Bar US Corporation
ISO 15835 TESTS ON BAR-US SIMGRIP LT REINFORCING BAR MECHANICAL SPLICES ASSEMBLED WITH BS4449 GRADE 460B REINFORCING BAR

Miami, Florida

Final Report
January 5, 2010
WJE No. 2009.5202.B

Prepared for:
Bar-US Corporation

Prepared by:
Wiss, Janney, Elstner Associates, Inc.
IAS Accredited Laboratory

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Miami, Florida

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Project Manager

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WJE | ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

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Bar US Corporation
ISO 15835 TESTS ON BAR-US SIMGRIP LT REINFORCING BAR MECHANICAL SPLICES ASSEMBLED WITH BS4449 GRADE 460B REINFORCING BAR

Mıami, Florida

INTRODUCTION

Wiss, Janney, Elstner Associates, Inc. (WJE) has conducted a series of tensile tests and reversed-loading low cycle tests on a reinforcing bar mechanical splice system for Bar-US Corporation (Bar-US). The tests were conducted on the Simgrip LT mechanical splices in metric bar size Nos. 20, 32 and 40 assembled using BS4449:1997 Grade 460B reinforcing bar. The tests were conducted in general accordance with ISO 15835-1 "Steels for the Reinforcement of Concrete - Reinforcement Couplers for Mechanical Splices of Bars - Part 1: Requirements" (2009) and ISO 15835-2 "Steels for the Reinforcement of Concrete - Reinforcement Couplers for Mechanical Splices of Bars - Part 2: Test Methods" (2009). The intent of the testing is to provide test data on splices assembled using BS4449 Grade 460 reinforcement, to be submitted to various authorities who are reviewing the splice system as part of these authorities' product review and acceptance process.

Unspliced control bar specimens were also tested. For each bar size, the control bars came from the same lots of bar that were used to make the splice specimens, which were assembled using Grade 460B reinforcing bar manufactured according to the requirements of "Specification for carbon steel bars for the reinforcement of concrete, BS4449:1997. The control bar tests were performed to determine the yield strength, yield strain, tensile strength, and final elongation of the unspliced reinforcing bar. The results of the control bar tests were compared to the tensile requirements of BS4449:1997.

DESCRIPTION OF THE SPLICE SYSTEM

Bar-US Simgrip LT Splice System

The Simgrip LT splice system consists of various components that are assembled together to form a splice. The standard splice consists of three components: two pieces of reinforcing bar and one threaded steel coupling devices. One end of each piece of reinforcing bar is cut square and placed into a machine that upsets or enlarges the end of the bar. Threads are then formed onto the upset ends of the reinforcing bars. One bar has threads cut over a longer length to allow for position splicing. Final assembly of the splice takes place in the field or in the shop by engaging the upset and threaded ends of the reinforcing bars into the threaded Simgrip LT coupling sleeve. An illustration of a splice assembly is shown in Figure 1.

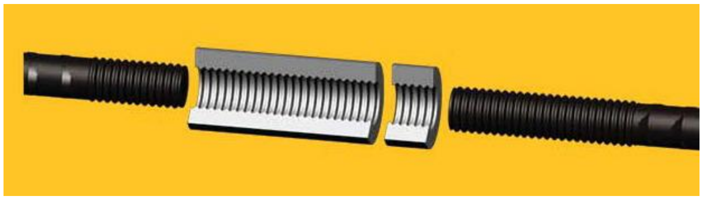

Figure 1. Schematic illustration of the Simgrip LT splice system. Note: product as tested did not include the locknut.

TEST PLAN, SPECIMEN ASSEMBLY AND TEST PROCEDURES

Test Plan

The test plan was made in general accordance with the testing requirements of ISO 15835-1. Table A.1 in ISO 15835-1 specifies that qualification testing of a mechanical splice system consist of tests performed on three samples of the largest size, three samples of a medium size and three samples of the smallest size. At the request of Bar-US, tests were planned for Simgrip LT splices assembled with reinforcing bar size Nos. 20, 32 and 40 and companion unspliced control bars in the same bar sizes. A summary of the test plan matrix is shown in Table 1.

Table 1- Test Plan Matrix

Bar Size No.	ISO 15835 Specimens		Control Specimens
	Category B Tensile Test	Category S2 Low Cycle Test	Unspliced BS4449 Grade 460B Reinforcing Bar
20	3	3	1
32	3	3	1
40	3	3	1

Control Bar Specimens and Reinforcing Bar Sources

Bar-US provided WJE with the unspliced control bar specimens. Bar-US indicated to WJE that all of the pieces of reinforcing bar in a given size came from the same lot of reinforcing steel. Bar-US also indicated that the reinforcing bars provided were procured as conforming to BS4449:1997 Grade 460B. Reinforcing bar mill certificates are provided in Appendix A.

Procedures for Control Bar Tensile Tests

Unspliced control bar specimens were tested monotonically in axial tension in accordance with "Steel for reinforcement and prestressing of concrete - Test methods Part 1: Reinforcing bars, wire rod and wire," ISO 15630-01:2002. A clip-on strain extensometer measured the elongation of each unspliced control bar test specimen. The electrical signal output from the clip-on strain extensometer and an electrical signal indication of the test machine load were recorded digitally using a computer. Force-elongation plots for all control bar specimens were produced by plotting the digital record. For the unspliced bar specimens, the gage length of the clip-on strain gage was 100 mm.

Percent total elongation at maximum force (A_{gt}) was measured on each bar after fracture as prescribed in ISO 15630-01 Section 5.3. A_{gt} was determined by first scribing a series of gage marks onto the central length of the untested specimen at 20 mm intervals over a total length of at least 100 mm. After the test, a measurement was made of the distance between two scribe points, at least 50 mm or two times the bar diameter (whichever is greater) from the fracture and having an original gage length of 100 mm. As specified by ISO 15630-01, A_{gt} was calculated as the percentage increase in length of the gage length plus the percent elastic elongation represented by the tensile strength R_m divided by Young's modulus. A similar measurement was made to obtain A_5 by measuring the distance between two scribe points having an original gage length of five times the diameter of the bar and centered across the fracture.

Procedures for Category B Tensile Tests

A monotonically increasing tensile load was applied until failure in accordance with Section 5.3 of ISO 15835-2. The test machine was operated under displacement control. The elongation (slip) across the splice was recorded until approximately 120 percent of actual bar yield was reached. The LVDT frame was subsequently removed from the specimen so that the instrument would not be damaged when the specimen fractured. For safety purposes, the test machine was temporarily paused with displacement held constant when an instrument was removed from the test specimen. After removal of the instrumentation, displacement was increased until the specimen fractured. The peak load indicated by the test machine and the observed type of fracture were recorded for each specimen. Corresponding stresses were determined using the nominal bar area. Measurements of total elongation at maximum force (A_{gt}) were made on the bars after fracture using the methods specified in ISO 15630-01 Section 5.3.

Procedures for Category S2 Low Cycle Tests

Category S2 reversed-load cyclic tests utilized the loading protocol shown in Table 2, as established by ISO 15835-2 Section 5.6.2. In the table, $\boldsymbol{R_{eH,\ spec}}$ is the specified minimum yield strength of the reinforcing bar, and $\boldsymbol{\varepsilon_y}$ is the strain of the reinforcing bar at the specified yield stress calculated using a Young's Modulus of 2 x 10^5 MPa.

Table 2 - ISO 15835 Category S2 testing protocol

Load Stage	Tension Elongation	Compression Force	No. of Cycles
1	$2\ \varepsilon_y L_g$	$0.5\ R_{eH,\ spec}$	4
2	$5\ \varepsilon_y L_g$	$0.5\ R_{eH,\ spec}$	4
3	Load in monotonic tension to failure		

Elongation (slip) across the splice was monitored during Stages 1, 2, and 3 by a pair of LVDTs installed in a frame having a fixed gage length of 200, 400 or 500 mm depending on the reinforcing bar size. Strain in the reinforcing bar was monitored for reference purposes during Stages 1, 2, and 3 at a point away from the splice affected zone using a clip-on strain gage with a gage length of 200 mm. Test machine piston position was also monitored. The instrumentation setup is schematically illustrated in Figure 2.

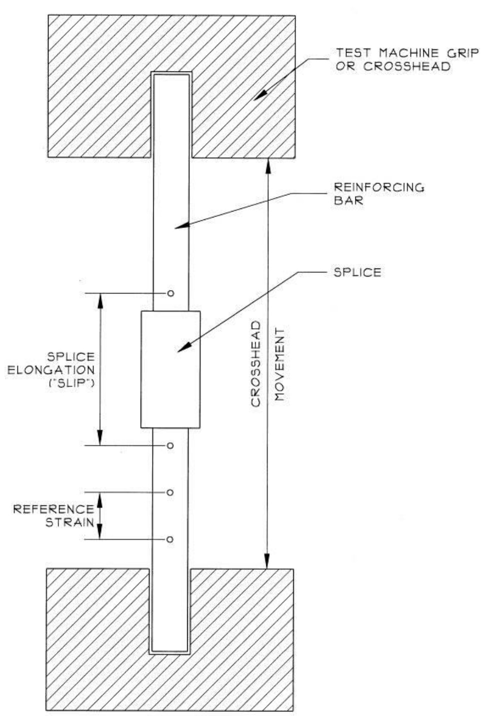

Figure 2. Schematic illustration of test instrumentation setup.

Compression loads and target displacements for Stages 1 and 2 were programmed into the test machine controller, which was operated under a hybrid displacement control/load control. The compression load in all cyclic load stages was set to $0.5*(\boldsymbol{A_n}*\boldsymbol{R_{eH,\ spec}})$, where $\boldsymbol{A_n}$ is the nominal bar area and $\boldsymbol{R_{eH,\ spec}}$ is the specified minimum yield strength of 460 MPa. The displacement targets for Stages 1 and 2 ($2\ \varepsilon_y L_g$ and $5\ \varepsilon_y L_g$, respectively) were determined using the calculated nominal yield strain and the instrument gage length specified in Section 5.1 of ISO 15835-2.

After Stages 1and 2 of cyclic loading, each splice specimen was monotonically loaded in tension to failure. The Stage 3 tests were carried out in accordance with ISO 15630-1. The test machine was operated under displacement control during Stage 3. The extensometer remained on the specimen and the elongation (slip) across the splice was recorded during the initial portion of the Stage 3 test to failure. When the test load reached a value of approximately 120 percent of actual bar yield, the LVDT frame was removed from the specimen so that the instrument would not be damaged when the specimen fractured. Similarly, the reference strain was also recorded as far into Stage 3 as was practicable. For safety purposes, the test machine was temporarily paused with displacement held constant when an instrument was removed from the test specimen. After removal of the instrumentation, displacement was increased until the specimen fractured. Test machine piston position was monitored by computer throughout the test, up to and including specimen fracture. The peak load indicated by the test machine and the observed type of fracture were recorded for each specimen. Corresponding stresses were determined using the nominal bar area. Total elongation at maximum force (A_{gt}) of the bar away from the mechanical splice was measured after fracture as prescribed in ISO 15630-01 Section 5.3.

Laboratory Accreditation and Test Machine Certification

WJE is an accredited testing laboratory, recognized by International Accreditation Service, Inc. (IAS) under Certificate TL-165. All tests were performed on a 1780 kN Tinus Olsen universal test machine having hydraulic grips. The Tinus Olsen test machine is located at the WJE headquarters office in Northbrook, Illinois. The current calibration certificates are included in Appendix B.

TEST RESULTS

The tests were carried out on December 21 and 22, 2009. All tests were directed by a WJE staff member who is a licensed structural engineer. The results of the tests are described in the following paragraphs.

Unspliced Control Bars

The results of the tests on the unspliced control bars are summarized in Table 3. The reported tensile properties of all specimens conform to the tensile requirements of BS4449:1997 Grade 460 reinforcing bars. Load-elongation curves for all control bar tests can be found in Appendix C.

Splices Tested for Category B Tensile Strength

Results of the tensile tests on bar specimens in accordance with ISO 15835-1 Category B are summarized in Table 4. Load-elongation (load-slip) curves can be found in Appendix D. The breaking strengths, mode of fracture, and measured A_{gt} values of the specimens are also summarized in Table 4. During the monotonic tensile testing to destruction, all specimens fractured in the reinforcing bar in a ductile fashion away from the splice. A photograph of this failure mode is shown in Figure 3.

For recognition under ISO 15835-1, spliced specimens using BS4449 reinforcing bars must develop a breaking strength of at least $R_{eH,spec} \cdot (R_m/R_{eH})_{spec}$. ISO 15835-1 also requires that specimens achieve a ductility of at least 70% of the specified characteristic A_{gt} value of the reinforcing bar. These requirements are summarized in Table 5. All specimens summarized in Table 4 conform to the strength and ductility requirements.

Splices Tested for Category S2 Cyclic Loading

Results of the cyclic tests on spliced bar specimens in accordance with ISO 15835-1 Category S2 are summarized in Table 6. Load-elongation (load-slip) curves can be found in Appendix E. The Stage 3 breaking strengths, mode of fracture and the measured A_{gt} values of the specimens are also noted in Table 6. During the Stage 3 testing to destruction, all specimens fractured in the reinforcing bar in a ductile fashion away from the splice, as was the case for splices tested for Category B tensile strength.

