

Memo

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From: H. de Melo e Silva, C. Brooks

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Date: July 14, 2011

Number: 20

Re: Field Deployment and Instrument Installation and Calibration Plan

SELECTION CRITERIA

The aim of the site selection process was to identify bridges that have varying degrees of degradation with potential to be identified and quantified using the remote sensing technologies. The end goal of the site selection was to identify three bridges within the State of Michigan that can be inspected (visual and detailed), tested, and evaluated using both traditional structural health monitoring techniques (strain gauges, deflectometers, accelerometers, live load vehicles, hammer-sounding, chain-drag, etc.) for correlation as well as remote sensing technologies (thermal infrared, 3D optics, radar, etc.).

To allow for a more comprehensive assessment of each technology, the selection criteria was defined accordingly by using the National Bridge Inventory (NBI) rating scale (see Table 1) along with current MDOT assessment practices. The “poor”, “fair”, and “satisfactory” selections were determined by correlating NBI deck ratings of four, five and six (or better) respectively. Finally, the remaining candidate bridges were separated by item “43: Main span(s) material type” of the Michigan Department of Transportation (MDOT) structure inventory and appraisal form (such as pre-stressed concrete box beam versus steel continuous). To further refine the selection process preliminary site visits and appraisals were conducted allowing for visual observation and validation of documented deficiencies recorded in past inspection reports.

Following the completion of the preliminary site visits, photographs were collected and organized. This image database was then used to generate discussion about each particular

bridge and the suite of technologies' implementation capability. All the technologies were judged individually for each bridge with a focus on four criteria; (1) presence of sensing deficiencies, (2) accessibility, (3) setup, and (4) sampling. During this process the deck top surface, bottom surface and bridge superstructure were of particular importance. Additionally, three supplemental bridges had been selected, one for each category in case of unforeseen issues will the selected bridges.

National Bridge Inventory Rating Scale:

9-Excellent Condition

8-Very Good Condition: No problems noted

7-Good Condition: Some minor problems

6-Satisfactory Condition: Structural elements show minor deterioration

5-Fair Condition: All primary structural elements are sound, but may have minor corrosion, cracking, or chipping. May include minor erosion on bridge piers.

4-Poor Condition: Advanced corrosion, deterioration, cracking, or chipping. Also, significant erosion of concrete bridge piers

3-Serious Condition: Corrosion, deterioration, cracking and chipping, or erosion of concrete bridge piers have seriously affected deck, superstructure, or substructure. Local failures possible.

2-Critical Condition: Advanced deterioration of deck, superstructure, or substructure. May have cracks in steel or concrete, or erosion may have removed substructure support. It may be necessary to close bridge until corrective action is taken.

1-"Imminent" Failure Condition: major deterioration or corrosion in deck, superstructure, or substructure, or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic, but corrective action may put it back in light service.

0-Failed Condition: Out of service, beyond corrective action.

Table 1: Table showing National Bridge Inventory (NBI) rating scale (0-to-9) and brief description.

The following deployment sites have been selected for field demonstration of remote sensing technologies (see the 'A', 'B', and 'C' pins in Figure 1):

- 'A' – MDOT structure n^o 1713 – Mannsiding Road over US-127 north bound
- 'B' – MDOT structure n^o 10892 – Willow Road over US-23
- 'C' – MDOT structure n^o 10940 – Freer Road over I-94

