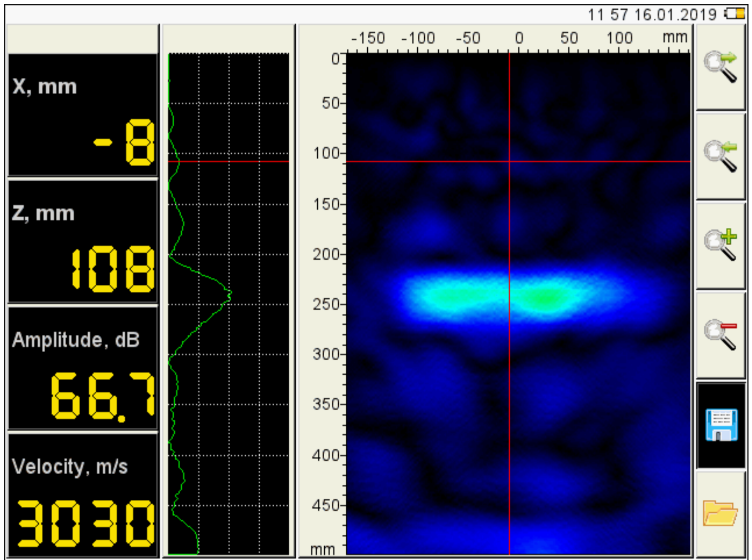
## DISTRICT 7

## Section 57: Maple Street (Downtown) (Effingham, IL)

**Table 79. Summary of Maple Street (Downtown) Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuratio n | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 15 | 12 | Not observed | Not observed | 1 lane per direction | Longitudinal cracking. (>50%) | *Construction date ~2000s* |

Ultrasound Evaluation:



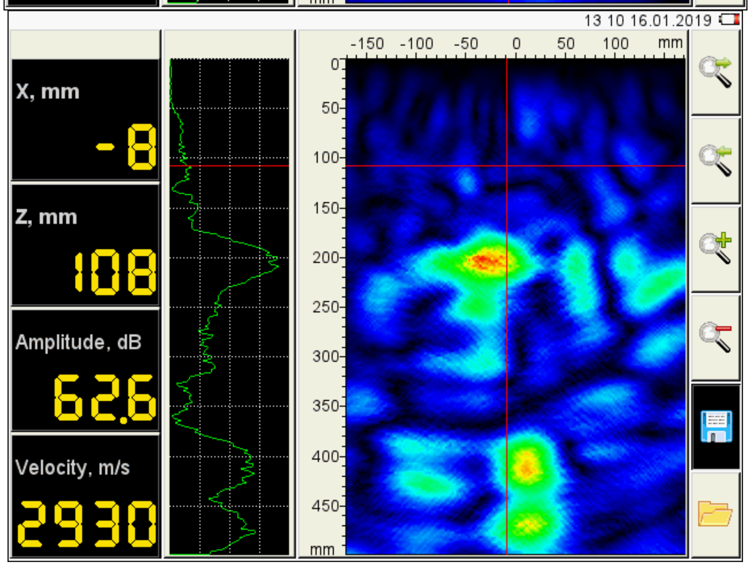




**Figure 108. Photos. Ultrasound images of Maple Street (downtown).**

**Figure 109. Photos. Maple Street (downtown).**

## Section 58: Maple Street (North) (Effingham, IL)

**Table 80. Summary of Maple Street (North) Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 15 | 12 | Variable | Variable | 1 lane per direction | Mid-panel cracking and longitudinal cracks (<30%) | *Construction date ~2000s* |

Ultrasound Evaluation:

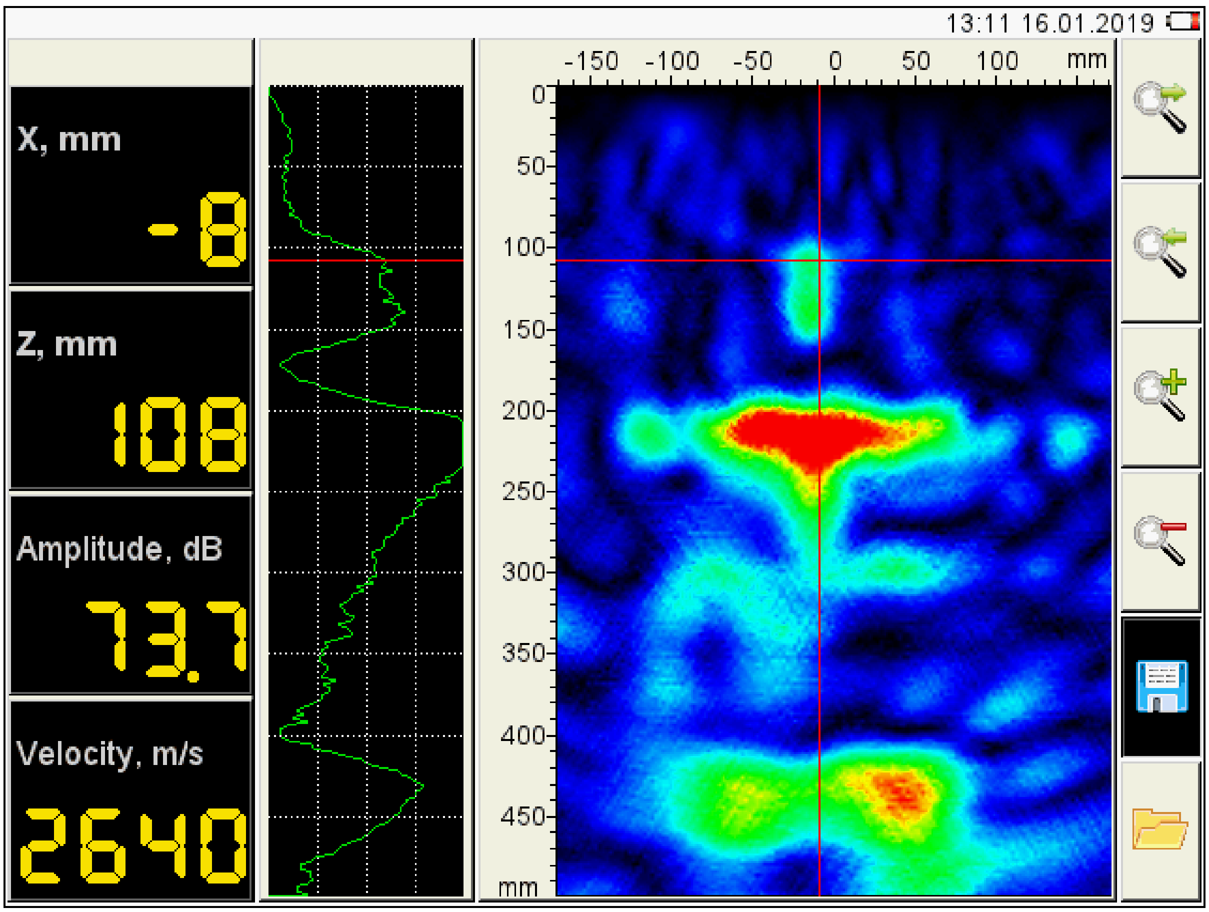



**Figure 110. Photos. Ultrasound images of Maple Street (North).**

**Figure 111. Photos. Maple Street (North).**

## Section 59: Ford Street (Effingham, IL)

**Table 81. Summary of Ford Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 9 | 13 | 20 | Not observed | Variable | 1 lane per direction | Transverse cracking (>30%) | Construction date ~2000s |

Ultrasound Evaluation:

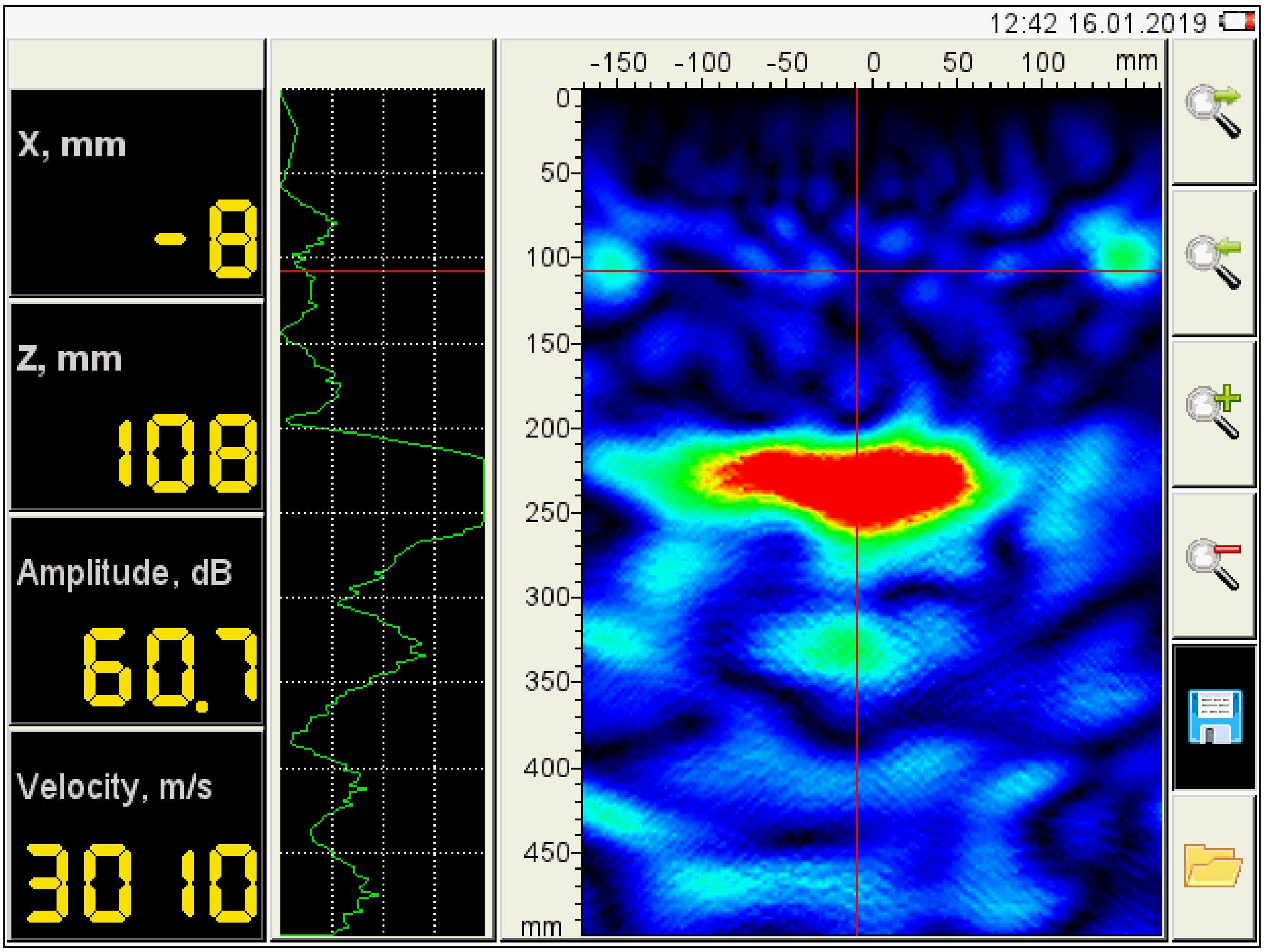



**Figure 112. Photos. Ultrasound images of Ford Street.**

**Figure 113. Photos. Ford Street.**

## Section 60: Merchant Street (Effingham, IL)

**Table 82. Summary of Merchant Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 9 | 12 | 12 | Not observed | Variable | 1 lane per direction | No distress observed | *Construction date ~2000s* |

