Non-Obtrusive Rehabilitation of Small Bridges and Large Culverts Using Corrugated Steel Pipe (CSP)

David J. Penny B.E.S. Marketing Manager
Corrugated Steel Pipe Institute
652 Bishop Street Unit 2A,
Cambridge Ontario N3H 4V6
djpenny@cspi.ca

Paper prepared for presentation at the

Structures, Innovations in Bridge Engineering, Rehabilitation Session

of the 2005 Annual Conference of the Transportation Association of Canada
Calgary, Alberta

ABSTRACT

Non Obtrusive Rehabilitation of Small Bridges and Large Culverts Using Corrugated Steel Pipe (CSP)

Structures, Innovations in Bridge Engineering, Rehabilitation

David J. Penny B.E.S. Marketing Manager
Corrugated Steel Pipe Institute 652 Bishop Street Unit 2A,
Cambridge Ontario N3H 4V6
djpenny@cspi.ca

Many bridges and culverts in Canada are in a serious state of disrepair or are structurally inadequate for modern operating conditions. The estimated cost to replace these structures is staggering. Materials and construction costs are often minor when compared to the social, environmental, heritage and economic impact costs of a bridge replacement.

Relining or building a structure within a structure is a solution that can minimize costs at all levels. As excavation and demolition of the old structure are avoided or more easily staged to manage detours, the costs and public impact are minimized. The construction techniques used for relining require a smaller access area, lower quantities of building materials and smaller construction equipment.

This paper will outline a number of techniques used to reline small bridges and larger culverts providing alternatives for consideration. It will be presented as a series of case studies of Ontario installations both recent and revisited. Methods and materials will be discussed as will significant site factors that influenced the decision to reline versus rebuild.

The Saint Paul Street Bridge, Brockville, an historic stone arch from the 1840s relined in 1976 using a closely fitting corrugated steel structural plate arch and grouting. (Case study was published September 2004 Environmental Science & Engineering Magazine).

The Gosling Lake / HWY 35, Dorset, an invert reline of twin corrugated steel structural plate pipe arches (CSSPA) using cast in place reinforced concrete, completed March 2004.

HWY 401 / 38, Kingston, a reinforced concrete railway underpass replacement using a deep corrugated steel box culvert erected and backfilled inside the original box, February 2005.

HWY 417, Limoges, a reline of long twin CSSPA using a close fit, slip lined polymer laminated corrugated steel pipe arch with internal couplers and grouting. The project is significant due to the high traffic volumes and the challenging soil conditions making bridge alternatives prohibitively expensive. Summer 2005.

Non-Obtrusive Rehabilitation of Small Bridges and Large Culverts Using Corrugated Steel Pipe (CSP)

Many bridges and culverts in Canada are in a serious state of disrepair or are structurally inadequate for modern conditions. The estimated cost to replace these structures is staggering. Materials and construction costs are often minor when compared to the social, environmental, heritage and economic impact costs of a bridge replacement.

Relining or building a structure within a structure is a solution that can minimize costs at all levels. As excavation and demolition of the old structure are avoided or more easily staged to manage detours, the costs and public impact are minimized. The construction techniques used for relining require a smaller access area, lower quantities of building materials and smaller construction equipment.

Several techniques are used to reline small bridges and larger culverts. A number of alternatives are provided for consideration. A series of case studies of Ontario installations both recent and revisited will demonstrate how unique site requirements were met. Methods and materials will be discussed, as will significant site factors that influenced the decision to reline rather than demolish and reconstruct.

If we look at Webster's definition of the words obtrusive and obtrude we understand them to mean "to thrust out or call to notice without warrant or request." The point of non- obtrusive rehabilitation is to perform the construction task without calling the action to notice. Rehabilitation implies something has changed requiring repair. This brings the action to public notice, often in a negative sense and generally suggests that some level of inconvenience and annoyance will follow.

