HEAVY MOVABLE STRUCTURES, INC.

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EMERGENCY COUNTERWEIGHT SHEAVE TRUNNION REPLACEMENT AT NS BRIDGE CD182.30

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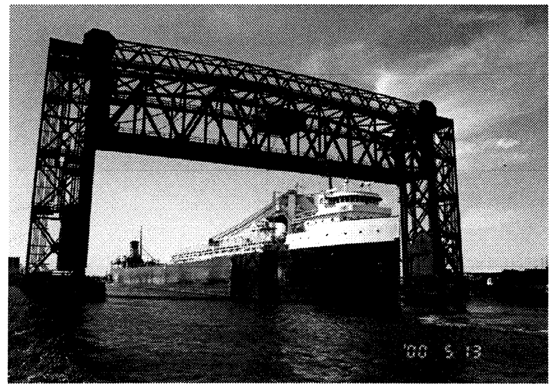
MACHINERY/MECHANISMS

INTRODUCTION



Bridge CD182.30 is a span drive vertical lift bridge erected circa 1956 and is currently owned and operated by Norfolk Southern Corporation. Ownership of the bridge transferred to Norfolk Southern Corporation as part of its recent acquisition of CONRAIL. The bridge is located at the mouth of the Cuyahoga River in Cleveland, Ohio and is a vital gateway both for rail and marine traffic. The bridge supports two tracks of rail traffic over the waterway and carriers over 60 trains a day including both freight and passenger traffic. Additionally, all inbound or outbound marine traffic on this heavily industrialized river must pass through this portal. With a limited vertical clearance of 8'-6 ½" between the bottom of the lift span truss and the Low Water Datum Elevation, the bridge must open for nearly all marine traffic, both commercial and recreational. With over 5400 openings on an annual basis, the bridge holds the distinction as Cleveland's most active movable bridge.

Norfolk Southern Corporation (the Railway) engaged Stafford Bandlow Engineering, Inc. (SBE) to perform an in-depth inspection of the primary support components on this structure in May 2000. The intent of the inspection was to determine the existing condition, to anticipate the remaining life, and to determine the suitability of the primary support components for continued service. The inspection findings revealed extensive deterioration of the support components which necessitated corrective action to ensure the continued safe and reliable operation of the lift span. The Railway subsequently retained SBE to provide design and construction support throughout the rehabilitation of these deficiencies.

Whereas usage has demonstrated that counterweight rope replacements must be placed under the expected long term maintenance requirements for vertical lift bridges, the true Achilles heel of the vertical lift design is fatigue failure of the counterweight sheave trunnions. This paper presents the rehabilitation of the primary support components at Cleveland's most active vertical lift bridge with specific focus on the rehabilitation of the sheave trunnion journals. Topics include the scoping of the rehabilitation work with the efforts to quantify the fatigue concern and address fatigue issues prior to rehabilitation, discovery of fatigue cracking during the construction work, the effort required to enact an in-progress conversion of the construction effort from rehabilitation to replacement, and finally the shortcomings of accepted NDT methods in identifying the trunnion cracks.

DESCRIPTION OF PRIMARY SUPPORT COMPONENTS

The lift span is 265 feet long from center to center of trunnion bearings and is 33 feet wide from center to center of outboard lift truss members. The lift span is counterbalanced by two main counterweights, one at each end of the span. The gross weight of the lift span is 3.29 million pounds per the original contract plans, and that of each counterweight is 1.64 million pounds.

The lift span is connected to the counterweights via 80 wire ropes. Each counterweight is suspended by a total of 40 wire ropes. The wire ropes are 2 1/4" in diameter and are composed of improved plow steel, preformed, right regular lay, 6x25 filler wire construction with hard fiber core. Each rope is 162'-10 ¼" long and weights approximately 1600 lbs.

The wire ropes are divided into four distinct groups based on the four counterweight sheave assemblies which support them. Two counterweight sheave assemblies are located atop each of the towers, with the center of each assembly located 13 feet off the transverse centerline of the bridge. Each assembly consists of two sheaves bolted together and affixed on a common trunnion which is straddle mounted in a pair of bronze sleeve bearings. Each sheave is 15' in diameter and 26" wide. The trunnion is 24" in diameter at the journal and 27" in diameter at the hub and is 112" long. The combined weight of each assembly is roughly 100,000 lbs.