Ultrasound Evaluation:

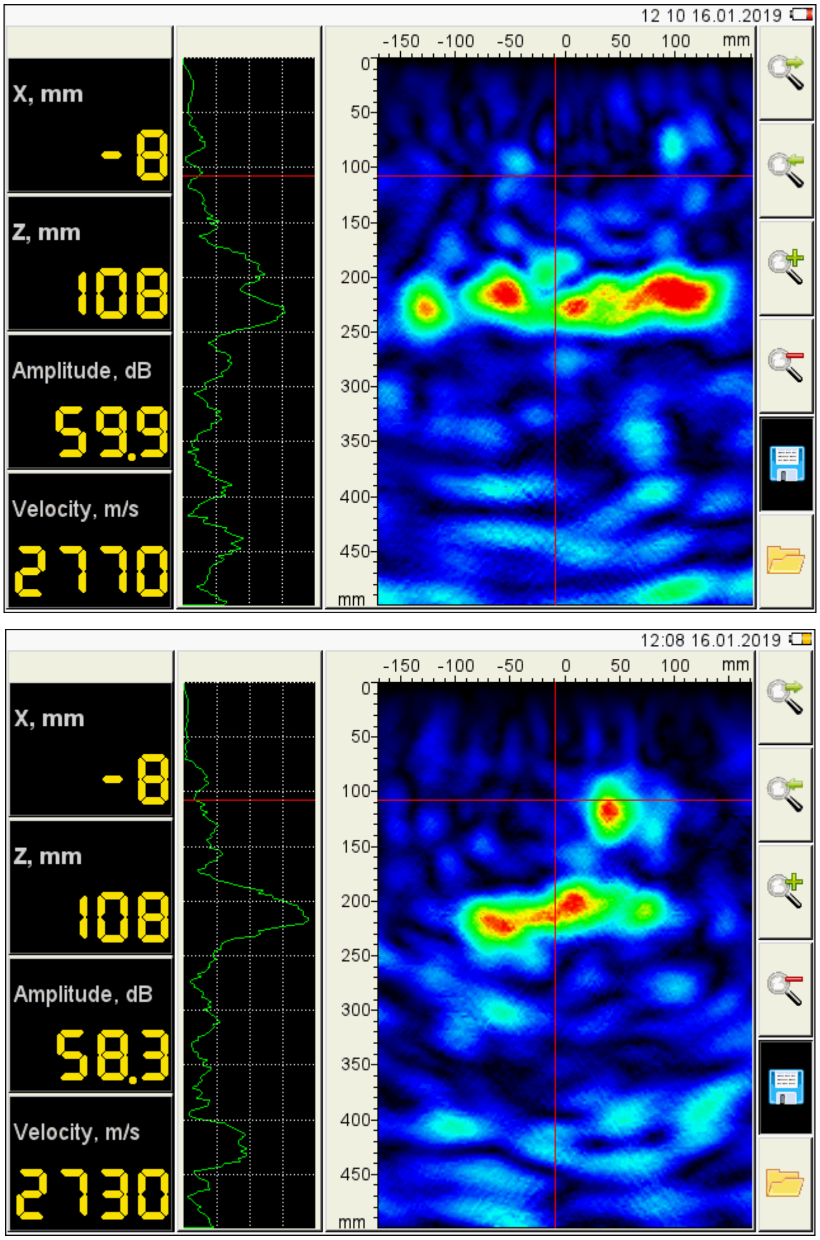



**Figure 114. Photos. Ultrasound images of Merchant Street.**

**Figure 115. Photo. Merchant Street.**

## DISTRICT 8

## Section 61: Harrison Street with Wesley Drive (Alton, IL)

**Table 83. Summary of Harrison Street with Wesley Drive Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 45 | 12 | 24 | Not observed | 2 lanes per direction | Transverse cracking and joint deterioration (~98%) | *Construction date ~2010s* |

Ultrasonic evaluation was conducted but no files saved.

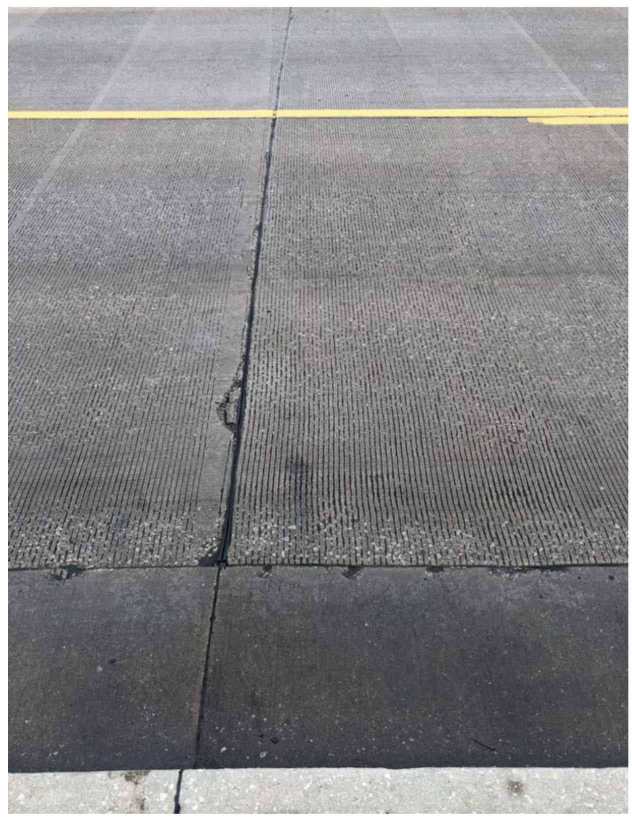


**Figure 116. Photos. Harrison Street with Wesley Drive.**

## Section 62: Matter Avenue (Columbia, IL)

**Table 84. Summary of Matter Avenue Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 15 | 11 | Not detected | 36 | 1 lane per direction | None | Construction date ~ 2010s |

Ultrasonic evaluation was conducted but no files saved.

**Figure 117. Photos. Matter Avenue.**

## Section 63: Koefil Lane (Highland, IL)

**Table 85. Summary of Koefil Lane Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 15 | 12 | 12 | 36 | *2 lanes per direction + bicycle lane* | No distress observed | Construction date ~2010s |

Ultrasound Evaluation:

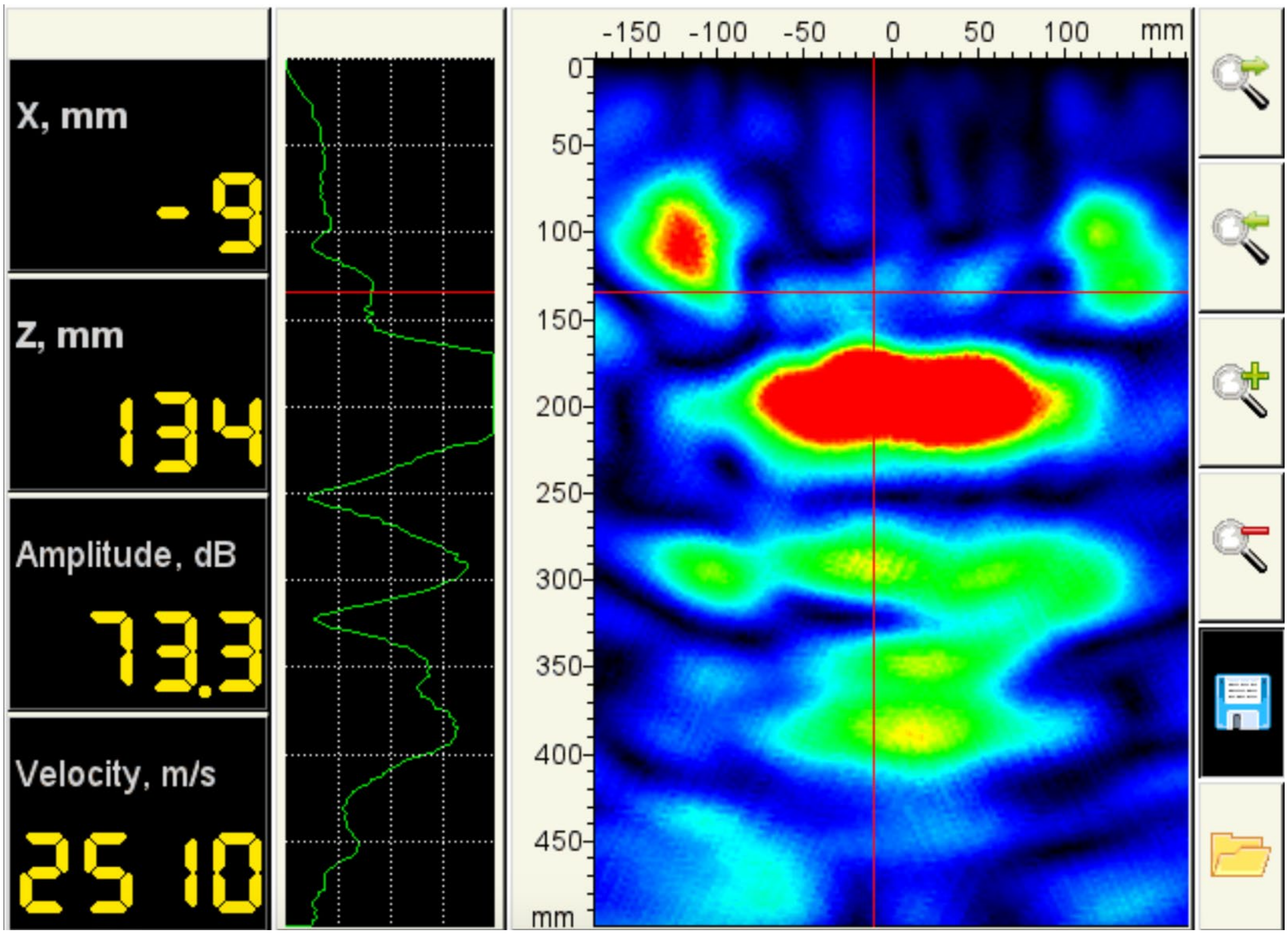



**Figure 118. Photos. Ultrasound image of Koefil Lane.**

**Figure 119. Photos. Koefil Lane.**

## Section 64: Bissel Road (East St. Louis, IL)

**Table 86. Summary of Bissel Road Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| Variable within 10-12 | 15 | 12 | 24 | 36 | 2 lanes per direction | No distress observed | Construction date ~ 2010s |

