Follow-up on the “Land-Bridge” at milepost 96.1-A near Morristown, TN

John R. Tomlin, PE
Engineer – Geotechnical Services
Bridge over troubled... water?
Problem Description

- Location:
  - 3.5 track miles south of Morristown, TN
  - Adjacent to Industrial Park on west
  - Rural/Agricultural on east
  - Typical Karst terrain
Problem Description

- Location

Source: Bing Maps 2010
Problem Description

- **USGS Karst Map**
  - Fissures, Tubes, and Caves over 1000 feet (300 m) long; 50 ft (15 m) to 250 ft (75 m) in Vertical Extent
  - In moderately to steeply dipping beds of Carbonate Rock
Problem Description

• History:
  – Historically Active Sinkhole Area for Railroad
    • 19 locations grouted from milepost 78.8-A to 164.0-A over 20 year period
  – Repair Methods Historically Employed:
    • Rock Fill
    • Pressure Injection Grouting
Problem Description

• Pre 1998:
  – Derailments caused by sinks over a several year period
    • Repaired with stone fill
    • Compaction Grouted
Problem Description

• 1998:
  - Large Sinkholes (drop-outs) begin forming in fields adjacent to tracks

• 1999:
  - Sinkholes develop under track, surface water washed overburden into drop-outs
  - Maintained with rock fill
  - 10 mph Slow Order placed for Train Traffic
    • (Typically 60 mph)
Problem Description

MP 96.1A Morristown, TN
Norfolk Southern Corporation
Ogden Project No. 8-4366-0003-0000

Photograph 1 – Aerial view of open sinks near track. Largest measures approximately 65 feet long, 40 feet wide and at least 35 feet deep. (3-31-99)
Photograph 3 – Oblique overhead view of site and widespread sinks in adjacent field. Note washout north of tracks in upper right corner of photo. (3/31-99)
Photograph 6 – Washout north of track at toe of rock fill. (3-31-99)
Photograph 8 – Three foot diameter opening at west end of washout north of track. Note adjacent rock pinnacle. Opening appears to bend horizontally beneath track (to left in photo). (3-31-99)
• March/April 1999: Exploration
  – Ogden Environmental (now AMEC) conducted a site investigation: 20 Boreholes
    • Power Auger for Overburden Thickness
    • Drive Sampling of overburden
    • 7 Borings into rock to assess degree and depth of weathering
Analysis

• Subsurface Conditions:
  – From Ogden report April 1999

Published geologic information (USGS 7.5 Minute Geologic Quadrangle for Talbot, Tennessee) indicates the bedrock unit at this site is siliceous, cherty Mascot Dolomite. That rock type is typically fine- to medium-grained with bedding thickness in the medium to thick range. The relatively pure limestone is highly susceptible to solution weathering along vertical joints, bedding planes and fractures, and therefore, the upper bedrock surface is quite irregular. Numerous cutters (deep soil-filled joints) and pinnacles are common. This condition was typically confirmed by the boring data where depth to refusal varies significantly over a relatively short horizontal distance.
Approx Scale
1' = 50'

Notes:
1. Track curve not to scale.
2. Boring drilled weeks of 3-29-99 and 4-3-99.
3. Boring locations by Ogden and are approximate.
4. Dropout locations as of 4-6-99.
5. Track 'plus' distances are relative to Milepost 96.
6. Elevation of high rail at Milepost 96.0 = 500.3 ft (masl), assumed.
7. Track gradient per track chart = 0.78% downhill to west.
8. Top of rail to top of tie = 8 inches.
9. Distances measured with cloth tape.
10. Boring elevations obtained by sight along level board to steel tape extended at boring location.
Analysis
Analysis

Subsurface Conditions:
From Ogden report April 1999

1. Deemed “High Risk” site
2. Surface Drainage needed to be modified
3. Subgrade Support needed to be improved
### TABLE 1
SUMMARY OF KARST REMEDIATION OPTIONS

