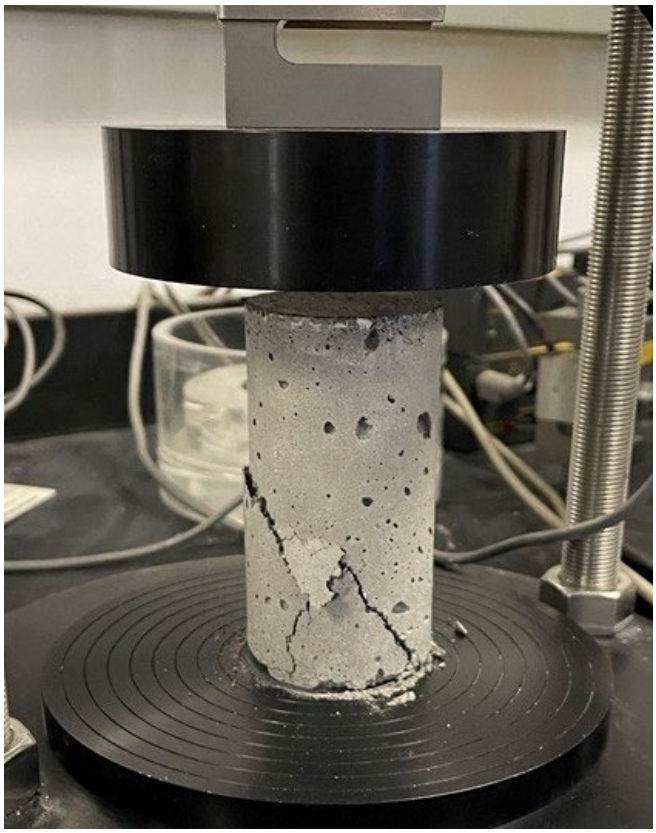
BUREAU OF RECLAMATION

Technical Report No. 8550-2022-23

Laboratory Testing of Crumb Rubber Grout

Prepared for: Kevin Foody, The Foody Group



U.S. Department of the Interior **September 2022**

Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photo – UCS test specimen of crumb rubber grout (Bureau of Reclamation/Justin Downs)

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Prepared for: Kevin Foody, The Foody Group

Prepared by: Justin Downs, P.E.

Bureau of Reclamation
Technical Service Center
Denver, Colorado

U.S. Department of the Interior **September 2022**

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JUSTIN DOWNS Digitally signed by JUSTIN DOWNS
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Civil Engineer, Geotechnical Laboratory and Field Support Group, 86-68550

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Civil Engineer, Geotechnical Laboratory and Field Support Group, 86-68550

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Technical Approval: Justin Downs, P.E.
Civil Engineer, Geotechnical Laboratory and Field Support Group, 86-68550

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Manager, Geotechnical Laboratory and Field Support Group, 86-68550

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Introduction

In March 2021, the Bureau of Reclamation's Technical Service Center was contacted by Mr. Kevin Foody of The Foody Group (Client) for laboratory mixing and testing of cementitious grout containing crumb rubber. A project management plan (PMP) was developed by Catherine Lucero, P.E. of the Technical Service Center's Concrete and Structural Laboratory group to define the technical data requested by the Client including fresh properties, strength and deformation characteristics, and shear wave velocity of the crumb rubber grout. The work was performed under Material Transfer Agreement number 21-MTA-RDO-1034. The Client supplied two buckets of crumb rubber and desired mix proportions to the Technical Service Center with the first mix of the crumb rubber grout taking place in August of 2021. Four individual mixes were batched and mixed; the final three were laboratory tested. Laboratory testing methods were iterative in nature during progression of the project to meet the Client's needs based on increasing understanding of the properties of the cured material. This technical report details the mix ingredients and their proportions, and the methods and results of the laboratory testing.

Scope of Work

The scope of work was defined by several Tasks included in the PMP. This Technical Report details the testing methods and results that fulfill the Tasks outlined in the PMP. The laboratory testing and the standards followed in general accordance by the Technical Service Center included:

1. Grout mixing proportions (ASTM C1437) and fresh properties testing (ASMT C305)
2. Unconfined compressive strength testing following ASTM D2166
3. Isotropically consolidated triaxial compression testing following ASTM D4767
4. Bender element testing for determination of shear wave velocity following ASTM D8295

Project management, grout batching and mixing, and fresh properties testing was performed by Catherine Lucero, P.E. of the Concrete and Structural Laboratory group. Remaining laboratory testing was performed by Justin Downs, P.E. of the Geotechnical Laboratory and Field Support group. Summaries of the testing methods and results are included in the following sections, and detailed test reports and specimen photographs are included in the Appendices at the end of this report.

Laboratory Batching and Mixing

The initial mixture proportions were provided by the Client and were adjusted in coordination with the Client to achieve a desirable consistency. Lab standard ASTM C150 Type I/II cement was used for all mixtures. Final mixture proportions are summarized in Table 1, assuming 1.8% air by volume. The grout has a water to cement (w/c) ratio of 0.71 and a flow of 96 when tested in accordance with ASTM C1437 (2021).

Table 1: Summary of grout mixture proportions used for each batch of cylinders.

	Specific Gravity	Single Batch Weight (g)	Batch Weight (lb/cy)
Cement	3.15	630	860
Crumb Rubber	1.15	649	891
Water	1	448	611.5

The mortar was mixed in a mechanical mixer meeting requirements of ASTM C305 (2021). The dry cement and crumb rubber were added to the dampened bowl and mixed on low speed until uniform. The water was added and mixed on low speed for three minutes. The mixer was stopped, the sides of the bowl were scraped, and the mortar was allowed to rest for one minute. The mortar was then mixed for one minute on high speed. The measured specific gravity is 1.11 and unit weight of 69 pcf using a mud balance. The specific gravity and unit weight were consistent for each of the three batches. The fresh mortar appeared to have a high volume of air when freshly mixed, which is reflected in the low density. Figures 1 and 2 show the freshly mixed grout before and after casting into cylinders, respectively.

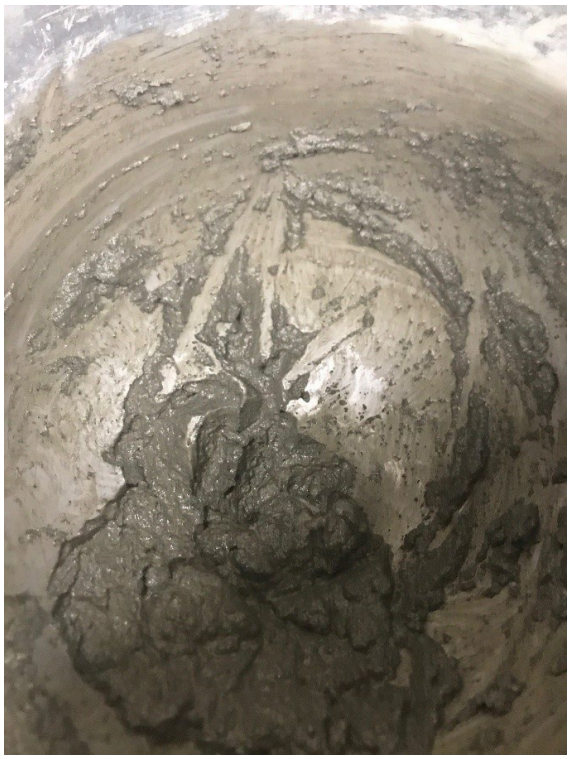

Figure 1: Freshly mixed grout in the mixer

Figure 2: Grout consolidated in 2-inch diameter cylinders

Laboratory Testing Methods and Results

Unconfined Compressive Strength Testing

Unconfined Compressive Strength (UCS) testing was performed in accordance with ASTM D2166 (2021). The specimens were prepared by casting the freshly mixed grout into nominally 2-inch diameter cylindrical molds for curing. The specimens were cured in a 100 percent humidity chamber, then extruded from the molds using low air pressure. Specimens were extruded at the desired cure age immediately before testing.

Once prepared, specimens were axially compressed at a strain rate of 0.5% axial strain per minute while monitoring the axial load. This strain rate was consistent across all UCS tests and triaxial compression tests reported herein. Axial stress was computed based on the cross-sectional area corrected for changes due to assumed radial straining caused by compressive loading.

A summary of UCS test results is provided in Table 2. Full test reports and specimen photographs are available in Appendix A.

Table 2: Summary of unconfined compressive strength test results.

Batch No.	Specimen No.	Age at Test (days)	UCS[1] (psi)	Axial Strain at Failure (%)
1	—	—	—	—
2	1	8	123.8	1.6
	1	28	188.8	1.6
	1	31	246.2	2.1
	2		206.7	2.1
	3		232.7	1.7
3	1	28	141.1	1.5
	2		166.4	1.8
	3		186.2	1.6
4	1	28	193.4	1.1
	2		223.8	2.1
	3		283.7	2.2

Notes:

[1]UCS testing performed in accordance with ASTM D2166.

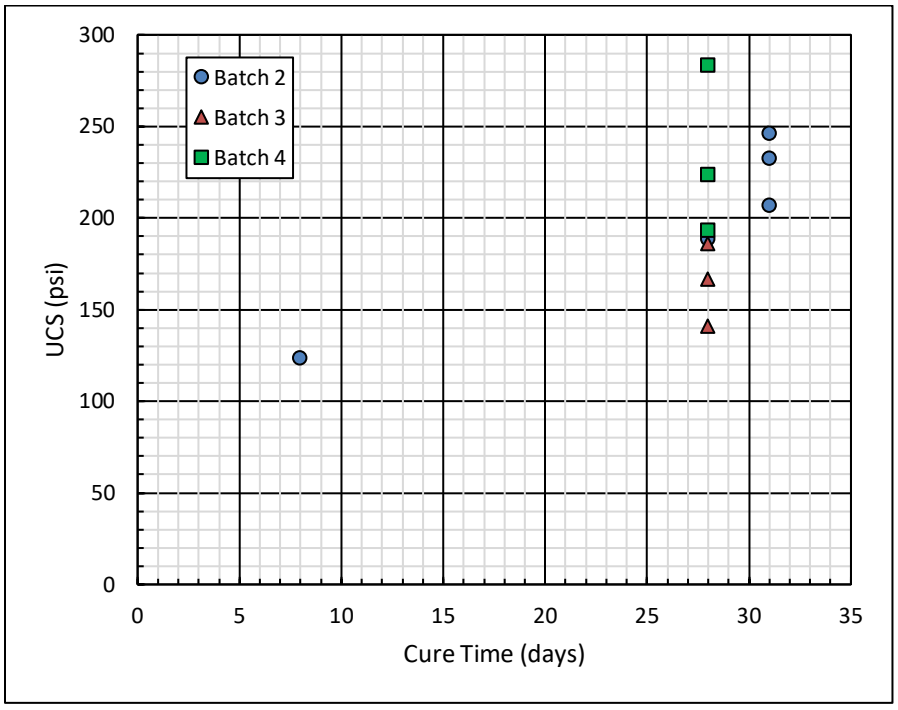

Figure 3: Unconfined compressive strength vs. cure time of all specimens tested

Isotropically Consolidated Triaxial Compression

Triaxial compression testing of the crumb rubber grout was performed per ASTM D4767 (2021). Specimens casted for triaxial compression testing were the same size as the 2-inch diameter UCS

specimens. Testing was performed at varying confining pressures selected in consultation with the Client.

