ENGINEERING EVALUATION

OLD TROLLEY BRIDGE OVER BRANCH BROOK
WATERTOWN/THOMASTON, CONNECTICUT

March 20, 2017

Prepared by:
Lenard Engineering, Inc.
2210 Main Street
Glastonbury, Connecticut
TABLE OF CONTENTS

1. INTRODUCTION
2. DESCRIPTION OF THE STRUCTURE
3. STRUCTURAL COMPUTATIONS
4. HYDROLOGY, HYDRAULICS, AND SCOUR
5. CONDITION OF THE STRUCTURE
6. RECOMMENDED ACTION AND ASSOCIATED CONSTRUCTION ESTIMATE

ATTACHMENTS

Attachment A
LOCATION PLAN

Attachment B
STRUCTURE PLANS 1 THROUGH 4 OF 4

Attachment C
STRUCTURAL COMPUTATIONS

Attachment D
FEMA FIRM MAPS

Attachment E
PHOTOGRAPHS

Attachment F
CONSTRUCTION COST ESTIMATE
1. INTRODUCTION

Lenard Engineering, Inc. (LEI) was retained on January 23, 2017 by the Town of Watertown to conduct a general engineering evaluation of the old trolley bridge spanning Branch Brook on the Watertown/Thomaston town line, approximately 300 feet upstream from the confluence of Branch Brook with the Naugatuck River. The Location Plan of the bridge is included in Attachment A.

The evaluation was requested because the Towns of Watertown and Thomaston are contemplating to utilize the structure in the future for pedestrian traffic, as part of a recreational trail project between the two municipalities. The evaluation entailed the assessment of the existing condition of the structure and the establishment of the scope of the necessary improvements with the estimated construction cost.

LEI visited the site on March 2, 2017, inspected and surveyed, then evaluated the structure for structural integrity, hydraulic performance, functionality. The cost of the necessary improvements was also calculated. Photographs of the existing structure are included in Attachment E.

The conclusion of the investigation is that the structure can be fitted for the intended use but only at the cost of significant improvements. The following report is a summary of LEI’s findings and conclusions as well as the recommended improvements with the associated estimated construction cost.

2. DESCRIPTION OF THE STRUCTURE

The structure is a concrete arch of 50 foot span oriented in the north-south direction. The curb-to-curb width of the dirt roadway on the structure is 11 feet with parapets on either side. The northwest and the southeast wingwalls are angled at 160 degrees and are 25 feet and 45 feet long respectively. The northeast and southwest wingwalls are 12 feet and 7 feet long respectively and are perpendicular to the parapets. The parapets and all wingwalls are 2 feet thick. There is no railing on the parapets (see Pictures 1 & 2).

The concrete arch is skewed at 39 degrees for improved channel hydraulics. The height of the arch is approximately 15 feet above the deepest point of the channel. The roadway on the bridge is on earth fill over the concrete arch. Assuming that the concrete arch is also 2 feet thick, the thickness of the earth fill varies between approximately 3 feet and 10 feet.

The structure is of either reinforced or unreinforced concrete; the presence of reinforcement in the concrete could not be verified. The geometry of the structure is pictured in Drawings 1 through 4 in Attachment B.

The year of construction of the bridge is uncertain. Based on its general configuration and the fact that it was built as a trolley bridge, it was likely constructed in the 1920’s.
3. STRUCTURAL COMPUTATIONS

The configuration of many structure components remain unknown (foundations, concrete reinforcement, etc.), therefore our structural computations focused on the concrete arch, the principal load bearing component of the structure. The load included the existing and proposed dead loads and the future live loads associated with the proposed use.

The dead loads included the concrete parapets and the arch, as well as earth overburden on the arch. We calculated the live loads based on the latest AASHTO LRFD Bridge Design Specification. The live loads are alternatively either pedestrian loads of 90 PSF applied over the entire bridge, or H10 vehicular load with the dynamic factor of 1.33 to represent a light service truck or an ambulance. The controlling load combination was calculated with the load factors of 1.25 and 1.75 for the dead and live loads respectively. We calculated the compression stresses in the arch at the shoulders and at the peak of the arch. We found that the controlling compression force in the arch is generated at the shoulder of the arch by the H10 vehicular live load.