<table>
<thead>
<tr>
<th>Option</th>
<th>Perceived Advantages</th>
<th>Perceived Disadvantages</th>
<th>Estimated Construction Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. At-Grade Bridge</td>
<td>Stand alone structure; relatively low risk of future track failure</td>
<td>High cost; may need temporary run-around</td>
<td>$1.47 million</td>
</tr>
<tr>
<td>2. Subgrade Repair with Permanent Run-Around Track</td>
<td>Positive subgrade repair; allows exposure and treatment of specific defects</td>
<td>Weather sensitive; high costs; need to acquire more right-of-way; probable traffic delays</td>
<td>$950,000</td>
</tr>
<tr>
<td>3. Subgrade Repair with Temporary Run-Around Track</td>
<td>Positive subgrade repair; allows exposure and treatment of specific defects</td>
<td>Have to move track twice; weather sensitive; high costs; probable traffic delays</td>
<td>$700,000</td>
</tr>
<tr>
<td>4. Compaction Grout Treatment</td>
<td>Good control over grout placement and take; successful performance in similar geologic settings for other railroad projects; low costs; low impact to traffic</td>
<td>Indirect treatment of specific defects; may not get &quot;complete&quot; coverage; moderate risk of future sinkhole recurrence; requires careful field engineering and adjustment to program.</td>
<td>$350,000</td>
</tr>
</tbody>
</table>
Solution

• NS chose the bridge solution
  – Best for long term
  – Feared cavern system more extensive than could be detected
  – Due to topography, surface water would continue to be an issue
### Solution

![Image of a technical drawing and material list]

---

**Estimated Costs:**
- **Capital:** $774,000
- **Expenses:** $28,000
- **Total:** $814,000

**Required Material List:**

<table>
<thead>
<tr>
<th>QTY</th>
<th>DESCRIPTION</th>
<th>WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>9 1/2&quot; D.O. CORED PIPE PLATING</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>HP212X35360-0 STEEL PLATING</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>MT4 x 12 x 30'-0</td>
<td>360 LBS</td>
</tr>
<tr>
<td>2</td>
<td>1/2&quot; DIA. THREADED ROD x 24'-6 FOR BACKWALLS</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>PRECAST CONCRETE BACKWALL FOR 54&quot; DEEP SPANS - BW54</td>
<td>11.7 TONS</td>
</tr>
<tr>
<td>3</td>
<td>PRECAST CONCRETE INT. CAP - B4X</td>
<td>14.4 TONS</td>
</tr>
<tr>
<td>3</td>
<td>PRECAST CONCRETE INT. CAP - B4M</td>
<td>13.5 TONS</td>
</tr>
<tr>
<td>30</td>
<td>8 x 20'-0 REBAR - A615 OR 60 - ANCHORS FOR BACKWALL &amp; SPANS</td>
<td></td>
</tr>
<tr>
<td>72</td>
<td>ELASTOMERIC BEARING PADS FOR CONCRETE BOX GRDERS</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>PRESTRESSED CONCRETE EXT. BOX SECTION 54&quot; DEEP x 40&quot;</td>
<td>43.0 TONS</td>
</tr>
<tr>
<td>4</td>
<td>PRESTRESSED CONCRETE INT. BOX SECTION 54&quot; DEEP x 40&quot;</td>
<td>40.9 TONS</td>
</tr>
<tr>
<td>6</td>
<td>PRESTRESSED CONCRETE EXT. BOX SECTION 60&quot; DEEP x 60&quot;</td>
<td>44.0 TONS</td>
</tr>
<tr>
<td>6</td>
<td>PRESTRESSED CONCRETE INT. BOX SECTION 60&quot; DEEP x 60&quot;</td>
<td>40.6 TONS</td>
</tr>
<tr>
<td>90</td>
<td>MARLINE GRADE TIES</td>
<td></td>
</tr>
</tbody>
</table>