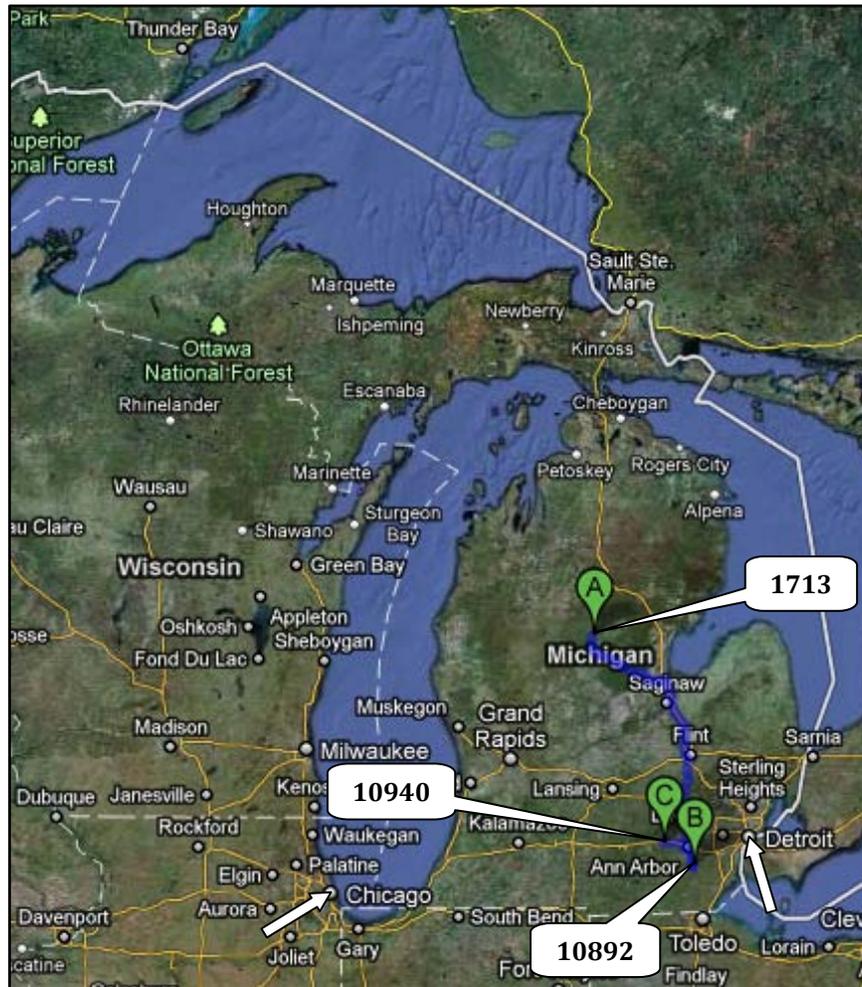


Figure 1: Location of all three bridges (poor 'A', fair 'B', & satisfactory 'C') in relationship to the State of Michigan and the cities of Chicago and Detroit.

“Poor Bridge” Selection

MDOT structure n^o 1713 – Mannsiding Road over US-127 north bound; located in Clare County approximately 10 miles north of Clare, Michigan was determined to be the best candidate for field demonstration (see Figure 2).

The field demonstration candidate structure serves Mannsiding Road; a “Major Collector” road. The bridge was constructed in 1966 and is a 3-span pre-stressed concrete multi-I-beam composite structure. The structure is 130'-6” in length, 31'-5” in width, which translate into 26' of open roadway riding surface. During 1996 the average daily traffic (ADT) over the structure was found to be 1,000 with 3 % being commercial.



Figure 2: Aerial view of MDOT structure nº 1713 – Mannsiding Road over US-127 north bound.

Currently the bridge has no posted speed limit restriction. The crossing spans north bound US-127; a National Highway System (NHS) route that is not within any federal-aid urban boundary. The bridge doesn't meet the desired minimum vertical clearance for NHS routes. This is located 2.3 miles south of M-61 or approximately 5.5 miles south of Harrison on US-127. The structure is part of an interchange serving the greater Harrison area, which is considered to be a rural environment. Figures 3 and 4 show two photos of the bridge - one taken in 2008 during a MDOT scoping/inspection that provided detailed condition information, and the other by the research team during a site visit in June 2011. The structure is located in Hatton Township within Clare County.

The current condition of the deck surface is an area of major focus and concern; it's rated at a "4" on the NBI scale. In 2008, a detailed inspection and scoping were completed of the top and bottom of the deck surface (project team has access to this report from MDOT). The scoping revealed that on the top surface of the concrete deck 176 ft² or 4.4 % of the deck was delaminated. Additional testing on the bottom surface revealed that 623 ft² or 15 % of the deck was in distress. The deck also possesses light scaling throughout and numerous transverse, longitudinal and diagonal cracks are present. In concern with the superstructure several high-load hits have resulted in scrapes and spalls but currently there is no sign of exposed reinforcing steel or pre-stressing strands. The bridge is scheduled for complete replacement in 2012/13.



Figures 3 & 4: Photos of the Mannsiding Road bridge, from a 2008 MDOT scoping report (left), and from a June 2011 site visit (right).

Due to the location and low ADT over the bridge, Mannsiding Road is very suitable for deployment of multiple technologies. Pertaining to the two major structural components of concern in this research project, the deck (top and bottom surface) and superstructure six technologies can be instituted. These six technologies that work for both deck and superstructure are;

- 3D Optics (3DO)
- Street-view Style Photography (SVSP)
- Thermal Infrared (ThIR)
- Digital Image Correlation (DIC)
- Light Detection and Ranging (LiDAR)
- Synthetic Aperture Radar (SAR)

“Fair Bridge” Selection

MDOT structure n^o 10892 – Willow Road over US-23; located in Washtenaw County approximately 3 miles north of Milan, Michigan was determined to be the best candidate for field demonstration (see Figure 5).

The field demonstration choice structure serves Willow Road; a “Major Collector” road. The bridge was constructed in 1962 and is a 4-span pre-stressed concrete multi-I-beam composite structure structure. The structure is 209’ in length, 30’-10” in width, which translate into 26’ of

open roadway riding surface with no availability for shoulder room. During 1997 the ADT over the structure was found to be 2,220 with 3 % being commercial.

Currently the bridge has no posted speed limit restriction. The crossing spans both north and south bound US-23; a NHS route that is not within any federal-aid urban boundary. The bridge does not meet the desired minimum vertical clearance for NHS routes. The structure is located in York Township within Washtenaw County.



Figure 5: Aerial view of MDOT structure n° 10892 - Willow Road over US-23.

The current condition of the deck surface is rated at a “5” on the NBI scale. In 2010, the inspection report indicates that open transverse cracks, diagonal cracks and areas of delamination are present throughout the deck. Concrete patching has been done to help minimize deterioration and prolong the service life of the bridge. Additionally areas on the bridge superstructure display desired sensing deficiencies over both the north and south bound lanes. This is attributed to several high-load hits which have resulted in scrapes and spalls but currently there is no sign of exposed reinforcing steel or pre-stressing strands. Figure 6 shows a photo of the bridge deck.



