OFFICE MEMORANDUM

MICHIGAN
DEPARTMENT OF STATE HIGHWAYS

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 71 TI-30. Research Report No. R-770.

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 structure 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 second 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 destruction. It was also noted that freeze-thaw testing produced well-defined cracks across the cores at the level of the reinforcing steel. These cracks apparently developed from continuous incipient fractures caused by the thermal expansion of the reinforcing steel.

In general it was found that the portion of each core that was severely damaged 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 preformed elliptical tubes.

TESTING AND RESEARCH DIVISION

Harry L. Patterson

Physical Research Engineer
Materials Research Unit

HLP:sjt

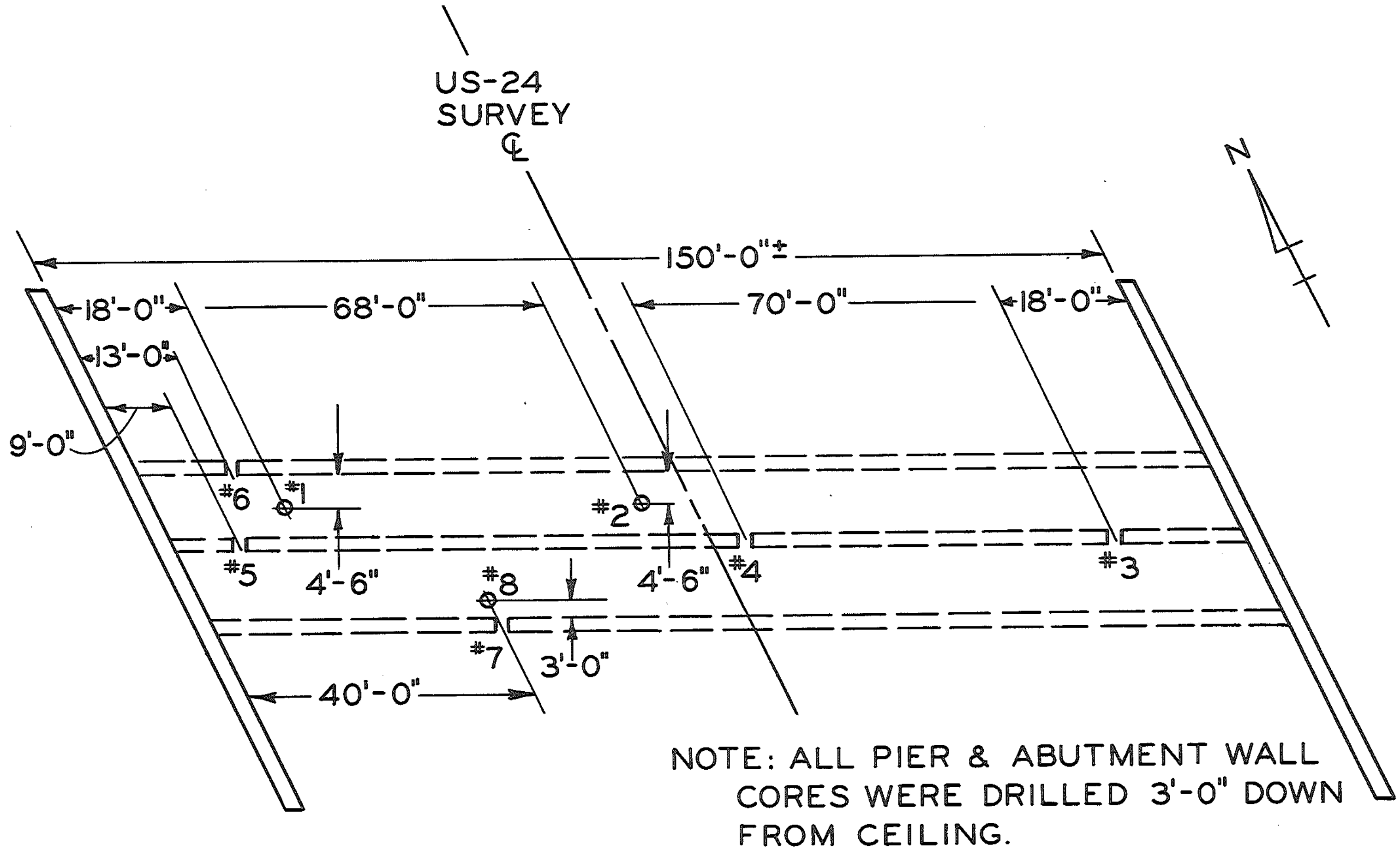

Figure 1. Core location plan
B02 of 63031
US 24/Franklin River

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 1
CORE INSPECTION DATA

Laboratory No.	Core No.	Length, in.	Steel Depth (in. to bar ℄)	Core Location	Visual Inspection	
					Before Freeze-thaw Testing	After 84 Freeze-thaw Cycles
71 CC-32	1	10	1.25 in. sq. bar @ 1.88	Ceiling at W end of N tube	Horizontal fracturing to 1/4 in. depth; discoloration to 1/2 in. depth.	Total concrete disintegration to 1 in. depth; heavy fracturing to 4-1/2 in. depth.
71 CC-33	2	11	No. 6 bar @ 2	Ceiling at center of N tube	Horizontal fracturing; discoloration to 1/2 in. depth.	Cracking over full depth; total disintegration to 1/2 in. depth; complete fracture-plane through core at steel depth.
71 CC-34	3	17.8	None	E end of pier wall	Blackened surface; no visible interior damage at ends.	Cracking over full depth; heavy fracturing at S end to 7 in.; heavy fracturing at N end to 3 in.
71 CC-35	4	18.3	No. 6 bar @ 14.3	Center of pier wall	Fracturing and discoloration damage to 1/8 in. depth at S end and 1/2 in. depth at N end.	Light fracturing to 2-1/2 in. depth at N end; S end not tested.
71 CC-36	5	18	No. 5 bar @ 3.8, 14.3	W end of pier wall	Discoloration to 1/4 in. at N and S ends; no other damage.	Light cracking to steel depth at N end; complete fracture through core at bar; S end not tested.
71 CC-37	6	9.5	None	W end of N tube abut. wall	Heavy surface spalling; vert. cracking to 3/4 in. depth.	Not tested.
71 CC 38	7	12	None	W end of S tube abut. wall	Heavy surface spalling; vert. cracking to 1/4 in. depth; discoloration to 1/2 in. depth.	Heavy fracturing to 3 in. depth; fine cracking to 9 in. depth.
71 CC-39	8	11.8	None	Ceiling at W end of S tube	Heavy surface spalling; horizontal cracking to 3/4 in. depth; discoloration to 1 in.	Total disintegration to 1/2 in. depth; heavy fracturing to 3 in. depth; fine cracking to 9 in. depth.