THE REAL SERVICE LIFE AND REPAIR METHODS
OF STEEL PIPE CULVERTS IN SWEDEN

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Abstract

The total bridge stock owned by the Swedish Road Administration (SRA) consisted, in the autumn 2006, of 15,300 bridges with an area of 4,460,000 m² of which 2,400 are pipe culverts with a total bridge area of 200,000 m². Of these pipe culverts about 2,270 are made of corrugated steel. This paper is based on a case study of these 2,270 steel pipe culverts in use and also about 110 demolished. This paper will describe the real life span and the status of the steel pipe culvert population. The paper will also show different measures for repair of steel pipe culverts. The mean age when major repair is necessary and associated costs is also addressed.

Key words: steel pipe culvert, real life span, repair methods

1. INTRODUCTION AND DEFINITIONS

A bridge is normally a manmade structure which purpose is to carry traffic over or around an obstacle made of man or nature. Since 1998 a bridge is defined in Sweden as a structure with the longest span exceeding two meters.

Pipe culverts of corrugated steel were introduced in Sweden in the mid 1950s. A pipe culvert is a low cost bridge which is, most of the times, quick and easy to construct, see Figure 1.1. The bridge area for a pipe culvert is defined as the span times the pipe culvert’s bottom length, see Figure 1.2.
2. TOOLS AND USED METHOD IN THE CASE STUDY

A bridge owner who has many thousands of bridges to manage knows that it is a complex task and therefore a bridge management system (BMS) is a must for the effective planning and procurement of new bridges and for the maintenance of the existing bridge stock.

2.1 BaTMan

The Swedish Road Administration (SRA) has since the mid 1970s used computerized BMS. The latest update of SRA’s BMS is called Bridge and Tunnel
Management system (BaTMan), which was introduced in 2004. BaTMan supports the management of a bridge structure during its whole lifecycle, from the design phase to the demolishing stage. BaTMan is an Internet based system, which means that users all the time have updated information about the actual bridges online (https://batman.vv.se).

2.2 Used method in the case study

The PhD student has gathered information from BaTMan during the autumn 2006. For every bridge he has recorded year of construction, material of the primary load bearing element, area of the bridge, span, if the bridge has connection with water, condition class, estimated costs for repair (if needed), performed repair and real costs, year of performed repair and year of demolition for bridges not in use anymore.

The gathered data about the bridges have been used as input in the software Excel from Microsoft. Microsoft’s Excel is a valuable tool regarding performing calculations, analyzing data and managing lists in spreadsheets.

3. REPAIR METHODS

The most common method to repair and strengthen pipe culverts of steel in Sweden is to apply shotcrete inside the culvert, see Figure 3.1. The work can be described in seven steps.

1) Embankment.
2) Diversion of the water.
3) Cleaning inside the pipe culvert.
4) Blasting of the pipe culverts bottom to take out all corrosion.
5) Casting the pipe culverts bottom with at least 100-150 mm steel fibre reinforced concrete.
6) Blasting the remaining part of the pipe culvert that will be shotcreted.
7) Apply shotcrete (steel fibre reinforced). If only the walls is shotcreted then epoxi is used to seal the transition between shotcrete and pipe culvert wall.

Figure 3.2 shows embankment for a single pipe culvert and diversion of water with a small pipe inside the pipe culvert.

If there is two pipe culvert one can start with embankment of pipe culvert 1 and divert water through pipe culvert 2, see Figure 3.3. After finishing work at pipe culvert 1 (step 3-7) then it is time for embankment of pipe culvert 2 and divert water through pipe culvert 1. Work at pipe culvert 2 can then be finished (step 3-7).
Figure 3.1. Shotcrete applied inside a steel pipe culvert

Figure 3.2. Embankment and diversion of water for a single pipe culvert

Figure 3.3. Embankment and diversion of water for two pipe culverts
4. CASE STUDY RESULTS

4.1 Steel pipe culverts in connection with water

Data for 2,274 steel pipe culverts have been gathered of which 1,833 have connection with water. Steel in connection with water and free oxygen means a potential risk for corrosion. Almost all of the recorded damages in the case study have been noted for steel pipe culverts in connection with water. Therefore, the results from the case study will focus on steel pipe culverts in connection with water. Figure 4.1, 4.2 and 4.3 shows steel culvert bridges divided by year of construction, span and bridge area. From the figures above one can see that a typical steel pipe culvert in Sweden have a span of 2-5 meter and a bridge area of 40-120 m².

![Figure 4.1](image1.png)

Figure 4.1. 1,833 steel pipe culverts divided by year of construction

![Figure 4.2](image2.png)

Figure 4.2. 1,833 steel pipe culverts divided by span
4.2 Condition of steel pipe culverts in connection with water

It is important that bridges are inspected regularly. The inspection intervals used in Sweden, see Table 4.1, do not differ much from similar systems in other countries, even if the denominations of the different steps are different.