Rehabilitation of small bridges and large culverts using corrugated steel pipe (CSP), or in some cases rehabilitating CSP using proven relining techniques, greatly reduces the need to intrude on the public. As the techniques tend to preserve much of the original structure and the status quo, negative impacts are minimized.

Before a project begins it is important to identify the issues that have brought the bridge or culvert to a point requiring rehabilitation. Sometimes this is simply population growth and development requiring longer structures or more hydraulically efficient conduits. More often the rehabilitation is required to deal with the deterioration over time of the structure. In these cases, repair techniques and materials that will arrest or minimize future deterioration must be selected.

Saint Paul Street Bridge, Brockville Ontario

In about 1977, the Engineering Department for the City of Brockville identified a need to rehabilitate the bridge over the mill raceway known as Buell's Creek. The bridge was an old stone arch of eight metre span and four metre rise within an earthen causeway. The City had acquired much of the land between the bridge and the waterfront as the former owners, a railway and oil company, had dismantled their storage and shipping facilities and moved away. There was a concern that the old arch was not structurally adequate for the modern highway loading that was required by the City.

The consulting engineer, Minnes and Thomas of Gananoque proposed to reline the bridge with a structural plate corrugated steel arch (SPCSA). As with all reline designs using corrugated steel pipe (CSP) the SPCSA was designed to carry the full highway loading. An arch was selected that would closely match the existing stonework leaving minimal space of approximately 150mm between the steel and the stone. The contract was completed by Welter Construction of Kingston.

Construction involved forming and pouring reinforced concrete footings along the interior base of the stone arch walls. The concrete was allowed to flow between the arch stones and into crevices in the bedrock to seal against future backfill loss. Galvanized steel, unbalanced channels were set in the top of the new footings to help guide the SPCSA into place and to secure it. A section of SPCSA arch, 3.7 metres long was erected in the raceway beside the arch. It was set on the concrete footing and pulled partway into the structure until a second section could be erected and attached to the first. This process continued until the entire SPCSA was in place within the old arch. The arch was secured to the unbalanced channel from inside the arch using special hook bolts. New concrete headwalls were formed and poured on both ends of the arch. These sealed the space between the new SPCSA and the stone arch. Free flowing grout was then pumped through preinstalled threaded grout fittings in the SPCSA. This filled all voids behind the steel including those voids between and behind the stones of the arch.

The non-obtrusive nature of this project seemed rather inconsequential at the time of construction as the site had operated for several years as an industrial storage facility. The contractor moved in and out; almost unnoticed, within two weeks.

The real non-obtrusive significance attributed to heritage preservation is more easily identified today. The Saint Paul Street Bridge is part of a beautiful urban park of historical significance. The bridge and several original buildings on the site date back to the 1840's. The mill site was originally settled by United Empire Loyalists circa 1790.

Gosling Lake / Highway 35 near Dorset Ontario

Twin Structural Plate Corrugated Steel Pipe Arch (SPCSPA) cross culverts, each with a span of 3.4metres, a rise of 2.2metres and length of 33metres had become a concern for the Ministry of Transportation. Several years of continuous contact with fast flowing, slightly abrasive, extremely pure water had perforated the invert plates of the structures. There was considerable section loss of the steel. The structures above the water line were in excellent condition with no indication of structural or corrosion damage.

They were built under relatively high fill on a causeway between two small lakes, which would make their removal and reconstruction difficult and expensive. Average Annual Daily Traffic (AADT) was relatively low at less than 1800 vehicles suggesting minimal public disruption however the options for detour were both limited and long.

The twin culvert design provided excellent possibilities for water management during construction.

A non-obtrusive rehabilitation was an obvious choice at this site.

The Ministry of Transportation Ontario developed a design to install reinforced concrete inverts in both pipes. Due to the section loss the new invert was designed as a structural beam to carry the loaded steel arch above. (Often a simple wire mesh reinforced concrete provides adequate strength if rehabilitation is done early enough.) The design called for the installation of a reinforcing steel cage and concrete, across the invert of each culvert and up each side or haunch, to a point above the normal water line. At this elevation the original culvert steel was sound and reinforcing steel could be attached by welding.

