Appendix A

Material Properties

A.1 Reinforcing Steel

Table A1 provides a summary of all reinforcing bar grades and sizes tested as part of this study. Batch numbers are underlined and the specimens in which the steel was utilized is also indicated. Subsequent sections provide tabulated summaries of tension test data from each grade of bar tested. Accompanying figures provide the axial stress-strain curves obtained from all bars tested. In all cases, stress is calculated as the applied load divided by the nominal bar area and strain is obtained from a 2 in. externally mounted clip gage. In each table, yield stress (f_y) determined using the 0.2% offset method and at strains of 0.0035, 0.005, 0.007 and 0.01 are indicated. Experimentally determined modulus values (E_{calc}) given are based on the secant modulus calculated at approximately $0.5f_y$. All tensions tests were conducted in compliance with ASTM E8 and were conducted on full bar sections (not machined coupons).

Table A1 Reinforcing steel tested in this study and its use in specimens.

ASTM Designation	Bar Size	Batch number and test specimen use				
A1035	#3	1: SR1 to SR5; P1035-3A	1B: P1035-3B	2: Type 1-4	3: Type 1-1 to 1-3[1]	
A1035	#4	1: all H; P1035-4A	1B: P1035-4B			
A1035	#5	1: F1; F3; D5-1; D5-2; all H; all fatigue	2: F4; F6; D5-3; D5-4			
A1035	#6	1: F2	2: F5			
A1035	#8	1: D8-1; D8-2; SR1 to SR4; all H	2: D8-3; D8-4; SR5			
A615	#3	1: D5-1; D5-2, D8-1, D8-2	2: D5-3; D5-4; D8-3; D8-4	3: all P615	4: all H; all fatigue	
A615	#4	1: F1 to F3; SR1 to SR4	2: F4-F6	3: Type 1-1 to Type 1-3	4: Type 1-4	5: all P615
A706	#4	1: tension tests only	2: tension tests only			
A706	#6	1: tension tests only	2: tension tests only			
A706	#8	1: tension tests only	2: tension tests only			
A496	D4	1: tension tests only				
A496	D8	1: tension tests only				
A496	D12	1: tension tests only				
A496	D20	1: tension tests only				
A496	D31	1: tension tests only				
A82	W4	1: tension tests only				
A82	W8	1: tension tests only				
A82	W12	1: tension tests only				
A955 (316)	#4	1: tension tests only				
A955 (316)	#6	1: tension tests only	2: tension tests only			
A955 (316)	#8	1: tension tests only				
A955 (2205)	#4	1: tension tests only	2: tension tests only			
A955 (2205)	#6	1: tension tests only	2: tension tests only			
A955 (2205)	#8	1: tension tests only				
A955 (N32)	#4	1: tension tests only				
A955 (N32)	#6	1: tension tests only				
A955 (N32)	#8	1: tension tests only				

[1] there is no test data available for A1035 #3 batch 3 bars; no additional samples accompanied the bar order.

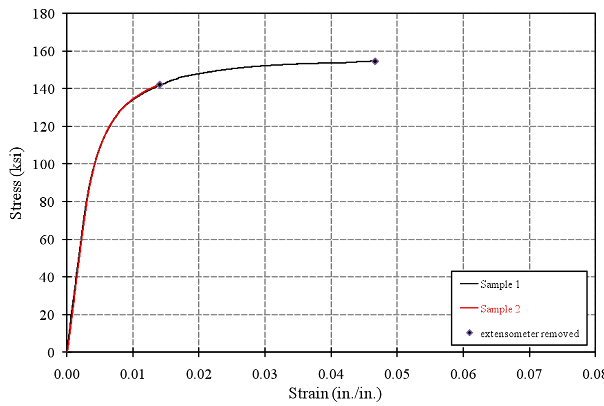
A.2 ASTM A1035 Material Properties

In addition to tensile properties shown in Table A2, the Ramberg-Osgood (R-O) parameters, *A*, *B* and *C* established from a best fit of the test data are provided. These parameters are established based on E = 29000 ksi. The R-O equation used in subsequent analyses using these bars is (Ramberg and Osgood 1943):

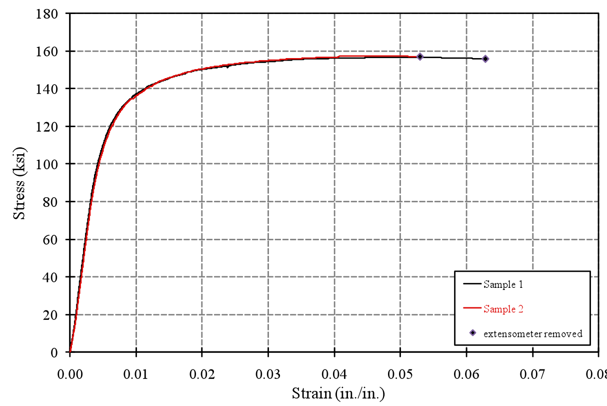
$$f = 29000\varepsilon\left\{A + \frac{1-A}{\left[1+\left(B\varepsilon\right)^{C}\right]^{1/C}}\right\} \leq f_{pu} \qquad \text{(ksi)} \qquad \text{(A-1)}$$

Table A2 Summary of A1035 tension properties.

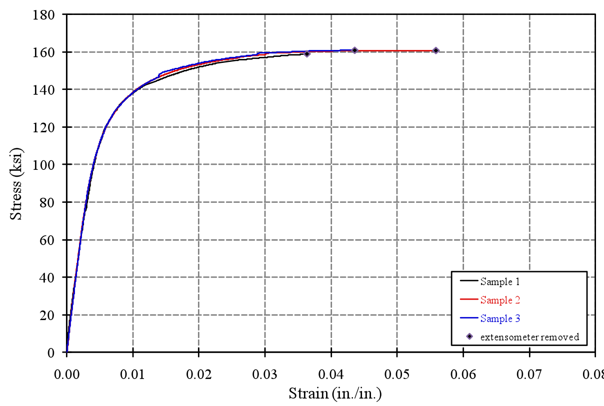
bar size		#8	#8	#6	#6	#5	#5	#4	#4	#3	#3	#3
batch		1	2	1	2	1	2	1	1B	1	1B	2
lab		PITT	PITT	PITT	PITT	PITT	PITT	UC	PITT	UC	PITT	UC
# of samples		2	2	3	2	3	3	3	3	3	3	3
f_y	ksi	154.6	157.1	161.3	165.3	164.1	164.9	174.0	172.3	156.0	157.6	164.1
$\varepsilon_{rutpure}$		0.115	0.167	0.103	0.145	0.103	0.137	0.075	0.071	0.111	0.111	0.070
E_{calc}	ksi	27378	25149	29001	27711	26074	27280	27850	32781	29800	28740	27740
f_y based on…												
ε = 0.0035	ksi	89.6	88.8	91.1	94.1	89.2	92.9	94.0	111.0	95.0	93.5	93.0
ε = 0.0050	ksi	108.8	110.1	111.7	117.9	112.5	115.0	117.0	130.3	112.0	113.5	117.2
ε = 0.0070	ksi	125.6	126.0	129.7	134.8	132.1	132.9	137.0	144.7	133.0	128.8	133.5
ε = 0.0100	ksi	134.4	137.1	138.6	148.6	143.2	147.2	156.0	155.9	144.0	138.0	146.6
0.2% offset	ksi	118.6	125.9	121.8	134.4	130.2	129.2	140.0	131.3	130.0	126.0	131.9
Ramberg-Osgood parameters…												
A		0.0554	0.0145	0.0203	0.0130	0.0145	0.0145		0.0040		0.0150	
B		2254	200	198	184	186	186		172		197	
C		2.94	2.4	2.4	2.5	2.3	2.5		2.8		2.6	



