IMPACT DAMAGE REPAIRS ON THE JOHNSON RIVER BRIDGE Bridge No. 518

Travis Arndt, P.E.

BIOGRAPHY

Travis Arndt is a Bridge Engineer with the Alaska Department of Transportation and Public Facilities. He earned a BCE (1999) and a MS (2001) from the University of Minnesota.

SUMMARY

On August 7, 2004 an unidentified, over height vehicle struck the historic Johnson River Bridge. The impact severed numerous portal members, while bending and twisting the sway bracing and truss members on two of the five truss spans.

A two-phased repair plan was developed to immediately replace the damaged portal members, while heat straightening and other repairs to the sway bracing and truss members were set-aside for the second phase.

A number of factors dictated the repair plan, namely: truss stability, material availability, site location, winter weather conditions, reduced daylight, lack of utility services, and traffic control. Traffic mitigation was very important, as the only detour route is an additional 265 miles long.

Several problems were encountered during the first phase of repairs, but were accommodated through field changes. The second phase repairs are awaiting funding.

Once the repairs are complete, this 60-year old historic truss bridge will continue to carry goods and visitors on their journey into our great state.

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BACKGROUND

The historic Alaska Highway is the only road linking Interior Alaska to Canada and the 48 contiguous states. The Alaska Highway connects Dawson Creek, British Columbia, Canada to Delta Junction, Alaska. Army Corps of Engineer Regiments first constructed the 1422-mile highway. Road construction officially began in March 1942 and was completed 8 months later. As originally constructed, 90-degree turns and 25 percent grades were common, but through continuous upgrades, the highway has been straightened, flattened and paved. Constructed as a military road, civilian access was restricted until 1948, when it became a public road. Today the Alaska Highway carries a steady stream of goods into Alaska, as well as a large number of our summer visitors.

Near historic milepost 1380, the Alaska Highway crosses the Johnson River. The Johnson River is a typical braided glacial stream. The river starts approximately 25 miles upstream of the bridge at the

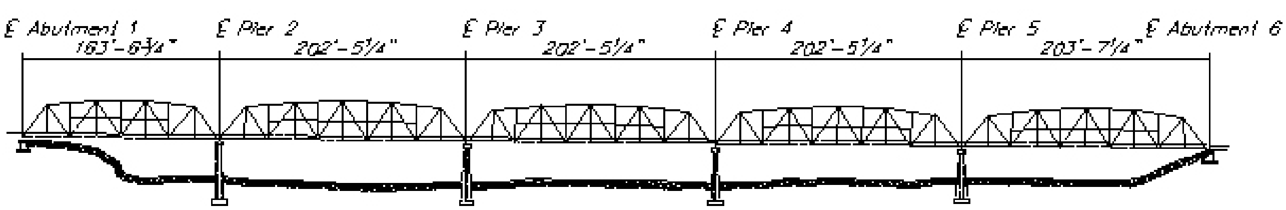

Figure 1: Johnson River Bridge

Figure 2: Severed Lower Chord in Span 4 Far End Portal

Figure 3: Severed Lower Chord in Span 5 Far End Portal

face of the Johnson Glacier, in the Alaska Range. It has carved a wide river plain with many braided channels. Spring melt, as well as periods of high temperatures and significant glacial melt, create flows that completely cover the river plain.

As the pioneer road was constructed, the rivers were quickly spanned with timber trestles. The trestles were used as the work bridges and replaced with the permanent bridges shortly thereafter. The Johnson River Bridge is a 970-foot, through-truss bridge erected in 1944. It is comprised of 5 spans, of which four are approximately 202 feet and one spans 163 feet. The bridge has a vertical clearance of 15 feet 9 inches with a posted vertical clearance of 15 feet 6 inches.