Ultrasound Evaluation:

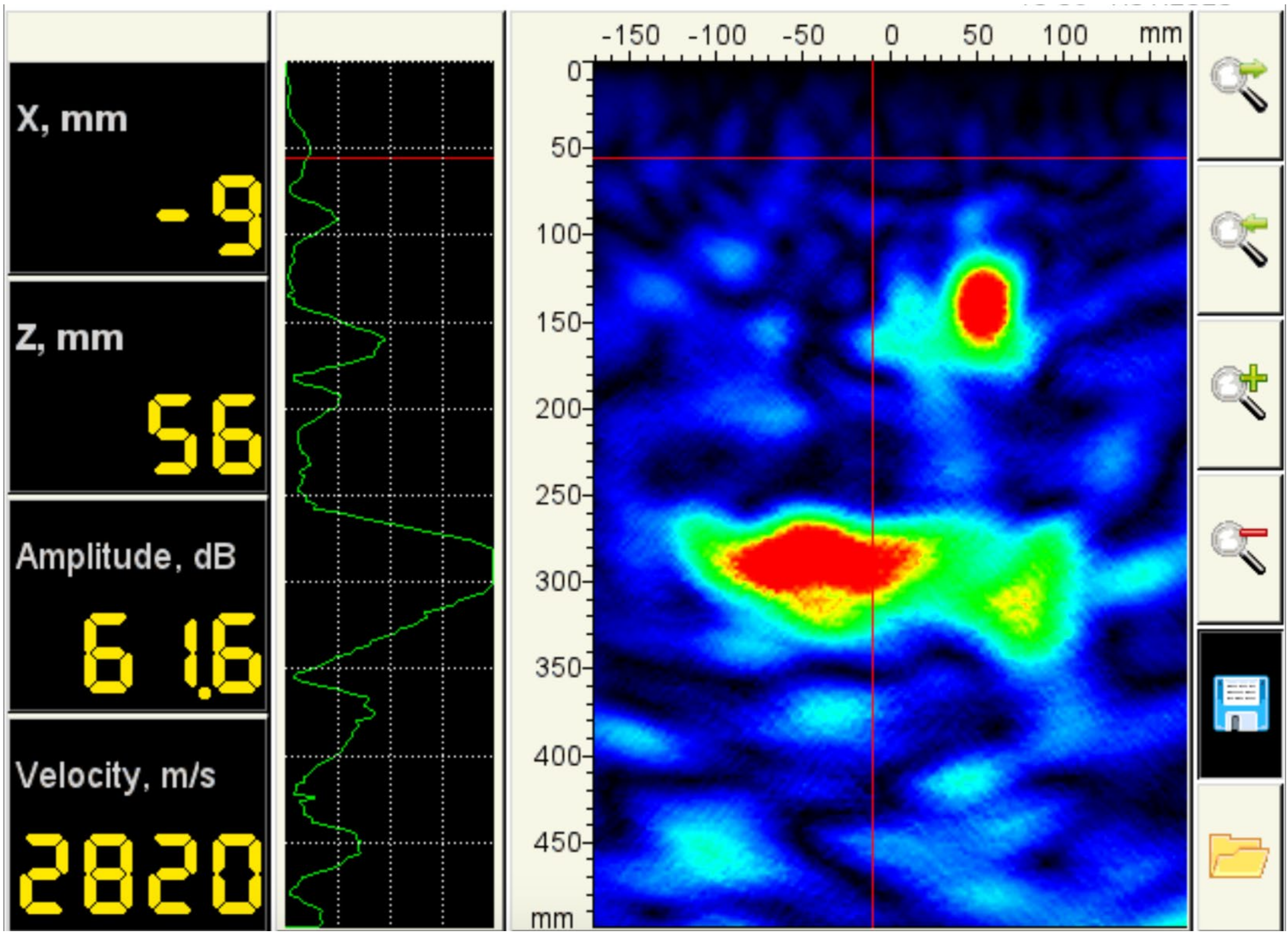



**Figure 120. Photos. Ultrasound image of Bissel Road.**

**Figure 121. Photos. Bissel Road.**

## Section 65: Bissel Road Section 2 (East St. Louis, IL)

**Table 87. Summary of Bissel Road Section 2 Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 7 | 18 | 12 | 12 | 72 | 1 lane per direction | Transverse cracking (>50%) | Construction date ~2010s |

Ultrasound Evaluation:

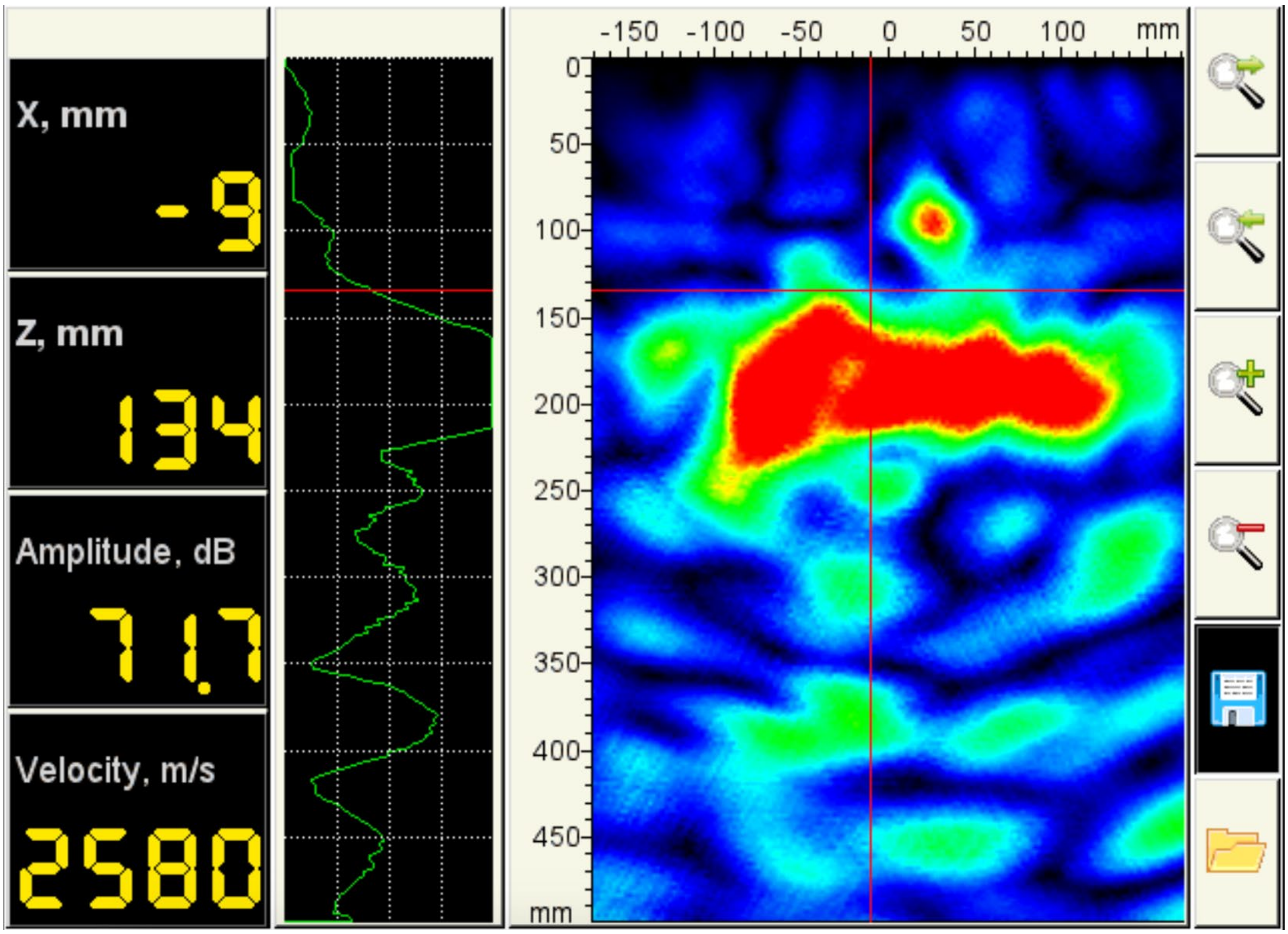



**Figure 122. Photos. Ultrasound image of Bissel Road section 2.**

**Figure 123. Photos. Bissel Road section 2.**

## Section 66: Central Street (East St. Louis, IL)

**Table 88. Summary of Central Street Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 8 | 30 | 14 | 12 | 36 | 1 lane per direction | Transverse cracking (>50%) | Construction date ~2010s |

Ultrasonic evaluation was conducted but no files were saved.

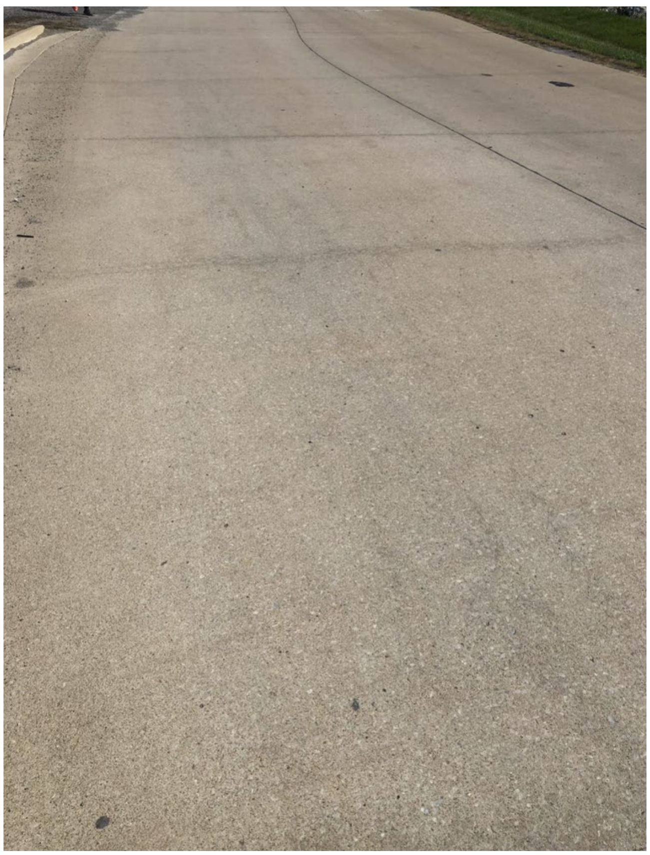


**Figure 124. Photos. Central Street.**

## Section 67: Troy Avenue (Troy, IL)

**Table 89. Summary of Troy Avenue Physical Evaluations**

| Thickness (in.) | Panel Length (ft) | Panel Width (ft) | Dowel Bar Spacing (in.) | Tie Bar Spacing (in.) | Lane Configuration | Visual Distress | Additional Observations |
|---|---|---|---|---|---|---|---|
| 10 | 15 | 13 | 12 | 36 | 2 lanes per direction + central lane | Longitudinal cracking (>50%) | Construction date ~2000s |

Ultrasonic evaluation was conducted but no files saved.