Figure 3. Representative fractured test specimens, showing bar break away from the mechanical splice

For recognition under ISO 15835-1, spliced specimens using BS4449 reinforcing bars must develop a breaking strength of at least $R_{eH,spec} \cdot (R_m/R_{eH})_{spec}$ and a ductility of at least 70 percent of the specified characteristic A_{gt} value of the reinforcing bar. ISO 15835-1 also requires that specimens achieve a residual elongation not exceeding 0.3 mm after Stage 1, and not exceeding 0.6 mm after Stage 2. These requirements are summarized in Table 5. All specimens summarized in Table 6 conform to the strength, ductility and residual elongation requirements summarized in Table 5.

APPLICATION TO ACI-318-08 BUILDING CODE

For recognition under the *ACI 318-08*, the Type 1 and Type 2 mechanical splice must conform to the tensile strength requirements found in *ACI 318-08* Chapter 21, "Special Provisions for Seismic Design," which require the use of Type 2 splices in sections of concrete members where yielding of reinforcement is likely to occur as a result of inelastic lateral displacements under earthquake loading. *ACI 318-08.* Section 21.1.6.1 states that a Type 1 splice shall conform to Section 12.14.3.2 which requires that the splice develop in tension and compression at least 125 percent of the specified yield strength of the reinforcing bar. Section 21.1.6.1 states that a Type 2 splice shall conform to the Type 1 requirements but also develop in tension the specified tensile strength of the spliced bar.

ACI 318-08 Section 21.1.5 also specifies that reinforcement in these areas must comply with ASTM A706. Because the Type 1 and Type 2 splices are defined within Chapter 21 of ACI 318, the specified tensile strength of the bar also includes the special requirements of Section 21.1.5. These special requirements for the reinforcing bar therefore carry over to the strength requirements for Type 1 and Type 2 splices.

ASTM A706 Grade 420 reinforcing bar has a specified yield of 420 MPa, and a specified ultimate tensile strength that is the larger of 560 MPa or 1.25 times the actual yield strength of the reinforcing bar. Review of the reinforcing bar data summarized in Table 3 shows that bars in size No. 32 and 40 comply with the mechanical tensile requirements of ASTM A706 Grade 420 reinforcing bar. The reinforcing bar in size No. 20 does not conform to the mechanical tensile strength requirements of ASTM A706 Grade 420.

Based on the reinforcing bar data summarized in Table 3, the Type 1 and Type 2 splice tensile strengths required to conform to *ACI-318-08* are summarized in Table 5. Review of the tensile strengths of the Category B tensile specimens and the Category S2 cyclic specimens in Tables 4 and 6 shows that specimens in size Nos. 20, 32 and 40 exceed the *ACI 318-08* minimum strength requirements for a Type 1 mechanical splice. Specimens in size No. 32 and 40 comply with the *ACI 318-08* minimum strength requirements for a Type 2 mechanical splice.

Splice specimens in size No. 20 do not conform to the minimum strength requirements for a Type 2 mechanical splice because the reinforcing bar used does not conform to the minimum strength requirements for ASTM A706 Grade 420 reinforcing bars. It is our opinion that the splice system in size No. 20 would be able to conform to these requirements had the BS4449 Grade 460B reinforcing bar used actually conformed to the tensile strength requirements of ASTM A706 Grade 420. The failure mode and the performance of the other tested sizes support this conclusion. It is our opinion that specimens in size No. 20, 32 and 40 all comply with the tensile requirements of *ACI 318-08* for Type 1 and 2 mechanical splices.

SUMMARY

WJE conducted a series of tests on reinforcing bar mechanical splices for Bar-US Corporation. The tests were conducted on spliced bar specimens in size Nos. 20, 32 and 40 made with the Simgrip LT coupling sleeves (without the locknut) and BS4449:1997 Grade 460B reinforcing bar. During the Category B tensile tests, all splice specimens met or exceeded the strength and ductility requirements of ISO 15835-1. During reversed-load low cycle tests, all specimens survived the Category S2 cyclic loading as prescribed by ISO 15835-2 and satisfied the residual elongation requirements of ISO 15835-1. These specimens were then loaded in monotonic tension to fracture. All Category S2 splice specimens met or exceeded minimum strength and ductility requirements according to provisions of ISO 15835-1.

Additionally, the ultimate tensile strength of splice specimens in size No. 20, 32 and 40 exceeded minimum strength requirements for a Type 1 mechanical splice on Grade 420 reinforcement according to provisions of *ACI 318-08*. The ultimate tensile strength of splice specimens in size No. 32 and 40 exceeded minimum strength requirements for a Type 2 mechanical splice on ASTM A 706 Grade 420 reinforcement according to provisions of *ACI 318-08*. It is our opinion that the splice specimens in size No. 20 would also have exceed minimum strength requirements for a Type 2 mechanical splice had the specimens been fabricated with reinforcing bar that conformed to ASTM A706 Grade 420 tensile strength requirements.

Table 3 - Control Bar Test Results

Test I.D. Number	Bar Size (mm)	Bar Area (mm^2)	Specified Bar Yield Strength ($R_{eH, spec}$) (MPa)	Specified Tensile/Yield (R_m / R_{eH})$_{spec}$ (min)	Specified A_{gt} (percent)	Yield Strength F_{eH} (kN)	Yield Strength (R_{eH}) (MPa)	Yield Strain ε_y (percent)	Tensile Strength (kN)	Tensile Strength (R_m) MPa	(R_m / R_{eH})	A_{gt} (percent)	A_5 (percent)
3774	20	314	460	1.08	5	159.0	506.4	0.33	191.2	608.9	1.20	9%	24%
3770	32	804	460	1.08	5	391.0	486.3	0.30	507.4	631.1	1.30	10%	25%
3769	40	1257	460	1.08	5	603.0	479.7	0.32	793.7	631.4	1.32	11%	20%

Table 4 - Category B Splice Tensile Test Results

Test I.D. Number	Bar Size (mm)	Bar Area (mm^2)	Bar Grade	Tensile Strength F_{max} (kN)	Tensile Strength (R_m) MPa	A_{gt} (percent)	R_m/ R_{eH}	Final Result
3775	20	314	460B	191.75	610.7	9.7%	1.21	Bar break
3776	20	314	460B	190.8	607.6	10.8%	1.20	Bar break
3777	20	314	460B	191.7	610.5	10.6%	1.21	Bar break
3760	32	804	460B	506.8	630.3	11.7%	1.30	Bar break
3761	32	804	460B	506.8	630.3	14.5%	1.30	Bar break
3764	32	804	460B	507.7	631.5	10.1%	1.30	Bar break
3762	40	1257	460B	788.1	627.0	10.1%	1.31	Bar break
3763	40	1257	460B	789.8	628.3	10.5%	1.31	Bar break
3765	40	1257	460B	793.1	630.9	10.0%	1.32	Bar break

Table 5 - ISO 15835-1 Requirements for Mechanical Splices

Reinforcing Bar Specified Properties (BS4449:1997 GR460B)					ISO 15835-1 Mechanical Splice System Tensile Requirements				ACI 318-08 Tensile Requirements (A706 Grade 420 Reinforcing Bar)			
Bar Size	Bar Area	Specified Yield Strength	Specified Tensile/Yield Ratio	Specified A_{gt}	Tensile Strength: Section 5.2.2	Tensile Ductility: Section 5.2.3	S2 Cyclic Residual Elongation: Section 5.5.2		Type 1	Type 2		
									125% Specified Yield	100% Specified Ultimate	125% Actual Yield	Larger of
		$(R_{eH})_{spec}$	$(R_m / R_{eH})_{spec}$		$R_{eH, spec}$ * $(R_m / R_{eH})_{spec}$	A_{gt} (min)	u_4 (max) (mm)	u_8 (max) (mm)				
(mm)	(mm^2)	(MPa)		(percent)	MPa	(percent)			(MPa)	(MPa)	(MPa)	(MPa)
20	314	460	1.08	5	496.8	3.5	0.3	0.6	525	550	633.0	633.0
32	804	460	1.08	5	496.8	3.5	0.3	0.6	525	550	607.9	607.9
40	1257	460	1.08	5	496.8	3.5	0.3	0.6	525	550	599.6	599.6

Table 6 -Category S2 Splice Low Cycle Test Results

Test I.D. Number	Bar Size	Bar Area	Bar Grade	Stage 1	Stage 2	Tensile Strength		A_{gt}	Residual Elongation		R_m / R_{eH}	Final Result
				$2\varepsilon_y L_g$ Cycles Applied	$5\varepsilon_y L_g$ Cycles Applied	F_{max}	(R_m)	(percent)	u_4	u_8		
	(mm)	(mm^2)				(kN)	MPa		(mm)	(mm)		
3778	20	314	460B	4	4	192.3	612.4	9%	0.02	0.12	1.21	Bar break
3779	20	314	460B	4	4	192.4	612.9	9%	0.01	0.08	1.21	Bar break
3780	20	314	460B	4	4	192.8	614.0	9%	0.03	0.13	1.21	Bar break
3771	32	804	460B	4	4	509.5	633.7	10%	0.19	0.47	1.30	Bar break
3772	32	804	460B	4	4	508.3	632.2	12%	0.15	0.36	1.30	Bar break
3773	32	804	460B	4	4	509.9	634.2	11%	0.15	0.37	1.30	Bar break
3766	40	1257	460B	4	4	784.3	623.9	10%	0.11	0.37	1.30	Bar break
3767	40	1257	460B	4	4	786.6	625.8	10%	0.20	0.47	1.30	Bar break
3768	40	1257	460B	4	4	786.8	625.9	11%	0.14	0.45	1.30	Bar break

APPENDICES

ENGINEERS
ARCHITECTS
MATERIALS SCIENTISTS

APPENDIX A
Reinforcing Bar Mill Certificates

300/F-09/01.QC

KROMAN KANGAL HADDEHANESİ

KALİTE BELGESİ

QUALITY CERTIFICATE

TARİH : **18/12/09**

REV. NO : 00

FİRMA
BUYER
BAR-US CORP

SİPARİŞ NO
ORDER NO

BELGE NO
DOCUMENT NO
28-0402

DÖKÜM NO (Heat)	KALİTE (Quality)	KESİT (Size)	BOY (Length)	KİMYASAL KOMPOZİSYON / CHEMICAL COMPOSITION IN PRODUCT							MEKANİK ÖZELLİKLER / MECHANICAL PROPERTIES				
				C %	Mn %	Si %	S %	P %	Cu %	CE %	ReH N/mm2	RM N/mm2	A %	Oran	Eğme
29-9257-0	BS4449	20 Ø	12,00	0,22	0,63	0,19	0,035	0,012	0,26	0,36	573	658	17	1,15	OK
29-9257-1	BS4449	25 Ø	12,00	0,21	0,63	0,20	0,032	0,014	0,30	0,36	501	649	19	1,30	OK
29-9257-2	BS4449	32 Ø	12,00	0,23	0,97	0,33	0,028	0,018	0,24	0,43	523	657	15	1,26	OK
29-9257-3	BS4449	40 Ø	12,00	0,24	0,96	0,29	0,019	0,016	0,28	0,44	597	737	16	1,23	OK
29-9257-4	BS4449	16 Ø	12,00	0,20	0,57	0,20	0,026	0,009	0,25	0,34	519	622	22	1,20	OK

ReH : Üst Akma Sınırı [Yield Strength]
Rm : Çekme Day. [Tensile Strength]
% A : Kopma Uzaması [Elongation]
TEST STANDART_ TS 138/EN 10002-1

Ü.P. KALİTE MÜDÜRLÜĞÜ

TSE

AŞIROĞLU CAD.NO:175 ÇAYIROVA - GEBZE / KOCAELİ
P.K. 24 41100 ÇAYIROVA- GEBZE / KOCAELİ
TEL. : 0(262) 679 20 00 FAKS: 0(262) 653 26 76

APPENDIX B
Test Machine Current Calibration Certificate

MTS Systems Corporation

14000 Technology Drive
Eden Prairie, MN 55344-2290

CALIBRATION CERT #1145.01

MTS Field Service

Certificate of Calibration

Customer

Name: Wiss, Janney, Elstner Associates, Inc.
Certificate Number: 2394-4590
System: Tinius Olsen 114585
Site: 508308
System ID: Tinius Olsen 114585
Location: Structural Lab
Country Code: USA

Equipment

Device Type: Force
Model: REVERE_400KIP
Serial No.: 665148
Controller/Conditioner Model: 493.21B
Serial No.: 1070201
Readout Device Model: 493.21B
Serial No.: 1070201
Channel: Force

MTS Field Service is accredited by the American Association for Laboratory Accreditation (A2LA Cert. No. 1145.01). The basis for this accreditation is the international standard for calibration laboratories, ISO/IEC 17025 "General Requirements for the Competence of Calibration and Testing Laboratories". Defined and documented measurement assurance techniques or uncertainty analyses are used to verify the adequacy of the measurement processes.

Calibrations are performed with standards whose values and measurements are traceable to the National Institute of Standards and Technology. MTS Reference Force Transducers are calibrated in compliance with ASTM E74.

When parameter(s) are certified to be within specified tolerance(s), the measured value(s) shall fall within the appropriate specification limit and the uncertainty of the measured value(s) shall be stated and provided to the customer for evaluation.

