

Rehabilitation Opportunities
For
NBDOT Steel Culvert Type Bridges

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Abstract:

The New Brunswick Department of Transportation (NBDOT) has about 475 culvert type bridges constructed of galvanized corrugated steel pipe materials (soil-steel structures). Since 1987, about 25 % have been rehabilitated by installing a concrete invert. A further 8 % of these steel pipe bridges have been replaced. Completed project costs for both rehabilitation and replacement have been tracked and compared. The comparison shows that rehabilitation of soil-steel structures is much more cost effective than replacement and less difficult to undertake.

Steel pipe rehabilitation is achieved by placing a structurally connected reinforced concrete layer on the deteriorated metal section. Usually this extends over the bottom half of the pipe. In addition, flow velocity and fish passage features are incorporated in the concrete invert as required by site conditions. A hybrid bridge structure with an extended service life is the result.

The paper addresses the following aspects of NBDOT experience: (1) history and material durability problems, (2) bridge inspection and condition assessment, (3) rationale for rehabilitation, (4) the current rehabilitation program and (5) typical rehabilitation.

History and Material Durability Problem:

Beginning in 1996, NBDOT started detailed evaluation of the performance of galvanized steel culverts that were “bridge” size, i.e. having a total span of 3 m or more. This work was prompted by maintenance requirements at some of these structures and concerns over the apparent deterioration of the bottom plates, as observed at most sites (Figure 1).

Figure 1: Typical SPCSP Bridge Showing Rust in Lower Quadrant



A randomly selected group of 54 steel culvert bridges were inspected as a representative sample. At each structure, water samples were taken, backfill conductivity was measured, ultrasonic steel plate thickness observations were recorded, evidence of bed load abrasion was noted as was bacterial pitting of the steel. The general shape was visually checked and measured if noteworthy. Finally a rating and the age of each structure were also recorded. After reviewing the results of the sample group of culvert type bridges inspected, NBDOT undertook an accelerated inspection of all of its corrugated steel pipe (CSP) and structural plate corrugated steel pipe (SPCSP) bridges in 1997/1998.

It is important to note that NBDOT had begun rehabilitating structures of this type at least ten years earlier, as needed (Figure 2). Methods and means described in transportation literature were followed during 1987 to 1997. However, the extent of the galvanized steel culvert durability problem in New Brunswick, and its causal factors, were not well understood.

Figure 2: SPCSP Bridge Rehabilitated in 1987



Coincident with the 1997/1998 accelerated structure inspections, a study of the deterioration (corrosion) taking place was conducted. This study keyed on the quality of surface waters in New Brunswick (chemical and biological factors were examined). A scaling index was further developed to evaluate the suitability of galvanized steel as a durable material for culvert type bridges.

This study revealed that many of New Brunswick's surface waters are "very soft" to "soft" and will corrode galvanized steel rather than depositing scales on the galvanizing (zinc) layer. As a result the zinc usually is gone from the invert in 3 to 5 years. Complicating factors, which tend to worsen the deterioration of the steel culvert material in the frequently wetted zone, were also identified. These include free carbon dioxide, dissolved chlorides (from atmospheric drift and mineral sources); sulfur reducing bacteria and organic acids.

The results of the 1997/1998 inspections indicated that the time window or “window of opportunity” was quite limited during which rehabilitation (repair) was an available option. This type of structure may be rehabilitated as long as the general shape remains, but once significant deformation takes place replacement is the only option.

Bridge Inspection and Condition :

Bridges in the NBDOT highway system are inspected once every two years by staff of the Maintenance and Traffic Branch. Standard inspection and reporting procedures are followed. In the case of CSP and SPCSP bridges, special procedures are also used. These are detailed in a report prepared for NBDOT entitled “ Steel Culvert Inspection Manual for the New Brunswick Department of Transportation.”

Previous work published by the United States Federal Highway Administration (FHWA) and other agencies was drawn upon in preparing the above noted Manual in 1998. The inclusion of ultra-sonic wall thickness measurements and a rating system tailored to conditions found in New Brunswick are major features of the Manual.

Inspections are compared with previous versions to detect any signs of change. When a structure is rated as Poor or Critical, a monitoring program is usually begun at once and maintained until the rehabilitation or replacement is completed. At this stage an engineering survey of the structure is completed.

If the structure is a likely candidate for rehabilitation, a special inspection is carried out by NBDOT Design Branch staff, using the form developed for this purpose (Figure 5) and a final decision is taken whether or not to attempt rehabilitation. The rehabilitation design work may be outsourced or performed in-house.