**Figure 125. Photos. Troy Avenue.**

# APPENDIX B: ADDITIONAL JOINT ACTIVATION ANALYSIS

Saw-cut contraction joints must propagate a full-depth crack in order allow slabs to move independently of each other and reduce the likelihood of premature transverse or longitudinal cracking. When a contraction joint does not activate, this causes an increase in the effective slab length as well as an increase in the slab's tensile stresses with respect to wheel loads and environmental factors. As these tensile stress levels approach and exceed the concrete strength, a crack will develop away from the intended joint location.

In order to assess joint activation in the field for bonded concrete overlays of asphalt (BCOA), an algorithm was developed by Tran and Roesler (2020b) that uses the MIRA shear wave response across the theoretical plane of the contraction joint. The algorithm uses the received signal energy from specific transducer pairings and calculates a normalized transmission energy (NTE) quantity. From the energy analysis, sensor pairings 2–7 and 2–11 resulted in the best prediction of whether a joint was activated. In addition to the optimal transducer pairings, a hyperplane model was determined for the final assessment. The hyperplane is the decision line that separates an activated joint with a crack (below the hyperplane) and a joint that has been sawn but is not activated (above the hyperplane).

An investigation was performed on six streets in Champaign, Illinois—Green Street, Healey Street, Gregory Avenue, Armory Drive, Curtis Road, and Logan Street—to check the existing algorithm developed by Tran and Roesler (2020b) and determine the percentage of transverse contraction joints that may not be activated on urban concrete pavements. An initial analysis was performed in 2019 along Healey Street for two adjacent joints that spanned a transverse crack. Figure 126 shows the results of the joint activation analysis between the two adjacent joints from Healey Street. Joint 1 is below the hyperplane, and Joint 2 is above the hyperplane. This can be interpreted as Joint 1 is an activated working joint and Joint 2 is an uncracked contraction joint. This initial analysis shows that some joints may not be activated and could be contributing to premature cracking in urban JPCP sections, which could indicate late sawing, inadequate saw-cut depth, or another reason.

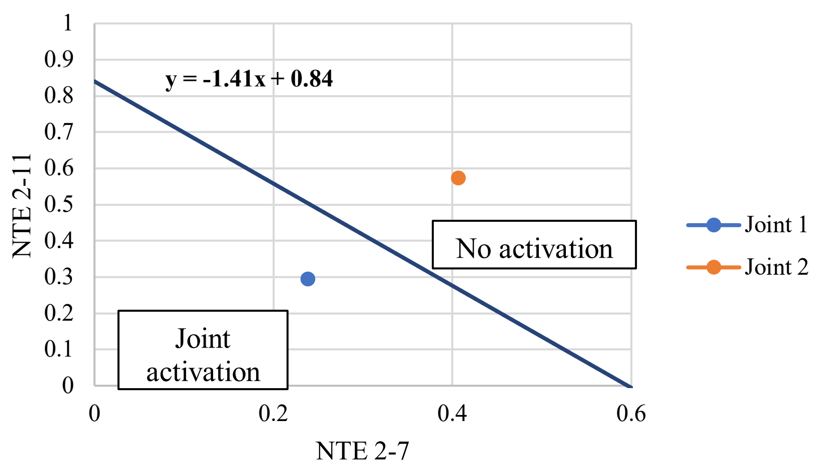



**Figure 126. Graph. Healey Street joint activation NTE results—2019.**

Subsequently, a more comprehensive analysis on six urban JPCP streets were examined in Champaign, Illinois, including an additional analysis on Healey Street. Some portions of the JPCPs were constructed at different times and/or had different structural designs. Therefore, a total of 10 distinct sections were examined and can be seen in Table 90.

**Table 90. Summary of Sections Evaluated with Ultrasonic Testing for Joint Activation**

| Section | Thickness (in.) | Slab Width (ft) | Slab Length (ft) | Distress | Construction Year |
|---|---|---|---|---|---|
| Green St. from 4th St. to Wright St. (Champaign, IL) | 8 | 11 | 15 | Transverse cracking and joint deterioration (>50%) | ~2005 |
| Logan St. (Champaign, IL) | 9–10 | 11 | 12.5 | Transverse cracking (50%) | 2010 |
| Healey St. from 4th St. to 5th St. (Champaign, IL) | 8 | 12 | 12.5 | Transverse cracking (>50%) | 2010s |
| Healey St. from 5th St. to 6th St. (Champaign, IL) | 8 | 12 | 12.5 | Transverse cracking (5%) | 2010s |
| Curtis Rd. from Prospect Ave. to Duncan Rd. (Champaign, IL) | 8 | 12 | 15 | Transverse cracking (>30%) | 2010s |
| Gregory St. from 1st St. to 4th St. (Champaign, IL) | 7–8[1] | 12 | 17 | Transverse cracking (>50%) | 2010s |
| Gregory St. from Oak St. to 1st St. (Champaign, IL) | 8 | 18 | 15 | Transverse cracking (>50%) | 2013 |
| Gregory St. from 4th St. to 6th St. (Champaign, IL) | 8 | 10.5 | 15 | Transverse cracking (>50%) | 2013 |
| Green St. from 1st St. to 4th St. (Champaign, IL) | 8 | 9 | 15 | 0 | ~2015 |
| E. Armory Ave. from 4th St. to Wright St. (Champaign, IL) | 12–13 | 12 | 12 | 0 | N/A |

## HEALEY STREET (CHAMPAIGN, IL)

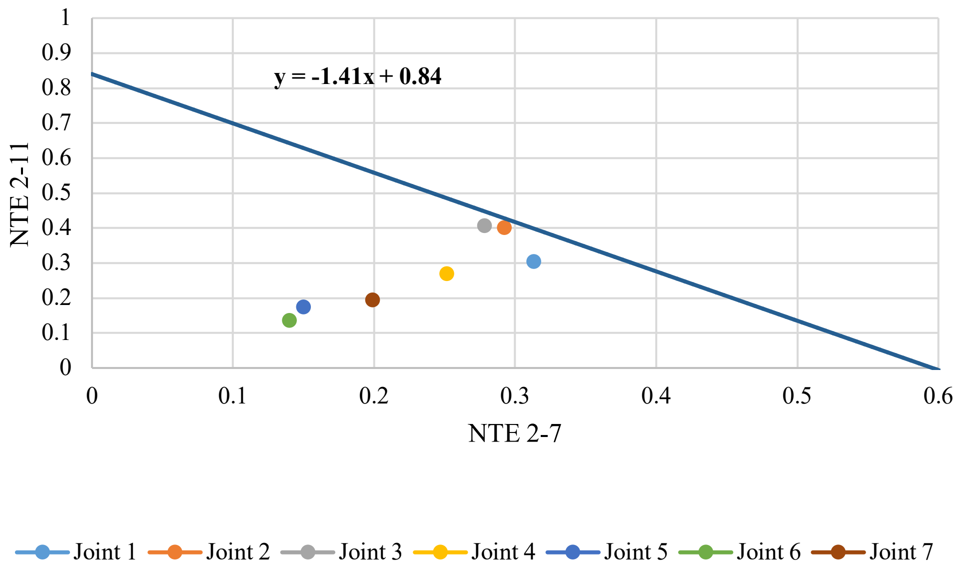
Table 91 presents the results obtained from Healey Street. This data includes two different dates of testing: April 7, 2019, and October 21, 2020. Three separate segments of Healey Street were tested, as seen in Figure 127. These segments were separated based on the observed cracking in each segment. The first segment (Healey Street between Second and Third Streets) was used in the initial analysis to assess if joint activation is a potential contributor in premature transverse crack development. The second segment (Healey Street between Fourth and Fifth Streets) appeared to have a transverse crack on every other slab, which is approximately 50% slab cracking. The joint activation analysis resulted in three joints that fall very close to the hyperplane and are reported as inconclusive, whereas the remaining joints were evaluated as being activated. These joints had widths approximately 0.25 in. with joint sealant (all sealed very well with some joints over-sealed). From visual inspection during testing, Joints 5 and 7 were wider than the other joints, implying active joints. In addition, the transverse crack between Joints 5 and 6 was very tight and low severity.

The third segment (Healey Street between Fifth and Sixth Streets) had very minimal cracking. Only one transverse crack was observed in this segment, between Joints 2 and 3. From the joint activation ultrasonic evaluation, all joints appear to be active and working joints. The transverse crack between Joints 2 and 3 potentially developed directly over the tie bars between the longitudinal construction joint with the curb and gutter shoulder.