CALIBRATION INFORMATION

As Found: In Tolerance — Max. Error As Found: -0.62 % — Calibration Date: 3-Sep-09
As Left: In Tolerance — Max. Error As Left: -0.42 % — Calibration Due: 3-Sep-10
Tolerance: +/-1.0% of Applied Force
Calibration Procedure: FS-CA 2122 Rev. A — ASTM E4-09
Full Scale Ranges: 400000 lbf, 100000 lbf
Note:

STANDARDS USED FOR CALIBRATION

MTS Asset Number	Manufacturer	Model Number	Description	Cal. Date	Cal. Due
16120	Interface Inc.	9840	Interface Box	23-Sep-08	23-Sep-09
17140	Fluke	189	DMM	6-Jul-09	6-Jul-10
15216	FLUKE	80T-150U	TEMP PROBE	23-Sep-08	23-Sep-09
16197	Interface	CX-0330-1	Standarizer	23-Sep-08	23-Sep-09
18178	Strainsense	500 Kip	500 Kip Load Cell	18-May-09	18-May-10
18178_1	Strainsense	500 kip	500kip load cell	18-May-09	18-May-10

Certified by: [signature]

Issued on: 3-Sep-09

ACS Version: 7.02

ACSRepRevU
GLD 14-Jul-09

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

 CALIBRATION CERT #1145.01

Customer

Name: Wiss, Janney, Elstner Associates, Inc.
Report Number: 2394-4590
System: Tinius Olsen 114585
Site: 508308
System ID: Tinius Olsen 114585
Location: Structural Lab
Country Code: USA

Equipment

Device Type: Force Model: REVERE_400KIP Serial No.: 665148
Controller/Conditioner Model: 493.21B Serial No.: 1070201
Readout Device Model: 493.21B Serial No.: 1070201 Channel: Force

Procedure

MTS Procedure: FS-CA 2122 Rev. A ACS Version: 7.02
Calibration has been performed in accordance with: ASTM E4-09
Method of Verification: Set-the-Force Method using Elastic Calibration Devices

Calibration Equipment Asset No.

Dead Weight Set: HighLevel Board: LowLevel Board: Standard Asset No.: 18178
DW Compensation: DMM: 17140 Digital Indicator: 16120 Lower Limit: 28990 lbf
Temperature Readout: 15216 Additional Equipment: Standardizer: 16197

Conditions

Ambient Temperature: 72.70 °F Polarity(+): Tension Bidirectional: Cable Length: 25 Feet

In Tolerance [X]
Out of Tolerance [ ]
As Found: [ ]
As Adjusted: [X]
Tolerance: +/-1.0% of Applied Force
As Found System Condition: **Good**

Conditioner Parameters

Excitation: 10.0000 Delta K: 1.0017 Zero Offset: 0.0000 Multiplier: Cal Res: kohms
Shunt Cal: Positive: -290914 Negative: Range Gain: PreAmp Gain: 260 Post Amp/FineGain: 1.29016 Polarity: Inverted

Calibration Data

Compression Range: 1
Resolution: 210 **Full Scale:** 400000
Report Units: lbf

Applied Percent of Full Scale Force	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	0.0	-63.0	0.0	0.00	63.0	-0.02	0.0	-48.0	0.0	0.00	48.0	-0.01	0.00	0.00
-20	-80029.0		29.0	0.04			-80035.0		35.0	0.04			0.01	
-40	-159960.0		40.0	-0.03			-159960.0		40.0	-0.03			0.00	
-60	-239810.0		190.0	-0.08			-239800.0		200.0	-0.08			0.00	
-80	-319590.0		410.0	-0.13			-319590.0		410.0	-0.13			0.00	
-100	-399260.0		740.0	-0.19			-399250.0		750.0	-0.19			0.00	

Tension Range: 1
Report Units: lbf

Applied Percent of Full Scale Force	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	0.0	125.0	0.0	0.00	125.0	0.03	0.0	69.0	0.0	0.00	69.0	0.02	0.00	0.01
20	79929.0		71.0	-0.09			79898.0		102.0	-0.13			0.04	
40	159980.0		20.0	-0.01			159950.0		50.0	-0.03			0.02	
60	240120.0		120.0	0.05			240080.0		80.0	0.03			0.02	
80	320330.0		330.0	0.10			320280.0		280.0	0.09			0.02	
100	400680.0		680.0	0.17			400630.0		630.0	0.16			0.01	

Errors at Zero are computed in % of Range.
Uncertainty of the data supplied is equal to or less than ±0.25% of reading for a confidence level of 95%.
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American Association of Laboratory Accreditation Certificate Number: 1145.01
MTS Reference Force Transducers are temperature compensated over the range of use.

Out of Tolerance in % column

Notes:

Performed By: James Rieder Field Service Engineer Date: 3-Sep-09

Signature: Next Customer Agreed Upon Calibration Date: 3-Sep-10

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GLD 14-Jul-09

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

 CALIBRATION CERT #1145.01

Customer Name: Wiss, Janney, Elstner Associates, Inc. Report Number: 2394-4590
System: Tinius Olsen 114585 Site: 508308
System ID: Tinius Olsen 114585 Location: Structural Lab Country Code: USA

Equipment
Device Type: Force Model: REVERE_400KIP Serial No.: 665148
Controller/Conditioner Model: 493.21B Serial No.: 1070201
Readout Device Model: 493.21B Serial No.: 1070201 Channel: Force

Procedure
MTS Procedure: FS-CA 2122 Rev. A ACS Version: 7.02
Calibration has been performed in accordance with: ASTM E4-09
Method of Verification: Set-the-Force Method using Elastic Calibration Devices

Calibration Equipment Asset No.
Dead Weight Set: HighLevel Board: LowLevel Board: Standard Asset No.: 18178
DW Compensation: DMM: 17140 Digital Indicator: 16120 Lower Limit: 28990 lbf
Temperature Readout: 15216 Additional Equipment: Standardizer: 16197

Conditions
Ambient Temperature: 0.00 °F Polarity(+): Tension Bidirectional: Cable Length: 25 Feet

In Tolerance	X	**As Found:**	X
Out of Tolerance		**As Adjusted:**	

Tolerance: +/-1.0% of Applied Force
As Found System Condition: Good

Conditioner Parameters
Excitation: 10.0000 Delta K: 0.9963 Zero Offset: 0.0000 Multiplier: Cal Res: kohms
Shunt Cal: Positive: -290914 Negative: Range Gain: PreAmp Gain: 260 Post Amp/FineGain: 1.29141 Polarity: Inverted

Calibration Data Range: 1
Compression Resolution: 210 Full Scale: 400000
Report Units: lbf

Applied Percent of Full Scale Force	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	0.0	-106.0	0.0	0.00	106.0	-0.03	0.0	-48.0	0.0	0.00	48.0	-0.01	0.00	0.01
-20	-79706.0		294.0	-0.37			-79691.0		309.0	-0.39			0.02	
-40	-159280.0		720.0	-0.45			-159260.0		740.0	-0.46			0.01	
-60	-238790.0		1210.0	-0.50			-238730.0		1270.0	-0.53			0.03	
-80	-318210.0		1790.0	-0.56			-318220.0		1780.0	-0.56			0.00	
-100	-397520.0		2480.0	-0.62			-397510.0		2490.0	-0.62			0.00	

Tension Range: 1
Report Units: lbf

Applied Percent of Full Scale Force	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	0.0	130.0	0.0	0.00	130.0	0.03	0.0	74.0	0.0	0.00	74.0	0.02	0.00	0.01
20	79998.0		2.0	0.00			79977.0		23.0	-0.03			0.03	
40	160120.0		120.0	0.08			160080.0		80.0	0.05			0.03	
60	240330.0		330.0	0.14			240290.0		290.0	0.12			0.02	
80	320620.0		620.0	0.19			320580.0		580.0	0.18			0.01	
100	401070.0		1070.0	0.27			401000.0		1000.0	0.25			0.02	

Errors at Zero are computed in % of Range.
Uncertainty of the data supplied is equal to or less than ±0.25% of reading for a confidence level of 95%.
Out of Tolerance in % column

Calibrations are performed with standards whose values and measurements are traceable to the National Institute of Standards and Technology.
American Association of Laboratory Accreditation Certificate Number: 1145.01
MTS Reference Force Transducers are temperature compensated over the range of use.

Notes:

Performed By: James Rieder Field Service Engineer Date: 3-Sep-09

Signature: [signature] Next Customer Agreed Upon Calibration Date: 3-Sep-10

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GLD 14-Jul-09

MTS

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

CALIBRATION CERT #1145.01

Customer

Name: Wiss, Janney, Elstner Associates, Inc.
Report Number: 2394-4590
System: Tinius Olsen 114585
Site: 508308
System ID: Tinius Olsen 114585
Location: Structural Lab
Country Code: USA

Equipment

Device Type: Force
Model: REVERE_400KIP
Serial No.: 665148
Controller/Conditioner Model: 493.21B
Serial No.: 1070201
Readout Device Model: 493.21B
Serial No.: 1070201
Channel: Force

Procedure

MTS Procedure: FS-CA 2122 Rev. A
ACS Version: 7.02
Calibration has been performed in accordance with: ASTM E4-09
Method of Verification: Set-the-Force Method using Elastic Calibration Devices

Calibration Equipment Asset No.

Dead Weight Set:
HighLevel Board:
LowLevel Board:
Standard Asset No.: 18178_1
DW Compensation:
DMM: 17140
Digital Indicator: 16120
Lower Limit: 10000 lbf
Temperature Readout: 15216
Additional Equipment:
Standardizer: 16197

Conditions

Ambient Temperature: 72.30 °F
Polarity(+): Tension
Bidirectional:
Cable Length: 25 Feet

In Tolerance [X]
Out of Tolerance [ ]
As Found: [X]
As Adjusted: [ ]
Tolerance: +/-1.0% of Applied Force
As Found System Condition: Good

Conditioner Parameters

Excitation: 10.0000
Delta K: 1.0012
Zero Offset: 0.0000
Multiplier:
Cal Res: kohms
Shunt Cal: Positive:
Negative:
Range Gain:
PreAmp Gain: 260
Post Amp/FineGain: 5.15438
Polarity: Inverted

Calibration Data

Compression
Range: 2
Resolution: 21.6
Full Scale: 100000
Report Units: lbf

Applied Percent of Full Scale Force	Series 1		Series 1 Errors				Series 2		Series 2 Errors				Repeatability Percent Error	
	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Asc	Desc
0	0.0	-41.6	0.0	0.00	41.6	-0.04	0.0	-35.0	0.0	0.00	35.0	-0.04	0.00	0.01
-20	-19957.0		43.0	-0.22			-19948.0		52.0	-0.26			0.05	
-40	-39902.0		98.0	-0.25			-39897.0		103.0	-0.26			0.01	
-60	-59853.0		147.0	-0.25			-59839.0		161.0	-0.27			0.02	
-80	-79802.0		198.0	-0.25			-79791.0		209.0	-0.26			0.01	
-100	-99744.0		256.0	-0.26			-99727.0		273.0	-0.27			0.02	

Tension
Range: 2
Report Units: lbf

Applied Percent of Full Scale Force	Series 1		Series 1 Errors				Series 2		Series 2 Errors				Repeatability Percent Error	
	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Asc	Desc
0	0.0	38.5	0.0	0.00	38.5	0.04	0.0	17.3	0.0	0.00	17.3	0.02	0.00	0.02
20	19919.0		81.0	-0.41			19919.0		81.0	-0.41			0.00	
40	39838.0		162.0	-0.41			39833.0		167.0	-0.42			0.01	
60	59759.0		241.0	-0.40			59758.0		242.0	-0.40			0.00	
80	79701.0		299.0	-0.37			79686.0		314.0	-0.39			0.02	
100	99634.0		366.0	-0.37			99630.0		370.0	-0.37			0.00	

Errors at Zero are computed in % of Range.
Uncertainty of the data supplied is equal to or less than ±0.25% of reading for a confidence level of 95%.
Out of Tolerance in % column
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American Association of Laboratory Accreditation Certificate Number: 1145.01
MTS Reference Force Transducers are temperature compensated over the range of use.

Notes:

Performed By: James Rieder
Field Service Engineer
Date: 3-Sep-09

Signature: [signature]

Next Customer Agreed Upon Calibration Date: 3-Sep-10

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GLD 14-Jul-09

MTS Systems Corporation

14000 Technology Drive
Eden Prairie, MN 55344-2290

CALIBRATION CERT #1145.01

MTS Field Service

Certificate of Calibration

Customer

Name: Wiss, Janney, Elstner Associates, Inc.
Certificate Number: 2394-4591
System: Tinius Olsen 114585
Site: 508308
System ID: Tinius Olsen 114585
Location: Structural Lab
Country Code: USA

Equipment

Device Type: Length
Model: COLLINS_LVDT
Serial No.: 572988
Controller/Conditioner Model: 493.21B
Serial No.: 10-70206
Readout Device Model: 493.21B
Serial No.: 10-70206
Channel: Displacement

MTS Field Service is accredited by the American Association for Laboratory Accreditation (A2LA Cert. No. 1145.01). The basis for this accreditation is the international standard for calibration laboratories, ISO/IEC 17025 "General Requirements for the Competence of Calibration and Testing Laboratories". Defined and documented measurement assurance techniques or uncertainty analyses are used to verify the adequacy of the measurement processes.