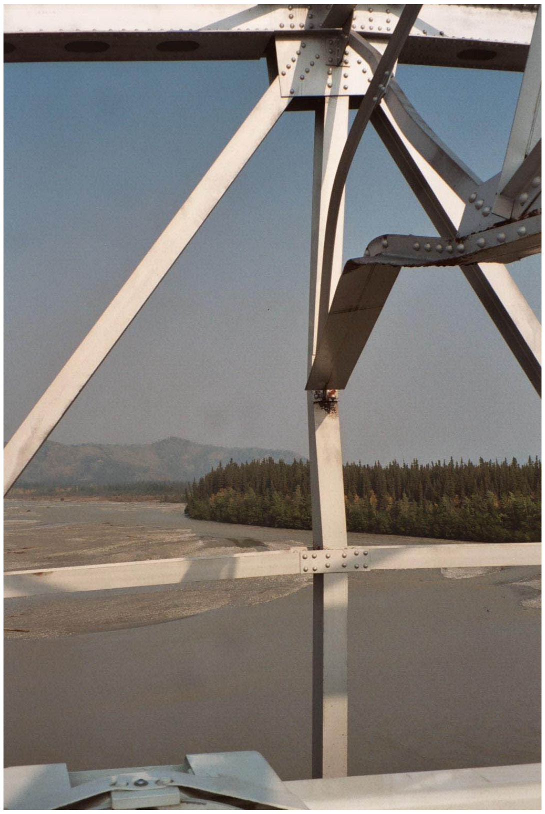

Figure 4: Damaged Sway Bracing

Since the Federal Government constructed the bridge during wartime, obtaining the original plans and construction documents was difficult. Fabricators were not told where their bridges would be built, rather they were contracted to build a certain number of truss spans for shipment. The military then secretly shipped and erected the bridges. Through the bridge serial numbers the manufacturer was found and plans obtained.

DAMAGE

On August 17, 2004 an unidentified vehicle struck and damaged the end portals, sway bracing and truss members on two spans. Based on the plastic deformations, the vehicle height was estimated to be at least 18 feet 6 inches.

As the vehicle entered each truss span, the impact severed the lower portal members, see Figures 2 and 3.

As the vehicle moved through the spans, it impacted the sway bracing between the trusses. This impact bent and twisted the sway bracing, as well as, the truss members to which they were connected. The impact severed a number of connection angles attaching the bracing to the trusses. Large deflections over small distances produced extensive yielding of several truss members. The resulting damage can be seen in Figures 4-8.

Figure 5: Connection of Sway Bracing to Truss

Figure 6: Deformed Connection Angles

Figure 7: Torn Connection Angle

Figure 8: Buckled Connection Plates

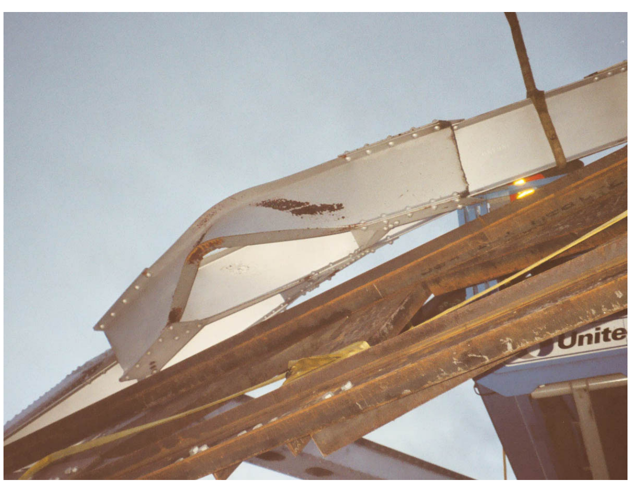

Figure 9: Damaged Span 4 Near End Portal In Place

As the vehicle exited each span, it pushed the portals upward and outward. These portals were plastically deformed approximately 40 inches from their original position. Looking at Figure 9, the top edge of the damaged portal should be aligned with the back edge of the temporary portal. The impact was so severe that many rivets were sheared. Several connections had only one or two out of a dozen rivets still intact.