Reinforced concrete cutoff walls were designed at both ends to direct flow into the culverts and to tie into the reinforced concrete inverts. Although there was some loss of total effective end area, a hydraulics check confirmed that the new capacity would be adequate for future needs.

Terra North of Sudbury was the successful contractor. Working during the winter freeze they took advantage of reduced stream flows. Winter construction also took advantage of lighter traffic in this summer resort area. An excellent working area off of the highway at the culvert entrance kept the work largely away from public view.

By diverting all of the flow into one pipe, it was possible to keep the other pipe relatively dry by pumping. The invert of this pipe was cleaned and the reinforcing steel installed. Concrete was poured in two stages in each pipe. The invert was poured first. Plywood forms were then attached at the haunch area using pre-welded threaded studs. The concrete haunches were then poured.

All work was completed before spring break up. The estimated service life of these SPCSPA's was extended considerably using this non-obtrusive rehabilitation method.

HWY 401 / HWY 38 Kingston Ontario

An old reinforced concrete railway underpass crosses the 401 at this location. The trains no longer run, but the right of way has significant recreation potential as a trail. Widening of the highway to accommodate access ramps and a desire to reduce grades and surface elevation made the bridge an obstruction to development. The bridge also showed signs of significant structural deterioration largely due to the inclusion of road salt over time.

Highway 401 is Ontario's primary high-speed artery linking Toronto and Montreal. The AADT at this site is 34,900 vehicles. The economics associated with slowing down this number of vehicles through detours is significant. The solution is to use demolition and construction techniques that minimize these delays.

The Ministry of Transportation Ontario and Consulting Engineers, The Greer Galloway Group of Peterborough and JT Gregg & Associates of Toronto elected to use a modified rehabilitation approach. The design involved building a new bridge within the old bridge while the old bridge remained fully operational. The ends of the longer, new bridge could serve as temporary detours during a relatively short period while the deck and those portions of the old bridge that were obstructions could be removed to allow completion of the new highway surface. This method reduced detour costs and inconvenience significantly but also eliminated many of the demolition and disposal costs.

As standard, DCSPA has a heavy 915gm/sq.M galvanized coating for corrosion protection. As with the original bridge, road salt is expected to be a factor in the durability of the new structure. The soil side of the galvanized steel plates located near the structure ends was coated with polymer for extra protection. This is done in a post fabrication, pre installation, quality controlled, in plant process.

The project involved the erection, installation and back fill of a Deep Corrugated Structural Plate Arch (DCSPA) with a span of 10.0metres, a rise of 6.475metres and a length of 62.48metres. All bridgework was completed from a working area that was removed from the highway traffic. The DCSPA structure was back filled to a height of fill one metre above the steel before the old bridge was demolished.

The general contractor for the project was Aecon of Toronto while Elliott Underground Construction Inc. of Schomberg erected the steel.

Trenches were excavated within the old structure in preparation for the casting of reinforced concrete footings for the DCSPA. Galvanized steel unbalanced channels were attached using post-installed anchor bolts. The DCSPA was erected one plate at a time using a boom truck working between the footings and under the existing bridge. The space between the old bridge and new structure at 600mm was enough to allow bolting access from both sides but necessitated the use of a nonshrinkable, free flowing grout for the backfill of the structure on both sides and to one metre above the DCSPA.

Once the old bridge deck was removed a granular fill was placed and compacted over the DCSPA to a depth of 1.8 to 3.3metres to facilitate final grading and paving of the highway. This was the only obtrusive portion of the bridge project and was closely coordinated to minimize construction time and the necessary associated detours and delays.

<u>HWY 417 Limoges Ontario</u>

Twin Structural Plate Corrugated Steel Pipe Arch (SPCSPA) cross culverts, each with a span of 4370mm, a rise of 2870mm, thickness 3mm, end area 9.76 sq.M. and length of 95metres had become a concern for the Ministry of Transportation. Several years of immersion in slow flowing water and high concentrations of road salt had caused perforations in the structures at and below the normal water line. At one location, backfill had washed into the pipe through perforations requiring temporary repairs. There were also indications that salt was migrating through the fill, particularly at pavement edges, causing corrosion at some of the upper bolt seams. A number of minor issues related to initial construction damage and vehicular impact were also noted.