SCOPING OF WORK

The scope for the rehabilitation work was developed based on the findings of the May 2000 inspection. The primary inspection findings comprised localized corrosion of the main counterweight ropes resulting in a significant reduction in rope strength and widespread severe abrasive deterioration of the main sheave trunnion journals.

Main Counterweight Ropes

Replacement of main counterweight ropes on vertical lift bridges has become a prevalent occurrence. Counterweight ropes may experience a loss in integrity due to wire breakage from loading and/or flexure or due to corrosive degradation. The ropes which fail due to the former reason have generally reached the end of their useful life. The ropes which fail due to the latter reason are generally in good condition with the exception of one problematic area, which often corresponds to the splay casting at the top of the lift girder. The portion of rope in contact with the splay casting tends to be inadequately lubricated, and traps debris which holds water and accelerates corrosion. This was the mode of deterioration at CD182.30 with one additional factor. Whereas the splay castings at many lift bridges are manufactured with a radius in the splay casting grooves to accommodate movement of the rope during span operation, the grooves in the splay castings at this bridge were straight with an abrupt edge at the top face. As a result, the castings tended to cut into the wires of the rope as the rope was pulled into hard contact with the casting when the bridge was raised. Therefore, the ropes tended to exhibit wire breaks at this location in addition to corrosive deterioration.

Sheave Trunnion Journals

The May 2000 inspection was initially intended as an in-depth inspection of the main counterweight ropes. During periods of downtime due to the numerous bridge openings and high volume of rail traffic, SBE performed a cursory inspection of the sheave trunnion journals; this was facilitated by the bearing configuration, which utilized a lightweight sheet metal enclosure and enabled easy access as opposed to a standard bearing cap. The cursory look at the journals revealed severe abrasive wear and warranted further investigation to determine their suitability for continued usage.

The surface finish of the journals ranged from 500 min. to 2000 min. as compared to the 8 min. finish required by AREMA for a new installation. Despite the severe abrasion of the journals, there was no readily apparent source for the wear. The lubricant appeared to be free of visible contaminants and an approximate check of bearing stress levels indicated that the bearings were designed in accordance with AREMA requirements. Given the lack of apparent sources, the following are proposed as potential sources for or contributors to the observed conditions:

Sheave Trunnion Journal: Severe abrasive wear of journal surface is evident by gaps between surface and straight edge.

- The carbon steel from which the trunnion was manufactured was not sufficiently harder than the mating bronze bushing.
- The bearing had operated with insufficient lubricant at some point in the past contributing to excessive heat buildup and a breakdown of the contact surfaces.
- The presence of industrial cement and cement aggregate plants surrounding the bridge could contribute to a high concentration of air borne abrasive particles. Such particles could infiltrate the bearing and provide the basis for the observed wear.

Whatever the basis for the onset of the abrasive wear, the wear particles had likely become embedded in the bushing due to the bearing design. The bearing utilized a fully sealed grease box . The advantage of this design is that the bearing is provided a continuous grease bath. The shortcoming is that contaminants which have entered the bearing cannot be flushed free. As a result, contaminants and/or wear particles recirculate in the bearing and further the deterioration of the contact surfaces. The abraded condition of the journals combined with the frequent operation of the bridge ensured that the degradation of the journals was a degenerative condition.

The abraded condition of the journals affected the machinery in several respects. The abrasion provided a significant increase in system friction. This served to decrease system efficiency, increase power consumption requirements, and increase the loading of all span drive machinery components. Additionally, where the abrasive wear extended into the journal fillets, it increased the stress concentration at that area detrimentally affecting the sheave's fatigue life. These adverse affects mandated rehabilitation of the trunnion journals. However, the primary factor affecting the viability of re-using the existing journals was fatigue life. Analytical and empirical methods were subsequently employed to determine the susceptibility of the trunnion journals to fatigue failure.

