SAMPLING AND ANALYSIS
OF
STRUCTURAL STEEL MEMBER
OF A
HIGHWAY BRIDGE

MICHIGAN DEPARTMENT OF TRANSPORTATION

MATERIALS and TECHNOLOGY DIVISION

SAMPLING AND ANALYSIS
OF
STRUCTURAL STEEL MEMBER
OF A
HIGHWAY BRIDGE

Case Studies 1974-1987

By

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Larry Pearson

Structural Research Laboratory
Materials and Technology Division

July 1987

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1.0 PROCEDURE FOR SAMPLING STRUCTURAL STEEL MEMBERS

Requests for sampling usually originate from Design Division. Obtain copies of the following:

a) General Plan of Site
b) General Plan of Structure
c) Structural Steel Details

Determine location of structure (bridge) and site limitations. Using these plans prepare proposed sample locations taking into account possible access problems such as railroad tracks, water under structure and heavy traffic flows. Occasionally Design will request samples to be taken from specific locations along the selected beams. If this is the case, remove samples from these locations requested and a sufficient number of additional samples to provide a good average for testing. If no specific locations are requested remove a minimum of 4 samples chosen randomly from beams exclusive of fascia beams. Samples are taken from compression areas, usually at center piers or abutments.

1.1 **Method of Removal**

Equipment required:
- 12 ft. tape
- Lumber crayon
- Portable bandsaw
- 100 ft. electric cord
- Portable generator
- Black felt marker
- Note pad for field notes

Using the sheet for "Layout of Specimen Removal From Bridge Steel Beams" (see page 4) mark on the bottom flange of the selected beam the size of sample needed. The location is usually at 1'-2' away from the ends of the beams. When this is done both ends of the sample must be tapered as shown in the center drawing of the layout sheet. Care must be take to prevent any sharp corners of nicks in the flange as these may contribute to fracturing of the beams. If sharp edges are created these must be ground out either by the crew removing the samples or a note must be written in the letter to Design suggesting that the contractor should perform the above work during the bridge repair contract.

1.2 **Specimen Preparation**

Specimens are prepared by the Materials & Technology Machine Shop using the "Layout of Specimen Removal From Bridge Steel Samples". This guide is based upon guidelines for specimen size in ASTM A-370.

1.3 **Testing**

Tests conducted are as follows:

<u>Charpy Impact Test</u> - To determine fracture toughness of the steel. ASTM A-370 Sections 19-23 and ASTM E-23.

Tensile Test - To determine yield and ultimate load strengths, percent elongation and percent reduction of area. ASTM A-370 Sections 5-13 and ASTM E-8.

Chemical Analysis - To determine elements present and percentage thereof in the steel. ASTM A-751.

NOTE: Most bridges which are sampled are A-36 or A-7 steel.

Charpy specimens are tested by immersion in an oil bath at +40 F for 24 hr.; then inserted into the Charpy machine and failed. The procedure for operation of the Charpy machine is in the Structures Unit files.

Chemistry samples are submitted to an outside Laboratory for analysis. Specific elements to test for are dependant upon the material used in the structural members. Elements generally requested are as follows:

Carbon **Phosphorous**
Silicon **Manganese**
Sulphur

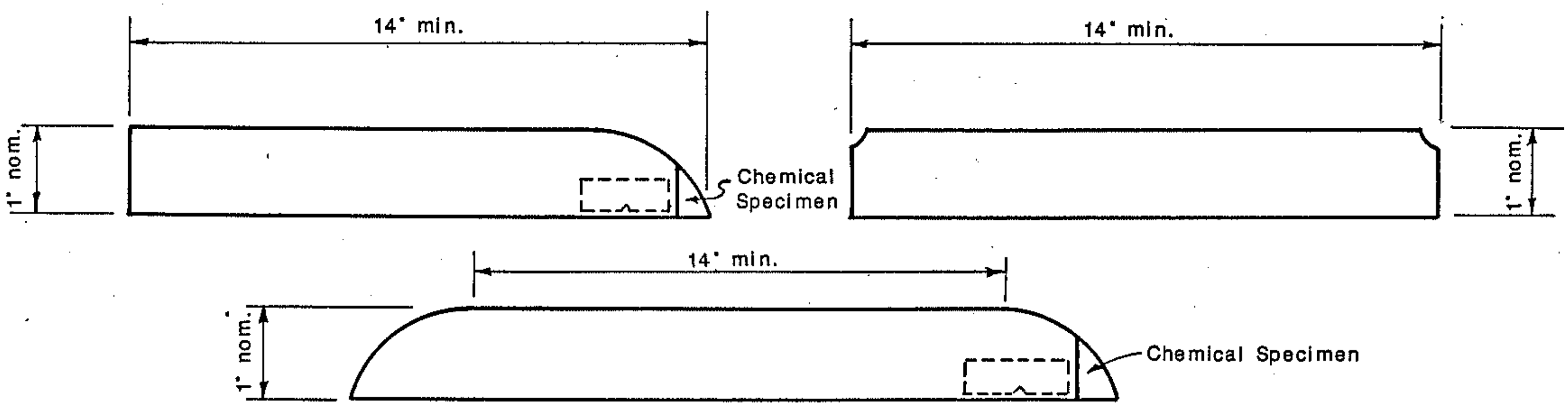
The analysis results are compared to the appropriate ASTM (A588, A572, A36, A7) for the steel used in the members.

Weldability is the general concern used to determine chemical elements needed. A chemical analysis is needed to determine weldability of steel. The chemical elements which affect weldability of steel are Carbon (C), Manganese (Mn) and Silicon (Si). The Carbon Equivalency (C.E.) is determined using the formula: C.E. = %C * (%Mn + %Si / 4).

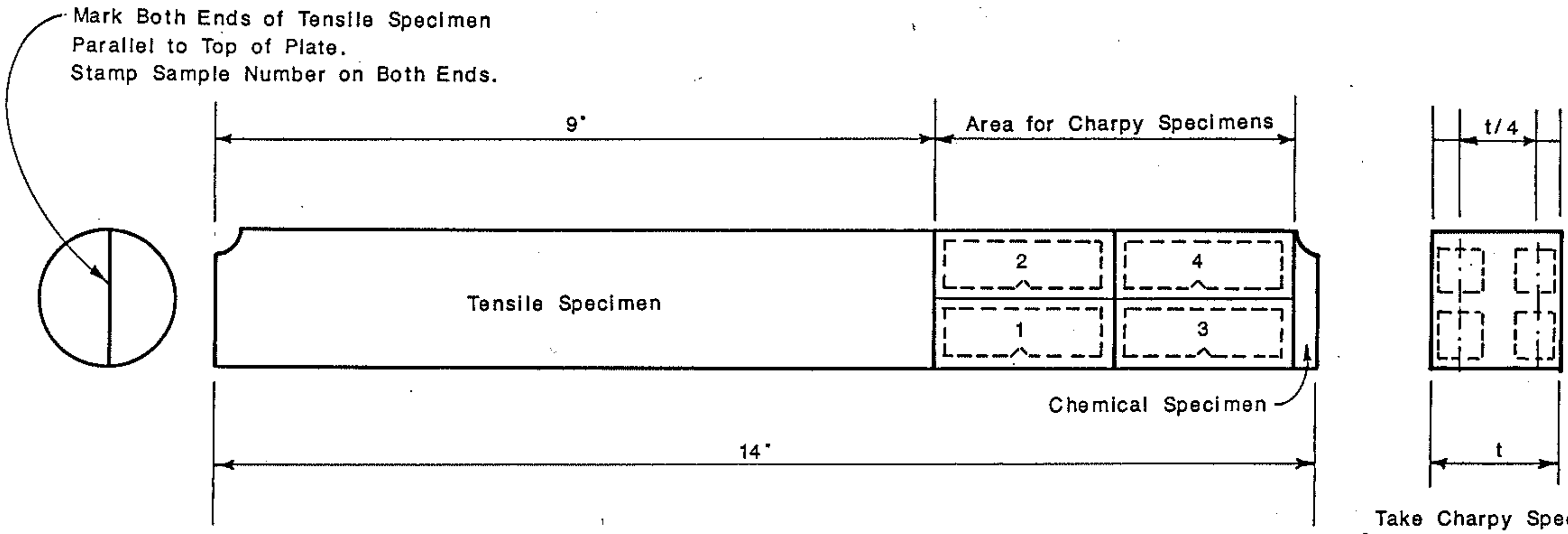
Tensile specimens are tested using the 20K MTS system following the written procedure in the procedure manual.

4. Reporting

Test data are analyzed and compared to required results for the appropriate steel (A588, A572, A36, A7). The results are conveyed to Design along with any comments and observations noted during removal of samples from beams. Examples of comments are corrosion of members, fracture and crack locations along members and settlement of substructure.



TYPICAL SPECIMENS AS REMOVED FROM STRUCTURES



Take Charpy Specimen at t/4 to ℄ or as Near as Practical from Either Top or Bottom of Plate.

NOTE: From Each plate, Remove and Indentify With Specimen Number a Sample to be Used for Chemical Analysis. Weight of Sample to be 6 Grams, Minimum.

LAYOUT OF SPECIMEN REMOVAL FROM BRIDGE STEEL SAMPLES

2.0 Chemical Analysis of Structural Steel

Chemical analysis of structural steel A7, A36, A572, A588 are presented in the following pages.

Typical Chemical Analysis 8071-641

Analytical Associates

Analytical Chemists

19380 Mt. Elliott
Detroit, Mich. 48234
(313) 369-9400

To: Michigan DOT
Testing & Research Laboratory
P. O. Box 30049
Lansing, MI 48909

Date: Feb. 21, 1980
Report No.: B-1847
P. O. No. 79-1471

Attention: K. S. Bancroft
Laboratory Technician

LABORATORY REPORT

Sample No. A-36

	# 1	# 2	# 3	# 4	# 5
	.35	.30	.31	.30	.28
C	0.22%	0.17%	0.18%	0.17%	0.16%
Mn	0.81%	0.77%	0.79%	0.76%	0.74%
P	0.010%	0.012%	0.011%	0.012%	0.010%
S	0.026%	0.022%	0.025%	0.024%	0.034%
Si	0.09%	0.10%	0.11%	0.10%	0.09%
Cr	0.03%	——	——	——	——
Mo	<0.01%	——	——	——	——
V	<0.005%	——	——	——	——
Ni	0.03%	——	——	——	——
Cu	0.06%	——	——	——	——

We certify the above analysis to be the true result obtained on the described sample(s).

Analytical Associates

by ____________________

Charles K. Deak

Sworn and subscribed before me a Notary Public in and for Wayne

County, State of Michigan this ________ day of ____________

19________.

Notary Public ____________________

My Commission Expires ____________________

Analytical Associates, Inc.
Analytical Chemists

19380 Mt. Elliott
Detroit, Mich. 48234
(313) 369-9400

To: Michigan DOT
Testing & Research Laboratory
P. O. Box 30049
Lansing, MI 48909

Date: Nov. 14, 1983
Report No.: C-6959

P. O. No. 83-1226

Attention: Mr. Larry J. Pearson

LABORATORY REPORT

Sample No. Description: Eight pieces - solids.
old ASTM's
A-36 A-7

	C	S	P	Si	Mn	
	0.12	0.028	0.020	0.04	0.65	
B-1	0.12%	0.028%	0.020%	0.03%	0.61%	.280
B-2	0.12%	0.026%	0.020%	0.03%	0.64%	.287
B-3	0.12%	0.028%	0.019%	0.03%	0.67%	.295
B-4	0.12%	0.028%	0.019%	0.04%	0.69%	.302
J-1	0.22%	0.014%	0.006%	0.04%	0.66%	.395
J-2	0.22%	0.015%	0.008%	0.05%	0.68%	.402
J-3	0.27%	0.033%	0.010%	0.06%	0.77%	.487
J-4	0.23%	0.018%	0.011%	0.05%	0.72%	.422
	0.23	0.020	0.009	0.05	0.71	

old- A7
A36

We certify the above analysis to be the true result obtained on the described sample(s).

Analytical Associates, Inc.

by ________

Charles K. Deak

Sworn and subscribed before me a Notary Public in and for Wayne

County, State of Michigan this ______ day of ______

19______

Notary Public ______

My Commission Expires ______

3.0 List of Bridge Projects Completed (1974-1987)

Structural Steel Samples for Weldability

PROJECT NO.	TITLE	PAGE
75 F-146	Steel Sampling of 76 Structures	61
73 TI-180	Cooley Bridge steel sampling and testing	11
74 TI-201	Steel yield strength determination of B01-04032; B02-12021; B02-46041; B02-50092 B02-63053; B03-73051	15
75 TI-275	Steel evaluation on vehicle damaged Structure I-94 Kalamazoo	87
75 TI-291	Evaluation of weldability of steel beams for bridge widening	19
78 TI-455	Steel sampling and strength determination M-26, South of Eagle River	23
78 TI-473	Sampling and testing steel from bridges B01-27041 and B02-17011	25
78 TI-513	Non-destructive testing and steel sampling of X06-82123, Wayne Co.	29
80 TI-641	Testing of steel on Northbound Portion of B01-70014, US-31 over the South channel of the Brand River	37
80 TI-702	Steel sampling and analysis of impacted bridge S02-82191; Woodruff Rd. over I-75	39
81 TI-769	Steel sampling on X01-82052; US-24 over RR. 4.5 Miles north of Flat Rock	41
83 TI-898	Testing of steel of floor beam flanges; Us-2 over Cut River (B01-49023-20719C)	43
83 TI-910	Steel sampling US-31 Grand Haven Bascule Bridge	45
83 TI-945	Determination of yield strength of structrual steel B01-43022-20716; US-10 over Baldwin Cr.	49

4.0 Letters

The copies of letters to Design Division are given here. These letters contain report of 1) chemical analysis; 2) tensile tests and 3) charpy test performed using the collected samples. The important findings of investigation are described in the conclusions.

PROJECT NO.	TITLE
73 TI-180	Cooley Bridge Steel Sampling and Testing
74 TI-201	Steel Yield Strength determination of B02-04032; B02-12021; B02-50092; B02-63053; B03-73051
75 TI-291	Evaluation of Weldability of Steel Beams for Bridge Widening
78 TI-455	Steel Sampling and Strength Determination M-26, South of Eagle River
78 TI-473	Sampling and Testing Steel from Bridges B01-27041 and B02-17011
78 TI-513	Non-destructive Testing and Steel Sampling of X06-82123, Wayne County
80 TI-641	Testing of Steel on Northbound Portion of B01-70014, US-31 over the South Channel of the Grand River
80 TI-702	Steel Sampling and Analysis of Impacted Bridge S02-82191; Woodruff Road over I-75
81 TI-769	Steel Sampling on X01-82052; US-24 over RR. 4.5 miles North of Flat Rock
83 TI-898	Testing of Steel of Floor Beam Flanges; US-2 over Cut River (B01-49023-20719C)
83 TI-910	Steel Sampling US-31 Grand Haven Bascule Bridge
83 TI-945	Determination of Yield Strength of Structural Steel B01-43022-20716; US-10 over Baldwin Creek
83 TI-960	Sampling and Analysis of Structural Steel (R01-58051-15205D) US-24 over the Ann Arbor RR. 0.08 Miles North of Michigan/Ohio Line
84 TI-979	Investigation of Welding Compatibility of Steel from B01-51021-21748C. M-55 over the Manistee River; 0.1 Miles East of US-31
84 TI-1038	Structural Steel Sampling and Testing S02-81041-23075D; I-94 over Wiard Rd. 2 Miles Southeast of Ypsilanti

OFFICE MEMORANDUM

MICHIGAN
DEPARTMENT OF STATE HIGHWAYS

To: M. Rothstein
Engineer of Design

From: K. A. Allemeier

Subject: Investigation of Chemical and Physical Properties of Structural Steel. B03 of 51021 - Cooley Bridge, M 55 over Pine River. Research Project 73 TI-180. Research Report No. R-894.

This report covers the results obtained from tensile and metallurgical evaluation of samples removed from structure B03 of 51021, Cooley Bridge, M 55 over the Pine River in Manistee County, as requested in your memo of October 22, 1973.

The purpose of this investigation was to determine the yield strength of the structural steel employed in various members of the structure. Your letter also stated a requirement that certain members must have a minimum yield strength of 33,000 psi, in order to allow full legal commercial vehicle loads on the bridge. All members tested exceeded that minimum.

Experimental Details

Twenty-six metallurgical samples were removed from various members of the structure. Their locations are given in Table 1.

The samples consisted of approximately 3/4-in. diameter plugs removed from the members with a metal cutting hole saw powered by a portable drill press.

The samples were submitted to the Charles C. Kawin Metallurgical Laboratories for chemical analysis.

Tension samples were removed from the suggested locations by sawing with a reciprocating saw. The samples were approximately 1 in. wide by 9 in. long by the thickness of the member. Sawing was initiated in all cases at the location where a metallurgical sample was removed in order to minimize sharp notches which could develop stress concentrations. In no instance was more than one tension sample removed from the same member. After removal, the member was cleaned and the area of removal was painted.

The samples were machined to ASTM specifications for flat tensile specimens utilizing a 2-in. gage length, except that instead of using the full thickness, all the specimens were machined to a reduced area, 0.250 in. thickness by 0.500 in. width. By doing this, it was possible, in some cases, to obtain two tension specimens from one sample. It also allowed the use of a more sensitive testing machine due to the smaller loads required for testing. Samples from which two tensile specimens were obtained, are designated "A" and "B" in Table 1.

The machined specimens were tested for yield and ultimate strength in a 20,000-lb capacity Instron machine equipped with autographic printout. The yield and ultimate strengths were obtained directly from the stress-strain plot. Since all traces exhibited a definite yield point (or "knee") in the curve, the highest point on the knee is reported as the yield strength. The stress at 0.2 percent strain varied from about 1,000 psi higher to 2,400 psi lower than the reported values, but in no case was below 33,000 psi.

Results

The results of the chemical analysis and tension tests are shown in Table 1. A brief discussion follows:

24 by 3/8-in. Web Plates - There were no tension samples obtained from these members. Chemical analysis of the metallurgical samples obtained from the plate indicate the composition to be quite similar to that of sample No. 7 which showed a tensile strength of 55,500 psi and a yield point of 38,800 psi. Therefore, we would expect the mechanical properties of the plate to be similar.

6 by 6 by 3/8-in. Angles - Chemical analysis showed no wide deviations from the norm. The average yield strength was 39,500 psi and the average ultimate strength 59,500 psi.

31-1/2 by 7/8-in. Web Plates - There were no tension samples obtained from these members. The mechanical properties should be similar to those of sample No. 15 which has approximately the same chemical composition. Sample No. 15 showed an average yield strength of 37,200 psi and an average ultimate strength of 63,100 psi.

6 by 6 by 7/8-in. Angles - Chemical anslysis showed no wide deviations from the norm. The average yield strength was 38,600 psi and the average ultimate strength 64,000 psi.

30W124 Intermediate Floor Beams - Chemical analysis of samples obtained from these members exhibited approximately 40 percent more manganese content than the average. The average yield strength was 38,750 psi and the average ultimate strength 64,150 psi. As can be seen, the variation in manganese content of these members did not seem to alter the strength significantly. Since manganese is usually added to provide toughness, this seems reasonable.

30W116 End Floor Beams - The chemical composition and mechanical properties of these members are quite similar to those of the intermediate floor beams. The average yield strength was 37,700 psi and the average ultimate strength 63,950 psi.

21W59 Stringers - Chemical analysis of samples obtained from these members showed greater phosphorous content than the average. Theoretically, increasing the phosphorous content of low carbon steels, up to a limit, increases strength. From the results of tension tests, this was found to be true. The average yield strength was 20 percent higher than the average of other samples and the average ultimate strength showed a 6 percent increase. Values for these members were 46,350 psi average yield strength and 67,400 psi average ultimate strength.

Conclusions

All categories showed mechanical properties above the required minimum of 33,000 psi yield strength.

On the basis of chemical and tension tests performed, the subject structure does not require posting for load limit.