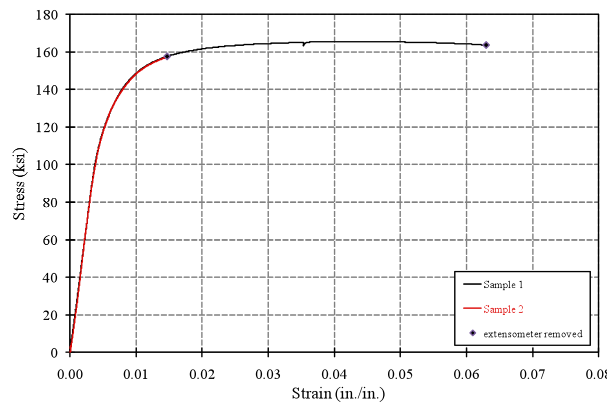
a) A1035 #8 batch 1



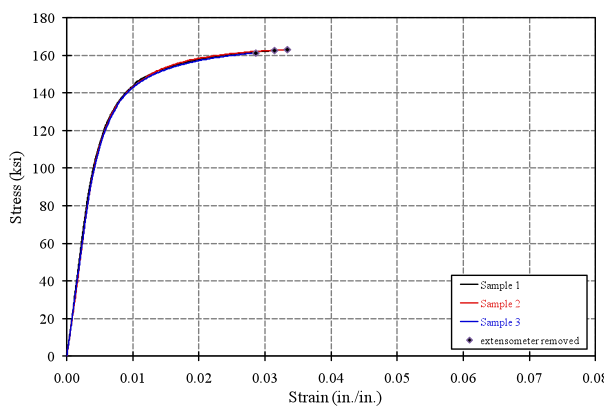
b) A1035 #8 batch 2



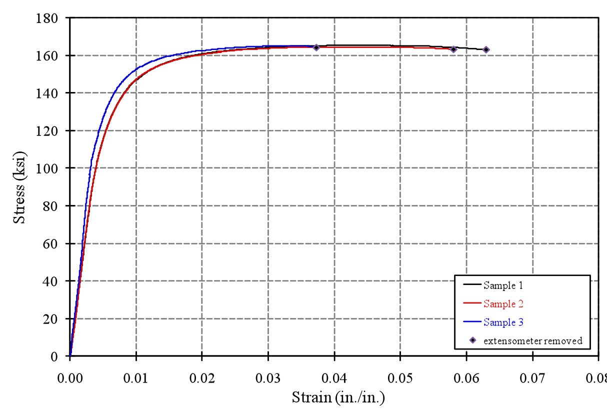
c) A1035 #6 batch 1



d) A1035 #6 batch 2

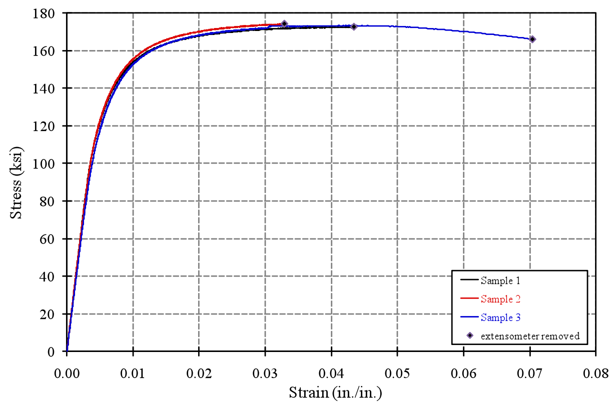


e) A1035 #5 batch 1

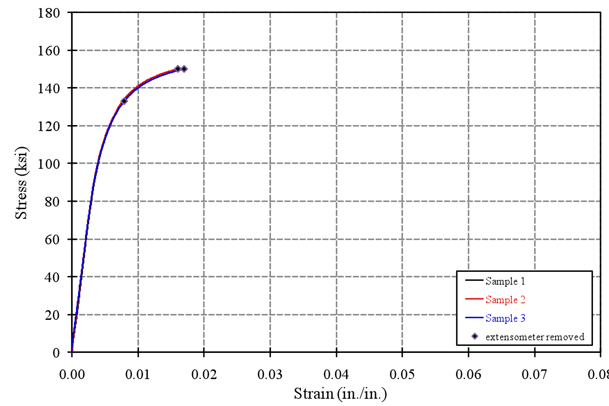


f) A1035 #5 batch 2

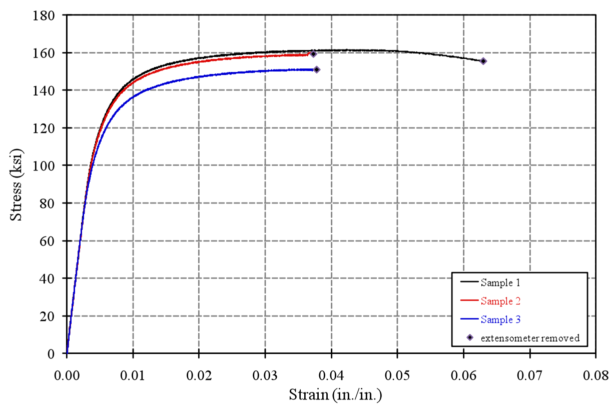
Figure A1 Axial stress-strain curves for A1035 reinforcing steel.



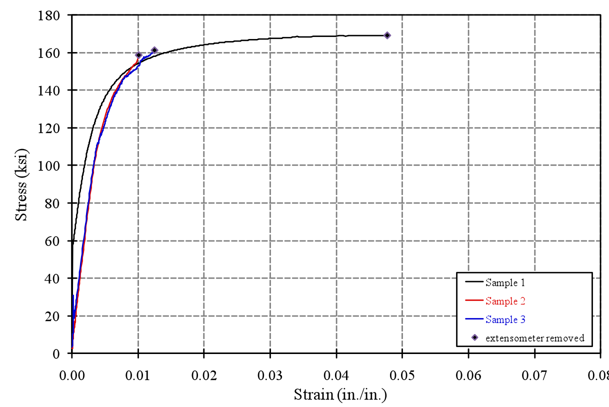
g) A1035 #4 batch 1



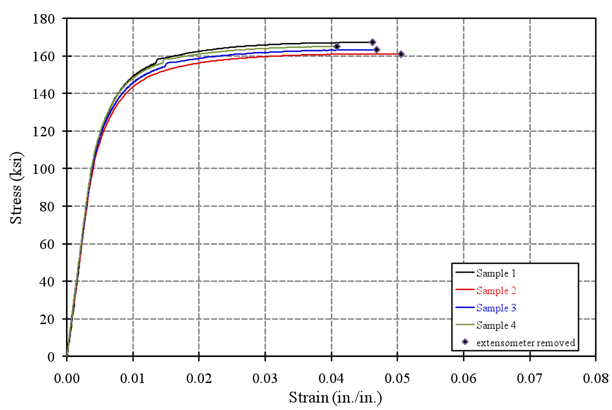
h) A1035 #4 batch 1B



i) A1035 #3 batch 1



j) A1035 #3 batch 1B



k) A1035 #3 batch 2

Figure A1 Axial stress-strain curves for A1035 reinforcing steel (continued).

ASTM A1035 Material Properties Reported By Others

Table A3 provides material properties of A1035 reinforcing steel reported in the available literature. It is noted that some references reported nominal material properties while others reported third-party values; these have not been included in Table A3. Figure A2 shows the data given in Table A3 plotted against bar size and includes the data from the present study reported in Table A2.

Table A3 Material properties of ASTM A 1035 reinforcing bars reported by others.

Citation	bar size	f_y calculated based on… (ksi)					f_u (ksi)	f_y/f_u[1]	ε_u	$\varepsilon_{rupture}$
		0.0035	0.0050	0.0070	0.0100	0.2% offset				
data provided by MMFX	#5	94	114	129	140	123	162	0.76	0.051	0.140
El-Hacha and Rizkalla 2002	#4	88	107	121	139	116	165	0.70	0.044	0.076
	#6	93	108	125	140	120	176	0.68	0.053	0.092
	#8	87	111	124	136	118	176	0.67	0.055	0.097
	#4	88	107	123	136	117	160	0.73	0.044	0.070
Smith Emory 2006 (compression tests)	#4	-	-	-	-	-	165		-	-
	#8	-	-	-	-	-	176		-	-
	#9	-	-	-	-	-	178		-	-
	#10	-	-	-	-	-	165		-	-
	#11	-	-	-	-	-	176		-	-
Michael 2004	#6	-	-	-	-	-	173		-	-
DeJong 2005	N/A	91	112	131	145	116	176	0.66	0.054	0.400
Ahlborn and DenHartigh 2002	#4	-	-	-	-	112	-		-	-
	#6	-	-	-	-	110	-		-	-
Vijay et al. 2002	#8	80	101	119	-	117	-		-	-
Restrepo 2006	#3	-	-	-	-	120	171	0.70	0.053	-
	#5	78	97	110	123	94	155	0.61	0.052	-
Seliem et al. 2006	#6	93	112	135	146	120	173	0.69	0.055	0.120
McNally 2003	#6	94	115	132	151	125	181	0.69	-	-
Hill et al. 2003	#4	92	115	133	149	112	180	0.62	0.038	0.121
Wipf et al. 2005	#5	-	-	-	-	114	164	0.70	-	0.072
Darwin et al. 2002	#5	-	-	121	-	120	160	0.75	-	0.072
	#6	-	-	143	-	142	173	0.82	-	0.071
	#6	-	-	135	-	132	165	0.80	-	0.070
Rizkalla et al. 2005	#4	97	128	145	156	140	174	0.83	0.047	-
	#5	100	121	135	145	128	162	0.80	0.045	-
Khader 2002	#6	-	-	-	-	152	183	0.79	-	0.096
average		90	111	129	142	121	170	0.72	0.049	0.115
COV		6.5%	7.2%	7.1%	6.0%	10.3%	4.5%	9.3%	11.2%	77%

- indicates that value may not be obtained from data presented; this may be because stress-strain curves are not presented or are truncated prior to reaching ultimate capacity or rupture.

