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Ownership/Public Use/Management

Inspection, Assessment and Repair of Movable Bridges for Local Authorities Using a System Approach

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Introduction

Volusia County consists of 1,207 square miles, including 47 miles of beaches along the Atlantic Ocean, but is known primarily as being the location of Daytona Beach. Tourism is big business within the county; nine million tourists visit the county each year, spending approximately $3.7 billion in 2000. Daytona Beach is host for numerous events that attract hundreds of thousands of attendees: NASCAR's Speed Week in February and Bike Week in March each attract over half a million visitors, with college students' annual Spring Break pilgrimage attracting almost two hundred thousand people. Another NASCAR event around Independence Day attracts another quarter of a million visitors. Their economic impact is on the order of $600 million, and is vital to the county's economy.

The Volusia County Public Works Department oversees maintenance and construction for over 1,500 miles of roadways and 53 bridges, including three bascule bridges. One bascule bridge is located at the north end of the county, while the remaining two are located in the heart of Daytona Beach; all three bridges are vital to the community. While newer high-level bridges have been built by the Florida Department of Transportation (FDOT) in Daytona Beach, public pressures and traffic congestion during peak tourism periods preclude consideration of removing the bridges from service. All three bridges are posted as hurricane evacuation routes.

The Florida Department of Transportation (FDOT) has constructed a new high level bridge between the two drawbridges, and built another bridge two miles north of Main Street, but the county cannot remove the Orange Avenue or Main Street bridges from service due to public pressure and traffic congestion during peak tourist periods.

The bridges are inspected every year as part of a FDOT-managed local government inspection program, so the county engineers are given annual updates as to their condition. From these reports, which typically do not offer much explanation as to why conditions are present, they would program repair work to fix the most significant deficiencies. This resulted in work being performed and additional work being required for adjacent items that could just as easily have been done when the previous work was contracted. In some cases, repairs were ineffective because they were not looking at root causes of problems, just how to fix a reported deficiency.

The county would like to be rid of these maintenance-intensive structures, whether by demolition or transferring ownership to the FDOT. However, that is not a viable option. Because of the large size of these bridges, constant maintenance requirements and problems encountered with their past programming of work (working from a reactive position was only allowing the county to provide band-aid repairs that did not consider longer-term issues), the county was interested in how much work would be required to keep the bridges safe, reliable and operable for another 20 years, and what that cost might be.

Description of Bridges

All three bridges were constructed in the mid to late 1950s; each bridge carries one lane of traffic eastbound and westbound. High Bridge Road (see Figure 1) measures 309' long between abutments, has a 27'-10" curb-to-curb roadway width with 9" high

Fig. 1 High Bridge Road Bridge, South Elevation

curbs and has a 3'-7" wide sidewalk along each side of the bridge. The Orange Avenue and Main Street bridges measure 1,447' and 2,129' between abutments, respectively, and have a 24' curb-to-curb roadway width with 9" high curbs and a 5' wide sidewalk along each side of the bridge. The fixed approach spans at all three bridges are about 36' long between expansion joints. All three bridges feature reinforced concrete approach span decks, sidewalks, curbs and post-and-beam railings, with no bituminous overlay present. All approach span superstructures sit on concrete pile bents with reinforced concrete caps.

All three bridges have double leaf, Hopkins trunnion steel bascule spans. Each leaf consists of two main bascule girders with framing consisting of four floorbeams and lines of stringers (5 at High Bridge, 4 at the other bridges) between bascule girders, spanning a 90' wide navigational channel. The main girders and deep floorbeam adjacent to the trunnion are of built-up riveted plate girder construction. The remaining floorbeams and stringers are rolled wide flange sections. The counterweight load for each leaf is transferred to the main girders by two transverse built-up riveted girders. An open steel grid deck comprises the roadway over the channel, with a concrete filled steel grid deck over the bascule piers. Sidewalks are comprised of steel diamond plate.

Fig. 2 Orange Avenue Bridge, North Elevation

The bascule span machinery at all three bridges typically uses two rack pinions operating on curved racks mounted to the underside of the bascule girders to open or close each leaf. Each set of leaf operating machinery consists of one electrical motor with an integral brake and an additional thrustor operated shoe-type brake. The motor drives the rack pinions through three couplings, a varying number of open reduction gear sets, a differential reducer, transverse shafts and bearings.