TESTING AND RESEARCH DIVISION

K. A. Allemeier

Acting Engineer of Testing and Research

KAA:MAC:bf

TABLE 1
LOCATIONS OF SAMPLE REMOVAL AND RESULTS OF CHEMICAL ANALYSIS AND TENSION TESTS

Structural Member	Sample No.	Location of Sample	Chemical Composition				Mechanical Properties	
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi
24 by 3/8 Web Plates	1	L0-L1, SW corner near Gussett, outside plate	0.15	0.44	0.012	0.029	--	--
	2	L0-L1, NW corner near Gussett, outside plate	0.16	0.47	0.014	0.022	--	--
	3	L0-L1, NE corner near Gussett, outside plate	0.17	0.45	0.011	0.018	--	--
	4	L0-L1, SE corner near Gussett, outside plate	0.17	0.44	0.011	0.020	--	--
6 by 6 by 3/8 Angles	5	L0-L1, SW corner near Gussett, outside top angle	0.21	0.47	0.016	0.025	40,100	65,300
	6	L0-L1, NW corner near Gussett, outside top angle	0.23	0.49	0.016	0.024	--	--
	7	L0-L1, NE corner near Gussett, outside top angle	0.15	0.41	0.011	0.023	38,800	55,500
	8	L0-L1, Outside top angle, SE near support	0.20	0.44	0.011	0.030	--	--
31-1/2 by 7/8 Web Plates	9	L4-L5, SW near Gussett, outside plate	0.21	0.44	0.013	0.023	--	--
	10	L4-L5, NW near Gussett, outside plate	0.24	0.51	0.013	0.018	--	--
	11	L4-L5, NE near Gussett, outside plate	0.20	0.49	0.016	0.026	--	--
	12	L4-L5, SE near Gussett, outside plate	0.20	0.50	0.017	0.026	--	--
6 by 6 by 7/8 Angles	13	L4-L5, SW near Gussett, outside top angle	0.29	0.51	0.018	0.026	A 39,700 B 40,300	64,700 65,100
	14	L4-L5, NW near Gussett, outside top angle	0.22	0.50	0.015	0.025	--	--
	15	L4-L5, NE near Gussett, inside top angle	0.20	0.48	0.015	0.023	A 36,600 B 37,800	62,600 63,600
	16	L4-L5, SE near Gussett, outside top angle	0.23	0.48	0.018	0.027	--	--
30W124 Intermediate Floor Beams	17	U1, NW near support bottom flange	0.21	0.76	0.015	0.025	A 39,700 B 39,600	64,300 64,800
	18	U1, SW near support bottom flange	0.20	0.79	0.014	0.026	--	--
	19	U1, SE near support bottom flange	0.20	0.78	0.013	0.022	A 37,700 B 38,000	63,500 64,000
	20	U1, NE near support bottom flange	0.20	0.78	0.014	0.022	--	--
21W59 Stringers	21	U0, West end, third stringer from south, inside bottom flange near support	0.19	0.61	0.061	0.034	47,600	68,100
	22	U0, West end, third stringer from north, inside bottom flange near support	0.17	0.60	0.061	0.034	--	--
	23	U0, East end, third stringer from north, inside bottom flange near support	0.19	0.62	0.058	0.032	45,100	66,700
	24	U0, East end, third stringer from south, inside bottom flange near support	0.17	0.62	0.058	0.034	--	--
30W116 End Floor Beams	25	U0, SW bottom flange near support	0.20	0.78	0.014	0.024	A 38,900 B 36,900	64,300 64,700
	26	U0, NE bottom flange near support	0.22	0.77	0.013	0.025	A 38,700 B 36,300	63,300 63,500

OFFICE MEMORANDUM

MICHIGAN
DEPARTMENT OF STATE HIGHWAYS

September 10, 1974

To: L. T. Oehler
Engineer of Research

From: M. A. Chiunti

Subject: Steel Strength Determination - Six Bridges.
Research Project 74 TI-201. Research Report No. R-935.

This letter transmits the results obtained from tensile and metallurgical evaluation of samples removed from six bridges containing steel of unknown properties, as requested in M. Rothstein's memo of January 31, 1974.

The purpose of this investigation was to determine the yield strength of the structural steel used in the various structures. The subject bridges have load carrying capacities that are below the 77 ton legal load limit; based on 75 percent of the assumed 30,000 psi yield strength. If the determined yield strengths are sufficiently higher, it may be possible to avoid posting the bridges for load restrictions.

Experimental Details

A total of 29 metallurgical samples were removed from the six bridges. The selected locations at each bridge, along with physical properties and chemistry, are given in Table 1. The samples were submitted to the Charles C. Kawin Metallurgical Laboratories for chemical analysis. Four tension samples were removed from each structure except for B02 of 12021 which has been widened and contains two different types of beams. Eight tension coupons were taken at this structure, four from each type of beam.

Tension samples were removed with a reciprocating saw. The samples were approximately 1 in. wide, by 9 in. long, by the thickness of the member. After sampling, the beam was cleaned and the area of removal repainted.

The yield and tensile strengths of the specimens were measured by testing in the Research Laboratory's electrohydraulic testing machine which gave an autographic printout of the stress-strain curve. Tension testing was done in accordance with ASTM Specification A-370, "Mechanical Testing of Steel Products," with the exception of specimen thickness. Instead of testing full thickness plate specimens, a subsize sheet type specimen was used with a cross-section of 0.25 by 0.50 in. A full size plate specimen would have exceeded the limitations of our equipment and would have required an

TABLE 1
LOCATIONS OF SAMPLE REMOVAL AND
RESULTS OF CHEMICAL ANALYSIS AND TENSION TESTS

Structure	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties		Flange Thickness in.	Meets Requirements of ASTM A7-33T[1]	Meets Requirements of ASTM A-36[1]
			C	Mn	P	S	Yield Strength psi	Ultimate Strength psi			
Unknown Const. Date, Widened in 1932. B02 of 12021 US 12 over Swan Creek northeast of Bronson	1	East end near abutment inside bottom flange of south fascia beam (widened portion)	0.15	0.65	0.024	0.033	38,900	58,300	0.620		X
	2	East end near abutment, outside bottom flange, 5th beam from south (original beam)	0.20	0.62	0.016	0.038	35,600	60,400	0.600	X	
	3	East end near abutment, inside bottom flange, 4th beam from north (original fascia)	0.22	0.61	0.016	0.043	38,600	62,600	0.600	X	X
	4	East end near abutment, inside bottom flange, 3rd beam from north (widened portion)	0.16	0.64	0.024	0.032	40,900	59,600	0.620		X
	5	East end near abutment, inside bottom flange, 3rd beam from south (widened portion)	0.14	0.66	0.022	0.033	38,500	58,700	0.620		X
	6	East end near abutment, outside bottom flange, 6th beam from south (original beam)	0.21	0.62	0.016	0.042	34,900	61,900	0.600	X	
	7	East end near abutment, inside bottom flange, 6th beam from north (original beam)	0.20	0.56	0.014	0.047	34,100	59,900	0.600		
	8	East end near abutment, inside bottom flange, 2nd beam from north (widened portion)	0.15	0.65	0.022	0.033	37,700	58,300	0.620		X
1928 B02 of 46041 M 34 over South Branch of Raisin River, southeast of Clayton	9	West end near abutment, inside bottom flange, south fascia (widened portion)	0.24	0.51	0.010	0.020	41,700	64,200	0.531	X	X
	10	West end near abutment, outside bottom flange, 2nd beam from south (original beam)	0.23	0.44	0.012	0.036	36,100	61,100	0.531	X	X
	11	East end near abutment, inside bottom flange, north fascia (widened portion)	0.24	0.51	0.012	0.019	47,200	64,900	0.531	X	X
	12	East end near abutment, outside bottom flange, 2nd beam from north (original beam)	0.23	0.44	0.012	0.034	33,600	60,200	0.531	X	
1932 B01 of 04032 US 23 over Thunder Bay River in Alpena	13	South span near pier, outside bottom flange, 2nd beam from east	0.16	0.71	0.034	0.038	A40,600 B38,700	62,600 61,700	1.000	X	X
	14	South span near pier, inside bottom flange, 3rd beam from east.	0.18	0.73	0.017	0.042	A37,800 B39,300	61,800 61,100	1.000	X	X
	15	North span near pier, outside bottom flange, 4th beam from west	0.18	0.69	0.018	0.023	A37,500 B40,600	62,100 62,200	1.000	X	X
	16	North span near pier, outside bottom flange, 5th beam from west.	0.18	0.72	0.016	0.038	A39,100 B37,500	60,200 60,500	1.000	X	X
	17	South span near pier, inside bottom flange, east fascia beam.	0.12	0.56	0.009	0.030	[2]		1.250	[2]	[2]
1930 B03 of 73051 M 13 over Pattie Dr 6 mi north of County Line	18	South end near abutment, inside bottom flange, west fascia beam.	0.22	0.70	0.018	0.042	A36,500 B35,300	62,300 61,500	1.100	X X	X
	19	South end near abutment, outside bottom flange, 2nd beam from west.	0.19	0.65	0.016	0.040	34,300	59,900	0.850		
	20	North end near abutment, inside bottom flange, east fascia beam	0.22	0.63	0.016	0.040	A35,000 B34,100	59,600 59,900	1.100		
	21	North end near abutment, outside bottom flange, 2nd beam from east.	0.20	0.63	0.015	0.045	34,100	58,300	0.850		

TABLE 1 (Cont.)
LOCATIONS OF SAMPLE REMOVAL AND
RESULTS OF CHEMICAL ANALYSIS AND TENSION TESTS

Structure	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties		Flange Thick-ness in.	Meets Require-ments of ASTM A7-33T[1]	Meets Require-ments of ASTM A-36[1]
			C	Mn	P	S	Yield Strength psi	Ultimate Strength psi			
	22	South end near abutment, inside bottom flange, east fascia beam.	0.25	0.72	0.034	0.039	39,800	66,500	0.787	X	X
1929 B02 of 63053 US 10 over Clinton River in Waterford	23	South end near abutment, outside bottom flange, 2nd beam from east.	0.23	0.78	0.019	0.042	41,200	64,400	0.690	X	X
	24	North end near abutment, inside bottom flange, 5th beam from east.	0.20	0.65	0.020	0.027	39,300	63,500	0.787	X	X
	25	North end near abutment, outside bottom flange, 6th beam from east.	0.19	0.76	0.017	0.036	40,900	63,400	0.690	X	X
	26	North end near abutment, inside bottom flange, east fascia beam.	0.21	0.48	0.030	0.027	34,200	59,400	0.810		
1931 B02 of 50092 M 19 over Salt River, east of New Haven	27	North end near abutment, outside bottom flange, 2nd beam from east.	0.18	0.87	0.015	0.025	42,100	65,400	0.606	X	X
	28	South end near abutment, inside bottom flange, west fascia beam.	0.23	0.65	0.030	0.025	A36,200 B37,200	65,000 66,100	0.810	X	X
	29	South end near abutment, outside bottom flange, 2nd beam from west.	0.13	0.73	0.014	0.024	39,800	59,100	0.606		X

[1] ASTM Specification Requirements (shapes)

ASTM Designation	Properties					
	Mechanical		Chemical Composition, percent			
	Tensile Strength, psi	Yield Strength, psi	C Max	Mn	P Max	S Max
A7-33T	60,000 to 72,000	33,000	----	----	0.04	0.05
A-36	58,000 to 80,000	36,000	0.26	----	0.04	0.05

[2] No tension sample obtained from fascia beam due to greater thickness of flange, metallurgical sample obtained for comparison purposes.

overall specimen length of 18 in., which would be impractical to remove from the structures involved. All yield strengths were measured using a rate of grip separation of 0.06 in. per minute. The yield strength was determined by the 0.2 percent offset method as described in ASTM A-370.

Samples of sufficient thickness were machined to produce two tension specimens. These are designated "A" and "B" in Table 1. Flange thickness values shown in the table are measured at the outside edge of the flange.

Results

The results of the chemical analysis and tension tests are shown in Table 1.

Average yield strengths exhibited by the samples from each structure are as follows:

Bridge No.	Average Yield Strength, psi
B02 of 12021	
Beams in Widened Portion	39,000
Original Beams	35,800
B02 of 46041	39,600
B01 of 04032	38,900
B03 of 73051	34,900
B02 of 63053	40,300
B02 of 50092	37,900

At all but one structure, the flange thickness of the interior beams was as stated in Mr. Rothstein's memo. Structure B01 of 04032 contains interior beams with a flange thickness of 1 in. instead of 0.635 in. as given.

Conclusions

The yield strength of the structural members tested are significantly higher than the assumed 30,000 psi yield strength and, therefore, it may be possible to raise or eliminate posted load limits depending on the results of design computations.

TESTING AND RESEARCH DIVISION

Manuel A. Chiunti

Highway Research Technician 09

MAC:bf

August 26, 1975

Bruce Benson
Maintenance Specialty Crew Coordinator

L. T. Oehler

Steel Beams Proposed for Use in Bridge Widening (Flint Location, Dort Highway over Creek) Research Project 75 TI-291.

At your request of August 2, 1975, we have made an analysis of some steel beams that had been salvaged and were being considered for use in a bridge widening job on Dort Highway in Flint, Michigan. Two samples of the subject beams were procured by the Research Laboratory. The first sample, identified as B1, was from a rolled beam 24 inches in depth with a 3/4 x 12-1/8-inch flange and a 0.475 inch thick web. The second sample, identified as B2, was from a rolled beam 24 inches in depth with a 1 x 12-1/8-inch flange and a 0.540 inch thick web. Both types of beams appeared to be in poor condition with extensive corrosion and pitting of the surfaces. The following data show the tensile and Charpy impact toughness properties of the beams.

Tensile Properties

Beam I. D.	Yield Point*(ksi)	Tensile Strength(ksi)	% Elongation (2 in. G. L.)
B1	29.7	57.8	48
B2	36.7	65.1	38
ASTM A 7 steel	33	60-70	24
ASTM A 36 steel	36	58-80	21

(*) Determined by the 0.2% offset strain method. Values represent the average of two specimens.

Charpy Impact Toughness

Beam I.D.	Testing Temperature °F	Average Energy* (ft-lbs.)
B1	+40	9
B1	+20	5
B1	0	4
B2	+40	20
B2	+20	10
B2	0	8

(*) Three Charpy specimens from each beam were tested at each temperature.

As seen in the table of tensile properties the specimens taken from beam B1 do not meet the requirements on yield point or tensile strength of either ASTM steel types A 7 or A 36. The specimens taken from beam B2 meet the requirements of both. The Charpy impact results show that the beam B1 has very low toughness, inspite of the extreme high ductility exhibited by the elongation of 48% in the tensile tests. Beam B2 has a higher level of toughness and does exceed the requirement of 15 ft-lbs. at +40°F that is currently specified on some critical main load carrying members that receive tensile stress. These results point out that high ductility, as measured by a slow loading test, does not insure that good impact notch toughness is present in the steel.

The alloy compositions of the two steels are listed in the following table. *

	Carbon	Manganese	Silicon	Phosphorus	Sulfur
Beam B1	0.19	0.60	0.06	0.016	0.039
Beam B2	0.23	0.60	0.10	0.011	0.028

(*) Values are percent by weight.

Both steels conform to the chemistry requirements of ASTM steels A 7 and A 36. No particular problem should be encountered with the weldability of the steels. In view of the low yield point present in the beams, overmatching of the weld metal yield point should be minimized.

If you have any further questions concerning the beams analyzed, please contact the Research Laboratory. Any questions on the welding procedures to be applied should be directed to Dan Hines, Welding Engineer, Testing and Research Division.

TESTING AND RESEARCH DIVISION

Engineer of Research

LTO:JDC:nag

cc: D. Hines

February 22, 1978

W. D. Bullen
Special Assignment Engineer - Structures

C. J. Arnold

Mechanical Properties of Bridge Steel Samples Removed from Structure B02 of 42021, M-26 over Eagle River, Keweenaw County, Research Project 78 TI-455.

Four steel samples were obtained from structure B02 of 42021, on February 15, 1978, for the purpose of determining values of mechanical properties to be used in design calculations for establishing the load carrying capacity of the structure.

The samples were removed from the two 20' floorbeams as shown on the sketch which you provided us. To prevent changes in physical properties due to the removal process, removal was done by sawing with a portable band saw. The samples were removed from the edge of the flange. The removed portion consisted of a coupon approximately 1 in. wide by 10 in. long. Because the samples were not of sufficient cross section to machine round 0.505 diameter specimens, standard sheet type specimens were prepared.

The samples were machined flat, with the maximum possible thickness maintained after removal of pitted areas. A 2 in. gage length was used.

The specimens were tested for yield and ultimate strength on the 20,000 lb. capacity MTS electrohydraulic machine, with automatic print-out of the load-strain curve. Yield strength data are reported at 0.2 percent strain. Samples 1 and 3 exhibited a yield point "knee" that is somewhat higher than the value at 0.2 percent strain. We are forwarding a copy of the load strain traces for your files.

Results of the tensile tests were as follows: (Reported to the nearest 50 psi.)

Sample No.	Location of Sample	Yield Strength, psi (0.2 percent offset)	Ultimate Strength, psi	Elongation, %
1	East floorbeam, east bottom flange near connection to north H. girder.	40,850	60,850	26

2	East floorbeam, west bottom flange near connection to south H. girder.	39,900	60,100	30
3	West floorbeam, west bottom flange near connection to south H. girder.	38,350	62,200	30
4	West floorbeam, east bottom flange near connection to north H. girder.	41,800	62,150	34

A sketch of the floorbeam cross section is also being forwarded for your records.

TESTING AND RESEARCH DIVISION

C. J. Arnold

C. J. Arnold, Supervisor
Structural Mechanics Group

CJA:MAC:lve

cc: L. T. Oehler
D. J. Kanellitsas

OFFICE MEMORANDUM

DATE: June 22, 1978

TO: W. D. Bullen
Special Assignment Engineer - Structures
Design Division

FROM: James D. Culp

SUBJECT: Mechanical Properties of Bridge Steel Samples Removed from Structures B01 of 27041, M-28 over Jackson Creek and B02 of 17011, M-123 over Tahquamenon River. Research Project 78 TI-455 473.

Samples of steel were removed from representative beams of the subject bridge structures on May 17 and 19, 1978. The samples were cut from the beams using a portable band saw to prevent any change in properties that might be induced by flame cutting. The samples were removed from the edge of the flanges in coupons approximately 1 in. wide by 10 in. long. Standard 0.505 in. diameter specimens were machined for testing. Results of the tensile tests were as follows: (reported to the nearest 50 psi)

B01 of 27041, M-28 over Jackson Creek

Sample Number	Sample Location	Yield Strength (psi) (0.2 percent offset)	Tensile Strength (psi)	Elongation, % (2 in. gage)
1	East Abutment 2nd beam from south North flange	40,600	71,050	36
2	East Abutment 3rd beam from South South flange	42,600	64,800	41
3	East Abutment 4th beam from North North flange	40,600	61,150	41
4	East Abutment 3rd beam from North South flange	40,400	63,800	40

B02 of 17011, M-123 over Tahquamenon River

Sample Number	Sample Location	Yield Strength (psi) (0.2 percent offset)	Tensile Strength (psi)	Elongation, % (2 in. gage)
1	North of first pier from the South 5th beam from East East flange	49,750	69,650	39

Sample Number	Sample Location	Yield Strength (psi) (0.2 percent offset)	Tensile Strength (psi)	Elongation, % (2 in. gage)
2	North of first pier from the South 3rd beam from East East flange	47,250	69,500	42
3	South of first pier from the North 4th beam from East West flange	44,800	66,650	40
4	South of first pier from the North 2nd beam from east West flange	46,450	66,650	41
5	North Abutment 3rd beam from East West flange	43,050	62,850	41
6	North Abutment 5th beam from East West flange	43,300	62,400	40

In addition to the tensile testing, chemical analyses were run on all the samples to check their weldability since you are contemplating the attachment of cover plates to the existing beams. The following table lists these results using the same sample numbers as referenced in the tables of tensile data.

	Chemical Analysis, % wt.				
Sample Number	C	Mn	P	S	Si
Bridge B01 of 27041					
1	0.272	0.91	0.032	0.028	0.03
2	0.199	0.83	0.009	0.027	0.03
3	0.210	0.71	0.008	0.028	0.03
4	0.202	0.76	0.009	0.028	0.04
Bridge B02 of 17011					
1	0.215	0.75	0.006	0.018	0.12
2	0.213	0.72	0.008	0.018	0.11
3	0.201	0.64	0.012	0.032	0.09
4	0.190	0.75	0.006	0.019	0.09
5	0.173	0.56	0.008	0.026	0.05
6	0.179	0.54	0.008	0.026	0.06
ASTM A-7 Specifications	--	--	0.04 max	0.05 max	--
ASTM A-36 Specifications	0.26 max	--	0.04 max	0.05 max	--

The sample analysis do conform to chemistry specification of ASTM steel types A-7 and A-36. The ranges of carbon and manganese represented indicate good weldability. The only precaution to stress in welding cover plates to the flanges on B01 of 27041 would be to exercise "low hydrogen" procedures such as cleaning all the weld area of paint and any foreign material and welding only with well dried electrodes and field conditions. Hydrogen embrittlement is a real threat on field welding of this type and special precautions are well worth the effort to preclude subsequent cracking which can easily occur.