At or near the 28-day cure age, specimens were extruded from their plastic curing molds using low pneumatic pressure. Once extruded, the surface area of each specimen was made smooth by applying plumber's putty to bug holes – the surface voids caused by air bubble collapse during curing. Smooth surface areas ensure that the applied chamber pressure resulted in an isotropic stress condition and helped to prevent tearing of the latex membranes against the sharp edges of the bug holes, thereby preventing leaks of cell water into the specimens during both application of confining pressure and shear test phases. Incisions were cut into the top and bottom ends of the specimens for fitting of bender element incorporated acrylic test caps. More detail of the bender element system is included in later sections of this report.

Application of confining pressure was incremental from atmospheric pressure to the final target confining pressure used during the shear phase of the test. Axial displacement was recorded during each confining pressure load increment for specimen height change calculations used in bender element testing. Specimens were not back pressure saturated, so no pore water pressure measurements were taken during the shear phase of testing. Additionally, the lack of back pressure saturation means that the crumb rubber grout likely did not generate significant excess pore water pressure during shear – meaning that the effective and total stress states were equal.

Specimens were sheared at 0.5% axial strain per minute, the same axial strain rate as the UCS specimens. Confining pressure was held constant during the shear phase, and shear continued at a constant rate either to 20% axial strain or until additional strain would not add value to characterization of the material behavior. Batch two specimens strained in the compression direction only. Testing methods were modified to include an unload/reload cycle during testing of batch three to further refine the elastic and plastic strain properties of the crumb rubber grout. During these unload/reload tests, specimens were compressed, then the axial strain direction was reversed at 0.5% per minute strain rate until the deviator stress was nearly zero (a full reduction of deviator stress was avoided so that specimens would not unseat from contact points). Immediately following the near full reduction of deviator stress, the specimens were again strained in the compression direction at 0.5% per minute. Triaxial compression testing of the batch four specimens included further refinement of the test procedures. Specimens were subjected to several unload/reload cycles at various axial strains during compression including:

1. At half of the anticipated deviator stress at failure – this stress was determined by averaging the batch four UCS values
2. At 5% axial strain – two successive unload/reload loops at this strain
3. At 7.5% axial strain
4. At 10% axial strain

A summary of triaxial compression testing is available in Table 3 below. Figures 4 through 6 present the results of the combined UCS and triaxial compression data sets for each batch of crumb rubber grout as Mohr's circles. The peak shear stress was averaged for each batch and is presented in the figures as the dashed line. Full stress-strain curves for each test, including the unload/reload cycle testing, are in Appendix B. Data labels of key points along the stress-strain curves were included for convenience.

Table 3: Summary of triaxial compression test results

Batch No.	Specimen No.	Age at Test (days)	Confining Stress (psi)	Peak Deviator Stress (psi)	Axial Strain at Peak Deviator Stress (%)
1	---	---	---	---	---
2	1	29	60	244.6	1.3
	1	31	90	282.5	1.4
	1	31	120	266.0	1.3
3	1	28	60	158.3	3.2
	2		60 (unload/reload)	184.8	2.0
	3		120 (unload/reload)	220.3	10.1
4	1	28	60 (unload/reload)	187.8	0.4
	2		90 (unload/reload)	234.2	1.0
	3		120 (unload/reload)	264.1	1.7

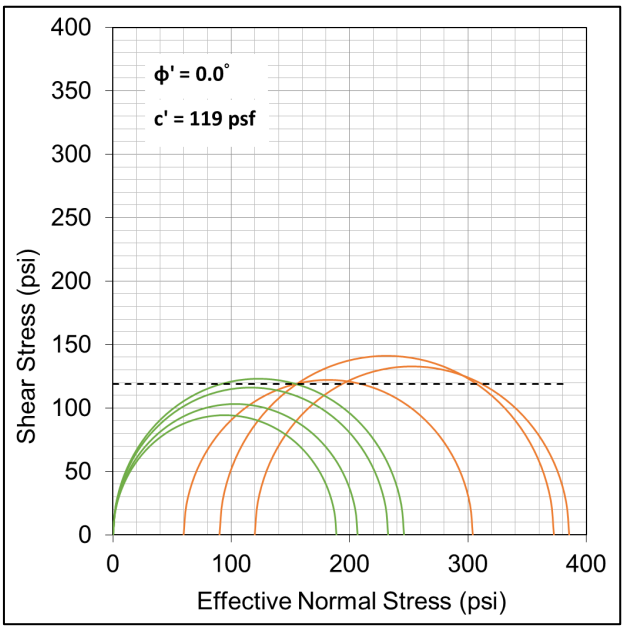

Figure 4: Batch 2 Mohr's circles – UCS (green) and triaxial compression tests (orange)

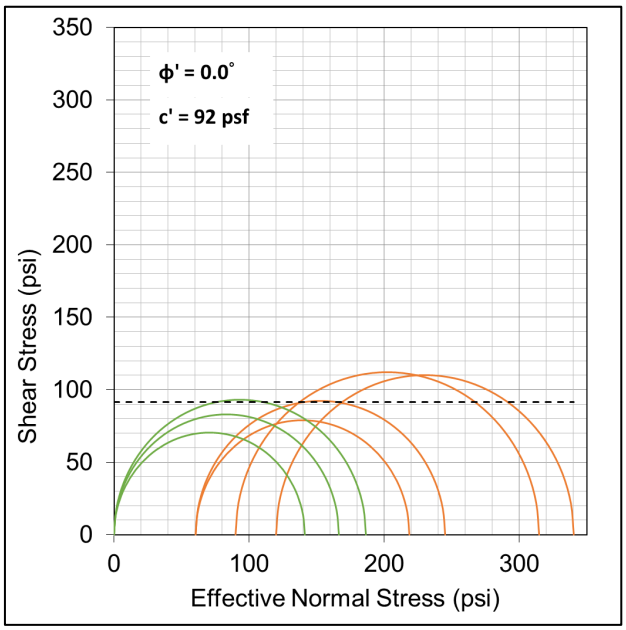

Figure 5: Batch 3 Mohr's circles – UCS (green) and triaxial compression tests (orange)

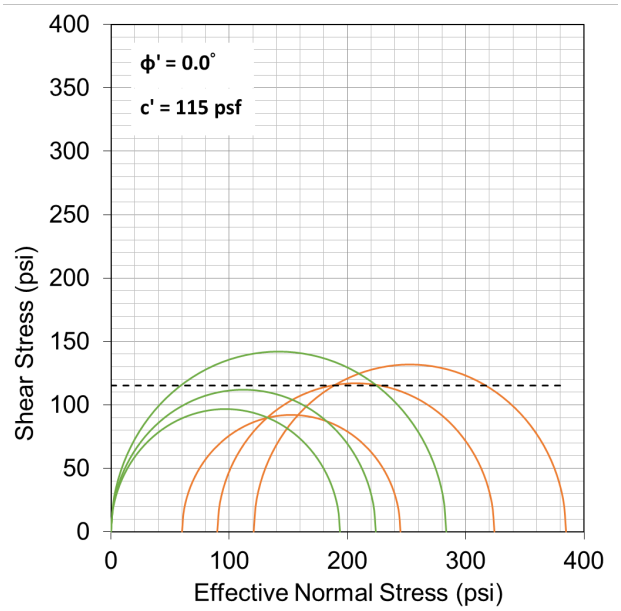

Figure 6: Batch 4 Mohr's circles – UCS (green) and triaxial compression tests (orange)

Bender Element Testing

Bender element tests were performed using a commercially available bender element system developed by GDS Instruments, Ltd. on triaxial compression specimens following ASTM D8295 (2021). Bender elements are piezoelectric ceramic objects that protrude into the top and bottom of the triaxial compression specimen. One element receives an excitation signal to create the source wave (compression wave or shear wave) and the opposing element receives the wave that is propagated through the soil, or in this case, the crumb rubber grout. Essentially, the bender elements provide a means to estimate the small-strain shear wave velocity (V_s) and compression wave velocity (V_p) of a material.

Shear waves were passed through the triaxial compression specimens in this testing. The time delay between the sinusoidal source wave and the received wave was measured. The interpretation technique used in this testing is known as the "peak-to-peak" method. Interpretation methods involving the selection of the first deflection of the receiver element may be unreliable because of the so-called near field effects (Viggiani and Atkinson, 1995). The wave travel distance was measured by subtracting the height of the bender elements from the specimen height. At each increase of confining stress, the wave travel distance was corrected for axial displacement. Cell water pressure surrounding the triaxial compression specimens was increased in increments, or load increments, until the target confining stress was reached for the shear phase of the test. At each load increment, a bender element test was performed to observe the relationship between wave speed and confining stress for the crumb rubber grout. Figures 7 through 9 located below illustrate this relationship for each batch of grout tested with bender elements. Note that an outlier in the user-defined shear-wave velocity data from the batch 4, 120-psi confining stress specimen was left off the plot for data visualization purposes. All bender element data, including this outlier, are reported in Appendix C.

The test reports included in Appendix C document the specimen dimensions and properties, wave travel distance, the travel time, the calculated wave velocities, the initial shear modulus (G_{max}), and the time traces for each bender element test. The raw data files from the bender element tests were post-processed through GDS BEAT (GDS Instruments, Ltd.), an Excel based analysis tool which performs semi-automated calculation of wave travel time by the cross-correlation and cross-power methods. The test reports document these values as well as the user defined travel times selected by the author on the day of testing (i.e., the peak-to-peak selections described above). The calculated values of wave velocity and G_{max} shown in the test reports in Appendix C were color referenced to their wave travel time source, whether it be from automated calculations of wave travel time by GDS BEAT, or from the user-defined travel times.