Figure 6: An example photo of the bridge deck of the Willow Road bridge taken on May 13, 2011 (note the variety of visible deck surface defects).

Due to the location and low ADT over the bridge, Willow Road is very suitable for deployment of multiple technologies. Pertaining to the two major structural components of concern in this research project, the deck (top and bottom surface) and superstructure five technologies can be instituted. These five technologies that work for both deck and superstructure are:

- 3D Optics (3DO)
- Street-view Style Photography (SVSP)
- Thermal Infrared (ThIR)
- Light Detection and Ranging (LiDAR)
- Synthetic Aperture Radar (SAR)

“Satisfactory Bridge” Selection

MDOT structure n^o 10940 – Freer Road over I-94; located in Washtenaw County approximately 1 mile east of M-52 in Chelsea, Michigan was determined to be the best candidate for field demonstration (see Figure 7).

The field demonstration candidate structure serves Freer Road; a “Major Collector” road. The bridge was constructed in 1960 and is a 4-span pre-stressed concrete multi-I-beam composite

structure. The structure possesses dimensions of 209' in length, 30'-10" in width, which translate into 26' of open roadway riding surface with no available for shoulder room. During 1997 the ADT over the structure was found to be 150 with 3 % being commercial.



Figure 7: Aerial view of MDOT structure n° 10940 - Freer Road over I-94.

Due to its low ADT, this structure will be the first to be tested which allows for researchers to work in an even safer environment while causing minimal disruption to local traffic going over the bridge.

Currently the bridge has no posted speed limit restriction. The crossing spans both east and west bound I-94; a NHS route that is not within any federal-aid urban boundary. The bridge does meet the desired minimum vertical clearance for NHS routes with a measured clearance of 16'. The structure is located in Lima Township within Washtenaw County.

The current condition of the deck surface is rated at a "6" on NBI scale. In 2010, the inspection report indicates that there were several areas of concrete patching accompanied by few tight transverse and diagonal cracks present on the deck. Concrete patches have been applied to help minimize deterioration and prolong the service life of the bridge. The report indicates that

there are also areas of interest on the superstructure where the concrete material has spalled and cracked. These areas of interest are located at the beam-end locations on the bottom flange. None of the spalled sections are currently deep enough to expose any reinforcing steel or pre-stressing strands (Figures 8 and 9 show two sample photos of the bridge).



Figures 8 & 9: Two sample photos taken of the Freer Road bridge over I-94 on May 13, 2011.

Due to the location and low ADT over the bridge, Freer Road is highly suitable for deployment of multiple technologies. Pertaining to the two major structural components of concern in this research project, the deck (top and bottom surface) and superstructure five technologies can be instituted. These five technologies that work for both deck and superstructure are:

- 3D Optics (3DO)
- Street-view Style Photography (SVSP)
- Thermal Infrared (ThIR)
- Light Detection and Ranging (LiDAR)
- Synthetic Aperture Radar (SAR)

FIELD DEMONSTRATION DESIGN

The proposed field demonstration time has been narrowed down to the first two weeks of August; actual days are pending weather and closure timing and availability. The first structure to be tested is planned to be the “satisfactory” condition bridge (MDOT n^o 10940), followed the “fair” condition bridge (MDOT n^o 10892), and the “poor” condition bridge (MDOT n^o 1713) respectively (see Figure 10).

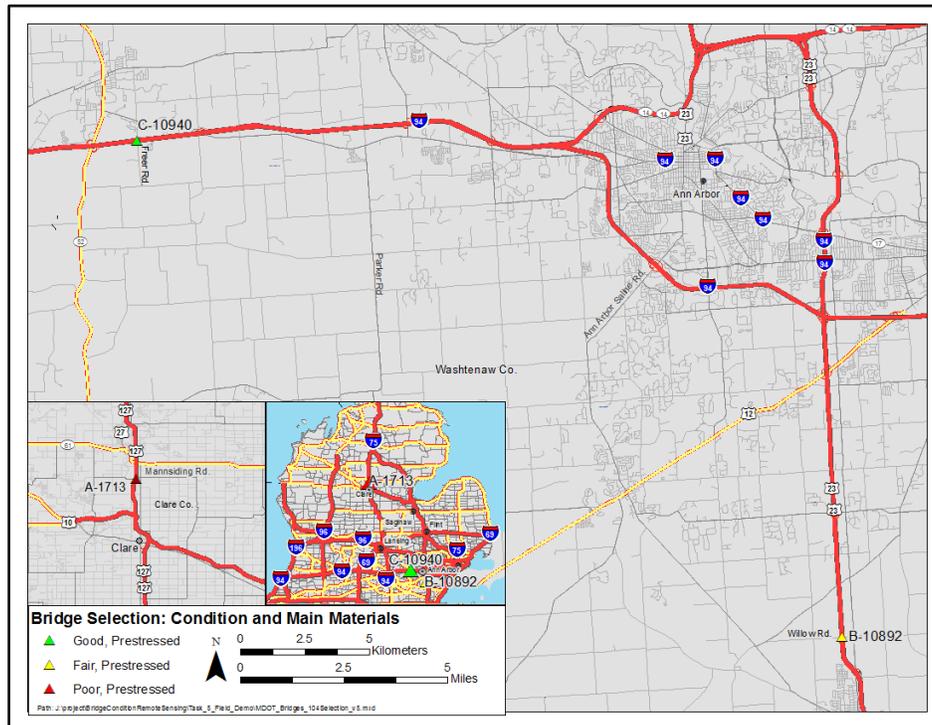


Figure 10: Close up of the locations of all three bridges shown in the Decision Support System (DSS) interface in relationship to Ann Arbor and the State of Michigan.