Rationale for Rehabilitation:

On average, the rehabilitation of existing CSP or SPCSP structures has been found to be about 20% of the cost of structure replacement. This average figure is based on the comparison of 114 rehabilitation projects and 34 replacement projects completed during 1987 to 2006 in New Brunswick. During this twenty-year period, the rehabilitation vs. replacement cost comparison has been found to range between 63% and 4%. The median value is 19.5 %. This is a significant economic argument in favor of rehabilitation, especially at deeply buried long pipes. Other factors also favor rehabilitation versus replacement. Rehabilitations cause no traffic disruptions. The work can be scheduled by the DOT/owner and is much less problematic environmentally. By comparison, replacement projects (whether planned or urgent as in the case of a structural failure) are much more extensive and disruptive.

When deciding whether or not to rehabilitate a CSP or SPCSP bridge, NBDOT considers several key factors. These include the extent of deterioration of the steel pipe (as noted in the inspection reports), its age, the severity of the rate of deterioration, the pipe length, the amount of embankment cover, the class of highway/daily traffic count and lastly, but not least, the hydraulic performance. If rehabilitated, the flood flow capacity would be somewhat reduced. The viability of the rehabilitation option and the project priority can be determined by considering these factors.

Also, in New Brunswick, a major environmental factor (which comes into play) is fish passage. This is almost always provided and enhanced beyond the existing situation. Provincial and Federal environmental regulatory requirements must be met in the design and construction of both rehabilitation and replacement projects.

Rehabilitation Program:

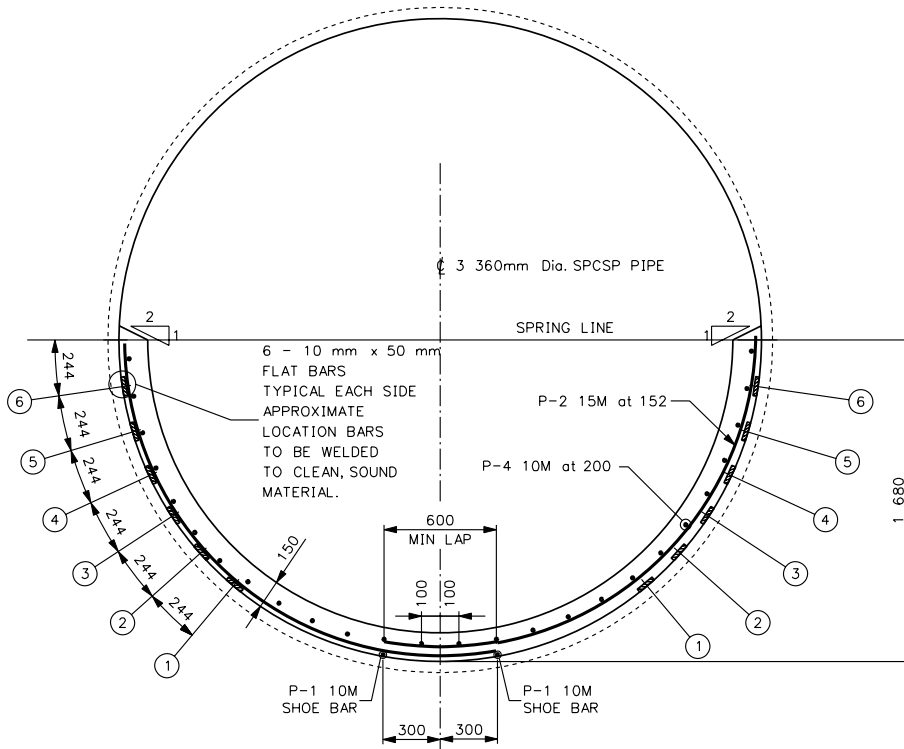
In 2006, NBDOT re-examined the progress to date concerning the rehabilitation of CSP and SPCSP bridges. During the period since 1987, our experience with soil-steel structures in New Brunswick has shown that the average service life at successful rehabilitations has been 24 years. By comparison, where replacement was necessary, the average service life was less than 30 years. The results of the 2006 re-examination showed that of a total of 474 galvanized steel culvert type bridges in service, 326 remained in need of rehabilitation or replacement. It was found that 77% of the 326 were more than 22 years old. Consequently, it was determined that a greater effort was required to take advantage of the remaining “window of opportunity” with respect to the rehabilitation option. A priority screening was carried out on these 326 structures, and approximately 140 were identified as having good rehabilitation potential, since they are still in good geometric shape and deeply buried.