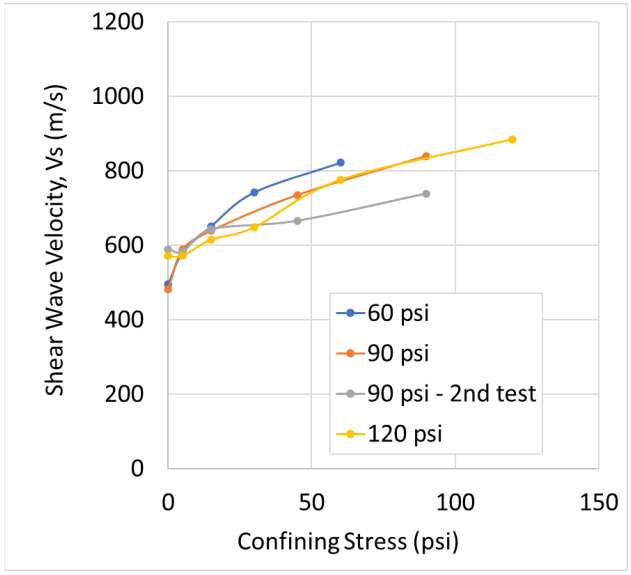

Figure 7: Batch 2 Vs (user-defined) vs. confining stress relationship

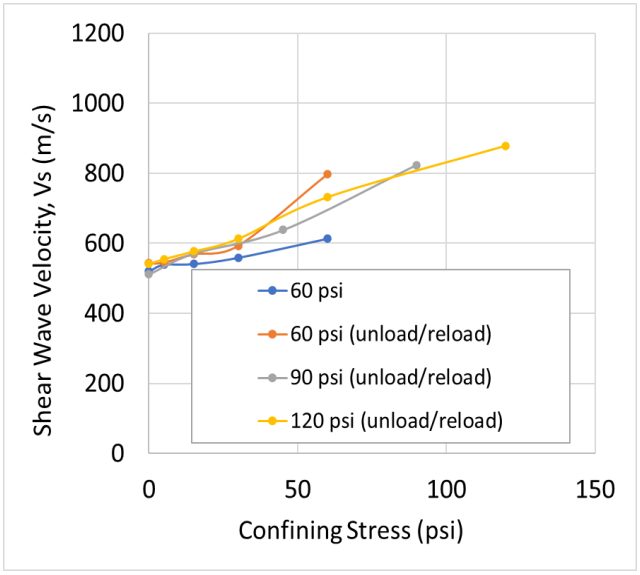

Figure 8: Batch 3 Vs (user-defined) vs. confining stress relationship

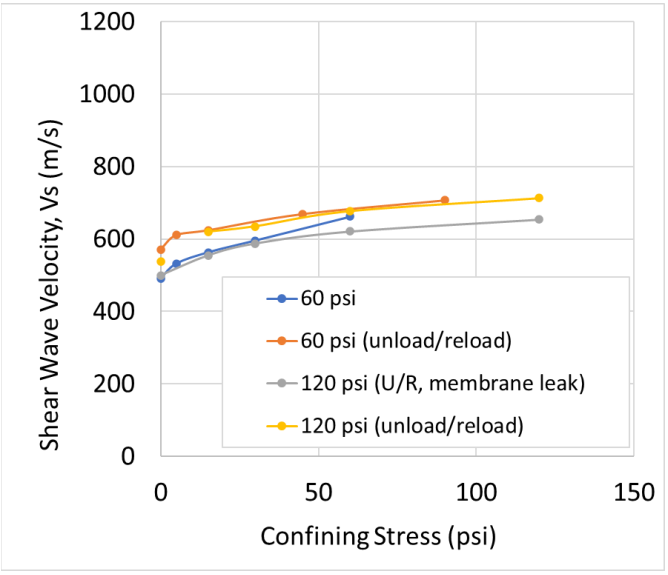

Figure 9: Batch 4 Vs (user-defined) vs. confining stress relationship

References

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Annual Book of ASTM Standards. (2021). Section 4 – Construction, Volume 04.08 – Soil and Rock (I): D421-D5876, ASTM International, West Conshohocken, PA, www.astm.org.

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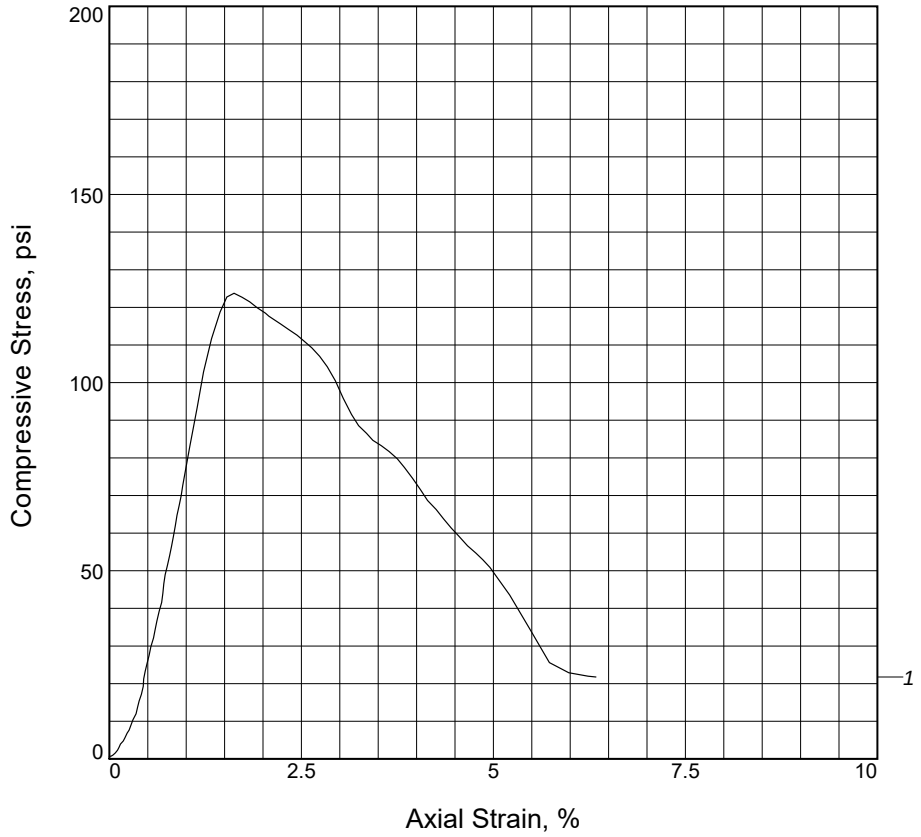
GDS BEAT. [Software]. GDS Instruments, Ltd., Hampshire, United Kingdom.

Viggiani, G. and Atkinson, J. H., (1995). "Interpretation of Bender Element Tests." *Geotechnique*, Vol. 45, Issue 1, pp. 149-154.

Appendix A

UCS Reports and Specimen Photos

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, psi	123.75			
Undrained shear strength, psi	61.87			
Failure strain, %	1.6			
Strain rate, %/min.	0.50			
Water content, %	N/A			
Wet density, pcf	68.2			
Dry density, pcf	N/A			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.045			
Specimen height, in.	4.012			
Height/diameter ratio	1.96			

Description: Mix date 7/13/2021. UCS test at 8-days after mixing.

LL =	**PL =**	**PI =**	**GS=**	**Type:** Crumb rubber 2-inch diameter specimen.

Project No.:
Date Sampled: 7/21/2021
Remarks:

Client: Kevin Foody

Project: Crumb Rubber Testing

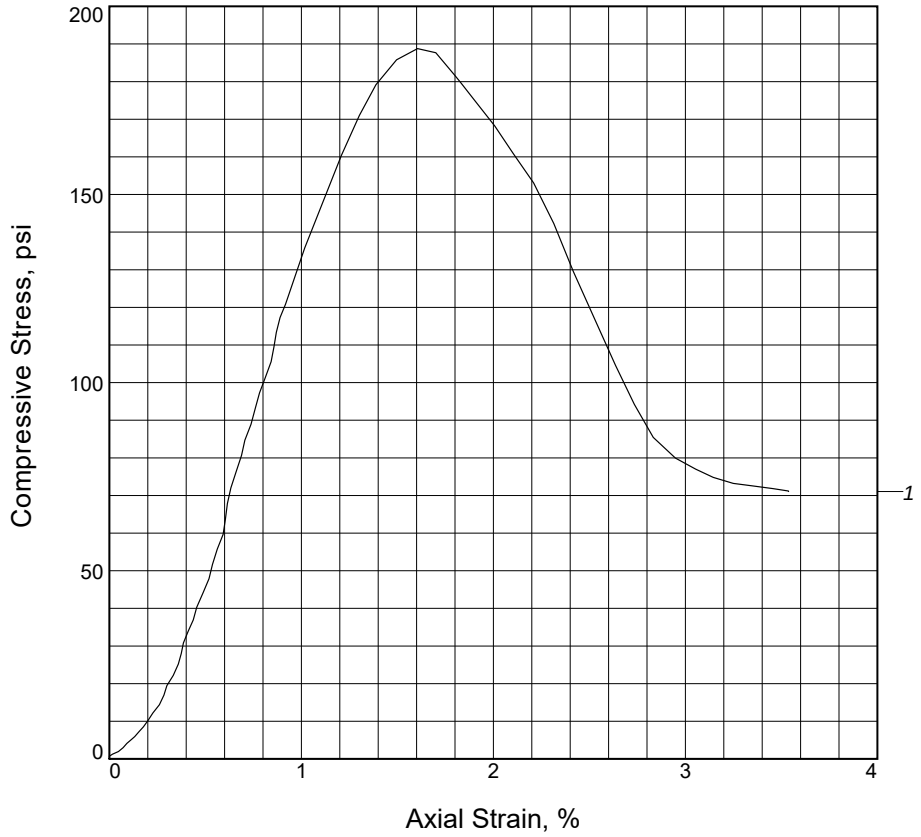
Source of Sample: 7/12/2021 Mix 2 **Depth:** N/A
Sample Number: Mix 2, 8 day UCS

Figure _____

UNCONFINED COMPRESSION TEST
BUREAU OF RECLAMATION
Denver, Colorado

Tested By: Downs **Checked By:** Foran

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, psi	188.77			
Undrained shear strength, psi	94.38			
Failure strain, %	1.6			
Strain rate, %/min.	0.49			
Water content, %	N/A			
Wet density, pcf	64.6			
Dry density, pcf	N/A			
Saturation, %	N/A			
Void ratio	N/A			
Specimen diameter, in.	2.045			
Specimen height, in.	4.015			
Height/diameter ratio	1.96			

Description: Mix date 7/13/2021. UCS test at 28-days after mixing.

LL =	**PL =**	**PI =**	**GS=**	**Type:** Crumb rubber, 2 inch diameter specimen

Project No.:
Date Sampled: 8/9/2021

Remarks:
Unconfined Compression strength test performed on one 2-inch by 4-inch cylindrical specimen.