The compression (cylinder) strength of the concrete is not exactly known, but based on the general condition of the structure we assumed it as 1,500 PSI. The calculated compression stress in the concrete arch at the shoulder from the controlling loading case is approximately 178 PSI, which is safely below the assumed cylinder strength of the concrete. The Structural Computations are included in Attachment C.

4. HYDROLOGY, HYDRAULICS, AND SCOUR

No full-scale hydrology/hydraulic investigation was done for the structure, but the FEMA FIS and the FEMA FIRM documents indicate that the structure does not overtop in the 100 year repeat frequency storm. The FEMA documents are included in Attachment D.

We examined the channel for stability and scour. The brook takes a left turn just upstream from the bridge (see the Location Plan and the Structure Layout Plan in Attachments A and B respectively), and accordingly the right embankment at that location and the south abutment of the bridge are under attack by the flow. The right embankment and the downstream channel appear stable (see Pictures 14, 15, and 16). The south abutment is prone to scour damage. There is no deep scour hole in front of the south abutment, but much of its footing is exposed due to channel erosion (see Picture 8). The brook is depositing sediment on the opposite embankment, and the north abutment is safe from scour (see Picture 9).
5. **GENERAL CONDITION OF THE STRUCTURE**

The structural concrete is severely deteriorated, and the rate of deterioration seems accelerating. The concrete is disintegrating due to frost/thaw action (see Pictures 5 and 6), and efflorescence can be seen over the entire underside of the arch (see Picture 8). Evidently the structure is not protected against water damage. Vegetation grows over and damaging the wingwalls (see Pictures 3, 4, 5, and 6). Scour related erosion can be observed along the southwest and southeast wingwalls and the south abutment.

6. **RECOMMENDED ACTION AND ASSOCIATED CONSTRUCTION ESTIMATE**

The bridge can be converted to carry pedestrian traffic but the following significant improvements are necessary and strongly recommended to stop the further deterioration of the structure:

a) Clear vegetation from the face of and around the wingwalls

b) Excavate the earth overburden on the concrete arch, repair the top of the arch and the inside of the parapets, place membrane waterproofing over the entire inside of the structure

c) Install weep holes at the low point of the arch

d) Remove the top 2 feet of the parapets and wingwalls. Pour new reinforced concrete caps over the parapets and wingwalls

e) Install pedestrian and/or bicycle railing on the new parapet concrete tops

f) Place new overburden of pervious structure backfill over the arch

g) Place subbase and build bituminous roadway over the bridge

h) Excavate channel in front of the north abutment. Move channel to the middle of the span. Place standard riprap protection in front of the abutments and wingwalls at the south side

i) Repair (patch and coat) the entire surface of the structure with polymer modified concrete compound

The estimated construction cost of the listed improvements is $356,000. The *Construction Cost Estimate* is included in Attachment F.
Attachment A
LOCATION PLAN
STRUCTURE - LAYOUT

SCALE: 1"=10'

APPROXIMATE SKEW ANGLE
EXISTING GRADE (TYP.)

TOW=109.31

2'-0" (ASSUMED)

R=38'±

WSE=98.0± (3/2/17)

25'-6"

24'-6"

ASSUMED TOW=117.00

TOP OF ARCH=110.3±

DOWNSTREAM ELEVATION – LOOKING WEST

SCALE: 1"=10'

GRAPHIC SCALE

( IN FEET )
ANCHOR STEEL PEDESTRIAL RAILING INTO NEW CONCRETE CAPPING ALONG PARAPETS.

POUR REINFORCED CONCRETE (CLASS "F") CAPPING OVER PARAPETS AND WINGWALLS. DRILL AND GROUT ANCHOR DOWELS INTO EX. CONCRETE STRUCTURE.

1.25" HMA SO.25
1.50" HMA SO.375
8" COMPACTED SUBBASE
COMPACTED STRUCTURAL BACKFILL
MEMBRANE WATERPROOFING (COLD LIQUID ELASTOMERIC)

CUT EX. PARAPET
EL. = 115.00

2'-0" 2'-0"

2'-0"

11'-0"

2'-0" 2'-0"

VARY

ASSUMED TOW = 117.00

2'-0" (ASSUMED)

DRILL 2 1/2" DIA. HOLES AT LOW POINTS (TYP.)