An Alaska Department of Transportation and Public Facilities (ADOT & PF) scour inspection team crossing the bridge initially spotted the damage shortly thereafter. As they approached the bridge, the roadway was littered with rivets, and the bent and torn steel was immediately visible. An ADOT & PF bridge inspection team completing fracture critical inspections was immediately rerouted to inspect and quantify the impact damage. Once the damage was quantified, a repair plan was developed.

Figure 10: Damaged Span 4 Near End Portal Removed

REPAIR CONDISERATIONS

There were a number of important factors to consider when developing the repair plan. Some of these included: stability of the truss spans, transverse load capacity, availability of steel sections, bridge location, lack of power and communications, weather and daylight conditions and traffic impacts.

Of primary concern was the stability of the truss spans. The end portals and sway bracing provide the necessary bracing to resist deflections from large loads and transmit transverse load to the bearings. When a large load crosses the span, the tops of the trusses try to rotate inward. This rotation is caused by the deflection of the floor beams, which imposes a transverse moment on the truss. As the tops of the truss try to rotate inward, the end portals and sway bracing resist the movement. With the portals and bracing already buckled, their ability to resist the inward movement was severely compromised.

The bridge is located in an area of high winds and seismic activity. Winds are funneled between mountains and down the Johnson River, making large gusts common. The bridge is less than 60 miles from the Denali Fault, which produced moment magnitude 6.7 and 7.9 earthquakes in the fall of 2002, see Figure 11.

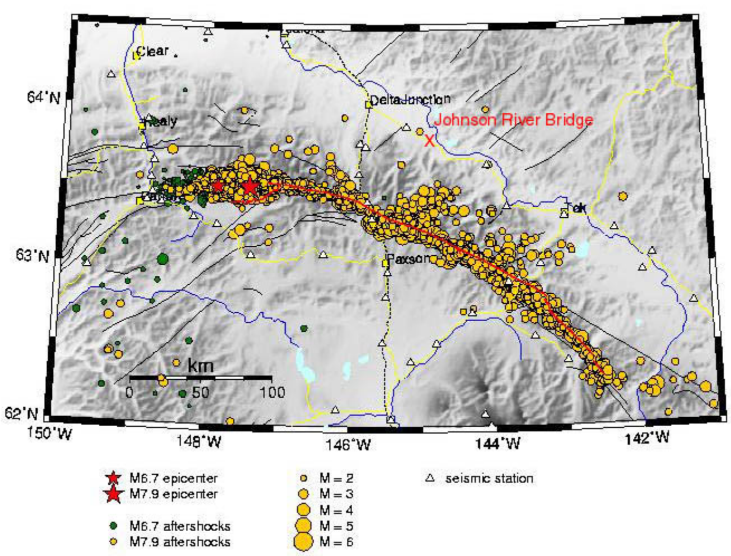

Figure 11: Fall 2002 Seismic Activity [(1)]

A transverse load path is critical in transmitting these loads to the bearings. The end portals and sway bracing combined with the trusses form a mechanism to resist the transverse loads. With the end portals and sway bracing damaged and ineffective, the truss spans had little transverse load capacity. Significant wind gusts or a seismic event could further damage the spans.

The lack of steel availability required proper planning to assure all the needed sections and hardware were ordered at one time to avoid delays. The proper length steel sections were not available within Alaska. Temporary bracing and lower portal members were nearly 30 feet long, while the longest channel sections available were only 20 feet long. Rather than splice sections, full-length sections were ordered from Washington. The sections were shipped from Seattle, Washington to Anchorage, Alaska via container ship, then trucked to Fairbanks, Alaska for fabrication and finally trucked to the bridge site.

