STATE OF FLORIDA
DEPARTMENT OF TRANSPORTATION

STATE MATERIALS OFFICE
STRUCTURAL MATERIALS LABORATORY
5007 NE 39th Avenue
Gainesville, Florida 32609
(352) 955-6600

PRELIMINARY REPORT OF THE REPLACEMENT BOLTS FOR USE IN THE HART BRIDGE

Author:	*Christopher C. Ferraro*
Approved:	*Michael Bergin*
Report Number	*FL/DOT/SMO/09-525*
Date:	*July 8, 2009*

EVALUATION PROGRAM

The intent of this laboratory testing regimen was to evaluate the hardness and tensile strength of the replacement bolts used in Hart Bridge #720107 in Duval County Florida. Six representative original samples (bolts and nuts) were obtained from the bridge structure. Four representative replacement bolts and nuts were also furnished for testing. The steel samples were provided to the State Materials Office for testing. The samples received by the State Materials office were inventoried, photo documented, and had impurities removed prior to hardness testing. Subsequent to hardness testing, the specimens were machined into coupons for tensile testing.

RESULTS

Tensile Testing

Subsequent to hardness testing, the bolts were machined into coupon specimens 3/8” in diameter and 2” in gage length, and the ends were threaded to allow for tensile testing. Figure 1 is a photograph of a typical coupon sample after machining. Subsequent to machining, the specimens were tested in tension in accordance with ASTM E8-08 with the following exception:

- 7.7.1 Cross-head movement rather was used to measure strain as a 2” extensometer was not available.

Figure 1 Photo of typical bolt prior to and subsequent to coupon fabrication

Despite the fact that the strain was not obtained as per the standardized test method, the results obtained for the tensile testing are repeatable, consistent, and sufficient for analysis. Figure 2, is a typical stress-strain diagram for the tensile testing.

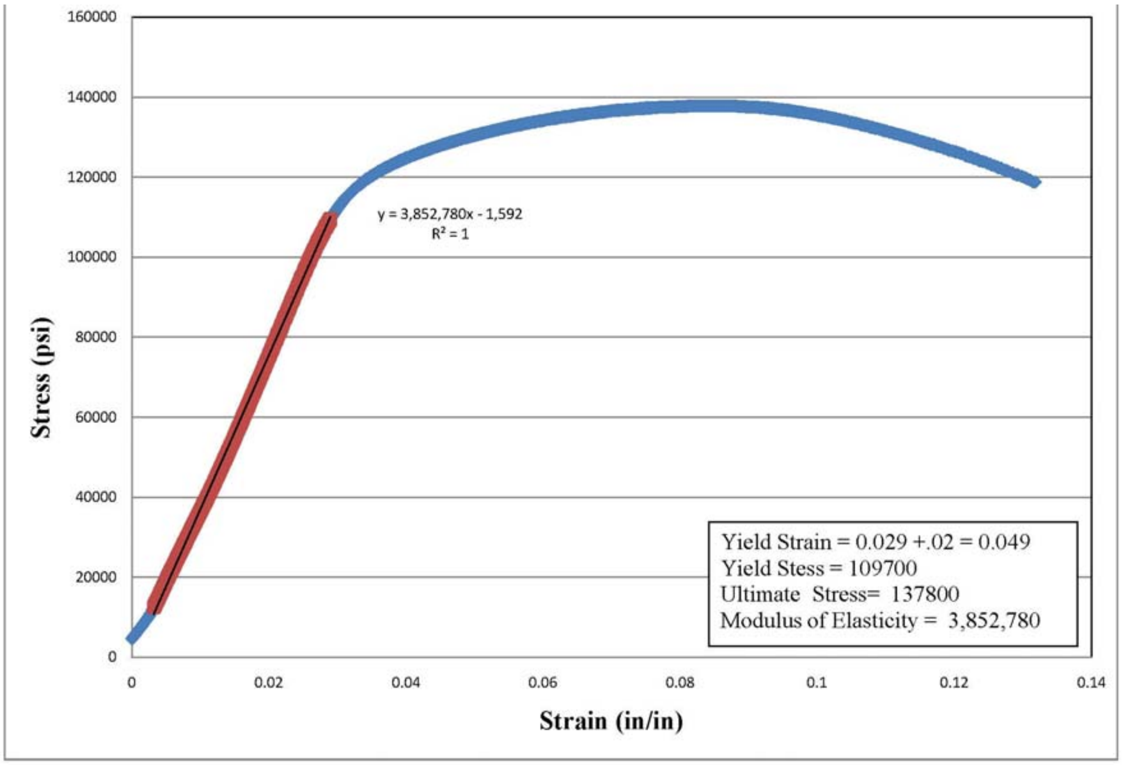


Figure 2 Typical Stress – Strain Diagram for Tensile Coupon / Bolt

As per figure 1, portion denoted with the best fit line was found to be the straight line or chord modulus as per ASTM E 8-08. The yield stress was obtained using the offset method as per 7.7.1, and the ultimate stress was determine to be the maximum stress as determined by loading. Table 1, provides a summary of results for the tensile testing of the bolts. The raw data for each bolt is presented in Appendix A.

As presented in Table 1. The average modulus of elasticity for the old bolts is higher than the average modulus for the new bolts. Conversely, the data indicates that the ultimate stress and yield stress for the new bolts is higher than the old bolts. However, a statistical T tests as presented in Appendix B indicates that the means for modulus of elasticity, ultimate stress and yield stress are not significantly different.

