MNSEA

Minnesota Structural Engineers Association

SEMINAR AND TRADE SHOW – MAY 9, 2023

Existing/Historic Structures

A Metallurgical Perspective

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ENGEL METALLURGICAL LTD

Who *Is* This Guy…?

BS, MS, PhD Degrees - Metallurgical Engineering

- Michigan Technological University

Ten years in the steel industry

- Steel product development
- Metallurgical quality
- Application Metallurgy Lab Manager

More than 20 years materials engineering consulting

- Engel Metallurgical Ltd

ENGEL METALLURGICAL LTD.
Who *are* we…?

A Metallurgical Engineering Consulting and Testing Company

- Engel Metallurgical was founded in 1983
- Located in Sauk Rapids, MN
- Employ 3 Metallurgical/Materials Engineers, 3 Metallurgical Technicians, and two administrative staff
- Operate an ISO 17025 accredited test lab
- Provide services to manufacturing companies, insurance companies, & attorneys

Services We Provide

- Complete materials support to manufacturing clients
  - Alloy grade and condition
  - Mechanical testing
  - Material selection
  - Weld procedure & welder qualification testing
  - Failure analysis

Services Related To Existing/Historic Structures

- Metallurgical characterization of structural members
  - Material specifications based on age of structure
  - Identify steel manufacturer(s)
  - Identify steel grade(s)/properties
  - Determine equivalent steel grade(s)
  - Assess weldability

Services Related To Existing/Historic Structures

- Field testing
  - Hardness testing
  - In-situ metallography
- Laboratory testing
  - Chemical analysis
  - Tensile testing
  - Metallography/microstructures
  - Weld/Welder qualification testing

Example Projects

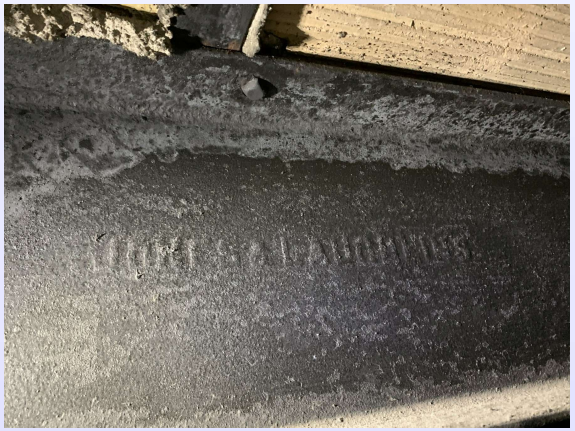
- American Swedish Institute – Carriage House
- Northrup Auditorium – University of Minnesota
- Franklin Heating Station Boiler Room – Mayo Clinic

American Swedish Institute – Carriage House

- Preliminary site visit to develop sampling plan prior to demolition
  - Exposed beams in attic space
  - Identified three steel beam producers
- Sample procurement for laboratory testing
  - Samples from structural members in areas to be modified
- Quantitative chemical analysis
- Tensile testing
- Metallography/microstructures
- Assessment of weldability

American Swedish Institute – Carriage House

Exposed Beams - Identification of Steel Producers for Various Members



American Swedish Institute – Carriage House

Sampling of Representative Steel Members

American Swedish Institute – Carriage House

TABLE III - CHEMICAL ANALYSIS RESULTS FOR TEN EXISTING BEAM SECTIONS AT ASI CARRIAGE HOUSE

	Composition, wt%									
Element	L497501 "1"	L497502 "2"	L497503 "3"	L497504 "4"	L497505 "5"	L497506 "6"	L497507 "7"	L497508 "8"	L497509 "9"	L497510 "10"
Carbon	0.05	0.09	0.08	0.08	0.08	0.08	0.07	0.09	0.07	0.09
Manganese	0.57	0.69	0.61	0.65	0.63	0.61	0.49	0.53	0.37	0.66
Phosphorus	0.049	0.068	0.0545	0.059	0.099	0.068	0.085	0.057	0.099	0.099
Sulfur	0.064	0.103	0.139	0.116	0.121	0.095	0.124	0.088	0.126	0.127
Silicon	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Nickel	0.008	0.008	0.009	0.009	0.009	0.009	0.009	0.01	0.01	0.01
Chromium	0.003	0.004	0.003	0.005	0.005	0.005	0.004	0.005	0.002	0.009
Molybdenum	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	0.02	0.02	0.02	0.02	0.03	0.02	0.002	0.03	0.003	0.01
Aluminum	0.001	0.002	0.002	0.002	0.005	0.002	0.001	0.005	0.002	0.001
Titanium	<0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	<0.001	<0.001
Vanadium	0.005	0.003	0.006	0.01	0.01	0.01	0.007	0.007	0.003	0.02
Columbium	0.004	0.002	0.004	0.005	0.004	0.006	0.003	0.002	0.001	0.002
Tungsten	<0.001	<0.001	<0.001	0.01	0.01	0.01	0.005	0.006	<0.001	0.002
Cobalt	0.005	0.005	0.005	0.006	0.006	0.007	0.006	0.007	0.006	0.006
Tin	<0.001	0.002	<0.001	0.001	0.002	0.005	<0.001	0.002	<0.001	<0.001
Iron	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance

American Swedish Institute – Carriage House

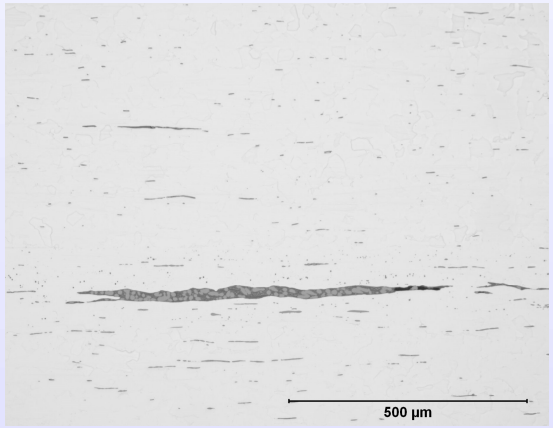
TABLE IV - TENSILE TEST RESULTS FOR BEAM SECTIONS FROM ASI CARRIAGE HOUSE

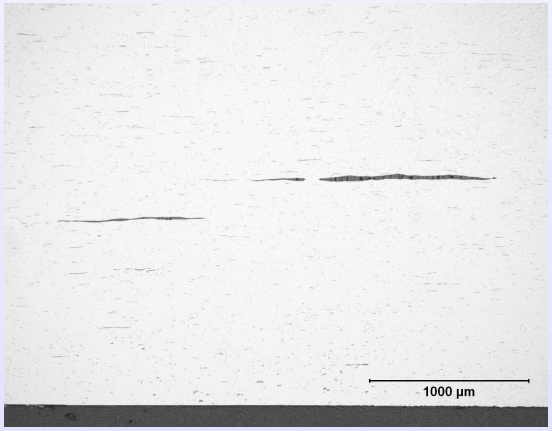
Sample No.	SID No.	Section Identity	Diameter, Inch	Width, Inch	Thickness, Inch	Tensile Strength, psi	Yield Point, psi	Elongation, %
L497511	20340	1	0.2494	--	--	56,900	34,000	34[b]
L497512	20341	2	--	0.4961	0.2487	63,800	46,500[a]	35[c]
L497513	20342	3	--	0.4962	0.3469	60,800	46,000	35[c]
L497514	20342	3	0.2506	--	--	60,900	50,700	34[b]
Required per ASTM A9 (1901)						60,000 - 70,000	0.5 x TS min.	
Required per ASTM A36/A36M-14						58,000 - 80,000	36,000 min.	21 min.

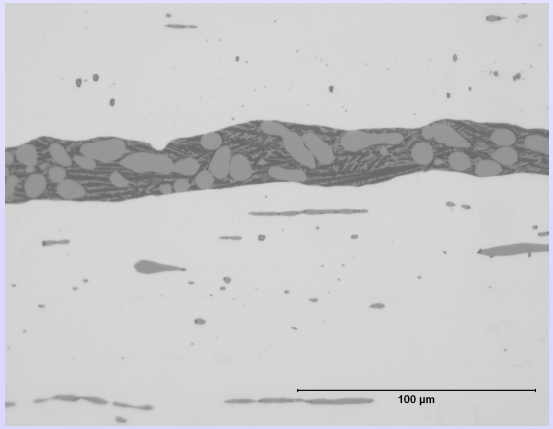
[a] 0.2% offset yield strength (yield point not observed)
[b] Elongation in 1 inch
[c] Elongation in 2 inches

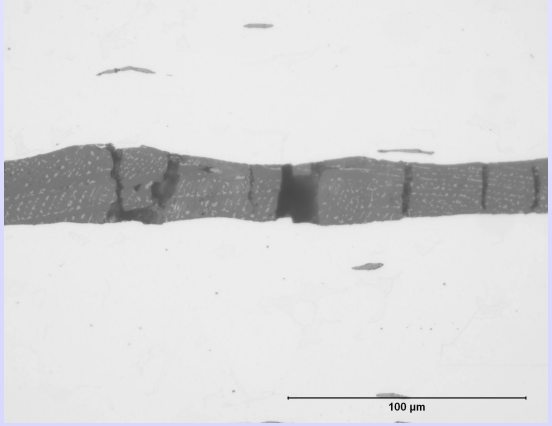
American Swedish Institute – Carriage House

Microstructure Evaluation









American Swedish Institute – Carriage House

CONCLUSIONS:

Based on the results of this evaluation, the following conclusions can be stated:

1. The historic steel beams used in the ASI Carriage House are a low carbon steel with elevated sulfur and phosphorus contents. The steel compositions are consistent with a former standard steel grade SAE 1111 (AISI B1111).

2. Beam sections "2" and "3" meet the mechanical property requirements specified in both ASTM A9(1901) and ASTM A36/A36M-14. Beam section "1" does not meet the mechanical property requirements specified in ASTM A36/A36M-14, and does not meet the tensile strength requirement specified in ASTM A9(1901).

3. Although the carbon equivalents of the beams at the ASI Carriage House are low, suggesting good weldability, the high sulfur and phosphorus contents and presence of large non-metallic inclusion stringers indicates that the weldability will be poor. Although welding may be possible, welding should not be done without development of qualified weld procedures. Any structural welds produced will require thorough non-destructive inspection.

4. The risks associated with bolting new structural members to existing beams is significantly lower than the risk associated with welding this material. Therefore, it is recommended to use bolted connections during the renovation unless welding is the only option.

5. If welding must be done, careful consideration must be given to the connection designs and weld configurations to minimize potential issues related to welding this material.

Northrup Auditorium – University of Minnesota

- On-site hardness testing of several structural shapes and rivets
- Estimation of tensile and yield strengths based on hardness testing and literature data
- Limited tensile testing performed
- Limited quantitative chemical analysis performed
- No assessment of weldability

Franklin Heating Station Boiler Room

Mayo Clinic

- Review of laboratory test results
  - Chemical analysis
  - Tensile testing
- Comparison with current steel grades
- Recommendations on weldability

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