[1] f_y based on 0.2% offset method

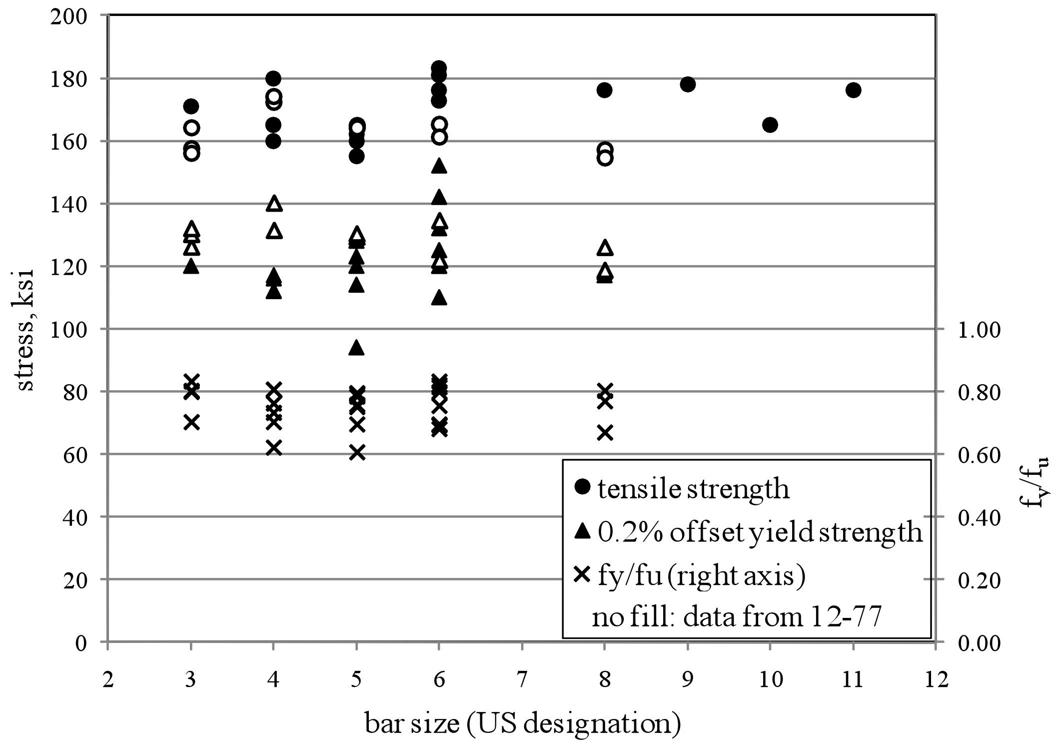
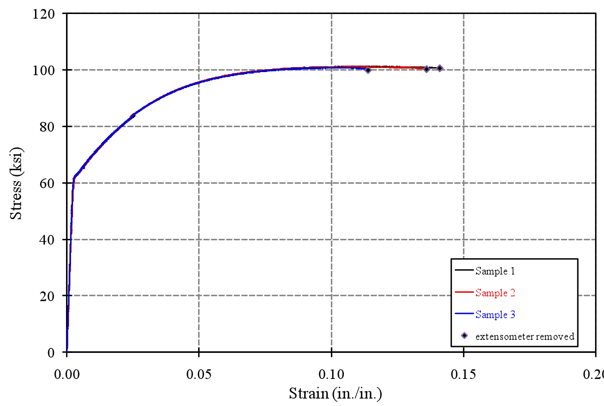


Figure A2 Variation of yield and tensile strength of A1035 reinforcement with bar size for bars tested by others (solid data points) and those tested in this study (no fill).

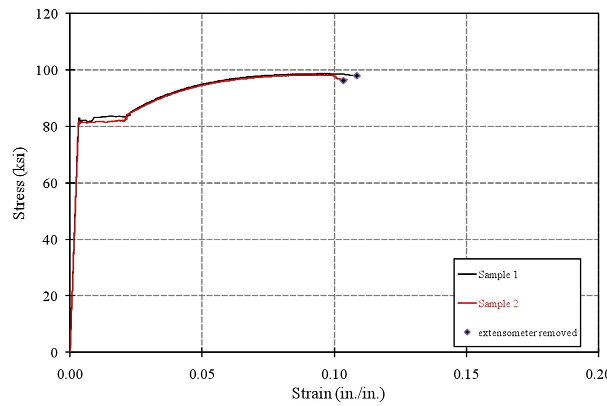
A.3 ASTM A615 Material Properties

Table A4 Summary of A615 tension properties.

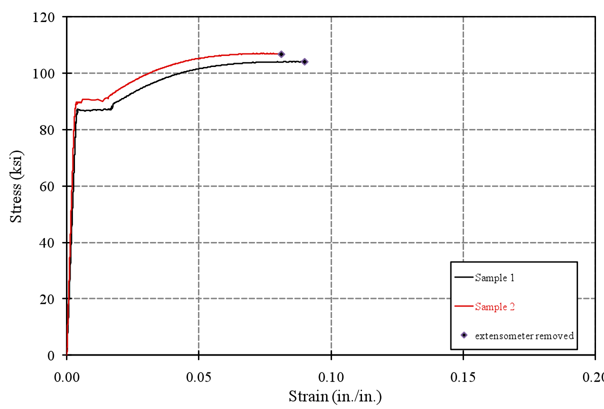
bar size		#4	#4	#4	#4	#4	#3	#3	#3	#3
batch		1	2	3	4	5	1	2	3	4
lab		UC	UC	UC	UC	PITT	UC	UC	PITT	PITT
# of samples		3	2	2	4	3	3	2	3	3
f_u	ksi	100.7	98.4	105.4	105.0	102.3	100.4	102.7	103.0	107.8
ε_u		n.r.	n.r.	n.r.	n.r.	0.205	n.r.	n.r.	0.153	0.133
E_{calc}	ksi	26934	25851	27596	23945	28635	29492	27268	29124	26178
f_y based on…										
ε = 0.0035	ksi	62.6	81.4	86.3	83.4	61.6	55.4	63.5	67.3	69.1
ε = 0.0050	ksi	64.2	81.9	88.2	92.9	64.3	65.3	63.5	68.4	73.0
ε = 0.0070	ksi	66.6	81.6	88.8	93.5	66.3	65.5	64.3	69.3	73.7
ε = 0.0100	ksi	70.1	82.4	88.7	90.3	69.3	67.8	67.9	70.6	75.1
0.2% offset	ksi	63.5	81.5	88.2	90.2	61.5	65.1	63.6	67.3	69.1