Table 1. Average Values for Physical Properties of Bolts as Per Tensile Testing

	Yield Strain (in/in)	Yield Stress (psi)	Ultimate Stress (psi)	Modulus of Elasticity (psi)
Old Bolt 1	0.0348	93800	118400	3493611
Old Bolt 2	0.0428	96500	115900	4523332
Old Bolt 3	0.049	109700	137800	3852780
Old Bolt 4	0.0508	125900	151500	4069243
	Average	**106475**	**130900**	**3984742**
	Yield Strain (in/in)	Yield Stress (psi)	Ultimate Stress (psi)	Modulus of Elasticity (psi)
New Bolt 1	0.0405	131100	139300	3917981
New Bolt 2	0.0578	132400	137600	3331354
New Bolt 3	0.0449	100000	129600	4073572
New Bolt 4	0.0491	102200	129900	3704711
	Average	**116425**	**134100**	**3756905**

Hardness Testing

Each of the specimens were tested for hardness according to The hardness testing program consisted of twenty individual Rockwell “150-C” hardness tests which were conducted on the rebar sample per the test procedure illustrated in ASTM E 18-05 (1). Table 2 provides a summary of average hardness values for each of the bolts. The specimens denoted as “old bolt” were taken from the bridge itself, and the specimens denoted as “new bolt” are the replacement bolts. The raw data obtained for the bolts can be found in Appendix A.

Table 2. Hardness Testing Results for Bolt Specimens

Sample ID	Mean (Rockwell Hardness, C-150)	Standard Deviation	Correction Factor	Mean + Correction Factor
Old Bolt #1	18.6	2.92	2.0	20.6
Old Bolt #2	12.0	5.72	2.0	14.0
Old Bolt #3	21.6	7.54	2.0	23.6
Old Bolt #4	24.5	2.96	2.0	26.5
Old Bolt #5	15.3	9.44	2.0	17.3
Old Bolt #6	13.9	5.46	2.0	15.9
Average	**17.65**	**5.67**	**2**	**19.7**
New Bolt #1	25.7	2.82	2.0	27.7
New Bolt #2	27.6	2.89	2.0	29.6
New Bolt #3	29.4	2.01	2.0	31.4
New Bolt #4	28.4	3.27	2.0	30.4
Average	**27.78**	**2.75**	**2**	**29.78**

The average hardness values for the new bolts are significantly larger than the old bolts per the statistical analysis provided in Appendix B. The most plausible reason for the difference in the hardness values is that old bolts have experienced a reduction in hardness near the surface due to prolonged exposure to the environment.

The standard specification for structural steel bolts, heat treated, 120/105 ksi minimum tensile strength (ASTM A 325-09) provides the physical requirements for structural bolts. Table 3 of ASTM A325-09 provides the hardness requirements, which states the Hardness value per Rockwell C-150 must be within the range of 25-34.The old bolts have hardness values below this range, and the new (non-exposed) bolts fall within this range.