ADOT&PF bridge maintenance personnel were tasked with repairing the damage. The members of the bridge maintenance crew are located at the various maintenance stations within the region. During fabrication of the temporary bracing and replacement members, the crew would be located in Fairbanks. For the bridge repairs, the men and their equipment had to be staged in the nearest town, Delta Junction, nearly an hour away from the bridge site.

Electric and telephone services are non-existent near the bridge. Not only are connections to electric service non-existent, the power lines and electric service themselves do not exist. Generators would need to be brought to the site to provide power. As with the electric service, landline telephone service does not exist in the area. Cellular coverage is spotty at best and the nearest location with any service is about 15 miles away. Satellite telephones would be needed to provide a means of communication.

Weather conditions and daylight hours would be quickly diminishing through the repair process. Development of the repair plan, ordering and shipping time for the steel sections and hardware, as well as, the fabrication would push the repairs into October. High temperatures for the area would be below 20°F and likely closer to 0°F. Snowstorms would be likely, while daylight hours would be rapidly dwindling.

Traffic maintenance was also important. During the summer months the Alaska Highway sees a steady stream of visitor traffic, primarily recreational vehicles (RVs). Fortunately the repairs would take place after the visitor traffic had mostly ended, however the highway still carries a significant level of truck traffic. Only one detour route exists to reroute traffic and it is an additional 265 miles long. Thus full closures would not be permitted. The repair plan had to be developed around a single lane closure with short full closures.

REPAIR PLAN

The repairs were divided into two phases. Phase I repairs were deemed necessary keeping the bridge in service, while the rest of the repairs were lumped into Phase II. To speed the repair process, the Northern Region Bridge Maintenance Crew was tasked with the Phase I repairs and the Phase II repairs will be assigned to a contractor through the bidding process.

Phase I focused on reestablishing the primary transverse load path. The end portals needed to be fixed as soon as possible to reestablish the transverse load path. Removing the damaged sections would further reduce the transverse load capacity. Therefore a temporary transverse load path had to be established to allow for the removal and replacement of the damaged members. The width of the piers is not much wider than the bearing, thus eliminating an external bracing system. Maintaining traffic prohibits, to a great extent, using a bracing system within the truss span. The chosen portal repair plan involved temporary portals bolted to the trusses above and below the damaged portals. With the temporary portals in place the vertical clearance was temporarily reduced to 11 feet, however one lane of traffic could be maintained while the repairs were ongoing. With the temporary portals bolted to the trusses, an alternate transverse load path was established. The damaged portal sections could then be removed and replaced. Implementation of the Phase I repairs began immediately.

The damaged truss members, sway bracing, and repainting were relegated to Phase II. Initial inspections did not note any tears or cracks in the truss members. Since the truss members are tension members, subsequent loadings would not be compromised. A significant transverse load path existed with the intact top bracing and newly repaired portals; therefore the damaged sway bracing was not of immediate concern. Phase II repairs will involve heat straightening the truss members as well as replacement of the sway bracing.

PHASE I REPAIRS

As the repair plan developed, the Bridge Maintenance Foreman verified steel availability. Noting that the proper length channel sections were not available within Alaska, the finalization of the repair plan became critical. Once it was determined to use the longer channel sections, an order was placed so that the shipping process could begin. The shorter sections were mostly available in Fairbanks, while the rest were located in Anchorage.

In order to speed onsite repairs, maintenance personnel prefabricated the replacement members and temporary portals at the Fairbanks Maintenance Shop. The temporary portals were also completely assembled, such that once trucked onsite, they could be immediately installed as one piece, see Figure 12.