The projected schedule currently estimates that at a minimum one day per bridge will be necessary to gather all data in a timely fashion since not all technologies can be deployed at the same time including some that are restricted by the time of day and the need to have the bridge deck clear of all personnel and equipment. Up to three days per bridge, if needed, are currently available thanks to MDOT. Additional days may be requested and scheduled if revisits are needed to collect additional or more refined data.

For establishing ground-truth, the research team is requesting that a MDOT certified bridge inspector be present during the field testing and inspect the entire structure for correlation purposes (e.g., delamination maps, spall maps, crack maps, roughness, etc) with all the remote sensing technologies being deployed on the three selected bridges.

3D Optics (3D0)

In order for the team's optical Nikon D5000 digital single lens reflect (DSLR) camera to capture the sharpest image of the suspect deck surface, lighting is a critical parameter. The conditions for optimal image capture are as follows: sun or artificial light source, a preferably dry surface,

no foreign surface containments and limited vehicle/pedestrian interference. It is not necessary for the lighting to stay consistent throughout the image collection process, but for best results it is preferred. This has been validated from previous testing completed at the Michigan Tech Research Institute (MTRI) showing that the sharpest three-dimensional models are generated by proper and consistent lighting conditions. This is associated with the post-processing software's ability to more accurately distinguish points of commonality between stereo pairs.

The MDOT certified inspector present would generate a scaled deck spall and roughness map allowing for the post-processed 3D photogrammetric data to be correlated with the inspection results. The team will follow the following steps for field deployment of the 3D optics system:

- Assemble the vehicle mount (see Figures 11 and 12)
- Attach the Nikon D5000 camera being used for the field test
- Drive across the bridge at a speed around 2 mph (4x4 low at idle speed)
- As the truck drives across bridge, camera will take photos at 1 fps
- Repeat pass on the other lane of the bridge

Once at the site, the vehicle mount for the 3D system is put together, the camera is mounted and the vehicle mount is strapped down to the bed of a truck. The camera is then connected to the computer and then tested to make sure there is a good connection and everything is working properly. Once everything is ready, the truck drives along the bridge at a slow speed (currently 1-to-3 mph); this has been achieved by putting the truck into 4x4 low and letting it idle across (see Figures 11 and 12). Note that potential future systems would be able to cross at higher speeds if more advanced digital cameras are used.



Figures 11 & 12: 3D Optics (3DO) data collection system deployed for pre-field demonstrations trials.

The camera is set to take photos once per second (1 fps) during the collects. The combination of the vehicle speed and the camera's continuous shooting allows for at least a 60 % overlap in the photos (which is necessary for 3D photogrammetry) and due to the height of the camera we are able to cover one full lane width on a bridge. On the selected bridges, we would need two passes to cover the entire bridge.

Street-view Style Photography (SVSP)

For field deployment of the team's SVSP system, the BridgeViewer Remote Camera System (RCS), two sets of steps are needed. The BridgeViewer RCS comes in two versions developed by MTRI, a (1) "Bridge Deck" version for imaging the surface of the deck, and a (2) "Bridge Underside" version for taking more rapid photography while traveling under a bridge to image the underside.

The deployment steps for bridge-deck version are:

- Take a picture of Garmin GPS unit being used to geo-tag the photos later
- Mount the cameras to the hood of the car (see Figure 13)
- Align the cameras so that their field of views overlap in the center of the lane
- Drive over bridge at 5 mph while capturing images once every four seconds

And the deployment steps for bridge-underside version are:

- Take a picture of Garmin GPS unit being used to geo-tag the photos later
- Assemble vehicle mount with camera and lights (see Figure 14)
- When approaching the bridge, turn on the lights and start taking photos at 1 fps
- Drive along both lanes to collect full coverage under the bridge

Both systems can be deployed during the field demonstrations and finished with data collection in less than 30 minutes each. Data will be processed in the MTRI GIS lab into a geo-tagged photo inventory of each bridge for inclusion in the Decision Support System (DSS) (see Figure 10).



Figures 13 & 14: Example deployments of the “Bridge Deck” (left) and “Bridge Underside” (right) versions of the BridgeViewer Remote Camera System (RCS).

Thermal Infrared (ThIR)

Several factors need to be considered for the FLIR SC640 or FLIR i7 ThIR cameras to capture the temperature differential on the concrete deck. These factors include: clear sky, sun, dry surface, no foreign surface containments and limited vehicle/pedestrian interference.