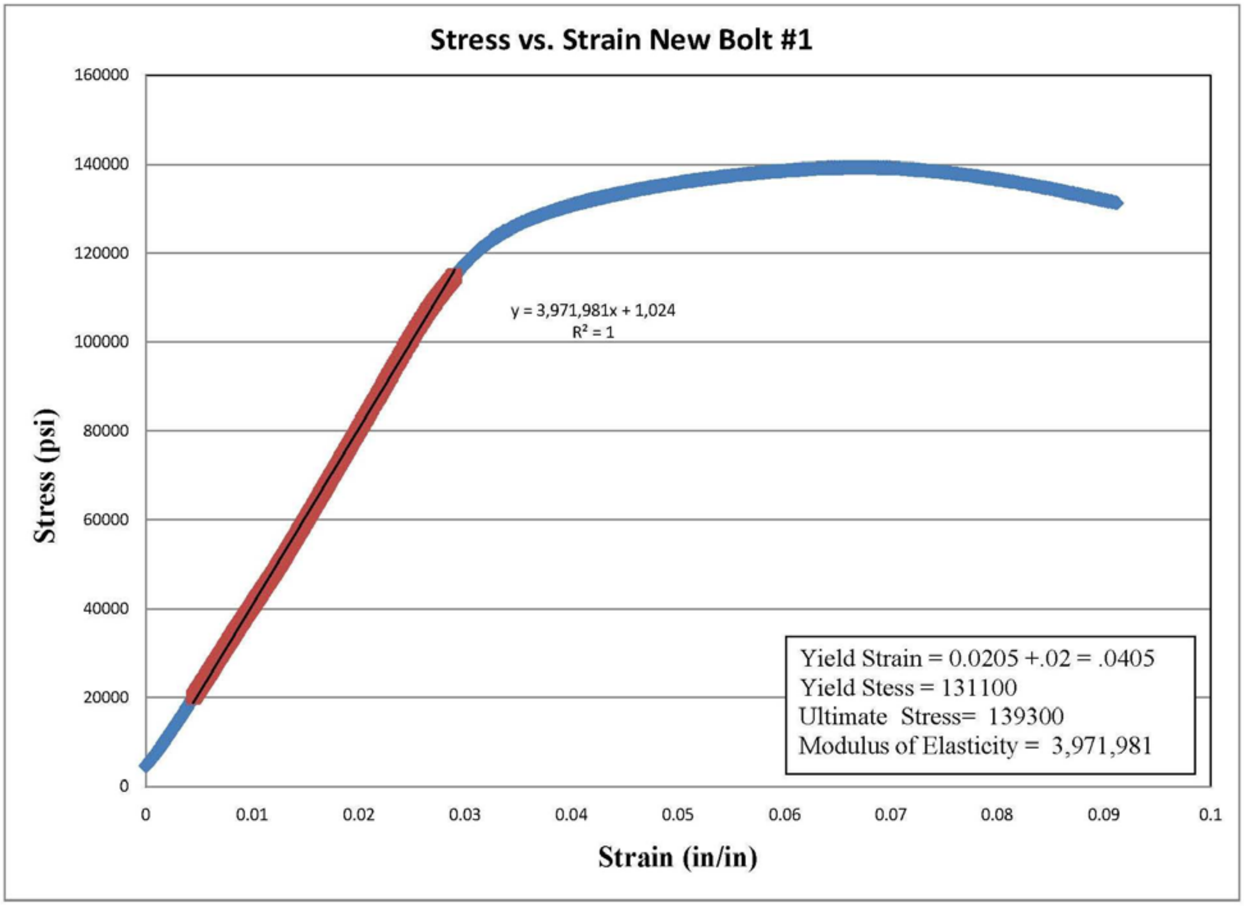
CONCLUSIONS

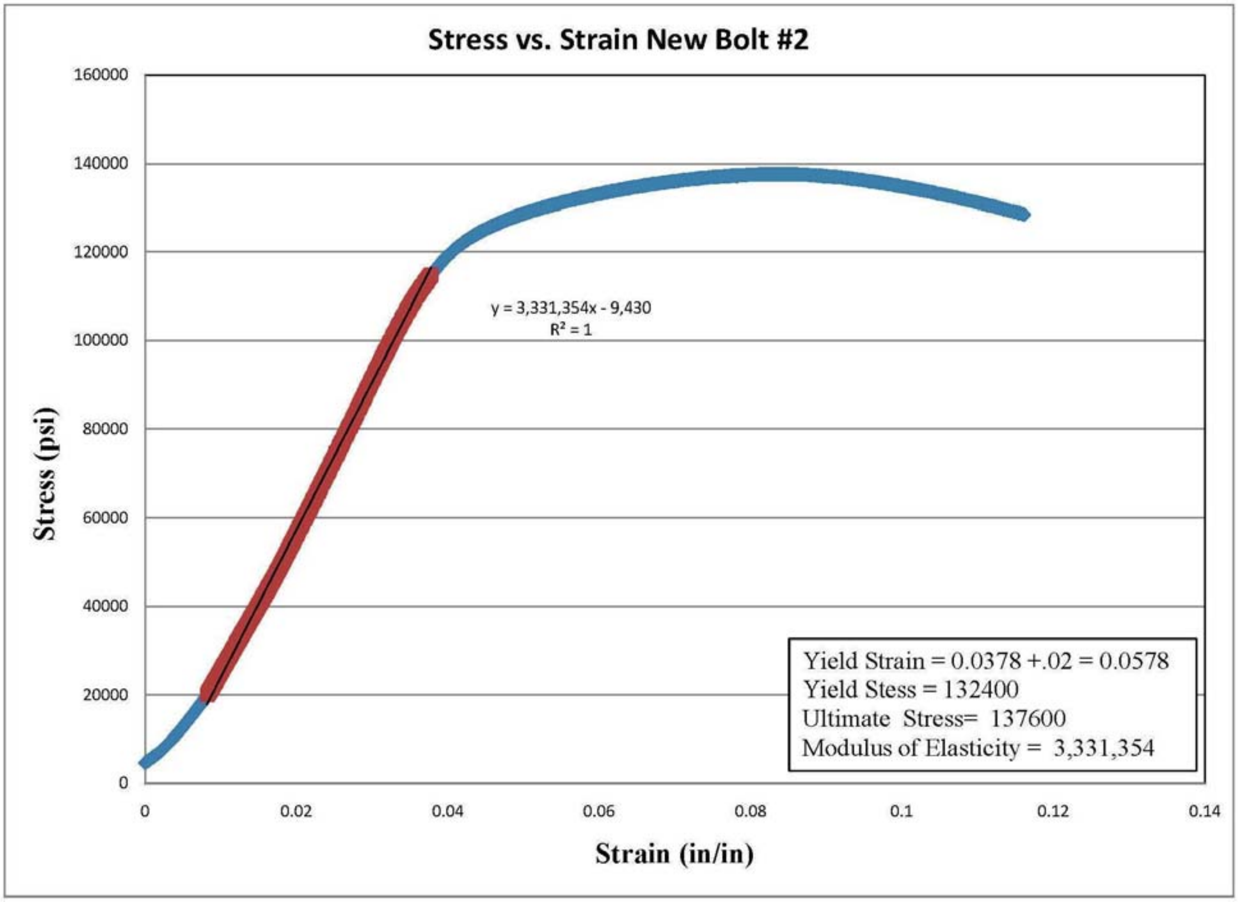
- The original bolts provided to the FDOT State Materials Office removed from the Hart Bridge are as ASTM A325 per the standard specification.
- The replacement bolts provided to the FDOT State Materials Office used for the Hart Bridge are as ASTM A325 per the standard specification.

