OFFICE MEMORANDUM

MICHIGAN
STATE HIGHWAY DEPARTMENT
JOHN C. MACKIE, COMMISSIONER

December 26, 1962

To: L. T. Oehler, Supervisor
Physical Research Section

From: C. J. Arnold

Subject: Chemical Analysis of Cover Plate Material from Bridges S09 and S10 of 82022 (I 94 over Ecorse Road). Research Project R-62 F-67. Report No. R-406.

In June 1962, the Research Laboratory Division reported a chemical analysis of stringer material from two overpass structures on I 94. Later, while operations were underway to replace the original cover plates on the stringers of these structures, R. L. Greenman, Assistant Testing and Research Engineer, requested that a similar analysis be made on the original cover plate material. During construction operations, it was impossible to obtain samples without interfering with the work, but arrangements were made to obtain samples after removal from the stringers.

Attached is a chemical analysis report prepared by the Charles C. Kawin Co. of Chicago, Illinois, on nine samples taken from the cover plates of seven beams of Bridges S09 and S10 of 82022. The beam letter designations are as on the plans, A through X, excluding I and O, starting at the northern edge of the westbound roadway proceeding to the southern edge of the eastbound roadway. Chemical quantities from ASTM specification A-373, "Structural Steel for Welding," applicable to plates 1/2 to 1 in. thick, are given for comparison with the test results in Table 1.

The ASTM gives no silicon requirement for plates less than 1 in. thick, although for plates 1 to 4 in. thick there is a percentage silicon requirement of 0.13 to 0.33. Since the silicon in structural steel is used primarily as a de-oxidizing and cleansing agent, silicon in the percentage range less than 0.30 would have negligible effect on physical properties of the steel. With the exception of the presence of silicon in the samples and a low manganese content in Sample No. 4 from Beam B, we conclude that the samples meet ASTM chemical requirements.

Figs. 1 through 5 show samples of cover plate submitted to the Research Laboratory Division after removal from the bridges. The samples appear to have been assembled from scraps of various sizes and shapes. They were joined by extremely poor welds, and the surface ground off to hide the welds. Fig. 5 shows the plate removed from

Beam F, Span 2, adjacent to the large fracture. There was evidently no fusion of the two plates. All that held the plates together was the weld metal, about 1/8 to 1/4 in. thick across the outside surface of the plate. The resulting discontinuity in the cover plate provided an extreme stress concentration in the flange at that point, which was the primary factor causing the flange to fracture and the crack to progress into the web.

It might be well to point out briefly the basic nature of a brittle fracture in which ductile metals, such as ASTM A-7 or A-373 steels, may break without any of the usual preceding plastic deformation or distortion. Basically, two types of strength can be distinguished in ductile materials. These are characterized by either a sliding or shear type displacement associated with plastic yielding (yield or shear strength), or a cleavage or sudden separation associated with a complete break or fracture (cleavage strength). Neither the yield strength nor cleavage strength of a material are constant, and a brittle fracture will occur when certain influencing factors are present which cause the cleavage strength of the material to be lower than the yield strength.

One of the chief influencing factors is temperature. With decreasing temperature the yield strength increases at a faster rate than the cleavage strength. Other factors which cause an increase in yield strength relative to cleavage strength, are increased rates of straining, increased hardness, stress concentration, and triaxial stress fields associated with residual stresses caused by welding. Of these considerations, stress concentrations are of paramount importance. When the other factors are present in such a manner as to insure that the cleavage strength is less than the yield strength, and the peak stress due to the stress concentration is greater than the cleavage strength, a brittle fracture will result. This fracture starts at the root of the stress concentration and generally propagates with repeated cycling because little energy is required to keep a brittle fracture going.

The purpose of this discussion is to emphasize that the chemical makeup of the steel is not necessarily the primary influence in determining whether a brittle fracture will occur. Considering the nature of the welding which was done in the fabrication of these beams, the extreme stress concentration and the residual welding stresses can be regarded as the primary causes of the ensuing fracture.

OFFICE OF TESTING AND RESEARCH

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TABLE 1
COMPARISON OF ASTM CHEMICAL SPECIFICATIONS FOR STRUCTURAL STEEL AND CHEMICAL ANALYSIS OF BRIDGE BEAM COVER PLATES

Element	C	Mn	Si	P	S
ASTM A-373	0.29 max.	0.46 to 0.94	-----	0.05 max.	0.063 max.
Beam R, Span 3	0.23	0.78	0.17	0.017	0.024
Beam L, Span 2	0.22	0.74	0.15	0.016	0.019
Beam F, Span 2	0.22	0.79	0.16	0.018	0.031
Beam F, Span 2	0.22	0.79	0.15	0.019	0.027
Beam Q, Span 3	0.19	0.75	0.15	0.014	0.022
Beam N, Span 3	0.20	0.77	0.16	0.016	0.020
Beam C, Span 2	0.20	0.76	0.15	0.013	0.017
Beam C, Span 2	0.21	0.75	0.14	0.017	0.023
Beam B, Span 2	0.25	0.43	0.05	0.013	0.017