Figure _____

Client: Kevin Foody

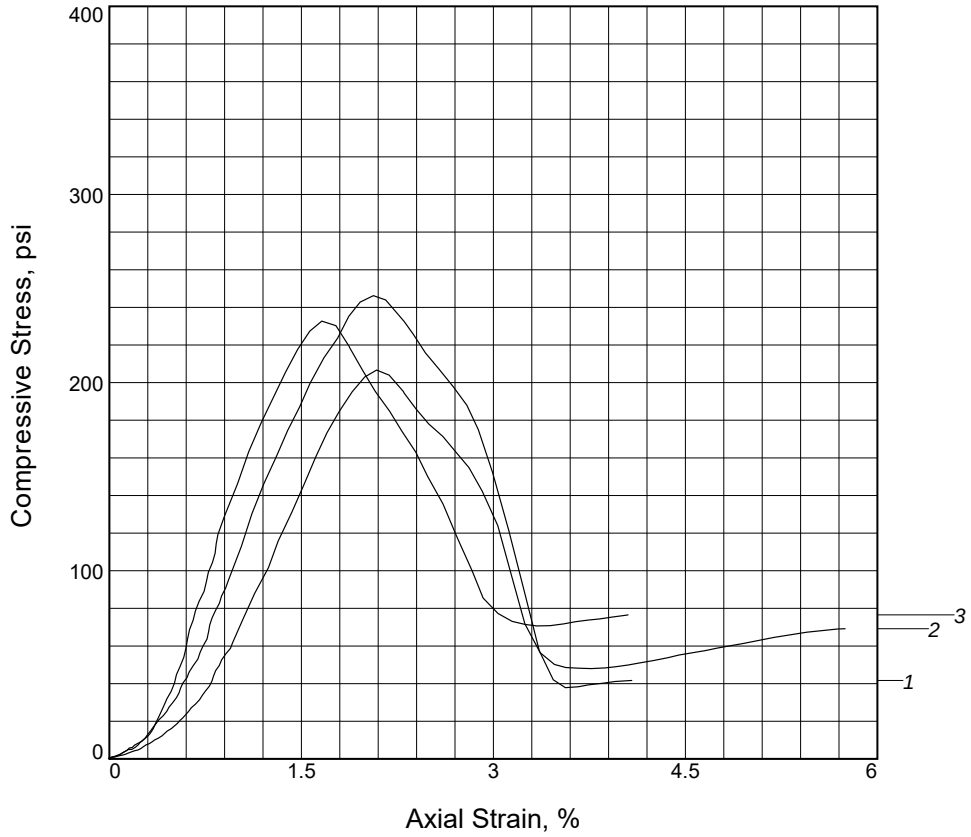
Project: Crumb Rubber Testing

Source of Sample: 7/12/2021 Mix 2 **Depth:** N/A
Sample Number: Mix 2, 28 day UCS

UNCONFINED COMPRESSION TEST
BUREAU OF RECLAMATION
Denver, Colorado

Tested By: Downs **Checked By:** Arany

UNCONFINED COMPRESSION TEST



Sample No.	1	2	3	
Unconfined strength, psi	246.23	206.67	232.65	
Undrained shear strength, psi	123.11	103.34	116.33	
Failure strain, %	2.1	2.1	1.7	
Strain rate, %/min.	0.49	0.49	0.49	
Water content, %	N/A	N/A	N/A	
Wet density, pcf	69.8	66.8	67.9	
Dry density, pcf	N/A	N/A	N/A	
Saturation, %	N/A	N/A	N/A	
Void ratio	N/A	N/A	N/A	
Specimen diameter, in.	2.045	2.044	2.045	
Specimen height, in.	4.022	4.035	4.020	
Height/diameter ratio	1.97	1.97	1.97	

Description: Mix date 7/13/2021. UCS tests at 31-days after mixing.

LL =	**PL =**	**PI =**	**GS=**	**Type:** Crumb rubber, 2-inch diameter specimen

Project No.:
Date Sampled: 8/12/2021

Remarks:
Unconfined Compression strength test performed on three 2-inch by 4-inch cylindrical specimens.

Figure _____

Client: Kevin Foody

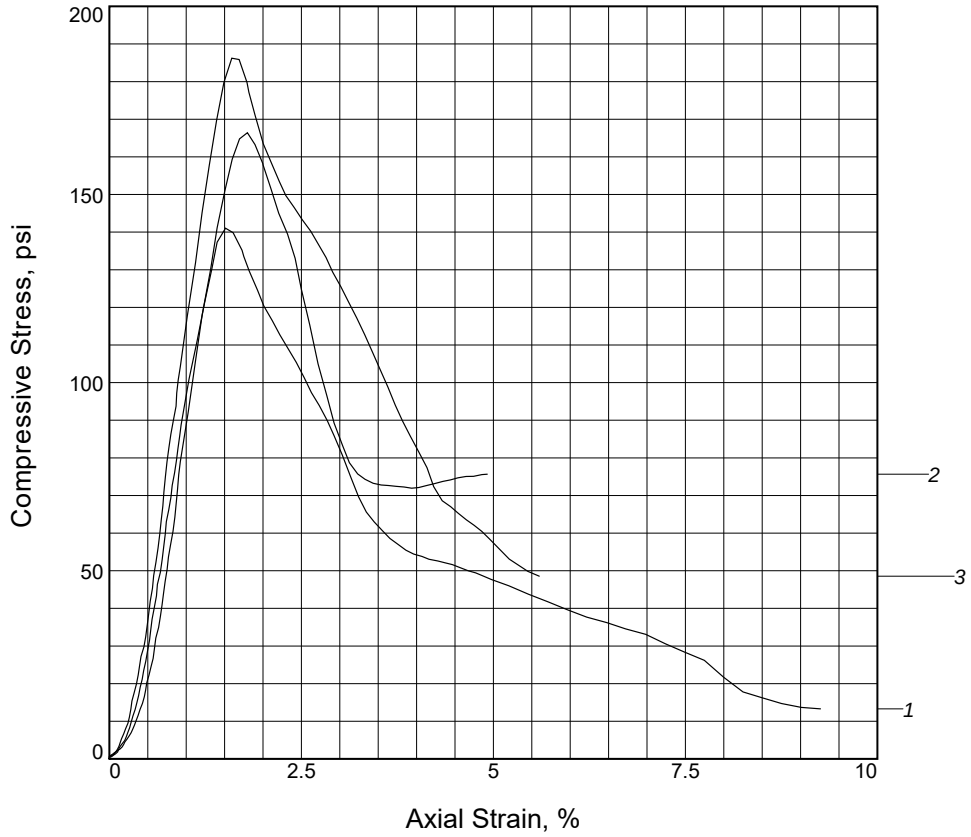
Project: Crumb Rubber Testing

Source of Sample: 7/12/2021 Mix 2 **Depth:** N/A
Sample Number: Mix 2, 31 day UCS

UNCONFINED COMPRESSION TEST
BUREAU OF RECLAMATION
Denver, Colorado

Tested By: Downs **Checked By:** Arany

UNCONFINED COMPRESSION TEST



Sample No.	1	2	3	
Unconfined strength, psi	141.06	166.40	186.23	
Undrained shear strength, psi	70.53	83.20	93.11	
Failure strain, %	1.5	1.8	1.6	
Strain rate, %/min.	0.50	0.49	0.49	
Water content, %	N/A	N/A	N/A	
Wet density, pcf	63.1	65.9	68.6	
Dry density, pcf	N/A	N/A	N/A	
Saturation, %	N/A	N/A	N/A	
Void ratio	N/A	N/A	N/A	
Specimen diameter, in.	2.037	2.046	2.046	
Specimen height, in.	4.026	4.021	4.014	
Height/diameter ratio	1.98	1.97	1.96	

Description: Mix date 8/17/2021. UCS tests at 28-days after mixing.

LL =	**PL =**	**PI =**	**GS=**	**Type:**

Project No.:

Date Sampled: 9/14/2021

Remarks:
Unconfined Compression strength test performed on three 2-inch by 4-inch cylindrical specimens.

Figure _____

Client: Kevin Foody

Project: Crumb Rubber Testing

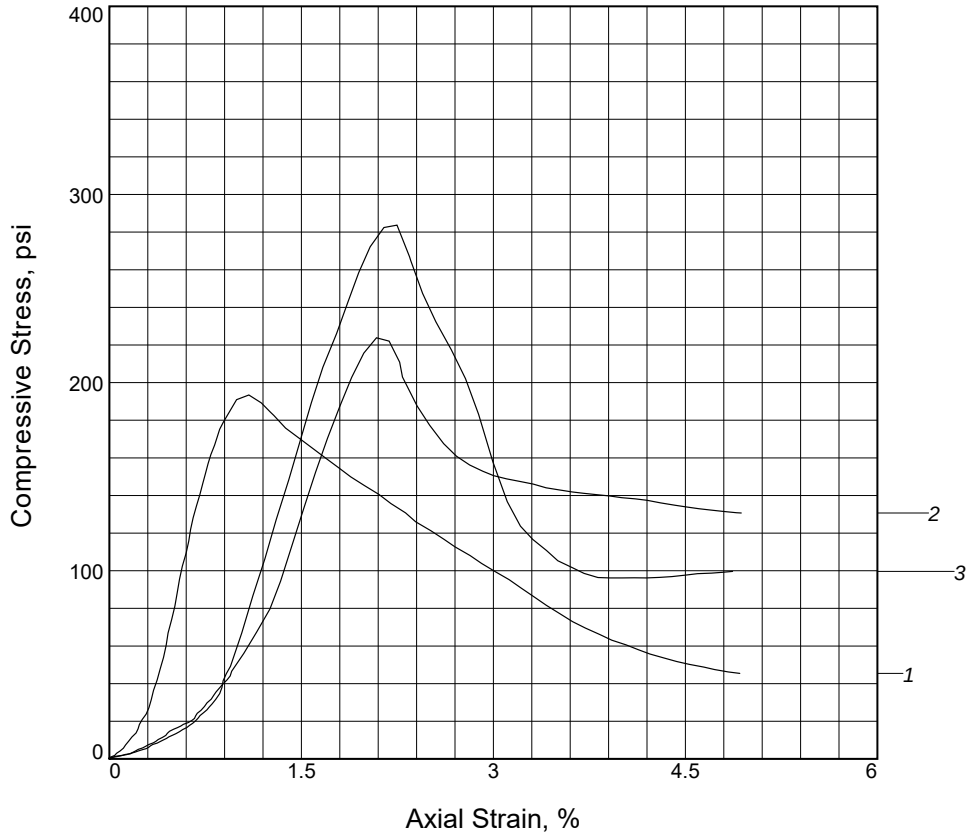
Source of Sample: 8/17/21 Mix 3 **Depth:** N/A

Sample Number: Mix 3, 28 day UCS

UNCONFINED COMPRESSION TEST
BUREAU OF RECLAMATION
Denver, Colorado

Tested By: Downs **Checked By:** Arany

UNCONFINED COMPRESSION TEST



Sample No.	1	2	3	
Unconfined strength, psi	193.40	223.81	283.71	
Undrained shear strength, psi	96.70	111.90	141.86	
Failure strain, %	1.1	2.1	2.2	
Strain rate, %/min.	0.49	0.49	0.49	
Water content, %	N/A	N/A	N/A	
Wet density, pcf	65.9	66.1	65.9	
Dry density, pcf	N/A	N/A	N/A	
Saturation, %	N/A	N/A	N/A	
Void ratio	N/A	N/A	N/A	
Specimen diameter, in.	2.044	2.044	2.038	
Specimen height, in.	4.011	4.037	4.017	
Height/diameter ratio	1.96	1.98	1.97	

Description: Mix date 11/29/2021. UCS tests at 28 and 30 days after mixing.

LL =	**PL =**	**PI =**	**GS=**	**Type:**

Project No.:

Date Sampled: 12/27/2021

Remarks:
Unconfined Compression strength test performed on three 2-inch by 4-inch cylindrical specimens.

