INNOVATIVE AND COST EFFECTIVE REPAIR OF HIGHWAY BRIDGES

ALAN E. HYMAN, P.E.[1]

The State of Florida Department of Transportation (FDOT), Maintenance Section is responsible for the mandatory safety inspection of all state and locally owned bridges. The Structures and Facilities unit is the section within Maintenance that is directly responsible for these inspections. District 5 of the FDOT comprises nine counties in central Florida, which includes Disneyworld, Kennedy Space Center and Daytona Beach. All bridges having an opening measured along the center of the roadway of more than 6.0m (20 feet) are inspected at regular intervals not to exceed 2 years. The District is comprised of 875 Stated Owned Bridges of which 8 are movables, 25 are high level of 20.0m (65 feet) or higher and 4 are segmental concrete box girders.

All inspections of state owned bridges are done by in-house bridge inspection teams lead by a Certified Bridge Inspector (CBI) or a Professional Engineer. Design resources include in-house staff from Maintenance or the District's Structures Design section, districtwide consultant contracts or individual bridge specific contracts, depending on the magnitude of the project. In addition the Tallahassee structures research group, formerly headed by Dr. Mohsen Shahawy has provided valuable resources to the District in developing bridge repair designs.

The District receives a budget of approximately $4,000,000 per year to accomplish these bridge repair and rehabilitation projects throughout the nine county area. This budget amount is based on the inventory of the District's bridges. Large dollar repairs exceeding this amount or specialized types of projects can be funded by special discretionary funding approved by the Department's Maintenance Office located in Tallahassee.

Most of the repair and rehabilitation work is performed by contract using the low bid process. The low bid process can be waived by executive declaration during emergency situations. The District has an in-house Heavy Bridge Crew that can undertake a great variety of work ranging from routine maintenance to fairly complex projects.

---

[1] FLORIDA DEPARTMENT OF TRANSPORATION, DISTRICT 5 MAINTENANCE ENGINEER

With the extensive inventory of bridges that exists in the District, problems arise that require remediation in an innovative and cost effective manner. A majority of the structural deficiencies that have required repair have been caused by corrosion, collision damage, poor construction, poor design or a combination of all these factors. Other factors contributing to structural deficiencies are increased traffic, bridge age and aggressive environment locations. Some of the repair methods used have included the following:

1. Full depth deck repair
2. Crutch bents
    a. New free standing installation
    b. Supported from pile bent or cap
3. Cathodic protection
4. Carbon fiber wraps
5. Prestressed strand splices
6. Joint repair and rehabilitation
7. Guniting of culvert walls

This paper describes some of these bridge repair projects that have been undertaken by the District in the past few years.

1. Full depth deck repair

A full depth repair of a reinforced concrete deck is performed when the concrete deteriorates to a state where patching or temporary repairs will no longer work. This type of repair is done on selected deteriorated areas of the deck and does not include full scale replacement of the superstructure or deck. The deteriorated concrete area is removed and new concrete is placed consisting of a high early strength mix capable of reaching a minimum compressive strength of 17mPA (3500 psi) in four (4) hours or less with a minimum 28-day compressive strength of 31 mPA (6400 psi). A commercially available bag mix is allowed, rather than ready mix concrete from an approved plant, if the bag mix meets all the specification requirements. All existing reinforcing steel remains in place with new rebar added, if needed. Any damaged or deteriorated rebar is replaced. Construction joints are permitted only at locations as shown on the plans. Any alternate locations require approval of the Engineer.

Lane closure restrictions, as determined by Traffic Operations, are required due to traffic conditions that dictate that all lanes are open during most daytime hours. The contractor removes only that portion of the deck that can be removed and replaced between the hours of 8:00PM and 6:00AM, Sunday through Thursday evenings. Immediately prior to placing the concrete, all contact surfaces between the existing concrete and new concrete being poured are cleaned and thoroughly coated with an epoxy bonding compound. Also, dowels are placed into existing concrete at these contact areas. The contractor is required to have provisions in place in the event that a complete travel lane cannot be opened before the specified time. A hot mix patch is not allowed on full depth repairs.

This type of deck repair has been used on the I-4 EB over Dirksen Drive Bridge in Volusia County (Bridge No. 790100) and the I-4 EB Bridge over US441 (Bridge No. 750204).