Calibrations are performed with standards whose values and measurements are traceable to the National Institute of Standards and Technology.

When parameter(s) are certified to be within specified tolerance(s), the measured value(s) shall fall within the appropriate specification limit and the uncertainty of the measured value(s) shall be stated and provided to the customer for evaluation.

CALIBRATION INFORMATION

As Found: In Tolerance
Max. Error As Found: 0.10 %
Calibration Date: 3-Sep-09
As Left: In Tolerance
Max. Error As Left: 0.10 %
Calibration Due: 3-Sep-10
Tolerance: +/-1.0% of Range
Calibration Procedure: FS-CA 2124 Rev. A
Full Scale Ranges: 6 inch
Note:

STANDARDS USED FOR CALIBRATION

MTS Asset Number	Manufacturer	Model Number	Description	Cal. Date	Cal. Due
17140	Fluke	189	DMM	6-Jul-09	6-Jul-10
15216	FLUKE	80T-150U	TEMP PROBE	23-Sep-08	23-Sep-09
19739	Boeckeler (9 pin)	DLG 460	Digital Linear Scale	12-Jan-09	12-Jan-10

Certified by: [signature]

Issued on: 3-Sep-09

ACS Version: 7.02

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MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

 CALIBRATION CERT #1145.01

Customer Name: Wiss, Janney, Elstner Associates, Inc.
Report Number: 2394-4591
System: Tinius Olsen 114585
Site: 508308
System ID: Tinius Olsen 114585 Location: Structural Lab
Country Code: USA

Equipment

Device Type: Length Model: COLLINS_LVDT Serial No.: 572988
Controller/Conditioner Model: 493.21B Serial No.: 10-70206
Readout Device Model: 493.21B Serial No.: 10-70206 Channel: Displacement

Procedure

MTS Procedure: FS-CA 2124 Rev. A ACS Version: 7.02
Calibration has been performed in accordance with: (none)
Method of Verification:

Calibration Equipment Asset No.

Dead Weight Set: HighLevel Board: LowLevel Board: Standard Asset No.: 19739
DW Compensation: DMM: 17140 Digital Indicator: Lower Limit:
Temperature Readout: 15216 Additional Equipment: Standardizer:

Conditions

Ambient Temperature: 72.80 °F Polarity(+): Retraction Bidirectional: Cable Length: 25 Feet

In Tolerance X **As Found:** X **Tolerance: +/-1.0% of Range**
Out of Tolerance **As Adjusted:** **As Found System Condition:** **Good**

Conditioner Parameters

Excitation: 10.0002 Delta K: 1.0021 Zero Offset: 0.0000 Multiplier: Phase: 43.59375
Cal Factor: Positive: Negative: Range Gain: PreAmp Gain: 1 Post Amp/FineGain: 0.96883 Polarity: Inverted

Calibration Data Range: 1
Extension Resolution: 0.012 Full Scale: 6
Report Units: inch 0.0000

Applied Percent of Full Scale Length	Series 1		Series 1 Errors				Series 2		Series 2 Errors				Repeatability Percent Error	
	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Asc	Desc
0	0.00000	-0.00023	0.00000	0.00	0.00023	0.00								
-10	-0.60105		0.00105	0.02										
-20	-1.20210		0.00210	0.04										
-40	-2.40600		0.00600	0.10										
-50	-3.00190		0.00190	0.03										
-60	-3.60560		0.00560	0.09										

Retraction Range: 1
Report Units: inch

Applied Percent of Full Scale Length	Series 1		Series 1 Errors				Series 2		Series 2 Errors				Repeatability Percent Error	
	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Asc	Desc
0	0.00000	-0.00001	0.00000	0.00	0.00001	0.00								
10	0.59798		0.00202	-0.03										
20	1.19670		0.00330	-0.06										
40	2.39830		0.00170	-0.03										
50	2.99940		0.00060	-0.01										
60	3.60320		0.00320	0.05										

Errors at Zero are computed in % of Range.
Uncertainty of the calibration data supplied is equal to or less than the greater of, ±0.25% of reading or ±50μ inches, for a confidence level of 95%.
Out of Tolerance in % column
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Calibrations are performed with standards whose values and measurements are traceable to the National Institute of Standards and Technology.
American Association of Laboratory Accreditation Certificate Number: 1145.01

Notes:

Performed By: James Rieder Field Service Engineer Date: 3-Sep-09

Signature: Next Customer Agreed Upon Calibration Date: 3-Sep-10

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APPENDIX C
Control Bar Load-Elongation Curves

Test I.D. No.	Bar Size	Bar Lot	Bar Area (mm^2)	Yield Strength, R_{eH}		Yield Strain, ε_{ya} (percent)	Tensile Strength		A_{gt} (percent)	A_5 (percent)
				(kN)	(MPa)		(kN)	(MPa)		
3774	20	A	314	159.0	506.4	0.33%	191.2	608.9	9%	20%

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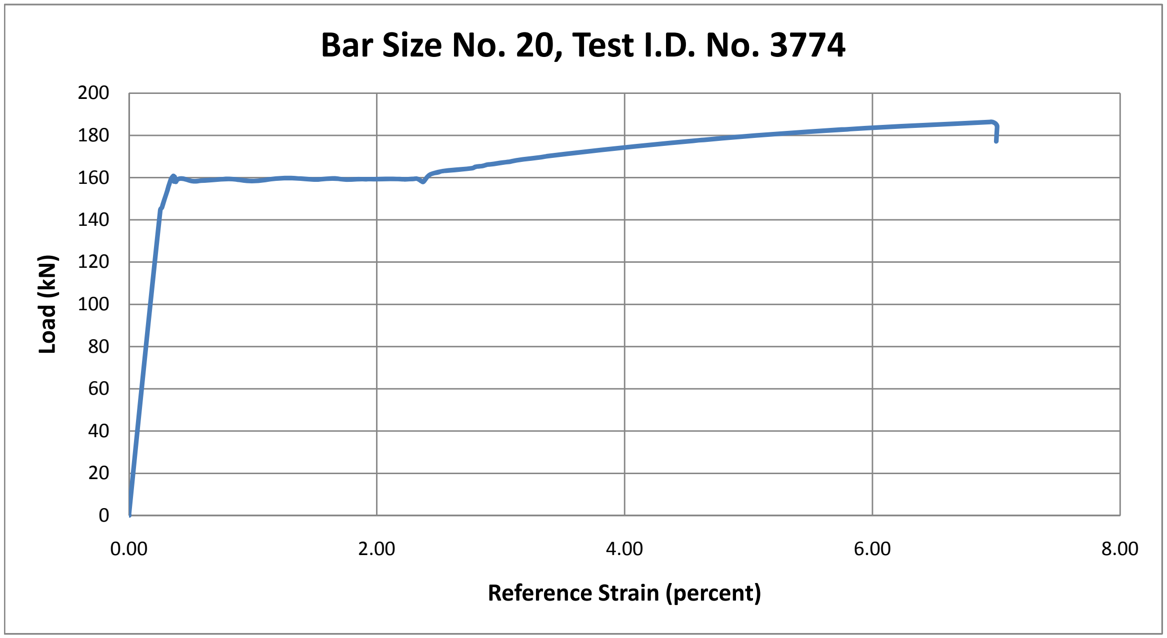

ISO 15835 Tensile Test
BS4449 Grade 460B
2009.5202
Northbrook, IL
SKG
12/22/2009
ISO 15835

Test I.D. No.	Bar Size	Bar Lot	Bar Area (mm^2)	Yield Strength, R_{eH}		Yield Strain, ε_{ya} (percent)	Tensile Strength		A_{gt} (percent)	A_5 (percent)
				(kN)	(MPa)		(kN)	(MPa)		
3770	32	A	804	391.0	486.3	0.30%	507.4	631.1	10%	25%

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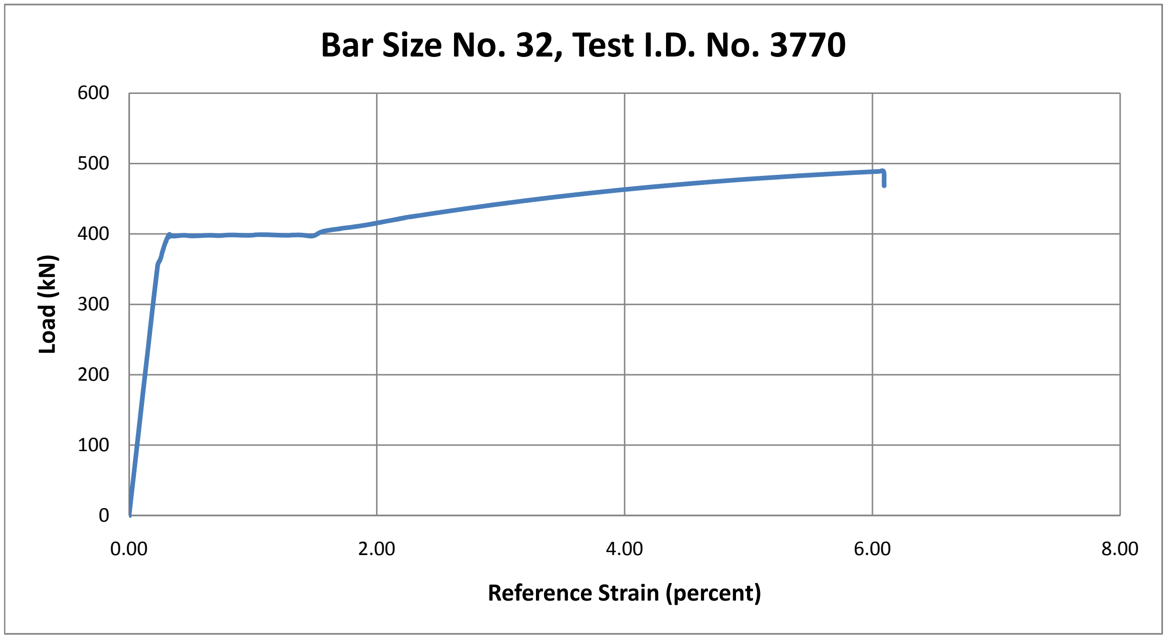

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12/22/2009
ISO 15835

Test I.D. No.	Bar Size	Bar Lot	Bar Area (mm^2)	Yield Strength, R_{eH}		Yield Strain, ε_{ya} (percent)	Tensile Strength		A_{gt} (percent)	A_5 (percent)
				(kN)	(MPa)		(kN)	(MPa)		
3769	40	A	1257	603.0	479.7	0.32%	793.7	631.4	11%	20%

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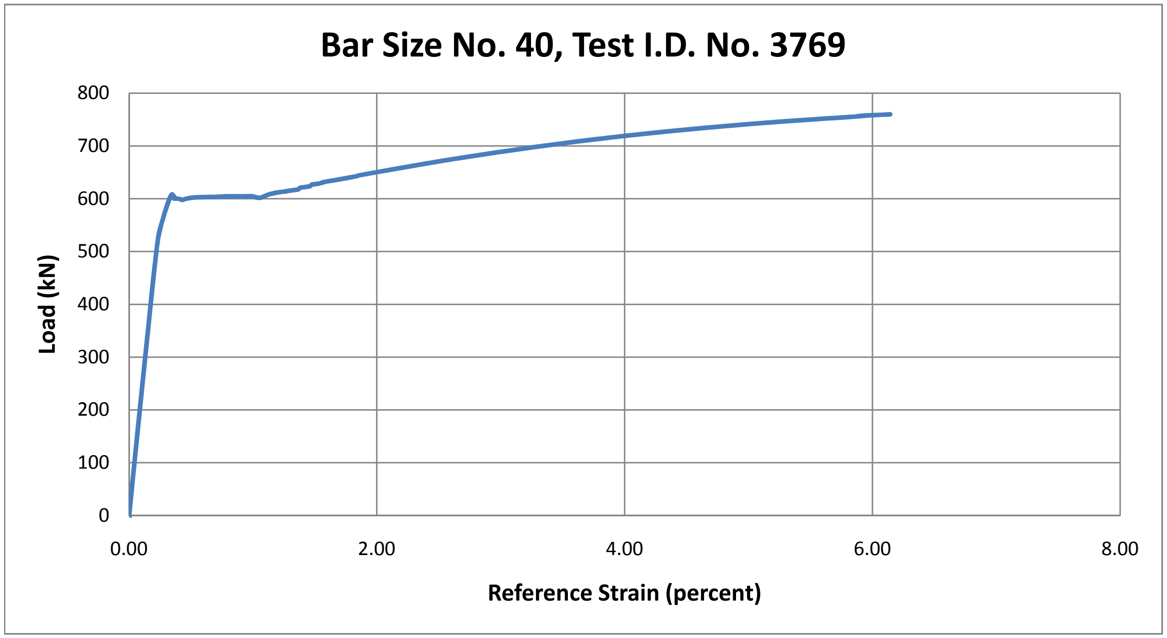

ISO 15835 Tensile Test
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SKG
12/22/2009
ISO 15835

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APPENDIX D
Splice Specimens Load-Slip Curves for Category B TensileTesting Protocol

Test I.D. No.	Bar Size	Bar Lot	Bar Area (mm^2)	Tensile Strength		A_{gt} (percent)	Final Result
				(kN)	(MPa)		
3775	20	A	314	191.8	610.7	10%	Bar break