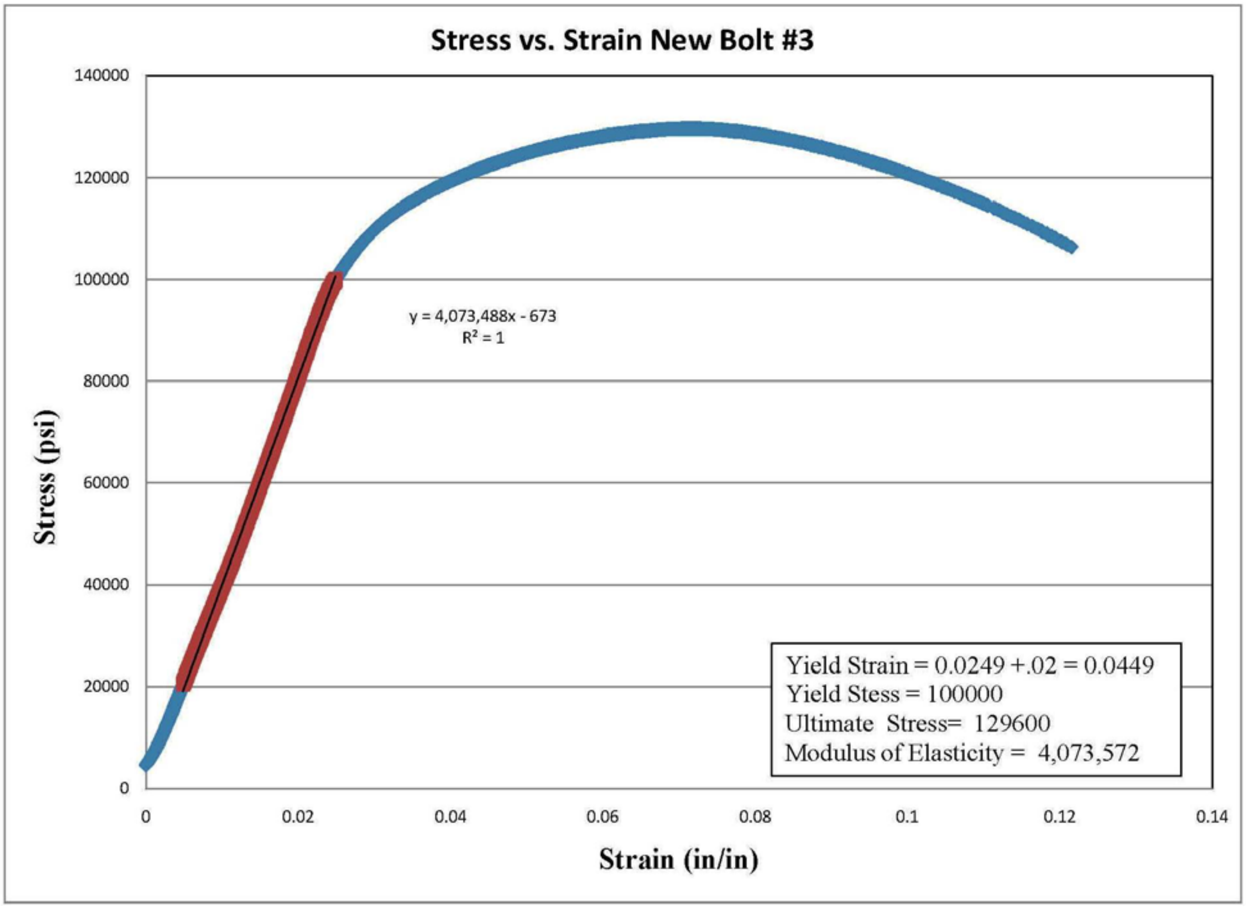
REFERENCES

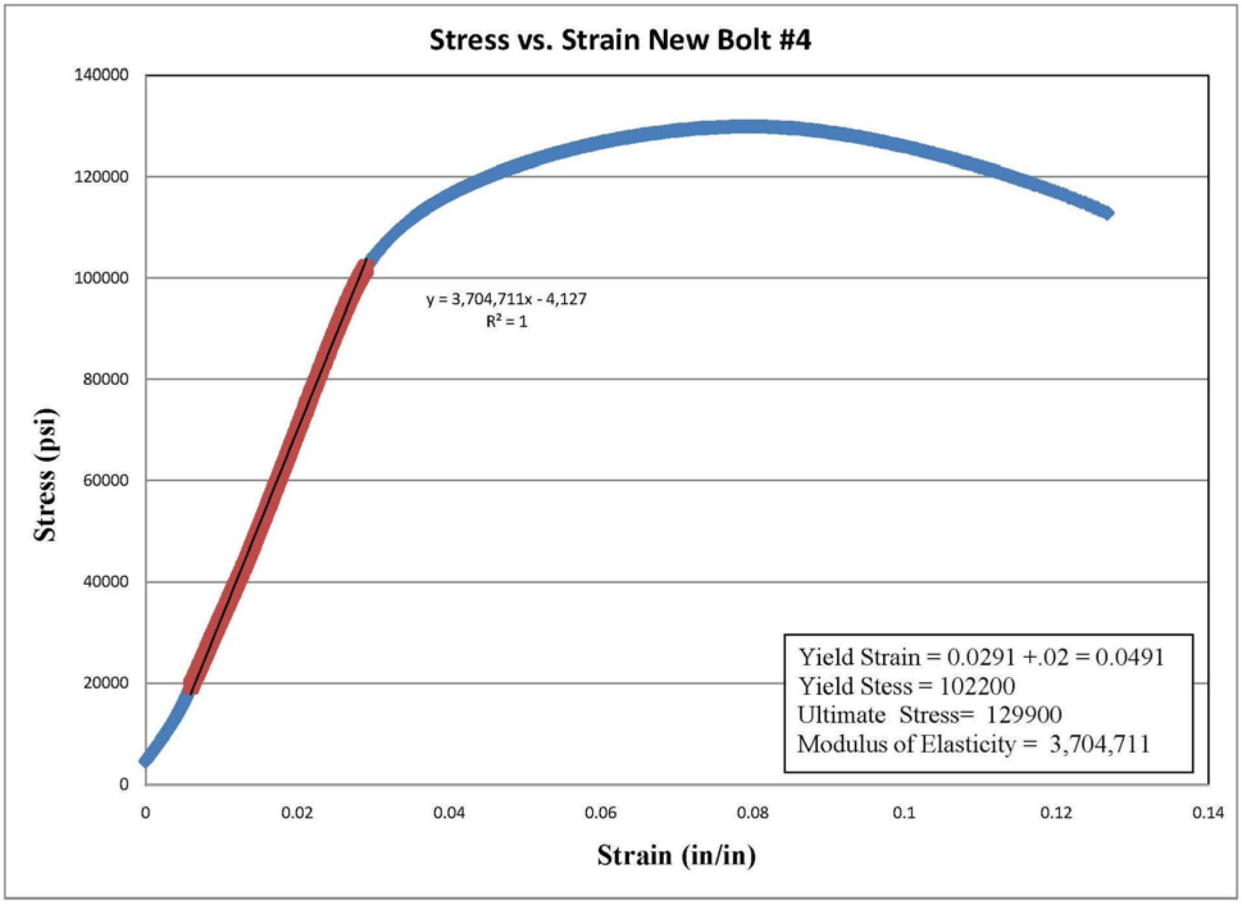
1. ASTM (2006) *Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials* (ASTM E 18-05) West Conshohocken, Pennsylvania: American Society for Testing and Materials
2. ASTM (2008) *Standard Test Methods for the Tension Testing of Metallic Materials* (ASTM E 8-08) West Conshohocken, Pennsylvania: American Society for Testing and Materials
3. ASTM (2006) *Standard Test Methods for and Definitions for Mechanical Testing of Steel Products* (ASTM A 370-05) West Conshohocken, Pennsylvania: American Society for Testing and Materials
4. ASTM (2009) *Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength* (ASTM A 325-09) West Conshohocken, Pennsylvania: American Society for Testing and Materials

