A Bridge Field Inspection Procedure To Check the Integrity of Pins in a Pin and Hanger Strap Connection

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Following the near collapse of an Interstate bridge in the City of St. Louis, Missouri, a procedure using ultrasound has been developed to check the integrity of the pin in a pin and hanger strap connection. Ultrasound is transmitted into the ends of pins and reflections from defects are displayed on the scope of the ultrasound instrument indicating the presence and location of cracks or wear. Using this procedure, 90 bridges containing 675 pin and hanger strap connections have been checked. Four percent of the pins have been found to be defective. The pins from the Interstate bridge in St. Louis were not removed intact. However, the predictions obtained with the ultrasound procedure correlated closely with the information obtained from the pins and pin pieces after they had been removed by burning. A pin pusher has since been developed, built, and used to remove pins intact. Eight pins were removed intact from one bridge and good correlation between predictions and actual conditions was found. Of the eight pins, it was predicted that one would be completely severed, one would be cracked, and six would be sound. After removal of the pins, the predictions were verified as accurate by visual examination. A limitation of the procedure is the inability to precisely predict the defect size. However, the threshold depth where a crack can be identified has been determined to be approximately ⅛ in.

The vulnerability of bridges with pin and hanger strap connections came into sharp focus in March 1987 following the near collapse of a bridge on Interstate 55 in the City of St. Louis, Missouri. At the time of the incident, the bridge was under contract for widening and rehabilitation. A contractor's workman discovered that one span carrying the northbound lane of I-55 had dropped about 1¾ in. at the finger plate expansion device. Further investigation revealed that 4 of the 12 pins in the hanger strap connections at this joint had failed. Total collapse of the span did not occur because the expansion joint was completely closed and some of the finger plate support steel came to rest on an abutting stringer.

The design parameters for this pin and hanger strap connection (Figure 1) as an expansion device assumed that the pin would be free to rotate in the web as the girders expanded and contracted in response to temperature changes. The pin was designed to resist the shear and bending forces resulting from dead load, live load, and impact forces. Torsional forces were not considered. This design assumption has been proven to be invalid because it has been found that the joint was frozen as a result of corrosion between the pin, the straps, and the web. Consequently, torsion forces exceeding the pin strength were developed.

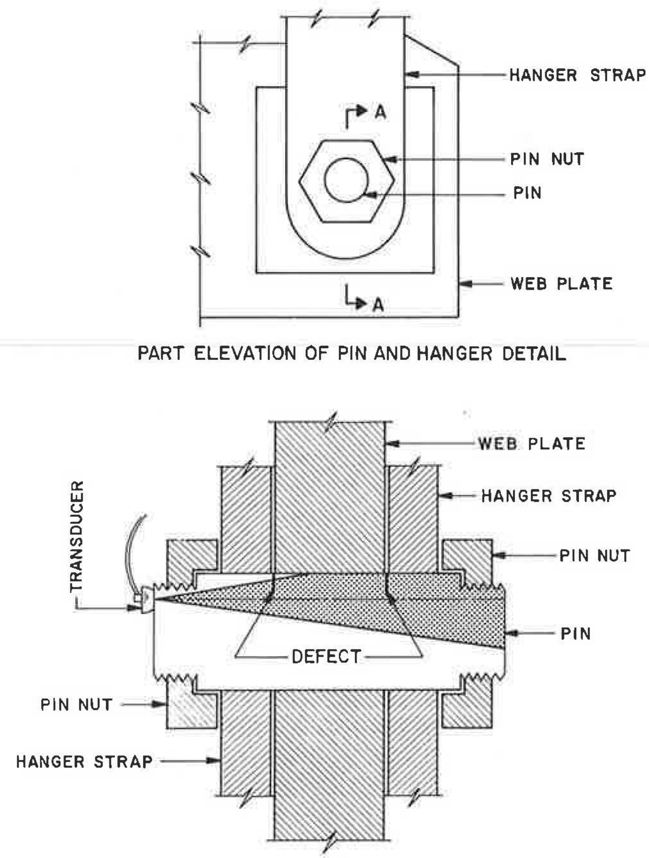

FIGURE 1 Part elevation of pin-and-hanger detail with enlarged section *A-A*.