Figure _____

Client: Kevin Foody

Project: Crumb Rubber Testing

Source of Sample: 11/29/2021 Mix 4 **Depth:** N/A

Sample Number: Mix 4, 28-day UCS

UNCONFINED COMPRESSION TEST
BUREAU OF RECLAMATION
Denver, Colorado

Tested By: Fontaine/Downs **Checked By:** Arany

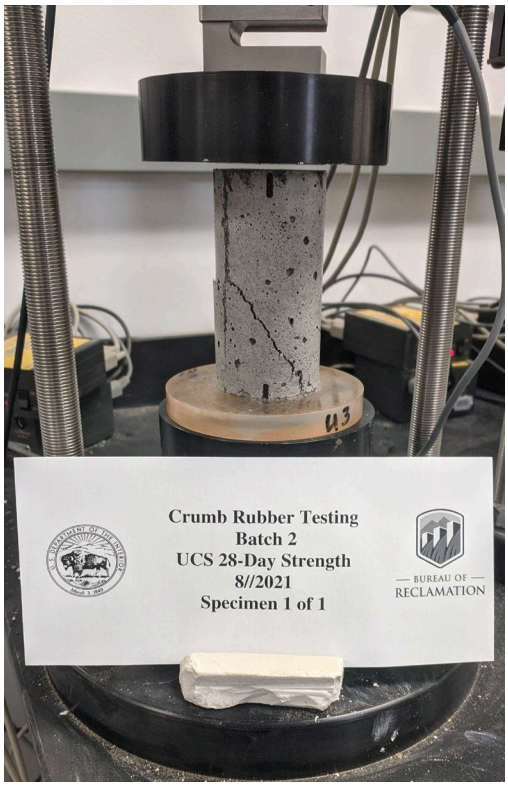


Figure A-1: Batch 2 UCS specimen 1 post-break

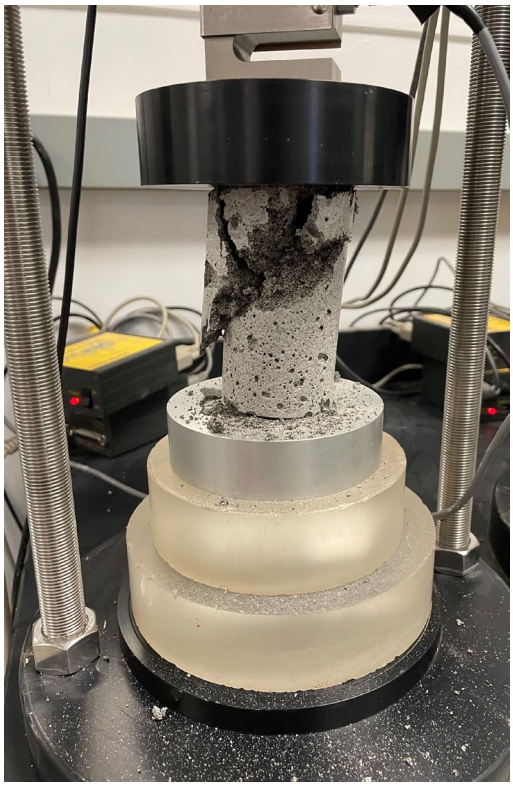


Figure A-2: Batch 3 UCS specimen 1 post-break

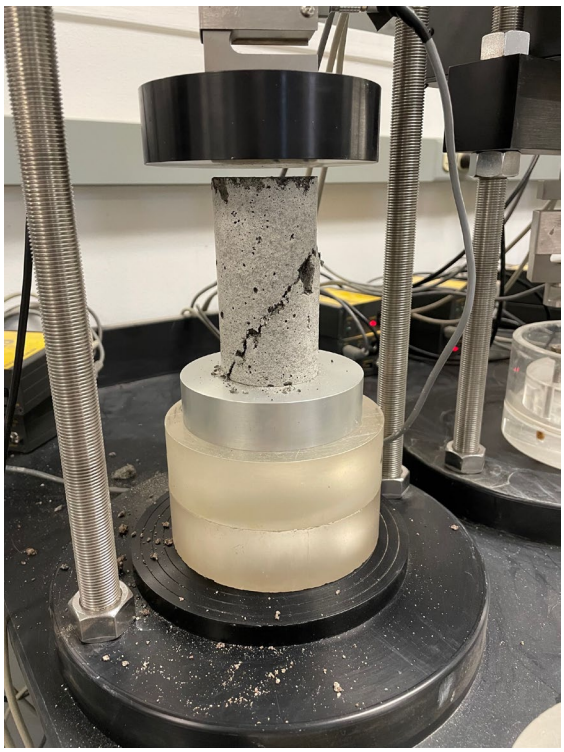