When all the provided criteria are satisfied, the image should be captured during the mid-morning to mid-day sun (10 am to 2 pm) for best results. This has been validated through previous laboratory testing completed at Michigan Technological University (MTU) showing that the largest radiant temperature differential occurs during this time period exposing anomalies and subsurface delaminations. This is associated with the disruption of heat transfer through the concrete deck in defective areas allowing for the defective areas to warm up sooner than areas with no defects and thus generating an area with higher temperature compared to an area of intact concrete.

For establishing ground-truth, the MDOT certified bridge inspector present during field demonstration would perform a hammer-sounding and/or a chain-drag on the deck surface. The inspector would also generate a scaled deck delamination map allowing for the post-processed infrared data to be correlated with the MDOT delamination survey results.

A pair of both ThIR and optical images are to be collected at predetermined intervals along the bridge deck using the SC640 and/or i7 for ThIR imaging and a Canon EOS 7D and/or Nikon

D5000 DSLR cameras for optical imaging (SC640 can also be used for taking optical photos and videos of the surface).

The SC640 camera will be mounted on a moving cart at an appropriate height to capture the required field-of-view (FOV). Table 2 includes the horizontal and vertical FOV for each specific height for the SC640 camera and the time intervals of taking images based on the speed of the camera. The number of required images in transverse and longitudinal direction can be determined based on horizontal and vertical FOV of the camera at the specific height, respectively.

Height (ft)	HFOV (ft)	VFOV (ft)	Speed (mph)	period of taking images (s)	freq (Hz)	Frames (n^0)
24	10.32	7.68	5	1.0450944	0.956851	1
12	5.16	3.84	5	0.5225472	1.913703	2
10	4.3	3.2	5	0.435456	2.296443	3
7	3.01	2.24	45	0.0338688	29.5257	30
7	3.01	2.24	6	0.254016	3.93676	4
7	3.01	2.24	1.5	1.016064	0.98419	1
6.5	2.795	2.08	1.4	1.01088	0.989237	1
6.2	2.666	1.984	1.3	1.038395077	0.963025	1
6	2.58	1.92	5	0.2612736	3.827405	4
6	2.58	1.92	1.3	1.004898462	0.995125	1
5	2.15	1.6	5	0.217728	4.592887	5

Table 2: HFOV and VFOV of the FLIR SC640 ThIR camera at various heights.

The ThIR camera can be set to take a sequence of images on specific time intervals or frame rate. Corresponding optical images can be captured either by the DSLR camera or by converting optical video captured by FLIR camera into images. Optical videos should be converted to images based on the specific time intervals to cover the required vertical FOV. Each of the images has to be correlated with their respective counterparts and assembled into a comprehensive “bridge deck photograph” revealing to the user all subsurface anomalies layered over an optical rendering.

The ThIR images will need to be stitched together to create a delamination map of the deck surface. The FLIR ThermaCAM software will be used to create boxes around the delaminated areas and calculate the area based on the number of pixels. The area of delamination can also

be calculated by comparing the boxed area to a reference area on the bridge deck. Figure 15 shows the cart with fabricated wooden frame for collecting the ThIR images. The height of the camera lens to the deck surface should be ~ 6.2 ft giving about a 2.67 ft by 1.98 ft FOV (5.29 ft^2), allowing for the ThIR camera to take images 1 fps while the cart rolls along at ~ 1.3 mph.



Figure 15: FLIR SC640 ThIR camera mounted on the cart for field demo.

Chalk lines will be drawn on the deck top surface to facilitate the data collection procedure. Figure 16 shows a diagram of the deck. As it can be seen in this figure, data collection of the whole bridge requires 8 passes. Duration of data collection will be approximately 20 minutes for Freer Road and Willow Road and 15 minutes for Mannsiding Road. This excludes the time duration between each pass.

For taking the ThIR images of the deck bottom surface, the height of the camera varies depending on the standing point (on the shoulders or on the highway below). ThIR images can be taken between each girder and stringer. Any false decking has to be removed prior to inspection. ThIR images can also be taken from pre-stressed concrete girders and stringers and can be saved based on the girder's number.

The experiment requires one hour of preparation and installation of equipments on the bridge deck. Once the installations are completed ThIR and optical image collection will commence, which is estimated to take up to four hours between 10 am to 2 pm.