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This near collapse of a bridge carrying 38,000 vehicles/day prompted the development of a procedure for nondestructive testing of pins because a visual inspection would give no indication of possible or imminent failure.

The options available for inspection of pins were quite limited. Visual inspection was totally unreliable and disassembly was not practical. Of the other nondestructive tests such as magnetic particle testing, dye-penetrant testing, radiography, and ultrasound, only ultrasound showed some promise of being feasible and practical. The only parts of the pins that were accessible for testing purposes were the ends.

The initial attempt to perfect an ultrasound testing procedure involved fabricating a pin of the same length as the pins that failed. The test pin differed from the pins in the bridge in that it did not have threaded ends. This was not considered to be a problem. In order to determine whether defects could be detected and located from the application of ultrasound at the end of pins, cuts of ¼ and ½ in. were made in the sample pin. After calibration of the ultrasound instrument, it was possible to identify defects and determine their lateral distance from the end of a pin. This was further verified by scanning from both ends of the pin. The initial testing was done with a 1-in.-diam transducer and the gain (or amplification of the reflected sound) required to identify the sample defects was noted.

With this very limited experience, the procedure was taken to the field and the remaining pins in the I-55 bridge were checked. The procedure failed to produce any indication of defects in the remainder of the pins in the bridge. This did not seem to be reasonable so the procedure was re-evaluated. It was concluded that the beam spread from the 1-in.-diam transducer was not reaching the body of the pins where defects would occur. To remedy this problem, the 1-in.-diam transducer (Figure 2) was changed to a ½-in.-diam transducer (Figure 3) to take advantage of the increased beam spread. After scanning the pins from both ends, indications of defects were found in most of the remaining pins on the I-55 structure. The contractor immediately placed falsework under the bridge to prevent collapse.

Verification of the predictions made with the ultrasound procedure was considered necessary because there were almost 100 bridges in the state with pin and hanger strap connections. To verify the predictions, the pins had to be removed intact. However, the contractor for the I-55 bridge was unable to push, pull, hammer, or otherwise force the pins from the girder. He resorted to the use of an oxygen-burning wand that burned a hole about ½-in. in diam through each pin. This relieved the pressure so that the pins could be forced out with a pneumatic hammer. The predictions obtained with the ultrasound procedure on this bridge correlated closely with a visual inspection obtained from the pins and pin pieces after they had been removed. The removal method of burning made it impossible to verify the predictions with the use of ultrasound.

The rudimentary procedure used on the I-55 bridge was adopted to begin checking all of the bridges in Missouri that had pin and hanger strap connections. It was very important to be able to verify that the testing procedure was in fact identifying as defective those pins that were truly defective and not identifying as defective those pins that were good. Consequently with the development of the procedure to test pins, a device later called the "pin pusher" (see Figure 4) was designed to permit recovery of the pins intact. To gain some idea of the force required to extract a frozen pin from a web, a hanger strap with part of a broken pin was put in a press in the laboratory and the pin removed. A force of 40 tons was required to press a

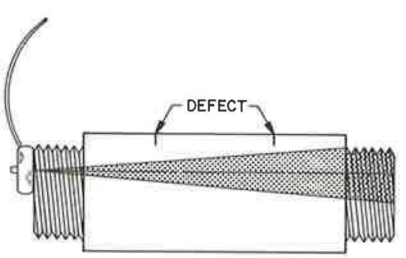

FIGURE 2 Beam spread with 1-in.-diam 3.5 MHz transducer.

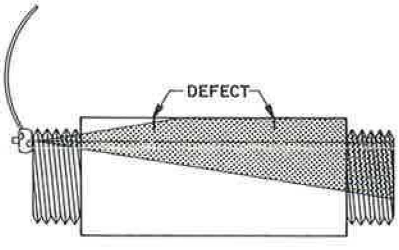

FIGURE 3 Beam spread with ½-in.-diam 3.5 MHz transducer.