Figure A-3: Batch 3 UCS specimen 2 post-break

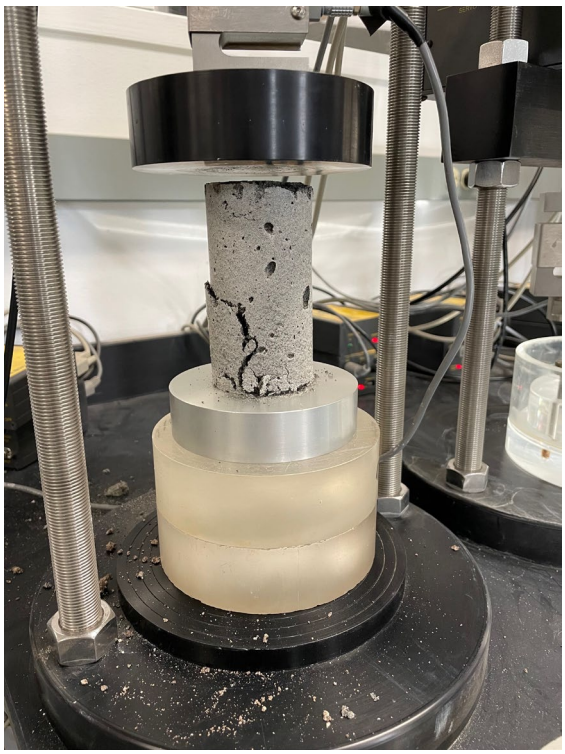


Figure A-4: Batch 3 UCS specimen 3 post-break

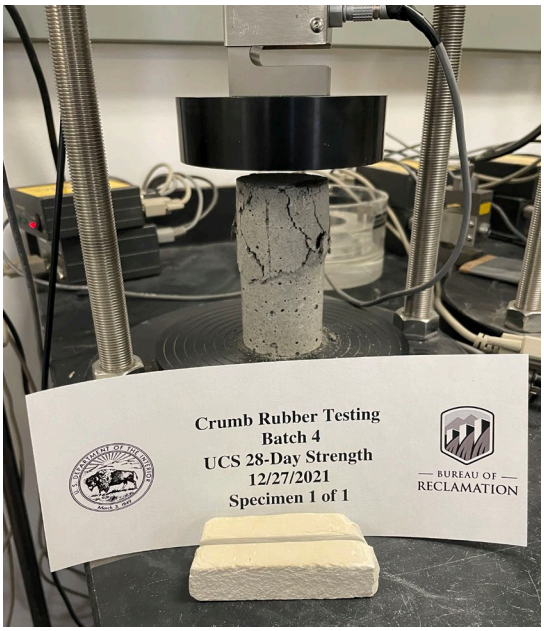


Figure A-5: Batch 4 UCS specimen 1 post-break

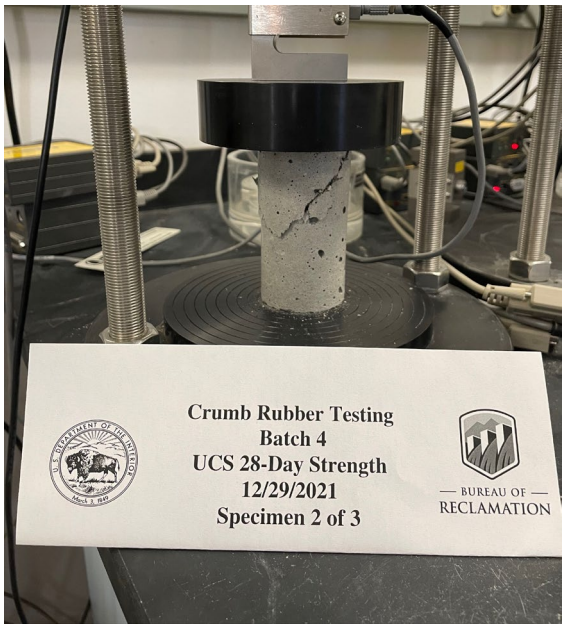


Figure A-6: Batch 4 UCS specimen 2 post-break

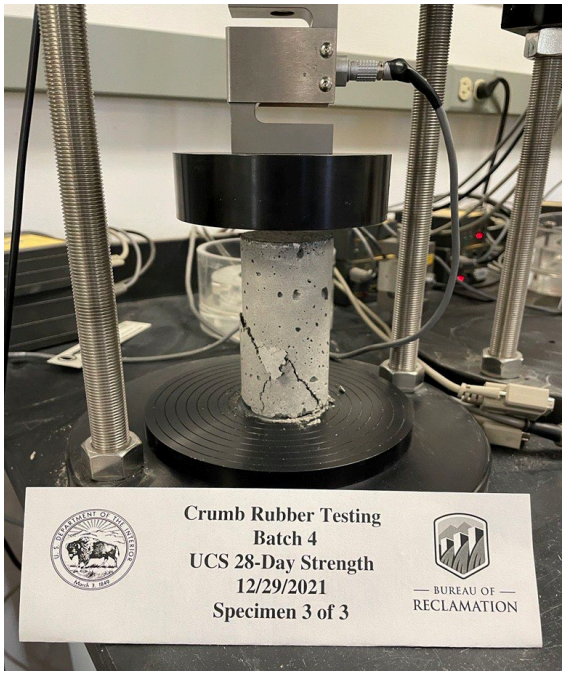
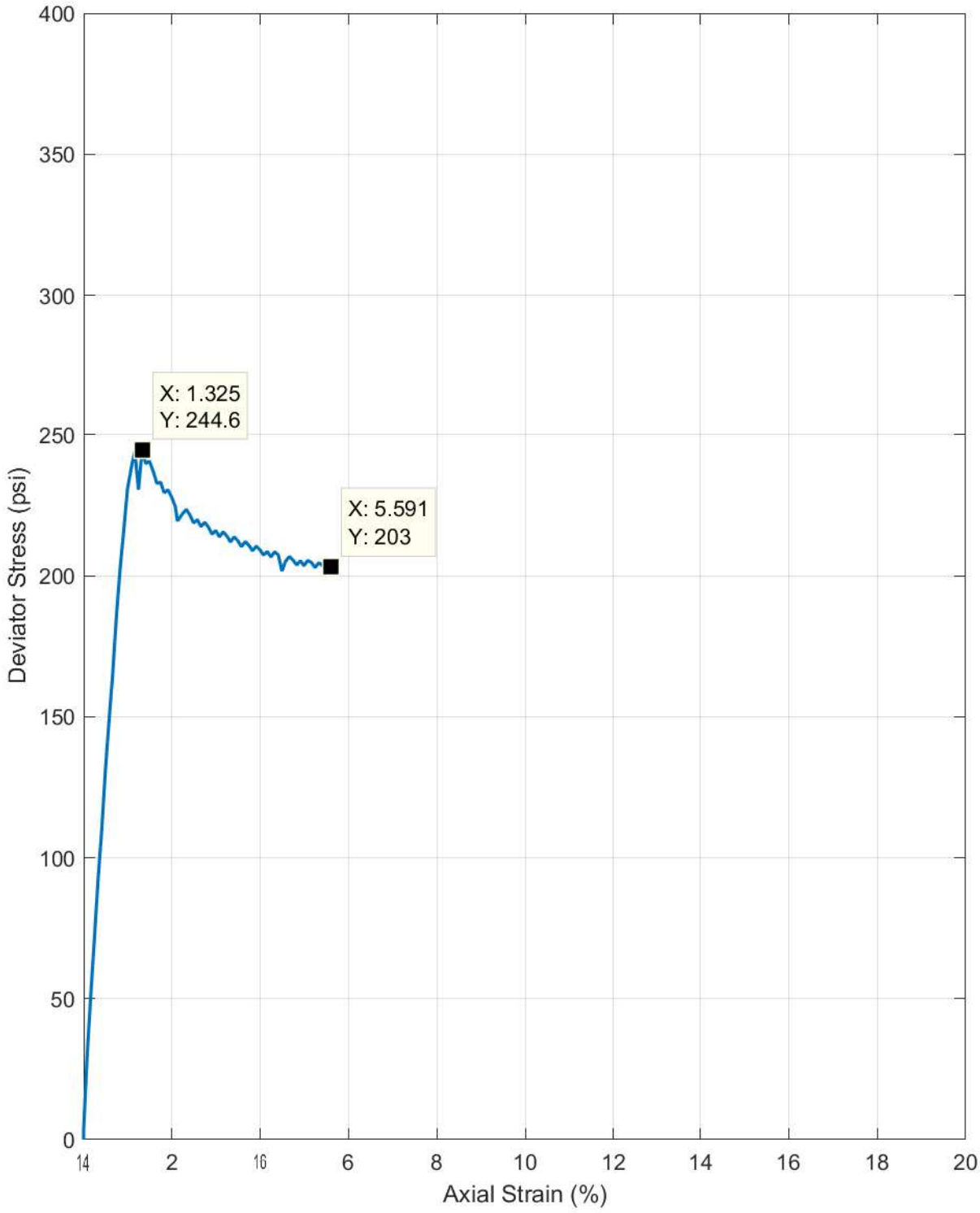
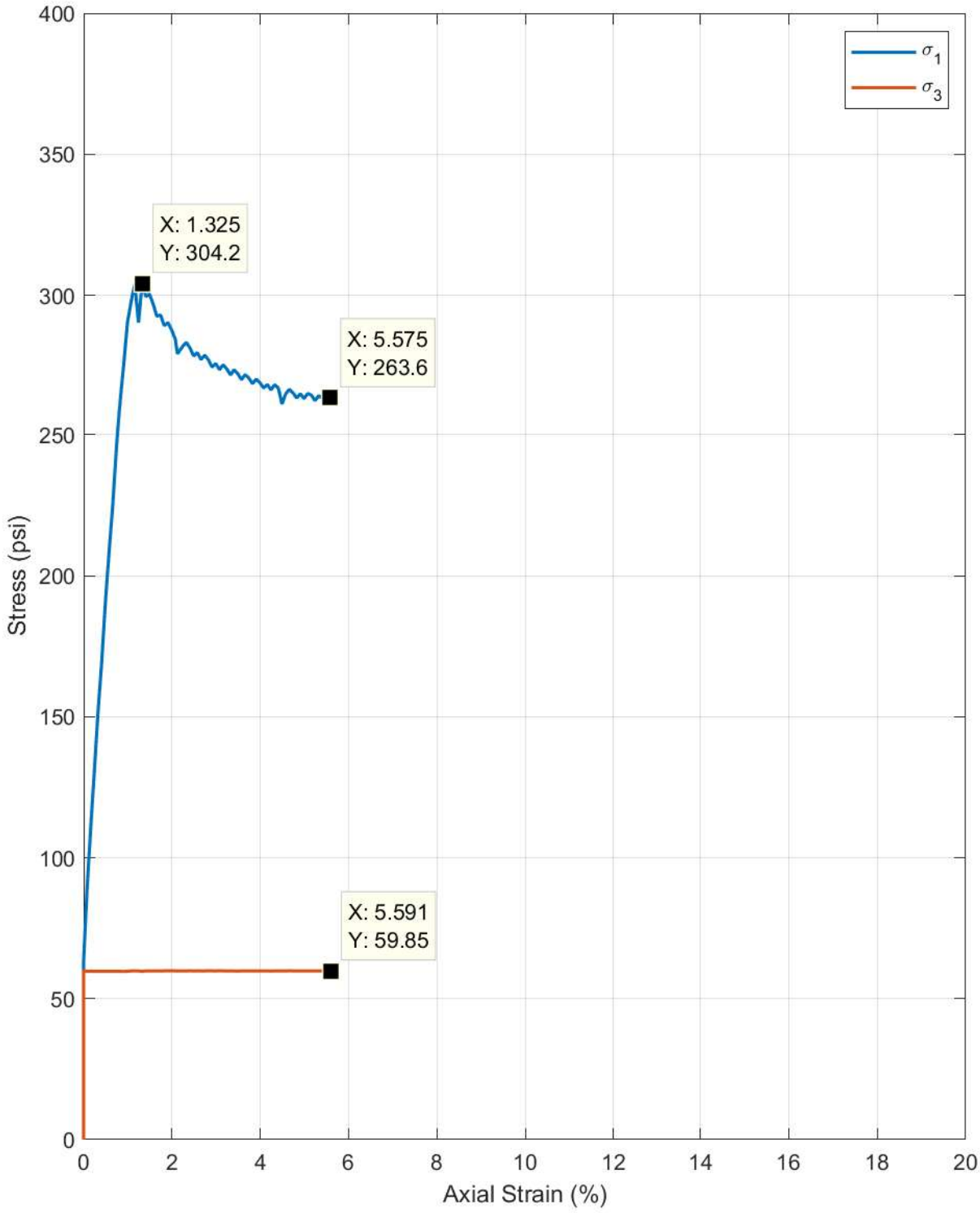


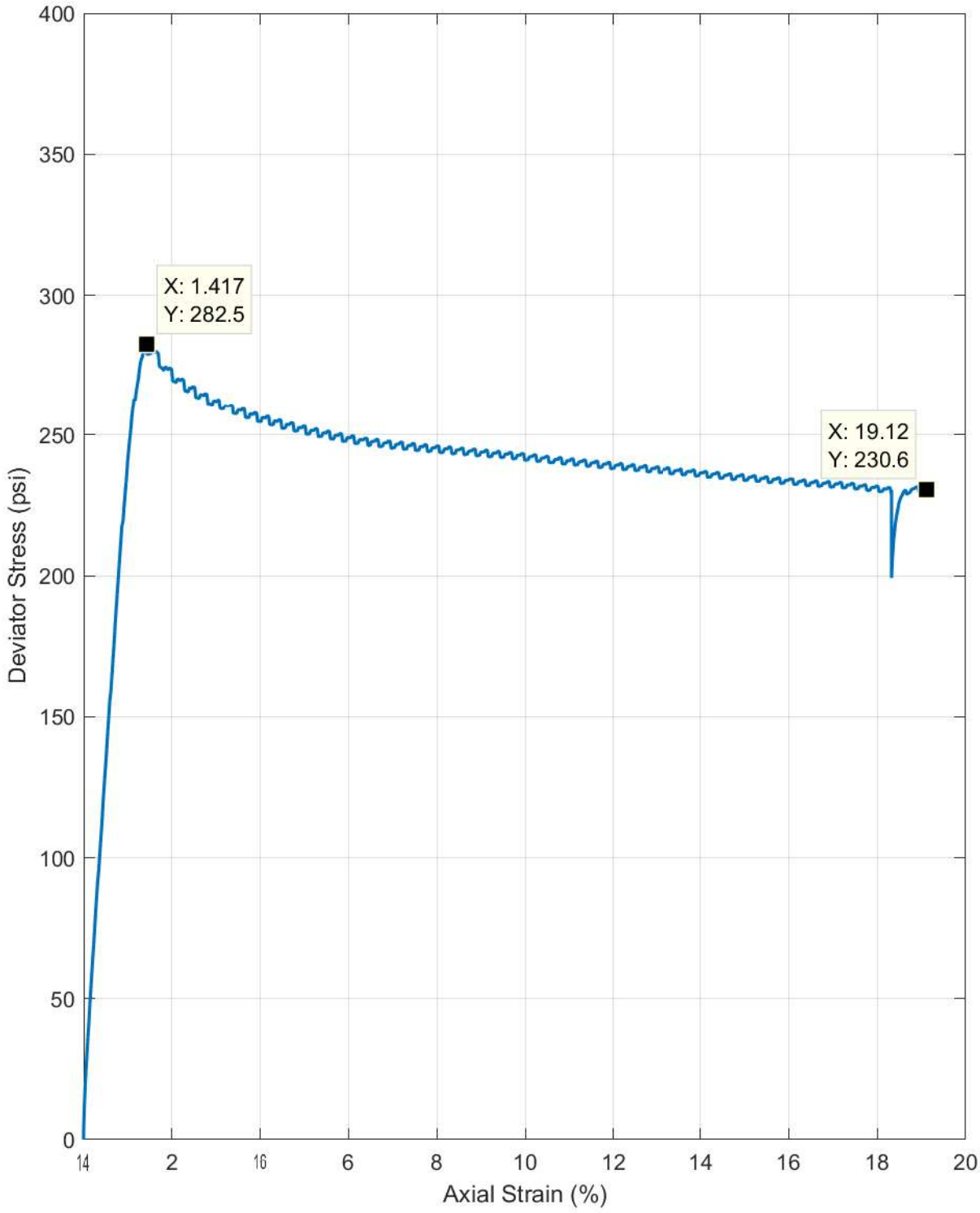
Figure A-7: Batch 4 UCS specimen 3 post-break

