EFFECTS OF HEAT STRAIGHTENING STRUCTURAL STEEL

FINAL REPORT
FOR
MLR-91-3

AUGUST 1992

Highway Division

Iowa Department of Transportation

EFFECTS OF HEAT STRAIGHTENING STRUCTURAL STEEL

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IOWA D.O.T. PROJECT MLR-91-3

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DISCLAIMER

ABSTRACT

Heat straightening of steel beams on bridges struck by over height trucks has become common practice in the recent years in Iowa. A study of the effects of this heat straightening on the steel beams thus straightened is needed.

Appropriate samples for mechanical and metallurgical tests were cut from the same rolled beam from the end which was heated and the end which was not heated and the test results were compared. The test results showed beyond doubt that the steel was being heated beyond the permitted temperature and that the impact properties are being drastically reduced by the current method of heat straightening.

INTRODUCTION

Iowa Department of Transportation has contracted heat straightening of bridge beams on seven or eight bridges in the past few years and more heat straightening is being contemplated for the future. Though maximum heating temperature is specified to be 1200° F, there has not been much effort to ensure this temperature limit is adhered to by the contractor. It was necessary to find out if there are any detrimental effects due to the heat straightening of the steel beams as practiced by the present contractor. An opportunity offered itself when a heat straightened beam was removed from a bridge. The mechanical and metallurgical properties of the rolled beam at the heat straightened end and the unaffected end were compared to make reasonable conclusions. More elaborate detailed studies may be required to make absolutely conclusive statements.

PROBLEM STATEMENT

Structural steel beams on bridges, which are heat straightened by the currently used procedure, had to be studied in order to find out if there is any deterioration of the steel properties by this process of heat straightening. This was achieved by comparing the properties of the heat straightened section with the unaffected section of the same steel beam.

OBJECTIVE

This study was intended to determine effect of heat straightening structural steel members of bridges by the currently used method. A heat straightened wide flange beam removed from the Ashworth Road bridge over I-35 in Polk County was studied. Mechanical and metallurgical properties of the heat straightened section were compared with that of the unheated section of the same beam.

PROCEDURE

A heat straightened 30 x 108 WF beam 39'6" long which was removed from Ashworth Road bridge over I-35 in Des Moines was selected for the study. Two 24" sections of this beam, one from the heat straightened end and the other from unheated end were selected for the various tests.

The following tests were conducted on samples from the two sections (heated and unheated) in accordance with applicable ASTM standards.

1. Tension test which include yield strength, ultimate tensile strength, % elongation, and % reduction in area.
2. Notch toughness test by Charpy V notch impact test at +40° F.
3. Brinell Hardness tests.
4. Grain size and micro structure.
5. Chemical analysis.

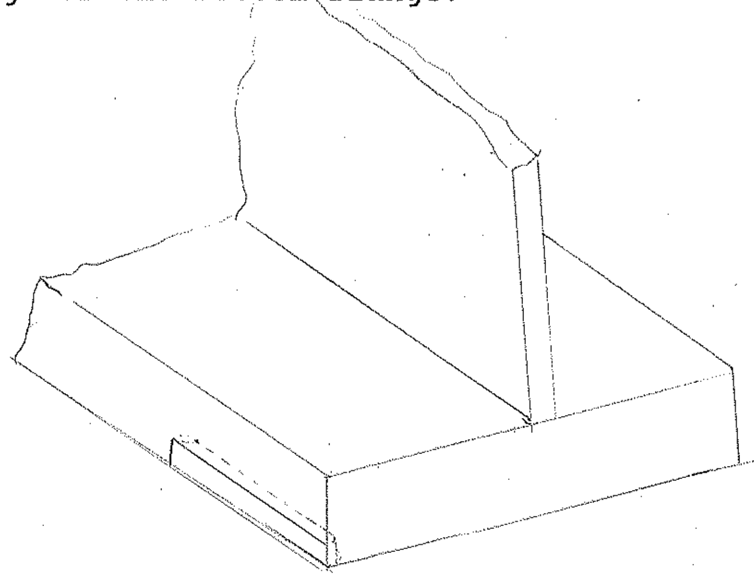
Sample Selection: In metallurgical studies sample selection is of utmost importance as even 1 or 2 inches difference in the location and orientation of the sample can have substantial effect on the test result. Since the 24" sections from the beam were cut in the field without much direction or control, there was much to be desired in the initial sample selection. As the original identity of the steel could not be traced back from available records, it was assumed to be ASTM A373 and the chemistry was checked by an independent laboratory.

The two 24" sections of the beam were carefully sectioned for different test specimens. At most, care was taken to see that samples from the heated section correspond identically to the sample from the unheated section in location, orientation and relative position on the rolled section.