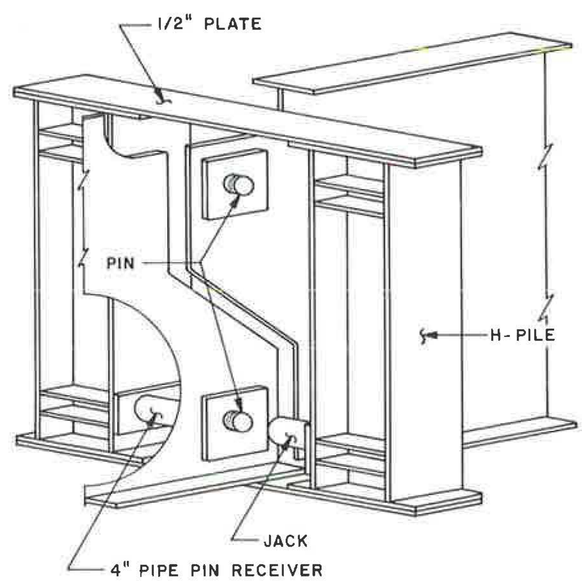

FIGURE 4 Pin pusher.

2-in. pin from a 2-in. thick hanger strap without the use of heat.

Based on this information, the pin pusher was designed and built to apply a force of 50 tons. The pin pusher has been used to remove 24 pins intact from two bridges that were found to have defective pins. Of the 8 pins from one bridge, it was predicted that 1 would be completely severed, 1 would be cracked, and 6 would be sound. After removal of the pins, it was found that 1 was severed, 2 were cracked and 5 were sound. After finding that one crack was missed in the original prediction, the test procedure was modified by increasing the amplification of the reflected sound that was transmitted through the pin. The increased amplification permitted the identification of smaller defects.

Of the 16 pins in the other bridge, it was predicted that 8 would be cracked and 8 would be sound. After removal of the 16 pins, it was found that 8 were cracked, 6 were sound, and 2 had corrosion grooves about ⅛ in. deep.

A typical inspection of a bridge with pin and hanger strap connections requires a minimum crew of four, a snooper truck capable of operating from the deck, and a supply truck containing signs for traffic control and miscellaneous tools and equipment. Initially, a 110-volt power supply generator was required to operate the ultrasonic testing instrument, however, a portable nicad battery pack is now being used. A power source is required to operate a portable grinder. The ultrasonic instrument weighs about 12 lb. and is carried in the snooper bucket by the inspector.

After reaching a pin, the inspector's first operation is to remove accumulated paint, rust, and scale from the end of the pin. This is done with a small hand-held grinder. It has not been necessary to have an extremely smooth finish on the end of the pin. A couplant such as glycerin is then applied to the end of the pin to facilitate the transfer of the sound waves from the transducer to the pin and back. The ultrasonic testing machine is calibrated to the length of the pin. The inspection consists of positioning the transducer on the end of the pin and slowly moving it over the entire area of the pin, while observing the scope of the ultrasonic instrument to determine if defects are present.

The reading on the scope of the machine for a good pin (Figure 5) shows an initial spike, a spike representing the far shoulder at the threaded end of the pin, a spike representing the end of the pin, and a flat line between the initial spike and the shoulder spike.

The reading for a defective pin (Figure 6) shows an initial spike, a spike on the scope at the location of the defect, a spike representing the far shoulder at the threaded end of the pin, and a spike representing the end of the pin. The reading for a pin with total failure shows an initial spike, a tall spike at the defect location, and that the spikes representing the far shoulder and the end of pin are gone. The location of the spike on the scope that indicates a defect will correspond to the distance of the defect from the end of the pin. The height of the spike is related to the size of the defect. A very shallow defect will produce a very short spike whereas a deeper defect will produce a higher spike.

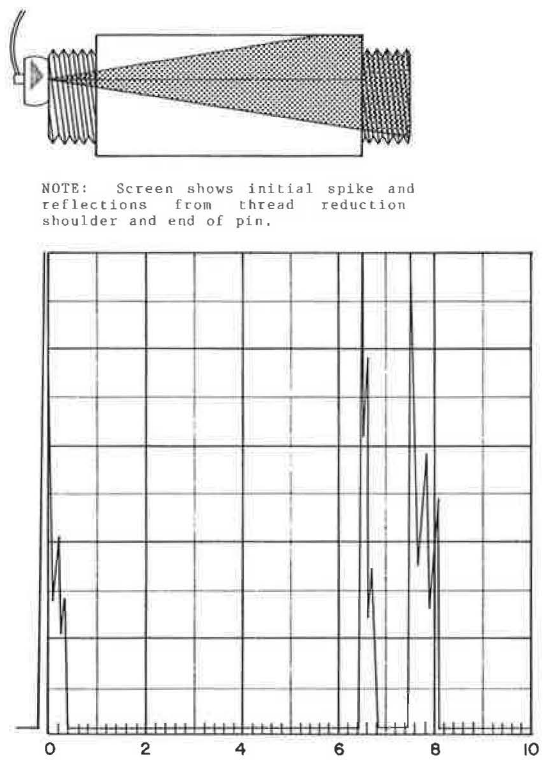

FIGURE 5 Screen of good pin.