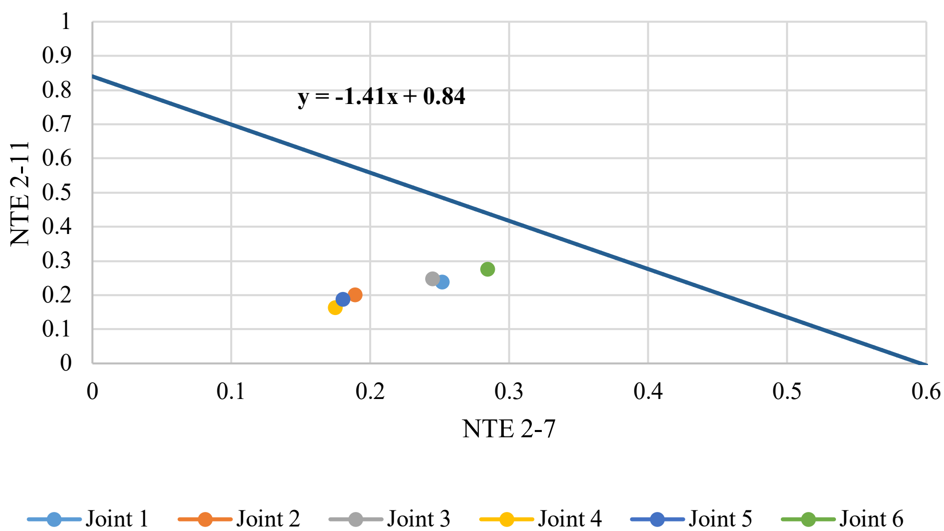
**Table 91. Joint Activation Analysis Results for Healey Street**

| Section No. and Location | Joint No. | Crack Identification | Evaluation Date | Ultrasonic Joint Evaluation |
|---|---|---|---|---|
| Healey St. from 2nd St. and 3rd St. | 1 | Transverse crack between Joints 1 and 2 | 4/7/2019 | Activated |
| Healey St. from 2nd St. and 3rd St. | 2 | | 4/7/2019 | Nonactivated |
| | | | | |
| Healey St. from 4th St. to 5th St. | 1 | Transverse crack between Joints 1 and 2 | 10/21/2020 | Inconclusive[1] |
| Healey St. from 4th St. to 5th St. | 2 | Transverse crack between Joints 1 and 2; No crack between Joints 2 and 3 | 10/21/2020 | Inconclusive[1] |
| Healey St. from 4th St. to 5th St. | 3 | No crack between Joints 2 and 3; Transverse crack between Joints 3 and 4 | 10/21/2020 | Inconclusive[1] |
| Healey St. from 4th St. to 5th St. | 4 | Transverse crack between Joints 3 and 4; No crack between Joints 4 and 5 | 10/21/2020 | Activated |
| Healey St. from 4th St. to 5th St. | 5 | No crack between Joints 4 and 5; Transverse crack between Joints 5 and 6 | 10/21/2020 | Activated |
| Healey St. from 4th St. to 5th St. | 6 | Transverse crack between Joints 5 and 6; Transverse crack between Joints 6 and 7 | 10/21/2020 | Activated |
| Healey St. from 4th St. to 5th St. | 7 | Transverse crack between Joints 6 and 7 | 10/21/2020 | Activated |
| | | | | |
| Healey St. from 5th St. to 6th St. | 1 | No crack between Joints 1 and 2 | 10/21/2020 | Activated |
| Healey St. from 5th St. to 6th St. | 2 | No crack between Joints 1 and 2; Transverse crack between Joints 2 and 3 | 10/21/2020 | Activated |
| Healey St. from 5th St. to 6th St. | 3 | Transverse crack between Joints 2 and 3; No crack between Joints 3 and 4 | 10/21/2020 | Activated |
| Healey St. from 5th St. to 6th St. | 4 | No crack between Joints 3 and 4; No crack between Joints 4 and 5 | 10/21/2020 | Activated |
| Healey St. from 5th St. to 6th St. | 5 | No crack between Joints 4 and 5; No crack between Joints 5 and 6 | 10/21/2020 | Activated |
| Healey St. from 5th St. to 6th St. | 6 | No crack between Joints 5 and 6 | 10/21/2020 | Activated |

[1] Inconclusive results indicate ultrasonic joint evaluation falls on or near the hyperplane.




(A) Healey Street from Fourth Street to Fifth Street




(B) Healey Street from Fifth Street to Sixth Street

**Figure 127. Graphs. Healey Street joint activation analysis NTE results—2020.**

## GREEN STREET

### Fourth Street to Wright Street (Champaign, IL)

The analysis along Green Street examined three different locations between the intersection of Wright Street and Fourth Street. The analysis conducted included testing joints spanning transverse cracks (see Figure 128), as well as joints that did not contain transverse cracks between them. Green

Street is a very busy street in Champaign, Illinois, which made testing more challenging than other sections. Therefore, only three to four adjacent joints were able to be evaluated per location. Table 92 summarizes the results of the joint evaluation conducted on the three testing locations on Green Street between Wright Street and Fourth Street in Champaign, Illinois. From this ultrasonic joint analysis, all joints tested along Green Street are activated and are not likely the main contribution to the transverse cracking (see Figure 129).

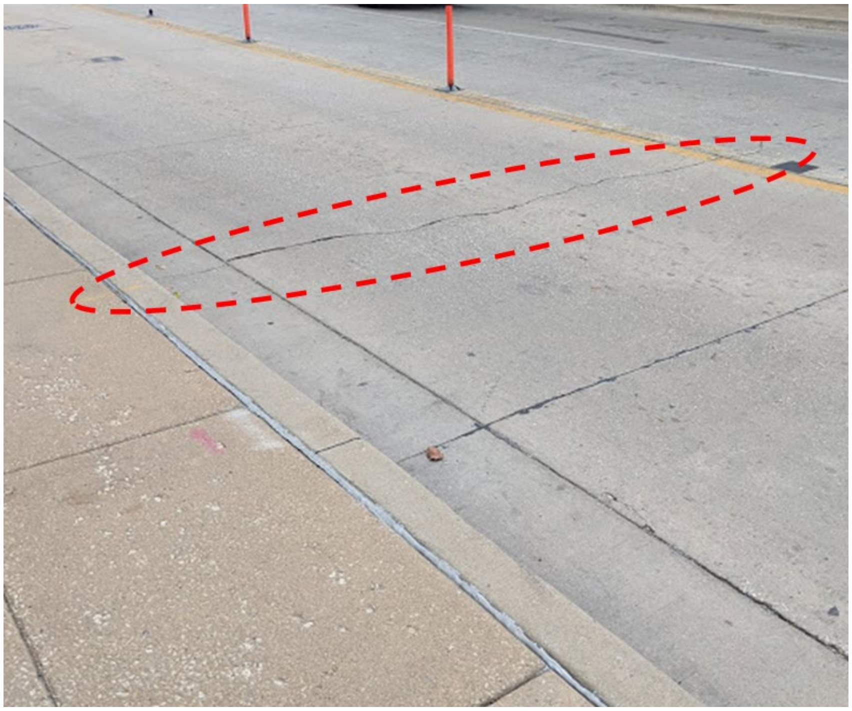
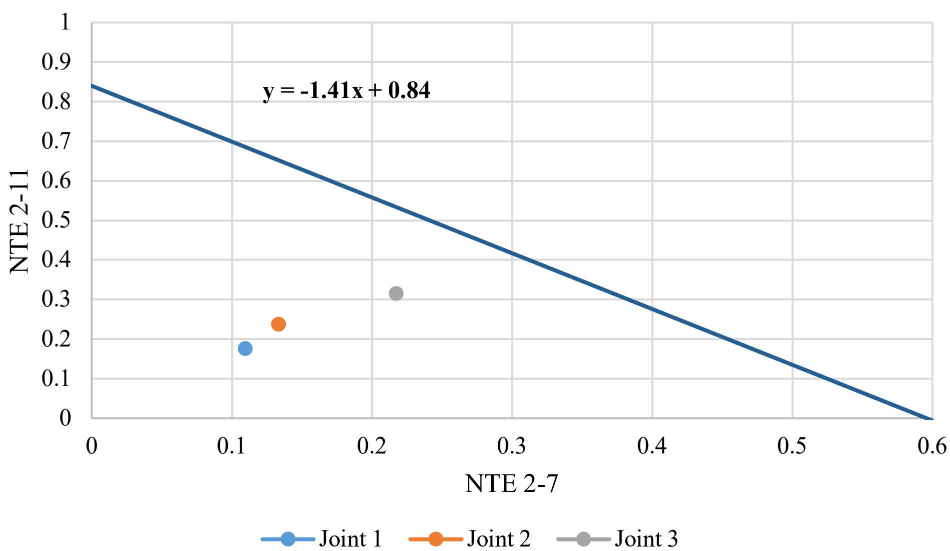
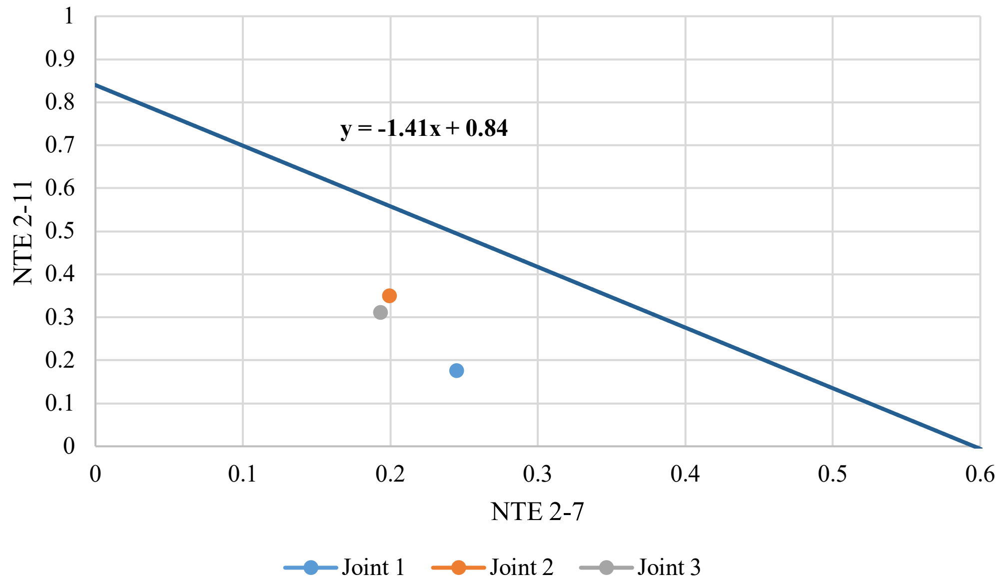


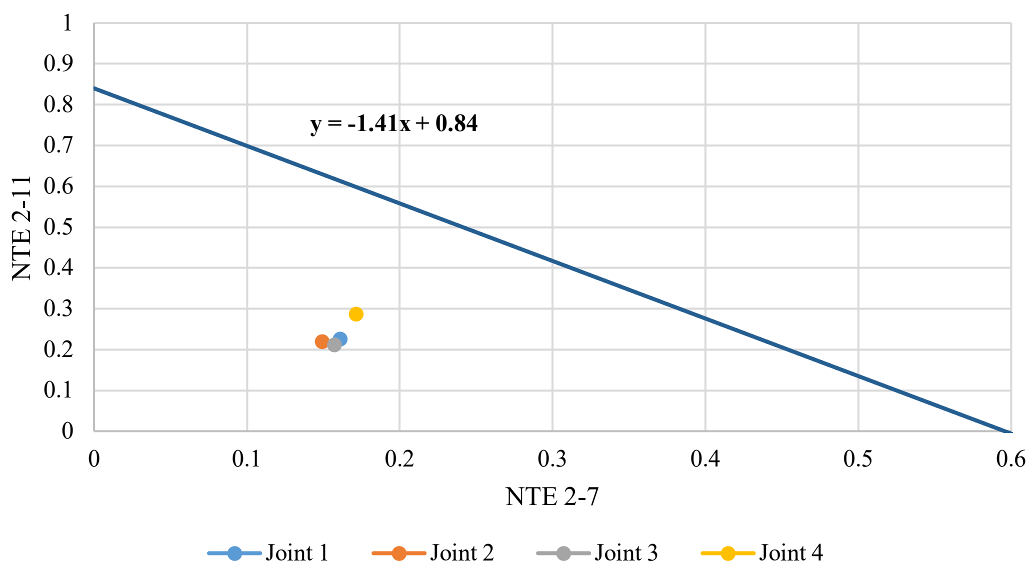
**Figure 128. Photo. Transverse crack on Green Street near Wright Street.**