WSE = 98.0± (3/2/17)

SECTION A-A
SCALE: 1" = 4'

GRAPHIC SCALE

( IN FEET )
Attachment C
STRUCTURAL COMPUTATIONS
**DEAD LOADS**

**WEIGHT OF THE ARCH**

\[
d = \sqrt{36^2 - 25^2} = 25.9'\]

\[
\alpha = \arctan \left( \frac{25.9'}{25.0'} \right) = 46^\circ
\]

**LENGTH OF THE ARCH**

\[
\text{Length} = \frac{2 \pi \times 36^\circ}{360^\circ} = \frac{57.3'}{2}
\]

**WEIGHT OF THE ARCH**

\[
\text{Weight} = (57.3')(11.0')(2.0')(150\, \text{pcf}) = 190,740 \, \text{LBS}
\]
WEIGHT OF PARAPETS

AREA OF THE CIRCULAR SEGMENTS:
\[ A_{cc} = \frac{R^2 \pi}{360 \cdot 36''} \cdot \left( \frac{92''}{230''} \right) - \frac{50.0' \times 25.9'}{2} = 393.0 \text{ SF} \]

ELEVATION AREA OF PARAPET:
\[ A_p = 50.0' \times 16.8' = 393.0 \text{ SF} = 1447.0 \text{ SF} \]

WEIGHT OF THE TWO PARAPETS:
\[ W_p = (2)(2')(1447.0 \text{ SF}) = 269400 \text{ LBS} \]

WEIGHT OF EARTH OVERBURDEN (APPROXIMATE):
\[ \sqrt{38'} = \frac{R^2 \pi}{360} = \frac{25'\times 25'}{2} = 151 \text{ SF} \]

\[ A_{OB} = (25')(11') = 157 \text{ SF} \]

\[ OB = (124 \text{ SF})(11') = 1370 \text{ SF} \]

\[ L = \arctan \left( \frac{25'}{29'} \right) = 40.76° \]
DEAD LOAD REACTIONS AT THE SHOULDERS

WEIGHT OF ARCH          190,740 LBS
WEIGHT OF PARAPETS      268,200 LBS
WEIGHT OF OVERBURIEN    768,300 LBS

\[(\frac{327,360}{163} LBS) = 2,000 LBS\]

SHOULDER FORCE =

\[R_{SD} = \frac{163,300 \, LBS}{2 \cos(46^\circ)} = 565,962 \, LBS\]

DEAD LOAD INTERNAL REACTION AT THE PEAK

\[R_{PD} = \frac{W_6 \, k_1}{2} + OB \, k_4 + \frac{W_6 \, k_2}{2} = R_{PD} \, k_3\]

\[= \frac{(163,680 \, LBS)(8.33)}{2} + (163,680 \, LBS)(8.33) + (190,740 \, LBS)(12.50)\]

\[= R_{PD} (11.15')\]

\[R_{PD} = 329,976 \, LBS\]
**Live Loads**

**Pedestrian Load** = 90 psf

On Full Deck = 11' x 50' x 90 psf = 49,500 lbs
On Half Deck = 11' x 25' x 90 psf = 24,750 lbs

**Arch Shoulder Reactions**

\[ R_{SL} = \frac{49,500 \text{ lbs}}{2(\cos(46^\circ))} = 35,629 \text{ lbs} \]

**Vehicular Load Controls**

**Internal Reaction at the Peak of the Arch**

\[ (R_{PL})(11.15') = (24,750 \text{ lbs})(12.50') \]

\[ R_{PL} = 29,747 \text{ lbs} \]

**Vehicular Load Controls**
Job: WATERTOWN, CT - TROLLEY BRIDGE

10 VEHICULAR BRIDGE WITH DYNAMIC FACTOR

D = DYNAMIC FACTOR = 1.33

ARCH SHOULDER REACTION:

\[ k = 50 \cos(46^\circ) = 34.73 \]

\[ (20k)(46^\circ) = R_{SL}(34.73) \]

\[ R_{SL} = 270.18 k \]

\[ (R_{SL})(1.33) = 361,150 \text{ LBS} \]