**Drywall Index:**

<table>
<thead>
<tr>
<th>DRWG. No.</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PROFILE &amp; REQUIRED LIST</td>
</tr>
<tr>
<td>2</td>
<td>GENERAL DETAILS</td>
</tr>
<tr>
<td>3</td>
<td>BACKWALL &amp; DBL 3 PILE END BENT INSTALLATION</td>
</tr>
<tr>
<td>4</td>
<td>DOUBLE FOUR PILE INT. BENT DETAIL</td>
</tr>
<tr>
<td>5</td>
<td>PRECAST CONCRETE BACKWALL FOR 54&quot; DEEP SPANS</td>
</tr>
<tr>
<td>6</td>
<td>PRECAST CONCRETE END CAP - B1</td>
</tr>
<tr>
<td>7</td>
<td>PRECAST CONCRETE INT. CAP - B4X</td>
</tr>
<tr>
<td>8</td>
<td>PRECAST CONCRETE INT. CAP - B4M</td>
</tr>
<tr>
<td>9</td>
<td>PRESTRESSED CONCRETE BOX GRDER 54&quot; DEEP x 40 FT</td>
</tr>
<tr>
<td>10</td>
<td>PRESTRESSED CONCRETE BOX GRDER 54&quot; DEEP x 40 FT</td>
</tr>
<tr>
<td>11</td>
<td>PRESTRESSED CONCRETE BOX GRDER 60&quot; DEEP x 60 FT</td>
</tr>
</tbody>
</table>

General Notes:
- Design: Cooper's E-80 with diesel impact. Pile bearing capacity 90 Tons. (60 Tn Design)
- Workmanship: To be in accordance with current A.R.E.A. Specifications for Concrete Railway Bridges.
- Pile Driving: Bent locations are to be verified in the field before driving piles.
- An accurate log shall be kept of all driven pile and sent to the chief eng. Bridges & Structures.

---

**Transport:** Norfolk Southern

**Milepost:** 96.1-A, Morristown, TN

**Concrete Ballast Deck Trestle Profile & Required List**

---

**References:**
- NS Norfolk Southern
- Milepost: 96.1-A
- Morristown, TN

---

**Other Notes:**
- 96.1-A 99 01
Solution

• Ballast Deck Bridge
  – Decking (top) and caps designed by NS
  – Micro-piles designed by AMEC
    • to be cored into competent rock
  – Estimated cost $820,000 to $1.47 million
Execution

• Hayward Baker contracted to install micro-piles
• Work done at night (10pm – 4am)
• Piling Procedures Developed
  – Procedures varied according to void seam width
    • < 6”
    • 6” – 60”
    • > 60”
  – Governed grout quantity and re-drilling
Daily Work Logs

HAYWARD BAKER

DAILY SITE REPORT

A Keller Company

DATE: Friday 12-3-99

JOB NO: 20051

PROJECT NAME: Norfork Southern

LOCATION: Morristown, Tennessee

CLIENT: Norfork Southern

WEATHER: Sunny, warm

ENGINEER: Mike Terry

TYPE OF WORK: MINIPILES

SITE ACTIVITY

B2/H1 Took 1 bag to topoff. Drilled B3/H2, Casing to 26’. Hammered rock to 26’ to 31’, Broken rock and Seams 31’ to 38’, Rock 41’ 44.5’. Seam 44.5’ to 45’, rock 45’ to 53. Set 40’bar and grouted, 70 bags.

Topoff B3/H5 w/5 bags.

Drilled B3/H6, casing to 38’ rock socket 38’ to 52’ broken seam 46’ to 47’.

Helped Myron (N/S) tamp rail ties.