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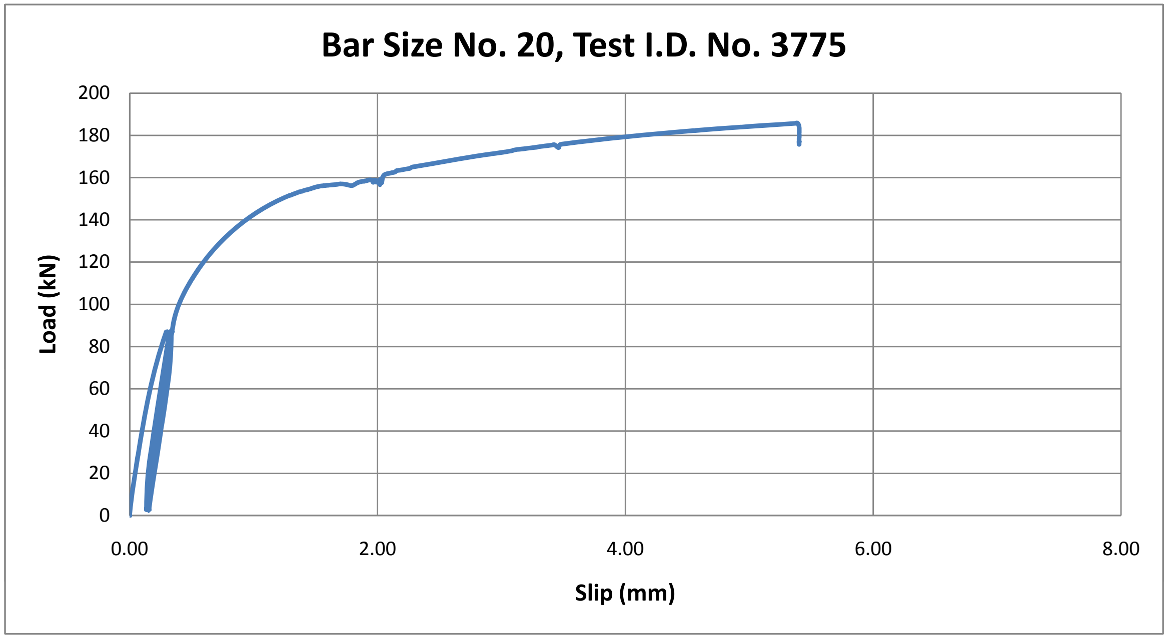
www.wje.com



ISO 15835 Category B Tensile Test
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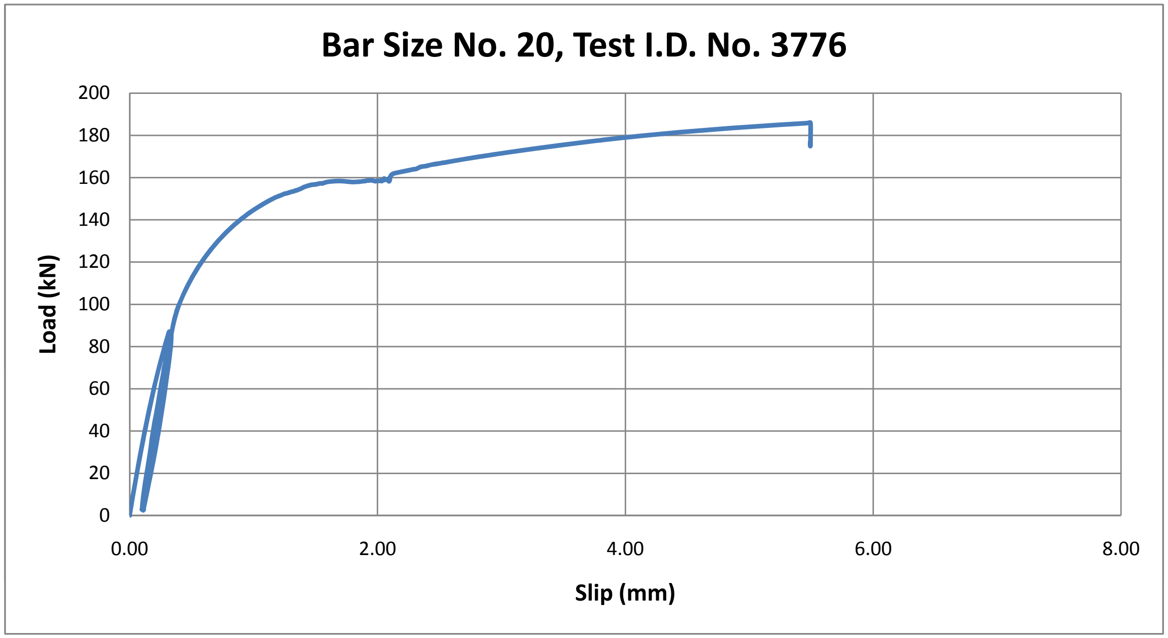
12/22/2009
ISO 15835

Test I.D. No.	Bar Size	Bar Lot	Bar Area (mm^2)	Tensile Strength		A_{gt} (percent)	Final Result
				(kN)	(MPa)		
3776	20	A	314	190.8	607.6	11%	Bar break



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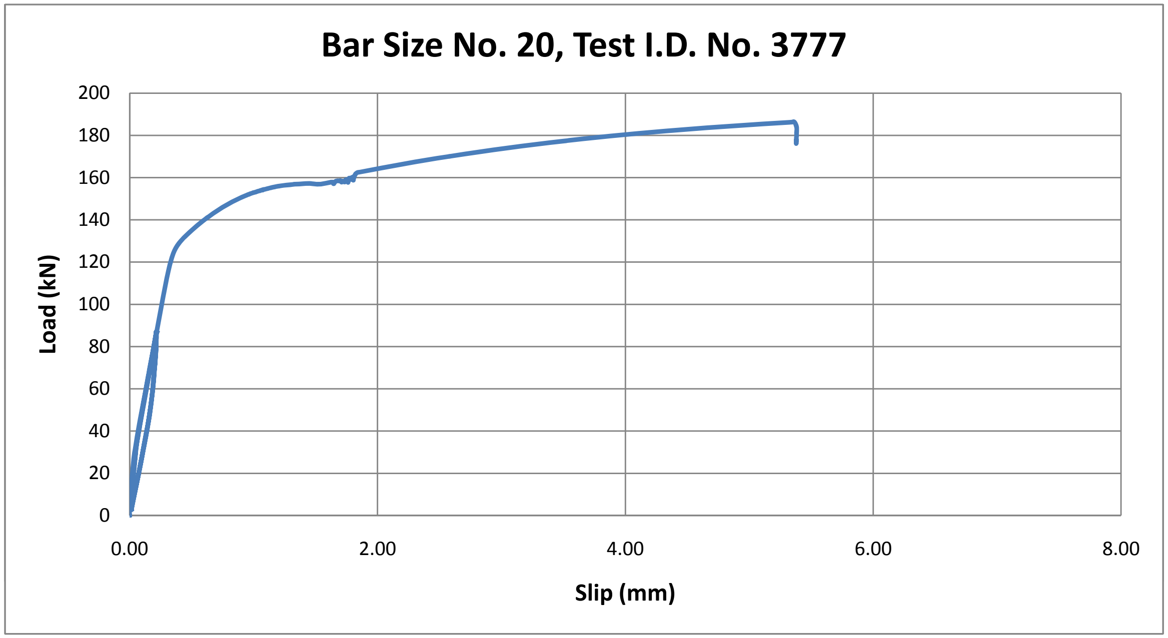
12/22/2009
ISO 15835

Test I.D. No.	Bar Size	Bar Lot	Bar Area (mm^2)	Tensile Strength		A_{gt} (percent)	Final Result
				(kN)	(MPa)		
3777	20	A	314	191.7	610.5	11%	Bar break



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ISO 15835

Test I.D. No.	Bar Size	Bar Lot	Bar Area (mm^2)	Tensile Strength		A_{gt} (percent)	Final Result
				(kN)	(MPa)		
3760	32	A	804	506.8	630.3	12%	Bar break

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

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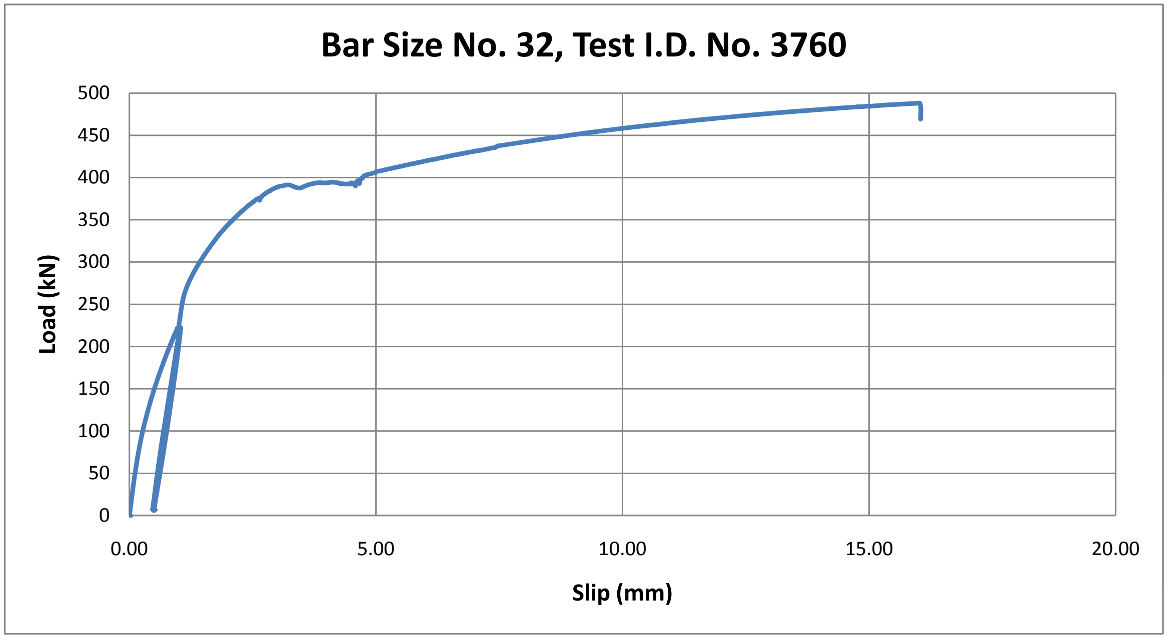

ISO 15835 Category B Tensile Test
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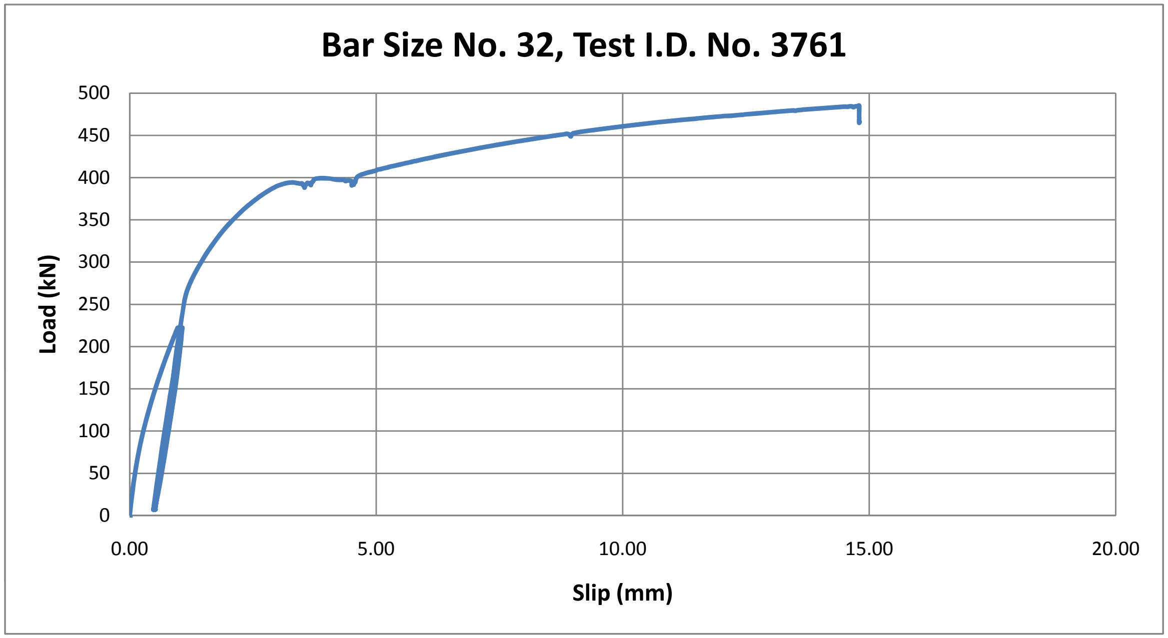
12/21/2009
ISO 15835

Test I.D. No.	Bar Size	Bar Lot	Bar Area (mm^2)	Tensile Strength		A_{gt} (percent)	Final Result
				(kN)	(MPa)		
3761	32	A	804	506.8	630.3	15%	Bar break