At High Bridge Road, two approach spans flank each side of the main span. The approach spans consist of four reinforced concrete tee beams. Plans are not available for the abutments, but they appear to be reinforced concrete cantilevered retaining wall abutments, probably supported on precast concrete piles. Closed bascule piers completely enclose the moving span counterweights. The roadway at the bascule piers is supported by a stringer-floorbeam system of rolled steel girders. The bascule span railings are comprised of riveted steel posts and rails using double angles for posts and channels for rails. The bascule span machinery components are mounted atop structural steel supports attached to the bascule pier. The bridge is posted with weight restrictions for Florida legal loads: 14 tons for single unit trucks and 19 tons for combination truck-trailer vehicles.

At Orange Avenue (see Figure 2) there are 34 approach spans, eight on the west approach and 26 on the east approach; each approach span consists of five reinforced concrete tee beams. On either side of the main span are 41'-4" long flanking spans, consisting of five rolled steel wide flange beams that act non-compositely with the reinforced concrete deck.

At Main Street (see Figure 3) there are 52 approach spans, 15 on the west approach and 37 on the east approach; each span consists of five prestressed concrete AASHTO Type I or Type B beams. On either side of the main span are 42' long flanking spans, consisting of five rolled steel wide flange beams that act compositely with the reinforced concrete deck.

Both Orange Avenue and Main Street have reinforced concrete bascule piers with open counterweight pits. Over the years, concrete pile jackets have been installed on many of the approach piles. The bascule spans have steel railings of riveted post and rail construction, using rolled wide flange steel sections for posts and channels for lower rails, with the top rail a wide bent plate. The machinery at Orange Avenue is Hopkins frame-mounted. The machinery at Main Street was mounted on reinforced concrete pedestals (since removed).

Fig. 3 Main Street Bridge, North Elevation

Project Goal

When starting the project, the county was unsure how much work was required to produce a comprehensive inspection, assessment and repair report. In determining the project scope of work, Lichtenstein worked with the county and its limited budget, taking into consideration issues most significant to the maintenance forces and to ensure that a thorough inspection was performed on elements most critical to the safe, reliable operation of the bridges. County interest and cooperation during this phase of the project kept costs at a level that fit within their budget.

Copies of previous inspection reports, including a special inspection and evaluation of the open gearing and reducers at the Main Street bridge, were provided by the county prior to the scope being written, to determine what had been done, how the bridges were performing, and where emphasis should be made during the planned inspection. The county also provided copies of all available plans, which were essentially limited to rehabilitation plans for work done since 1988. Original design plans for the High Bridge Road bridge were deteriorated and mostly illegible; original design plans for the other bridges were not available. Over a year after this project was completed, the original design plans for the Orange Avenue and Main Street bridges were found outside the county.

To minimize project fees, the county provided maintenance personnel from their Road and Bridge Department to assist with removal of bearing caps and other mechanical components to perform a complete and thorough inspection. The county hired a local contractor to provide manpower in removing and reinstalling trunnion caps.

Additionally, the county was able to borrow the FDOT underbridge inspection unit (UBIU) for five working days (one week). Inspection using this unit was planned to maximize its use, ensuring thorough coverage of the bascule spans at all three bridges and as much of the higher approach spans as possible. Where the inspection of the superstructure underside and substructure units were not able to be performed using the UBIU, the county provided its work boat and an operator to complete inspection of these bridge components.

Condition of Bridges

The assessment report addressed each bridge independently and discussed the conditions found at each bridge. Over the years, the bridges had received maintenance and some minor repairs to keep them operational and in serviceable condition. The county was unable to find plans for any work performed on the bridges prior to 1988, so the history of the bridges prior to that is uncertain.

Typical Conditions Found at All Three Bridges

Typical conditions for the approach spans at all three bridges included mostly moderate-sized spalls and levels of cracking in concrete components. Joints were in poor condition or had deteriorated such that significant lengths of the joints were open, allowing water and debris to pass through them. Bridge rails were found to be substandard, meeting neither AASHTO nor FDOT requirements. Piles and pile jackets at all three bridges were found to have widespread cracking and spalls in the splash zone, some with exposed reinforcing steel.

The bascule spans for all three bridges had corrosion at various locations, with pack rust causing bulging of the exterior flange plate between rivets, up to _" in some locations. The steel components had areas of peeling paint throughout. Isolated welds connecting the open steel grid deck to the bascule girders and stringers had cracked. The sidewalk plates had widespread corrosion on the underside, with numerous areas of loss to the plates adjacent to their connections to the sidewalk brackets (see Figure 4). The top rail on the bascule spans had areas of 100% loss adjacent to the posts. Typical losses throughout the steel members ranged up to 1/8" deep. Where seat angles were present under stringers, bascule span floorbeams had losses in localized areas up to full web thickness, creating up to 1" diameter holes. Tie plates between the sidewalk brackets and main girder had up to 80% section loss.