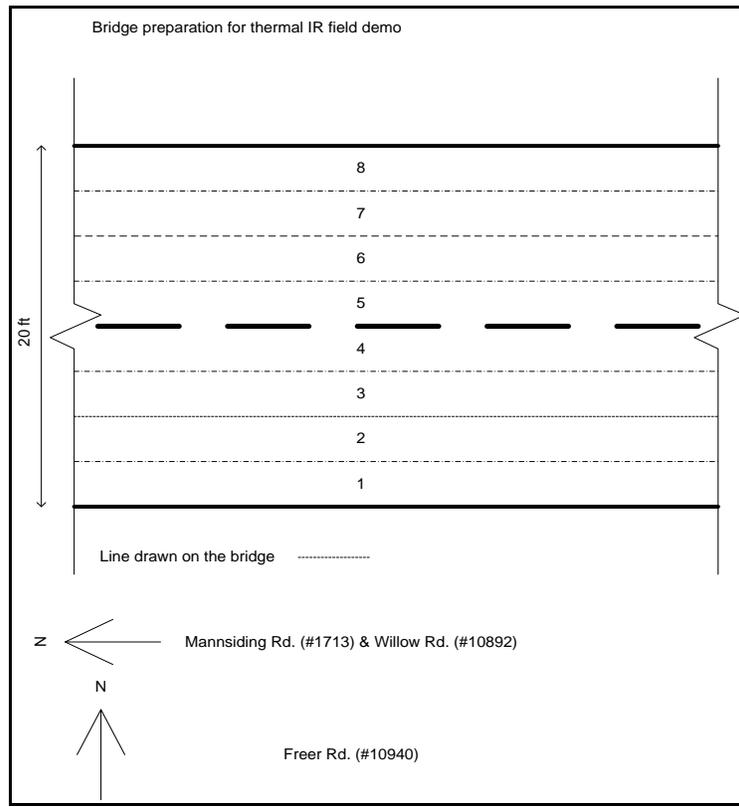


Figure 16: Diagram of the deck surface showing lanes which ThIR camera-equipped cart will travel on.

Digital Image Correlation (DIC)

DIC will be used on MDOT structure n^o 1713 – Mannsiding Road over US-127 north bound. The Mannsiding Road bridge will be used to verify the capabilities of the technique and application for structural health measurements such as displacement and strains. DIC will not be deployed on the two other bridges due to the involved permitting process for live-load testing. Procedures involved in the field demonstration consist of:

- Field setup design
- Deployment of field instrumentation
- Live load testing (loaded trucks)
- DIC testing (image collection)
- Post-processing of data

Mannsiding Road bridge has 3 major spans; to prepare for the load test, the bridge will be instrumented with traditional equipment such as deflectometers for deflection monitoring; and gauges for strain data collection. Several accelerometers will be placed near the testing locations to monitor the frequency range on the bridge. The instrumentation plan originally focused on the midspan and quarter point locations of the span. Since the midspan is over highway, US-127, and if the center of the midspan is not accessible, testing locations are suggested for the side spans and near the quarter points of the midspan. Therefore, each testing location would have a deflectometer and two strain gauges for validation measurements.

Implementation of DIC consists of markers or a spray-paint pattern of contrasting dots on the structural I-beam span to be measured. Through experimentation, it is suggested that the appropriate size distribution can be achieved by obstructing the direct flow of paint from the nozzle by using one's finger placed 0.5-to-1 inch in front of the nozzle opening.

A pre-determined bridge span is to be stressed by both a quasi-static and dynamic live-load generated by a live-load test truck. During loading, images will be captured by a Canon EOS 7D DSLR on the exterior girder of the superstructure at the quarter points of the midspan and on the side span near the abutment locations. In order to establish ground-truth with DIC tests, deflectometers and strain gages will be mounted at the previously discussed locations of interest along the exterior girder on the extreme tension face of the bottom flange of the girder for deflection and strain measurements.

The quasi-static test is to evaluate static deflection of a structural element through both remote sensing instrumentation and traditional sensing technology, then correlating the results. There will be a weighted truck of (e.g., 37.5 kip) for the load testing on Mannsiding Road. All of the quasi-static tests are to be performed at "crawl" speeds of 10 mph or less, to minimize the dynamic amplification and allow the truck to follow lines marked on the bridge deck. The required recording rate for the displacement and strain data is 20 Hz, which covers the entire spectrum of the predicted truck crossing. The dynamic test will be performed to determine how accurately the remote sensing technology can capture an optically sense bridge vibration. The dynamic tests are to be performed at posted speed to mimic actual service conditions. For this test situation the displacement and strain data sample rate is to be set at 200 Hz to cover the entire spectrum produce by highway speeds. A minimum of three repetitions per load combination is requested for both the quasi-static and dynamic load testing with the truck crossing in the same direction as previously.

A series of digital images per location of interest are to be collected at fixed intervals using the EOS 7D with a zoom capable lens (e.g., 300 mm). The camera is to be placed 15 ft (which can

vary) from the target surface on a rigid tripod at no more than a horizontal angle of 180° and a vertical angle of 90°. The images are numbered automatically by the camera's firmware, and each of the images is to be correlated with the known load applied during the load test to the bridge span at that time.

The experiment requires 3-to-4 hours of preparation work applying and calibrating the required deflectometers and strain gages on the selected bridge span. Once bridge preparations are completed, live-load stressing of the bridge span, collecting optical images and displacement and strain data will take nearly 2-to-4 hours.

Data collected from the conventional instrumentation and DIC procedures from the load test will be processed and analyzed. The information gathered from the cameras will be processed in computer software tools such as The MathWorks MATLAB and Correlated Solutions Vic-2D for strain and displacement measurements. This will be verified with the conventional strain gauge sensors and deflectometer devices used on the bridge. This data will also be correlated with an FEM of Mannsiding Road to compare simulated behavior with actual bridge response.