2. Crutch bents

The SR528 WB over the Banana River Bridge (Bridge No. 700028) was severely damaged due to a barge hit during Hurricane Floyd in 1998. The errant barge took out pilings in two (2) pile supported bents that compromised the structural integrity of the support systems. During the damage assessment, it was determined that an emergency contract was the only alternative since the bridge was closed and westbound traffic was diverted to the eastbound bridge resulting in one lane in each direction rather than two.

Using the District's existing consultant contract and with input from the Structures and Facilities Engineer, it was decided to install crutch bents at each location using four (4) 0.45m (18 inch) square prestressed concrete piling driven to 490kN (55 tons). These piling support a reinforced concrete cap spanned by two (2) AASHTO Type V prestressed concrete beams placed transversely from the existing AASHTO Type III beams used in both spans. The piles were driven and pile caps formed with elevations used from the existing as-built plans. The transverse type V beams were placed temporarily on top of the concrete cap on a 12.7mm (½ inch) temporary neoprene pad. The distance was measured between the bottom of the existing longitudinal Type III beams and the transverse Type V beams from the crutch bent, with a beam seat cast atop of the transverse beam. After the beam seat attained a compressive strength of 7 mPA (1500psi), the transverse Type V beams at all four locations were jacked simultaneously. A Type V neoprene bearing pad was placed under each longitudinal beam. See Figure 1 for a detail of the type of repairs made to this bridge.

For less intensive work the Heavy Bridge Crew has performed some fairly significant repairs. The crew has installed temporary helper bents by supporting steel frames from existing caps and columns and supporting existing longitudinal beams. This method is used for deteriorated beam caps where the support has deteriorated significantly.

3. Cathodic protection

Cathodic protection is used to halt further deterioration of deficient reinforced or prestressed concrete piling. Cathodic protection stops further corrosion in chloride contaminated concrete pilings by shifting or transferring the corrosion process from the reinforcing steel or strands to the anodic metals of the system. Cathodic protection works by introducing an additional metal to the concrete to act as an anode so that the reinforcing steel becomes a cathode that causes the corrosion process to stop. There are two types of cathodic protection systems 1) Sacrificial system 2) Impressed current system. Cathodic protection projects are developed with co-operation with the Corrosion Laboratory of the State Materials Office located in Gainesville, Florida.

The sacrificial type system adds anodes of several metals, usually magnesium or zinc, which is used to protect the remaining steel reinforcing. The impressed current system reverses the direction of the current from the reinforcing steel using a direct current and directs this current to the metal anode. Current is discharged from the electrified anodes into the steel, polarizing or neuralizing the most anodic areas of the reinforcing steel, therefore overpowering the corrosion activity of the steel. Several bridges have had impressed current cathodic protection systems installed, including SR528 over Sykes Creek (Bridge No. 700025 and 700112) and SR520 over the Banana River (Bridge No. 700069).

An impressed current type of cathodic protection system is installed by placing pile jackets around the deteriorated piling with fiberglass integral pile jacket filled with Portland cement grout filler. A 12.7mm (1/2 inch) current distributor bar is installed for a positive connection with an insulating heat shrink sleeve placed over this bar. A negative connection is made to the existing prestressing strands or reinforcing steel. A preinstalled titanium anode mesh is imbedded into the integral pile jacket. Wires are routed through the pile jacket to a rectifier connection box. A positive lead is connected to the current distributor bars. All of the cathodic protection positive, negative and reference electrode wires are routed to the rectifier. From the rectifier, the reference electrode wires are routed to the remote monitoring unit. The remote monitoring unit uses telegraphy so that the Corrosion Lab can remotely check on the status of the entire system. A silver/silver chloride constant voltage reference electrode is installed on every interior pile. Each reference electrode is provided with an "on pile" test station. New reinforcement is electrically connected to the existing pile reinforcement by welding or using mechanical connectors as approved by the engineers. Electrical continuity between the new and existing reinforcement is tested prior to placing of jackets. A 120/240 (Single Phase) A.C. power source is used with the rectifier to produce DC voltage in the system for protection of the existing reinforcement. A schematic of an impressed current cathodic protection system is described in Figure 2.

4. Carbon Fiber Wraps

The US192 over the Indian River East Relief bridge (Bridge No. 700173) was rehabilitated using Carbon Fiber-Reinforced Polymers (CFRP) uniaxial laminate sheets. Composite materials are created by saturating a fiber sheet, typically made of carbon or glass, with a chemical resin matrix. Then, one or more layers of overlay are applied to the structural surface.