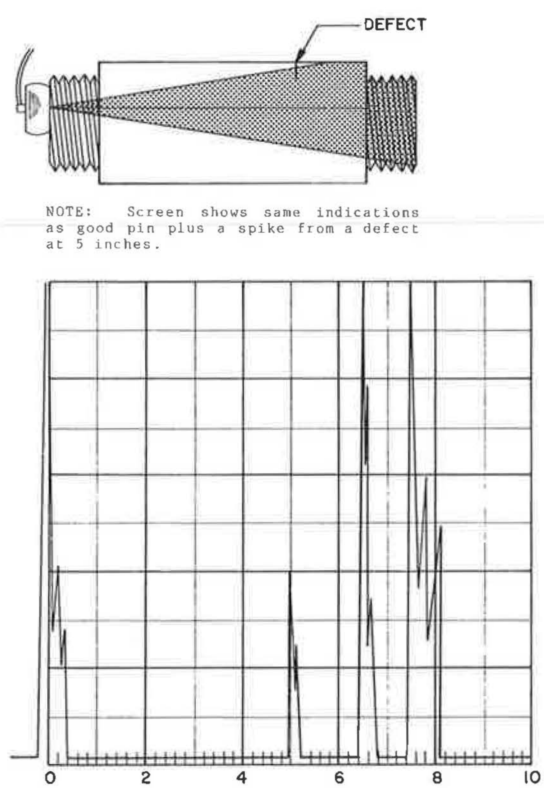

FIGURE 6 Screen of pin with defect.

Pins are checked from each end. This allows full coverage of the body of the pin and allows the location of the defect to be measured from each end of the pin. This method helps to verify the exact location of a defect.

Cracks normal to the length of the pin can be identified but seams or other defects parallel to the length of the pin cannot normally be detected. Due to their shape, it has been difficult to detect shallow corrosion grooves with the straight beam ½-in. diam transducer. To solve this problem, a ½-in. diam 18° angle beam transducer has been used to direct the sound beam more nearly normal to the defect. The application of the sound beam more normal to the defect results in more reflected sound being displayed on the scope. Consequently, the presence of the shallow corrosion grooves can be identified.

For each pin inspection, a written record is made indicating the date and condition of the pin. This information will be used as historical data for future inspections. If defects are found, an assessment is made about how serious they are and a decision is then made on whether to restrict traffic on the bridge, provide shoring, or allow traffic to continue until the pin can be replaced or the connection modified.

On completion of the inspection, the pin ends are repainted with a primer to protect them from rusting and to serve as a quick indicator that the pin has been inspected. A color-coding system is used to indicate the year of the inspection.

The ultrasonic equipment in this inspection procedure had an initial cost of $6,228 in 1987. If the inspection crew is based in the area of the bridges to be inspected, they can inspect approximately 20 pins during a 10-hr work day. This includes setting up and removing traffic control devices. Most of the bridges inspected up to the present (January 1988) are approximately 20-yr old. Defects have been found ranging from those ⅛ in. deep to total failure of the pins.

Based on experience with this procedure, the authors have concluded that the procedure has been valuable in determining defective pins in an early stage of distress. It has been successful in determining the location on the perimeter of the pin where the defect occurs. It is limited in that the readings do not specifically indicate the exact depth of the defect, however, the relative size of defects is proportional to the amount of signal reflected. It is also difficult to determine from the inspection whether the defect is caused by wear or corrosion or is in fact a crack. In order to maintain confidence concerning the integrity of pin connections, the authors have concluded that bridges with no indications should be inspected at 2-yr intervals; bridges with only slight indications should be inspected annually; and bridges with several slight or moderate indications should be scheduled for pin replacement or retrofit.

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