Light Detecting and Ranging (LiDAR)

Compared to traditional surveying equipment, a LiDAR instrument can collect millions of data points in a single pass of a suspect object allowing for detailed analysis to be completed. The issue arises when the object has many faces producing "shadows" or "blind spots" in the instrumentation field of sight. This line of sight issue can be resolved by repositioning the device allowing for the hidden sections of the object to be revealed. This allows for a full three dimensional rendering of the object after the multiple collection points are fused together. Lastly, since light is absorbed by water LiDAR cannot penetrate any water barrier, so the bridge surface should be dry allowing for limited interference.

For establishing ground-truth, the research team is requesting that a MDOT certified bridge inspector be present during field demonstration and performs a visual inspection of the surface condition. Cracking, scaling, and spalling should be identified and documented allowing for the research team to correlate the inspection results with the post-processed three dimensional LiDAR rendering.

Prior to initializing the LiDAR data collection, a minimum of four points of commonality must be established in order to triangulate and validate a local coordinate system. By establishing these points of commonality the independent LiDAR images can be referenced in a common local

coordinate system allowing for a layered three-dimensional rendering eliminating the presence of “shadows”. For this particular field demonstration, six retro reflective prisms should be used to generate the required points of commonality. The reasoning for instituting two additional points of commonality is attributed to the increased flexibility and accuracy of the data collection process. To clarify, the two additional points allows the LiDAR unit to be located anywhere within the area of concern where a minimum of four points were in direct line of sight to the device. Additionally, when all six points are visible in retrospect to the LiDAR unit’s position, data accuracy of the scanned bridge will increased.

Once a local coordinate system is established the optical camera mounted on the LiDAR unit will have to be adjusted for lighting conditions. The purpose of this optical camera is to allow the integration of a color scale into the generated LiDAR rendering.

Testing should last roughly four hours, which includes setup, six to eight separate scan locations and demobilization. A simple survey location map has been constructed to help accelerate the actual selection during data collection (see Figure 17). To be more precise, once the crew is on-site it will 30 minutes to assemble, and position the Riegl LMS-Z210ii LiDAR unit (see Figure 18) in the first scanning location along with the six retro reflective prisms for the points of commonality. Note the opportunity to gain access to MDOT's terrestrial Leica LiDAR system for deployment at the three bridge sites, in coordination with MDOT LiDAR experts is being investigated.

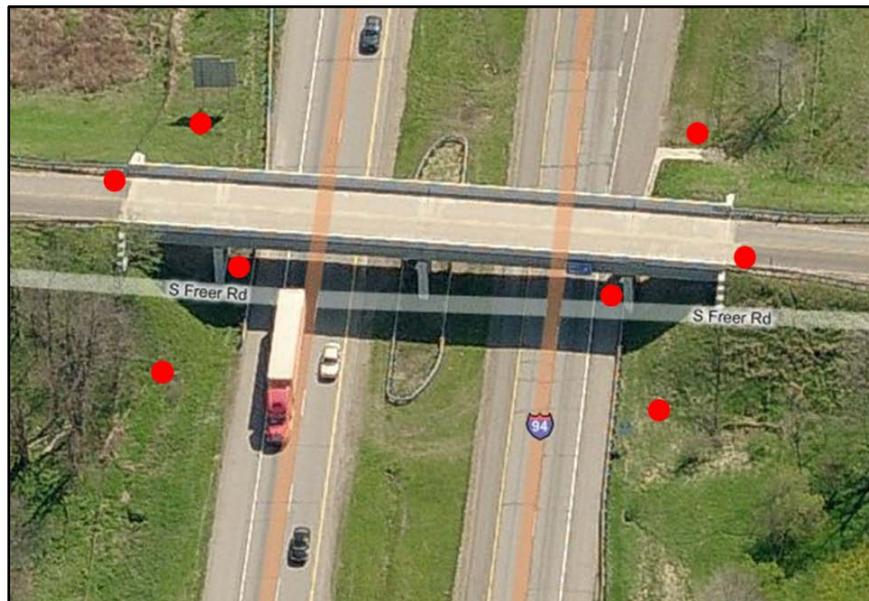


Figure 17: Possible survey points for Freer Road bridge.

When the equipment positions is fixed, an initial LiDAR scan lasting approximately five minutes of the entire surrounding area must be completed allowing for the technician to establish the points of commonality within the image by identifying the center of the retro reflective prisms. Once the points are located, a more detail scan at a higher resolution lasting approximately ten minutes is completed by selecting a window on interest from the initial rendered image. The previously discussed process is to then be repeated five to seven additional times allowing for a final three-dimensional rendering of the subject bridge.

Additional to the bridge surface condition scanning, MTU is planning on utilizing the equipment to measure deflections during live load testing in correlation with DIC. This portion of the data collection is expedited to take an additional 30 minutes for data collection.



Figure 18: Typical Reigl LiDAR unit setup.

The experiment requires one hour of preparation and installation of equipments on-site. Once the installations are completed the LiDAR survey and optical image collection is estimated to take around four hours.

Synthetic Aperture Radar (SAR)

MTRI's 2D Radar will look at bridge deck top surface to detect sub-surface delaminations. The radar will be setup in one lane and image the other lane, requiring blocking of two lanes (see Figure 19). No vehicle or pedestrian traffic should be present on the bridge during data collection.