The reinforced concrete T-beams of this bridge were seriously deteriorated from corrosion of the reinforcing steel from exposure to wave action of the salt water due to the very low clearance, approximately 1.5m (5 feet). Also the concrete was of questionable quality as only several beams of one (1) span were affected. In the deficient beams there were many areas of delamination, severe spalling of the concrete plus exposure and loss of section of the reinforcing steel. The District's Heavy Bridge Crew performed extensive rehabilitation of the cross section of the

beam, which was followed up by the external repair procedure performed by Dr. Shahawy of the Structural Research Center.
In this rehabilitation, uniaxial sheets of CFRP were attached to all exposed sides of the repaired concrete T-beams. Surface preparation of the T-beams consisted of mechanical scarification of the concrete with grinders. Adhesive used was the standard amine resin used previously in repairs by the Structural Research Center team. This initial repair started to show signs of failure approximately a year and a half after the repairs were done. One beam had a visible crack through the CFRP and on one beam, the CFRP was delaminating from possible expansion of the steel reinforcement that was still being exposed to salt water intrusion. The concrete was separating but was being contained by the CFRP wrap, this occurred in several beams.

The Structural Research Group made additional repairs to the beams:

- removal of existing areas of the CFRP where there was separation. These areas were prepared as performed previously, before any additional CFRP was applied. The entire exposed area was sand blasted after removal of the CFRP. Surfaces were pressure washed prior to installation of new CFRP.
- epoxy injection of small and moderate sized air voids.
- Rehabilitation of the deteriorated concrete T-beam cross was performed as before by the Heavy Bridge Crew.
- addition of a second biaxial weave CFRP.

This method was also used on the SR40 over the Halifax River bridge (Bridge No. 790048) where an entire pier was wrapped using CFRP. For this project, the contractor built a steel sheeting cofferdam around the pier and subsequently dewatered it. The Structural Research lab supplied all materials associated with the Carbon Fiber Wrapping and performed all work regarding its application. The contractor was responsible for supplying an adequate work platform to be used by the FDOT employees. This method was used on one main span pier (Pier No. 8), while the other main span pier (Pier No. 9) used a post-tensioning type of rehabilitation around the entire pier.

5. Prestressed strand splices

Strand splices are used when prestressed tendons are severely damaged, usually by vehicular impact. The bottom rows of tendons are most often severed with accompanying significant loss of concrete section. If it is determined that the beam can be saved, the District's Heavy Bridge Crew has done repairs.

Typically, an outside fascia beam is impacted, therefore traffic can be removed from the affected beam, due to a shoulder or lane shift on top. The Heavy Bridge Crew removes all concrete and cleans the cross section and cuts the severed tendons to a point where they are still anchored into existing sound concrete of the AASHTO beam. The splice used is a mechanical coupler manufactured by several vendors. Typically, this mechanical splice uses a chuck with a threaded coupling that is attached to the sound ends of the existing tendon and a turnbuckle to induce tension back into the tendon. Preloading can be used to restore the original load into the structure. Preloading the beam induces tensile forces into the bottom flange and tendons at mid-span. This preload is kept on the beam while the original concrete section is restored. The preload is removed after the restored concrete section reaches desired strength. Preload is applied to the beam by a truck atop the effected beam.

The Heavy Bridge Crew has done this type of repair on several AASHTO beam bridges within the District. The Crew has performed all phases of the repair, including preparation of the damaged beam section, installation of the mechanical splices and restoration of the concrete section. Since the beams are usually fascia beams, if the bridge in question is to be replaced or widened, it is recommended that the repaired beam be replaced during construction. The Heavy Bridge Crew is supervised by the District Structures and Facilities Engineer. All inspections, repairs and rehabilitation work that the crew performs are directed by a staff professional engineer.

