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IMPLEMENTATION OF REMOTE SENSING TECHNOLOGY ON THE I-64 BRIDGE OVER US 60
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IMPLEMENTATION OF REMOTE SENSING TECHNOLOGY ON THE I-64 BRIDGE OVER US60

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U.S. Department of Transportation

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Remote sensing devices have been implemented on the I-64 Bridges over US60 in Franklin County, KY. One of the girders in the westbound bridge has been previously repaired due to unexpected fatigue cracking. The exterior girder in the eastbound bridge has shown signs of impacts due to the traversing trucks on US60. Sensing and recording devices such as strain and temperature gauges, infrared sensors, ultrasonic height detectors, and an accelerometer have been installed. Specifically, eleven strain gauges are used on the repaired girder, impacted girders, and girders adjacent to them. Two sets of infrared sensors, ultrasonic detectors, and video cameras are placed to capture the impacting truck(s). Overall structural responses will be studied through data collected from the strain and temperature gauges, and accelerometer.

Data are stored on-site, but the investigator has the flexibility of transmitting or viewing the data, live or stored, via an internet connection.
EXECUTIVE SUMMARY

The three-span parallel bridges of I-64 over US 60 are the first bridges in the state of Kentucky implemented with sensing technology and devices that allow monitoring of the bridge from a station afar. The bridge is located approximately twenty miles away from its monitoring station at the Kentucky Transportation Center, University of Kentucky, Lexington, KY.

One of the girders in the westbound bridge has previously been repaired by steel plate bonding due to unexpected fatigue cracking in the welding material. The exterior girder in the eastbound bridge has exhibited signs of impact due to trucks traversing underneath the bridge. Devices such as strain gauges, temperature gauges, infrared sensors, ultrasonic height detectors, accelerometers, and video cameras have been implemented and they will help determine and study the response of the bridge under ambient and impact conditions.

Specifically, eleven strain and temperature gauges are used. One strain gauge is placed on the repaired girder. The remaining gauges were placed in the adjacent girder, girders in the opposite end of the same bridge, and similar girders in the adjacent eastbound bridge. Two infrared sensors and two ultrasonic height detectors are used, one of each set in each of the individual bridges. The potential impact will be detected when the infrared sensor is triggered, signifying the passing of a truck that has sufficient height to cause impact. Ultrasonic detectors are subsequently activated to take measurement of the truck’s height. The ultrasonic detectors have a range up to ten feet. Visual evidence of the impacting truck will be subsequently captured by the two on-site cameras.

A station that houses an AC power outlet supplied by the Frankfort Plant Board which powers a DC supply that provides current to the infra-red and ultrasonic sensors is constructed on-site. The recorded data (i.e., strain readings, acceleration or vibration) will be stored at an on-site station, and are accessible at the remote station via an internet connection established using a cable modem; thus the data and visual images of the bridge site can be viewed live.
ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

EXECUTIVE SUMMARY i
ACKNOWLEDGEMENTS ii
LIST OF FIGURES iv

1. INTRODUCTION

1.1 THE I-64 BRIDGES OVER US 60 1
1.2 PROJECT OBJECTIVE AND SCOPE 1

2. IMPLEMENTATION OF REMOTE SENSING TECHNOLOGY 4

2.1 SENSING TECHNOLOGY AND DEVICES 4
2.1.1 Strain Gauges 4
2.1.2 Temperature Gauges 5
2.1.3 Infrared Sensors 9
2.1.4 Ultrasonic Height Detector 9
2.1.5 Accelerometer 10
2.1.6 Video Camera 11