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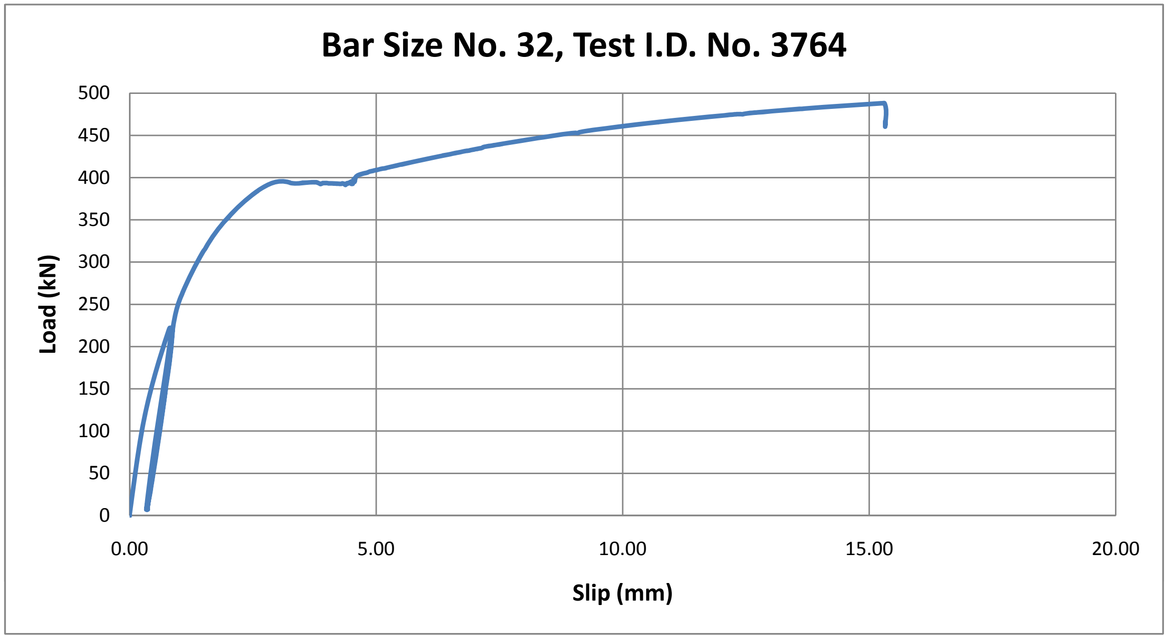
Test I.D. No.	Bar Size	Bar Lot	Bar Area (mm^2)	Tensile Strength		A_{gt} (percent)	Final Result
				(kN)	(MPa)		
3764	32	A	804	507.7	631.5	11%	Bar break



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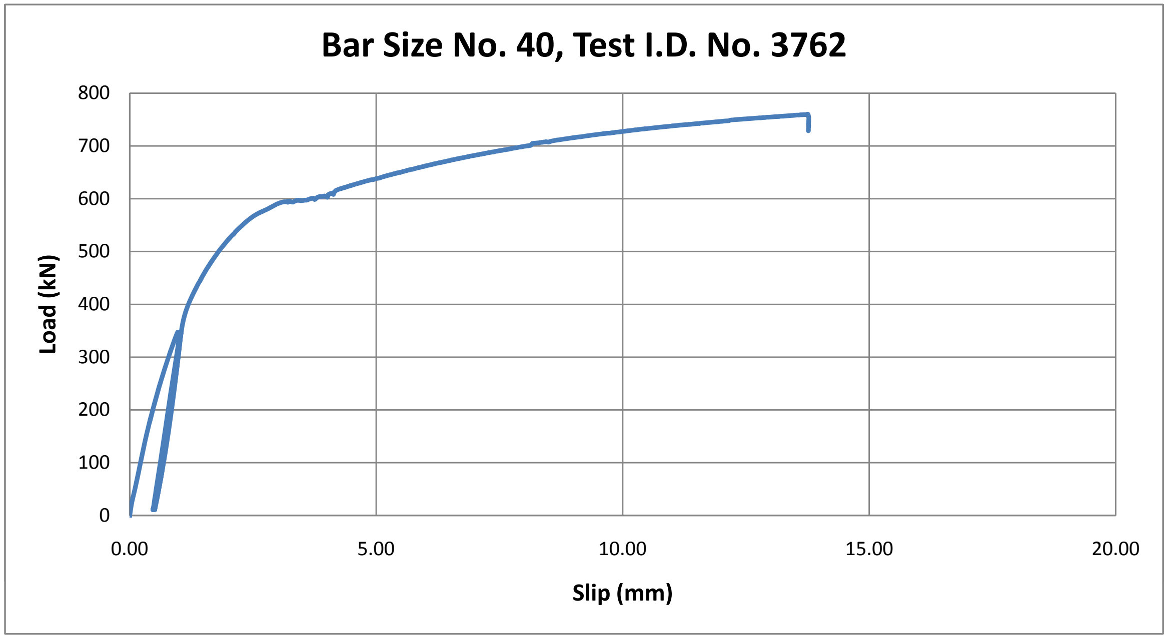
Test I.D. No.	Bar Size	Bar Lot	Bar Area (mm^2)	Tensile Strength		A_{gt} (percent)	Final Result
				(kN)	(MPa)		
3762	40	A	1257	788.1	627.0	10%	Bar break



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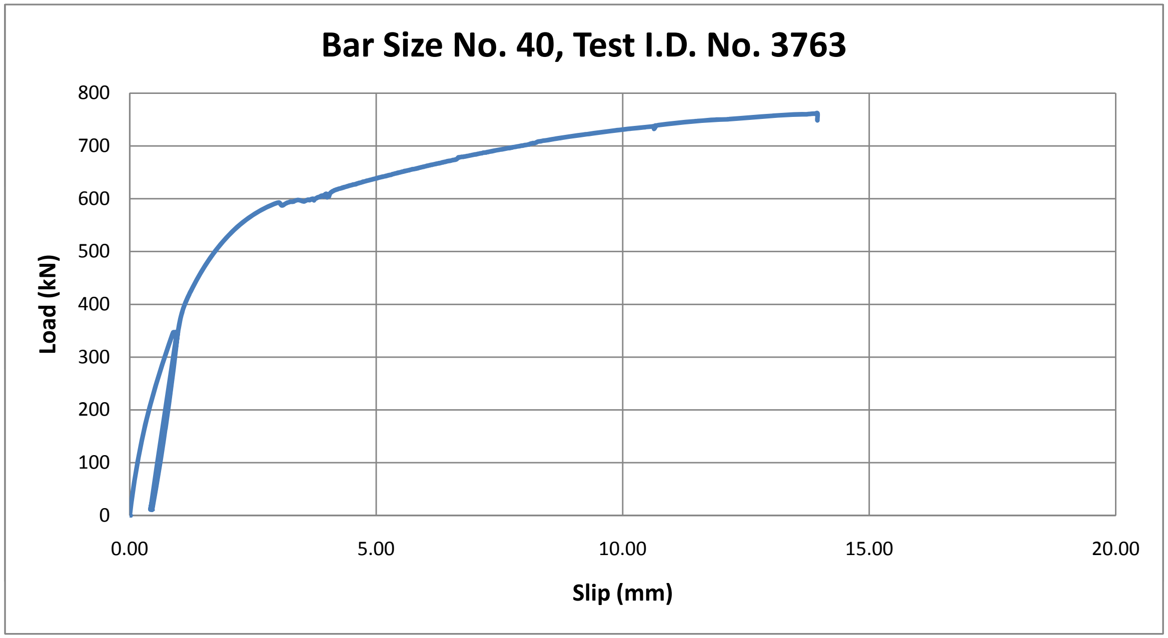
				(kN)	(MPa)		
3763	40	A	1257	789.8	628.3	10%	Bar break



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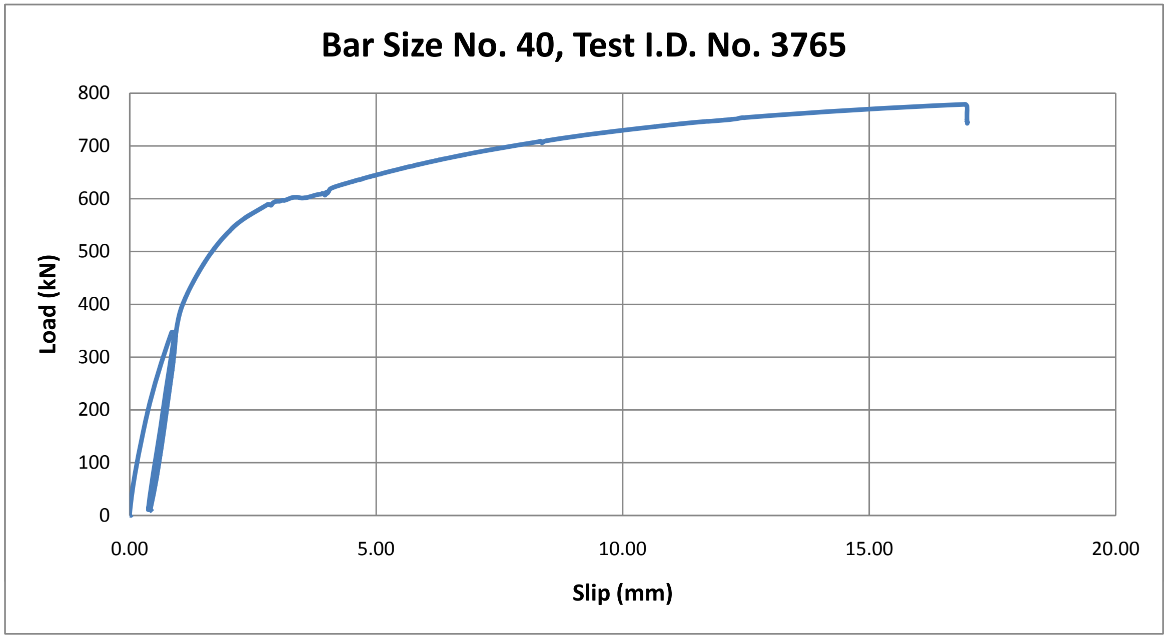
Test I.D. No.	Bar Size	Bar Lot	Bar Area (mm^2)	Tensile Strength		A_{gt} (percent)	Final Result
				(kN)	(MPa)		
3765	40	A	1257	793.1	630.9	10%	Bar break



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APPENDIX E
Splice Specimens Load-Slip Curves for Category S2 Testing Protocol

Test I.D. Number	Bar Size (mm)	Bar Area (mm^2)	Bar Lot	Specified Bar Yield Strength ($R_{eH, spec}$) (MPa)	Stage 1 $2_{\varepsilon y}L_g$ Cycles Applied	Stage 2 $5_{\varepsilon y}L_g$ Cycles Applied	Residual Elongation u_4 (mm)	Residual Elongation u_8 (mm)	Tensile Strength F_{max} (kN)	Tensile Strength (R_m) MPa	A_{gt} (percent)	Final Result
3778	20	314	A	460	4	4	0.02	0.12	192.3	612.4	9%	Bar break

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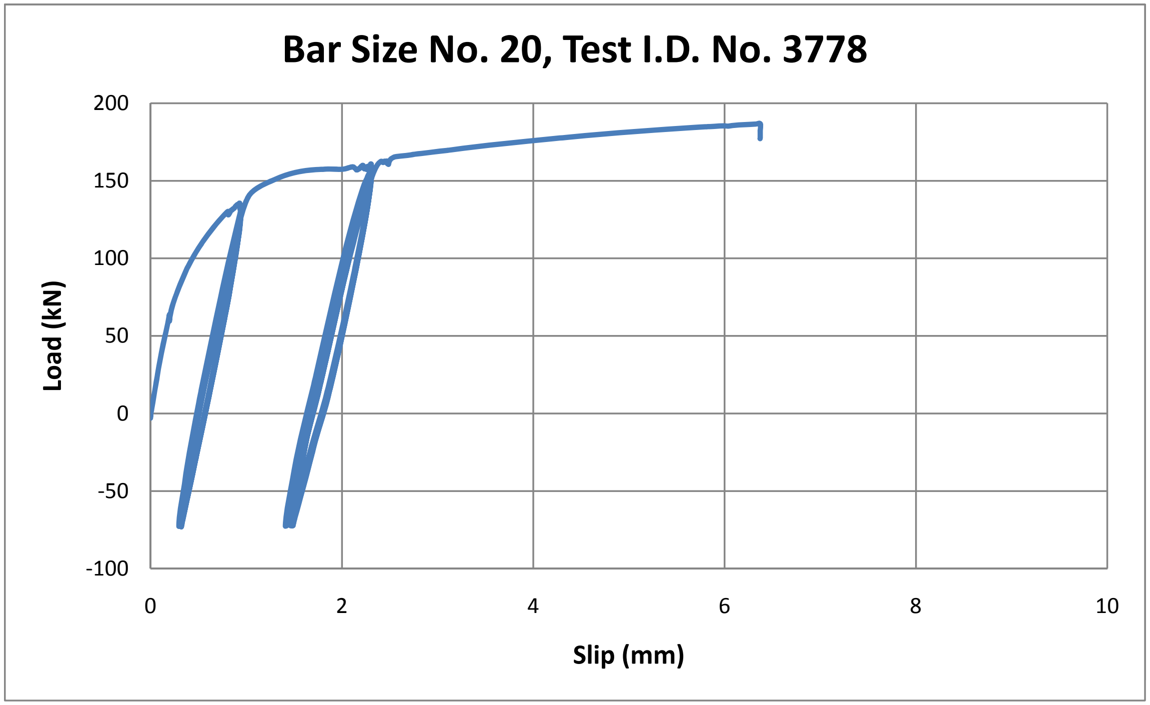