6. Joint repair and rehabilitation

A bridge joint is a relatively minor structural element but one that is prone to failure and cause significant traffic problems. The header material is susceptible to failure and cause problems much more than the seal itself. This is the one element that is most likely to fail in a bridge and indeed has in numerous occasions. The types of bridge joints that were built during original bridge construction and found throughout the District's inventory of bridges are:

- Open joint
- Armored open joint
- Armored sealed joint
- Strip seal joint system
- Sliding steel plates
- Finger joints
- Modular joint system

Due to their nature, deck joints require constant maintenance, monitoring and inspection. Deterioration or failure usually occurs outside of the routine inspection process. Telltale signs of possible imminent failure are spalls, separation showing on the deck top and/or a noticeable noise. Since a good number of joint problems occur between routine inspections, they are frequently reported by a third party expressing concern of the situation. Other signs of eminent joint failure are:

- loose, torn or missing seals
- loose, damaged or missing steel elements
- cracked or spalled concrete around joint area
- noise from joint due to vehicle loadings

The District has tried some joint replacements with commercially available systems using proprietary materials such as elastomeric concrete for the header materials. One extensive joint replacement project on I-4 used a proprietary type of system but experienced numerous failures where the entire joint had to be replaced once again. Since many of the previously used joint systems were experiencing problems, the District Structures and Facilities Engineer along with the Structures Design Section concluded that a simplified and more reliable typical joint detail needed to be developed. A common joint detail was developed to accommodate small to moderate span movements.

This typical joint detail requires a header blockout to be removed from the concrete slab on both sides of the joint. This blockout is replaced with High Early Strength (HES) concrete that meets requirements described in the Department's Standard Specifications. The blockout is doweled to the existing concrete with rebar placed before pouring of the HES concrete. All surfaces of the joint are air or sand blasted clean of any moisture, debris and contaminates. The opened joint is then sealed using a foam backer rod and topped with a pourable low-modulus silicon sealant. The pourable joint sealant and HES header concrete are manufactured by several vendors that meet all requirements of the Specifications. The sealant and backer rod selected are sized to perform satisfactorily for the joint opening range as described on the plans. A typical joint detail developed for use in District 5 is shown in Figure 3.

7. Guniting of culvert walls

Deficiencies in reinforced concrete culverts are due to chemical attack, which can be from either fresh or salt water. The deterioration of the concrete results in reduced cover, delamination, spalling and overall deficiency of the concrete. This often leaves honeycombed concrete, which allows intrusion of chemicals resulting in further corrosion of the reinforcing steel and deterioration of the concrete. The District has an aggressive program to repair the many concrete culverts suffering from this type of deficiency.

To perform this type of work, the concrete must be in the dry, therefore the culvert must be dewatered. A watertight barrier is provided by the contractor to allow dewatering of the culvert barrels and wingwalls during construction. Usually both sides of the barrel being worked on require a positive barrier so dewatering can take place. Once the barrel is dewatered, any silt is removed so that all four sides of the interior culvert barrel are exposed. If the water level fluctuates frequently, the contractor needs to assure that the barrels will remain dewatered during the guniting process. Preparation of the deteriorated concrete walls include sandblasting to remove deficient concrete plus cleaning and blasting all reinforcing steel. Once the concrete surface is prepared and ready, the surfaces are coated with a layer of gunite in compliance with all technical and manufacturer's specifications. For multiple barrel culverts, one barrel is done at a time, so that water flow can be maintained through the remaining barrels.

In summary, there are several proven techniques that can be used when determining what type of bridge repairs to undertake due to various reasons causing structural deficiencies. Each situation is unique and requires a thoughtful analytic procedure to determine which course of action to be taken. This paper presented several instances where innovative and cost effective bridge repairs were undertaken to remedy a variety of structural deficiencies.