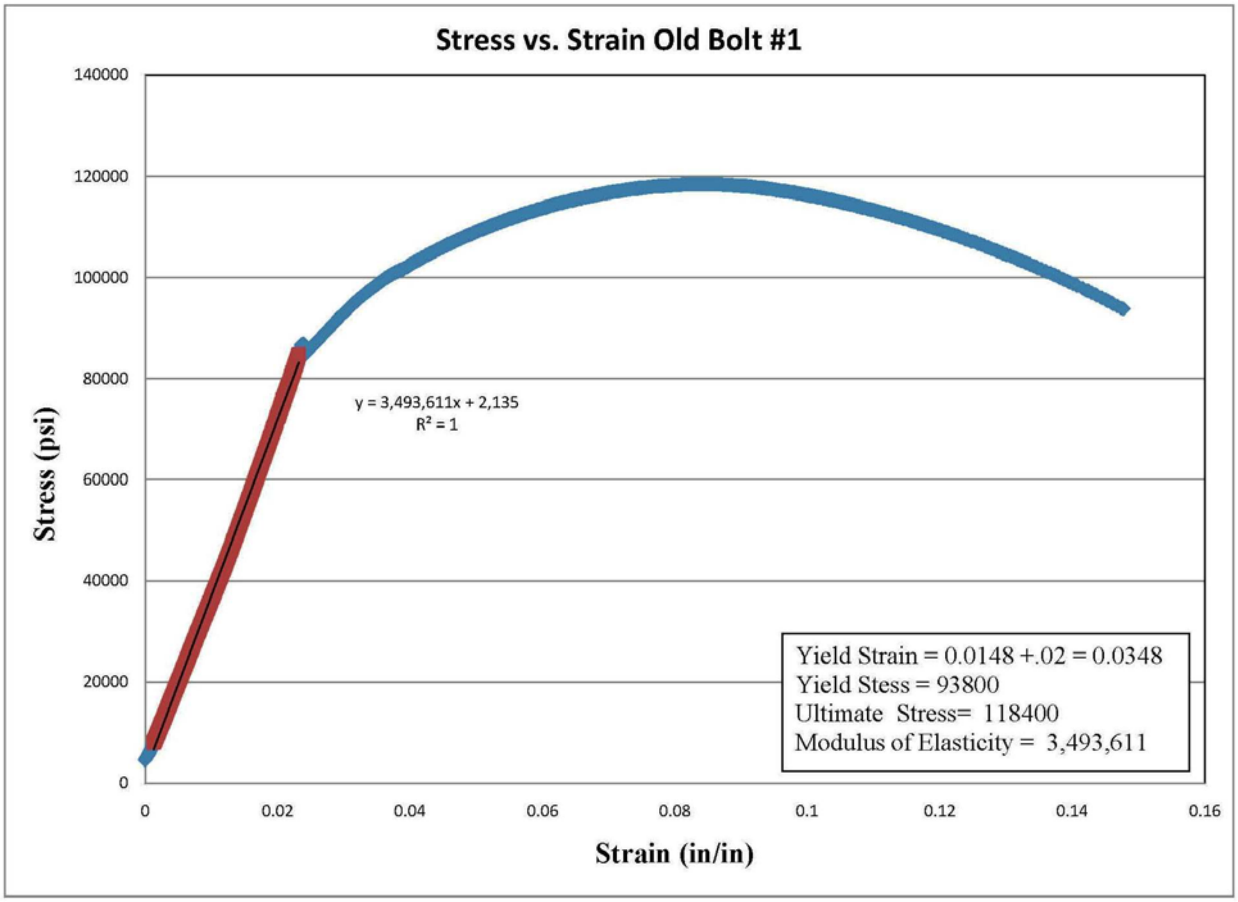
APPENDIX A – RAW DATA

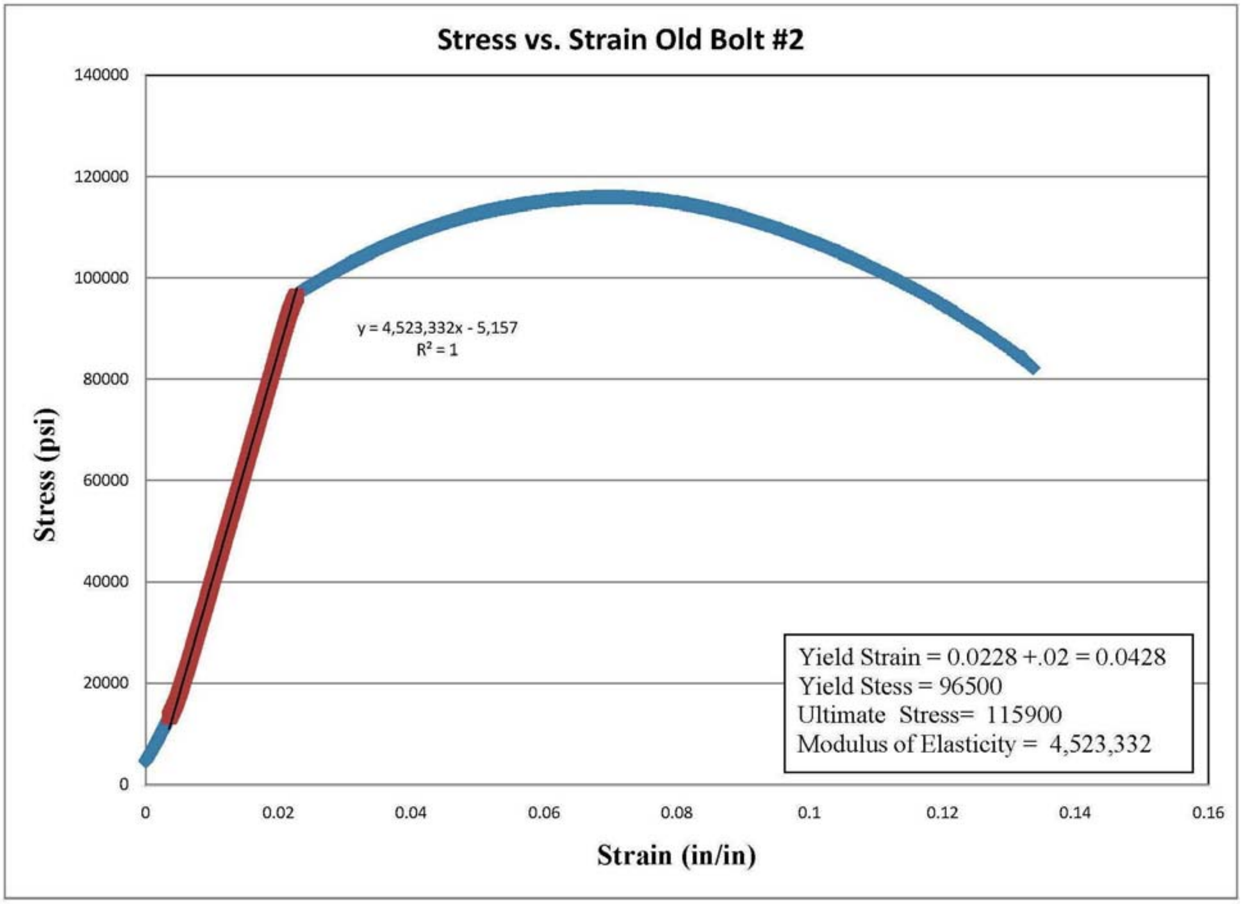


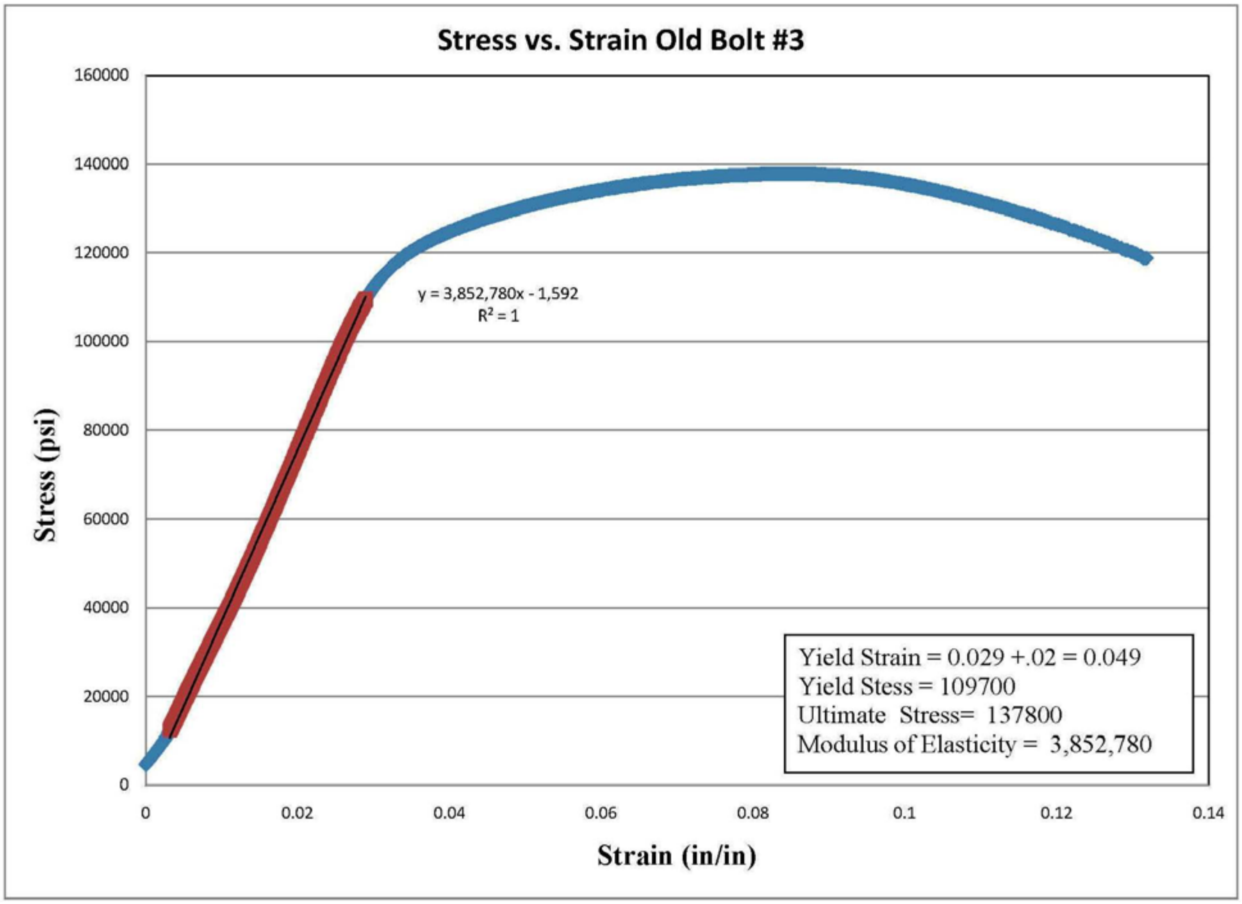

Stress vs. Strain New Bolt #2
Stress (psi)
160000
140000
120000
100000
80000
60000
40000
20000
0
Strain (in/in)
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
y = 3,331,354x - 9,430
R² = 1
Yield Strain = 0.0378 +.02 = 0.0578
Yield Stess = 132400
Ultimate Stress= 137600
Modulus of Elasticity = 3,331,354