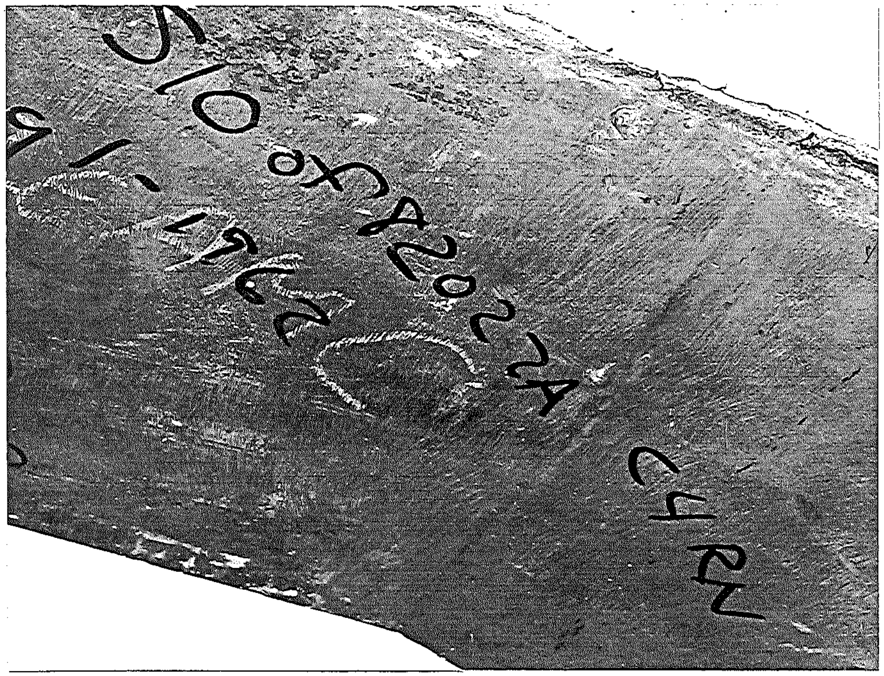

Figure 1 (upper left). Outside surface of cover plate. Other surface shown in Figs. 2 and 3.

Figure 2 (above). Fabrication of cover plate from scraps. Folded paper shows depth of groove. Welded only on other surface.

Figure 3 (left). Another view of same area of cover plate.

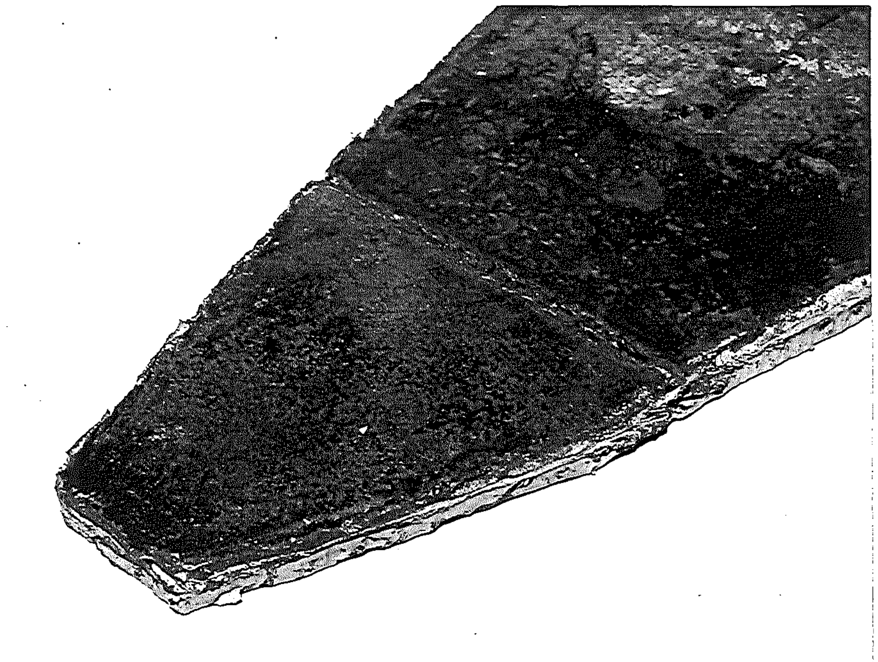

Figure 4. Tapered end section of cover plate, showing scrap welded on for proper outward appearance.

Figure 5. Weld which caused large brittle fracture in bridge. Note weld only at upper surface.