TESTING AND RESEARCH DIVISION

James D. Culp

James D. Culp, P.E.
Transportation Research Engineer
Structural Mechanics Group
Research Laboratory Section

JDC:cgc

cc: L. T. Oehler
C. J. Arnold THIS COPY FOR
A. J. Marusich
E. Wiedenhoefer

OFFICE MEMORANDUM

DATE: September 21, 1979

TO: W. J. MacCreery, Engineer of Design
K. A. Allemeier, Engineer of Testing and Research

FROM: J. D. Culp

SUBJECT: Design Recommendation for Bolt Splice Repair of Railroad Bridge X06 of 82123
Research Project 78 TI-513

The following recommendations pertain to the design and repair of the nonredundant railroad bridge X06 of 82123 that has defective electroslag weldments. Most of these recommendations have already been discussed at some length with Messrs. S. Ajluni and W. Turner, who have been assigned the responsibility of designing the bolt splices. The recommendations that follow, represent some special considerations that pertain to the defective nature of the electroslag weldments that are being spliced and are based on repairs that have been made on other bridge structures in the United States with similar defective electroslag weldments.

Item 1:

The following list of 18 butt weldments are either in an area of tension stress or stress reversal and should be repaired by bolt splicing. The welds are numbered from the east abutment to the west abutment (1 through 7) and are designated as north girder (N) or south girder (S) and top flange (T) or bottom flange (B). (e.g. 1NB if the first butt weld from the east abutment of the north girder on the bottom flange).

1NB	1SB
2NT	2ST
3NB	3SB
3NT	3ST
4NB	4SB
4NT	4ST
5NT	5ST
6NB	6SB
7NB	7SB

This constitutes a total of 18 butt weldments in the bridge that should be spliced out of the 28 butt weldments in the bridge. Out of these 18 weldments, 3NB, 7NB, 4ST, 6SB and 7SB were shown to have rejectable flaws in the initial inspection conducted in the fall of 1977 through the spring of 1978. Weldment 7SB is the one recently reinspected to access the status of the flaws that were found in the earlier inspection.

Our field inspection of the weldments in the top flanges of both girders indicate that weldments 2ST, 3ST, 4ST and 5ST were produced by the submerged arc process. There is a possibility that the accompanying weldments on the bottom flange are likewise submerged arc weldments, but this has not been verified. This would include weldments 3SB and 4SB that are on the recommended repair list. It is my recommendation that these weldments be spliced as planned because of the criticallity of their location in this nonredundant structure. One of these weldments, 4ST, was shown by the previous nondestructive testing to have defects and it would seem prudent at this time to include the submerged arc weldments in the repair rather than spend additional time and money on trying to assess their current flaw status and fracture toughness.

Item 2:

After the flange splices have been completed and put back into service, there is a real possibility that the spliced weldments could still fail. Two conditions could lead to this failure after splicing. The first condition is the possibility that the existing flaw sizes in some of the weldments could already be at "critical size" to cause brittle fracture under the applied dead load (which will remain on the weldments even after splicing) when cold temperatures are reached in the winter. The second condition is that fatigue crack growth is still possible inthe spliced weldments because of the inability to insure that the splice plates will assume all of the live load cyclic stress. Any live load stress applied to the weldments would also increase the chance of brittle fracture. To guard against the possibility of these failures occurring, the following special precautions should be taken to prevent the cracking from spreading beyond the butt weld area.

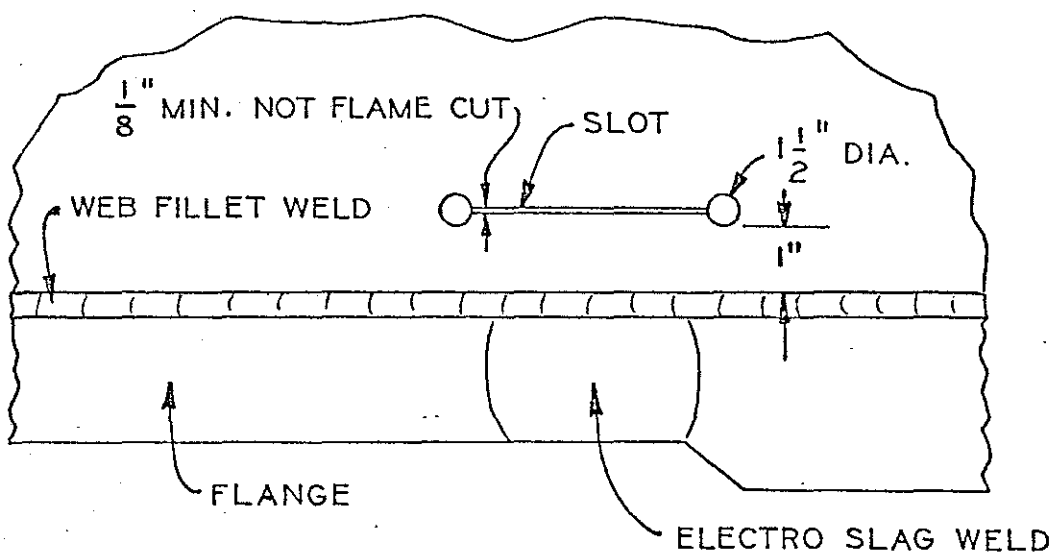
a) The steel plates used in the splice should have enough fracture toughness to absorb their design loading as impact loading at the "lowest anticipated service temperature" (LAST) of -20° F. This can be accomplished by specifying the Charpy V-notch impact requirement of the steel plate in accordance with the attached Table 1.5.4 and Figure 1.5.4.1 of the FHWA's recommended "Fracture Control Plan for New Bridges with Fracture Critical Members," Volume 11, June, 1978. This will essentially call for a charpy impact requirement of 25 or 30-ft/lbs at -20° F, depending on plate thickness and/or actual measure yield strength.

b) The steel used for the splice plates should be one of the following because of the special toughness requirements. Several options could be proposed to aid in rapid availability. (Listed in order of priority starting with the most desirable steel.)

i) ASTM A 633, Grade D
ii) ASTM A 633, Grade C
iii) ASTM A 588, Grades A, B, C, or F
iv) ASTM A 537, Class 1
v) ASTM A 242

Except for the A 242 these steels are all available with a 50 ksi yield strength up to 2.5 inch plate thickness. The filler plates required by the thickness transition should be A 588 steel. No special toughness requirements are necessary for them, since they will not carry stress across the joint.

c) A section of each web immediately above the flange weld should be removed with a smooth contour to provide a crack arrest mechanism for either a propagating fatigue crack or a rapid brittle fracture. This could be accomplished by drilling and reaming a 1-1/2 inch diameter hole outside of the cross sectional extremities of the flange weld where it passes beneath the web and then cutting a smooth slot horizontally in the web to join the holes. The holes could be easily located 1 inch above the flange to web fillet weld (see sketch).



The exact location of the holes will have to be determined at each web location by grinding and etching the flange weldments. This work could be done by Research Laboratory personnel during the construction phase. These cope holes and slots will need to be plugged and sealed to prevent the entrance of water into the box girder. The web slotting will have to be completed prior to the installation of the flange splice plates.

d) Mill test reports that are available on X06 of 82123 indicate that the A 588 Grade B steel in the bridge has sufficiently high toughness to withstand the shock of impact loading through the splice plates should a butt weld failure occur. The minimum existing properties as shown on these mill reports are listed as follows:

Thickness, In.	Yield Strength psi	Tensile Strength psi	Elongation % 2 in. gage	Charpy Impacts at 40°F, ft-lb (3 specimens tested)
3-5/8	50,200 62,800	70,400 80,800	30 25	46-45-51
3	52,700 54,500	77,700 78,500	27 26	59-14-30
2-5/8	52,200 54,500	75,800 77,500	28 28	70-28-113
2-1/4	54,700 55,000	76,200 75,000	28 27	28-32-38
1-5/8	60,700	84,200	24	14-15-18
1-1/2	64,400 65,100	81,000 82,600	19 20	78-99-24
1-1/4	58,000 58,300	80,000 77,600	22 28	61-60-90
1-1/8 (flange)	63,400	83,600	26	18-20-31
1-1/8 (web)	56,800	83,800	25	32-22-15

Item 3:

The joint splices should be designed to prevent the entrance of water between the plates and to prevent any subsequent corrosion problems. Considering this, the exterior splice plate should be one piece (full flange width). The interior splice plates could be split into two sections to facilitate handling inside of the box girders.

The filler plates required at the thickness transitions should either be cut and ground to closely conform to the actual transitions or some other method employed to plug and caulk the sloping gap at each end fo the spliced joint.

Item 4:

The completed splices should be coated with an inorganic zinc paint and a brown vinyl top coat. A detailed painting specification will be supplied by G. Tinklenberg as soon as possible. Basically, the preparation required will involve the following items:

a) All splice and fill plates should be blast-cleaned in the shop after fabrication and coated with a wash primer of 1/2 mil thickness to prevent rusting. This wash primer will be removed in the field just prior to bolting the splice.

b) The flange material on the beams should be blast-cleaned to a white finish before bolting to remove as much salt contamination as possible from the bare, weathered surfaces. The interior flange sections may be blast cleaned or ground to remove all mill scale, rust and debris from the faying surface.

c) After all drilling has been completed, the splice plates, fill plates and flanges should be thoroughly cleaned to remove cutting oil, sand and debris. All burrs should be removed.

d) After the splices have been installed, they should be cleaned and painted in accordance with the painting specification to be supplied by G. Tinklenberg.

Item 5:

Incidental to the repair splicing, we strongly recommend that the flange edges on both girders be marked and ground to remove the sharp notches and gouges that are present in the tension or stress reversal regions. These notches are prevalent and could easily lead to fatigue crack initiation sites in the future. The Soils and Materials Section of the Testing and Research Division could handle the marking of these areas and the inspection of the grinding.

Item 6:

If permissible by design check, I would like to request that two 2-inch diameter cores be removed from weldment 7SB by hole sawing through the weld from the inside of the box girder. The exact location of the cores will be determined by Research Laboratory personnel using ultrasonic testing prior to the drilling of bolt holes. The cores will be located near both ends of the flaw which has been defined in the weld and will serve to study the nature of the defect and if fatigue crack growth has occurred in the joint. The hole cutting may have the beneficial effect of providing a crack arrest mechanism for the defective area. The cores would only constitute a reduction of about 8 percent in the net section through the weld. The results of this flaw analysis will be extremely valuable in the understanding of the field problems being experienced with electroslag weldments.

The cores shall be removed by the contractor under the direct supervision of Research Laboratory personnel.

Item 7:

A corrosion problem on the box girders that needs to be remedied is the leakage of water into the ends of the box sections through the cope holes and plates. These should be plugged and the interior area of the box near the ends blasted and cleaned out to remove the corrosion products now present. This could be done by highway maintenance personnel and should not be attempted until the splicing contract has been completed.

If any questions arise concerning the reasoning behind these recommendations, feel free to call. I have been working closely on this matter with Messrs. S. Ajluni and W. Turner and will give top priority to anything that I can do to be of assistance.

TESTING AND RESEARCH DIVISION

James D. Culp
Transportation Research Engineer
Structural Mechanics Group

JDC:lve

Attachment

cc: A. Vankampen
D. F. Malott
S. M. Ajluni
W. C. Turner
W. D. Bullen
M. S. VanAuken
G. R. Cudney
P. Milliman
C. J. Arnold
G. J. Hill
G. L. Tinklenberg

TABLE 1.5.4

CHARPY-IMPACT REQUIREMENT[a] for FRACTURE CRITICAL MEMBERS

YIELD[b] STRENGTH (ksi)	MINIMUM CVN-IMPACT (ft-lb)[c] AT THE LAST[d] FOR SPECIFIED THICKNESS RANGES (in.)		
	up to 2	over 2 to 2 1/2	over 2 1/2 to 3
from 36 to 60	25	30	35
over 60 to 70	30	35	40
over 70 to 80	35	40	45
over 80 to 90	40	45	50
over 90 to 100	45	(e)	(e)
over 100 to 110	50	(e)	(e)
over 110 to 120	55	(e)	(e)

NOTES: (a) The CVN-impact testing shall be "P" (plate) frequency testing; when more than one flange or web is stripped from a larger plate, only the larger plate need be tested. The Charpy test pieces shall be coded with respect to heat/plate number and that code shall be recorded on the mill-test report of the steel supplier with the test result. ~~The fracture appearance at the LAST shall be no less than 80 percent shear (see ASTM A370-75, Section 23.2.2.1). If the fracture appearance in any one specimen is less than 80 percent shear (fibrous), a retest shall be made and the fracture appearance of each of the three retest specimens shall equal or exceed the 80 percent shear requirement. If the retest specimens fail to meet the fracture appearance, ASTM E208 testing is required.~~

(b) The yield strength is the value given in the certified MILL TEST REPORT.

(c) Average of three (3) tests. If the energy value for more than one of the three test specimens is below the minimum average requirement, or if the energy value for one of the three specimens is less than 75 percent of the specified minimum average requirement, a retest shall be made and the energy value obtained from each of the three retest specimens shall equal or exceed the specified minimum average requirement.

(d) The lowest anticipated service temperature (the LAST) shall be based on the isoline in Figure 1.5.4.1 nearest the geographical location of the structure.

(e) Plate in excess of 2-inch thick shall not be used in FCMs when the yield strength exceeds 90 ksi.

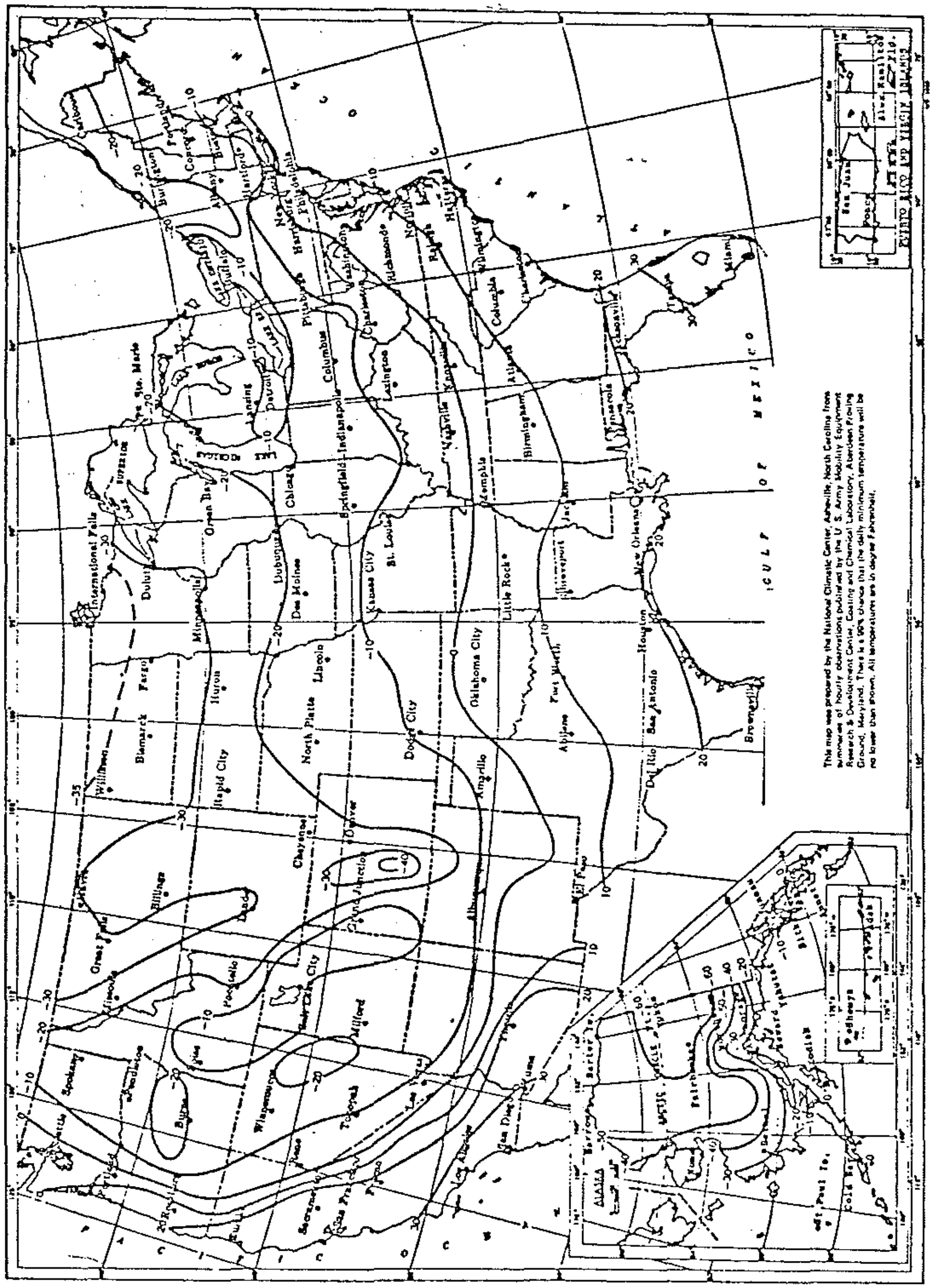


FIGURE 1.5.4.1 - ISOLINES FOR FIRST-PERCENTILE MINIMUM TEMPERATURES, the basis for determining the lowest anticipated service temperature (LAST) for fracture critical members (FCMs).

FIGURE 1.5.4.1 - ISOLINES FOR FIRST-PERCENTILE MINIMUM TEMPERATURES, the basis for determining the lowest anticipated service temperature (LAST) for fracture critical members (FCMs).

OFFICE MEMORANDUM

DATE: February 28, 1980

TO: R. C. Fuhr
Design Supervising Engineer-Bridge
Design Division

FROM: C. J. Arnold

SUBJECT: B01 of 70014 - US-31 over S. Channel of the Grand River
Research Project 80 TI-641

Sampling and analysis of steel from the subject structure have been completed at your request. Samples were removed from stringers U and X near Abutment A of the structure, and also from S and W near Abutment B.

The chemistry of the steel is suitable for welding shear connectors. Tensile and impact properties were as follows:

Sample	Stringer	σ_y (psi)	σ_u (psi)	Red. of Area, %	Elong. at Break, %	Charpy Impact Value (ft lbs at 40°F) 1	2	3	4	Avg.
1	X, at Abut. A	43000	66000	66	41	72	43	59	45	55
2	U, at Abut. A	41500	62000	69	42	179	112	199	115	151
3	W, at Abut. B	45500	63000	70	44	222	111	239	---	191
4	S, at Abut. B	44000	62500	67	43	199	164	228	192	196

The above values indicate that the steel meets requirements for ASTM A-36. If you have any questions concerning methods or results, please give me a call.

TESTING AND RESEARCH DIVISION

C. J. Arnold

C. J. Arnold - Supervisor
Structural Mechanics Group
Research Laboratory Section

CJA:cgc

cc: A. VanKampen
L. T. Oehler

OFFICE MEMORANDUM

DATE: February 13, 1981

TO: C. J. Arnold
Supervisor, Structural Mechanics

FROM: K. S. Bancroft

SUBJECT: S02 of 82191, Woodruff Road over I-75
Research Project 80 TI-702

A crack was discovered on the first interior beam from the north on the structure carrying Woodruff Road over I-75. This beam and the adjacent beams had been impacted by a vehicle carrying a high load. A statewide repair crew fixed the damaged beam by field welding the crack.

As requested, samples were taken out of the structure to determine the properties of the steel. Five beams were sampled from span 5, over the outside shoulder of northbound I-75. These samples were cut from the north bottom flange with a portable band saw. Locations of the samples are as follows:

#1 - 1st interior beam from the south, north flange.
#2 - 3rd interior beam from the south, north flange.
#3 - 5th interior beam from the south, north flange.
#4 - 2nd interior beam from the north, north flange.
#5 - 1st interior beam from the north, north flange.

Sample Number 5 was from the beam that had been repaired. All the beams appeared to have been hit at one time or another.

These samples were machined into tensile specimens, V-notch Charpy specimens, and chemical samples. Results from the analysis of these samples were as follows:

Tensile Requirements
ASTM A36

Tensile Strength, psi	58,000 - 80,000
Yield Point, min., psi	36,000
Elongation, in 2 in., min. %	21

Tensile Analysis

Sample No.	#1	#2	#3	#4	#5
Tensile Strength, psi.	59,701	58,500	58,500	64,000	57,750
Yield Point, min., psi.	41,542	38,500	38,250	41,750	39,500
Elongation in 2 in., %	43.5	36.5	42.5	41.5	42.0
Red. of Area, %	68.3	71.0	71.8	69.1	68.2

Chemical Requirements
ASTM A36

Carbon Max. %	0.26
Manganese, %	0.85 - 1.35
Phosphorus, max. %	0.04
Sulfur, max. %	0.05
Silicon, %	0.15 - 0.40

Chemical Analysis

Sample No.	#1	#2	#3	#4	#5
Carbon, %	0.16	0.17	0.16	0.22	0.17
Manganese, %	0.57	0.61	0.61	0.58	0.64
Phsophorus, %	0.020	0.015	0.015	0.010	0.015
Sulfur, %	0.021	0.024	0.024	0.011	0.027
Silison, %	0.09	0.09	0.09	0.08	0.10

Charpy Data

Sample No.	#1	#2	#3	#4	#5
Average ft-lbs at 40°F	166	222	208	91	168

The tensile analysis show that most of the samples met the minimum tensile requirements based on ASTM A36 specifications. The tensile strength of sample no. 5 was slightly lower than the minimum required. Sample no. 4 exhibited the highest tensile strength and yield point along with the lowest Charpy value. This can probably be attributed to the higher carbon content present in this specimen. The chemical analysis also showed that none of the samples met the requirements for the elements manganese and silicon.