2.2 POWERING SENSING TECHNOLOGY AND DEVICES 13
2.3 SITE-TO-REMOTE STATION CONNECTION 13

3. SUMMARY AND CONCLUSION 14
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.1</td>
<td>I-64 Bridges over US60</td>
<td>2</td>
</tr>
<tr>
<td>Figure 1.2</td>
<td>Steel plate girders in the westbound bridge near the approach. An interior girder that was previously repaired is shown</td>
<td>3</td>
</tr>
<tr>
<td>Figure 1.3</td>
<td>Repair of Girder 3 using steel plate bonding</td>
<td>3</td>
</tr>
<tr>
<td>Figure 2.1</td>
<td>An overview of the remote sensing technology implementation plan</td>
<td>5</td>
</tr>
<tr>
<td>Figure 2.2</td>
<td>Implementation of strain gauges on the westbound bridge</td>
<td>6</td>
</tr>
<tr>
<td>Figure 2.3</td>
<td>Implementation of strain gauges on the eastbound bridge</td>
<td>7</td>
</tr>
<tr>
<td>Figure 2.4</td>
<td>Implementation of infrared, ultrasonic height, and impact sensors on the parallel bridges</td>
<td>8</td>
</tr>
<tr>
<td>Figure 2.5</td>
<td>Infrared sensor</td>
<td>9</td>
</tr>
<tr>
<td>Figure 2.6</td>
<td>Ultrasonic height detector</td>
<td>10</td>
</tr>
<tr>
<td>Figure 2.7</td>
<td>Unit of an accelerometer</td>
<td>11</td>
</tr>
<tr>
<td>Figure 2.8</td>
<td>A on-site power station</td>
<td>12</td>
</tr>
<tr>
<td>Figure 2.9</td>
<td>A view of the electric conduits connected from the power source to respective devices</td>
<td>12</td>
</tr>
<tr>
<td>Figure 2.10</td>
<td>A ultrasonic height detector (UH-1) installed onto a girder</td>
<td>13</td>
</tr>
</tbody>
</table>
1. INTRODUCTION

This report documents the efforts put forth by the Kentucky Transportation Center (KTC) at the University of Kentucky (UK) in implementing sensing technology to monitor and study the behavior of the I-64 Bridges over US 60.

1.1 THE I-64 BRIDGES OVER US 60

The I-64 Bridges over US 60 are located in Franklin County, KY. The parallel bridges – Eastbound and Westbound – are of composite steel-concrete type, that starts at station 2651 + 34.32 and ends at station 2634 + 34.70, giving this bridge an overall length of 296-ft 5-in (~ 90 m) from out-to-out. As depicted in Fig. 1.1, the bridges have three spans of lengths 78’-0” (~ 24 m), 139’-0” (~ 42 m), and 78’-0” (~ 24 m), respectively.

A 7½” (~ 190 mm)-thick concrete bridge deck is supported by six continuous plate girders of varying-and-constant depth type. The substructure consists of two end abutments and two piers. The average pier height is 20’-0” (~ 6095 mm); one of the piers is 19’-6” (~ 5945 mm) and the other is 20’-6” (~ 6250 mm). The I-64 bridges were designed to accommodate two 12’-0” (~ 3660 mm) traveling lanes, a 10’-0” (~ 3050 mm) right shoulder and a 5’-3” (~ 1600 mm) left shoulder, giving it a 39'-3” (11965 mm) clear roadway. Due to the orientation of I-64, the bridges have a skew angle of 19°19’20” (Fig. 1.1).

An interior girder (Girder 3 in Fig. 1.1.b), between the end abutment and supporting pier, of the westbound bridge has been repaired by steel plate bonding due to fatigue cracking of the weld material. Fig. 1.2 shows the location of the interior girder and Fig. 1.3 shows the repaired section of the girder. In addition, the underside of an exterior girder (Girder 1 in Fig. 1.1.c), which has the least height-to-ground distance, of the eastbound bridge has shown signs of impact. It is suspected that the impact is caused by certain truck types traversing on the eastbound route of US 60 beneath the bridge.

1.2 PROJECT OBJECTIVE AND SCOPE

The primary objective of this study is to implement sensing technology that can monitor from afar the behavior and response of the I-64 Bridges over US 60 from potential impact. Sensing technology was set up at various locations of the bridge; data is to be transmitted to a computer at the University of Kentucky to be analyzed, compared, and viewed in elapsed or real time.