<u>1. Analytical Method</u>

Study was conducted to determine the stress at the sheave trunnion fillet adjusted for an appropriate stress concentration, the sheave trunnion endurance limit, and the resultant fatigue life. Calculations indicated that the adjusted stress exceeded the endurance limit so that fatigue life was indeed a concern. The calculated fatigue life was then compared to the actual bridge opening history provided by the Railway to determine the remaining life expectancy for the trunnions. This comparison indicated that the actual opening history marginally exceeded the theoretical fatigue life

2. Empirical Method
Non Destructive Testing of the journal fillets was conducted to verify the physical integrity of the fillets. The NDT company was consulted prior to the field work to establish what test method would best identify fatigue cracks for the given application. Dry Magnetic Particle Testing was chosen as the optimum test procedure. Despite the scoring of the journal surface, the company was confident that an indication due to a crack would be markedly different than the scoring. The fillets for all trunnions were subjected to evaluation over the full 360 degree circumference. The testing was conducted by a Level II technician in accordance with accepted practice and witnessed by SBE. No defects or indications were noted.

The findings of the analytical and empirical studies were evaluated together to determine what course of action should be undertaken regarding the existing trunnions. Whereas the analytical method indicated that the bridge opening history had marginally exceeded the trunnion fatigue life, the empirical method attested to the integrity of the trunnions. The formulas employed by the analytical method utilize several variables which must be selected. Conservative assumptions were made in the selection of these variables as complete information was not available. As a result, the calculated theoretical fatigue life was intended as a minimum/conservative value. The findings of the empirical tests substantiated that the calculated fatigue life was more conservative than the actual fatigue life, as it was expected that the testing would have revealed cracks if the actual fatigue life had in fact been exceeded. Therefore, rehabilitation of the existing trunnion journals appeared feasible.

REHABILITATION DESIGN

The primary objective of the rehabilitation was the replacement of the main counterweight ropes and the rehabilitation of the trunnion journals. However, the design also implemented several modifications to the original design to address the following factors which had contributed to the degradation which provided the impetus for this work.

1. Where main counterweight ropes experience a loss of integrity due to corrosive degradation, the corrective action is primarily a maintenance concern. The detrimental effects of the lift girder splay casting at this bridge, however, required redress. Three modifications to the splay casting were enacted to counter the adverse effect of the existing castings on the ropes. First, the new design specified a taper to the splay casting grooves to accommodate movement of the ropes during span operation. Second, the new design specified a radius at the leading edge of the splay casting grooves to eliminate point contact with the rope. Third, the new castings were manufactured from bronze so that the castings would be sacrificial to the ropes.

2. Factors contributing to the abrasive wear of the sheave trunnion journals include abrasive particles/contaminants trapped in the bearing and inadequate lubrication of the bearing load zone. These factors were addressed as follows:

   a. The sealed grease bath employed in the old design was abandoned in favor of a standard open end bearing cap. This design change enables contaminants and wear particles to be flushed from the housing.

b. Each existing journal is provided with three grease grooves in accordance with AREMA requirements. However, there is no provision to directly lubricate these grooves; the grooves were apparently intended to carry grease from the grease bath through the load zone. The new design specifies that the ends of the trunnion journals, which are now accessible due to the implementation of the open end bearing cap, be drilled and tapped for grease fittings so that each of the trunnion grease grooves may be directly lubricated.

c. The existing bushings were not equipped with grease grooves. The new bushings are provided with grease grooves to provide direct lubrication to the journals throughout the load zone. These grooves are drilled and piped to both bearing faces; grease fittings are provided in the bushings at each end of the trunnion and clean out plugs are provided at the bearing thrust face.

3. Sheave trunnion fatigue life concerns were addressed as follows:

a. The machining of the trunnion journals eliminates abrasive stress risers which could compound the fillet stress riser.

b. The stress concentration due to the fillet radius is the prime factor affecting whether the critical stress will exceed the material's endurance limit and become a fatigue problem. The new design addresses this issue by specifying that the existing fillet radius be machined from ¾" to 1 ½". While not eliminating the fatigue concern, this modification provides a 40% increase in the fatigue life. Based on the current age of the bridge, this would extend the trunnion service life by a minimum of 20 to 30 years.

c. The design specified that the fillets would be shotpeened following the machining operation. The shotpeening induces residual compressive stresses into the surface of the material and provides an additional measure of protection against the formation of fatigue cracks, which initiate due to tensile stress.