(A) Green Street near Wright Street




(B) Green Street near Sixth Street




(C) Green Street near Fifth Street

**Figure 129. Graphs. Green Street between Wright Street and Fourth Street joint activation analysis NTE results.**

**Table 92. Joint Activation Analysis Results for Green Street between Wright Street and Fourth Street**

| Section No. and Location | Joint No. | Crack Identification | Evaluation Date | Ultrasonic Joint Evaluation |
|---|---|---|---|---|
| Green St. near Wright St | 1 | Transverse crack between Joints 1 and 2 | 9/23/2020 | Activated |
| Green St. near Wright St. | 2 | Transverse crack between Joints 1 and 2; Transverse crack between Joints 2 and 3 | 9/23/2020 | Activated |
| Green St. near Wright St. | 3 | Transverse crack between Joints 2 and 3 | 9/23/2020 | Activated |
| | | | | |
| Green St. near 6th St. | 1 | Transverse crack between Joints 1 and 2 | 9/23/2020 | Activated |
| Green St. near 6th St. | 2 | Transverse crack between Joints 1 and 2; No crack between Joints 2 and 3 | 9/23/2020 | Activated |
| Green St. near 6th St. | 3 | No crack between Joints 2 and 3 | 9/23/2020 | Activated |
| | | | | |
| Green St. near 5th St. | 1 | No crack between Joints 1 and 2 | 9/23/2020 | Activated |
| Green St. near 5th St. | 2 | No crack between Joints 1 and 2; Transverse crack between Joints 2 and 3 | 9/23/2020 | Activated |
| Green St. near 5th St. | 3 | Transverse crack between Joints 2 and 3; No crack between Joints 3 and 4 | 9/23/2020 | Activated |
| Green St. near 5th St. | 4 | No crack between Joints 3 and 4; Transverse crack between Joints 4 and 5 | 9/23/2020 | Activated |
| Green St. near 5th St. | 5 | Transverse crack between Joints 4 and 5 | 9/23/2020 | Activated |

## First Street to Fourth Street (Champaign, IL)

Green Street between the intersection of First Street and Fourth Street was constructed at a different date and with a different design than Green Street between Fourth Street and Wright Street. Table 93 summarizes the results of the joint evaluation conducted on Green Street between First Street and Fourth Street in Champaign, Illinois. This section consisted of 15 ft × 9 ft panels (L × W), with a curb and gutter shoulder. This section did not have any cracking present and was performing well. From the ultrasonic joint analysis, all joints tested along Green Street resulted inconclusive or not activated, as seen in Figure 130. Additionally, Joint 8 was concluded as not activated based on the NTE analysis results, but this joint appears to be a construction joint.

**Table 93. Joint Activation Analysis Results for Green Street between First Street and Fourth Street**

| Section No. and Location | Joint No. | Crack Identification | Evaluation Date | Ultrasonic Joint Evaluation |
|---|---|---|---|---|
| Green St. from 1st St. to 4th St. | 1 | No crack between Joints 1 and 2 | 10/28/2020 | Inconclusive[1] |
| Green St. from 1st St. to 4th St. | 2 | No crack between Joints 1 and 2; No crack between Joints 2 and 3 | 10/28/2020 | Inconclusive[1] |
| Green St. from 1st St. to 4th St. | 3 | No crack between Joints 2 and 3; No crack between Joints 3 and 4 | 10/28/2020 | Inconclusive[1] |
| Green St. from 1st St. to 4th St. | 4 | No crack between Joints 3 and 4; No crack between Joints 4 and 5 | 10/28/2020 | Inconclusive[1] |
| Green St. from 1st St. to 4th St. | 5 | No crack between Joints 4 and 5; No crack between Joints 5 and 6 | 10/28/2020 | Not activated |
| Green St. from 1st St. to 4th St. | 6 | No crack between Joints 5 and 6; No crack between Joints 6 and 7 | 10/28/2020 | Inconclusive[1] |
| Green St. from 1st St. to 4th St. | 7 | No crack between Joints 6 and 7; No crack between Joints 7 and 8 | 10/28/2020 | Inconclusive[1] |
| Green St. from 1st St. to 4th St. | 8 | No crack between Joints 7 and 8; No crack between Joints 8 and 9 | 10/28/2020 | Not activated[2] |
| Green St. from 1st St. to 4th St. | 9 | No crack between Joints 8 and 9; No crack between Joints 9 and 10 | 10/28/2020 | Inconclusive[1] |
| Green St. from 1st St. to 4th St. | 10 | No crack between Joints 9 and 10 | 10/28/2020 | Not activated |

[1] Inconclusive results indicate ultrasonic joint evaluation falls on or near the hyperplane.

[2] Not activated—Joint 8: This is a construction joint. It is unclear why the NTE results indicate not activated.

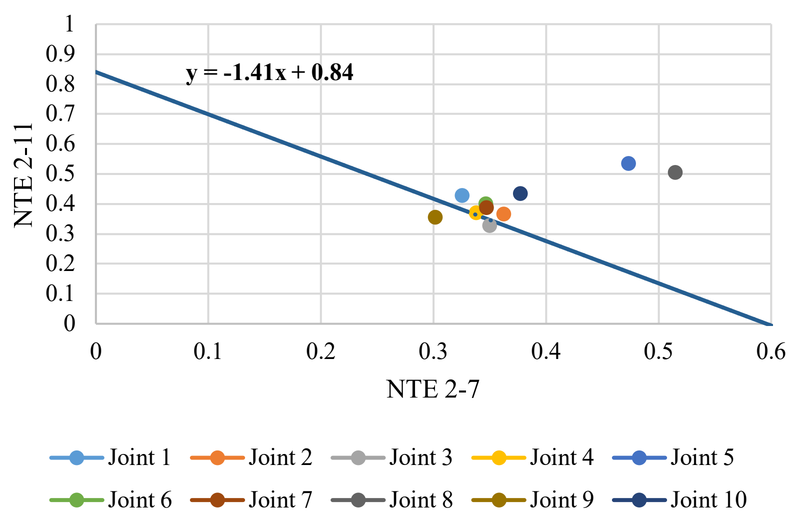



**Figure 130. Graph. Green Street near Second Street joint activation analysis NTE results.**

## GREGORY DRIVE (CHAMPAIGN, IL)

Similar to Green Street, the analysis performed along Gregory Drive was broken into three segments between the intersection of Oak Street and Sixth Street. These three different segments were either constructed at different dates or constructed with different geometry designs. Table 94 summarizes the results of the joint evaluation conducted along Gregory Drive between Oak Street and First Street in Champaign, Illinois, along with Figure 131-A. The joint spacing was not conventional in this section with 15 ft × 18 ft (L × W) panels. The eastbound lane was tested, and the first panel had a longitudinal crack spanning the slab and intersecting Joint 1. There were no anomalies observed based on dowel bar and tie bar spacing and depths. However, dowels were observed at a depth of 3.15 in. (80 mm) instead of 4 in. (100 mm).

**Table 94. Joint Activation Analysis Results for Gregory Drive between Oak Street and First Street**

| Section No. and Location | Joint No. | Crack Identification | Evaluation Date | Ultrasonic Joint Evaluation |
|---|---|---|---|---|
| Gregory Dr. from Oak St. to 1st St. | 1 | No crack between Joints 1 and 2 | 10/21/2020 | Inconclusive[1] |
| Gregory Dr. from Oak St. to 1st St. | 2 | No crack between Joints 1 and 2; No crack between Joints 2 and 3 | 10/21/2020 | Not Activated |
| Gregory Dr. from Oak St. to 1st St. | 3 | No crack between Joints 2 and 3; Transverse crack between Joints 3 and 4 | 10/21/2020 | Activated |
| Gregory Dr. from Oak St. to 1st St. | 4 | Transverse crack between Joints 3 and 4; No crack between Joints 4 and 5 | 10/21/2020 | Not Activated |
| Gregory Dr. from Oak St. to 1st St. | 5 | No crack between Joints 4 and 5; No crack between Joints 5 and 6 | 10/21/2020 | Activated |
| Gregory Dr. from Oak St. to 1st St. | 6 | No crack between Joints 5 and 6; No crack between Joints 6 and 7 | 10/21/2020 | Activated |
| Gregory Dr. from Oak St. to 1st St. | 7 | No crack between Joints 6 and 7; Transverse crack between Joints 7 and 8 | 10/21/2020 | Activated |
| Gregory Dr. from Oak St. to 1st St. | 8 | Transverse crack between Joints 7 and 8; No crack between Joints 8 and 9 | 10/21/2020 | Inconclusive[1] |
| Gregory Dr. from Oak St. to 1st St. | 9 | No crack between Joints 8 and 9; No crack between Joints 9 and 10 | 10/21/2020 | Activated |
| Gregory Dr. from Oak St. to 1st St. | 10 | No crack between Joints 9 and 10 | 10/21/2020 | Inconclusive[1] |

[1] Inconclusive results indicate ultrasonic joint evaluation falls on or near the hyperplane.

Table 95 summarizes the results of the joint evaluation conducted along Gregory Drive between First Street and Fourth Street in Champaign, Illinois. The joint spacing was nonconventional in this section with 17 ft × 13 ft (L × W) panels and also contained a bike lane in the westbound direction (17 ft by 5 ft) with a curb and gutter shoulder. The westbound lane was tested and included nine consecutive joints. There were several anomalies observed based on the dowel bar and tie bar spacing and depths. Dowels were observed in every other joint (Joint 2, 4, 6, and 8) and spaced at 36 in. on center (100 mm depth). These joints with the dowels had longitudinal cracking developing over the dowels. Joint 2 included dowels; however, they were observed to be at a depth of 2 in. (50 mm); there is a mid-panel transverse crack and a corner break (Approach Joint 3) on the same slab between Joints 2 and 3. For the joints without reinforcement (Joints 1, 3, 5, and 7), transverse joint faulting was observed. These anomalies observed within this section are most likely contributing significantly to the observed distress because all joints observed within the ultrasonic analysis appear to be activated and working joints (See Figure 131-B and Table 95).

Table 96 summarizes the results of the joint evaluation conducted along Gregory Drive between Fourth Street and Sixth Street in Champaign, Illinois. The joint spacing was more conventional in this section with 15 ft × 11 ft (L × W) panels and also contained a bike lane in the westbound direction (15 ft by 5 ft) with a curb and gutter shoulder. There were no anomalies observed when performing the ultrasonic investigation in this section. All joints observed within this section are believed to be activated, except for Joint 1, which falls near the hyperplane (inconclusive). Figure 131-C presents the NTE results for the joints in this section and show they fall below the hyperplane.