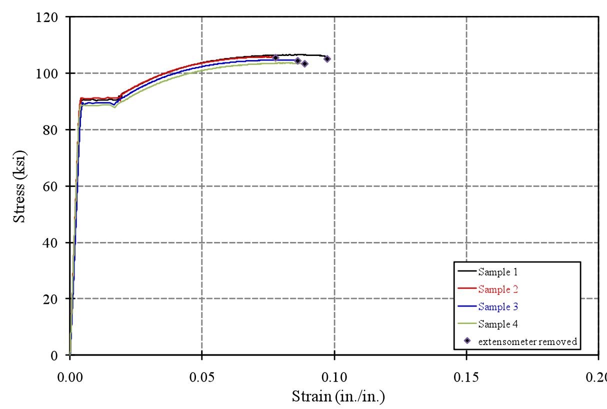
a) A615 #4 batch 1



b) A615 #4 batch 2

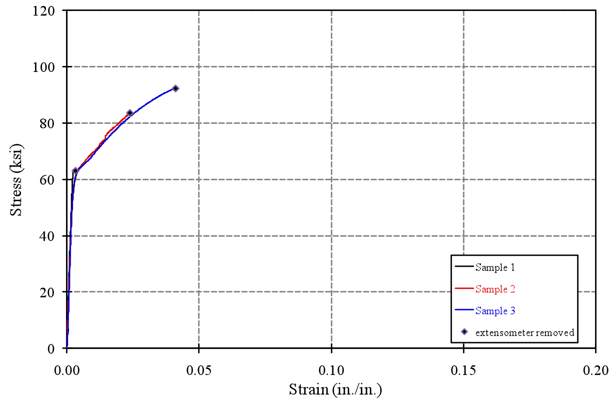


c) A615 #4 batch 3

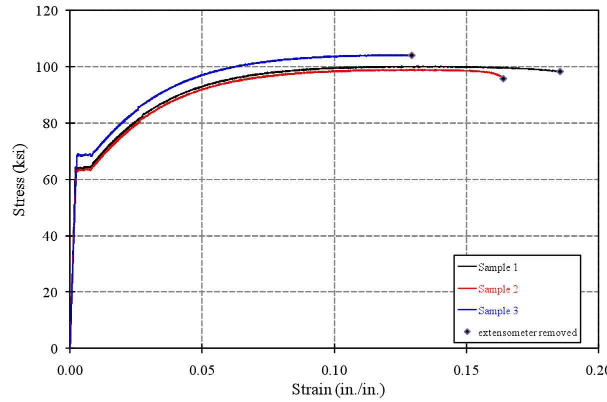


d) A615 #4 batch 4

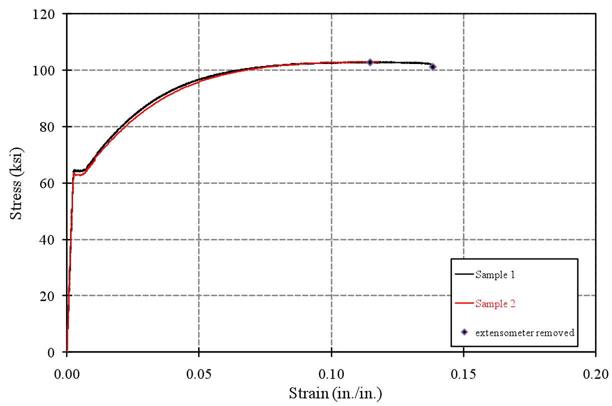
Figure A3 Axial stress-strain curves for A615 reinforcing steel.



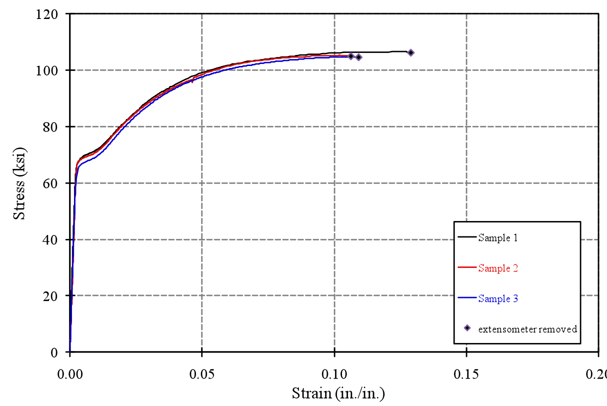
e) A615 #4 batch 5



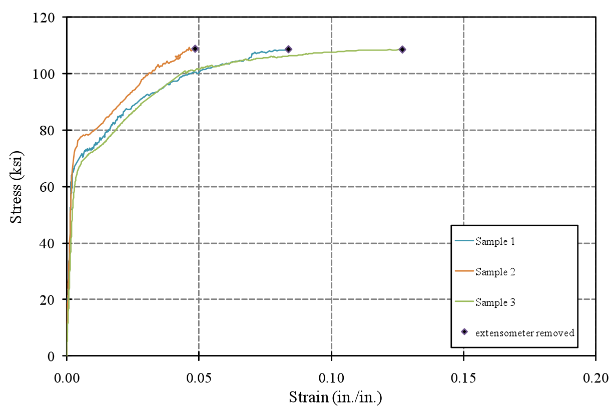
f) A615 #3 batch 1



g) A615 #3 batch 2



h) A615 #3 batch 3



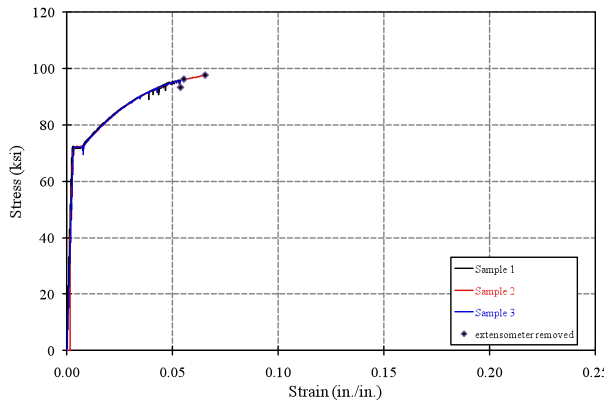
i) A615 #3 batch 4

Figure A3 Axial stress-strain curves for A615 reinforcing steel (continued).

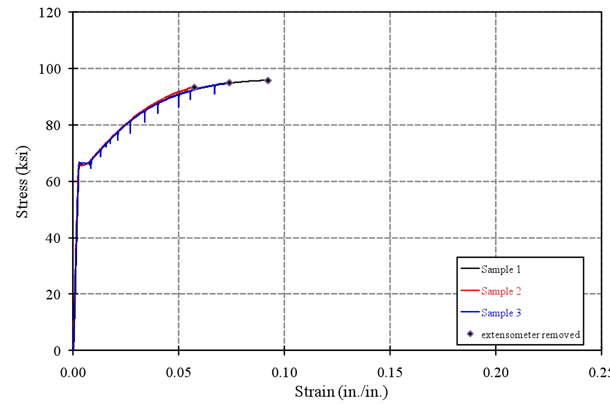
A.4 ASTM A706 Material Properties

Table A5 Summary of A706 tension properties.

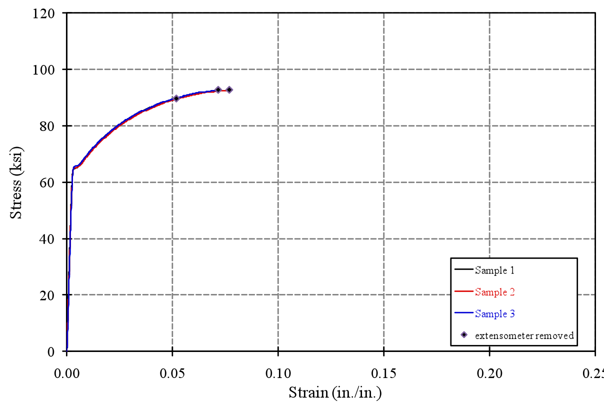
bar size		#4	#4	#6	#6	#8	#8
batch		1	2	1	2	1	2
lab		UC	UC	PITT	PITT	PITT	PITT
# of samples		3	3	3	3	3	3
f_u	ksi	99.4	88.9	94.7	93.0	99.7	96.5
ε_u		0.146	n.r.	0.202	0.201	0.204	0.133
E_{calc}	ksi	27401	27316	25674	24767	27006	25002
f_y based on…							
$\varepsilon = 0.0035$	ksi	66.7	64.7	65.1	69.0	72.0	66.0
$\varepsilon = 0.0050$	ksi	72.7	64.7	65.5	68.9	72.0	66.0
$\varepsilon = 0.0070$	ksi	76.3	64.7	67.0	69.0	72.3	66.4
$\varepsilon = 0.0100$	ksi	79.6	64.8	69.9	68.6	73.8	68.8
0.2% offset	ksi	71.6	64.8	65.7	68.1	72.3	66.5