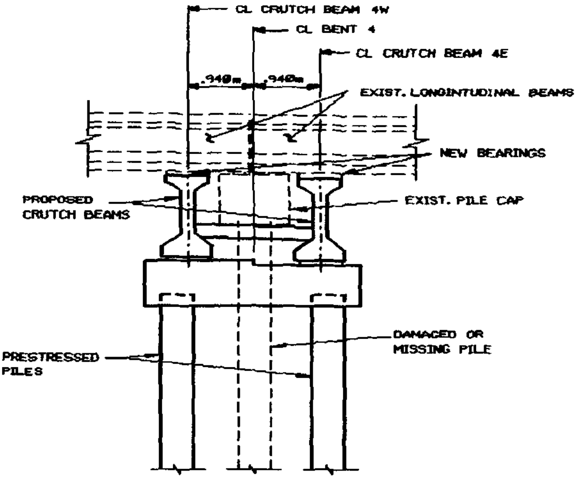

FIGURE 1: TYPICAL CRUTCH BENT DETAIL

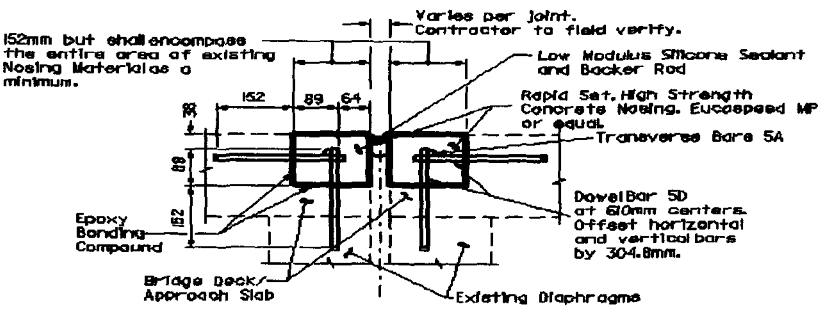

FIGURE 2: TYPICAL JOINT DETAIL

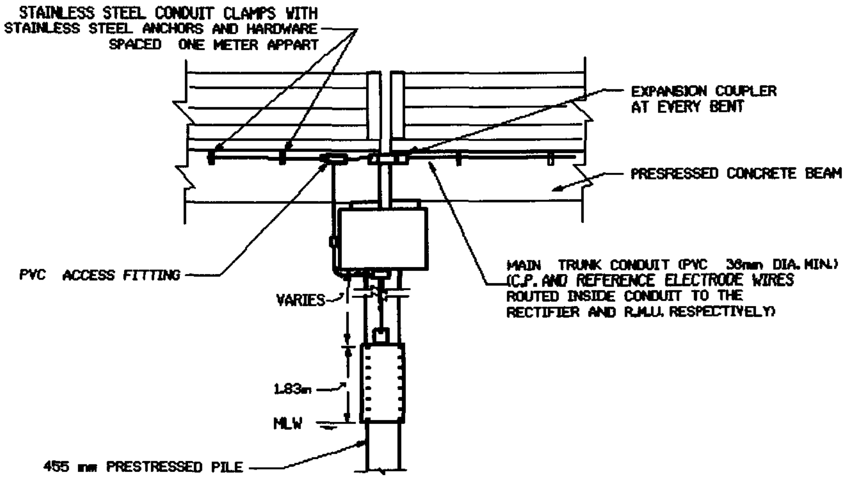

FIGURE 3: TYPICAL CATHODIC PROTECTION DETAIL

References:

Hyman, Alan E. (1997) *Introduction to Bridge Maintenance,* Florida Department of Transportation, Course No. BT-07-0042

Parsons, Brinckerhoff, edited by Louis G. Silano (1993) *Bridge Inspection and Rehabilitation,* John Wiley & Sons, Inc., New York

Tonias, Demetrios E. (1995) *Bridge Engineering,* McGraw-Hill, Inc., New York

Studies on the Use of Powder Actuated Nails in Pile Repair

Jeff Fischer[1], Gray Mullins[1], Rajan Sen[1] and Moussa Issa[2]

Abstract

The bond between original and new material is of critical importance in any repair. In an effort to improve bond, the Florida Department of Transportation recently proposed the use of powder actuated nails as shear connectors in the repair of corrosion-damaged prestressed piles. This paper presents results from an experimental study that investigated the efficacy of such repairs. In the study, six one-third scale repaired prestressed columns were tested under concentric axial loads. The repairs were carried out in accordance with current specifications on sections where damage had been simulated during fabrication. Two different shear connector arrangements were investigated. The results indicated that improvement in performance was relatively modest. However, damage caused by the installation of the powder-actuated nails could be problematic.

Introduction

Corrosion damaged piles are commonly repaired by pile jacketing. In this method, jackets consisting of removable or stay-in-place forms are installed around a pile and subsequently filled with concrete, mortar or epoxy. This type of repair is referred to as *non-structural* and is carried out where damage is minor. In case of extreme damage, *structural* repairs are carried out in which a reinforcement cage is incorporated inside the jacket to provide increased capacity.

----

[1] Department of Civil and Environmental Engineering, University of South Florida
Tampa, FL 33620
[2] T Y Lin International, Chicago, IL