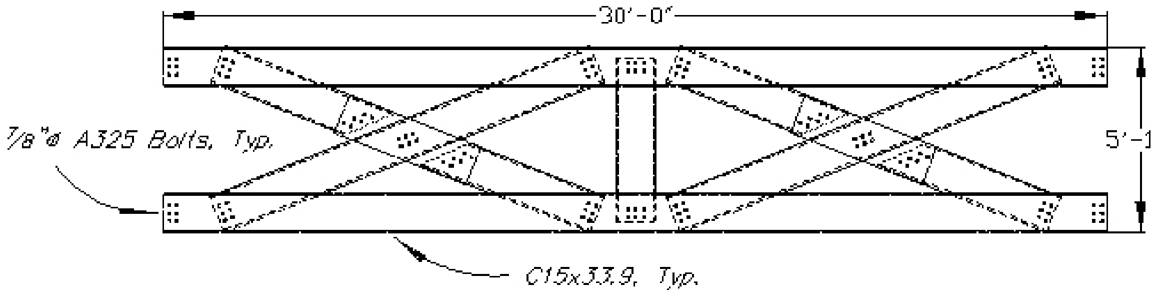

Figure 12: Temporary Portal

Following fabrication, the temporary portals and replacement sections were stockpiled until completion and then trucked to the bridge site.

ONSITE REPAIRS

The traffic control plan was implemented once all the materials and equipment were staged onsite. In order to complete the repairs while maintaining traffic, the bridge was limited to a single lane with a restricted vertical clearance. Several full closures were required, however they were kept to a minimum and limited to an hour. To maintain single lane traffic, the traffic control plan called for continuous flagging with a pilot car. Two crews of three people rotated 12-hour shifts. The flaggers were also tasked with enforcing the 11-foot vertical clearance, which was needed to protect the temporary portals. To aid the flaggers in this task, flashing signboards were installed in Delta Junction and Tok notifying vehicles, notifications were aired on local radio stations a week prior to work beginning and notices were posted at the weigh stations around the state. Run under bars were constructed at the turnouts to verify vehicle height, see Figure 13.

Several trucks removed their stacks and ladders in order to meet the vertical clearance requirements and avoid the detour route. A number of vehicles did not heed the signs and notices and were turned back towards the detour or waited for the intervals between portal repairs when the temporary portals were removed.

Figure 13: Run Under Bar

With the traffic restricted, the repair process began. The first step was to install the temporary portals. For the temporary portals to lie flat against the trusses, several rivet heads were removed. Small angle sections were C-clamped to the trusses to help align the temporary portals. The temporary portal were lifted and set into place against the angles. Using the holes drilled in the ends of the temporary portals as guides, a magnetic drill was used to drill through the truss members, see Figure 14. A325 bolts were inserted and tensioned to fasten the temporary portals to the trusses.

Figure 14: Drilling to Attach Temporary Portal to Truss

Figure 15: Damaged Section Removed

Removal of the damaged members began once the temporary portals were installed, Figure 15.

Rivets were used in the original assembly. In order to salvage as many of the connection plates as possible, the connections themselves were disassembled. The rivets were removed by first cutting off one of the heads and gouging out the rivet body with a torch. The rivets could then be driven out with a hammer and punch. Since care was taken, the connection plates could generally be reused once they were reflattened. With all the damaged members removed, new sections were lifted into place, aligned and bolted, see Figures 16 and 17.

Figure 16: Installing New Member

Figure 17: Aligning Bolt Holes

Figure 18: Rigging to Remove a Temporary Portal

Once the new sections were erected and secured, the original transverse load path was reestablished. With the repair of the portal completed, the temporary portals could be removed. They were unbolted, lifted off the trusses and moved to the next portal, see Figures 18-20.

Bolted cover plates were installed where the temporary portals were attached to the trusses. This leaves the holes in the trusses accessible for future repairs. The temporary portals will be stored nearby as well to more easily allow for future repairs. Finally the portals will be entirely repainted as part of Phase II.