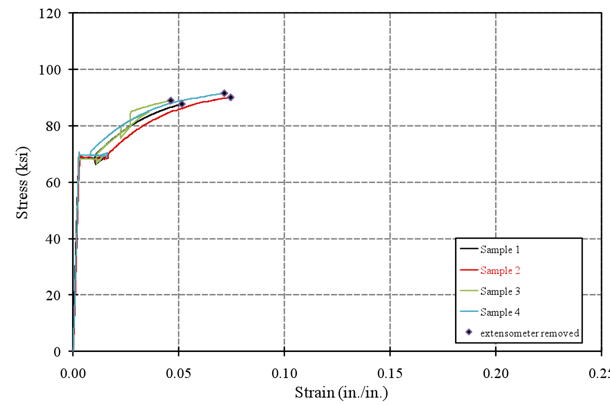
a) A706 #8 batch 1



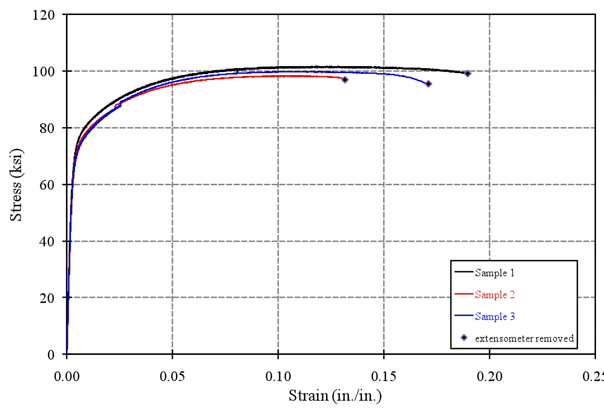
b) A706 #8 batch 2



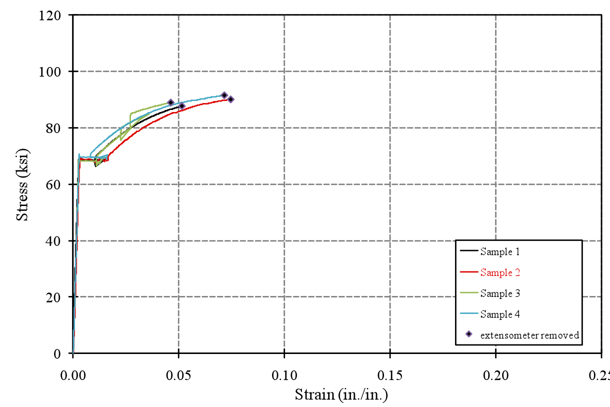
c) A706 #6 batch 1



d) A706 #6 batch 2



e) A706 #4 batch 1



f) A706 #4 batch 2

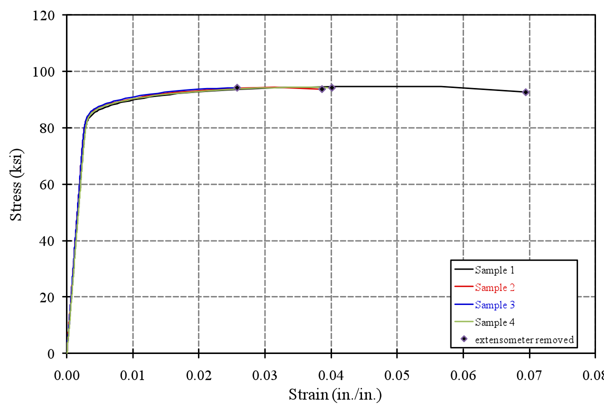
Figure A4 Axial stress-strain curves for A706 reinforcing steel.

A.5 ASTM A496 and A82 Material Properties

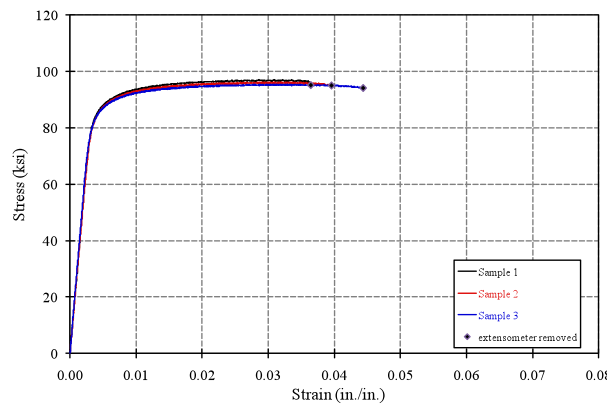
Both deformed (A496, designated D) and undeformed (A82, designated W) wire were tested as indicated in Table A6.

Table A6 Summary of A496 tension properties.

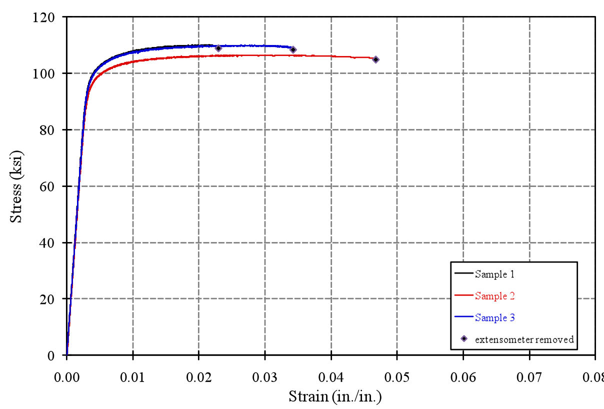
		A496					A82		
bar size		D4	D8	D12	D20	D31	W4	W8	W12
lab		PITT	UC	UC	UC	PITT	PITT	UC	UC
# of samples		4	3	3	3	3	3	3	3
f_u	ksi	94.5	94.7	107.3	99.9	109.8	104.1	94.1	103
ε_u		0.074	0.047	0.057	0.065	0.083	n.r.	0.054	0.056
E_{calc}	ksi	30203	27244	32769	29013	29244	33507	28859	31517
f_y based on…									
ε = 0.0035	ksi	84.8	81.5	96.3	83.2	81.9	95.8	87.6	93.5
ε = 0.0050	ksi	87.2	87.4	101.5	89.2	90.5	99.6	90.3	97.6
ε = 0.0070	ksi	88.4	90.7	104.3	93.4	96.5	101.5	91.9	99.9
ε = 0.0100	ksi	90.5	92.9	106.4	96.7	101.4	102.7	93.0	101.7
0.2% offset	ksi	84.1	87.6	98.7	89.2	91.3	95.7	91.0	98.4



