July 9, 1971

To: L. T. Oehler
    Engineer of Research

From: H. L. Patterson

Subject: Extent of Gasoline Fire Damage to B02 of 63031, US 24 and US 10
        Over the Franklin River in Bingham Farms. Research Project

In a letter to Max N. Clyde dated March 29, 1971, Paul J. Marek requested
that cores be taken from the subject twin box culvert and tested. The struc-
ture was damaged by fire when a gasoline tanker truck burned last January
and the burning gasoline flowed through both culvert tubes.

The cores were cut on April 7, 1971, from the locations shown on the sketch
in Figure 1, and were received in the Research Laboratory on April 12,
1971. The cores were inspected, an initial measurement of their resonant
vibration frequencies was made, and freeze–thaw testing was begun. Cores
too short to produce a reliable resonance were not tested. After 84 freeze-
thaw cycles in air–water, (ASTM C 291), the cores were removed for a sec-
ond resonance measurement and were found to be in an advanced state of
deterioration. Further freeze–thaw testing was suspended and the cores
were closely inspected.

Figure 2 shows views of cores No. 1 and No. 2 before and after freeze–thaw
testing. These cores were taken from the ceiling area where the heat from
the fire was the most intense. In Table 1 the core measurements and the
visual inspection data before and after freeze–thaw testing are recorded.
The concrete near the surface from which the water of hydration was driven
by the heat of the fire was particularly vulnerable to freeze–thaw destruc-
tion. It was also noted that freeze–thaw testing produced well-defined cracks
across the cores at the level of the reinforcing steel. These cracks ap-
parently developed from continuous incipient fractures caused by the ther-
mal expansion of the reinforcing steel.

In general it was found that the portion of each core that was severely dam-
aged by the fire had disintegrated. The remainder of the core sustained
damage ranging from heavy fracturing adjacent to the disintegrated portion,
to hair line cracking over the remainder of the core. The latter feature
was due to freeze–thaw disruption of the old non–air–entrained concrete
(poured in 1931).

Air–entrainment in concrete exposed to fire is particularly valuable in that
it offers protection in two ways: First, it offers some degree of insulation
from the heat of the fire to the interior depth of the concrete; second, it provides the concrete with some resilience against the forces of thermal expansion. The air-entrainment is also required for concrete to withstand freeze–thaw cycles in a moist environment.

A study of available literature reveals that portland cement concrete exposed to fire expands due to its normal thermal coefficient of expansion and, for a rapid rise in temperature, reaches a maximum expansion at 570°F. Above this temperature, contraction begins due to the shrinkage caused by loss of absorbed water. This shrinkage will ultimately equal or exceed a 0.5 percent decrease from the original concrete dimensions and will result in severe cracking. Additional shrinkage occurs at temperatures above 840°F when the free calcium hydroxide in the concrete loses its water of hydration. Although this fire-induced damage from expansion and shrinkage is severe, it is not complete since the eventual exposure of this concrete to moisture will cause the calcium oxide to re-hydrate, swell in excess of its original dimensions, and cause further disruption.

From the results of freeze–thaw testing of the cores, it can be assumed that an incipient fracture–plane exists at, and runs parallel to, the plane of the reinforcing bars along the ceiling and higher wall areas of both tubes where the fire damage was severe. It can be assumed further that moisture will penetrate the damaged concrete and will eventually reach these bars where the resulting volume expansion of rust will cause the cover concrete to spall off. Thermal expansion spalling, as noted in the detailed inspection by Maintenance Division personnel in March 1971, has already exposed some steel, particularly the 1-in. square bars with shallow concrete cover in the ceiling area. The impairment of this reinforcing steel, especially the positive moment bars in the ceiling, will curtail the designed function of this structure and jeopardize its future performance. Before any extension is added to this culvert, its designed load-carrying capacity should be restored.