Although potential impact of trucks is only anticipated to occur to the exterior girder in the eastbound bridge due to approaching traffic, remote sensing technology was implemented to both westbound and eastbound bridges that are parallel to each other. Due to the similar nature of both bridges in terms of dimensions and expected loading, the effects from the potential impact on the eastbound bridge (i.e., the subject) can therefore be compared to the westbound bridge (i.e., the base).
(a) Elevation view

(b) Top view of the westbound I-64 Bridge over US 60

(c) Top view of the eastbound I-64 Bridge over US 60

Fig. 1.1 – I-64 Bridges over US60.
Fig. 1.2 – Steel plate girders in the westbound bridge near the approach. An interior girder that was previously repaired is shown.

Fig. 1.3 – Repair of Girder 3 using steel plate bonding.
2. IMPLEMENTATION OF REMOTE SENSING TECHNOLOGY (RST)

Sensing technology installed on the I-64 Bridge over US 60 allows collected data (i.e., on the bridge site) to be transmitted to a station (i.e., a remote location) at the University of Kentucky to be viewed, compared, and analyzed in elapsed or real time. This chapter presents information on the variety of sensing technologies used in this project, including an overall implementation plan.

2.1 SENSING TECHNOLOGY AND DEVICES

Different devices are being employed in this project: strain gauges, temperature gauges, infrared sensors, ultrasonic height detectors, accelerometer, and video cameras. Their functions and locations are explained with the aid of Figs. 2.1 – 2.4:

2.1.1 Strain Gauges

Eleven locations are implemented with strain gauges (indicated as SG-#). Five strain gauges are in the westbound I-64 bridge, and the remaining ones are in the eastbound bridge. In the westbound I-64 bridge, the first strain gauge, denoted SG-1, is placed on the vertical face of the bottom flange of Girder 3 facing Girder 4, and SG-2 placed on Girder 4 is opposite of SG-1, facing girder 3 [Fig. 2.1 (schematic) and Fig. 2.2 (detailed)].

SG-3 and SG-4 are placed on the same girders – Girder 3 and Girder 4 – but at the opposite end of the westbound I-64 bridge (see Figs. 2.1 and 2.2). It should be noted that SG-1 is on the repaired steel plate girder, and used to monitor the strain effect under ambient condition. SG-2 to SG-4 are therefore placed either at opposite end or in the adjacent girder of the westbound I-64 bridge for quantitative comparison and study. SG-9 is placed on the vertical face of the bottom flange inside of Girder 1 of the westbound bridge.

On the eastbound bridge, SG-5 is placed on the vertical face of the bottom flange of Girder 4, facing SG-6 in Girder 3 [Fig. 2.1 (schematic) and Fig. 2.3 (detailed)]. It should be pointed out that the numbering of girders of each bridge follows the on-coming traffic direction on route US 60. For example, the I-64 westbound bridge faces the on-coming traffic on route 60, and hence the first and the exterior girder in this case is Girder 1 in that particular direction. Conversely, the I-64 eastbound bridge faces the on-coming westbound traffic on route US 60; therefore, the first and the exterior girder in this case is Girder 1. SG-7 is placed on the vertical face of the bottom flange of Girder 4, facing SG-8 in Girder 3 [Fig. 2.1 (schematic) and Fig. 2.3 (detailed)]. SG-5 – SG-8 are in the either end span of the bridge.

SG-10 and SG-11 are placed on the interior vertical faces of Girder 6 and Girder 1, respectively. SG-5 to SG-8 are present to study the strain effect under ambient condition and to compare quantitatively, as they are either opposite or adjacent to one another. The strain effects due to potential impacts are studied through SG-9 to SG-11. SG-10 – SG-11 are in the middle...
span of the eastbound I-64 bridge. It should be noted that an accelerometer and SG-11 in Girder 1 of the eastbound I-64 bridge make up an impact detector (ID).

2.1.2 Temperature Gauges

Temperature gauges are installed, at the locations of the strain gauges (Figs 2.1 – 2.3), for temperature recordings.

Fig. 2.1 – An overview of the remote sensing technology implementation plan.
Fig. 2.2 – Implementation of strain gauges on the westbound bridge.