SCHEDULING AND AWARD OF CONTRACT

In evaluating how the rehabilitation would be implemented in the field, it was clear that the sheave trunnion rehabilitation work made the rope replacement task into an ancillary item. The logistics of rehabilitating the trunnions dictated that the sheaves would need to be unloaded, and the bridge taken out of operational service, in order to perform this work. The ability to perform the rehabilitation work under rail traffic was a necessity for the Railway since the bridge functions as a vital link in the rail network, attested to by the high volume of rail traffic which it carries on a daily basis. However, taking the bridge out of service in the lowered position during shipping season would effectively halt all marine commerce in Cleveland. In order to address both concerns, the work needed to be scheduled during the winter channel closure. The Railway approached the Coast Guard with this plan and received approval for separate 21 day channel closures over the 2002 and 2003 winter closures. Therefore, it was necessary to perform the work one tower at a time. The East Tower, which exhibited worse journal wear, was scheduled for 2002. The West Tower was scheduled for 2003.

The Railway advertised the Contract in early 2001 and received minimal interest. However, given the condition of the components and the approved closure dates, the work could not be delayed. The Contract was awarded to Tri State Steel, Strongsville, OH. Tri State, which is a structural outfit and does not have mechanical expertise, performed the rope replacement and provided general contractor services.

Tri State selected mechanical sub-consultant In Place Machining of Milwaukee, WI to perform the trunnion rehabilitation work and alignment of the finished assemblies. Advance Bronze of Cleveland, OH provided the new bushings and performed the rehabilitation of the bearing bases.

CONSTRUCTION PERIOD

Given the extent of the required repairs and the limited channel closure, it was anticipated that construction operations would proceed 24 hours per day when performing those tasks on the critical path to returning the bridge to service. Therefore, the project specifications required that the Contractor develop a detailed work plan and schedule addressing each of 14 critical path tasks to demonstrate how the work would be completed in the allotted 21 day closure. Since the work was being conducted on the shores of Lake Erie in the dead of winter, it was anticipated that the schedule would need to provide some cushion to account for severe weather delays. Severe weather was in fact encountered as the project progressed, however, another development ultimately had far greater impact on the project. The discovery of cracks in the sheave trunnion journals 11 days into the closure effectively negated the original schedule and necessitated a complete restructuring in order to facilitate the changeover from rehabilitation to replacement. The following is a synopsis of significant project dates:

DATE	EVENT
Jan 28 2002	Kick off Project.
Jan 30, 2002	Complete rope removal at NE corner.
Feb 04, 2002	Initiate machining of NE Sheave journals.
Feb 07, 2002	Initiate machining of SE Sheave journals.
	Discover cracks in both fillets for NE Sheave.
Jan 30, 2002	Complete rope removal at NE corner.
Feb 04, 2002	Initiate machining of NE Sheave journals.
Feb 07, 2002	Initiate machining of SE Sheave journals.
	Discover cracks in both fillets for NE Sheave.
Feb 08-15, 2002	Locate crane with capacity to pick 100,000 lb. sheave assembly.
Feb 15, 2002	NDT investigation of cracks at all fillet locations
Feb 18, 2002	**Original Completion Date for Work.**
Feb 15-22, 2002	Prep footing and setup crane. Prep tower for removal of NE sheave.
Feb 23, 2002	Complete setup of crane and remove NE sheave.
Feb 24, 2002	Delivery of NE sheave at machine shop.
Feb 25, 2002	Resume field operation to rehabilitate SE sheave.
	Take delivery of 1st trunnion forging at machine shop.
Feb 27, 2002	Discover cracks in SE sheave fillets.
	Take delivery of 2nd trunnion forging at machine shop.
Mar 02, 2002	Complete SE journal rehabilitation.
Mar 06, 2002	Complete installation of ropes on SE sheave.
Mar 08, 2002	Received shipment of NE sheave at site.
Mar 13, 2002	Complete installation of ropes on NE sheave.
Mar 15, 2002	Start of Shipping Season.
Mar 16, 2002	**Return bridge to service.**
Mar 25, 2002	Predicted completion work for West Tower.