TESTING AND RESEARCH DIVISION

Kurt S. Bancroft
Engineering Technician
Structural Mechanics Group

KSB:lve

OFFICE MEMORANDUM

MICHIGAN DEPARTMENT OF TRANSPORTATION

DATE: October 22, 1981

TO: R. C. Fuhr
Design Division

FROM: C. J. Arnold

SUBJECT: Sampling and Chemical Analysis of R01-82052
Research Project 81 TI-769

As requested, samples have been removed and chemical analysis performed on the structural beams and bearing plates on R01 of 82052. These evaluations were made to determine the weldability of the structural steel used in the bridge. The analysis showed acceptability for welding.

On August 28, 1981, a request was received from the Design Division to sample and conduct chemical analysis of the structural steel used in R01 of 82052, US-24 (Telegraph Road) over the P.C.R.R. The Department is considering options for reconstruction of this structure, and the weldability of the structural steel is one of the determining factors for reuse of the existing beams.

A sample from each of eleven (11) beams (at the abutments), and four (4) random samples from the bearing plates were submitted to chemical analysis. The following Carbon Equivalency formula was used to evaluate weldability:

$$C.E. = \%\,C + \frac{\%Mn}{6} + \frac{\%Ni}{20} + \frac{\%Cr}{10} + \frac{\%Cu}{40} - \frac{\%Mo}{50} - \frac{\%V}{10}$$

In this case, Carbon and Manganese content are the only applicable elements required to compute the Carbon Equivalency.

The largest computed carbon equivalency for the structural beams was 0.332. One of the four randomly sampled bearing plates contained a carbon equivalency of 0.460. The other three bearing plate equivalency values were in the range between 0.298 and 0.333.

Steels having carbon equivalents of less than 0.40 generally are considered to be weldable in the thicknesses involved here. The one bearing plate with the carbon equivalency value of 0.460 appears to be an isolated case. If the welding required on the bearing plates is of a non-critical nature, special considerations may not be required.

The structural beams meet specification chemical requirements of both ASTM A 7-33T and ASTM A 36-33. Two of the four bearing plates sampled, meet chemical requirements of ASTM A 36-33, the other two do not meet requirements of A-36 but will meet chemical requirements of A 7-33T. This is due to a higher carbon content.

The structural steel used in R01 of 82052, as indicated by all but one sample can be considered as being weldable without special precautions such as pre-heating or post heating. However, the personnel that performed the steel sampling indicated that there is considerable corrosion of the structural steel. Welding under these conditions requires additional considerations in cleaning and preparation in order to obtain suitable welds. Also, welding personnel and procedures must be qualified. Field welding under such conditions is quite difficult to do well. I suggest that you contact J. D. Culp in order to obtain specific welding requirements that should be included in the contract to advise the contractor of the special considerations involved.

TESTING AND RESEARCH DIVISION

C J Arnold

Supervising Engineer
Structural Research Unit
Research Laboratory Section

CJA:LJP:lve

cc: L. T. Oehler
M. A. Chiunti
L. J. Pearson

THIS COPY FOR

OFFICE MEMORANDUM

DATE: May 2, 1983

TO: W. D. Bullen
Design Division

FROM: C. J. Arnold

SUBJECT: Mechanical Properties of Bridge Steel Samples Removed from Structure B01 of 49023, US-2 over Cut River, Mackinac County
Research Project 83 TI-898

Six steel samples were obtained from B01 of 49023, on April 14, 1983, for the purpose of determining values of mechanical properties to be used in design calculations for establishing the load carrying capacity of the structure.

The samples were removed from the six 30" floorbeams as shown on the attached plan. To prevent changes in physical properties due to the removal process, removal was done by sawing with a portable band saw. The samples were removed from the edge of the bottom flange. The removed portion consisted of a coupon approximately 1 in. wide and 14 in. long.

The removed samples were machined to standard 0.505 in. diameter reduced section specimens and tested for yield and ultimate strength on the 20,000 lb capacity MTS electrohydraulic machine with automatic print-out of the load-strain curve. Yield strength data are reported at 0.2 percent strain. The samples were submitted for chemical analysis and four Charpy impact specimens were tested from each beam. Results of the tests are shown on the attached sheet. The samples met the physical and chemical requirements for A-36 steel.

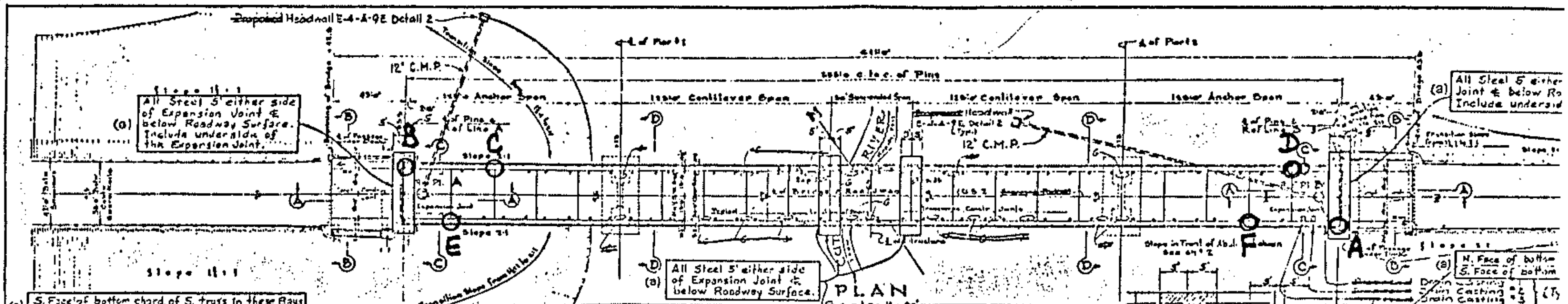
Per the conversation of 4-22-83, please include in the contract repair by grinding and painting the areas where the samples were removed.

TESTING AND RESEARCH DIVISION

C. J. Arnold - Supervising Engineer
Structural Research Unit
Research Laboratory Section

CJA·LJP:cgc
Attachments

cc: L. T. Oehler



SAMPLE	CHEMISTRY				CHARPY				TENSILE			
	CARBON	SULFUR	PHOSPHOROUS	MANGANESE	1	2	3	4	YIELD	ULTIMATE	% RED. OF AREA	% ELONGATION
A	0.20	0.037	0.018	0.51	26	20	12	18	40,000	59,500	65.6	40
B	0.21	0.033	0.014	0.49	31	63	24	53	39,750	60,000	66.7	41.2
C	0.25	0.030	0.013	0.43	10	10	—	—	36,386	60,643	62.3	41
D	0.26	0.034	0.012	0.44	12	12	10	12	37,313	60,572	61	38.8
E	0.25	0.032	0.012	0.43	22	11	12	13	37,814	61,558	63.2	39
F	0.26	0.028	0.016	0.43	6	7	8	8	36,634	60,891	61.2	40
STM A-36	MAX 0.26	MAX 0.05	MAX 0.04	-----					33,000	58,000 to 80,000		21% MIN.
STM A-7-33T	----	MAX 0.05	MAX 0.04	----					36,000	60,000 to 72,000		24% MIN.

OFFICE MEMORANDUM

DATE: May 11, 1983

TO: W. D. Bullen
Design Division

FROM: C. J. Arnold

SUBJECT: Steel Sampling, US-31 Bascule Bridge RP 83 TI-910

In response to your request to provide data concerning weldability of the longitudinal floorbeams in the Bascule Bridge on US-31 in the City of Grand Haven, samples were removed from four beams.

The samples for chemical analysis were removed from the end of the beams, at the center of the span. The locations are as follows:

Sample No. 1 North Span
2nd longitudinal beam east of west sidewalk at
Bridge Transverse centerline.
Bottom flange east corner.

Sample No. 2 North Span
10th longitudinal beam east of west sidewalk at
Bridge Transverse centerline.
Bottom flange east corner.

Sample No. 3 South Span
2nd longitudinal beam east of west sidewalk at
Bridge Transverse centerline.
Bottom flange west corner.

Sample No. 4 North Span
2nd longitudinal beam west of east sidewalk at
Bridge Transverse centerline.
Bottom flange east corner.

The samples were removed using a portable band saw to prevent damage to the beams and specimens, the results of the chemical analysis are shown on the attached Laboratory Report.

There are several formulas for computing carbon equivalency; in order to determine weldability. Computations using these formulas, show the beams to be a mild carbon steel, which is weldable without pre-heating.

If we can be of further assistance, please contact us.

TESTING AND RESEARCH DIVISION

C. J. Arnold

C. J. Arnold-Supervising Engineer
Structural Research Unit

CJA:LJP:kls
cc: J. D. Culp
J. Reinecke
file ← THIS COPY FOR

OFFICE MEMORANDUM

MICHIGAN DEPARTMENT OF TRANSPORTATION

DATE: December 14, 1983

TO: L. T. Oehler
Engineer of Research

FROM: C. J. Arnold

SUBJECT: Research Project 83 TI-945

Attached is a copy of the results of our investigation as reported to W. J. MacCreery, Engineer of Design.

The investigation has been completed and we recommend the project be closed.

TESTING AND RESEARCH DIVISION

C. J. Arnold - Supervising Engineer
Structural Research Unit

CJA:cgc
Attachment

cc: M. L. O'Toole
J. W. Reincke
L. J. Pearson THIS COPY FOR

OFFICE MEMORANDUM

DATE: December 14, 1983

TO: W. J. MacCreery
Engineer of Design

FROM: K. A. Allemeier

SUBJECT: Sampling and Chemical Analysis of US-10 over B01 of 43022 (Baldwin River) and B01 of 67021 (Johnson Creek)
Research Project 83 TI-945

On September 16, 1983, a request was received from the Design Division to sample and determine strength and chemical properties of the structural steel in B01 of 43022, US-10 over Baldwin River. Subsequently, we were also asked to evaluate the chemical properties of the structural steel in B01 of 67021, US-10 over Johnson Creek, for the purpose of determining weldability. Tensile and Charpy values were also requested for B01 of 43022. The Department is considering options for reconstruction of these structures, and the weldability of the structural steel is one of the determining factors for reuse of the existing beams. Four samples were removed from each of the structures, and were submitted for chemical analysis. The following carbon equivalency formula was used to evaluate weldability.

$$C.E. = \%C + \frac{\%Mn + \%Si}{4}$$

For B01 of 43022, the largest computed carbon equivalency was 0.302, with the low being 0.280. Steel in the beam thickness range of this structure having a carbon equivalency of less than 0.40 is generally considered to be weldable. Thus, the analysis showed acceptability for welding and a review of the specifications shows beams meet the chemical specification requirements for both ASTM A7-33T and ASTM A36-33.

Tensile specimens were tested to determine the yield and ultimate strengths of the structural beams. Charpy specimens determined impact properties. Results follow:

Specimen	Yield	Ultimate	Elongation
B-1	41,000 psi	57,800 psi	44%
B-2	42,000 psi	57,000 psi	44
B-3	40,100 psi	56,400 psi	35%
B-4	43,500 psi	58,000 psi	44
	ASTM SPECIFICATION REQUIREMENTS		
A7-33T	33,000 psi min.	60,000 - 72,000 psi	24% min.
A36-33	36,000 psi min.	58,000 - 80,000 psi	21% min.

All specimens meet the minimum requirement for yield strength, however, only one specimen met the required ultimate strength for ASTM A36-33. Charpy impact tests resulted in CVN values ranging from 85 ft-lb to 228 ft-lb, at 40°F. These values indicate this steel to be very ductile or tough. The structural steel used in B01 of 43022, can be considered weldable but may require special precautions such as preheating, surface preparation, and low hydrogen practice. However, the low ultimate strength should be noted.

For B01 of 67021, the highest and lowest carbon equivalencies for the structural beams were 0.477 and 0.395, respectively. Once again, steels are considered weldable for the beam thickness involved if the carbon equivalency is less than 0.40. The high values obtained from our analysis indicate that this structure is not weldable without special provisions such as extra preheat and post-heating.

The use of stick electrodes should be avoided when field welding cover plates to existing beams. Numerous stops and starts in an uncontrolled environment may reduce full length cover plates from a Category B detail to Category C. The weld termination of cover plates less than full length is a Category E detail. I suggest that the Structural Welding Engineer review the proposed design plans for recommendations as to the specific welding requirements or other special considerations that should be included for both structures.

TESTING AND RESEARCH DIVISION

Engineer of Testing and Research

KAA:LJP:cgc

cc: M. L. O'Toole
L. T. Oehler
C. J. Arnold
J. W. Reincke

OFFICE MEMORANDUM

DATE: December 13, 1984

TO: R. C. Fuhr
Supervising Engineer - Bridge
Design Division

FROM: C. J. Arnold

SUBJECT: Sampling and Chemical Analysis of R01 of 58051-15205D.
US-24 over Ann Arbor Railroad
Research Project 83 TI-960

Steel sampling and testing has been completed on the subject structure in response to your request. Strength and chemical content were determined. The Department has scheduled the deck for replacement and the painting of the structural steel. Weldability is one of the factors of interest in determining whether existing beams should be reused.

Four samples were submitted for chemical analysis. The following carbon equivalency formula was used to determine weldability.

$$C.E. = \%C + \frac{\%Mn + \%Si}{4}$$

The largest computed carbon equivalency was 0.40, with the lowest being 0.33. Steel in the beam thickness range of this structure, that has a carbon equivalency of less than 0.40 is generally considered to be weldable. Thus, the analysis shows borderline acceptability for welding. A review of the specifications shows the beams meet the chemical specification requirements for both ASTM A7-33T and ASTM A-36-33.

Tensile specimens were tested to determine the yield and ultimate strengths of the structural beams. Because previous experimentation has shown that the strength of the web and the flange directly under the web may be up to 10% less than the strength at the edge of the flange where the samples are removed, a 10% reduction is applied to this type of work. Results follow:

Description	Specimen	Yield	Ultimate	Elongation
South End of 4th Beam from East Side	A	38,100 psi	57,200 psi	44%
South End of 2nd Beam from East Side	B	40,500 psi	63,400 psi	39%
North End of 6th Beam from East Side	C	42,900 psi	63,500 psi	44%
North End of 9th Beam from East Side	D	42,400 psi	64,000 psi	41%
		41,000 Avg.	62,000 Avg.	42% Avg.
10% Reduction		36,900 psi	55,800 psi	

ASTM SPECIFICATION REQUIREMENTS

A7-33T	33,000 psi min.	60,000 - 72,000 psi	25% min.
A36-33	36,000 psi min.	58,000 - 80,000 psi	21% min.

Based upon the 10% reduction in values, one specimen failed to meet the ASTM Specification for yield strength of A36, and none of the specimens meet either ASTM requirements for ultimate strength. This may affect your decision to reuse the steel, and since our sampling was quite meager, we recommend a conservative approach.

Charpy impact specimens were tested at 40°F to determine impact strengths. The results follow:

	SPECIMEN A	SPECIMEN B	SPECIMEN C	SPECIMEN D
	103	53	40	58
	204	27	28	35
	55	41	30	39
	---	36	42	27
Average	121	39	35	40

Because the two unusually high values were from the same beam, the results from this beam were discounted as being non representative. Thus, the remaining twelve specimens averaged 38 ft-lb with the high being 58 ft-lb and the low being 27 ft-lb.

We investigated the structure for corrosion damage caused by deck leakage and found several areas of section loss. The worst beam areas were generally within the first four to six feet from the headwalls. Other isolated areas of corrosion were noticed but could not be reached with the equipment available. Measurements of section loss were taken in both sound areas and corroded areas of typical beams using a micrometer and a D-meter (ultrasonic testing). Rust and other debris were removed to the extent practical without the aid of grinding or sand-blasting. We strongly suspect from general appearances and past experience, there may be areas with deeper pits or more extensive corrosion losses than those we measured; perhaps up to twice the losses noted below.

Flange thicknesses in uncorroded areas just adjacent to a measured corroded area were approximately 0.80"; in corroded sections we found readings in a 0.59" to 0.64" range. Web thicknesses in sound areas were 0.56" to 0.58"; we observed corroded web thicknesses in 0.52" to 0.53". The top flanges could not be measured but visual observation showed serious corrosion to be present in these same areas.

The outside pier bent bases are corroded, especially the rivets and anchor bolts/nuts which have significant section loss. The cross-members at the outside bents are severely corroded. When comparing the corrison of this structure with R01 of 58052 (81 TI-769, 10/22/81), the loss of section due to corrosion on this structure does not appear as great. Barring the discovery of an unusual amount of deterioration on the top flanges when they are exposed, it appears that the damage to these beams is sufficiently localized to be dealt with at the time of reconstruction, without as many problems as were encountered in the previous work.

The Structural Welding Engineer should review the proposed design plans for recommendations as to the specific welding requirements or some special considerations, such as preheat and low hydrogen practice, that should be included for the repair and rehabilitation of this structure.

TESTING AND RESEARCH DIVISION

C. J. Arnold

C. J. Arnold - Supervising Engineer
Structural Research Unit
Research Laboratory Section

CJA:LJP:cgc

cc: M. L. O'Toole
L. T. Oehler
J. W. Reincke THIS COPY FOR

OFFICE MEMORANDUM

DATE: June 5, 1984

TO: F. Russman
Design Division

FROM: C. J. Arnold

SUBJECT: Tensile and Chemical Analysis of B01-51021
Research Project 84 TI-979

As requested, samples have been removed, tests performed and chemical analysis done on the structural beams of B01 of 51021.

On February 7, 1984, a request was received from the Design Division to sample and conduct tensile and charpy tests and chemical analysis of the structural steel used in B01 of 51021, US-31 over the Manistee River. The Department is considering options for reconstruction of this structure and strength of the structural steel is a determining factor.

Personnel from the Structural Research Unit, removed two (2) specimens from the west end of the structure to supplement four (4) samples previously removed. The six (6) samples met the requirements for yield stength of A-36 steel, but are slightly low in ultimate strength. A 10% reduction is applied in this type of work, because previous experimentation has shown that the strength of the flange directly under the web and of the web may be up to 10% less than the strengths at the edge of flange where the samples are removed. Measured strengths were as follows:

Yield, psi		Ultimate, psi		Elongation	
44,000		62,000		42%	
42,000		59,500		44%	
44,300		65,700		43%	
42,000		59,500		43%	
42,500		61,800		40.5%	
47,750		65,500		40%	
43,800	Avg.	62,300	Avg.	42%	Avg.
39,400	Reduced 10%	56,100	Reduced 10%		
36,000	ASTM A-36 Spec.	58,000-80,000	ASTM A-36 Spec,	21%	Min.

The charpy values tested at +40 or ranged from a low of 14 ft. lbs. to a high of 169 ft. lbs. with an average of 101 Ft. lbs. The chemical composition met the A-36 requirements.

We are requesting that a note be added to the contract to stabilize a saw cut in the second interior beam from the northeast end of the bridge. Our personnel experienced equipment failure and were unable to complete a saw cut for removal of a specimen. We suggest a hole be drilled at the end of the cut to prevent further cracking of the flange.

TESTING AND RESEARCH DIVISION

C J Arnold

Supervising Engineer
Structural Research Unit

CJA:LJP:kls

cc: L. T. Oehler ← THIS COPY FOR

OFFICE MEMORANDUM

MICHIGAN DEPARTMENT OF TRANSPORTATION

DATE: February 6, 1985

TO: R. C. Fuhr
Design Supervising Engineer

FROM: C. J. Arnold

SUBJECT: Sampling and Chemical Analysis of S02 of 81041 I-94 over Wiard Rd.
2 Miles SE of Ypsilanti
Research Project 84 TI-1038

On October 30, 1984, a request was received from the Design Division to sample and determine strength and weldability of the structural steel in S02 of 81041, I-94 over Wiard Rd. Nine samples were removed from the structure. These included the five locations specified by Design plus a few extras for better averaging. The locations are as follows:

Sample No.	Location		
1	East Bound Rwy.	Beam "K"	1' from Abut. A
2	West Bound Rwy.	Beam "B"	1' from Abut. C
3	West Bound Rwy.	Beam "D"	1' from Abut. D
4	East Bound Rwy.	Beam "R"	1' from Abut. B
5	East Bound Rwy.	Beam "Q"	15" west of Pier #2
6	East Bound Rwy.	Beam "R"	15" west of Pier #2
7	West Bound Rwy.	Beam "H"	15" east of Pier #5
8	West Bound Rwy.	Beam "C"	15" east of Pier #5
9	East Bound Rwy.	Beam "L"	15" east of Pier #2

A sample from each location was submitted for chemical analysis. The following carbon equivalency formula was used to evaluated weldability.

$$C.E. = \%C + \frac{\%MN + \%Si}{4}$$

The highest computed carbon equivalency was 0.45, with the low being 0.35. Five of the beams had a carbon equivalency of 0.40 or greater. Carbon equivalents of 0.40 or greater generally require that special precautions such as preheating, surface preparation, and low hydrogen practice be followed in order to obtain sound welds with adequate physical properties.