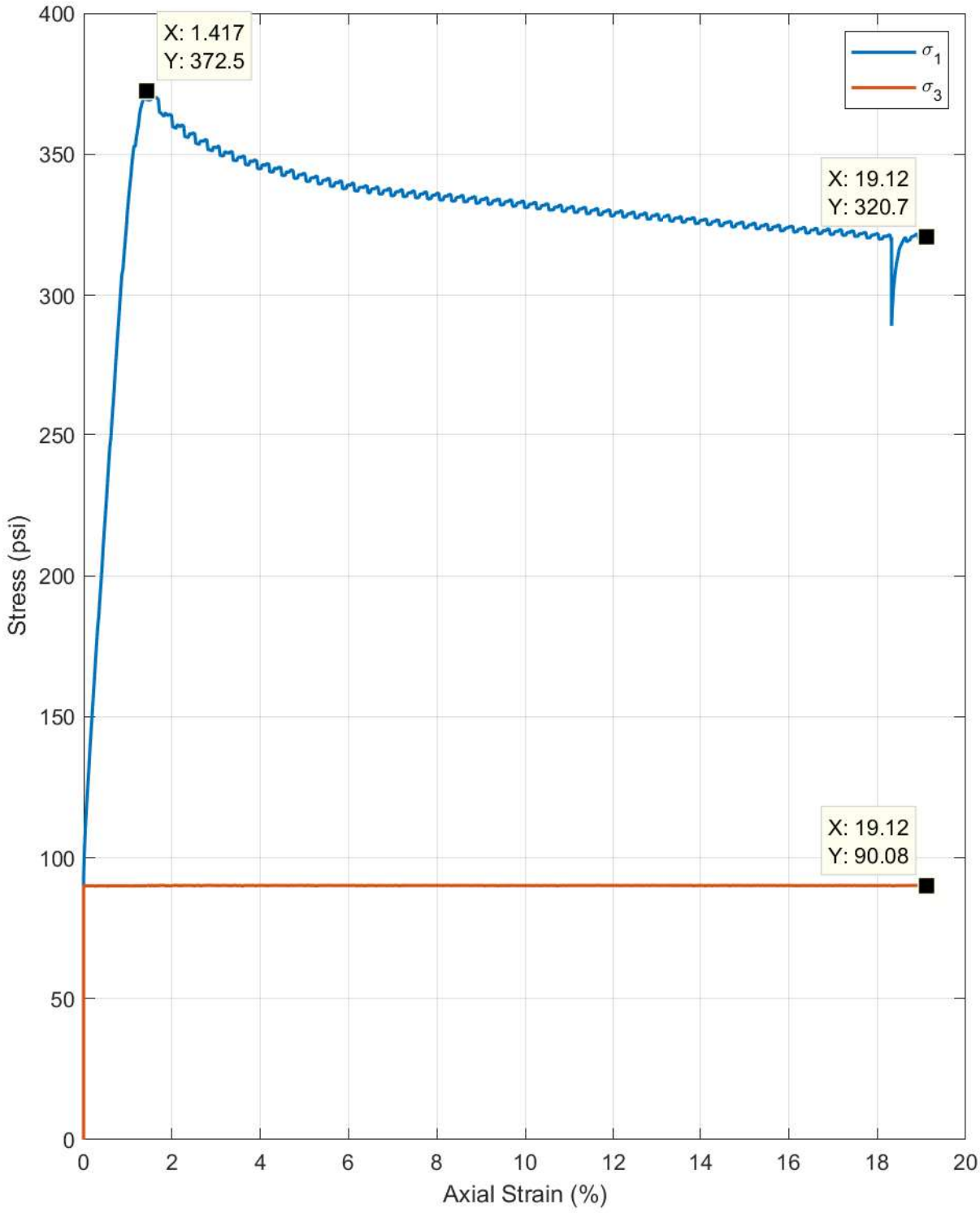
Appendix B

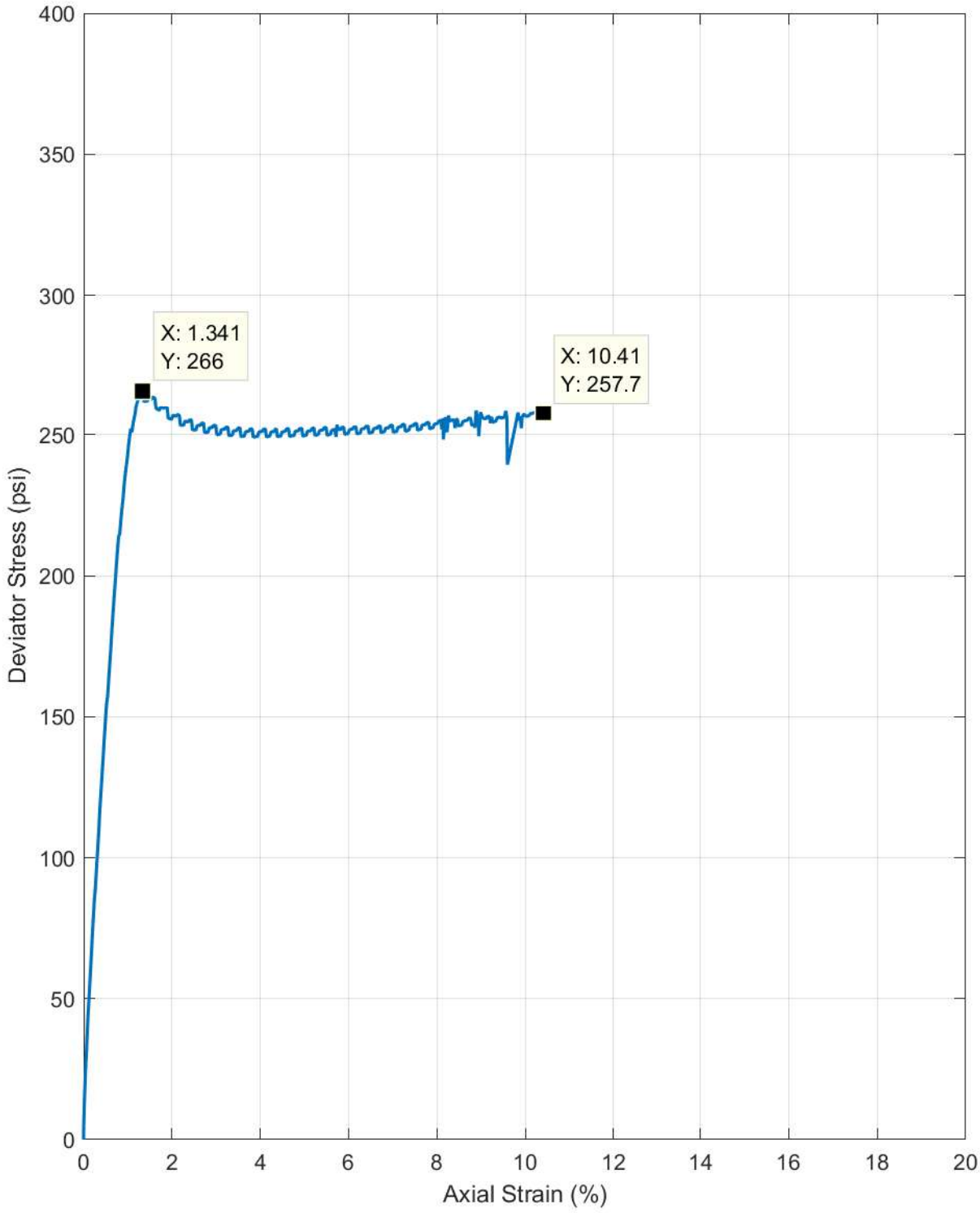
Triaxial Compression Test Reports

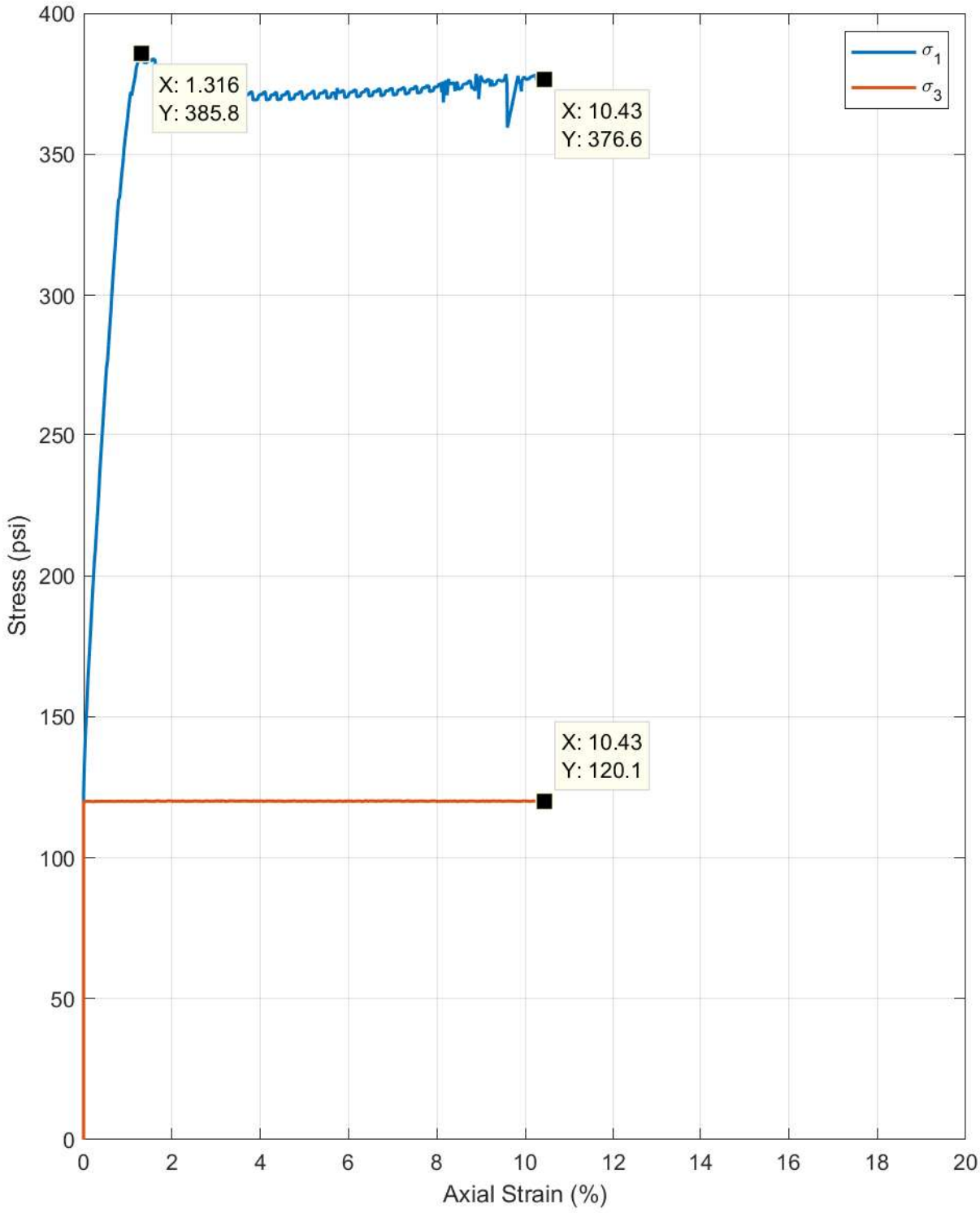

X: 1.325
Y: 244.6
X: 5.591
Y: 203
Deviator Stress (psi)
Axial Strain (%)
400
350
300
250
200
150
100
50
0
14
2
16
6
8
10
12
14
16
18
20