Fig. 4 Holes in sidewalk plate, Main Street Bridge

Our mechanical inspections revealed numerous bearings that had clearances exceeding an RC9 fit. Several bearings had wear indicative of heavy thrust loading. Lubricants in bearings appeared to be contaminated with water at several locations. Brakes were typically set to provide torques far in excess of where they should have been set. The differential speed reducers had oil leaking from all shaft extensions. The auxiliary drive sprocket was permanently mounted to the each reducer and was found to be a safety hazard, as the sprockets rotate at high rates of speed during normal operation. No covers were present.

Electrically, the installations at all three bridges had numerous details that did not meet the National Electric Code (NEC). Additionally, safety disconnect switches were not present for the drive motors, brakes or span locks. The electrical and mechanical installations at the three bridges were predominantly original construction, so availability of spare parts was an issue as the bridges continued to age.

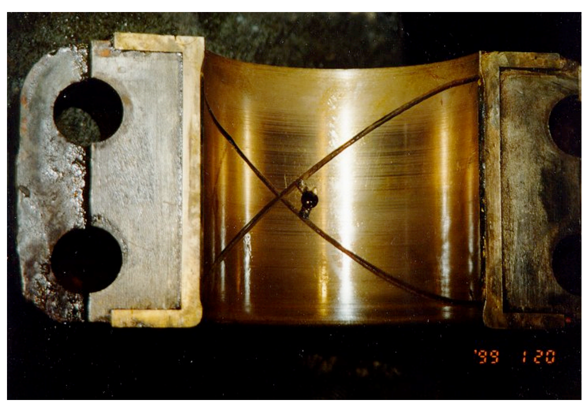

Fig. 5 Misaligned lube port, High Bridge Road Bridge

Bridge-Specific Conditions

At High Bridge Road, the bearing cap grease grooves formed an 'X' pattern, but the lube ports only partially intersected one groove; at one location the lube port did not intersect either groove (see Figure 5).

Makeshift channels had been gouged into the bushing to connect the groove to the port. With the spans fully opened, the visible portions of the trunnion journals at High Bridge Road revealed significant scoring, with metallic particles visible in the grease at one location. The bronze bushings in the base of the housings did not have any grease grooves resulting in a lack of directly applied lubricant. Due to corrosion caused by moisture-trapping debris, the cap bolts at one trunnion bearing had to be replaced during the inspection.

At Orange Avenue, the flanking span decks had significant cracking up to 1/8" wide throughout the deck top, and map cracking up to 1/16" wide on the deck underside (see Figure 6). The Hopkins Frame support for the machinery at this bridge had several cracked welds between the main vertical wide flange supports and a stiffening plate.

Fig. 6 Flanking span concrete deck, Orange Avenue Bridge

At Orange Avenue and Main Street, the bottom 1' of the counterweights dip into the river when the bridge is opened at higher tides, causing severe corrosion. The outstanding side of the bottom flanges of the main girders and counterweight girder at this location exhibit substantial losses.

At Main Street, the south side of the bascule span had been hit by a marine vessel, causing localized collision damage, including three 2" long tears in the bottom flange cover plates.

The machinery at Main Street had some operational issues prior to the inspection. County personnel had commented on some smoke coming from one of the bearings when periodically operated. Upon opening the bearing in question, no fresh lubricant was found on the journal and hardened grease deposits were found on the journal and cap, including in the grease grooves and lube port, indicative of excess heat build-up. Upon replacing the bearing cap following its examination, the bridge had operational problems; shims were added to make the bridge operational. The bearing experienced no heat build-up or operational problems after this work was done. Several of the other bearings had wear over less than 25% of the available contact area.

During prior repair work done at Main Street, problems were encountered during bearing installation. Epoxy used for anchor bolts had apparently failed and the anchor bolts pulled out of the pedestals under operating loads, allowing the bearings to move. The county had installed a restraint fastened to the back side of the concrete supports to limit movement (see Figure 7).