Due to the high carbon equivalents in the beams tested, the Structural Welding Engineer, should be contacted to review the proposed welding procedures. Two of the beams have carbon content just above specifications; the rest meet the chemical requirements for both ASTM A7-33T and ASTM A36-33.

Tensile specimens were tested to determine the yield and ultimate strengths of the structural beams. Previous experimentation has shown that the strength of the web, and the flange directly under the web, may be up to 10% less than the strength at the edge of the flange where the samples were removed. Therefore, a 10% reduction is applied to strength values obtained from flange-edge specimens. Results follow:

TEST RESULTS					10% Reduction	
Sample No.	Yield PSI	Ultimate PSI	Red. of Area %	Elongation %	Yield PSI	Ultimate PSI
1	37,000	61,000	66	41	33,300	54,900
2	40,500	62,000	65	41	36,400	55,800
3	38,000	64,500	65	40	34,200	58,000
4	39,000	65,000	62	40	35,100	58,500
5	40,000	60,500	68	37	36,000	54,400
6	36,000	61,000	68	41	32,400	54,900
7	38,000	61,000	67	42	34,200	54,900
8	38,500	64,000	64	41	34,600	57,600
9	35,000	58,500	65	41	31,500	52,600
Avg.	38,000	62,000	65	40	34,000	56,000

ASTM SPECIFICATION REQUIREMENTS

A7-33T	33,000 PSI Min	60,000 - 72,000 PSI	24% Min.
A36-33	36,000 PSI Min	58,000 - 80,000 PSI	21% Min.

Based upon the 10% reduction in values, two specimens failed to meet the minimum yield strength for A7-33 and seven failed to meet yield strength for A36-33. All specimens failed to meet ultimate strength requirements for A7-33 and seven specimens did not meet the requirements of A36-33 for ultimate strength. This may affect your decision to reuse the steel, and since our sampling was meager, we recommend a conservative approach.

Charpy impact tests resulted in CVN Values ranging from 14 ft-lb to 100 ft-lb, at 40°F. The average value was 43 ft-lb.

The use of stick electrodes should be avoided when field welding cover plates to existing beams. Numerous stops and starts in an uncontrolled environment may reduce full length cover plates from a Category B detail to Category C. The weld termination of cover plates less then full length is a Category E detail.

Should you decide to reinforce and reuse these beams in the new structures, please have the welding engineer make specific recommendations for preheat, process, etc., or other special welding considerations that should be included. Also, if the beams are to be reused, removal to a fabrication shop for necessary reinforcement is strongly recommended over field welding.

TESTING AND RESEARCH DIVISION

C J Arnold

C. J. Arnold, Supervising Engineer
Structural Research Unit

THIS COPY FOR

CJA:LJP:kat
cc: L. T. Oehler
J. D. Culp
J. W. Reincke

5. **Reports**

Project	75 F-146	Steel Sampling of 76 Structures
Project	75 F-275	Steel Evaluation on Vehicle Damaged Structure I-94 Kalamazoo

STEEL SAMPLING, 76 STRUCTURES

C. J. Arnold

Research Laboratory Section
Testing and Research Division
Research Project 75 F-146
Research Report No. R-1018

Michigan State Highway Commission
Peter B. Fletcher, Chairman; Carl V. Pellonpaa,
Vice-Chairman, Hannes Meyers, Jr., Weston E. Vivian
John P. Woodford, Director
Lansing, August 1976

This report covers the results of physical and chemical evaluations of more than 300 specimens removed from 76 bridges, statewide. The project was initiated by a letter to M. N. Clyde from M. Rothstein, dated July 21, 1975. Subsequently, a list of bridges was furnished to the Research Laboratory by the Design Division.

Samples were removed from the structures by a Testing and Research Division field crew during the winter of 1975-76. Removal was done by sawing, to prevent changes in physical properties due to the removal process. Tensile specimens were prepared and tested in the Laboratory, and chemical analyses were done by the Kawin Co. in Chicago.

Most of the specimens were machined to the standard 0.505-in. diameter tensile bar. In the few cases, where the flange was too thin for the round specimen, flat plate specimens were prepared. A 2-in. gage length was used for all cases. Physical properties from the two types of test bar are comparable.

The specimens were tested for yield and ultimate strength on the 20,000-lb capacity MTS electrohydraulic machine, with automatic printout of the load-strain curve. Since there was a large amount of data, and the load-strain characteristics varied considerably, all yield strength data are reported at 0.2 percent strain for the sake of uniformity. Some specimens exhibited a definite yield point "knee" that is somewhat higher than the value at 0.2 percent strain. The load-strain curves have been retained, so if there are specific sites where design calculations indicate critical or borderline values, the traces can be examined again before making a final determination.

The attached tables show the results of the evaluation to date, and are submitted for use in calculating revised load capacities. Tensile and yield strengths are provided for all locations requested, with the exception of one beam on B02 of 23092, M 99 over the Grand River, where yield and ultimate strength data were lost due to an equipment problem. Since the other three specimens were well above minimum requirements, thickness is the same, and chemistry is quite similar, we can safely assume that the missing yield strength is comparable to the others.

Samples were removed from the outside edges of the flanges, near the ends of the beams. Therefore, the results of the tests are not directly comparable to the usual steel strengths reported by the steel companies, since their samples are removed from the web, as per the ASTM procedure.

Limited experimentation here in the Laboratory has shown that the yield strength may vary by as much as 20 percent with location in the beam, and is lower in the central portion of the flange. Since the flange is the most highly stressed part of the beam, and may have considerably lower yield strength than that reported by the steel company's tests on the web, it might be well to consider this factor when making overload calculations on structures. While the specimens tested in this experiment were removed from the edge of the flange and may indicate a higher yield strength than would be found near the middle of the flange, the results reported are probably quite comparable to the yield strengths usually reported for new steel. Since most of the specimens exceeded the minimum specified yield strength by several thousand psi, Design staff may wish to consider this factor more closely on those few locations where the indicated yield strengths are marginal.

The scope of this project was expanded slightly from that requested, to provide some very valuable research information related to the impact resistance of the steel from the older structures. Beam samples were made large enough to allow for four Charpy specimens from each sample. Machining of the Charpy impact specimens is not yet complete, so no impact results are included at this time. However, preliminary results on a few structures show impact values of 50 to 150 ft-lb, which is considerably higher than for much of the steel purchased during the past several years. A complete report on the project will be issued when the remaining evaluation is completed. If there are any questions regarding the work done or the results as presented, please call on the author for further details.

Structure	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
B03 of 27041 M 28 over Presque Isle River 1.6 miles west of Ontonagon County Line	1-1-1	East end near abutment, south bottom flange, second beam from north.	0.12	0.68	0.013	0.031	42,500	59,000	72	46
	1-1-2	East end near abutment, north bottom flange, third beam from north.	0.12	0.68	0.013	0.032	44,500	60,250	63	40
	1-1-3	East end near abutment, south bottom flange, third beam from south.	0.16	0.80	0.018	0.035	46,500	63,000	70	43
	1-1-4	East end near abutment, north bottom flange, second beam from south.	0.14	0.65	0.014	0.035	41,500	59,000	64	44
B02 of 36023 M 69 over Michigamme River 5.8 miles east of Crystal Falls	1-2-1	West end near abutment, south bottom flange, second beam from north.	0.14	0.75	0.013	0.039	44,000	61,500	70	42
	1-2-2	West end near abutment, north bottom flange, third beam from north.	0.14	0.72	0.014	0.041	42,000	55,600	73	42
	1-2-3	West end near abutment, south bottom flange, third beam from south.	0.15	0.73	0.015	0.038	41,700	59,800	69	42
	1-2-4	West end near abutment, north bottom flange, second beam from south.	0.15	0.75	0.012	0.037	44,000	61,000	70	44
X01 of 52061 M 28 over LS&I Railroad 0.7 miles east of US 41	1-3-1	East span near abutment, south bottom flange, second beam from north.	0.26	0.67	0.011	0.026	40,500	69,000	64	40
	1-3-2	East span near abutment, north bottom flange, third beam from north.	0.26	0.66	0.010	0.024	44,400	69,900	63	38
	1-3-3	East span near abutment, south bottom flange, third beam from south.	0.26	0.65	0.011	0.023	44,300	69,200	63	40
	1-3-4	East span near abutment, north bottom flange, second beam from south.	0.26	0.65	0.009	0.026	44,500	69,000	63	40
B01 of 55022 US 2, US 41 over Cedar River 0.6 miles east of Powers	1-4-1	Single span near abutment, south bottom flange, second beam from north.	0.15	0.76	0.017	0.030	46,800	61,700	67	40
	1-4-2	Single span near abutment, north bottom flange, third beam from north.	0.15	0.72	0.013	0.036	44,000	62,000	67	38
	1-4-3	Single span near abutment, south bottom flange, third beam from south.	0.15	0.74	0.014	0.030	41,800	61,200	63	44
	1-4-4	Single span near abutment, north bottom flange, second beam from south.	0.15	0.72	0.016	0.035	42,800	61,200	69	42

Bridge	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
B03 of 27041 M 28 over Presque Isle River 1.0 miles west of Ontonagon County Line	1-1-1	East end near abutment, south bottom flange, second beam from north.	0.12	0.68	0.013	0.031	42,500	59,000	72	46
	1-1-2	East end near abutment, north bottom flange, third beam from north.	0.12	0.68	0.013	0.032	44,500	60,250	63	40
	1-1-3	East end near abutment, south bottom flange, third beam from south.	0.16	0.80	0.018	0.035	46,500	63,000	70	43
	1-1-4	East end near abutment, north bottom flange, second beam from south.	0.14	0.65	0.014	0.035	41,500	59,000	64	44
B02 of 36023 M 69 over Michigamme River 5.8 miles east of Crystal Falls	1-2-1	West end near abutment, south bottom flange, second beam from north.	0.14	0.75	0.013	0.039	44,000	61,500	70	42
	1-2-2	West end near abutment, north bottom flange, third beam from north.	0.14	0.72	0.014	0.041	42,000	55,600	73	42
	1-2-3	West end near abutment, south bottom flange, third beam from south.	0.15	0.73	0.015	0.038	41,700	59,800	69	42
	1-2-4	West end near abutment, north bottom flange, second beam from south.	0.15	0.75	0.012	0.037	44,000	61,000	70	44
X01 of 52061 M 28 over LS&I Railroad 0.7 miles east of US 41	1-3-1	East span near abutment, south bottom flange, second beam from north.	0.26	0.67	0.011	0.026	40,500	69,000	64	40
	1-3-2	East span near abutment, north bottom flange, third beam from north.	0.26	0.66	0.010	0.024	44,400	69,900	63	38
	1-3-3	East span near abutment, south bottom flange, third beam from south.	0.26	0.65	0.011	0.023	44,300	69,200	63	40
	1-3-4	East span near abutment, north bottom flange, second beam from south.	0.26	0.65	0.009	0.026	44,500	69,000	63	40
B01 of 55022 US 2, US 41 over Cedar River 0.0 miles east of Powers	1-4-1	Single span near abutment, south bottom flange, second beam from north.	0.15	0.76	0.017	0.030	46,800	61,700	67	40
	1-4-2	Single span near abutment, north bottom flange, third beam from north.	0.15	0.72	0.013	0.036	44,000	62,000	67	38
	1-4-3	Single span near abutment, south bottom flange, third beam from south.	0.15	0.74	0.014	0.030	41,300	61,200	63	44
	1-4-4	Single span near abutment, north bottom flange, second beam from south.	0.15	0.72	0.016	0.035	42,800	61,200	69	42

Bridge	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
B03 of 66022 M 28 over south branch Ontonagon River 4.7 miles west of US 45	1-5-1	West span near abutment, south bottom flange, second beam from north.	0.13	0.55	0.011	0.041	40,100	56,400	63	43
	1-5-2	West span near abutment, north bottom flange, third beam from north.	0.15	0.58	0.022	0.039	42,500	60,700	62	44
	1-5-3	West span near abutment, south bottom flange, third beam from south.	0.13	0.56	0.010	0.045	41,000	55,700	64	44
	1-5-4	West span near abutment, north bottom flange, second beam from south.	0.13	0.54	0.011	0.042	41,600	56,500	63	48
X01 of 02021 M 94 over Soo Line Railroad 5.2 miles southwest of Munising	2-1-1	South span near abutment, east bottom flange, second beam from west.	0.16	0.68	0.010	0.024	42,800	61,700	68	40
	2-1-2	South span near abutment, west bottom flange, third beam from west.	0.16	0.59	0.022	0.032	38,800	59,200	66	40
	2-1-3	South span near abutment, east bottom flange, third beam from east.	0.16	0.67	0.020	0.040	39,300	60,700	68	42
	2-1-4	South span near abutment, west bottom flange, second beam from east.	0.16	0.68	0.014	0.035	37,400	59,100	67	44
B01 of 17043 M 48 over Munuscong River 1.6 miles east of M 129	2-2-1	East end near abutment, south bottom flange, second beam from north.	0.17	0.61	0.012	0.037	44,700	62,300	68	42
	2-2-2	East end near abutment, north bottom flange, third beam from north.	0.20	0.65	0.010	0.032	45,500	63,500	66	43
	2-2-3	East end near abutment, south bottom flange, third beam from south.	0.17	0.64	0.010	0.044	43,500	62,000	66	43
	2-2-4	East end near abutment, north bottom flange, second beam from south.	0.17	0.65	0.009	0.040	46,500	62,500	65	41
B02 of 21024 US 2 over Rapid River 0.4 miles east of US 41	2-3-1	West span near abutment, south bottom flange, second beam from north.	0.16	0.62	0.010	0.022	32,500	54,500	70	44
	2-3-2	West span near abutment, north bottom flange, third beam from north.	0.15	0.61	0.009	0.022	33,000	54,500	72	45
	2-3-3	West span near abutment, south bottom flange, third beam from south.	0.16	0.62	0.011	0.022	33,000	55,000	70	46
	2-3-4	West span near abutment, north bottom flange, second beam from south.	0.15	0.61	0.010	0.025	33,300	55,200	70	46

	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
B06 of 21024 US 2 over Bull Run Creek 1.3 miles east of Nahma Junction	2-4-1	West end near abutment, south bottom flange, second beam from north.	0.21	0.74	0.009	0.021	40,500	63,000	68	42
	2-4-2	West end near abutment, north bottom flange, third beam from north.	0.20	0.62	0.009	0.025	41,300	61,200	66	42
	2-4-3	West end near abutment, south bottom flange, third beam from south.	0.20	0.62	0.011	0.022	39,000	60,500	66	43
	2-4-4	West end near abutment, north bottom flange, second beam from south.	0.20	0.73	0.009	0.020	41,200	62,800	67	42
B08 of 21024 US 2 over Little Fishdam River 2.0 miles northeast of Isabella	2-5-1	East end near abutment, south bottom flange, second beam from north.	0.19	0.62	0.012	0.026	39,000	62,000	66	41
	2-5-2	East end near abutment, north bottom flange, third beam from north.	0.20	0.63	0.013	0.022	38,000	62,000	68	42
	2-5-3	East end near abutment, south bottom flange, third beam from south.	0.20	0.64	0.014	0.019	38,000	61,500	65	42
	2-5-4	East end near abutment, north bottom flange, second beam from south.	0.19	0.62	0.013	0.019	38,500	62,000	68	44
B02 of 21031 M 35 over Ford River 4.0 miles southwest of Escanaba	2-6-1	West span near abutment, south bottom flange, second beam from north.	0.18	0.55	0.011	0.036	36,500	59,000	66	44
	2-6-2	West span near abutment, north bottom flange, third beam from north.	0.22	0.66	0.028	0.038	42,000	65,500	65	40
	2-6-3	West span near abutment, south bottom flange, third beam from south.	0.18	0.55	0.012	0.033	37,800	57,700	66	42
	2-6-4	West span near abutment, north bottom flange, second beam from south.	0.21	0.64	0.028	0.038	41,800	63,700	64	38
B02 of 21051 US 41 over Rapid River 7.2 miles north of US 2	2-7-1	North end near abutment, east bottom flange, second beam from west.	0.22	0.58	0.013	0.024	37,500	61,500	65	41
	2-7-2	North end near abutment, west bottom flange, third beam from west.	0.22	0.57	0.010	0.024	37,500	61,500	65	42
	2-7-3	North end near abutment, east bottom flange, third beam from east.	0.22	0.58	0.009	0.022	40,000	62,500	62	42
	2-7-4	North end near abutment, west bottom flange, second beam from east.	0.22	0.56	0.010	0.021	38,500	61,500	64	40

Structure	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
B02 of 48042 M 28 over west branch Sage River 5.5 miles east of M 123	2-8-1	East end near abutment, south bottom flange, second beam from north.	0.19	0.66	0.014	0.021	40,000	62,500	66	41
	2-8-2	East end near abutment, north bottom flange, third beam from north.	0.18	0.67	0.009	0.020	40,800	62,200	68	44
	2-8-3	East end near abutment, south bottom flange, third beam from south.	0.18	0.68	0.011	0.020	40,000	63,000	66	40
	2-8-4	East end near abutment, north bottom flange, second beam from south.	0.19	0.67	0.012	0.021	43,300	62,700	68	42
X01 of 49021 US 2 over Soo Line Railroad 5.0 miles west of M 117	2-9-1	Span 2 near pier 2, south bottom flange, second beam from north.	0.23	0.60	0.013	0.025	33,500	63,000	64	40
	2-9-2	Span 2 near pier 2, north bottom flange, third beam from north.	0.22	0.65	0.025	0.031	36,300	63,700	62	39
	2-9-3	Span 2 near pier 1, north bottom flange, third beam from south.	0.23	0.60	0.014	0.025	33,800	63,200	68	38
	2-9-4	Span 2 near pier 1, north bottom flange, second beam from south.	0.24	0.60	0.015	0.026	35,100	62,900	63	42
B01 of 05031 M 88 over Intermediate River in Bellaire	3-1-1	North end near abutment, west bottom flange, second beam from east.	0.16	0.61	0.018	0.027	37,500	57,000	67	44
	3-1-2	North end near abutment, east bottom flange, third beam from east.	0.16	0.66	0.013	0.020	37,000	57,500	69	43
	3-1-3	North end near abutment, west bottom flange, third beam from west.	0.16	0.61	0.011	0.032	38,000	56,000	70	45
	3-1-4	North end near abutment, east bottom flange, second beam from west.	0.15	0.61	0.008	0.028	37,500	56,000	69	43
B01 of 18031 US 27 BR over south branch Tobacco River in Clare	3-2-1	North end near abutment, east bottom flange, second beam from west.	0.13	0.67	0.013	0.024	40,100	57,400	66	43
	3-2-2	North end near abutment, west bottom flange, third beam from west.	0.15	0.72	0.010	0.021	42,600	59,900	69	43
	3-2-3	North end near abutment, east bottom flange, third beam from east.	0.15	0.71	0.014	0.020	40,000	59,000	71	42
	3-2-4	North end near abutment, west bottom flange, second beam from east.	0.13	0.66	0.010	0.024	39,500	57,500	69	44

Bridge	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
B01 of 51021 M 55 over Manistee River 0.1 miles east of US 31	3-3-1	South span near abutment, east bottom flange, second beam from west.	0.14	0.76	0.023	0.024	44,000	62,000	71	42
	3-3-2	South span near abutment, west bottom flange, third beam from west.	0.14	0.65	0.010	0.020	42,000	59,500	75	44
	3-3-3	South span near abutment, east bottom flange, third beam from east.	0.17	0.82	0.013	0.021	44,300	65,700	72	43
	3-3-4	South span near abutment, west bottom flange, second beam from east.	0.14	0.69	0.011	0.019	42,000	59,500	70	43
B01 of 57022 M 55 over west branch Muskegon River 3.4 miles west of Roscommon County Line	3-4-1	East end near abutment, south bottom flange, second beam from north.	0.16	0.74	0.013	0.018	38,500	59,000	69	43
	3-4-2	East end near abutment, north bottom flange, third beam from north.	0.14	0.76	0.012	0.025	36,300	57,200	70	50
	3-4-3	East end near abutment, south bottom flange, third beam from south.	0.16	0.73	0.011	0.020	38,100	58,900	69	44
	3-4-4	East end near abutment, north bottom flange, second beam from south.	0.16	0.71	0.012	0.021	36,500	59,000	68	43
B02 of 57022 M 55 over Muskegon River 1.8 miles west of Roscommon County Line	3-5-1	West span near abutment, south bottom flange, second beam from north.	0.15	0.70	0.010	0.021	41,800	61,200	70	44
	3-5-2	West span near abutment, north bottom flange, third beam from north.	0.14	0.76	0.012	0.024	40,000	59,000	72	44
	3-5-3	West span near abutment, south bottom flange, third beam from south.	0.14	0.69	0.009	0.027	45,000	61,000	70	42
	3-5-4	West span near abutment, north bottom flange, second beam from south.	0.14	0.69	0.010	0.028	43,000	59,500	72	44
B03 of 67022 US 10 over Muskegon River in Evart	3-6-1	West span near abutment, south bottom flange, fourth beam from north.	0.14	0.63	0.013	0.024	40,800	59,200	69	44
	3-6-2	West span near abutment, north bottom flange, fifth beam from north.	0.13	0.66	0.013	0.024	43,000	60,000	71	46
	3-6-3	East span near abutment, south bottom flange, fourth beam from south.	0.13	0.66	0.013	0.016	42,000	60,000	68	43
	3-6-4	East span near abutment, south bottom flange, fifth beam from south.	0.14	0.70	0.014	0.018	49,000	64,000	68	40