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Test I.D. Number	Bar Size (mm)	Bar Area (mm^2)	Bar Lot	Specified Bar Yield Strength ($R_{eH, spec}$) (MPa)	Stage 1 $2_{\varepsilon y}L_g$ Cycles Applied	Stage 2 $5_{\varepsilon y}L_g$ Cycles Applied	Residual Elongation u_4 (mm)	u_8 (mm)	Tensile Strength F_{max} (kN)	(R_m) MPa	A_{gt} (percent)	Final Result
3779	20	314	A	460	4	4	0.01	0.08	192.4	612.9	9%	Bar break

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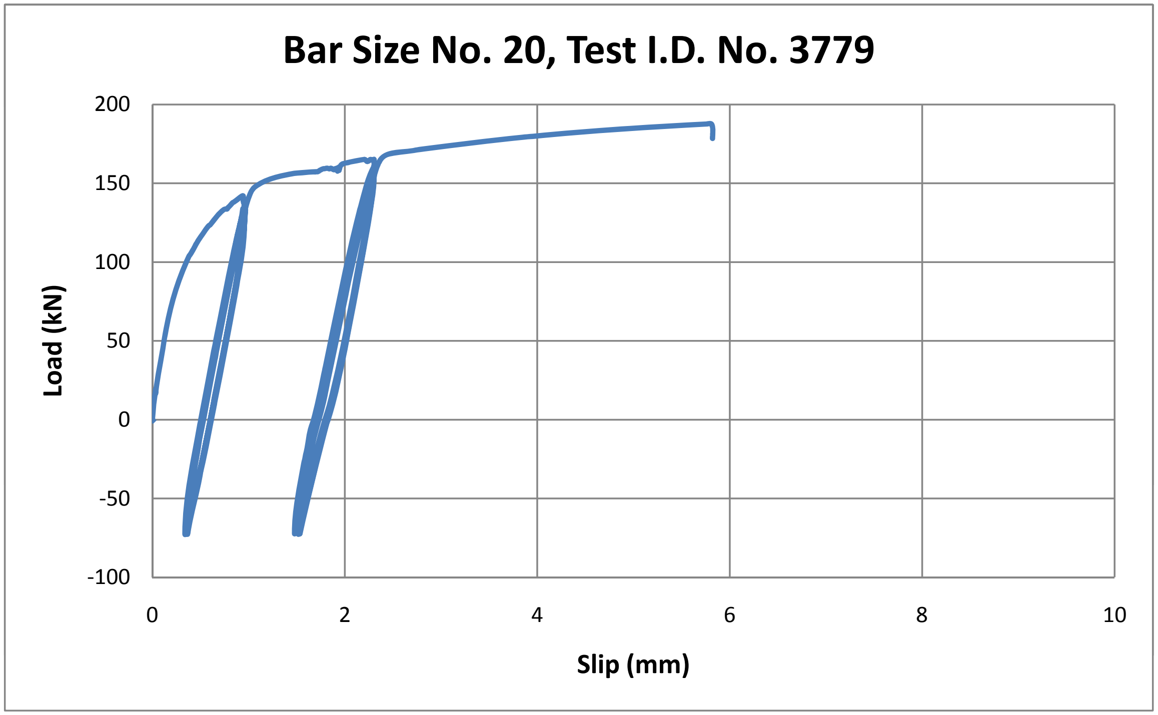

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Test I.D. Number	Bar Size (mm)	Bar Area (mm^2)	Bar Lot	Specified Bar Yield Strength ($R_{eH, spec}$) (MPa)	Stage 1 $2_{\varepsilon y}L_g$ Cycles Applied	Stage 2 $5_{\varepsilon y}L_g$ Cycles Applied	Residual Elongation u_4 (mm)	u_8 (mm)	Tensile Strength F_{max} (kN)	(R_m) MPa	A_{gt} (percent)	Final Result
3780	20	314	A	460	4	4	0.03	0.13	192.8	614.0	9%	Bar break

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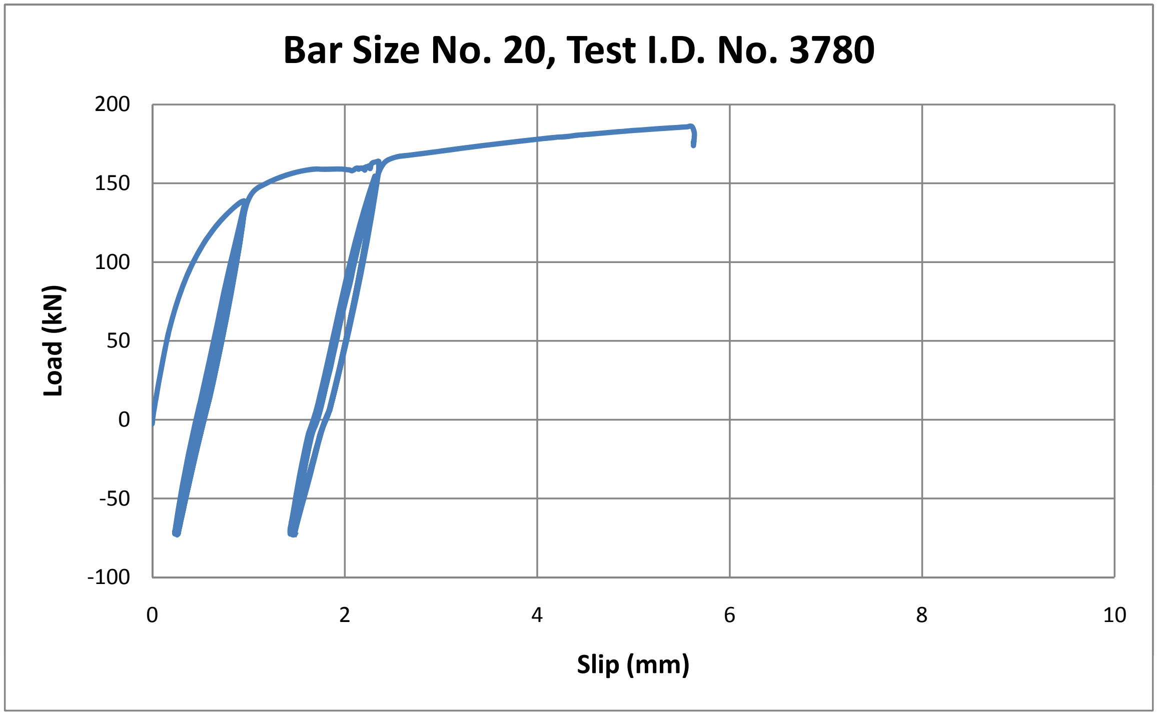

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Test I.D. Number	Bar Size (mm)	Bar Area (mm^2)	Bar Lot	Specified Bar Yield Strength ($R_{eH, spec}$) (MPa)	Stage 1 $2_{\varepsilon y}L_g$ Cycles Applied	Stage 2 $5_{\varepsilon y}L_g$ Cycles Applied	Residual Elongation u_4 (mm)	Residual Elongation u_8 (mm)	Tensile Strength F_{max} (kN)	Tensile Strength (R_m) MPa	A_{gt} (percent)	Final Result
3771	32	804	A	460	4	4	0.19	0.47	509.5	633.7	10%	Bar break

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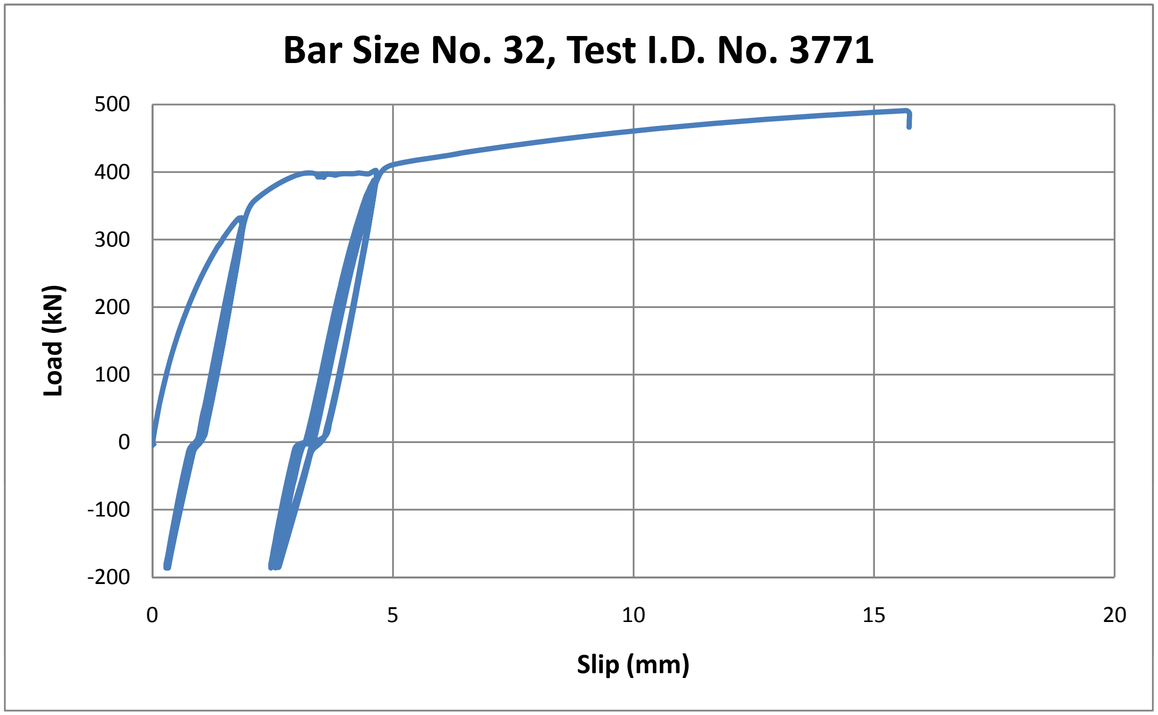

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Test I.D. Number	Bar Size (mm)	Bar Area (mm^2)	Bar Lot	Specified Bar Yield Strength ($R_{eH, spec}$) (MPa)	Stage 1 $2_{\varepsilon y}L_g$ Cycles Applied	Stage 2 $5_{\varepsilon y}L_g$ Cycles Applied	Residual Elongation u_4 (mm)	u_8 (mm)	Tensile Strength F_{max} (kN)	(R_m) MPa	A_{gt} (percent)	Final Result
3772	32	804	A	460	4	4	0.15	0.36	508.3	632.2	12%	Bar break

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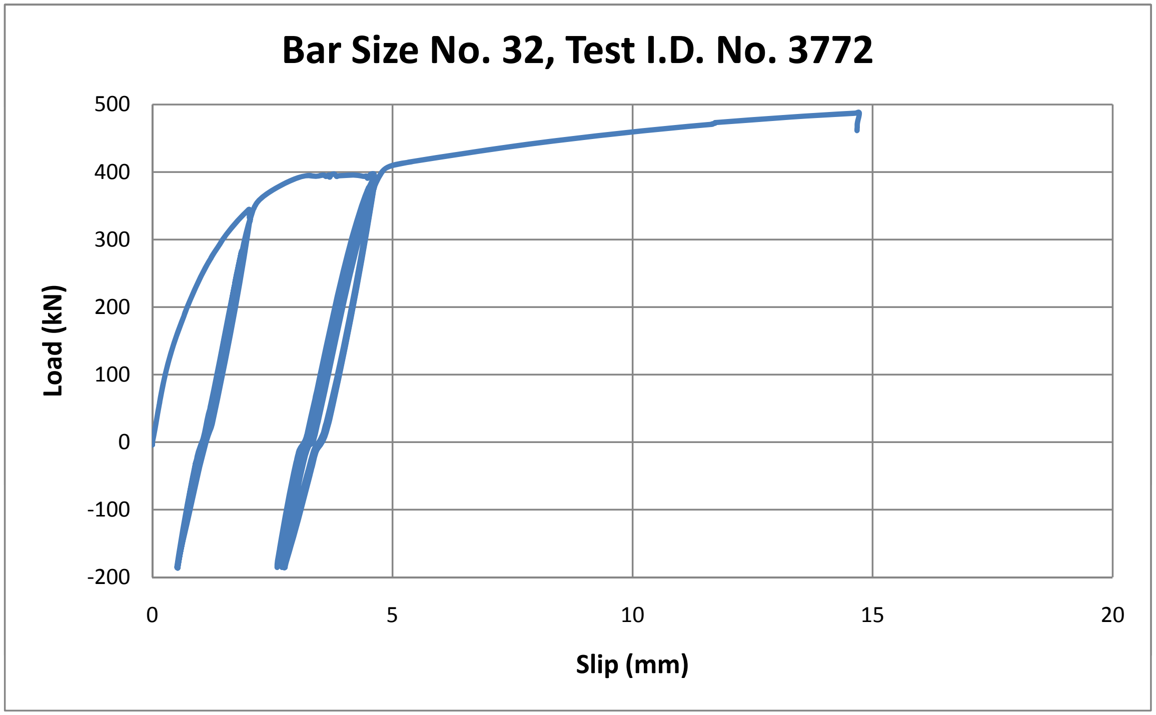