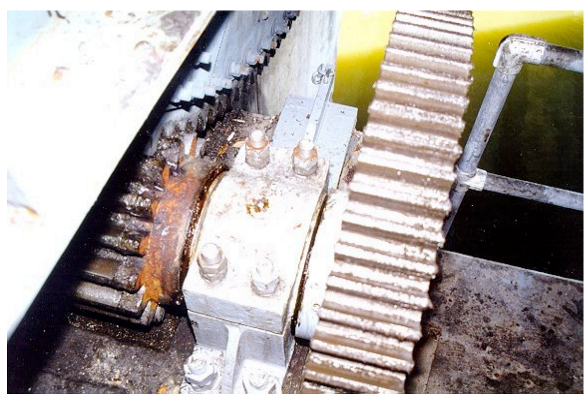

Fig. 7 Restraint at back of concrete support, Main Street Bridge

Assessment of Bridges

Knowing that the county was looking for a way to include all three bridges in its maintenance and repair plans, the seriousness of the deficiencies and the need for additional maintenance were discussed. In some cases, personnel responsible for maintaining the bridges did not understand some of the reasons for certain types of maintenance, particularly for the machinery (e.g. using the correct types of lubricant), and in some cases were not aware that some mechanical elements needed periodic maintenance (e.g. couplings). In addition to detailing how those components should be maintained, discussions detailing how deterioration to one element might affect other elements were included, as well as multiple repair options if possible.

Each bridge component was discussed individually, including possible methods of repair, the reasoning behind the repair and when the work should be planned: in the short term (less than 5 years), medium term (5 to 10 years), long term (10 to 20 years) or multiple occurrences. Repairs necessary for the three bridges were discussed in sufficient detail that county personnel would clearly understand how repairs would be performed and why they were recommended for that distinct time period. Elements considered substandard, such as railings, had their limitations described, but work to upgrade the elements was recommended only as an option.

In three cases, additional analyses outside the scope of the initial investigation were needed. These analyses included:

1. Determine the significance of the beam end cracks on the Orange Avenue approach spans
2. Determine the proper torque settings for the brakes at all three bridges
3. Determine torque requirements for the auxiliary drives at all three bridges

Prioritizing Work

Past experiences in inspection, rehabilitation and design of movable bridges were used to look at the current deficiencies and project when deficiencies would reach a stage where repairs were required, taking into consideration when a repair would provide a maximum benefit for the county given their limited budgets. Each discipline (structural, mechanical, electrical) created repair lists in this manner for each individual bridge.

Once this was done, a master list of all repairs and upgrades for the three bridges were combined and ordered based on the following criteria:

1. Public Safety Issues Requiring Prompt Attention (none found at these bridges)
2. Operational Requirements
3. Other Safety Issues (maintenance forces, future public safety issues)
4. General Bridge Maintenance

Ranking the repair items relative to each other within the above criteria was done using engineering judgment and past experiences with similar types of bridges in Florida, considering typical conditions that are found and how they impact the function of other components. Work required more than once within the 20-year timeframe were listed as many times as necessary to span the 20 years (ex. pourable joint seals, fender system lower timber wale replacement). Work items were ranked considering each bridge as equally important to the County, along with estimated costs for each item, with work items common to all three bridges given the same priority (see Figure 8).