Structure	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
B01 of 04021 M 32 over south branch Thunder Bay River 4.7 miles east of Montmorency County Line	4-1-1	West end near abutment, south bottom flange, second beam from north.	0.22	0.75	0.022	0.025	39,900	65,500	65	40
	4-1-2	West end near abutment, north bottom flange, third beam from north.	0.22	0.73	0.018	0.028	40,500	66,000	64	40
	4-1-3	West end near abutment, south bottom flange, third beam from south.	0.22	0.76	0.020	0.027	38,700	64,800	62	41
	4-1-4	West end near abutment, north bottom flange, second beam from south.	0.22	0.75	0.023	0.027	41,800	66,700	62	40
B03 of 04021 M 32 over south branch Thunder Bay River 7.3 miles west of Alpena	4-2-1	West end near abutment, south bottom flange, second beam from north.	0.18	0.61	0.021	0.036	37,300	57,700	66	44
	4-2-2	West end near abutment, north bottom flange, third beam from north.	0.19	0.66	0.014	0.037	39,000	60,000	64	42
	4-2-3	West end near abutment, south bottom flange, third beam from south.	0.23	0.76	0.014	0.041	42,000	66,000	64	45
	4-2-4	West end near abutment, north bottom flange, second beam from south.	0.23	0.70	0.018	0.040	40,300	63,700	64	41
S03 of 20016 US 27 northbound under Fletcher Rd 2.4 miles NE of Roscommon County Line	4-3-1	West span near abutment, south bottom flange, second beam from north.	0.22	0.65	0.005	0.023	41,500	64,300	65	41
	4-3-2	West span near abutment, north bottom flange, third beam from north.	0.22	0.63	0.004	0.025	41,000	64,000	64	42
	4-3-3	West span near abutment, north bottom flange, second beam from south.	0.21	0.72	0.003	0.021	43,000	66,000	67	42
S01 of 65041 I 75 under Greenwood Rd 7.0 miles south of West Branch	4-4-1	Span 3 near pier 2, north bottom flange, second beam from north.	0.20	0.67	0.003	0.019	44,300	63,200	70	44
	4-4-2	Span 3 near pier 2, south bottom flange, third beam from north.	0.19	0.72	0.005	0.018	44,500	64,000	69	39
	4-4-3	Span 3 near pier 2, north bottom flange, second beam from south.	0.18	0.70	0.005	0.018	42,500	63,000	70	42

Bridge	Sample No.	Location of Sample	Chemical Composition percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
S01 of 69014 I 75 under Parmator Rd 3.0 miles north of M 32	4-5-1	West span near abutment, south bottom flange, second beam from north.	0.17	0.65	0.006	0.026	39,700	62,300	68	42
	4-5-2	West span near abutment, north bottom flange, third beam from north.	0.21	0.54	0.005	0.020	40,000	63,500	64	41
	4-5-3	West span near abutment, south bottom flange, third beam from south.	0.18	0.65	0.005	0.020	38,000	62,000	67	41
	4-5-4	West span near abutment, north bottom flange, second beam from south.	0.18	0.66	0.007	0.028	39,500	62,000	66	44
B01 of 19031 US 27 over Looking Glass River 6.3 miles north of Ingham County Line	5-1-1	North end near abutment, west bottom flange, third beam from east.	0.18	0.56	0.005	0.025	44,200	60,800	70	38
	5-1-2	North end near abutment, east bottom flange, fourth beam from east.	0.17	0.56	0.011	0.025	43,500	60,500	68	44
	5-1-3	North end near abutment, west bottom flange, fourth beam from west.	0.17	0.58	0.007	0.022	43,000	60,500	68	42
	5-1-4	North end near abutment, east bottom flange, third beam from west.	0.17	0.56	0.005	0.026	40,500	60,500	70	44
B04 of 34062 M 21 over Stoney Creek 1.5 miles east of Muir	5-2-1	West end near abutment, south bottom flange, second beam from north.	0.18	0.66	0.012	0.031	39,800	58,200	65	45
	5-2-2	West end near abutment, north bottom flange, third beam from north.	0.20	0.68	0.009	0.042	40,000	61,500	65	42
	5-2-3	West end near abutment, south bottom flange, third beam from south.	0.18	0.65	0.008	0.034	37,500	59,000	66	42
	5-2-4	West end near abutment, north bottom flange, second beam from south.	0.17	0.63	0.007	0.033	41,500	58,500	67	42
B03 of 34062 M 21 over Maple River 1.0 miles east of Muir	5-3-1	West end near abutment, south bottom flange, second beam from north.	0.21	0.68	0.018	0.045	41,400	61,600	63	40
	5-3-2	West end near abutment, north bottom flange, third beam from north.	0.22	0.71	0.036	0.050	40,800	58,700	63	41
	5-3-3	West end near abutment, south bottom flange, third beam from south.	0.23	0.73	0.036	0.050	43,000	67,000	64	38
	5-3-4	West end near abutment, north bottom flange, second beam from south.	0.19	0.63	0.022	0.044	40,800	62,200	65	41

Bridge	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
B01 of 34062 M 21 over Prairie Creek 2.0 miles east of M 66	5-4-1	West end near abutment, south bottom flange, second beam from north.	0.21	0.71	0.010	0.030	40,000	62,000	70	42
	5-4-2	West end near abutment, north bottom flange, third beam from north.	0.20	0.65	0.008	0.026	42,500	63,000	66	44
	5-4-3	East end near abutment, south bottom flange, third beam from south.	0.20	0.70	0.011	0.023	41,000	63,000	66	43
	5-4-4	East end near abutment, north bottom flange, second beam from south.	0.20	0.65	0.007	0.027	42,000	62,500	66	42
X01 of 41061 M 11 over C&O Railroad and M 21 BR in Grandville	5-5-1	Span 3 near pier 3, south bottom flange, second beam from north.	0.24	0.60	0.014	0.025	41,500	69,000	60	38
	5-5-2	Span 3 near pier 3, north bottom flange, third beam from north.	0.25	0.60	0.016	0.029	40,500	69,000	59	39
	5-5-3	Span 3 near pier 3, south bottom flange, third beam from south.	0.17	0.55	0.013	0.018	41,500	60,500	59	34
	5-5-4	Span 3 near pier 3, north bottom flange, second beam from south.	0.18	0.55	0.017	0.015	42,000	61,500	64	32
B02 of 62031 M 37 over White River 0.3 miles south of White Cloud	5-6-1	North end near abutment, east bottom flange, second beam from west.	0.17	0.62	0.030	0.042	36,000	57,500	67	44
	5-6-2	North end near abutment, west bottom flange, third beam from west.	0.18	0.64	0.035	0.046	36,200	59,800	68	40
	5-6-3	North end near abutment, east bottom flange, third beam from east.	0.17	0.63	0.032	0.046	37,500	59,000	68	44
	5-6-4	North end near abutment, west bottom flange, second beam from east.	0.17	0.63	0.031	0.046	34,000	57,000	68	41
B03 of 70041 M 45 over Sand Creek 2.7 miles west of Kent County Line	5-7-1	West end near abutment, north bottom flange, second beam from north.	0.14	0.61	0.012	0.037	36,500	55,500	72	46
	5-7-2	West end near abutment, south bottom flange, third beam from north.	0.17	0.79	0.018	0.050	48,300	66,700	69	37
	5-7-3	West end near abutment, north bottom flange, third beam from south.	0.14	0.62	0.012	0.044	39,000	57,500	70	45
	5-7-4	West end near abutment, south bottom flange, second beam from south.	0.13	0.62	0.011	0.035	40,500	55,500	72	46

Structure	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
S01 of 70064 I 96 under old US 16 2.5 miles southeast of Muskegon County Line	5-8-1	Span 2 near pier 1, south bottom flange, second beam from north.	0.26	0.47	0.014	0.029	47,800	68,500	56	28
	5-8-2	Span 2 near pier 1, north bottom flange, third beam from north.	0.26	0.48	0.010	0.024	37,900	66,200	54	32
	5-8-3	Span 2 near pier 1, south bottom flange, third beam from south.	0.26	0.46	0.012	0.027	38,400	65,800	54	36
	5-8-4	Span 2 near pier 1, north bottom flange, second beam from south.	0.28	0.46	0.013	0.025	46,400	66,800	54	35
B01 of 06072 US 23 over north branch Pine River 1.8 miles northeast of Standish	6-1-1	Single span near abutment, south bottom flange, second beam from north.	0.22	0.58	0.009	0.041	35,500	60,500	61	41
	6-1-2	Single span near abutment, north bottom flange, third beam from north.	0.22	0.57	0.012	0.039	36,500	60,000	64	42
	6-1-3	Single span near abutment, south bottom flange, third beam from south.	0.20	0.53	0.010	0.038	34,500	58,000	65	42
	6-1-4	Single span near abutment, north bottom flange, second beam from south.	0.21	0.58	0.012	0.040	40,500	60,000	64	40
B01 of 09011 M 84 over Dutch Creek 5.7 miles southwest of Bay City P.O.	6-2-1	South end near abutment, east bottom flange, second beam from west.	0.18	0.86	0.016	0.045	46,500	64,000	69	42
	6-2-2	South end near abutment, west bottom flange, third beam from west.	0.16	0.83	0.016	0.044	43,800	63,200	69	42
	6-2-3	South end near abutment, east bottom flange, third beam from east.	0.12	0.56	0.010	0.041	49,500	64,000	66	41
	6-2-4	South end near abutment, west bottom flange, second beam from east.	0.17	0.85	0.016	0.045	45,300	64,200	69	40

Bridge	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
B02 of 09032 M 84, M 13 over west channel Saginaw River in Bay City	6-3-1C	Span 2 near pier 1, north bottom cover plate, second girder from north.	0.24	0.53	0.008	0.030	40,300	65,500	55	37
	6-3-2C	Span 2 near pier 1, north bottom cover plate, third girder from north.	0.24	0.52	0.007	0.028	42,100	64,800	59	37
	6-3-3C	Span 2 near pier 1, north bottom cover plate, third girder from south.	0.24	0.53	0.008	0.029	40,500	64,500	60	38
	6-3-4C	Span 2 near pier 1, north bottom cover plate, second girder from south.	0.24	0.53	0.007	0.030	41,000	64,800	57	36
	6-3-1F	Span 2 10 ft from pier 1, north bottom flange, second girder from north.	0.24	0.57	0.026	0.037	40,100	64,400	58	40
	6-3-2F	Span 2 10 ft from pier 1, north bottom flange, third girder from north.	0.23	0.58	0.026	0.034	39,000	63,700	59	38
	6-3-3F	Span 2 10 ft from pier 1, north bottom flange, third girder from south.	0.25	0.57	0.026	0.039	39,400	64,800	58	41
	6-3-4F	Span 2 10 ft from pier 1, north bottom flange, second girder from south.	0.23	0.59	0.026	0.036	39,700	64,000	58	37
B01 of 09033 M 13 over Kawkawlin River in Kawkawlin	6-4-1	Span 2 near north abutment, east bottom flange, second beam from west.	0.17	0.62	0.014	0.030	39,500	61,500	65	38
	6-4-2	Span 2 near north abutment, west bottom flange, third beam from west.	0.17	0.56	0.011	0.034	41,300	60,700	67	42
	6-4-3	Span 2 near north abutment, east bottom flange, third beam from east.	0.16	0.55	0.014	0.034	43,500	61,500	66	34
	6-4-4	Span 2 near north abutment, west bottom flange, second beam from east.	0.15	0.67	0.016	0.032	42,000	60,000	67	44
B01 of 25011 M 13 over Mistequay Creek 2.3 miles north of M 21	6-5-1	Single span near abutment, east bottom flange, second beam from west.	0.19	0.70	0.026	0.031	37,500	61,000	64	42
	6-5-2	Single span near abutment, west bottom flange, third beam from west.	0.23	0.76	0.014	0.025	41,500	64,000	66	39
	6-5-3	Single span near abutment, east bottom flange, third beam from east.	0.22	0.71	0.011	0.024	40,500	64,000	66	41
	6-5-4	Single span near abutment, west bottom flange, second beam from east.	0.22	0.74	0.011	0.026	42,000	64,500	65	41

Structure	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
S02 of 25031 US 23 under Lahring Rd 1.0 miles north of Fenton	6-6-1	West span near abutment, south bottom flange, second beam from north.	0.20	0.67	0.020	0.032	45,000	66,000	65	40
	6-6-2	West span near abutment, north bottom flange, third beam from north.	0.20	0.67	0.016	0.034	44,000	65,000	65	40
	6-6-3	West span near abutment, south bottom flange, third beam from south.	0.21	0.64	0.014	0.025	42,000	66,000	66	42
	6-6-4	West span near abutment, north bottom flange, second beam from south.	0.21	0.63	0.014	0.027	43,500	66,500	66	42
B04 of 73051 M 13 over Flint River 7.2 miles south of M 46	6-7-1	South span near abutment, east bottom flange, second beam from west.	0.22	0.58	0.014	0.025	38,300	61,700	65	43
	6-7-2	South span near abutment, west bottom flange, third beam from west.	0.22	0.57	0.014	0.024	37,500	62,000	66	44
	6-7-3	South span near abutment, east bottom flange, third beam from east.	0.21	0.56	0.016	0.020	40,000	61,500	67	40
	6-7-4	South span near abutment, west bottom flange, second beam from east.	0.21	0.57	0.013	0.024	40,500	62,500	65	42
B05 of 73051 M 13 over Birch Run outlet drain 7.1 miles south of M 46	6-8-1	Span 2 near pier 1, east bottom flange, second beam from west.	0.23	0.56	0.014	0.029	39,100	63,900	64	42
	6-8-2	Span 2 near pier 1, west bottom flange, third beam from west.	0.22	0.55	0.011	0.026	42,000	64,000	63	40
	6-8-3	Span 2 near pier 1, east bottom flange, third beam from east.	0.23	0.55	0.013	0.022	40,500	64,500	60	39
	6-8-4	Span 2 near pier 1, west bottom flange, second beam from east.	0.23	0.55	0.016	0.033	40,600	64,900	63	40
S02 of 73111 I 75, US 10, US 23 under King Rd 2.8 miles southeast of M 46	6-9-1	Span 2 near pier 1, south bottom flange, second beam from north.	0.21	0.68	0.008	0.023	59,700	73,100	63	34
	6-9-2	Span 2 near pier 1, south bottom flange, third beam from north.	0.21	0.62	0.008	0.020	43,100	64,400	67	39
	6-9-3	Span 2 near pier 1, south bottom flange, third beam from south.	0.22	0.60	0.008	0.022	42,000	64,000	66	42
	6-9-4	Span 2 near pier 1, south bottom flange, second beam from south.	0.21	0.57	0.008	0.022	43,000	63,500	67	42

Structure	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
S03 of 73111 I 75, US 10, US 23 under Ross Rd 0.8 miles south of M 40	6-10-1	Span 2 near pier 1, south bottom flange, second beam from north.	0.19	0.67	0.016	0.025	46,300	63,200	66	41
	6-10-2	Span 2 near pier 1, north bottom flange, third beam from north.	0.21	0.69	0.015	0.027	41,000	63,500	68	42
	6-10-3	Span 2 near pier 1, south bottom flange, third beam from south.	0.20	0.69	0.015	0.026	43,000	63,000	66	42
	6-10-4	Span 2 near pier 1, north bottom flange, second beam from south.	0.19	0.68	0.013	0.026	40,200	62,300	66	44
D03 of 73131 M 83 over Cheboyganing Creek 0.1 miles south of M 15	6-11-1	South end near abutment, east bottom flange, second beam from west.	0.18	0.68	0.014	0.020	48,700	64,300	71	44
	6-11-2	South end near abutment, west bottom flange, third beam from west.	0.19	0.70	0.016	0.018	46,500	65,500	66	40
	6-11-3	South end near abutment, east bottom flange, third beam from east.	0.19	0.69	0.010	0.022	52,000	65,500	68	42
	6-11-4	South end near abutment, west bottom flange, second beam from east.	0.18	0.68	0.013	0.020	48,800	64,200	63	41
S08 of 76023 I 69 under Durant Rd 0.8 miles northeast of M 71	6-12-1	Span 2 near south expansion hinge, east bottom flange, second beam from west.	0.28	0.67	0.010	0.023	37,800	67,700	61	40
	6-12-2	Span 2 near south expansion hinge, east bottom flange, third beam from west.	0.27	0.75	0.009	0.022	41,000	68,500	63	39
	6-12-3	Span 2 near south expansion hinge, east bottom flange, third beam from east.	0.28	0.66	0.008	0.025	42,000	67,000	62	41
	6-12-4	Span 2 near south expansion hinge, east bottom flange, second beam from east.	0.28	0.67	0.008	0.027	40,500	67,500	62	40
D02 of 76041 M 71 over Shiawassee River 2.3 miles northwest of I 69	6-13-1	East span near abutment, south bottom flange, second beam from north.	0.22	0.66	0.008	0.020	40,000	62,500	67	42
	6-13-2	East span near abutment, north bottom flange, third beam from north.	0.26	1.10	0.014	0.020	44,000	75,500	68	35
	6-13-3	East span near abutment, south bottom flange, third beam from south.	0.20	0.75	0.036	0.017	41,500	66,000	66	40
	6-13-4	East span near abutment, north bottom flange, second beam from south.	0.25	1.11	0.018	0.018	46,800	74,400	67	40

Bridge	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
B01 of 09032 M 84, M 13 over east channel Saginaw River in Bay City	6-14-1	Third floor beam north end, east flange.	0.15	0.60	0.010	0.016	45,500	60,500	68	43
	6-14-2	West end of east span, south flange, second beam from north.	0.22	0.50	0.014	0.019	38,500	60,500	61	38
	6-14-3	East end of east span, north flange, second beam from north.	0.20	0.50	0.016	0.017	37,800	62,200	62	40
	6-14-4	East end of east span, north flange, second beam from south.	0.22	0.49	0.013	0.018	35,600	61,900	62	38
	6-14-5	West end of east span, south flange, second beam from south.	0.19	0.50	0.013	0.017	37,500	60,000	65	36
	6-14-6	Third floor beam south end, west flange.	0.16	0.58	0.016	0.016	41,200	59,400	70	42
B02 of 03034 I 196, US 31 under 130th Ave in Douglas	7-1-1	West end near abutment, south bottom flange, second beam from north.	0.23	0.61	0.010	0.024	40,000	65,500	64	40
	7-1-2	West end near abutment, north bottom flange, third beam from north.	0.22	0.60	0.013	0.022	42,500	65,500	64	40
	7-1-3	West end near abutment, south bottom flange, third beam from south.	0.24	0.62	0.012	0.025	42,000	65,500	64	38
	7-1-4	West end near abutment, north bottom flange, second beam from south.	0.24	0.63	0.013	0.020	41,500	65,500	64	41
B03 of 11015 I 94 under Kruger Rd 1.1 miles south of Union Pier	7-2-1	East end near abutment, south bottom flange, second beam from north.	0.28	0.70	0.015	0.027	46,000	72,000	61	38
	7-2-2	East end near abutment, north bottom flange, third beam from north.	0.22	0.66	0.013	0.028	41,300	64,700	65	41
	7-2-3	East end near abutment, south bottom flange, third beam from south.	0.23	0.66	0.016	0.022	40,000	65,000	65	41
	7-2-4	East end near abutment, north bottom flange, second beam from south.	0.22	0.67	0.015	0.024	40,800	65,200	64	41