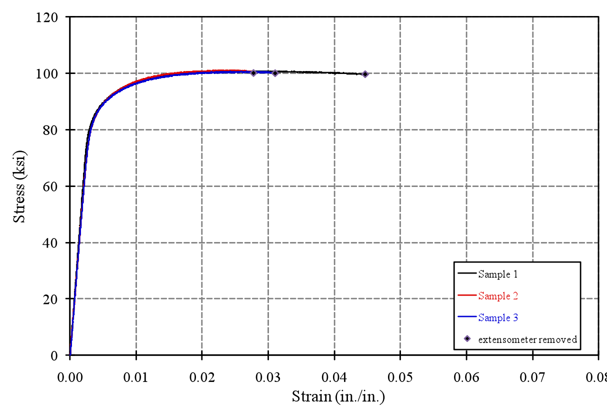
a) A496 D4 deformed wire



b) A496 D8 deformed wire

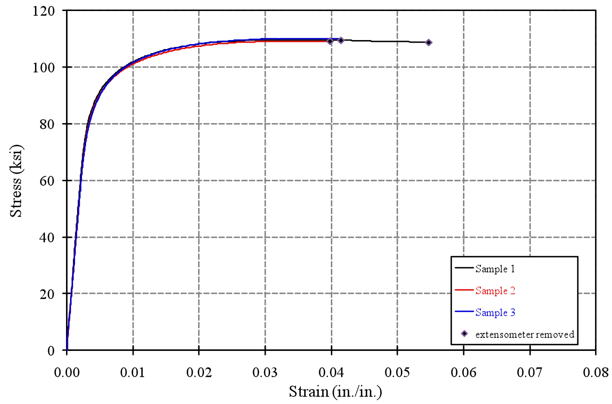


c) A496 D12 deformed wire

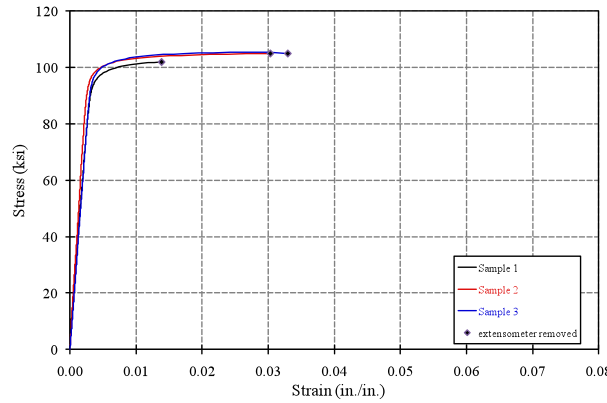


d) A496 D20 deformed wire

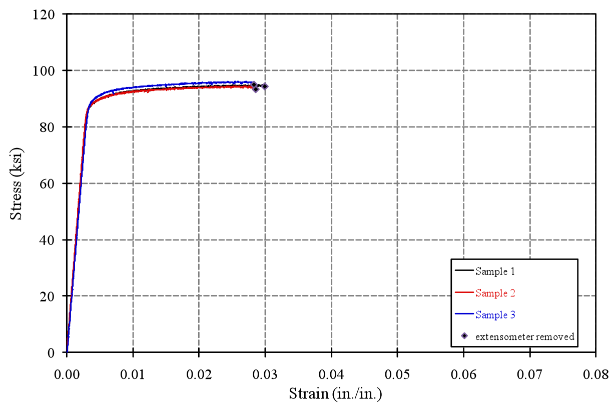
Figure A5 Axial stress-strain curves for A496 and A82 steel reinforcing wire.



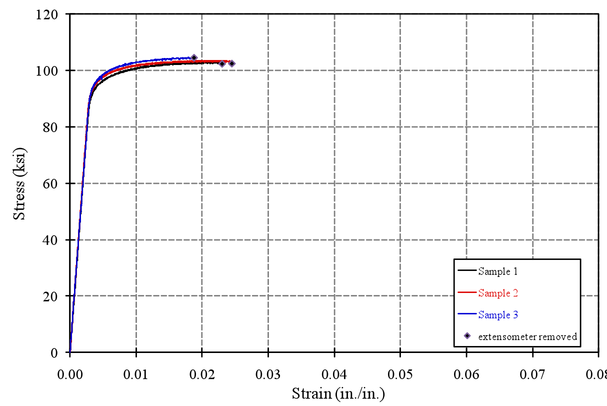
e) A496 D31 deformed wire



f) A82 W4 plain wire



g) A82 W8 plain wire



h) A82 W12 plain wire

Figure A5 Axial stress-strain curves for A496 and A82 steel reinforcing wire (continued).

A.6 ASTM A955 Material Properties

Three types of stainless steel listed below were tested as indicated in Table A7; all are compliant with A955.

- 316LN austenitic stainless steel having low carbon content, making it a 'weldable' stainless steel.
- 2205 duplex (mixed phase austenitic and ferritic) stainless steel having 22% chromium and 5% nickel content.
- N32 austenitic stainless steel having high manganese and low nickel content.

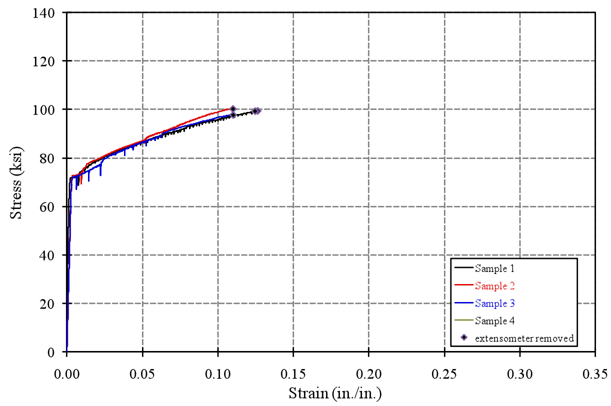
A summary of the chemical content (provided by supplier) of each material is provided in Table A8. For comparison, the composition of A615 and A1035 are also shown in Table A8.

Table A7 Summary of A955 tension properties.

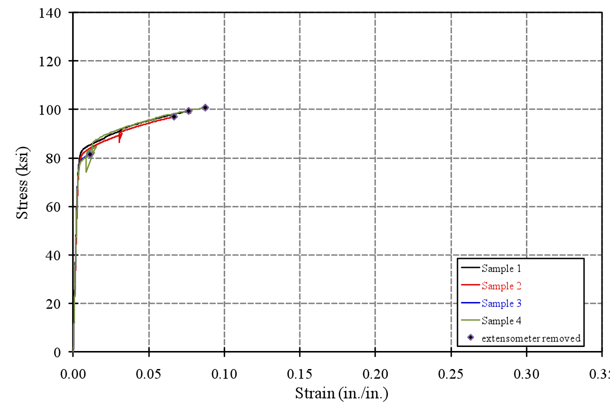
Type		316LN				2205					N32		
bar size		#4	#6	#6	#8	#4	#4	#6	#6	#8	#4	#6	#8
batch		1	1	2	1	1	2	1	2	1	1	1	1
lab		UC	PITT	PITT	PITT	UC	UC	PITT	PITT	PITT	UC	PITT	PITT
# of samples		3	3	2	4	3	2	3	1	3	3	4	2
f_u	ksi	102.8	109.6	103.7	104.4	119.0	120.2	109.1	113.3	114.6	116.8	116.5	114.2
ε_u		0.284	0.309	0.384	0.213	0.224	n.r.	0.323	0.284	n.r.	0.424	0.461	0.237
E_{calc}	ksi	23438	24219	23750	23019	23414	24314	23349	23348	24069	27916	26027	27249
f_y based on…													
ε = 0.0035	ksi	72.7	74.6	68.0	69.0	72.2	71.9	73.3	70.5	68.6	79.4	75.1	70.6
ε = 0.0050	ksi	80.6	80.3	69.8	69.2	90.5	86.7	89.4	81.3	82.2	81.3	77.6	76.1
ε = 0.0070	ksi	83.2	82.0	70.4	72.6	101.6	96.1	91.4	89.1	90.9	82.0	78.6	77.3
ε = 0.0100	ksi	84.4	83.2	71.6	73.8	106.8	101.3	95.0	94.3	96.0	83.5	80.3	78.7
0.2% offset	ksi	80.9	80.8	69.3	72.0	99.1	91.2	88.4	84.0	85.5	81.5	77.4	75.8

Table A8 Chemical composition of stainless steel bars considered in this study.

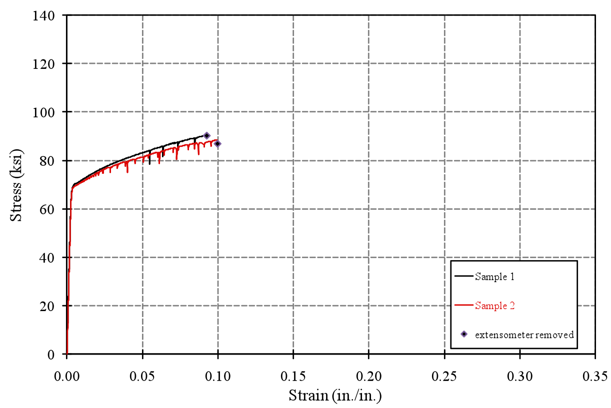
designation	UNS designation	%Cr	%Ni	%C	%Mn	%Si	%P	%S	%N	%Mo	%Fe
316LN	S31653	16-18	10-14	0.03	< 2	< 1	< 0.045	< 0.030	0.10-0.16	2-3	balance
2205	S31803	21-23	4.5-6.5	0.03	< 2	< 1	< 0.030	< 0.020	0.08-0.20	2.5-3.5	balance
N32	S24100	16.5-19	0.5-2.5	0.15	11-14	<1	< 0.060	< 0.030	0.20-0.45	-	balance
A615		-	-	< 0.50		-	< 0.060		-	-	balance
A1035		8-10.9	-	0.15	< 1.5	< 0.5	< 0.035	< 0.045	< 0.05	-	balance