Figure 19: Removing a Temporary Portal

Figure 20: Completed Portal Repair

PROBLEMS ENCOUNTERED IN PHASE I

The attachment of the temporary portals went smoothly for the two portals with severed members, but where the portals that were pushed up and outward, the installation ran into problems. The damage was more severe than just deflecting the end portal, as noted by the inspectors. The portals had been pushed to a point where the truss members had deflected and rotated as well. As the vehicle pushed the portal outward, the force pulled the two truss members nearly 2 inches closer together at the top, which also rotated them about their long axis. The resulting rotation caused an inch differential deflection between the outside and inside faces of the members. The hole pattern in the temporary portals was not capable of accommodating such movement. One possible solution was to disassemble the damaged portals without the use of the temporary portals. This solution was discounted due to the known wind conditions and lack of any transverse load path with the end portal completely removed. A second possible solution involved bolting the temporary portals as drilled and trimming the replacement members to fit the new configuration. This solution was discounted due to the change in truss geometry, future implications for vehicle clearance and the unknowns surrounding if the other replacement members could be erected and bolted into this new configuration. A third solution involved slotting the holes in the temporary portals. The end distances and spacing of the holes was reviewed and would allow for slotting. In this case the bolts could not be tightened, however the shear capacity of the bolts would provide adequate resistance. The trusses would be able to move outwards once the damaged sections were removed, but the bolts would bear should significant transverse loads arise. Since the truss members could move outwards, the already fabricated members could be used. This solution was clearly the best option, so work began to modify the temporary portals. The bolt holes in the temporary portals were slotted onsite to accommodate the required movement, see Figures 21-22. With a method to accommodate the needed movement completed, the temporary portals were erected and repairs continued.

Figure 21: Slotting Holes in Temporary Portals

Figure 22: Finished Slots in Temporary Portals

Additional repair work was required with the severely deflected portals. The repair plan assumed that once the damage sections were removed the outward deflection would be minimized as the portals loosened. Unfortunately with the damaged sections removed, the remainder did not relax into its original position. The portal maintained an outward deflection. This deflection can be see in Figure 23, the connection plate should be in contact with the new lower portal member.