INTERNAL REACTION AT THE PEAK OF THE ARCH:

\[ (R_{PL})(11.5^\circ) = 20,000 \text{ LBS} \quad (20' - 2.8') \]

\[ R_{PL} = 38,609 \text{ LBS} \]

\[ (R_{PL})(1.33) = 51,350 \text{ LBS} \]

CONTROLS
**LOAD COMBINATIONS**

\[ F_{DL} = 1.25 \quad \text{TABLES 3.4.1-1} \]
\[ F_{LL} = 1.75 \quad \text{AASHTO-ITFD} \]

**SHOULDER REACTION**

\[ R_{SS} F_{DL} + R_{SL} F_{LL} = \]
\[ = (565,902 \text{ LBS})(1.25) + (36,150 \text{ LBS})(1.75) = 770,715 \text{ LBS} \]

**INTERNAL REACTION AT THE PEAK OF THE ARCH**

\[ R_{PD} F_{DL} + R_{PL} F_{LL} = \]
\[ = (329,976 \text{ LBS})(1.25) + (51,350 \text{ LBS})(1.75) = 502,333 \text{ LBS} \]

**CONCRETE COMPRESSION IN ARCH AT THE SHOULDER**

\[ f_c = \frac{R_S}{A} \]
\[ A = (15' \times 2' \times 144 \text{ in}^2/\text{ft}^2) = 4,320 \text{ in}^2 \]
\[ f_c = \frac{770,715 \text{ LBS}}{4,320 \text{ in}^2} = 178 \text{ PSI} < f_c' \approx 1,500 \text{ PSI} \text{ (ASSUMED)} \]
Attachment D
FEMA MAPS
was developed between the log of the 2-year flood and the drainage area and it was found that for New England, discharges vary in accordance with the drainage area raised to the exponent power of 0.70.

There are no discharge records for Branch Brook. In 1970, the COE completed Black Rock Dam, located on Branch Brook about two miles above the mouth. Discharges from the dam are controlled by gate operations. The anticipated releases for the 10- and 50-year events would probably not exceed the non-damaging downstream channel capacity and these releases would not be made until downstream flood conditions subsided. The 100- and 500-year discharges are estimated based on hydrographs of major events routed through the reservoir. On Branch Brook above Wigwam Reservoir, peak discharge frequencies were determined by using relationships based on records for the USGS gaging station on nearby Leadmine Brook and then relating it to the Branch Brook watershed based on a direct drainage area relationship. A regional study was not undertaken to determine the drainage area-discharge relationship for Leadmine and Branch Brooks. However, the runoff characteristics of Leadmine Brook are considered to be similar to those of Branch Brook.

A summary of drainage area-peak discharge relationships is shown in Table 1, "Summary of Discharges."

<table>
<thead>
<tr>
<th>FLOODING SOURCE AND LOCATION</th>
<th>DRAINAGE AREA (sq. miles)</th>
<th>PEAK DISCHARGES (cfs)</th>
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<td>10-YEAR</td>
<td>50-YEAR</td>
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<td><strong>NAUGATUCK RIVER</strong></td>
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<td>At downstream corporate</td>
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<td>limits</td>
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<td>At upstream corporate</td>
<td>131</td>
<td>5,000</td>
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<tr>
<td>limits</td>
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<td></td>
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<tr>
<td><strong>BRANCH BROOK</strong></td>
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<td>At mouth</td>
<td>22.8</td>
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<td>At Black Rock Dam</td>
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<td>At Wigwam Dam</td>
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<td><strong>STEELE BROOK</strong></td>
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<td>At downstream corporate</td>
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<td>Above Wattles Brook</td>
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<td>Below Smith Pond Brook</td>
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<td>confluence</td>
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Attachment E

PHOTOGRAPHS
Picture 1 – Roadway on Bridge – Looking South

Picture 2 – Roadway on Bridge – Looking North
Picture 3 – Southeast Corner of Parapet

Picture 4 – Easterly Parapet
Picture 9 – Underside of Arch – Looking North

Picture 10 – Downstream (East) Fascia with Wingwalls
Picture 13 – Downstream Fascia

Picture 14 – Westerly Embankment – Upstream
Attachment F
CONSTRUCTION COST ESTIMATE
Estimate