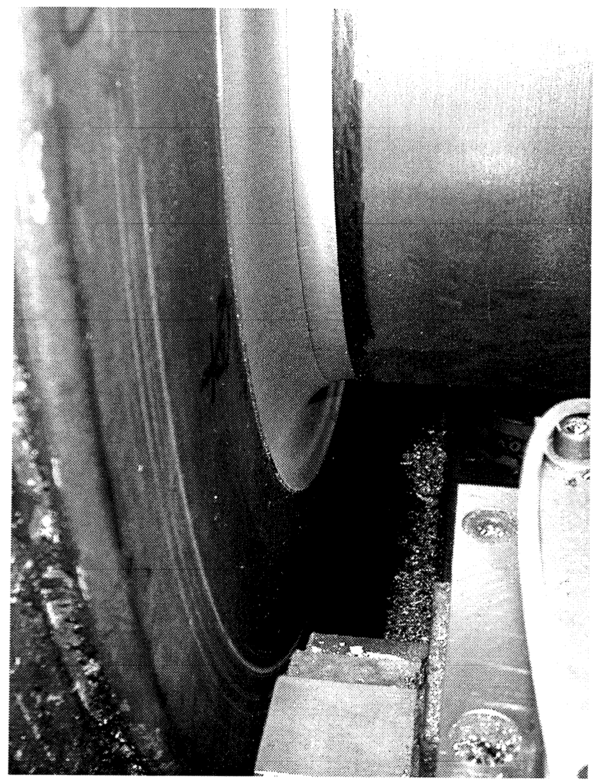
Following is a discussion of the course taken by the project following the discovery of fatigue cracks at the NE sheave trunnion fillets on February 8, 2002. Once the cracks had been verified by NDT methods, the Railway concurred with SBE's recommendation that all trunnions would require replacement on the basis that the remaining trunnions were susceptible to the initiation of fatigue failure in the short term if cracking had not already initiated. SBE set about identifying forging manufacturers and machine shops capable of performing the necessary work, while the Railway updated the Coast Guard regarding the developing situation. Within one day of the crack discovery, purchase orders had been placed for four forgings and a local machine shop, which had the ability to work two sheave assemblies simultaneously, had been selected to perform the work.

Based on the delivery dates provided by the forging manufacture and machine shop, project schedules were developed to determine the completion dates based on performing the replacement work at the East Tower and West Tower simultaneously (April 25), or sequentially (May 25) with limited operations following the completion of the East Tower (March 25). The Railway presented these options to the Coast Guard to see which was most desirable, and the Coast Guard in turn contacted the Cleveland shipping community for feedback. The response was that closure of the river into April would have a catastrophic effect on the marine community and could not be tolerated. Moreover, the Coast Guard stipulated that all efforts should be made to have the channel opened by the beginning of the shipping season. The Railway's options became to either have the bridge operational in March, or to float the lift span out of the channel while the rehabilitation work was completed. Due to vital link which the bridge provided for the Railway, floating the span out was considered the final alternative. Additional testing and study was subsequently conducted, and confirmed that the West tower trunnions could operate without undue risk until the 2003 season when they could be replaced during the winter closure. Therefore, all effort was focused on improving the predicted completion date of March 25, 2002. Following a meeting with the machine shop to discuss machining and assembly issues, SBE proposed a modification to the original trunnion design. The original trunnion had an integral ring at its centerline intended to position each sheave half during assembly. Since the sheave was to be re-used, this ring could be eliminated and the new trunnion could be assembled with the existing sheave assembly. This change in assembly procedure eliminated the need to separate the sheave halves for re-assembly, which work would have required the changeout of the 48 turned bolts that secure the two sheave halves together. This modification to the original trunnion design and assembly procedure resulted in a 2 to 3 day reduction in machining and assembly, and resulted in considerable savings. The Railway further attempted to shorten the closure by foregoing replacement of the SE sheave during the 2002 season, reasoning that the rehabilitation of this trunnion could be completed in shorter time than its replacement. This course of action was chosen at great cost to the railway, since twice the equipment and mobilization would now be required during the 2003 season than otherwise would have been required if the East tower were completed in 2002. These actions, however, ensured that the bridge would be returned to service in less time than it would have taken to float it out of the channel.