6 hr. track time: 1st 4:20 pm to 11:10 pm.
### Execution

- **Field Reports**
- **Production Summaries**

#### TO DATE PRODUCTION SUMMARY

<table>
<thead>
<tr>
<th>Date</th>
<th>Hole # (last/ho)</th>
<th>Drilled Depth (FT)</th>
<th>Redrill Depth (FT)</th>
<th>Date Grouting Complete</th>
<th>Total Grout (Bags)</th>
<th>Redrill Grout (Bags)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-11</td>
<td>B1 / H3</td>
<td>68</td>
<td></td>
<td>11-13</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>11-13</td>
<td>B1 / H1</td>
<td>62</td>
<td></td>
<td>11-18</td>
<td>162</td>
<td></td>
</tr>
<tr>
<td>11-15</td>
<td>B1 / H3</td>
<td></td>
<td>68</td>
<td>11-18</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>11-16</td>
<td>B1 / H5</td>
<td>64</td>
<td></td>
<td>11-18</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>11-17</td>
<td>B2 / H4</td>
<td>53</td>
<td></td>
<td>11-18</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>11-18</td>
<td>B2 / H8</td>
<td>52</td>
<td></td>
<td>11-20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>11-19</td>
<td>B2 / H6</td>
<td>50</td>
<td></td>
<td>11-22</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>11-19</td>
<td>B1 / H4</td>
<td>65</td>
<td></td>
<td>11-22</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>11-20</td>
<td>B1 / H2</td>
<td>62</td>
<td></td>
<td>11-22</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>11-20</td>
<td>B1 / H6</td>
<td>64</td>
<td></td>
<td>11-22</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>11-22</td>
<td>B2 / H3</td>
<td>55</td>
<td></td>
<td>12-02</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>11-22</td>
<td>B2 / H7</td>
<td>51</td>
<td></td>
<td>12-02</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>11-23</td>
<td>B2 / H1</td>
<td>54</td>
<td></td>
<td>12-03</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>11-29</td>
<td>B2 / H2</td>
<td>71</td>
<td></td>
<td>12-04</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>11-30</td>
<td>B2 / H5</td>
<td>52</td>
<td></td>
<td>12-03</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>11-30</td>
<td>B3 / H4</td>
<td>49</td>
<td></td>
<td>12-02</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>12-01</td>
<td>B3 / H1</td>
<td>51</td>
<td></td>
<td>12-02</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>12-02</td>
<td>B3 / H5</td>
<td>49</td>
<td></td>
<td>12-03</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>12-02</td>
<td>B3 / H7</td>
<td>48</td>
<td></td>
<td>12-04</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>12-03</td>
<td>B3 / H2</td>
<td>53</td>
<td></td>
<td>12-04</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>12-03</td>
<td>B3 / H6</td>
<td>52</td>
<td></td>
<td>12-06</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>12-04</td>
<td>B3 / H3</td>
<td>44</td>
<td></td>
<td>12-07</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>12-06</td>
<td>B4 / H4</td>
<td>41</td>
<td></td>
<td>12-07</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>12-06</td>
<td>B4 / H8</td>
<td>49</td>
<td></td>
<td>12-07</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>12-07</td>
<td>B4 / H1</td>
<td>63</td>
<td></td>
<td>12-07</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>12-07</td>
<td>B4 / H5</td>
<td>49</td>
<td></td>
<td>12-07</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>12-08</td>
<td>B4 / H8</td>
<td>49</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Page 1 Totals:** 1365 | 1765 | 25 | 0
Execution

- Construction Issues

MEMORANDUM

DATE: December 23, 1999
TO: File
FROM: GCM
RE: 96.1-A Sink Hole
CC: [Names]

Kaz called to report this A.M. that small sinkhole opened up under rear wheel of pickup yesterday afternoon. The hole was approx. 30” Dia. x 48” Deep. It was located 105’ West of Bent #6 and 35’ North of C-L Track. Filled with Rip-Rap. Hayward-Baker is demobilizing from the site.
Follow-Up

- Annual Bridge Inspections
- Drive-by inspections
- 10-Year Photos
10-Year Thoughts...

- Final Cost = $1,088,000 (1999 dollars)
- Few issues at location since construction
  - Cost savings un-calculable
- Depending on rock properties, a land bridge is a viable option if conditions warrant
Questions?