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Test I.D. Number	Bar Size (mm)	Bar Area (mm^2)	Bar Lot	Specified Bar Yield Strength ($R_{eH, spec}$) (MPa)	Stage 1 $2_{\varepsilon y}L_g$ Cycles Applied	Stage 2 $5_{\varepsilon y}L_g$ Cycles Applied	Residual Elongation u_4 (mm)	u_8 (mm)	Tensile Strength F_{max} (kN)	(R_m) MPa	A_{gt} (percent)	Final Result
3773	32	804	A	460	4	4	0.15	0.37	509.9	634.2	11%	Bar break

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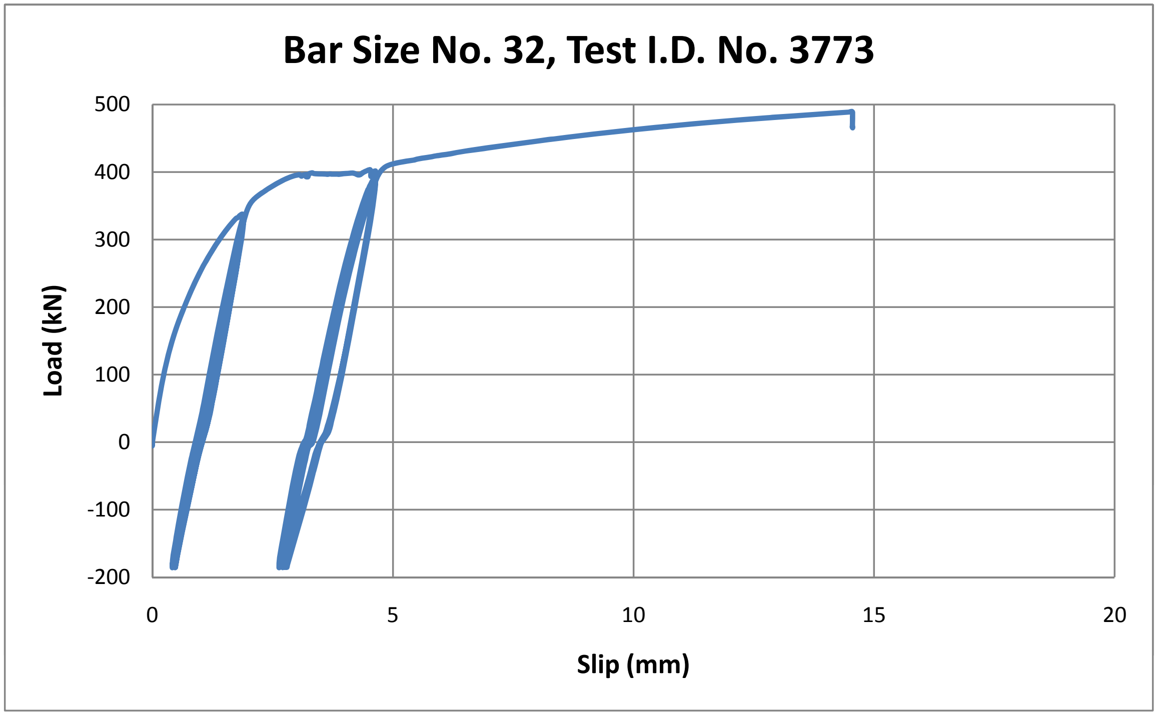

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Test I.D. Number	Bar Size (mm)	Bar Area (mm^2)	Bar Lot	Specified Bar Yield Strength ($R_{eH, spec}$) (MPa)	Stage 1 $2_{\varepsilon y}L_g$ Cycles Applied	Stage 2 $5_{\varepsilon y}L_g$ Cycles Applied	Residual Elongation		Tensile Strength		A_{gt} (percent)	Final Result
							u_4 (mm)	u_8 (mm)	F_{max} (kN)	(R_m) MPa		
3766	40	1257	A	460	4	4	0.11	0.37	784.3	623.9	10%	Bar break

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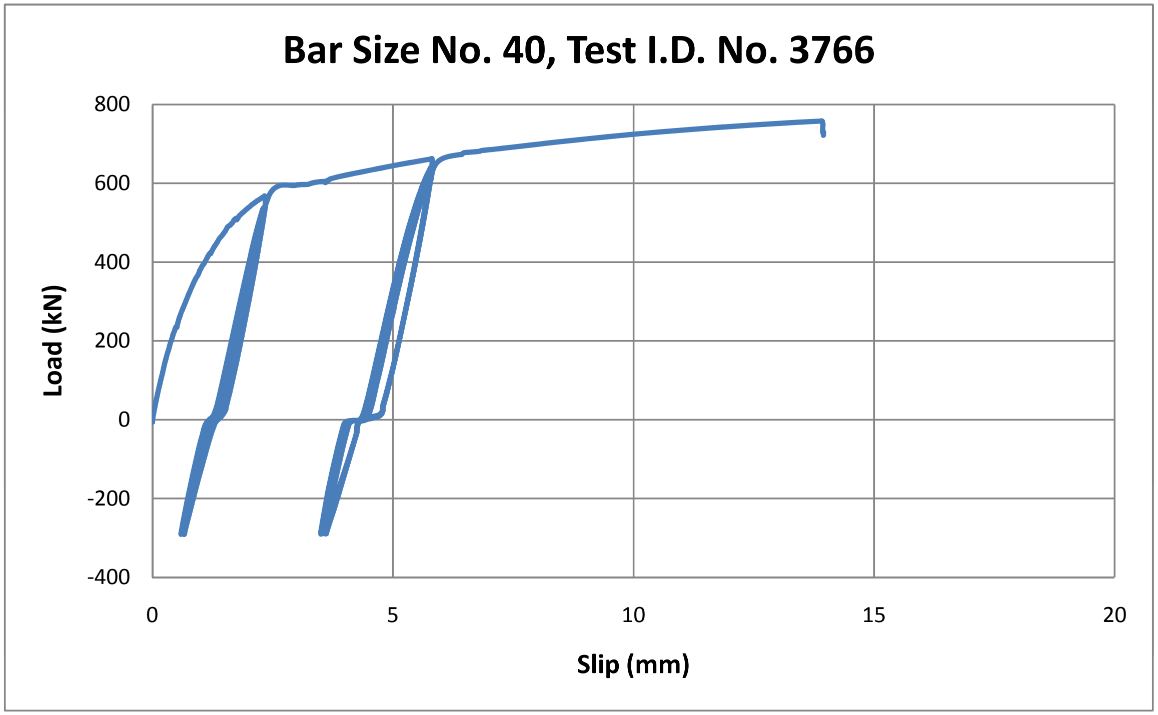

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Test I.D. Number	Bar Size (mm)	Bar Area (mm^2)	Bar Lot	Specified Bar Yield Strength ($R_{eH, spec}$) (MPa)	Stage 1 $2_{\varepsilon y}L_g$ Cycles Applied	Stage 2 $5_{\varepsilon y}L_g$ Cycles Applied	Residual Elongation u_4 (mm)	Residual Elongation u_8 (mm)	Tensile Strength F_{max} (kN)	Tensile Strength (R_m) MPa	A_{gt} (percent)	Final Result
3767	40	1257	A	460	4	4	0.20	0.47	784.3	623.9	10%	Bar break

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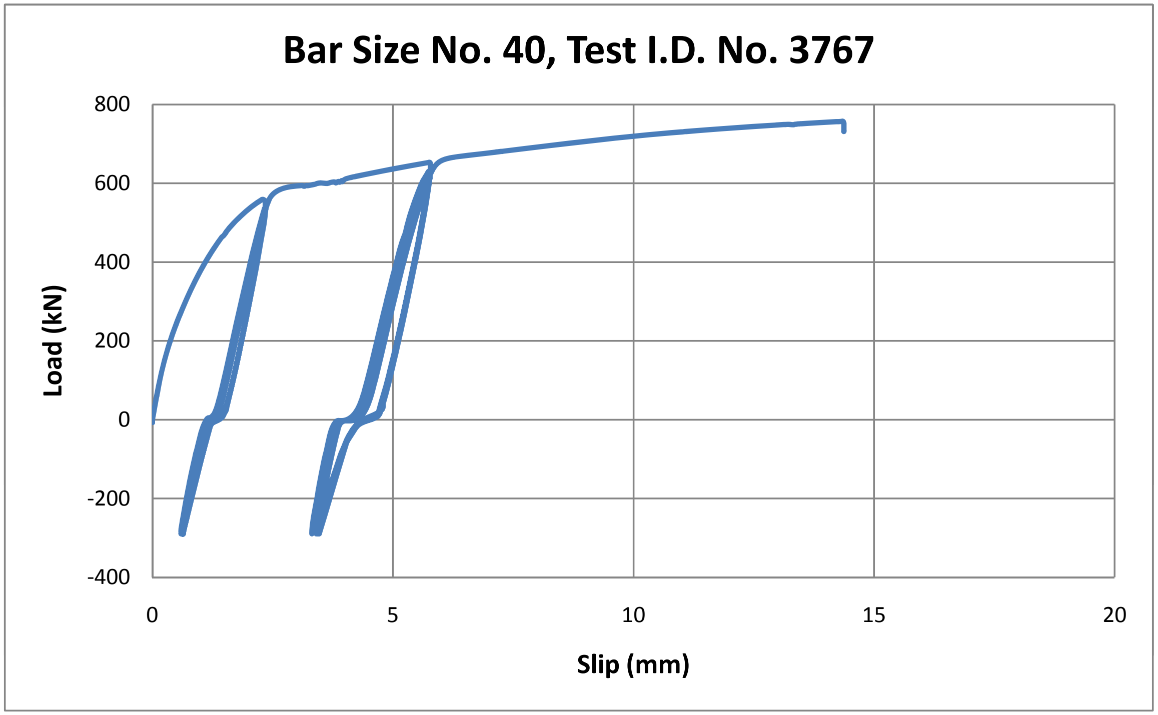

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Test I.D. Number	Bar Size (mm)	Bar Area (mm^2)	Bar Lot	Specified Bar Yield Strength ($R_{eH, spec}$) (MPa)	Stage 1 $2_{\varepsilon y}L_g$ Cycles Applied	Stage 2 $5_{\varepsilon y}L_g$ Cycles Applied	Residual Elongation u_4 (mm)	u_8 (mm)	Tensile Strength F_{max} (kN)	(R_m) MPa	A_{gt} (percent)	Final Result
3768	40	1257	A	460	4	4	0.14	0.45	784.3	623.9	11%	Bar break

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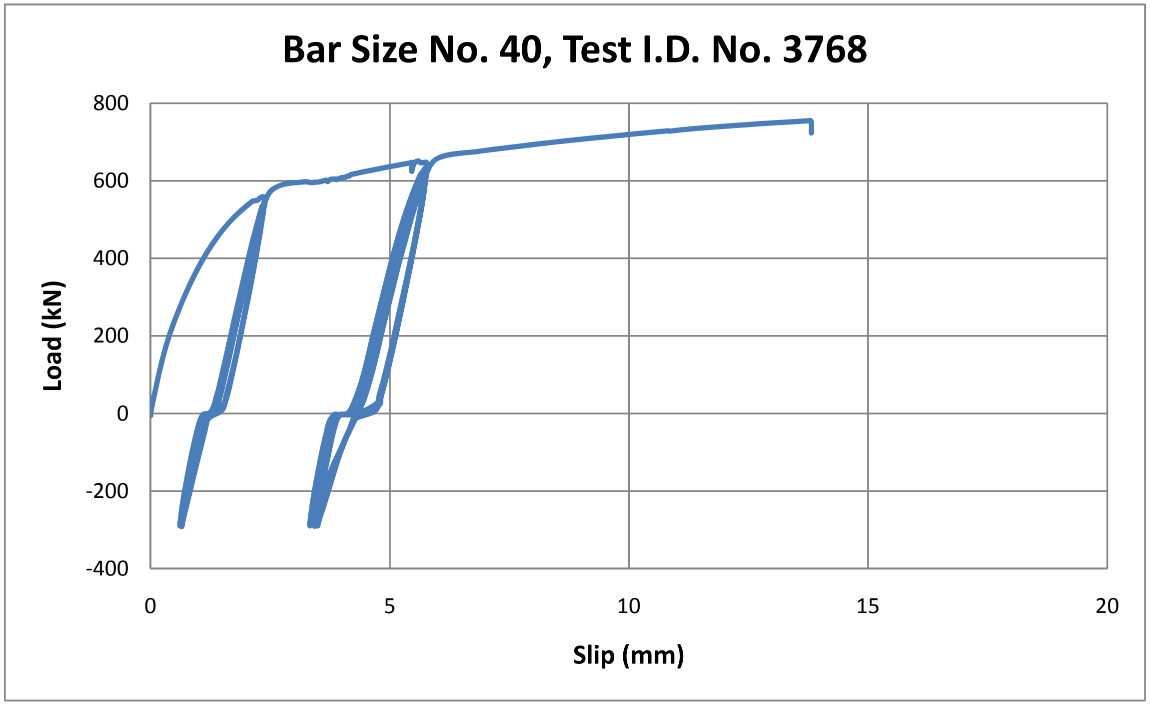

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