The project ultimately ran approximately one month over the original scheduled completion date. However, the fact that the bridge was returned to service nine days ahead of the modified completion date and only one day past the start of the shipping season is a testament to the all out effort expended throughout the work. A two shift crew worked continuously from January 28 through February 8, and then again from February 25 through March 16, often in extreme weather conditions in the effort to complete this work. Their effort deserves recognition.

CRACK DETECTION RETROSPECTIVE

The accurate evaluation of component integrity is of paramount importance during the scoping phase of a rehabilitation project in order to provide a timely and cost-effective construction period. This fact is compounded where rehabilitation work must be performed on a strict timeline. The scoping of the subject project had been undertaken with due diligence, utilizing accepted Non Destructive Testing techniques to validate the physical integrity of the critical components. These methods failed to identify defects which altered the course of the project. The following discussion presents the initial identification of the crack(s), measures taken to quantify the crack depth, subsequent attempts to identify the cracks utilizing various NDT methods, and shortcomings of the various NDT methods apparent through direct comparison.



On the morning of February 07, 2002 at shift changeover, the rehabilitation of the NE sheave trunnion journals was near completion. The night shift had completed the machining operation to enlarge the fillet radius and were in the process of polishing the radius with a flapper wheel. A cursory inspection of the work to evaluate the surface finish revealed a distinct line near the toe of the fillet extending the full circumference of the outboard trunnion. The line was so uniform and distinct that two experienced machinists initially dismissed it as the interface between the sheave hub and trunnion shaft when questioned as to its origin. While aware that these fillets had tested negative for cracks during the scoping phase, little possibility existed that the visible lines were other than fatigue cracks. NDT personnel were immediately contacted to validate the visual assessment. Since a surface indication was clearly visible, the NDT technician opted to perform a Ultrasonic (UT) test using a 70 degree surface probe in order to determine the depth of propagation if the indication was in fact a crack. The UT method verified that the observed indication was a crack as it had propagated to a depth of 5/8" to 3/4" below the surface of the journal, and that it extended the full 360 degrees about the circumference. Note that ¼" material had been removed from the journal as part of the rehab work, therefore the observed crack had actually propagated 7/8" to 1 1/8" below the original journal surface. The fillet for the inboard journal was subsequently inspected and a crack was also confirmed at this location although less extensive than the outboard crack.

Given the presence of the crack at this location, the decision was made to test the fillets for the other three trunnions using both the UT method and the Dry Magnetic Particle (DMP) method. In discussing the failure of the prior testing to identify the crack, the technician indicated that while the DMP method would definitely provide indication of a crack, the scoring present on the journal may have masked the indication. Therefore, it was decided that limited areas in all fillets to be tested would be ground smooth with a hand grinder to eliminate scoring if present. The subsequent testing provided crack indications at the NW trunnion via DMP, but the UT did not detect depth to the indication. No indications were found at the SE or SW trunnions.

Following the verification of the trunnion cracks, the rehabilitation work was suspended while a course of action was determined. The need to replace the NE trunnion was apparent. As discussed previously, time concerns forced the decision to continue rehabilitation of the SE trunnions On February 25, field operations resumed with the machining of the SE trunnion journals. On February 27, as the machinists were in the process of enlarging the trunnion fillets, indications became apparent near the toe of the fillets. The machinists indicated their belief that Wet Fluorescent Magnetic Particle (WFMP) was the preferable test method for this application as it was more sensitive than the DMP method; the machinists provided their own WFMP equipment to substantiate the surface indications. The NDT firm was then called upon to validate the indications and to determine depth of propagation. In side by side tests, the WFMP method positively identified the indication, whereas the DMP method provided only faint indication. The UT did not detect depth to the indication. Based on these findings, the decision was made to excavate the crack by enlarging the fillet and radially undercutting the journal surface. Through an incremental machining process, the WFMP proved to be much more sensitive than the DMP and was ultimately the basis for confirming that the root of the crack had been removed at approximately 0.100" below the journal surface.