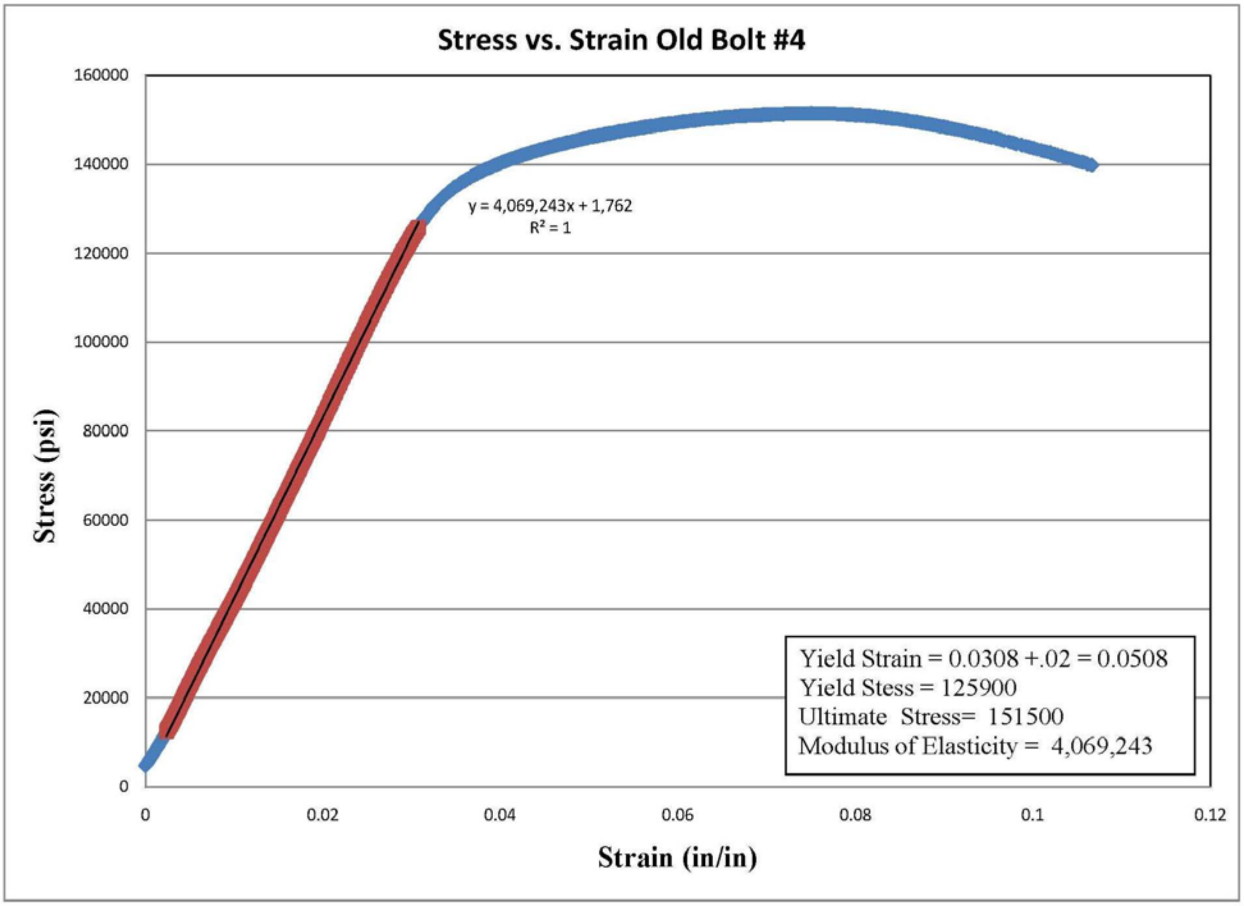

Stress vs. Strain New Bolt #3
140000
120000
100000
80000
60000
40000
20000
0
Stress (psi)
y = 4,073,488x - 673
R² = 1
Yield Strain = 0.0249 +.02 = 0.0449
Yield Stess = 100000
Ultimate Stress= 129600
Modulus of Elasticity = 4,073,572
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
Strain (in/in)


Stress vs. Strain New Bolt #4
Stress (psi)
Strain (in/in)
140000
120000
100000
80000
60000
40000
20000
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
y = 3,704,711x - 4,127
R² = 1
Yield Strain = 0.0291 +.02 = 0.0491
Yield Stess = 102200
Ultimate Stress= 129900
Modulus of Elasticity = 3,704,711


Stress vs. Strain Old Bolt #1
140000
120000
100000
80000
60000
40000
20000
0
Stress (psi)
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Strain (in/in)
y = 3,493,611x + 2,135
R² = 1
Yield Strain = 0.0148 +.02 = 0.0348
Yield Stess = 93800
Ultimate Stress= 118400
Modulus of Elasticity = 3,493,611


Stress vs. Strain Old Bolt #2
Stress (psi)
Strain (in/in)
140000
120000
100000
80000
60000
40000
20000
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
y = 4,523,332x - 5,157
R² = 1
Yield Strain = 0.0228 +.02 = 0.0428
Yield Stess = 96500
Ultimate Stress= 115900
Modulus of Elasticity = 4,523,332


Stress vs. Strain Old Bolt #3
Stress (psi)
Strain (in/in)
160000
140000
120000
100000
80000
60000
40000
20000
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
y = 3,852,780x - 1,592
R² = 1
Yield Strain = 0.029 +.02 = 0.049
Yield Stess = 109700
Ultimate Stress= 137800
Modulus of Elasticity = 3,852,780