An AADT of 19,800 vehicles on this main link between Ottawa and Montreal suggested the potential for high costs and safety issues related to detours. The height of cover over the pipe was minimal. This normally favors traditional CSP installation versus reline methods as the long length and light weight steel pipe can generally be installed quickly with minimal excavation, bed preparation, connection and backfill time.

In this case it was the soil under the pipe that favored a reline solution. This part of the Ottawa Valley consists of Lida clay soil. This material is highly saturated and quite unstable when disturbed. Removal and replacement of the pipes would require extensive de watering and shoring. Culverts, heavier than CSP, would require significant bedding improvements to reduce settlement and joint separation. As the pipes are larger than 3.0metre span they are classified as bridges and would therefore require a complete bridge engineering review of the site and design if they were replaced.

The Ministry of Transportation Ontario and Consulting Engineer Morrison Hershfield of Ottawa recognized the significant cost advantages that could be provided by relining the existing structures using Corrugated Steel Pipe Arch (CSPA) and a slip lining process.

Initial survey of the pipe suggested that a CSPA liner with a span of 3650mm, rise 2280mm and end area 6.6 sq. M. would fit well. Hydraulic requirements directed the decision to a larger liner 3890mm x 2690mm with end area of 8.24 sq. M. This larger liner would meet the hydraulic requirements but would provide a number of challenges in the installation due to the closer fit. A more detailed survey of the existing or host pipes would be required prior to fabrication of the liner to confirm that the liner would fit.

The proposed liner is a CSPA 3890mm span x 2690mm rise x 3.5mm thickness. The corrugation profile is 125 x 25mm. In recognition of the corrosive nature due to road salt of the water and fill and the design service life requirement for bridges, a polymer laminated corrugated steel pipe was proposed. The CSPA will be supplied in lengths to be specified by the installation contractor. These can be 3metre to 15metre lengths and will be determined based on optimizing freight costs to the site and distortions of line and grade in the host pipes. Shorter lengths are easier to insert but require more couplers. Each pipe will have factory installed threaded grout fittings, adjustment screws, an internal coupler band and access hole in the top for a hold down support.

The proposed method of construction is to divert all water to one pipe allowing the removal of silt and cleaning of the other pipe. Once cleaned the pipe will be carefully measured to confirm fit and any major obstructions will be removed. Slider rails of plastic lumber of sufficient height to clear existing bolt heads will be secured to the invert of the host pipe. The CSPA liner pipes will be pulled into position in the host pipe and adjusted to line and grade with adjustment screws. Wood blocks will be used to lock each end in position. In some cases, it is anticipated that temporary minor distortion of the liner pipe may be required to clear constricted areas of the host pipe during insertion.

As consecutive pipes are pulled into place they will be adjusted and coupled. A house jack will be inserted through the top opening of each pipe and set on top of longitudinally positioned timber on the invert of the liner to transfer loads due to floatation during grouting operations.

Once all or a significant portion of the liner is in place, the area at the ends between the host and liner will be sealed off. Grout will be pumped into the space between host and liner, in stages starting at the lowest grout fittings. Each lift will be allowed to set before adding more grout to minimize floatation. The house jacks will be removed before the last lift of grout.

The pipe ends will be finished with appropriate cut off protection.

Once one pipe is lined, the stream will be diverted into it so the second pipe can be relined in similar fashion to the first.

These project reviews discuss unique approaches for the non-obtrusive rehabilitation of small bridges and large culverts. They demonstrate the versatility of CSP as a construction tool to make rehabilitation a safe and economical alternative to demolition and new construction. They also demonstrate CSP as a bridge and drainage product that has a service life potential well beyond the first design life of most projects.