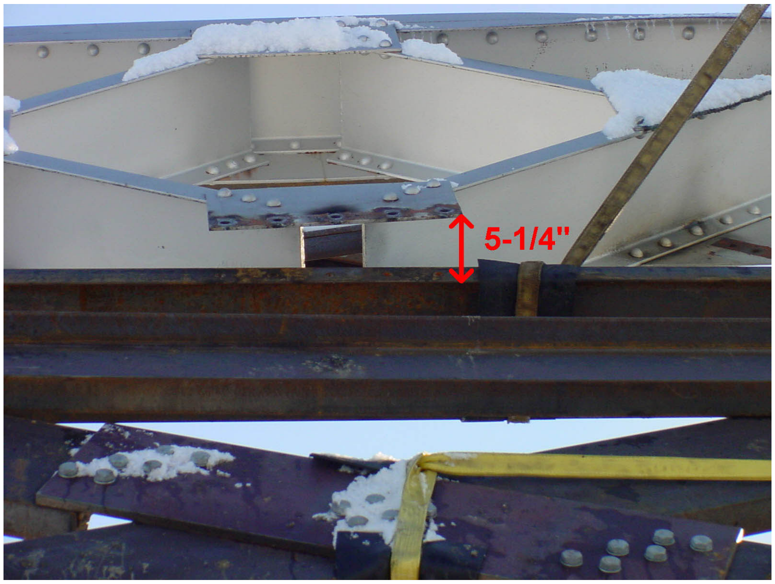

Figure 23: Remaining Outward Deflection

Additional damaged members were removed, however the 5-1/4" separation did not close. Multiple thread rods were inserted through the holes in the connection plates and new lower portal member. An attempt to pull the portal into place with the thread rod failed. With the temporary portals in place there was a definite transverse load path established; thus the decision was made to fully disassemble the end portal. Work began carefully disassembling each member and connection plate. Once the portal was completely disassembled, each member and connection plate was checked for straightness, twist, and flatness. The connection plates that connected the portal to the truss were found to have a slight bend. This 3-degree bend was enough to produce the measured offsets. Several additional members were discarded based on these checks. With the additional disassembly and rejected members, additional channel sections as wells as many more nuts, bolts, and washers had to be ordered. Since channel sections were used, tapered or wedge washers were also required. The original tapered washers order was more than the local suppliers had in stock. Now we were in need of the additional tapered washers immediately. The additional tapered washers were shipped airfreight in order to receive them in a timely fashion. Once the new sections arrived, they were fabricated to replace the other damaged sections. With the entire portal removed, the truss members nearly returned to their original positions, however some of the deflection remained. New connection plates were match marked and custom drilled to account for this slight difference. Erection of the portal members progressed smoothly.

PHASE II REPAIRS

Heat straightening the truss members, replacing the sway bracing and repainting the effected areas are not necessary to maintain traffic. Since the repairs were not critical, it was not imperative they be completed during the period of cold weather and minimal daylight. Thus, they have been scheduled for warmer weather and longer daylight hours. Currently, the Phase II repairs are on hold until funding is secured.

Damage measurements, including displacements and rotations, were recorded during the initial damage inspection, as well as, during the Phase I repairs. These damage measurements have been coupled with the as-built drawings to be provided to the heat-straightening contractor. The heat-straightening specifications require the contractor to have five years experience performing heat-straightening repairs, while averaging at least four heat-straightening projects per year. The contractor will be required to calculate the heat patterns and jacking forces. The maximum allowed steel temperature is 1200°F. The contractor must verify the temperature with one or more of the following, temperature sensitive crayons, a pyrometer, or an infrared non-contact thermometer. Jacking forces may be applied externally or by using the damaged sway bracing members. If the jacking force is applied externally, the force must be measured and recorded. Conversely, the damaged sway bracing members can be used to apply the jacking forces to the truss members by heat-straightening the sway bracing as well. The contractor is required to globally straighten the truss members to within ½ inch over 20 feet and within in ¼ inch for local web and flange deformations.

Once the truss members have been straightened, the sway bracing members will be removed and replaced in their entirety. The sway bracing members will be galvanized prior to erection to minimize field painting.

Once the repairs have been completed, repainting will begin. The existing paint system consists of a lead based primer with an aluminum topcoat. The existing paint system on the end portals and straightened truss members will be completely removed. Following the abrasive blasting, priming and repainting will complete the process.

CONCLUSIONS

Following the impact of an unknown, over height vehicle, the Johnson River Bridge suffered significant damage. The end portals were either severed or plastically deformed approximately 40 inches out of position. The sway bracing was dramatically bent out of shape and the truss members to whom they were connected also were plastically deformed.

Immediate inspections provided working descriptions, measurements and photographs to develop a repair plan. Repairs were divided into two phases depending on the urgency of the repairs. Phase I repairs focused on reestablishing a transverse load path primarily for wind and seismic loads. It involved providing a temporary transverse load path with temporary portals, while the damaged portal members were removed and replaced. Phase II repairs will focus on heat-straightening the deformed truss members, entirely replacing the sway bracing and repainting the end portals and heat-straightened truss members.

Figure 24: Bridge Maintenance Crew and Completed Portal

Phase I repair have been successfully completed. Several problems arose during the repair process, but were overcome onsite. The temporary portals were modified to allow the additional deflection in the truss members to relax, while still providing the transverse load path. Simple replacement of the damaged members was not sufficient for several portals, and thus they had to be completely removed and rebuilt member by member. The repair plans and specifications for Phase II have been completed. The bidding process and contractor selection will begin once funding sources have been secured.

With the repairs complete, this 60-year old historic truss bridge will continue to carry goods and visitors on their journey into our great state.

REFERENCES

1. Alaska Earthquake Information Center, "M7.9 Denali fault earthquake of November 3, 2002." http://www.giseis.alaska.edu/Seis/M7.9_quake_2002/M7.9_quake.html