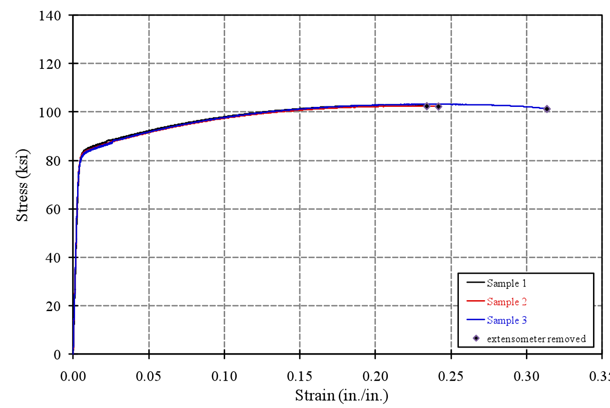
a) A955 (316) #8 batch 1



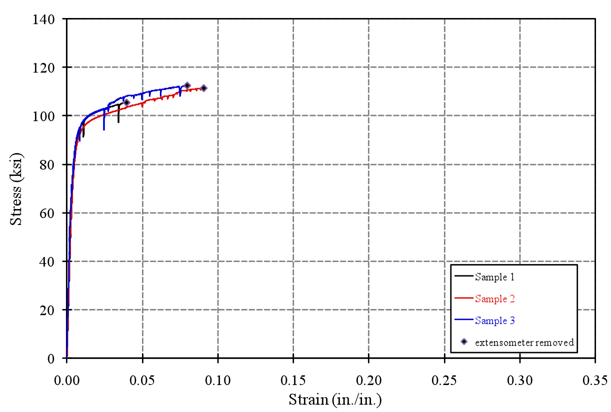
b) A955 (316) #6 batch 1



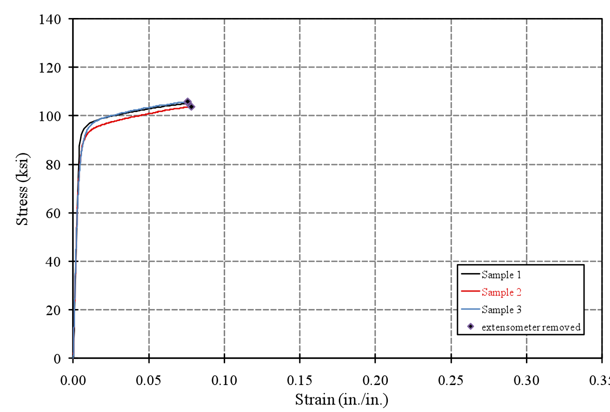
c) A955 (316) #6 batch 2



d) A955 (316) #4 batch 1

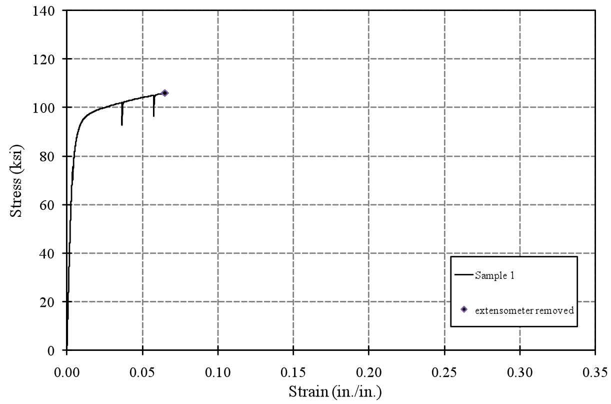


e) A955 (2205) #8 batch 1

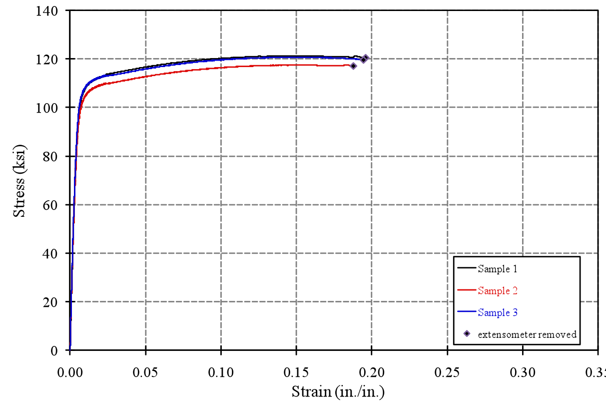


f) A955 (2205) #6 batch 1

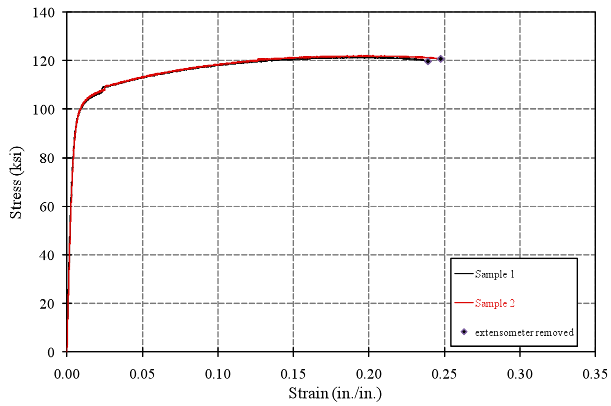
Figure A6 Axial stress-strain curves for A955 stainless steel reinforcing steel.



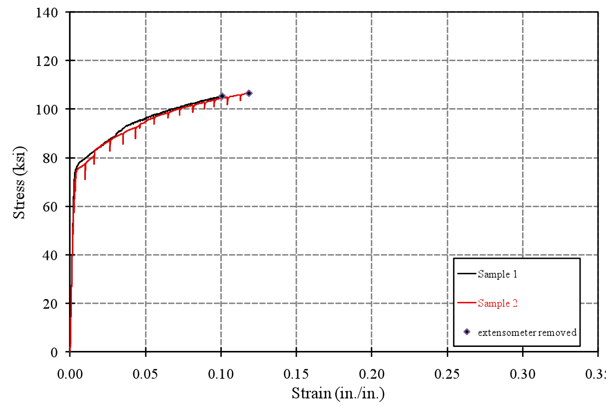
g) A955 (2205) #6 batch 2



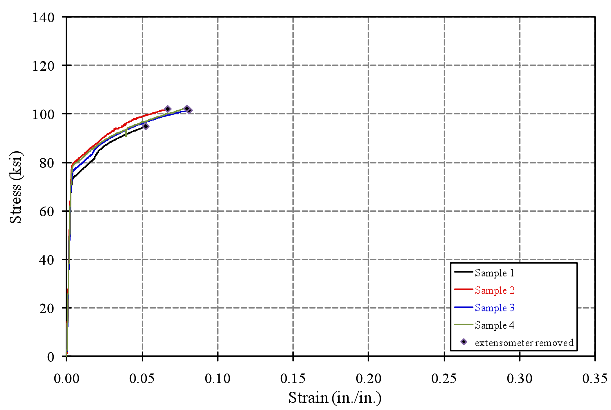
h) A955 (2205) #4 batch 1



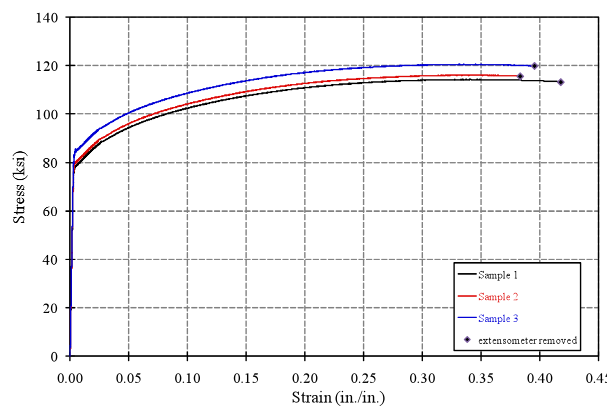
i) A955 (2205) #4 batch 2



j) A955 (N32) #8 batch 1



k) A955 (N32) #6 batch 1



l) A955 (N32) #4 batch 1

Figure A6 Axial stress-strain curves for A955 stainless steel reinforcing steel (continued).

A.7 Corrosion Performance of Reinforcing Steel

Table A9 provides quantitative comparison of corrosion performance of A615, A1035 and 316 stainless steel reinforcing bars as reported in the literature. Values in parentheses are ratios of the performance parameter listed normalized to the reported performance of A615 steel. Ratios greater than unity indicate superior performance. It is significant that a) there are a large number of performance measures which have been considered; and b) these often yield different comparative performance assessments.