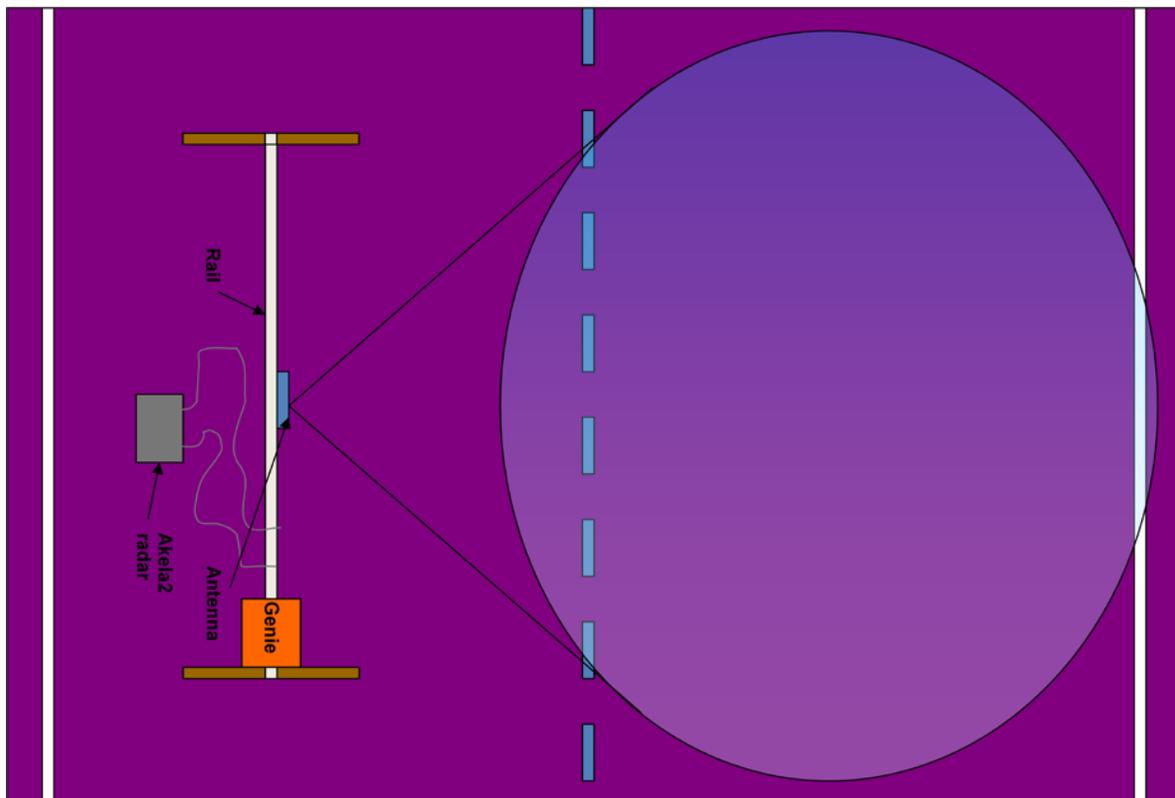


Figure 19: The setup of the project's 2D radar sensing system for detecting bridge delaminations.

Initial translator setup and radar calibration is anticipated to take approximately one hour. These steps include assembling translator fixture with radar antenna, cabling radar to the antenna, cable power from a generator, and setting up fiducials. This will be at a minimum a two person job.

Data collection for three 5 m by 10 m (50 m²) scenes will take approximately two hours. Multiple passes at two heights will be done. Moving to a new patch will require minimal time (about 15 minutes). The translator can be moved without breaking down the unit. The radar itself is disconnected, moved, and re-connected at the next patch to be scanned.

Equipment break-down and removal is expected to take one hour. Total collection time for three scenes will be about four hours (including setup and break-down). Environmental requirements are dry, but no time of day constraint (radar data can be collected at day or night). Ground-truth of bridge delamination will be needed, from chain-drag surveys and possible deck coring.

Interferometric Synthetic Aperture Radar (InSAR)

InSAR analysis methods are currently underway for the project, but are being used at three bridges that have undergone an elevation change (e.g., settlement, heave) and can be detected through the use of multiple SAR satellite images. As this does not need any deployment of equipment or personnel for this satellite imagery-based analysis, no further deployment planning is needed for this field study.

SAFETY PLAN

For actual field demonstration the United States Department of Transportation (USDOT) and MDOT require the wear of personal protective equipment (PPE) at all times. The use of PPE on site will follow, and be in accordance with, USDOT and MDOT's PPE policies. Instructions and adequate training will be provided prior to actual field test date.

In order to ensure inspector, researcher, traffic, and pedestrian safety during field demonstration a MDOT, Washtenaw-, and Clare-County Road Commission approved traffic plan will be instituted with full- and or partial-bridge and lane closures enforced were necessary to guarantee a safe and undisturbed work site. Hood mounted amber warning lights will also be deployed where necessary (e.g., data collection vehicles traveling below posted speed limit).

In all, municipal, county, state, and federal laws, safety and other wise, will be followed.