A possible solution might be to line the tubes with either a circular or half-elliptical corrugated steel tube section and fill the remaining spandrel area with concrete which could be pumped in from the ends. If this arrangement or some suitable alternate repair would fail to provide an adequate water flow capacity, a more expensive solution involving demolition might have to be considered. This might require the complete replacement of the present double tube culvert with an equivalent such as one or two large pre-formed elliptical tubes.

TESTING AND RESEARCH DIVISION

[Signature]
Physical Research Engineer
Materials Research Unit

HLP:sjt
Figure 2. Views of concrete cores taken from the ceiling at the center and west end of the north tube before (left) and after (right) freeze-thaw testing. The right photo clearly shows the vulnerability of severely fire-damaged concrete to freeze-thaw deterioration. (Cores shown inverted).
<table>
<thead>
<tr>
<th>Laboratory No.</th>
<th>Core No.</th>
<th>Length, in.</th>
<th>Steel Depth (in. to bar</th>
<th>Core Location</th>
<th>Visual Inspection Before Freeze-thaw Testing</th>
<th>Visual Inspection After 84 Freeze-thaw Cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>71 CC-32</td>
<td>1</td>
<td>10</td>
<td>1.25 in. sq. bar @ 1.88</td>
<td>Ceiling at W end of N tube</td>
<td>Horizontal fracturing to 1/4 in. depth; discoloration to 1/2 in. depth.</td>
<td>Total concrete disintegration to 1 in. depth; heavy fracturing to 4-1/2 in. depth.</td>
</tr>
<tr>
<td>71 CC-33</td>
<td>2</td>
<td>11</td>
<td>No. 6 bar @ 2</td>
<td>Ceiling at center of N tube</td>
<td>Horizontal fracturing; discoloration to 1/2 in. depth.</td>
<td>Cracking over full depth; total disintegration to 1/2 in. depth; complete fracture-plane through core at steel depth.</td>
</tr>
<tr>
<td>71 CC-34</td>
<td>3</td>
<td>17.8</td>
<td>None</td>
<td>E end of pier wall</td>
<td>Blackened surface; no visible interior damage at ends.</td>
<td>Cracking over full depth; heavy fracturing at S end to 7 in.; heavy fracturing at N end to 3 in.</td>
</tr>
<tr>
<td>71 CC-35</td>
<td>4</td>
<td>18.3</td>
<td>No. 6 bar @ 14.3</td>
<td>Center of pier wall</td>
<td>Fracturing and discoloration damage to 1/8 in. depth at S end and 1/2 in. depth at N end.</td>
<td>Light fracturing to 2-1/2 in. depth at N end; S end not tested.</td>
</tr>
<tr>
<td>71 CC-36</td>
<td>5</td>
<td>18</td>
<td>No. 5 bar @ 3.8, 14.3</td>
<td>W end of pier wall</td>
<td>Discoloration to 1/4 in. at N and S ends; no other damage.</td>
<td>Light cracking to steel depth at N end; complete fracture through core at bar; S end not tested.</td>
</tr>
<tr>
<td>71 CC-37</td>
<td>6</td>
<td>9.5</td>
<td>None</td>
<td>W end of N tube abut. wall</td>
<td>Heavy surface spalling; vert. cracking to 3/4 in. depth.</td>
<td>Not tested.</td>
</tr>
<tr>
<td>71 CC-38</td>
<td>7</td>
<td>12</td>
<td>None</td>
<td>W end of S tube abut. wall</td>
<td>Heavy surface spalling; vert. cracking to 1/4 in. depth; discoloration to 1/2 in. depth.</td>
<td>Heavy fracturing to 3 in. depth; fine cracking to 9 in. depth.</td>
</tr>
<tr>
<td>71 CC-39</td>
<td>8</td>
<td>11.8</td>
<td>None</td>
<td>Ceiling at W end of S tube</td>
<td>Heavy surface spalling; horizontal cracking to 3/4 in. depth; discoloration to 1 in.</td>
<td>Total disintegration to 1/2 in. depth; heavy fracturing to 3 in. depth; fine cracking to 9 in. depth.</td>
</tr>
</tbody>
</table>