Estimated Cost: $309,335.15
Contingency: 15.00%

Estimated Total: $355,735.42

REHABILITATION OF OLD CONCRETE TROLLEY BRIDGE OVER THE BRANCH BROOK TOWNS OF WATERTOWN AND THOMASTON

Base Date: 03/20/17
Spec Year: 11
Unit System: E

Work Type: STRUCTURAL CONCRETE
Highway Type: LOCAL USE - Local
Urban/Rural Type: Rural
Season: SUMMER 6/21 - 9/20
County: WATERTOWN
Latitude of Midpoint: 413830
Longitude of Midpoint: 730450
District: 4
Federal/State Project Number: N/A

Estimate Type: Preliminary Evaluation

Prepared by Lenard Engineering, Inc.
Checked by PM
Approved by PM
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3:20:19PM
Tuesday, March 21, 2017
Page 2 of 3
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Total for Group 0001: $309,335.15
CALCULATION OF QUANTITIES

003 EARTH EXCAVATION

\[(50') \times (11') - (50') \times \left(\frac{2}{3}\right) \times (12') \times (11') = (\text{OVER ARCH}) 1,650 \text{ CF}\]
\[2 \times (11') \times (11') \times (10') \div 2 = (\text{OUTSIDE ARCH}) 1,210 \text{ CF}\]

\[2,860 \text{ CF} \div 27 = 106.7\text{ CY}\]

005 FORMATION OF SUBGRADE

\[(70') \times (11') = 770 \text{ SF} = 770 \text{ SF} \div 9 = 86.66\text{ SY}\]

006 SUBBASE

\[(770 \text{ SF}) \times \left(\frac{3}{12}\right) = 513 \text{ CF} = 513 \text{ CF} \div 27 = 19 \text{ CY}\]

007 PERVIOUS STRUCTURE BACKFILL

\[\text{EARTH EX} - \text{SUBBASE} = 106.7 \text{ CY} - 19 \text{ CY} = 87.7 \text{ CY}\]

008 SEDIMENTATION CONTROL SYSTEM

\[(4) \times (25 \text{ LF}) = 100 \text{ LF}\]
009  HMA  S 0.375
(770 SF) (1.5"/2) (150 PCF)/2,000 = 7.2 TON

010  HMA  S 0.25
(770 SF) (1.25"/2) (150 PCF)/2,000 = 6.0 TON

011  REMOVAL OF SUPERSTRUCTURE CONC.
(46' + 50' + 12' + 7' + 50' + 25') (2') (2')/27 = 28 CY

012  CLASS "F" CONCRETE
(SAME AS CONCRETE REMOVAL) 28 CY

014  SAW - CUTTING CONCRETE
45' + 50' + 12' + 7' + 50' + 25' = 189 LF

015  DEFORMED STEEL BARS
(28 CY OF CONC.) (75 LBS/CY) = 2,100 LBS

016  DRILLING HOLES AND GROUTING PIGEWS
(189 LF) (1 PIGEWS/3 LF) = 63 EA
017 STANDARD RIPRAP

\[(10') (10') (2.5') / 127 = 65 \text{ CY}\]

018 MEMBRANE WATERPROOFING

\[\text{OVER THE ARCH: } (2) (40') (7') / 4 \times (11' + 4' + 4') = 1,194 \text{ SF} = 1,194 \text{ SF} / 19 = 63 \text{ SF}\]

0013 VARIABLE DEPTH WITCH

**Fascias:** 
\[50' \times 11' - 50' \times \left(\frac{10}{3}\right) \times 10' \times 2 = 1,083 \text{ SF}\]

**Underside of Arch:** 
\[(2 \times 38') 11'/4 \times 11' = 537 \text{ SF}\]

**NW Wingwall:** 
\[\left(\frac{15' + 3'}{2}\right) (25') = 225 \text{ SF}\]

**SW Wingwall:** 
\[20' \times 7' = 140 \text{ SF}\]

**NE Wingwall:** 
\[12' \times \left(\frac{17' + 8'}{2}\right) = 150 \text{ SF}\]

**SE Wingwall:** 
\[\left(\frac{18' + 6'}{2}\right) \times 45' = 540 \text{ SF}\]

**Assume 15'' thickness:** 
\[(2,645 \text{ SF}) (\frac{1}{12}) = 830 \text{ CY}\]

Use 500 CY to account for the inside face of the walls.