**Table 95. Joint Activation Analysis Results for Gregory Drive between First Street and Fourth Street**

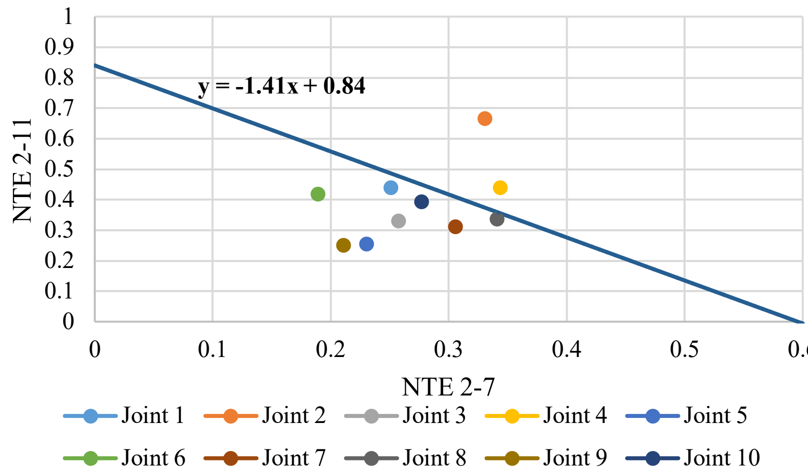
| Section No. and Location | Joint No. | Crack Identification | Evaluation Date | Ultrasonic Joint Evaluation |
|---|---|---|---|---|
| Gregory Dr. from 1st St. to 4th St. | 1 | No crack between Joints 1 and 2 | 10/21/2020 | Activated |
| Gregory Dr. from 1st St. to 4th St. | 2 | No crack between Joints 1 and 2; Transverse crack between Joints 2 and 3 | 10/21/2020 | Activated |
| Gregory Dr. from 1st St. to 4th St. | 3 | Transverse crack between Joints 2 and 3; No crack between Joints 3 and 4 | 10/21/2020 | Activated |
| Gregory Dr. from 1st St. to 4th St. | 4 | No crack between Joints 3 and 4; Transverse crack between Joints 4 and 5 | 10/21/2020 | Activated |
| Gregory Dr. from 1st St. to 4th St. | 5 | Transverse crack between Joints 4 and 5; No crack between Joints 5 and 6 | 10/21/2020 | Activated |
| Gregory Dr. from 1st St. to 4th St. | 6 | No crack between Joints 5 and 6; Transverse crack between Joints 6 and 7 | 10/21/2020 | Activated |
| Gregory Dr. from 1st St. to 4th St. | 7 | Transverse crack between Joints 6 and 7; No crack between Joints 7 and 8 | 10/21/2020 | Activated |
| Gregory Dr. from 1st St. to 4th St. | 8 | No crack between Joints 7 and 8; No crack between Joints 8 and 9 | 10/21/2020 | Activated |
| Gregory Dr. from 1st St. to 4th St. | 9 | No crack between Joints 8 and 9 | 10/21/2020 | Activated |

[1] Inconclusive results indicate ultrasonic joint evaluation falls on or near the hyperplane.

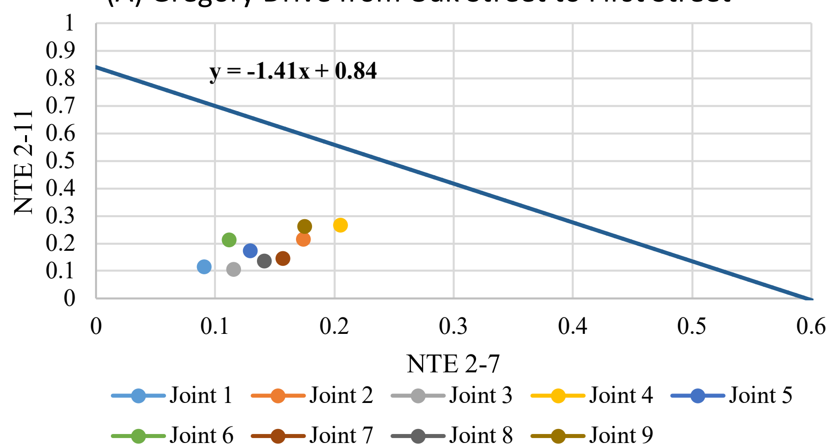
**Table 96. Joint Activation Analysis Results for Gregory Drive between Fourth Street and Sixth Street**

| Section No. and Location | Joint No. | Crack Identification | Evaluation Date | Ultrasonic Joint Evaluation |
|---|---|---|---|---|
| Gregory Dr. from 4th St. to 6th St. | 1 | Transverse crack between Joints 1 and 2 | 10/21/2020 | Inconclusive[1] |
| Gregory Dr. from 4th St. to 6th St. | 2 | Transverse crack between Joints 1 and 2; Transverse crack between Joints 2 and 3 | 10/21/2020 | Activated |
| Gregory Dr. from 4th St. to 6th St. | 3 | Transverse crack between Joints 2 and 3; No crack between Joints 3 and 4 | 10/21/2020 | Activated |
| Gregory Dr. from 4th St. to 6th St. | 4 | No crack between Joints 3 and 4; Transverse crack between Joints 4 and 5 | 10/21/2020 | Activated |
| Gregory Dr. from 4th St. to 6th St. | 5 | Transverse crack between Joints 4 and 5; No crack between Joints 5 and 6 | 10/21/2020 | Activated |
| Gregory Dr. from 4th St. to 6th St. | 6 | No crack between Joints 5 and 6 | 10/21/2020 | Activated |

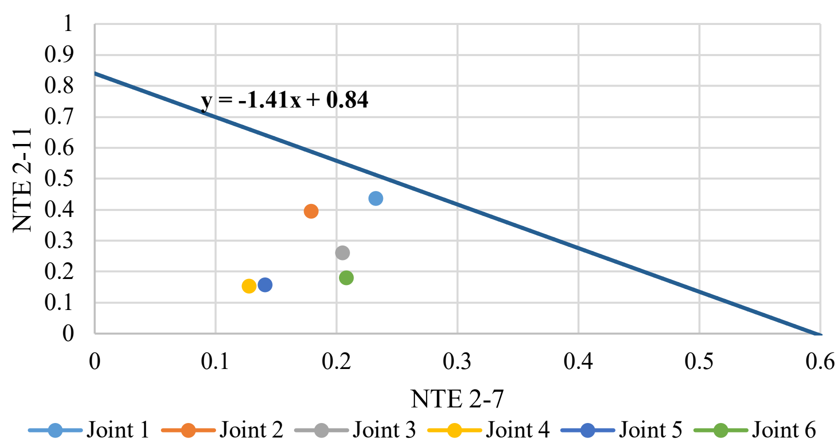
[1] Inconclusive results indicate ultrasonic joint evaluation falls on or near the hyperplane.




(A) Gregory Drive from Oak Street to First Street




(B) Gregory Drive from First Street to Fourth Street




(C) Gregory Drive from Fourth Street to Sixth Street

**Figure 131. Graphs. Gregory Drive joint activation analysis NTE results.**

## LOGAN STREET (CHAMPAIGN, IL)

The analysis performed along Logan Street was conducted between First Street and Neil Street. This section is along a bus route but has minimal traffic volume. Table 97 summarizes the results of the joint evaluation conducted along Logan Street near the intersection of Water Street heading westbound towards the underpass in Champaign, Illinois. The joint spacing in this section was 12.5 ft × 10.5 ft (L × W) panels with a curb and gutter shoulder. There were no anomalies observed based on dowel bar and tie bar spacing and depths. Figure 132 presents the NTE results. It can be observed that Joint 1 is activated; however, the remaining joints were inconclusive as they fall very close to the hyperplane. The three transverse cracks observed were all wide with spalling and were sealed. Based on these widths and apparent age of the joint sealant in the cracks, these cracks developed a number of years ago and, likely, shortly after construction. Inconclusive joints can mean activated joints or nonactivated joints with the transverse cracks are acting as the transverse joints.

**Table 97. Joint Activation Analysis Results for Logan Street between First Street and Neil Street**

| Section No. and Location | Joint No. | Crack Identification | Evaluation Date | Ultrasonic Joint Evaluation |
|---|---|---|---|---|
| Logan St. from 1st St. to Neil St. | 1 | No crack between Joints 1 and 2 | 10/28/2020 | Activated |
| Logan St. from 1st St. to Neil St. | 2 | No crack between Joints 1 and 2; Transverse crack between Joints 2 and 3 | 10/28/2020 | Inconclusive[1] |
| Logan St. from 1st St. to Neil St. | 3 | Transverse crack between Joints 2 and 3; Transverse crack between Joints 3 and 4 | 10/28/2020 | Inconclusive[1] |
| Logan St. from 1st St. to Neil St. | 4 | Transverse crack between Joints 3 and 4; Transverse crack between Joints 4 and 5 | 10/28/2020 | Inconclusive[1] |
| Logan St. from 1st St. to Neil St. | 5 | Transverse crack between Joints 4 and 5; No crack between Joints 5 and 6 | 10/28/2020 | Inconclusive[1] |
| Logan St. from 1st St. to Neil St. | 6 | No crack between Joints 5 and 6 | 10/28/2020 | Inconclusive[1] |

[1] Inconclusive results indicate ultrasonic joint evaluation falls on or near the hyperplane.

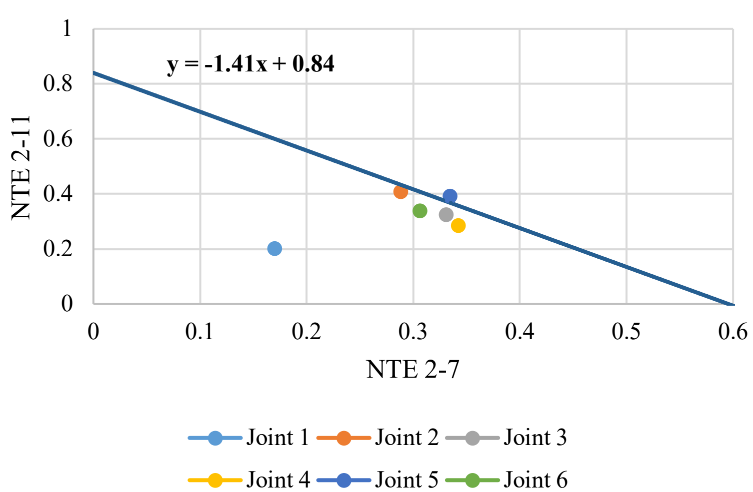



**Figure 132. Graph. Logan Street joint activation analysis NTE results.**

## CURTIS ROAD (CHAMPAIGN, IL)

The analysis performed along Curtis Road was conducted between Prospect Avenue and Duncan Road. This roadway section consists of two lanes in each direction with a central median island for part of the section. The joint spacing in this section was 15 ft × 12 ft (L × W) panels with an asphalt outer shoulder. There were no anomalies observed based on dowel bar and tie bar spacing and depths. Table 98 summarizes the results of the joint evaluation conducted along Curtis Road near the intersection of Wynstone Drive in Champaign, Illinois. Testing was conducted in the eastbound lane heading westbound. The eastbound lanes had a significant amount of transverse cracking, whereas the westbound direction had a very low percentage of transverse cracks. Ten joints were tested and spanned transverse cracks. Most of the transverse cracks were developing faulting and spalling; the cracks between Joints 6 and 7 and between Joints 8 and 9 were tight and working cracks. Figure 133 presents the NTE results and indicates five of the joints are likely not activated and five joints are inconclusive. It is possible that the poor joint activation led to the premature transverse cracking to develop early in the life of this section.