Table A9 Quantitative measures of corrosion performance.

Performance Measure	Units	A615	A1035	316 stainless	Citation
time to corrosion initiation (accelerated laboratory test)	days	92	245 (2.7)	>1082 (>11.7)	Clemena and Virmani, 2004
time to corrosion initiation (extrapolated *in situ* testing)	years	-	42-46	50-58	Springstone, 2004
corrosion rate (mortar block macrocell)	μm/year	12.1	3.2 (3.8)	-	Wipf et al. 2005
		17.6	10 – 12 (≈1.6)	-	Darwin et al. 2002
		20	10 (2.0)	0.1 (200)	Hartt et al., 2004
corrosion rate (in air macrocell)	μm/year	36	12-25 (1.4-3.0)	-	Darwin et al. 2002
corrosion rate (accelerated salt-fog test)	μm/year	915	625 (1.5)	1.2 (760)	Wiss Janney, Elstner Associates, 2006.
weight loss (1500 hour salt exposure)	%	2.54%	0.52% (4.9)	-	LaDOT&D (reported by AMEC 2006)
weight loss (2000 hour salt exposure)	%	2.1%	0.61% (3.4)	0.0%	New Jersey DOT (as reported by AMEC 2006)
chloride threshold	ppm	520	2720 (5.2)	>5630 (>10.8)	Clemena and Virmani, 2004
	kg/m^3	0.52	4.6 (8.8)	10.8 (20.7)	Trejo and Pillai, 2004
PREN (pitting resistance equivalent) PREN = %Cr + 3.3(%Mo) + 16(%N)		0	10	25	Trinnea, 2006
polarization resistance (ratio)	(ratio)	(1)	(35)	(73)	Mancio et al. 2007
current density	corrosion rate	rapid	moderate	low	Mancio et al. 2007

A.8 Concrete Mix Designs and Material Properties Used in This Study

The mix designs and measured material properties of concrete used to cast the specimens used in this study are given in Tables A10 and A11 for the concrete used at the Universities of Pittsburgh (PITT) and Cincinnati (UC), respectively. The test specimens for which each batch was used are also indicated.

Table A10 Concrete mix designs and material properties of those mixes used at PITT.

Mix		A		B		C	
Provider		Frank Bryan, Pittsburgh		Frank Bryan, Pittsburgh		Frank Bryan, Pittsburgh	
Test Specimens		all P specimens cast 1		all P specimens cast 2		all H specimens both fatigue specimens	
design f_c'	psi	4000		4000		10000	
cast date		10/10/2008		10/24/2008		10/16/2008	
		Qty	**source**	**Qty**	**source**	**Qty**	**source**
cement	lbs/cy	400	Essroc Cement Type I	400	Essroc Cement Type I	825	Lehigh Cement Type I/II
fine agg	lbs/cy	1346	TriState Type A Sand	1346	TriState Type A Sand	1105	TriState Type A Sand
coarse agg	lbs/cy	1450	TriState #57 Gravel; Tristate	1450	Tristate #57 Gravel; Tristate	1454	Georgetown S&G #8 Gravel
coarse agg	lbs/cy	300	TriState #8 Gravel; Tristate	300	Tristate #8 Gravel; Tristate	430	TriState shot gravel
water	lbs/cy	254	Pittsburgh	254	Pittsburgh	24	Pittsburgh
SF	lbs/cy	175	Type C Essroc	175	Type C Essroc	67	Elkem
HRWR	oz/cy	4	Axim 800N	4	Axim 800N	125	AXIM Allegro 122
stabilizer	oz/cy	-	-	-	-	38	MB Delvo
w/c		0.44		0.44		0.27	
unit weight	lbs/cf	146		146		151	
slump	in.	6		6		6	
air content	%	not tested		not tested		not tested	
		strength	**age (days)**	**strength**	**age (days)**	**strength**	**age (days)**
f_c	psi	6020	28	4220	28	6620	7
		7120	104[1]	5800	90[1]	7820	28
						9710	56

[1] midpoint of test schedule

Table A11 Concrete mix designs and material properties of those mixes used at UC.

Mix		**D**		**E**		**F**	
Provider		Hilltop, Cincinnati		Mid-States Concrete, South Beloit, IL		Prestress Services, Melbourne, KY	
Test Specimens		F1, F2, F3, D5-1, D5-2, D8-1, D8-2, SR1, SR2, SR3, and SR4		F4, F5, F6, D5-3, D5-4, D8-3,D8-4, and SR5		SP1, SP2, and SP3 girders	
design f_c'	psi	10000		15000		10000	
cast date		09/30/08 & 02/19/09		08/31/09		05/22/09	
		Qty	**source**	**Qty**	**source**	**Qty**	**source**
cement	lbs/cy	825	Lehigh, TypeI/II	700	Type 3 Cement	752	Buzzi Unicem, Type III
fine agg	lbs/cy	980	Hilltop, Concrete Sand	800	Sand	889	Hilltop, Natural Sand
coarse agg	lbs/cy	1425	Hilltop, #57 Gravel	1220	1/4" Stone	1826	Hilltop, #8 Gravel
coarse agg	lbs/cy	430	Hilltop, #8 Gravel	600	5/8" Stone	-	-
water	lbs/cy	290	Cincinnati	175	South Beloit	305	Melbourne
SF	lbs/cy	67	Rheomac SF 100	100	Axim Catexol SF-D	50	Rheomac SF 100
HRWR	oz/cy	125	Glenium 7500	175	Axim 2100 PC	120	Superflo 2000RM
stabilizer	oz/cy	36	Delvo	-	-	38	LC - 400R
w/c		0.33		0.25		0.38	
unit weight	lbs/cf	149		150		142	
slump	in.	4		27 (slump flow)		9	
air content	%	1.5		not tested		4.7	
		strength	**age (days)**	**strength**[1]	**age (days)**	**strength**	**age (days)**
f_c	psi	11150	14	15960	78 (D5-3)	11930	46 (SP1)
		12170	21 (SR1)	14580	78 (D5-4)	12380	146 (SP2)
		12720	28 (D5-1,2)	14640	115 (D8-3)	13070	178 (SP3)
		12890	42 (D8-1,2, F1, F2, F3, & SR2)	14190	115 (D8-4)		
		13040	49 (SR3)	16500	115 (F4)		
		13080	97 (SR4)	16330	115 (F5)		
				16930	115 (F6)		
				16880	115 (SR5)		

[1] core samples

Table A11 Concrete mix designs and material properties of those mixes used at UC (continued).

Mix		G		H		J	
Provider		Prestress Services, Melbourne, KY		Prestress Services, Melbourne, KY		Prestress Services, Melbourne, KY	
Test Specimens		SP1, SP2, and SP3 slabs		SP4 girder		SP4 slab	
design f_c'	psi	5000		10000		5000	
cast date		06/04/09		01/14/09		12/21/09	
		Qty	**source**	**Qty**	**source**	**Qty**	**source**
cement	lbs/cy	733	Buzzi Unicem, Type III	752	Buzzi Unicem, Type III	733	Buzzi Unicem, Type III
fine agg	lbs/cy	1011	Hilltop, Natural Sand	904	Hilltop, Natural Sand	1025	Hilltop, Natural Sand
coarse agg	lbs/cy	1874	Hilltop, #8 Gravel	1853	Hilltop, #8 Gravel	1910	Hilltop, #8 Gravel
coarse agg	lbs/cy	-	-	-	-	-	-
water	lbs/cy	279	Melbourne	289	Melbourne	249	Melbourne
SF	lbs/cy	-	-	50	Rheomac SF 100	-	-
HRWR	oz/cy	59	Superflo 2000RM	120	Superflo 2000RM	73	Superflo 2000RM
stabilizer	oz/cy	37	LC - 400R	15	LC - 400R	7	LC - 400R
w/c		0.39		0.36		0.34	
unit weight	lbs/cf	144		142		145	
slump	in.	8		6.5		8	
air content	%	5		3.5		5	
		strength	**age (days)**	**strength**	**age (days)**	**strength**	**age (days)**
f_c	psi	7220	33 (SP1)	10160	28	6280	45 (SP4)
		9970	133 (SP2)	10530	45 (SP4)		
		10080	165 (SP3)				