Stress vs. Strain Old Bolt #4
Stress (psi)
160000
140000
120000
100000
80000
60000
40000
20000
0
y = 4,069,243x + 1,762
$R^2 = 1$
Yield Strain = 0.0308 +.02 = 0.0508
Yield Stess = 125900
Ultimate Stress= 151500
Modulus of Elasticity = 4,069,243
0
0.02
0.04
0.06
0.08
0.1
0.12
Strain (in/in)

Structural Materials Evaluation and Research Laboratory Raw Data Worksheet	**Rockwell Hardness of Metallic Materials (ASTM E 18-05)**	**Date: 7/01/2009**	
		By: C. Ferraro	**Page 1 of 1**

Project Name: Hart Bridge Bolt Testing

Tested By: C.Ferraro

Sample Type: Bolt

Test Type: B - 100 | C - 150

Old Bolt #1		*Old Bolt #2*		*Old Bolt #3*		*Old Bolt #4*	
Test #	*Hardness #*	Test #	*Hardness #*	Test #	*Hardness #*	Test #	*Hardness #*
1	17.3	1	13.4	1	29.5	1	22.1
2	14.9	2	8.5	2	18.3	2	23.6
3	21.4	3	1.5	3	19.4	3	19.1
4	19.0	4	9.9	4	13.7	4	21.7
5	16.0	5	3.8	5	24.8	5	25.5
6	17.2	6	20.1	6	13.0	6	20.2
7	15.1	7	14.1	7	29.5	7	27.7
8	21.5	8	15.6	8	19.0	8	23.2
9	16.1	9	19.4	9	18.2	9	22.6
10	20.6	10	13.9	10	13.7	10	25.0
11	15.5	11	12.5	11	14.5	11	26.9
12	19.1	12	8.7	12	19.6	12	24.0
13	19.9	13	17.3	13	19.0	13	23.6
14	20.2	14	8.9	14	31.3	14	24.3
15	22.4	15	9.9	15	25.4	15	24.0
16	22.8	16	23.0	16	19.4	16	24.1
17	15.4	17	8.4	17	12.3	17	24.5
18	17.1	18	7.4	18	41.9	18	30.4
19	16.1	19	7.2	19	28.4	19	30.2
20	23.8	20	16.7	20	21.7	20	27.7

Pre Calibration Reading	22.1
Post Calibration Reading	21.8
Test Block Reading	22.69± 1.0

Structural Materials Evaluation and Research Laboratory Raw Data Worksheet	**Rockwell Hardness of Metallic Materials (ASTM E 18-05)**	**Date: 7/01/2009**	
		By: C. Ferraro	**Page 1 of 1**

Project Name: Hartt Bridge Bolt Testing

Tested By: C. Ferraro

Sample Type: Bolt

Test Type: B - 100 | C - 150

Old Bolt #1		*Old Bolt #2*		*Old Bolt #3*		*Old Bolt #4*	
Test #	*Hardness #*	Test #	*Hardness #*	Test #	*Hardness #*	Test #	*Hardness #*
1	20.2	1	28.4	1	30.2	1	30.1
2	28.9	2	26.7	2	33.7	2	30.0
3	30.2	3	23.0	3	31.1	3	22.8
4	24.9	4	28.4	4	32.9	4	22.8
5	28.9	5	31.2	5	30.5	5	30.4
6	21.8	6	28.9	6	32.0	6	31.7
7	27.2	7	22.7	7	29.5	7	25.5
8	28.7	8	24.9	8	27.8	8	31.3
9	25.4	9	22.7	9	29.5	9	31.0
10	21.1	10	30.2	10	26.0	10	30.3
11	20.7	11	28.5	11	28.1	11	28.9
12	27.7	12	30.8	12	26.9	12	23.7
13	27.1	13	29.5	13	28.3	13	27.5
14	23.1	14	27.5	14	28.1	14	31.3
15	23.0	15	29.1	15	28.5	15	28.3
16	25.8	16	28.5	16	29.1	16	
17	28.0	17		17	30.3	17	
18	27.5	18		18	27.4	18	
19	26.5	19		19	29.5	19	
20	26.9	20		20	28.8	20	

Pre Calibration Reading	22.1
Post Calibration Reading	21.8
Test Block Reading	22.69± 1.0

APPENDIX B – STATISTICAL ANALYSIS

Table B1 - Hardness Analysis

	Old Bolts	*New Bolts*
Mean	19.65	29.775
Variance	22.987	2.455833
Observations	6	4
Hypothesized Mean Difference	0	
df	6	
t Stat	-4.80234	
P(T<=t) one-tail	0.001497	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.002994	
t Critical two-tail	2.446912	

Table B2 – Yield Stress Analysis

	Old Bolt Yield Stress	*Old Bolt Yield Stress*
Mean	106475	116425
Variance	215962500	314229166.7
Observations	4	4
Pearson Correlation	-0.863263226	
Hypothesized Mean Difference	0	
df	3	
t Stat	-0.635696237	
P(T<=t) one-tail	0.285075459	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	0.570150918	
t Critical two-tail	3.182446305	

Table B3 – Ultimate Stress Analysis

	Ultimate Stress Old	*Ultimate Stress New*
Mean	130900	134100
Variance	284406666.7	25726666.67
Observations	4	4
Pearson Correlation	-0.916039723	
Hypothesized Mean Difference	0	
df	3	
t Stat	-0.296205312	
P(T<=t) one-tail	0.393197295	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	0.786394589	
t Critical two-tail	3.182446305	

Table B4 – Modulus of Elasticity Analysis

	Old Bolt E	*New Bolt E*
Mean	3984741.5	3756904.5
Variance	1.85281E+11	1.03347E+11
Observations	4	4
Pearson Correlation	-0.853958719	
Hypothesized Mean Difference	0	
df	3	
t Stat	0.628910763	
P(T<=t) one-tail	0.287017387	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	0.574034775	
t Critical two-tail	3.182446305	