**Table 98. Joint Activation Analysis Results for Curtis Road between Prospect Avenue and Duncan Road**

| Section No. and Location | Joint No. | Crack Identification | Evaluation Date | Ultrasonic Joint Evaluation |
|---|---|---|---|---|
| Curtis Rd. near Wynstone Dr. | 1 | No crack between Joints 1 and 2 | 10/28/2020 | Not activated |
| Curtis Rd. near Wynstone Dr. | 2 | No crack between Joints 1 and 2; Transverse crack between Joints 2 and 3 | 10/28/2020 | Inconclusive[1] |
| Curtis Rd. near Wynstone Dr. | 3 | Transverse crack between Joints 2 and 3; Transverse crack between Joints 3 and 4 | 10/28/2020 | Inconclusive[1] |
| Curtis Rd. near Wynstone Dr. | 4 | Transverse crack between Joints 3 and 4; Transverse crack between Joints 4 and 5 | 10/28/2020 | Not activated |
| Curtis Rd. near Wynstone Dr. | 5 | Transverse crack between Joints 4 and 5; Transverse crack between Joints 5 and 6 | 10/28/2020 | Not activated |
| Curtis Rd. near Wynstone Dr. | 6 | Transverse crack between Joints 5 and 6; Transverse crack between Joints 6 and 7 | 10/28/2020 | Inconclusive[1] |
| Curtis Rd. near Wynstone Dr. | 7 | Transverse crack between Joints 6 and 7; No crack between Joints 7 and 8 | 10/28/2020 | Not activated |
| Curtis Rd. near Wynstone Dr. | 8 | No crack between Joints 7 and 8; Transverse crack between Joints 8 and 9 | 10/28/2020 | Inconclusive[1] |
| Curtis Rd. near Wynstone Dr. | 9 | Transverse crack between Joints 8 and 9; Transverse crack between Joints 9 and 10 | 10/28/2020 | Not activated |
| Curtis Rd. near Wynstone Dr. | 10 | Transverse crack between Joints 9 and 10 | 10/28/2020 | Inconclusive[1] |

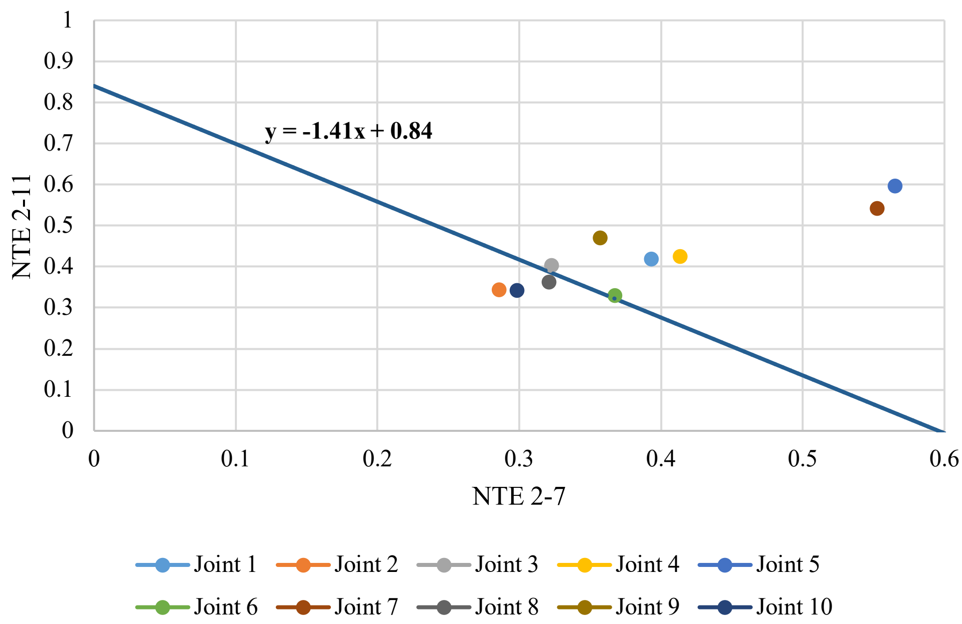



**Figure 133. Graph. Curtis Road joint activation analysis NTE results.**

## EAST ARMORY DRIVE (CHAMPAIGN, IL)

The MIRA measurements were performed along East Armory Drive between Wright Street and Sixth Street. This section is primarily trafficked by buses and delivery trucks. The thickness recorded from ultrasonic testing was between 12 to 13 in. (300–325 mm). Testing was performed heading east in the eastbound lane (one-way street). The joint spacing was 12 ft × 12 ft on average, as the panels were tapered from Sixth Street toward Wright Street. There were no anomalies observed based on dowel bar and tie bar spacing and depths. Table 99 summarizes the results of the joint evaluation conducted along East Armory Drive near Sixth Street in Champaign, Illinois. There were no observed transverse cracks in this newly constructed section. Figure 134 presents the NTE results from the analysis. The results indicate three joints are not activated and the remaining seven are activated. The three joints that were identified as not activated (Joints 2, 3, and 10) spanned a drain. Additionally, Joint 9 was a construction joint. It is possible a transverse crack may develop between Joints 2 and 3.

**Table 99. Joint Activation Analysis Results for East Armory Avenue between Wright and Sixth Streets**

| Section No. and Location | Joint No. | Crack Identification | Evaluation Date | Ultrasonic Joint Evaluation |
|---|---|---|---|---|
| E. Armory Dr. near 6th St. | 1 | No crack between Joints 1 and 2 | 10/28/2020 | Activated |
| E. Armory Dr. near 6th St. | 2 | No crack between Joints 1 and 2; No crack between Joints 2 and 3 | 10/28/2020 | Not activated |
| E. Armory Dr. near 6th St. | 3 | No crack between Joints 2 and 3; No crack between Joints 3 and 4 | 10/28/2020 | Not activated |
| E. Armory Dr. near 6th St. | 4 | No crack between Joints 3 and 4; No crack between Joints 4 and 5 | 10/28/2020 | Activated |
| E. Armory Dr. near 6th St. | 5 | No crack between Joints 4 and 5; No crack between Joints 5 and 6 | 10/28/2020 | Activated |
| E. Armory Dr. near 6th St. | 6 | No crack between Joints 5 and 6; No crack between Joints 6 and 7 | 10/28/2020 | Activated |
| E. Armory Dr. near 6th St. | 7 | No crack between Joints 6 and 7; No crack between Joints 7 and 8 | 10/28/2020 | Activated |
| E. Armory Dr. near 6th St. | 8 | No crack between Joints 7 and 8; No crack between Joints 8 and 9 | 10/28/2020 | Activated |
| E. Armory Dr. near 6th St. | 9 | No crack between Joints 8 and 9; No crack between Joints 9 and 10 | 10/28/2020 | Activated |
| E. Armory Dr. near 6th St. | 10 | No crack between Joints 9 and 10 | 10/28/2020 | Not activated |

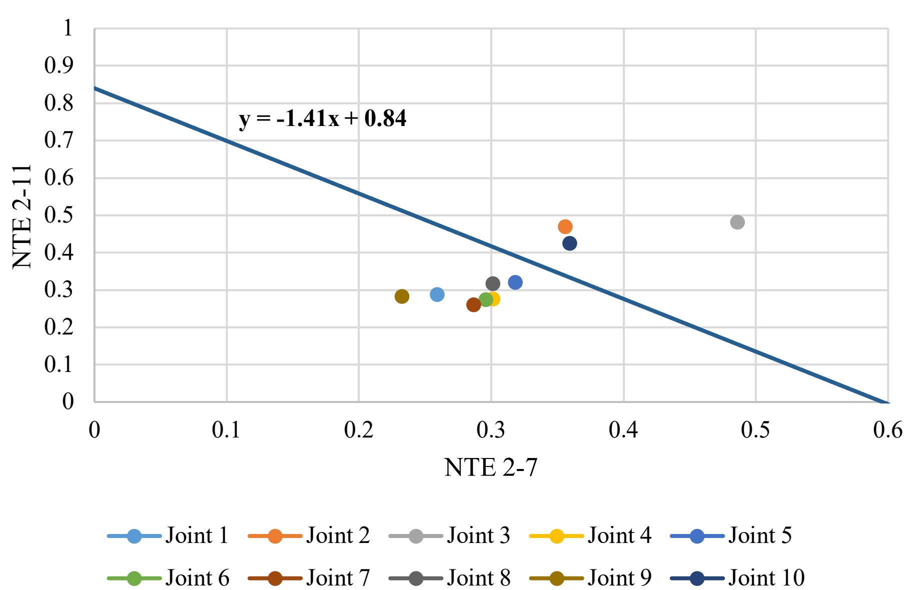



**Figure 134. Graph. East Armory Drive joint activation analysis NTE results.**

A total of 87 joints were tested on these six roads with MIRA. The MIRA testing and analysis of the sensors showed that 14 out of 87 joints (14%) are likely not activated and could be contributing to premature cracking. The section with the most nonactivated joints was Curtis Road (5 out of 10 joints). The following summary are the number of nonactivated joints on the roads surveyed: Healey Street (1/15), Green Street to Wright Street to Fourth Street (0/11), Green Street to Fourth Street to First Street (3/10), Gregory Drive (2/25), Logan Street (0/6), Curtis Road (5/10), and East Armory Avenue (3/10). It is important to ensure joint activation early in the service life, i.e., shortly after saw cutting has been performed, in order to prematurely as the stress to strength ratio is exceeded. Therefore, techniques to better predict the timing of contraction joint sawing is going to improve joint activation. Sections like Green Street between Fourth and Wright Streets, which have all activated joints, must have other contributing factors, e.g., nonlubricated dowels, that are the primary mechanism for the observed transverse cracking.

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