An action plan was recommended to optimize the resources that would eventually be required. This plan calls for 35 rehabilitation projects per year over the next few years. Designs are carried out by in-house staff and by consultants. The initial group of rehabilitation projects under the action plan was contracted in 2007.

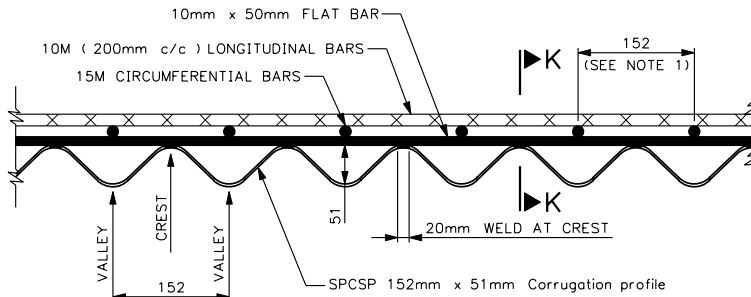
Typical Rehabilitation:

A typical CSP or SPCSP rehabilitation project consists of placing a reinforced concrete lining (150 mm to 250 mm thick) over the deteriorated part of the structure (the bottom quadrant and sides). This “concrete invert” is structurally connected to the sound part (above the rust line) of the corrugated steel by welded bars, which are in turn tied to the reinforcement. The design is based on transferring the embankment thrust load from the steel to the reinforced concrete. The extent of the welded connections is determined by the thrust load calculations. Details of a typical rehabilitation are shown in Figure 3. Until 2007, conventional formed concrete was used almost exclusively. For new contracts in 2007, an optional shotcrete specification has been developed. Figure 4 shows a large but typical SPCSP rehabilitation. This rehabilitated SPCSP has the reinforced concrete invert extending up to the springline and fish passage weirs, which also provide hydraulic roughness.

Figure 3 – Typical Rehabilitation Design

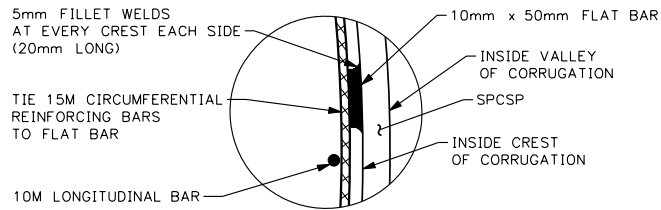


TYPICAL SPCSP REHABILITATION



NOTES:

1. CIRCUMFERENTIAL BARS MUST BE TIED TO FLAT BARS AT MID-POINT OF VALLEY.



SECTION K-K

Figure 4 – Completion of Typical Rehabilitation



Conclusions:

Rehabilitation of soil-steel bridges by the installation of reinforced concrete inverts is a cost-effective way of extending the service life of this type of structure. However, routine detailed inspection is essential to scheduling rehabilitation work while the time limited “window of opportunity” still exists. Rehabilitation work should be prioritized based on age of structure, the severity of deterioration, pipe length and embankment cover, class of highway/daily traffic count and hydraulic capacity.

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FIGURE 5 – INSPECTION REPORT

NEW BRUNSWICK DEPARTMENT OF TRANSPORTATION CULVERT REHABILITATION INSPECTION REPORT

Bridge Number : _____ **District** : _____
Bridge Name : _____
Highway # : _____
Inspection Date : _____
Located in Tidal Zone: Y / N
Perforated Plates: Y / N
Bacteria Nodules: Y / N
Location of Rust Line (Inside the Pipe) : _____ **N from Top Center**

CROSS SECTIONAL SHAPE:

- (1) **Sag or Deflection – Vertical:** _____

- (2) **Misalignment or Bulging – Horizontal:** _____

- (3) **Buckling – Note Location:** _____

Abrasive Material Present: _____

MISCELLANEOUS:

- (4) **Debris:** _____

- (5) **Fish Passage – Situation at Present:** _____
- Species Observed _____

- (6) **Other:** _____

Retaining Walls:

- o Gabions: o Stable, o Unstable, o Rusted, o Loss of Stones
- o T-Beams: o Stable, o Unstable, o Cracking or Spalling
- o Other: _____ o Stable, o Unstable

“Rehab” Design by Consultant: Y / N

Comments: _____

Photographs: Y / N

Signature: _____

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