BRIDGE	REPAIR DESCRIPTION	ITEM COST	PRIORITY	*
Highbridge Rd.	Repair sidewalk support beams at Bascule Pier 4.	$2,400.00	1	S
Orange Ave.	Perform load rating analysis of approach span tee beams using most current inspection findings.	$3,000.00	2	S
Highbridge Rd.	**Trunnion Bearings:** Rehabilitate all bearings. Machine the journals. Replace the bushings. Provide grease grooves in the new bushings. Rehabilitate the housings, install lube ports to correspond with the grease grooves in the new bushings. Replace all	$226,800.00	3	M
Main St.	**Bearings:** Replace existing concrete bearing pedestals with steel weldments. Improve bearing alignment to the extent possible. Clean and paint all bearings.	$167,400.00	4	M
Highbridge Rd.	**Automatic Transfer Switch:** Install a dedicated conduit for the low voltage generator start circuit. Bond the generator frame to the local grounding electrode. Install an equipment ground conductor between the generator and the ATS.	$700.00	5	E
Orange Ave.	**Automatic Transfer Switch:** Install a dedicated conduit for the low voltage generator start circuit. Bond the generator frame to the local grounding electrode. Install an equipment ground conductor between the generator and the ATS.	$700.00	6	E
Orange Ave.	Replace concrete deck on flanking span, including bracket rehab.	$40,000.00	7	S
Highbridge Rd.	**Open Gear Sets:** Replace heavily corroded rack (G1 gear) mounting bolts.	$25,900.00	8	M
Highbridge Rd.	**Brakes:** Replace the brake shoe linings for Machinery Brake, West Leaf.	V.C.M.P.	9	M
Highbridge Rd.	**Brakes:** Adjust gap at thrustors to 7/8" in accordance with manufacturer's recommendations.	V.C.M.P.	10	M
Main St.	**Brakes:** Machinery Brake, West Leaf: Rehabilitate existing brake so that brake shoes set firmly against the brake wheel and hand release mechanism is easy to operate.	V.C.M.P.	11	M
Orange Ave.	**Brakes:** Machinery Brake, East Leaf: Adjust brake shoes so that both shoes contact brake wheel and provide torque with thrustor in set position.	V.C.M.P.	12	M
Highbridge Rd.	**Span Seated Limit Switches:** Replace fully closed proximity switch with mechanical type plunger limit switch in NEMA 4X enclosure.	$290.00	13	E
Main St.	**Span Seated Limit Switches:** Replace fully closed proximity switch with mechanical type plunger limit switch in NEMA 4X enclosure.	$290.00	13	E
Orange Ave.	**Span Seated Limit Switches:** Replace fully closed proximity switch with mechanical type plunger limit switch in NEMA 4X enclosure.	$290.00	13	E

Fig. 8 Example rankings from prioritized work item list. V.C.M.P. denotes county maintenance personnel

Estimated costs included construction costs and engineering fees. Mobilization costs were not included, since it was assumed that the work items would be grouped when work was planned, to minimize traffic disruption and inconvenience to the public. Maintenance of traffic costs were calculated by determining the cost for various types of traffic control setups, assuming a closure of at least one week, and converted to a per day item for three types of roadway closures: full bridge closure, single lane closures leaving the road open to unidirectional traffic (one way only) and single lane closures maintaining two way traffic (flagger operations).

Grouping work for planning upcoming repair contracts was not done as part of the list, since County budgets in future years would vary and be the limiting factor on how much work could be undertaken on projects within a given year.

Work items that we felt could be accomplished by the dedicated county bridge crews were not included with costs on this list, since in-house repairs would not require significant closures to any of the bridges and there were no mobilization, construction or engineering costs. If the county wanted to incorporate these items into repair contracts, it would be handled at that time and the costs estimated as part of any engineer's construction cost estimate for the project.

Funding Possibilities

As part of the scope of work, various programs that might provide financial assistance to the County for repairs, including programs authorized by the Transportation Equity Act for the 21st Century (TEA-21) and agency program eligibility requirements of the U.S. Department of Transportation's Federal Highway Administration and the Florida Department of Transportation, were investigated.

At the time that the assessment report was prepared, it was determined that work at the three bridges would likely not qualify the county for outside financial assistance. Unfortunately for the county, its generally pro-active intent towards maintaining the three bridges would make the possibility of receiving any grant monies less likely, since keeping the bridges in serviceable condition would make any repairs or replacement less urgent.

Action Since the Report

The final Inspection and Assessment Report was presented to the county in August 1999. Since the report was accepted, the county has undertaken numerous items from the priority list.

The first item on the list, repair of the sidewalk support beams at the east bascule pier at High Bridge Road, was accomplished just after the report was submitted; repair details were prepared for the county, who performed the work in-house.

The second item on the list was to perform an updated load rating on the concrete tee beam approach spans at Orange Avenue to investigate the effects of the widespread beam end cracking. Done in 2000, the results of the analyses showed that that the cracks did not require urgent repairs.

In 2000, plans were prepared to replace the trunnion bearings at High Bridge Road with spherical roller bearings and adjust the other machinery bearings in the gear train (items 3, 33 and 35 on the final priority list). Work was completed in 2001.

In 2000, plans were prepared for replacement of the concrete bearing pedestals at Main Street with steel weldments providing a common support for all four bearings at each corner of the span (item 4). As part of this work, an analysis of the existing machinery was also performed to determine the source of problems with the span drive bearings, including movement of rack pinion shaft bearings, heat build-up, poor alignment and corrosion of the bearing journals. The analysis indicated that the span drive bearings were sufficiently sized; overheating of the bearings was most likely due to physical deficiencies with the bushings and housings, including small grease grooves, no chamfers at bushing split lines and poor alignment. The scope of the work involved in the repair project was increased to include re-setting the motor and machinery brake torque settings, modifying the bushing design for all bearings and specifying appropriate alignment tolerances and clearances for all rehabilitated bearings (items 11 and 24). Work was completed in 2001 (see Figure 9).