NOTES:
SEE Section A - A
SG-1 ~ Strain gauge (#1) placed on the vertical face of the bottom flange (not on the cover plate) in Girder 3 facing Girder 4
SG-2 ~ Strain gauge (#2) placed on the vertical face of the bottom flange in Girder 4 facing Girder 3

SEE Section B - B
SG-3 ~ Strain gauge (#3) placed on the vertical face of the bottom flange (not on the cover plate) in Girder 3 facing Girder 4
SG-4 ~ Strain gauge (#4) placed on the vertical face of the bottom flange in Girder 4 facing Girder 3

SG-9 ~ Strain gauge (#9) placed on the vertical face of the bottom flange in Girder 1 facing Girder 2

Note: Girders in East- and Westbound are equally spaced at 7'-3" (Total 36'-3")
Fig. 2.3 – Implementation of strain gauges on the eastbound bridge.

NOTES:
SEE Section C - C
SG-5 ~ Strain gauge (#5) placed on the vertical face of the bottom flange in Girder 4 facing Girder 3
SG-6 ~ Strain gauge (#6) placed on the vertical face of the bottom flange in Girder 3 facing Girder 4

SEE Section D - D
SG-7 ~ Strain gauge (#7) placed on the vertical face of the bottom flange in Girder 4 facing Girder 3
SG-8 ~ Strain gauge (#8) placed on the vertical face of the bottom flange in Girder 3 facing Girder 4

SEE Section E - E
SG-10 ~ Strain gauge (#10) placed on the vertical face of the bottom flange in Girder 2 facing Girder 1
(Placed halfway between the cross frame and the transition plate)
SG-11 ~ Strain gauge (#11) placed on the vertical face of the bottom flange in Girder 1 facing Eastbound US60
(Placed halfway between the cover plate and the transition plate)

Note that SG-11 will be paired with an accelerometer to form an impact detector (ID)
Fig. 2.4 – Implementation of infrared, ultrasonic height, and impact sensors on the parallel bridges.
2.1.3 Infrared Sensors

Two infrared sensors are employed in this study. A typical infrared transmitter is shown in Fig. 2.5.

The two infrared sensors are denoted as IR-1 and IR-2 in Fig. 2.1 or Fig. 2.4. The infrared sensors served as a detector of trucks, which travel in the eastbound US 60, that would result in an impact to Girder 1 in the eastbound I-64 Bridge. When the infrared mechanism is interrupted, presumably due to a truck, the sensor will simultaneously trigger its adjacent ultrasonic height detector and video camera to measure the truck height and to capture images of the truck, respectively. IR-1 is installed on a cross frame between Girder 1 and Girder 2 above Pier 1 (Emitter) and Pier 2 (Receiver) in the westbound I-64 Bridge whereas IR-2 is installed on a cross frame between Girder 5 and Girder 6 above Pier 1 (Emitter) and Pier 2 (Receiver) in the eastbound I-64 Bridge (Fig. 2.1 or Fig. 2.4).

IR-1, ultrasonic height detector 1 (UH-1) – to be elaborated further in the text – as a group forms Detector 1 which is responsible for measuring and capturing the truck’s height in a designated area. Similarly, Detector 2 is comprised of IR-2, UH-2, VC-1 and VC-2 for the same purposes in another area.

2.1.4 Ultrasonic Height Detector

A typical ultrasonic height detector employed in this project is shown in Fig. 2.6. An ultrasonic height detector functions by sending a pulse-wave of specific frequency. When the pulse-wave encounters a solid surface (e.g., hood of a truck), the wave will reflect and return to
the source. The distance the wave traveled to and back can then be determined from the time it took to travel to and back. The specific UH unit has an effective range up to 10 ft. As indicated in previous discussion, the UH units are functional continuously. The two UH units are placed onto the same girder locations where the IR units are (Fig. 2.1 and Fig. 2.4).

![Image of Ultrasonic height detector](image)

**Fig. 2.6 – Ultrasonic height detector.**

### 2.1.5 Accelerometer

An accelerometer is an instrument for measuring acceleration, as well as detecting and measuring vibrations. A typical unit consists of three accelerometers as shown in Fig. 2.7. In this project, a single accelerometer is employed, oriented along the centerline of the bridge.