Based on the preceding tests, the following observations regarding the NDT methods are warranted:

- The surface detection methods are contingent upon the condition of the surface. Abrasion, scoring, corrosion or other discontinuities may mask indications due to critical defects.

- The strength of an indication is a likely indication of its magnitude; surface cracks appeared as faint indications, deeper cracks provided strong indication. This is particularly significant in conjunction with the preceding item in that surface cracks proved to be indistinguishable from the severe surface wear (scoring).

- WFMP proved to be more sensitive than DMP, continuing to detect indications after DMP had stopped.

- Dye penetrant was applied to the NE sheave trunnion fillet which exhibited the most pronounced crack. The dye penetrant did not provide indication over a large region where the crack was clearly visible. The dye penetrant only provided an indication for the bottom 120 degrees of the circumference. This suggests that the compressive stresses in the top half of the trunnion from the bending moment induced by the weight of the sheave (even without the external rope loads) are sufficient to prevent indication via dye penetrant. Since the top 180 degrees of a trunnion fillet are typically all that is accessible for inspection, the dye penetrant method is an ineffective means of troubleshooting fatigue cracks in trunnions.

- The UT method may be used to identify the location and length of cracks, however it requires knowledge of the component geometry and is limited by the transducer 'line of sight': blind spots may exist due to component geometry which are not detected by the transducer. Where cracks have only initiated and/or do not extend past the discontinuity formed by the fillet, UT is ineffective.

Based on the preceding work, it is the author's recommendation that sheave trunnion fatigue cracks be investigated as follows:

1. Remove all scoring or other imperfections from the area to be tested via sanding or grinding. It is imperative that the test surface be smooth and free from visible defects.

2. Employ the Wet Fluorescent Magnetic Particle method to identify the presence of surface indications.

3. Employ the Ultrasonic method to identify the depth of any indications identified in step 2. This may be best enacted by working a surface probe (70 degree or similar) in the vicinity of the indication. The longitudinal wave method may also be used if the crack has propagated past the blind spot caused by the fillet geometry; however, the longitudinal method was ineffective in identifying the crack at the NE sheave after the surface probe had detected its depth.

These methods have been used on a subsequent inspection of the Main Street Bridge in Jacksonville, Florida and have positively identified surface fatigue cracks.

CONCLUSIONS

The susceptibility of sheave trunnions on vertical lift bridges to fatigue failure first came to widespread attention following the 1978 trunnion failure at the Shippingsport Bridge over the Illinois River near La Salle, Illinois. Many bridges have suffered trunnion fatigue cracks since that time and bridge CD182.30 adds another data point in the continuing trunnion fatigue problem. While fatigue cracks leading to actual failures are rare, the identification of fatigue cracks are as likely to dictate that a bridge be taken out of service permanently (to vehicular and/or rail traffic) as to be repaired.

The community as a whole, and owners in particular, could benefit from the preparation of a comprehensive database on existing failures/cracks. Pertinent information would include predicted fatigue life, trunnion material properties, condition of components, actual cycles to fatigue crack/failure, method of identifying crack, information on rate of crack propagation, and the success of methods taken to extend trunnion life. This database would assist in evaluating the susceptibility of a given trunnion to fatigue, in physically identifying the presence of cracks and/or determining the initiation of a crack, and in determining the optimal course of action to address the fatigue issue.

AFTERWORD

With the return of bridge CD182.30 to service on March 16, 2002, less than half of the work entailed by this rehabilitation project had been completed. The remaining work is schedule for the 2003 winter closure. To ensure a timely construction period in 2003, the Railway has directed the complete replacement of the remaining trunnions, sheaves, and bearings so that the extent of the work is removal and replacement and no delays or surprises are experienced due to the rehabilitation of existing conditions. An NDT program is currently underway to monitor the propagation of the known fatigue cracks until the 2003 replacement.