Bridge	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
S05 of 11015 I 94 under Lakeside Rd 1.3 miles south of Lakeside	7-3-1	South end near abutment, west bottom flange, second beam from east.	0.22	0.68	0.020	0.027	42,800	68,300	64	36
	7-3-2	South end near abutment, east bottom flange, third beam from east.	0.22	0.61	0.004	0.020	42,000	65,500	65	41
	7-3-3	South end near abutment, west bottom flange, third beam from west.	0.22	0.68	0.004	0.021	41,500	66,800	65	41
	7-3-4	South end near abutment, east bottom flange, second beam from west.	0.22	0.63	0.003	0.017	41,500	65,500	63	41
S06 of 11015 I 94 under Warren Woods Rd 1.0 miles southeast of Lakeside	7-4-1	East end near abutment, south bottom flange, second beam from north.	0.24	0.64	0.003	0.023	41,000	66,000	64	40
	7-4-2	East end near abutment, north bottom flange, third beam from north.	0.22	0.64	0.009	0.027	42,000	66,000	63	40
	7-4-3	East end near abutment, south bottom flange, third beam from south.	0.26	0.65	0.008	0.023	42,500	66,500	65	41
	7-4-4	East end near abutment, north bottom flange, second beam from south.	0.24	0.63	0.003	0.024	39,500	64,500	64	42
S05 of 11111 I 196 under Riverside Rd 0.6 miles north of Riverside	7-5-1	West end near abutment, south bottom flange, second beam from north.	0.26	0.68	0.003	0.021	42,100	69,000	63	36
	7-5-2	West end near abutment, north bottom flange, third beam from north.	0.21	0.66	0.003	0.021	42,000	63,000	66	42
	7-5-3	West end near abutment, south bottom flange, third beam from south.	0.27	0.66	0.003	0.026	39,000	67,000	61	36
	7-5-4	West end near abutment, north bottom flange, second beam from south.	0.26	0.67	0.003	0.028	40,000	68,000	62	35
B02 of 03023 M 89 over Schnable River 4.8 miles northwest of Otsego	7-6-1	East end near abutment, south bottom flange, second beam from north.	0.13	0.53	0.003	0.034	41,500	57,500	69	45
	7-6-2	East end near abutment, north bottom flange, third beam from north.	0.13	0.52	0.003	0.030	44,000	58,000	71	44
	7-6-3	East end near abutment, south bottom flange, third beam from south.	0.13	0.68	0.003	0.034	44,500	60,000	71	46
	7-6-4	East end near abutment, north bottom flange, second beam from south.	0.13	0.50	0.003	0.031	40,000	58,500	65	44

Bridge	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
B03 of 03072 M 40 over south Branch Creek 4.0 miles southeast of Ottawa County Line	7-7-1	East end near abutment, north bottom flange, second beam from south.	0.20	0.49	0.005	0.032	38,500	59,000	66	42
	7-7-2	East end near abutment, south bottom flange, third beam from south.	0.19	0.46	0.004	0.030	36,000	59,000	64	40
	7-7-3	East end near abutment, north bottom flange, third beam from north.	0.21	0.53	0.002	0.035	40,000	60,500	67	44
	7-7-4	East end near abutment, south bottom flange, second beam from north.	0.19	0.46	0.003	0.035	36,000	59,000	64	43
B04 of 03072 M 40 over north Branch Creek 2.4 miles southeast of Ottawa County Line	7-8-1	East end near abutment, south bottom flange, second beam from north.	0.20	0.58	0.002	0.037	40,000	59,500	66	42
	7-8-2	East end near abutment, north bottom flange, third beam from north.	0.19	0.46	0.005	0.036	36,500	59,500	64	39
	7-8-3	East end near abutment, south bottom flange, third beam from south.	0.20	0.47	0.005	0.028	36,500	59,500	64	36
	7-8-4	East end near abutment, north bottom flange, second beam from south.	0.19	0.46	0.002	0.033	35,500	58,000	64	42
S11 of 11015 I 94 under Browntown Rd 2.0 miles south of Bridgman	7-9-1	West span near pier 2, south bottom flange, second beam from north.	0.23	0.78	0.016	0.023	42,500	69,500	65	40
	7-9-2	West span near pier 2, north bottom flange, third beam from north.	0.24	0.80	0.013	0.025	42,600	70,300	63	34
	7-9-3	West span near pier 2, south bottom flange, third beam from south.	0.23	0.81	0.013	0.024	42,300	68,700	65	40
	7-9-4	West span near pier 2, north bottom flange, second beam from south.	0.24	0.80	0.016	0.022	42,000	68,000	64	36
B01 of 13031 M 66 over Nottawassoppe River in Athens	7-10-1	North end near abutment, east bottom flange, second beam from west.	0.21	0.63	0.028	0.054	38,300	62,900	62	40
	7-10-2	North end near abutment, west bottom flange, third beam from west.	0.20	0.71	0.022	0.032	40,000	64,500	68	42
	7-10-3	North end near abutment, east bottom flange, third beam from east.	0.21	0.69	0.017	0.032	40,800	65,700	65	42
	7-10-4	North end near abutment, west bottom flange, second beam from east.	0.22	0.71	0.022	0.030	39,100	63,900	65	44

Structure	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
S03 of 13074 I 69 under "N" Drive north 3.8 miles north of I 94	7-11-1	Span 3 near pier 2, south bottom flange, second beam from north.	0.18	0.82	0.008	0.022	38,000	62,000	68	43
	7-11-2	Span 3 near pier 2, north bottom flange, third beam from north.	0.18	0.84	0.007	0.022	37,800	61,700	67	40
	7-11-3	Span 3 near pier 2, north bottom flange, second beam from south.	0.18	0.82	0.008	0.022	36,000	61,000	69	42
B01 of 13092 M 99 over Kalamazoo River south limits of Albion	7-12-1	North end near abutment, west bottom flange, second beam from east.	0.24	0.60	0.028	0.027	41,500	67,500	63	39
	7-12-2	North end near abutment, east bottom flange, third beam from east.	0.23	0.59	0.025	0.024	41,700	69,300	61	39
	7-12-3	North end near abutment, west bottom flange, third beam from west.	0.24	0.59	0.024	0.024	39,500	68,000	62	38
	7-12-4	North end near abutment, east bottom flange, second beam from west.	0.24	0.58	0.031	0.024	38,800	68,200	60	40
B05 of 78042 M 60 and M 66 over Nottawa Creek 1.2 miles east of junction M 66	7-13-1	West end near abutment, south bottom flange, second beam from north.	0.21	0.57	0.009	0.033	36,000	59,000	65	44
	7-13-2	West end near abutment, north bottom flange, third beam from north.	0.18	0.63	0.011	0.027	35,000	57,500	68	44
	7-13-3	West end near abutment, south bottom flange, third beam from south.	0.17	0.65	0.007	0.027	36,300	57,800	68	46
	7-13-4	West end near abutment, north bottom flange, second beam from south.	0.24	0.62	0.009	0.024	38,300	61,800	63	36
B01 of 78052 M 66 over Prairie River 2.1 miles south of south junction M 86	7-14-1	South end near abutment, east bottom flange, second beam from west.	0.19	0.64	0.021	0.027	39,500	59,000	67	43
	7-14-2	South end near abutment, west bottom flange, third beam from west.	0.19	0.65	0.017	0.044	49,500	59,500	67	44
	7-14-3	South end near abutment, east bottom flange, third beam from east.	0.20	0.68	0.026	0.033	37,800	60,200	66	42
	7-14-4	South end near abutment, west bottom flange, second beam from east.	0.16	0.66	0.018	0.033	41,300	58,700	66	44

	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
B02 of 78061 M 86 over Prairie River 6.4 miles southeast of M 60	7-15-1	West end near abutment, south bottom flange, second beam from north.	0.15	0.74	0.052	0.046	45,700	63,100	64	42
	7-15-2	West end near abutment, north bottom flange, third beam from north.	0.17	0.75	0.056	0.054	44,000	63,300	65	42
	7-15-3	West end near abutment, south bottom flange, third beam from south.	0.15	0.72	0.056	0.051	47,400	64,500	62	42
	7-15-4	West end near abutment, north bottom flange, second beam from south.	0.16	0.73	0.052	0.046	44,900	63,700	65	42
B01 of 78081 M 216 over Flowerfield Creek 1.0 miles west of US 131	7-16-1	Single span near abutment, south bottom flange, second beam from north.	0.20	0.57	0.004	0.033	45,800	63,000	62	38
	7-16-2	Single span near abutment, south bottom flange, third beam from north.	0.20	0.60	0.020	0.034	50,000	65,600	59	38
	7-16-3	Single span near abutment, south bottom flange, third beam from south.	0.13	0.61	0.023	0.042	48,100	62,100	62	36
	7-16-4	Single span near abutment, south bottom flange, second beam from south.	0.20	0.56	0.015	0.038	45,600	64,100	56	40
S07 of 47065 I 96 under Chilson Rd 3.0 miles southeast of M 155	8-1-1	South end near abutment, west bottom flange, second beam from east.	0.23	0.61	0.011	0.024	40,300	65,200	63	42
	8-1-2	South end near abutment, west bottom flange, third beam from east.	0.25	0.64	0.012	0.023	40,500	65,500	65	40
	8-1-3	South end near abutment, east bottom flange, third beam from west.	0.23	0.61	0.009	0.023	39,300	65,200	61	42
	8-1-4	South end near abutment, east bottom flange, second beam from west.	0.25	0.71	0.010	0.025	46,300	68,200	64	36
S05 of 47013 US 23 southbound under Grand River Ave 0.5 miles south of I 96	8-2-1	East end near abutment, south bottom flange, second beam from north.	0.19	0.65	0.009	0.025	40,500	61,000	68	42
	8-2-2	East end near abutment, north bottom flange, third beam from north.	0.26	0.64	0.010	0.031	41,300	66,700	62	36
	8-2-3	East end near abutment, south bottom flange, third beam from south.	0.26	0.65	0.013	0.022	42,000	67,000	64	41
	8-2-4	East end near abutment, north bottom flange, second beam from south.	0.18	0.64	0.008	0.026	40,300	61,200	65	44

Bridge	Sample No.	Location of Sample	Chemical Composition, percent				Mechanical Properties			
			C	Mn	P	S	Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
B02 of 23052 M 50 over Thornapple River 9.5 miles northwest of Charlotte	8-3-1	West end near abutment, south bottom flange, second beam from north.	0.16	0.56	0.012	0.027	36,500	56,500	67	43
	8-3-2	West end near abutment, north bottom flange, third beam from north.	0.16	0.53	0.011	0.024	34,500	54,000	69	44
	8-3-3	East end near abutment, south bottom flange, third beam from south.	0.16	0.54	0.014	0.029	37,000	56,000	68	43
	8-3-4	East end near abutment, north bottom flange, second beam from south.	0.16	0.54	0.013	0.026	36,000	56,500	68	46
B02 of 23092 M 99 over Grand River 2.2 miles southwest and south of Ingham County Line	8-4-1	North end near abutment, east bottom flange, second beam from west.	0.18	0.65	0.015	0.047	39,500	59,000	66	43
	8-4-2	North end near abutment, west bottom flange, third beam from west.	0.20	0.85	0.036	0.044	42,500	67,000	62	38
	8-4-3	North end near abutment, east bottom flange, third beam from east.	0.18	0.64	0.015	0.046	39,000	59,000	67	42
	8-4-4	North end near abutment, west bottom flange, second beam from east.	0.16	0.60	0.019	0.045	N/A	N/A	64	44
B02 of 38071 M 50, US 27 BR over Grand River 3.0 miles southeast of Jackson	8-5-1	North end near abutment, east bottom flange, second beam from west.	0.11	0.61	0.020	0.043	42,800	57,700	70	44
	8-5-2	North end near abutment, west bottom flange, third beam from west.	0.11	0.62	0.019	0.041	42,000	58,000	69	44
	8-5-3	North end near abutment, east bottom flange, third beam from east.	0.14	0.70	0.017	0.034	42,000	62,000	69	41
	8-5-4	North end near abutment, west bottom flange, second beam from east.	0.15	0.70	0.015	0.030	41,000	61,500	69	42
S06 of 47013 US 23 northbound under Grand River Ave 0.5 miles south of I 96	8-6-1	Span 2 near pier 1, south bottom flange, second beam from north.	0.19	0.68	0.010	0.033	50,500	68,000	69	40
	8-6-2	Span 2 near pier 1, north bottom flange, third beam from north.	0.23	0.72	0.011	0.026	43,000	68,500	65	39
	8-6-3	Span 2 near pier 1, south bottom flange, third beam from south.	0.23	0.73	0.011	0.026	44,800	65,700	68	40
	8-6-4	Span 2 near pier 1, north bottom flange, second beam from south.	0.20	0.65	0.009	0.029	44,000	69,000	64	39

Bridge	Sample No.	Location of Sample	Chemical Composition, percent: C	Mn	P	S	Mechanical Properties: Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
S01 of 58033 US 23 under Milwaukee Rd 3.7 miles north of M 50	8-7-1	Span 2 near pier 1, south bottom flange, second beam from north.	0.19	0.64	0.010	0.025	47,800	65,200	65	42
	8-7-2	Span 2 near pier 1, north bottom flange, third beam from north.	0.20	0.63	0.011	0.025	45,000	65,500	69	42
	8-7-3	Span 2 near pier 1, south bottom flange, third beam from south.	0.19	0.61	0.010	0.024	44,800	65,200	67	44
	8-7-4	Span 2 near pier 1, north bottom flange, second beam from south.	0.18	0.60	0.008	0.021	49,000	65,000	68	43
B03 of 47061 I 96 BL over south branch Shiawassee River 1.9 miles west of Howell	8-8-1	South end near abutment, west bottom flange, second beam from east.	0.19	0.71	0.034	0.031	39,500	63,500	65	42
	8-8-2	South end near abutment, east bottom flange, third beam from east.	0.15	0.52	0.031	0.021	42,300	59,200	70	44
	8-8-3	South end near abutment, west bottom flange, third beam from west.	0.14	0.55	0.027	0.018	36,300	57,200	69	44
	8-8-4	South end near abutment, east bottom flange, second beam from west.	0.18	0.73	0.029	0.020	38,000	61,000	68	43
S07 of 63022 I 96 under Novi Rd in Novi	9-1-1	North end near abutment, east bottom flange, second beam from west.	0.26	0.69	0.010	0.026	41,800	66,200	63	41
	9-1-2	North end near abutment, west bottom flange, third beam from west.	0.25	0.70	0.012	0.025	40,500	66,000	62	39
	9-1-3	North end near abutment east bottom flange, third beam from east.	0.25	0.71	0.005	0.016	42,100	66,300	65	40
	9-1-4	North end near abutment, west bottom flange, second beam from east.	0.26	0.70	0.009	0.021	40,100	66,000	64	40
B01 of 82141 M 102 eastbound over Rouge River 0.1 miles west of US 24	9-2-1	West end near abutment, north bottom flange, third beam from south.	0.17	0.61	0.029	0.038	36,900	58,500	64	44
	9-2-2	West end near abutment, south bottom flange, fourth beam from south.	0.18	0.59	0.024	0.035	44,100	68,600	55	39
	9-2-3	West end near abutment, north bottom flange, fourth beam from north.	0.18	0.60	0.025	0.041	37,700	61,200	58	40
	9-2-4	West end near abutment, south bottom flange, third beam from north.	0.17	0.59	0.024	0.037	37,400	61,000	60	40

Bridge	Sample No.	Location of Sample	Chemical Composition, percent C	Mn	P	S	Mechanical Properties: Yield Strength, psi	Ultimate Strength, psi	Reduction of Area, percent	Elongation, percent
B02 of 82141 M 102 westbound over Rouge River 0.1 miles west of US 24	9-3-1	West end near abutment, north bottom flange, third beam from south.	0.17	0.58	0.017	0.024	35,200	57,400	63	40
	9-3-2	West end near abutment, south bottom flange, fourth beam from south.	0.17	0.59	0.024	0.036	37,400	58,300	63	43
	9-3-3	West end near abutment, north bottom flange, fourth beam from north.	0.14	0.56	0.016	0.022	33,400	51,600	67	42
	9-3-4	West end near abutment, south bottom flange, third beam from north.	0.24	0.51	0.023	0.040	37,800	61,500	59	36
B01 of 77011 M 19 over Belle River 0.3 miles north of Macomb County Line	9-4-1	South end near abutment, west bottom flange, second beam from east.	0.21	0.48	0.016	0.026	40,900	62,400	57	41
	9-4-2	South end near abutment, east bottom flange, third beam from east.	0.20	0.47	0.017	0.027	39,800	62,200	59	42
	9-4-3	South end near abutment, east bottom flange, third beam from west.	0.20	0.46	0.015	0.023	40,700	62,900	59	42
	9-4-4	South end near abutment, west bottom flange, second beam from west.	0.22	0.50	0.019	0.022	40,200	64,700	56	40
B01 of 77052 M 29 over Belle River in Marine City	9-5-1	Span 1 near pier 2, north bottom flange, second beam from north.	0.23	0.60	0.020	0.033	42,400	65,100	57	41
	9-5-2	Span 1 near pier 2, north bottom flange, third beam from north.	0.24	0.59	0.023	0.033	43,300	66,100	58	40
	9-5-3	Span 1 near pier 2, south bottom flange, third beam from south.	0.24	0.66	0.049	0.034	45,600	70,600	56	40
	9-5-4	Span 1 near pier 2, south bottom flange, second beam from south.	0.24	0.67	0.046	0.033	44,100	69,900	60	40

ASTM Designation	Properties: Mechanical: Tensile Strength, psi	Yield Strength, psi	Chemical Composition, percent: C Maximum	Mn	P Maximum	S Maximum
A7-33T	60,000 to 72,000	33,000	—	--	0.04	0.05
A-36	58,000 to 80,000	36,000	0.26	—	0.04	0.05

STEEL EVALUATION OF VEHICLE-DAMAGED STRUCTURE (S08 OF 39022), 38th ST OVER I 94 NEAR KALAMAZOO

J. D. Culp

Research Laboratory Section
Testing and Research Division
Research Project 75 TI-275
Research Report No. R-1029

Michigan State Highway Commission
Peter B. Fletcher, Chairman; Carl V. Pellonpaa,
Vice-Chairman, Hannes Meyers, Jr., Weston E. Vivian
John P. Woodford, Director
Lansing, November 1976

The purpose of this investigation was to determine the physical properties of the steel in a beam that developed brittle fracture when struck by a vehicle.

On March 14, 1975 the bridge structure S08 of 39022, which carries 38th St over I 94 near Kalamazoo, was damaged by a truck trailer that was transporting two large fork-lift trucks. The truck was traveling in the westbound lane when a post on one of the fork-lifts struck several of the bridge beams. The fork-lift post extended to a height of slightly over 14 ft and the minimum underclearance of the bridge is posted as 13 ft - 11 in. The east fascia beam was struck first, apparently driving the fork-lift downward. The fork-lift then rebounded and the first interior beam received an impact on the east edge sufficient to fracture the beam in two and pull it from the structure onto the pavement below. Several other beams were hit by the fork-lift as the truck passed under the bridge but no other beams were fractured or dislodged from the structure. Figure 1a shows the east fascia beam that was hit, and Figure 1b shows the remaining fractured end of the first interior beam that was dislodged and the damage incurred by the second interior beam. Note that since there were no shear developers on the top of the beam it was free to pull loose from the bridge deck once the section at the diaphragm had completely fractured. In addition to the damage done to the beams, many of the connecting diaphragms in the span were twisted and many of the connecting bolts were sheared due to the large lateral loads that were transferred by the repeated impacts. The beam dislodged from the structure (Fig. 1a) was impacted on the edge of the flange at about mid-span. The fracture occurred at an intermediate diaphragm since it provided a fixation point against the lateral movement produced by the impact. The beam fractured at the south intermediate diaphragm but sheared loose from the north intermediate diaphragm. The beam also fractured at the point of impact, with the fracture running within 2 in. of the far edge of the flange and part way up the web (Fig. 2). No injuries were incurred in the accident, although one lane of I 94 was blocked by the beam until it could be removed.

The failure of this bridge beam occurred under an unusual and extreme impact loading. Normal loading on the bridge would not produce a fracture of this type and the mechanical properties of the beam were not suspected as being inadequate for the intended use. Our interest in studying the properties of the steel in the beam was due to the apparent brittle behavior of the steel at the points of fracture. The fascia beam and second interior beam both received a similar impact loading but they did not fracture like the first interior beam. Analysis of the fractured surface of the beam revealed that the crack originated at a rivet hole where the diaphragm con-

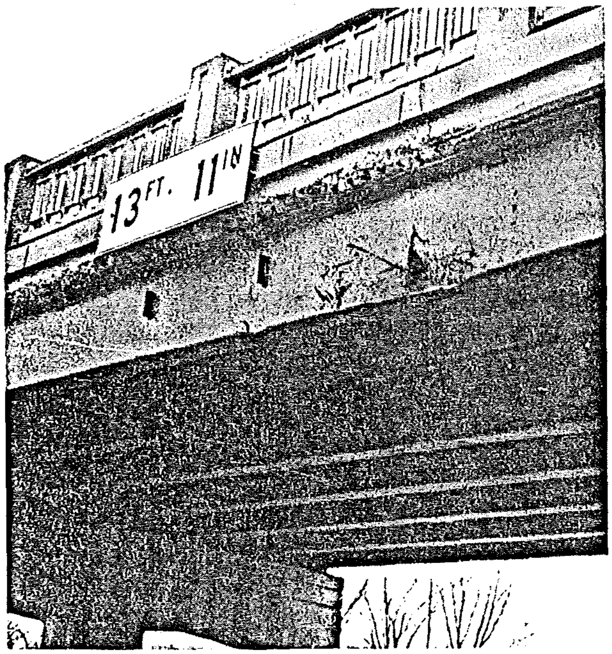


Figure 1a. East fascia of damaged span showing impact point of the fork-lift.