The accelerometer is coupled with SG-11 to form Impact Detector (ID), as shown in Fig. 2.1 and Fig. 2.4. The unit is continuously operational in order to take measurements of acceleration and vibration, whether Girder 1 in the eastbound I-64 bridge is impacted or not.
2.1.6 Video Camera

Two video cameras (VC) – VC-1 and VC-2 – are employed in this project. The video cameras are designed such that they serve as a surveillant device that is able to transmit ‘live’ feeds from the bridge site; some delay is expected due to relay of live images from the site to the remote station situated in Kentucky Transportation Center, UK. As indicated earlier, IR-1 and UH-1 make up Group 1; VC-1, VC-2, IR-2, and UH-2 form Group 2. Therefore, as a second function, when triggered by the signal from an IR device, the VC will capture still images, for identification purposes in a latter stage, truck type that would cause impact, coming towards and leaving the bridge site.

2.2 POWERING SENSING TECHNOLOGY AND DEVICES

The success of remote sensing technology depends largely on the continuous functioning of the devices. Therefore, the premise behind the continuous use of the proposed sensing technology and devices is the notion that the electrical current used to power these devices can be supplied continuously.

A station that houses an AC power outlet supplied by the Frankfort Plant Board which powers a DC supply that provides current to the infra-red and ultrasonic sensors is constructed on-site (Fig. 2.8). This ensures continuous and abundant supply of proper power to these devices. Fig. 2.9 shows a partial view of electric conduits used to house on-site wiring to respective devices. Fig. 2.10 shows an ultrasonic height detector (UH-1) installed onto a girder.
Fig. 2.8 – An on-site power station.

Fig. 2.9 – A view of the electric conduits connected from the power source to respective devices.
2.3 SITE-TO-REMOTE STATION CONNECTION

An internet connection has been installed at the site by the Frankfort Plant Board and connected to the computer using a cable modem. The field computer uses Windows XP as its operating system, allowing the use of remote connection and file sharing over internet connections. In addition, another remote connection and file sharing program, Ultra VNC, has been installed. This allows the viewing and editing of data files acquired by the computer. The video cameras are connected directly to the internet, and are viewable from any computer with an internet connection by accessing the camera’s IP address. Recording video is accomplished with software provided by the camera manufacturer, Stardot Technologies.

The computer program was developed with National Instrument’s Labview, which incorporates the use of email and text messaging, allowing the computer to notify specified email addresses and/or cell phones in the event an impact is detected.
3 SUMMARY AND CONCLUSION

The three-span parallel bridges of I-64 over US60 are the first bridges in the state of Kentucky implemented with sensing technology and devices that allow monitoring from a station afar. The bridge is located approximately twenty miles away from its monitoring station at the Kentucky Transportation Center, University of Kentucky, Lexington, KY.

One of the girders in the westbound bridge has previously been repaired by steel plate bonding due to unexpected fatigue cracking in the welding material. The exterior girder in the eastbound bridge has exhibited signs of impact due to truck traversing underneath the bridge. Devices such as strain gauges, temperature gauges, infrared sensors, ultrasonic height detectors, accelerometers, and video cameras will help determine and study the response of the bridge under ambient and impact conditions.

Specifically, eleven strain and temperature gauges are used. One strain gauge is placed on the repaired girder. The remaining gauges were placed in the adjacent girder, girders in the opposite end of the same bridge, or similar girders in the adjacent eastbound bridge. Two infrared sensors and two ultrasonic height detectors are used, one each for each individual bridge. The potential impact will be detected when the infrared sensor is triggered, signifying the passing of a truck that has sufficient height to cause impact. Ultrasonic detectors are subsequently activated to take measurement of the truck’s height. The ultrasonic detectors have a range up to ten feet. Visual evidence of the impacting truck will be subsequently captured by the two on-site cameras.

A station that houses an AC power outlet supplied by the Frankfort Plant Board which powers a DC supply that provides current to the infra-red and ultrasonic sensors is constructed on-site. The recorded data (i.e., strain readings, acceleration or vibration) will be stored at an on-site station, and are accessible at the remote station via an internet connection established using a cable modem; thus the data and visual images of the bridge site can be viewed live.