<table>
<thead>
<tr>
<th>Regular inspection</th>
<th>General inspection</th>
<th>Major inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 year</td>
<td>3 years</td>
<td>6 years</td>
</tr>
</tbody>
</table>

The results of the inspection are reported in two ways, a functional classification (condition classes) and an economical classification. The condition class, see Table 4.2, can be an integer number 0, 1, 2 or 3, dependant on how serious the damage at the time of inspection is and the impact to traffic safety.

<table>
<thead>
<tr>
<th>Condition Class (CC)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC 0</td>
<td>Expected loss of designed function beyond 10 years</td>
</tr>
<tr>
<td>CC 1</td>
<td>Loss of designed function expected within 10 years</td>
</tr>
<tr>
<td>CC 2</td>
<td>Loss of designed function expected within 3 years</td>
</tr>
<tr>
<td>CC 3</td>
<td>Total loss of designed function at the time of inspection</td>
</tr>
</tbody>
</table>

Figure 4.4 shows actual Condition Classes for steel pipe culverts in connection with water. Demolished steel pipe culverts are also included. From Figure 4.4 one can see that most steel pipe culverts constructed from mid 1950s to mid 1980s have a Condition Class of 1-3 (CC 1-3) with a need to be repaired or have had some major repair (R CC 0) or have been demolished (Dem).
4.3 Major repairs carried out

229 major repairs have been recorded in the case study. Almost all have been to apply shotcrete inside the steel pipe culvert. The mean age of 215 performed repairs with shotcrete is 32 years, with a typical range of 25-39 years.

Costs for 175 performed repairs with shotcrete have also been recorded. The cost can be divided by bridge area. The mean cost is around 7 kSEK/m$^2$, with a typical range of 4-10 kSEK/m$^2$.

4.4 Demolished bridges

103 demolished steel pipe culverts have been noted. The mean age is 34 years, with a typical range of 26-42 years.

Costs for 29 demolished and replaced bridges have been recorded. The mean cost is around 15 kSEK/m$^2$, with a typical range of 9-21 kSEK/m$^2$.

4.5 Planned major repairs

In Figure 4.4 there is 686 steel pipe culverts with a CC of 1, 2 or 3. To complement the information about condition class the inspector suggest a repair method and a rough estimate of the cost to repair.

Figure 4.5 shows suggested repair methods for 686 steel pipe culverts. 482 bridges are suggested to be repaired with shotcrete inside the pipe. The estimated mean cost is around 3.5 kSEK/m$^2$, with a typical range of 1-6 kSEK/m$^2$.

102 bridges are suggested to be demolished and replaced with new steel pipe culverts. The estimated mean cost is around 11 kSEK/m$^2$, with a typical range of 3-19 kSEK/m$^2$. 
The estimated total cost for the suggested repair methods in Figure 4.5 is about 200 MSEK in BaTMan. The estimated cost in BaTMAn does not consider a contractors establishing cost and that the performed work, most of the time, will cover the whole pipe and not just the damaged part of it.

If one compare the cost for performed work with the cost for planned work a ”swell-factor” of about 2 can be used. That means that the real cost in Figure 4.5 can be estimated to about 400 MSEK:

5. CONCLUSIONS

A steel pipe culvert is a low-cost bridge that has a real life span of 25-42 years before major repairs need to be carried out or the pipe need to be replaced. The mean age at demolition is around 60 years for other bridge types in Sweden.

Most steel pipe culverts constructed from mid 1950s to mid 1980s in Sweden have a Condition Class of 1-3 with a need to be repaired or have had some major repair or have been demolished.

The most common repair method in Sweden is to apply shotcrete inside the steel pipe culvert. The mean cost is around 7 kSEK/m², with a typical range of 4-10 kSEK/m². This repair method have a expected life length of at least 20 years.

The mean cost for demolish an old steel pipe bridge and replace it with a new is around 15 kSEK/m², with a typical range of 9-21 kSEK/m².
The estimated total cost for repair of 686 damaged steel pipe culverts in Sweden is about 200 MSEK. Using a ”swell-factor” of about 2 means that real cost can be estimated to about 400 MSEK.

**RZECZYWISTA ŻYWOTNOŚĆ I METODY NAPRAW STALOWYCH PRZEPUSTÓW Z BLACH FALISTYCH W SZWECJI**

**Streszczenie**

Jesienią 2006 roku całkowity inwentarz mostów będący w gestii Szwedzkiej Administracji drogowej wynosił 15 300 mostów o powierzchni 4,460 000 m² z czego 2400 obiektów to były przepusty drogowe o powierzchni 200 000 m². Z tego 2270 wykonane były ze stalowych blach falistych. Referat omawia badania tych 2270 przepustów oraz 110 zniszczonych przepustów. Referat opisuje rzeczywistą trwałość obiektów i kondycję populacji przepustów stalowych. Podane są również różne metody stosowane do naprawy przepustów stalowych. W tekście umieszczono wzmianki dotyczące średniego wieku przepustów wymagających zabiegów utrzymaniowych oraz kosztów tych działań.

Słowa kluczowe: przepusty stalowe z blach falistych, rzeczywista żywotność, metody napraw