Fig. 9 New machinery supports, Main Street Bridge

In 2001, plans were prepared for various rehabilitation items at Orange Avenue. Work included replacement of the concrete deck and railings on the flanking spans (item 7), cleaning and painting the flanking span steel beams and bearings, repairing the worst spalls on the deck, superstructure and substructure elements (item 25), replace bracket tie plate at one location (item 26), replace bascule span sidewalk plates (item 27), replace top portion of bascule span steel railings (item 29), provide bolts to supplement existing cracked welds at Hopkins frames (item 32) and hydrodemolishing the top 1” of concrete in the filled steel grid deck and repouring it with latex modified concrete (item 84). Work was completed in 2003 (see Figure 10).

In 2003, plans were prepared for replacement of the span locks at all three bridges, which currently have three different types of span locks, with electro-mechanically actuated span lock machinery and new lock bars, using the same sized components at all three bridges to ease the county's maintenance burden (items 36, 37 and 38). As part of this work, the live load supports were shimmed as needed (item 41) and platforms installed at High Bridge Road and Main Street where none had previously existed. The main spans were balanced using strain gage balance testing techniques. Work was scheduled to be completed by October 2004.

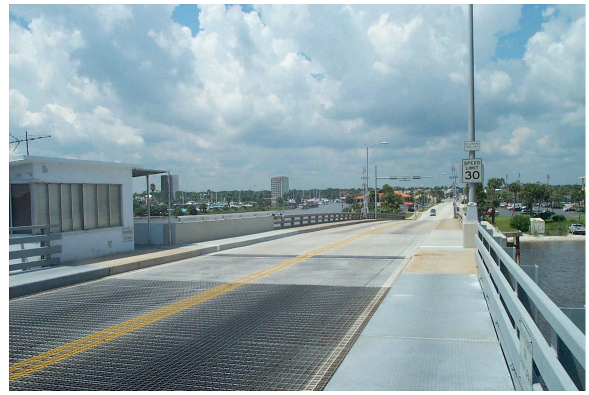

Fig. 10 Completed rehabilitation work at Orange Avenue Bridge

In scheduling such projects, the county has used the list as a basis for work, combining items to fit within its budget each year and to take advantage of the savings that are inherent in combining multiple work items based on location (all work at one bridge) or type of work (same work at all bridges).

To date, the county has accomplished all work tasks that required urgent action based on the initial 1999 inspection. The county has also accomplished several items that would be characterized as operational issues or general bridge maintenance. Since the inception of the inspection and assessment project, the county has had no major operational failures of the bridges, causing significant bridge closures and inconvenience to the traveling public.

The county has not undertaken many of the electrical repairs and safety improvements that were included in the final assessment report. Electrical items are mostly related to conditions that do not meet the National Electric Code and include the installation of the automatic transfer switches, limit switches and general wiring. Work items recommending the addition of guards over exposed sprockets for the auxiliary drives at all three bridges also have not been done.

Additionally, recommended adjustment of machinery components and costly items of maintenance have not been undertaken. These items include rehabilitation work to the speed reducers and couplings, cleaning and painting the steel superstructures and steel repairs. Also included are concrete repairs to the High Bridge Road and Main Street bridges.

Conclusions

With the limited budgets available to county and municipal agencies, public works departments must continually strive to make efficient use of allocated dollars to repair and maintain bridges. Planning such work is typically done in a reactive environment, making emergency repairs after a bridge component has failed or responding to very serious physical conditions that may compromise public safety.

By using a system approach, looking at similar types of bridges or all bridges within a jurisdiction, more efficient use of dollars can be accomplished. This allows the owner to look at the maintenance/repair of bridges with an eye for the long term, promoting savings by issuing similar types of repairs for multiple structures at a time.

The use of a prioritized repair/maintenance list for a whole inventory of structures simplifies the task of determining what work should be done, by putting all data into a common list that is easily accessible and understood. Using this methodology and providing a comprehensive discussion of various elements along with their effect on other bridge components, the local authorities should be able to minimize the occurrences of deficiencies requiring prompt action and more easily deal with the various types of information that are received (inspection reports, county drive-by inspections, public complaints, etc.), as well as have a valuable reference for probable repair costs at all times.

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