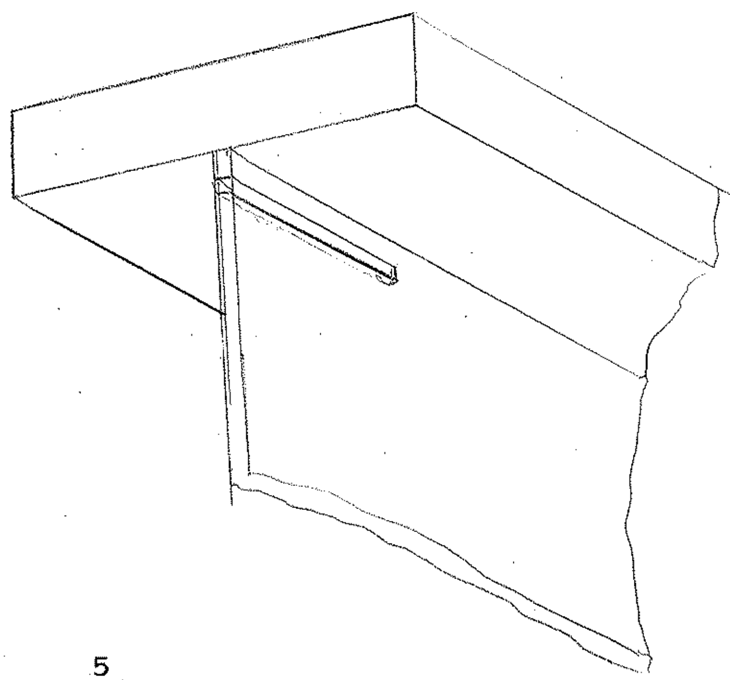
The following samples were selected from the heated and unheated sections.

Tension Samples:

1. Longitudinal edge of the bottom flange.



2. Longitudinal sample from the top section of the web just below the top flange.



Hardness and Impact Test Samples

Flange

Samples for Charpy impact test were selected from the bottom face at about 1-1/2" from the edge of the flange with the Charpy notch on the bottom face. Hardness measurements were made on the charpy samples on the notched face.

Web Charpy samples from the web were slected from the near side face just below the top flange. Hardness measurements were made on the broken charpy samples on the notch face.

Metallurgical Sample for Micro Structure and Grain Size

The bottom face of the flange was studied to compare the micro structure.

TEST RESULTS:

Summary of test results on heat straightened beams removed from Ashworth Road overpass.

	FLANGE		WEB	
	Unheated Section	Heated Section	Unheated Section	Heated Section
Yield Strength (PSI)	37,400	59,000	45,300	57,400
Tensile Strength (PSI)	64,100	69,200	63,700	72,200
Ratio of Yield and Tensile	58%	85%	71%	80%
% Elongation 2" Gauge length	36%	26%	34%	22.5%
% Reduction in Area	62%	61%	60.4%	51.8%
Charpy V Notch @ 40°F. Ft. Lb.	19,22,16	6, 7, 9	16,11,10	*, 4, 6
Brinell (500 Kg) Hardness	119,114,107	139,143,143	119,114,109	150,158,143

Chemical Analysis:		% Wt.
	Carbon	0.289
	Manganese	0.647
	Silicon	0.032
	Sulphur	0.031
	Phosphorus	0.009

Micro Structure: The micro structure comparison between the heated piece and unheated piece clearly shows evidence of recrystallization. That is the steel has been heated above the lower critical tempeature of about 1330° F. and partly austenitized and recrystillized into finer grains.

Discussion of Test Results and General Comments

Plain carbon hot rolled structural steel commonly used in bridges, is always rolled at a few degrees above the upper critical temperature of about 1650° F., and all the mechanical deformation is done in an austenitic phase. The rolled steel is cooled in still air to give a uniform ferrite-pearlite micro structure with good mechanical properties. Reheating this steel to about 700° degrees will not affect the mechanical properties adversely. In heat straightening, maximum beneficial effect is achieved below 750° F. When heated above the lower critical temperature of about 1330° F., the steel begins to go into solid solution called Austenite phase. This is the most important solid state transformation in ferrous metallurgy and if not understood and properly controlled can ruin the properties of the steel.

As evident from the micro structure and physical properties, the process of heat straightening being used now, heats the steel beyond the lower critical temperature and recrystallizes the steel. Consequently the metallurgical transformations taking place has increased the tensile strength and hardness at the same time reducing the ductility. With a finer grain size better impact properties are expected, but achieving this by heating into the inter critical temperatures region has been proved conclusively to be destructive also as evidenced by these test results.

A reasonable control of temperature could be achieved using one of the various temperature measuring techniques such as bi-metal thermocouples, radiation or optical pyrometers or temperature indicating crayons. The contractor should be required to continuously monitor the temperature using one of the techniques which is practical in the situation.

CONCLUSION:

The present method of using a gas welding torch to heat straighten damaged bridge beams, heats the steel well into the intercritical temperature range and hence ruins the impact properties of the steel. More care should be given to prevent the steel from being heated beyond 1200° F. as provided in the special provisions of the specification.