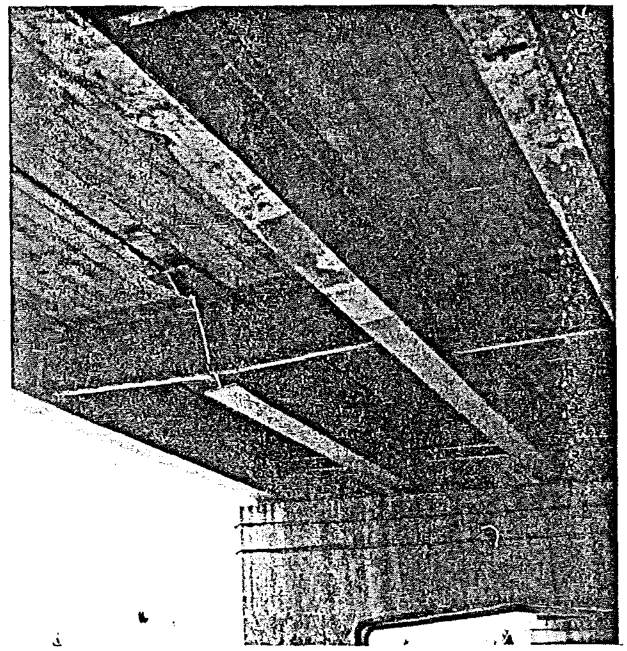


Figure 1b. First interior beam fractured at the connecting diaphragm and dislodged from bridge.

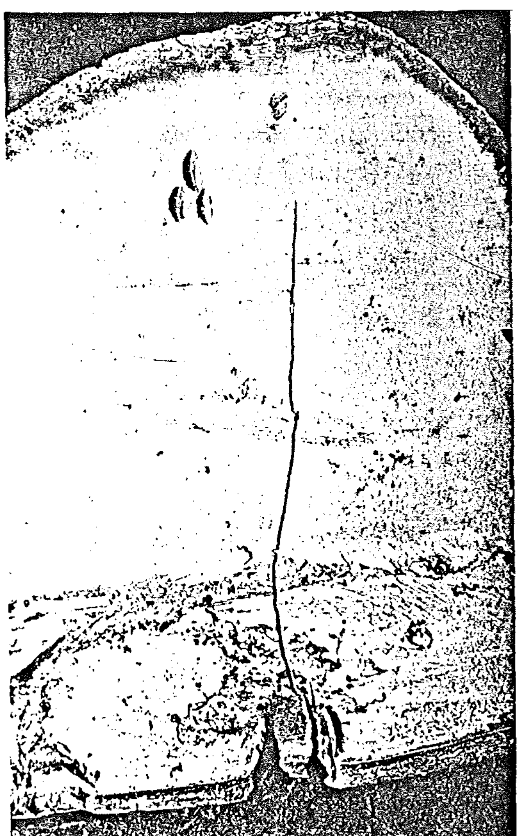
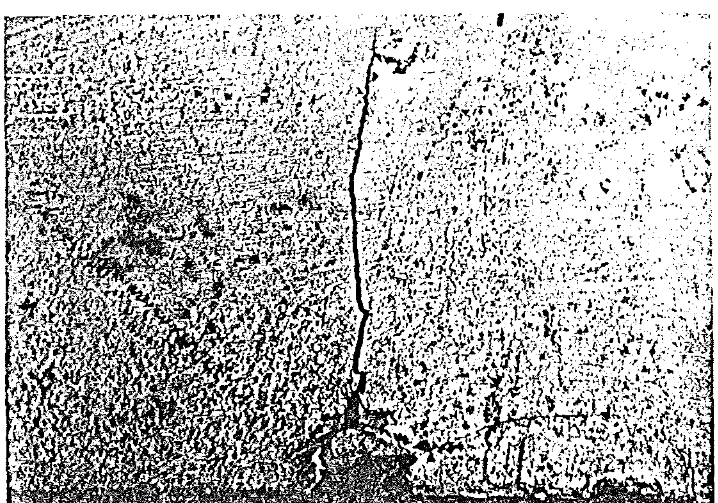


Figure 2a. Fracture at the point of impact on the first interior beam. Crack is shown running through the flange and part way up the web.

Figure 2b. Bottom side of the flange at the point of impact showing crack stopping before reaching far side of the flange.



nector angle attached to the web. This is evident in Figure 3 where the fractured web shows a "chevron pattern" (or V-pattern) of striations which is seen to point back to the edge of the rivet hole, thus depicting the origin of the crack. Figure 3 also shows a similar chevron pattern in the web on the other side of the same rivet hole which points back to the origin of the fracture on that section of the beam. There was no evidence of fatigue damage at the rivet hole, thus the fracture was totally initiated by the impact loading. Once the crack began propagating in both directions from the rivet hole, it ran completely through the top and bottom flanges of the beam, thus dislodging the beam from the structure. The fracture through the bottom flange and the upper portion of the web appeared to be predominantly brittle in mode and the fracture through the top flange was predominantly of a shear mode. The air temperature at the site was reportedly below 40 F at the time of the accident which could have contributed to the brittle behavior of the steel. An interesting feature of the fracture, as seen in Figure 4, was the sharp changes in the direction that the crack experienced as it traversed the web. At one location, shown in Figure 5a, the crack changed direction by nearly 90° at a location where the web was severely laminated. Figure 5b also shows multiple mid-plane laminations in the beam as revealed by the fractured surface. No particular significance can be attributed to the effect of the laminations on the crack propagation since the loading geometry during the failure is unknown and obviously included some twisting as the beam was torn free. A shift in the loading direction during failure could have contributed significantly to the changes in crack direction noted. The section of the fractured beam that remains in the structure is supposed to be sent to the Research Laboratory after it has been removed from the bridge. We plan to conduct ultrasonic tests on the web of this beam to define the extent of lamination in the beam.

The beams in the damaged span of the bridge were W30 x 124, which have a nominal depth of 30 in., a flange size of 15/16 x 10-1/2 in. and a web thickness of 5/8 in. A chemical analysis of the steel yielded the following percentages by weight: 0.32 carbon, 0.71 manganese, 0.05 silicon, 0.015 phosphorous, 0.029 sulfur and 0.05 copper. This conforms to the chemical requirements of ASTM A7 steel which only limits phosphorous and sulfur content. The carbon content of the steel is quite high. This high carbon content will contribute to a low fracture toughness. The ASTM A36 steel specification limits carbon to a maximum of 0.30 on a check analysis. The bridge under investigation was constructed around 1950, however, which is prior to the advent of A36 steel. Tensile tests were conducted on the top and bottom flanges of the beam to characterize its strength properties. The results of these tests are shown in Table 1. ASTM standard round specimens (0.505 in. diameter), were used in the tensile tests and

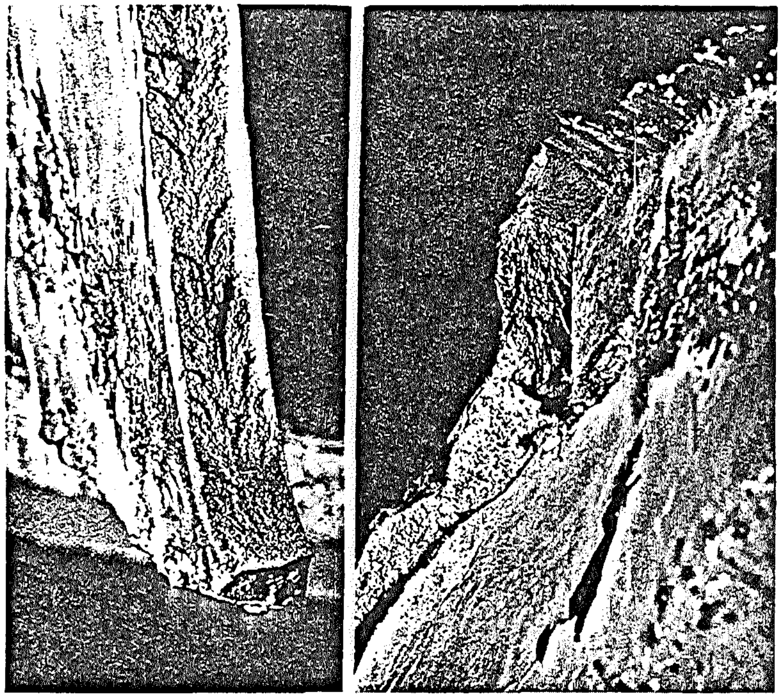


Figure 3. Chevron patterns in beam web pointing to the rivet hole as the fracture origin. Upper portion (left) and lower portion (right).

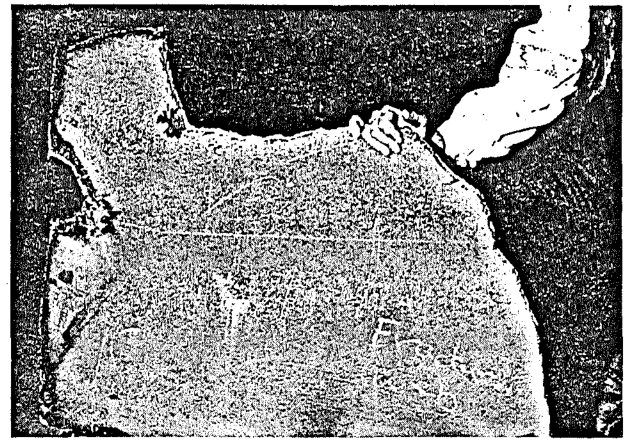


Figure 4. Irregular crack propagation path in the beam web (web plate is oriented up in picture as in the beam).

Figure 5a. Nearly 90° change in the direction of crack propagation in beam web at an area of midplane lamination.

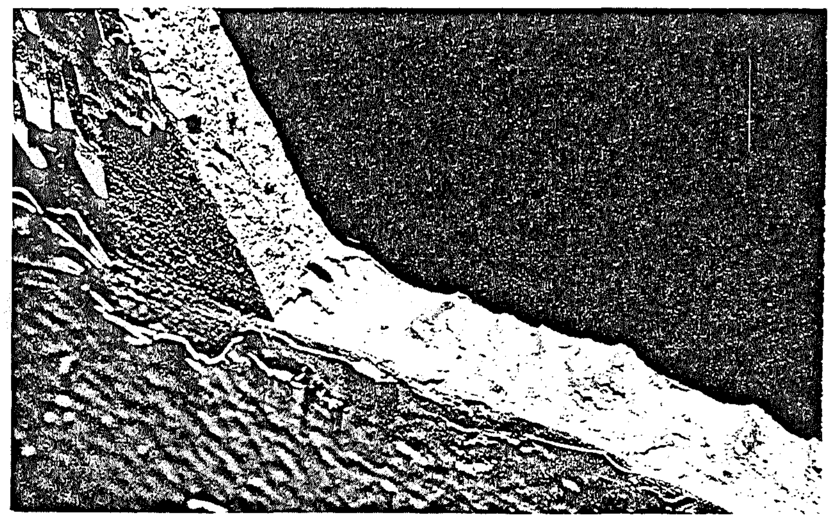
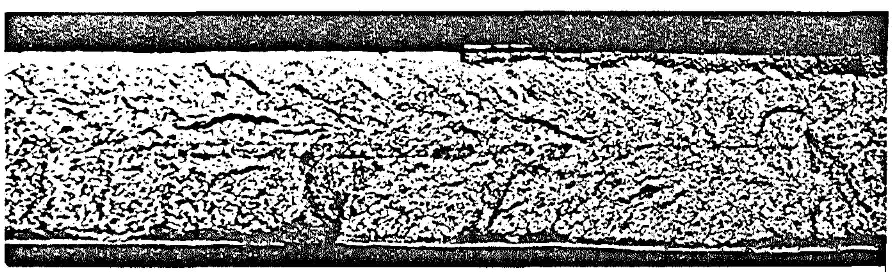


Figure 5b. Multiple laminations visible in beam web on the fractured surface.



the specimens were removed longitudinally from the flanges starting from the flange tip (specimen 1) and progressing to the web/flange junction (specimen 5).

TABLE 1
TENSILE PROPERTIES OF STEEL TAKEN FROM THE FRACTURED BEAM
(Specimens are numbered 1 to 5 starting at flange tip and ending at the web/flange junction.)

Specimen No.	Yield Strength,[1] psi	Tensile Strength, psi	Elongation,[2] percent	Reduction of Area, percent
TF-1[3]	47,400	73,900	37	57
TF-2	45,300	73,800	39	56
TF-3	43,000	74,000	38	57
TF-4	33,700	75,400	39	54
TF-5	32,000	74,700	36	55
BF-1[3]	41,200	72,400	38	58
BF-2	41,300	73,900	37	57
BF-3	41,200	73,900	38	55
BF-4	40,200	74,100	38	56
BF-5	33,300	74,200	36	55

[1] Yield strength taken as the stress at the "sharp kneed" yield point on the stress-strain curve or the 0.2 percent offset if no sharp yield was present.

[2] 2-in. gage length

[3] TF denotes specimen from top beam flange. BF denotes specimen from bottom beam flange.

Table 1 reveals a significant decrease in the yield strength of the steel from the flange tip to the web/flange junction (32 percent in top flange and 19 percent in bottom flange). The other tensile properties are fairly uniform across the section. Such a variation in yield strength is common in rolled shapes such as this beam and can be attributed to the difference in plastic deformation experienced in the rolling process and to the different rates of cooling that occur in the beam. The flange tip and web receive the most plastic work during the rolling process and the web/flange junction

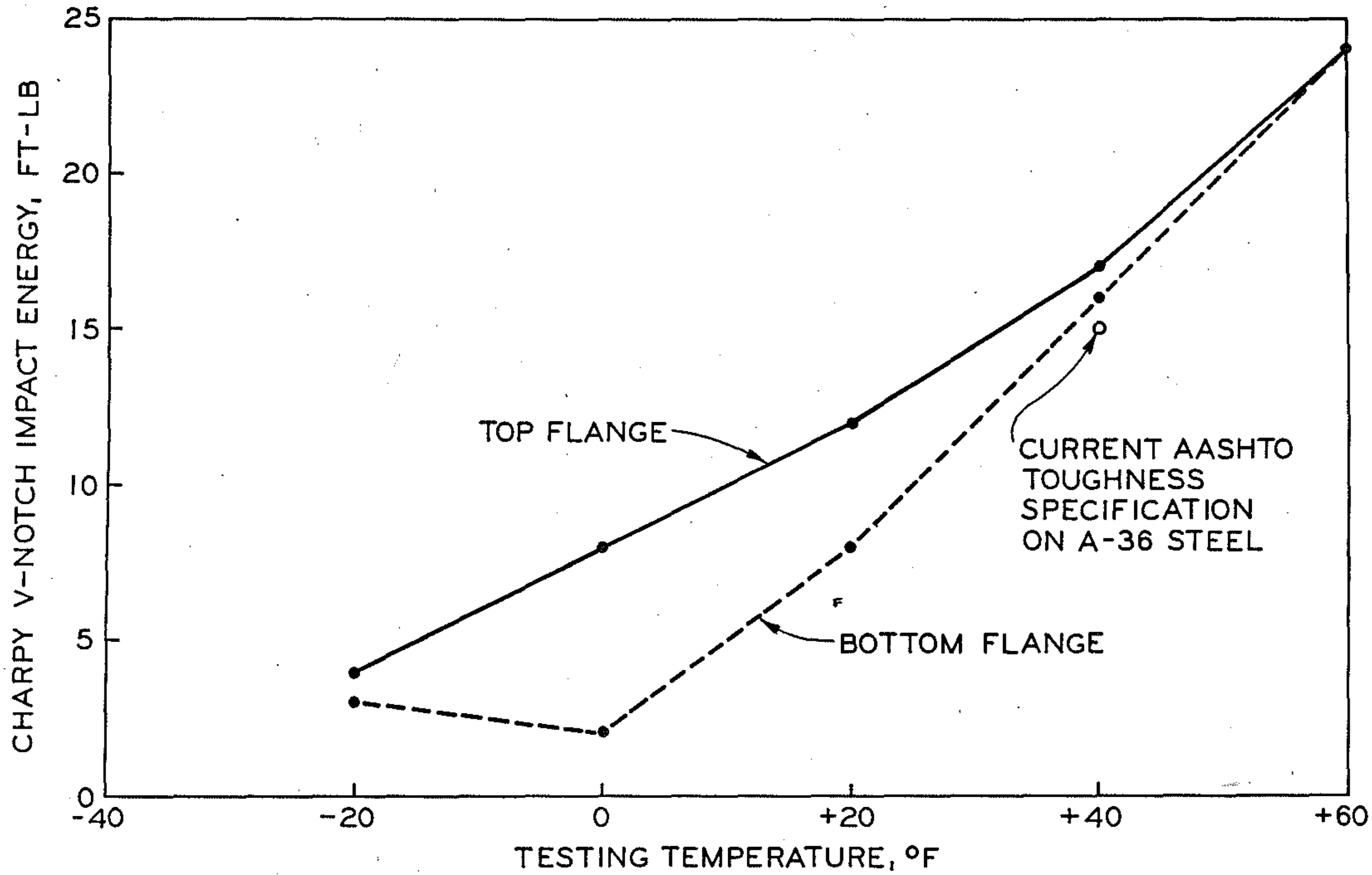


Figure 6. Energy transition-temperature curves for the top and bottom flanges of the fractured beam.

receives the least. The flange legs and web also cool faster than their junction, which results in a finer grain structure and a corresponding higher yield strength.

The yield strength commonly reported for a rolled I-beam is measured from a specimen taken from an unspecified location in the beam web. Our experience has shown that yield strength in the web is usually equal to or greater than that measured at the flange tip. This is understandable because of the work involved in reducing the web thickness and the rapid cooling experienced by the thin web section. Thus, the specimens TF-1 and BF-1 would closely represent the ASTM specified tensile properties and easily meet the minimum requirements of either A7 or A36 steel.

Note that as measured by the 'static' tensile properties of 'elongation' and 'reduction of area,' the steel would be considered to possess high ductility. It will next be shown that this high ductility does not correspond to a high fracture toughness in this beam. Standard Charpy V-notch impact tests were run on steel taken from the top and bottom flanges of the beam. At a test temperature of +40 F sets of three specimens each were tested. The top flange had an average impact energy of 17 ft-lb and the bottom flange an average of 16 ft-lb. When this bridge was constructed there were no specifications covering the impact energy of bridge steels. Recently we have adopted the AASHTO Toughness Specification which would call for a minimum acceptance level of 15 ft-lb at +40 F for a beam of this type made of A36 steel. Hence the beam tested would meet this minimum requirement. It is interesting to note the energy temperature transition that occurred in this beam as sets of three specimens each were tested at decreasing temperatures down to -20 F (Fig. 6). The bottom flange is seen to develop a low of only 2 ft-lb at 0 F which would indeed predict a brittle behavior at this temperature under a high loading rate. The top flange developed 7 ft-lb at 0 F which would indicate a slightly higher resistance to brittle behavior than the bottom flange. Such a difference in the mode of fracture was evident in the top and bottom flanges, but this may have been due to a shift in the loading geometry during fracture. The temperature of the beam at the time of the accident was reported as below 40 F and possibly belowthe freezing point. A case in point here is that the specification of a minimum toughness level at a specified temperature (e.g., 15 ft-lb at 40 F) does not preclude brittle behavior at a lower temperature if the steel undergoes a rapid energy transition below the specified acceptance test temperature. (The rate of loading also is a very important consideration here.) This problem is currently receiving considerable attention in the field of structural steel fracture toughness research. The current method of specifying toughness for structural steel may prove to be inadequate in the future, but currently it is serving the function of rejecting heats of steel that exhibit extremely low toughness. We are quite sure that some of our existing structures contain such brittle steels.

Conclusions

The fracture experienced by this beam was initiated by a severe and unusual, concentrated impact loading, applied by a traveling fork-lift column. The properties of the beam, even though they were unusual, cannot be deemed as inadequate for the intended loading. However, the observed fracture behavior of the beam as related to the measured properties has graphically demonstrated the fact that brittle fractures can occur in so-called ductile materials, and this study has been helpful in our attempt to understand such phenomena.

The steel in the beam that fractured and was dislodged from the damaged bridge was seen to meet all of the ASTM requirements for A7 steel that existed at the time the structure was built. Further, Charpy impact testing of the steel in the top and bottom flanges revealed that they both exceed the current AASHTO toughness requirement on A36 steel of 15 ft-lb at 40 F, Charpy V-notch impact energy. Lowering the impact test temperature indicated a rapid decrease in the corresponding toughness of the bottom flange and not as severe a decrease in the top flange. This transitional behavior undoubtably contributed to the different fracture modes observed in the two flanges.