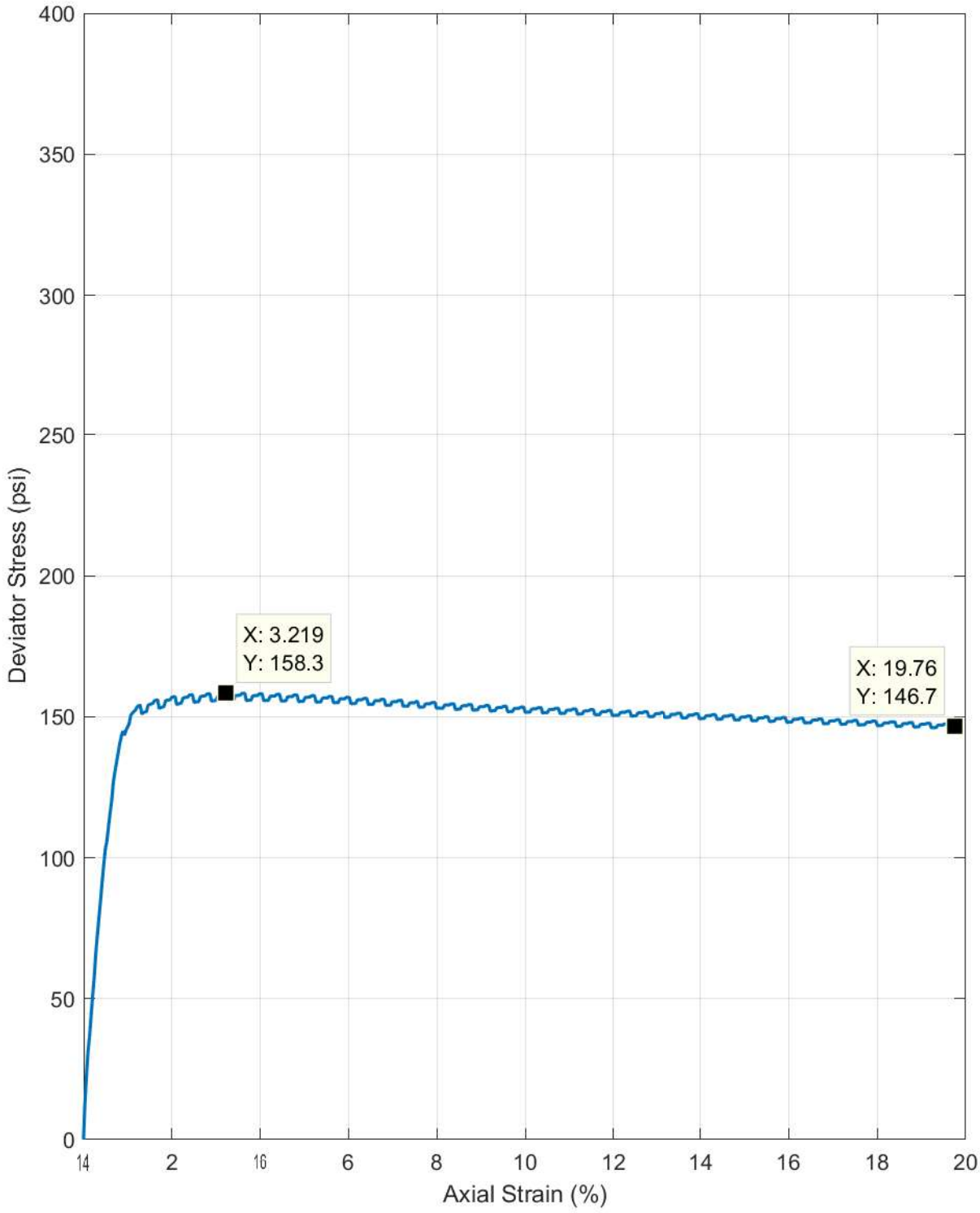

400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
14
16
18
20
Stress (psi)
Axial Strain (%)
σ_1
σ_3
X: 1.325
Y: 304.2
X: 5.575
Y: 263.6
X: 5.591
Y: 59.85

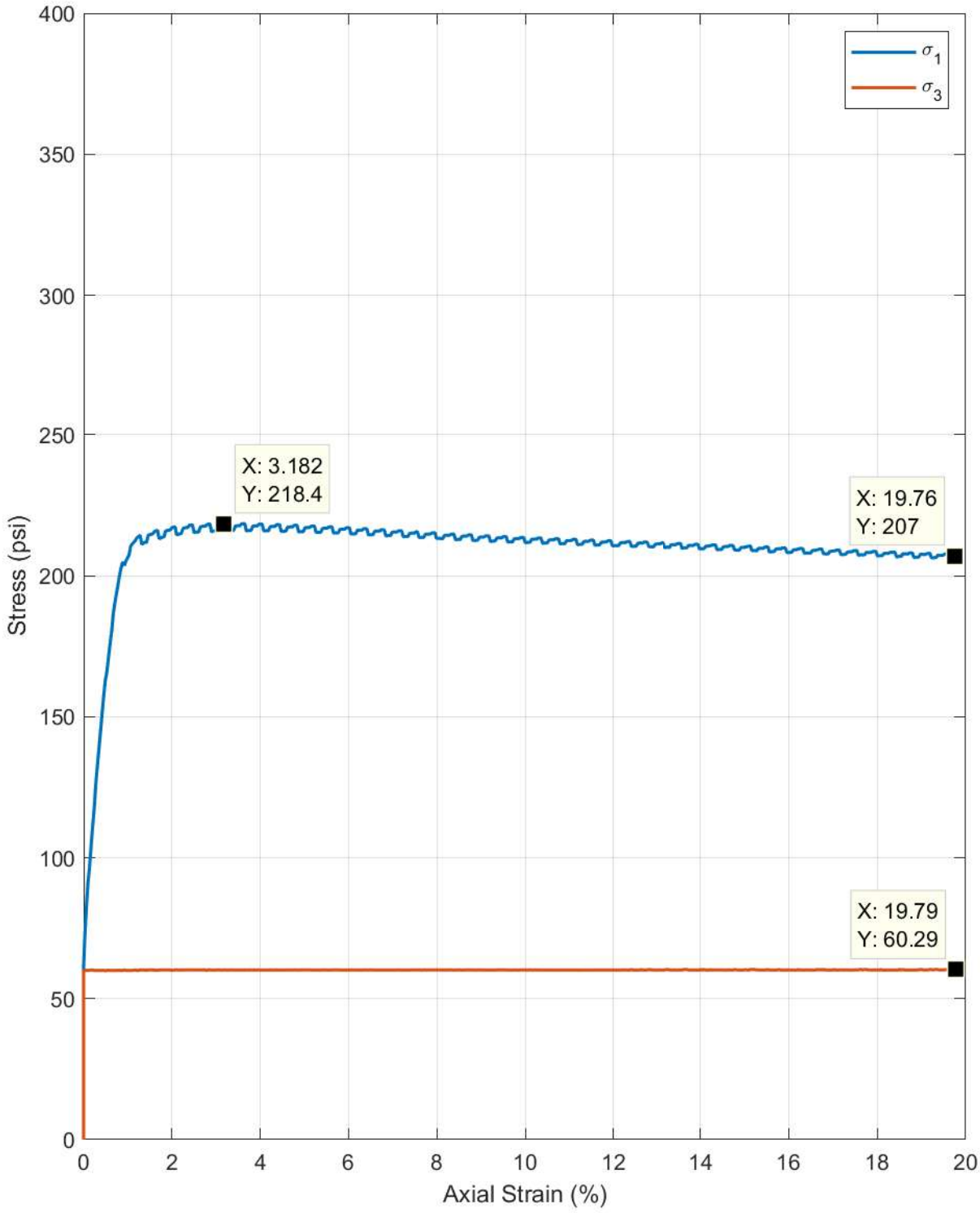

X: 1.417
Y: 282.5
X: 19.12
Y: 230.6
Deviator Stress (psi)
Axial Strain (%)
400
350
300
250
200
150
100
50
0
14
2
16
6
8
10
12
14
16
18
20

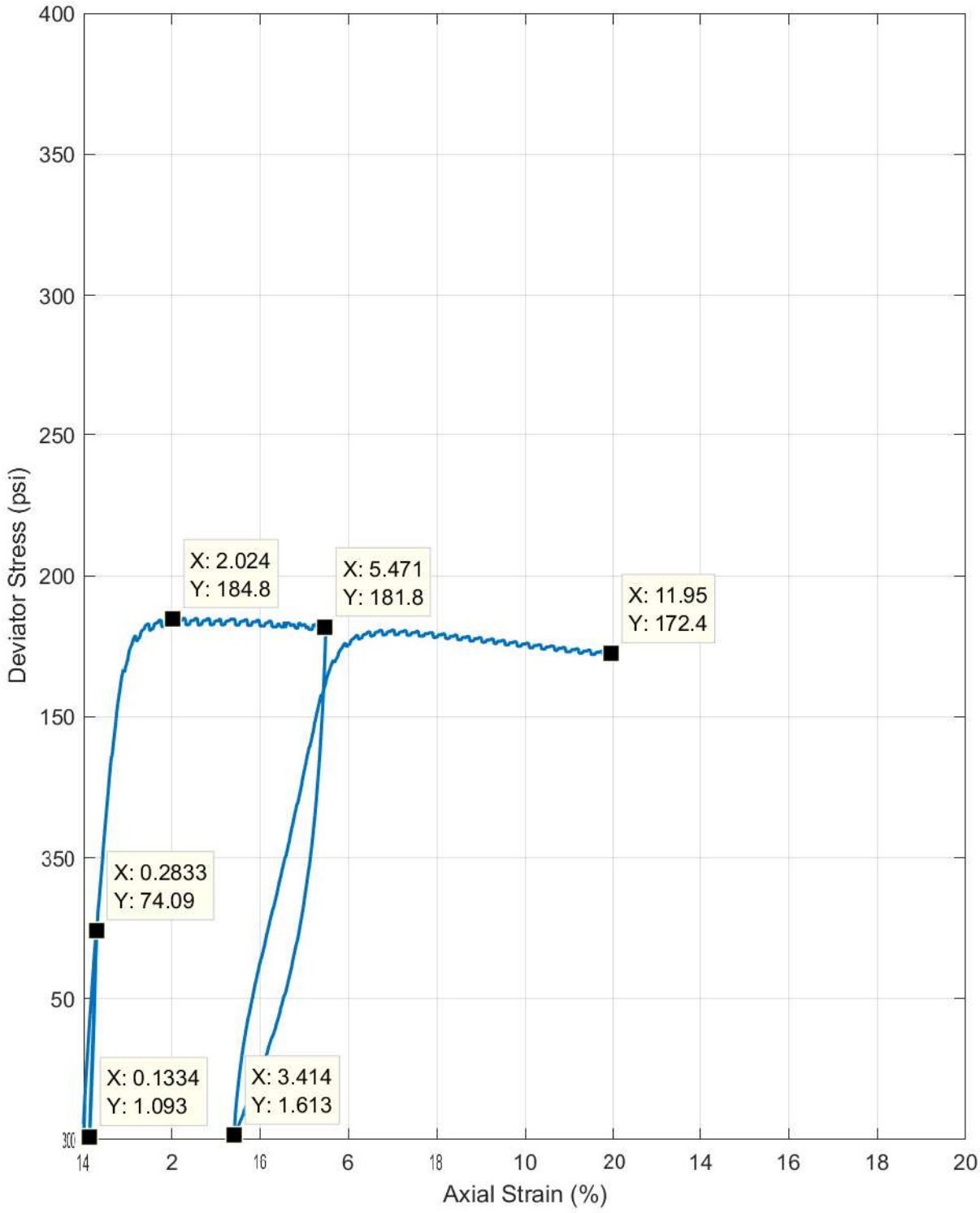

X: 1.417
Y: 372.5
X: 19.12
Y: 320.7
X: 19.12
Y: 90.08
σ_1
σ_3
Stress (psi)
Axial Strain (%)
0
50
100
150
200
250
300
350
400
0
2
4
6
8
10
12
14
16
18
20

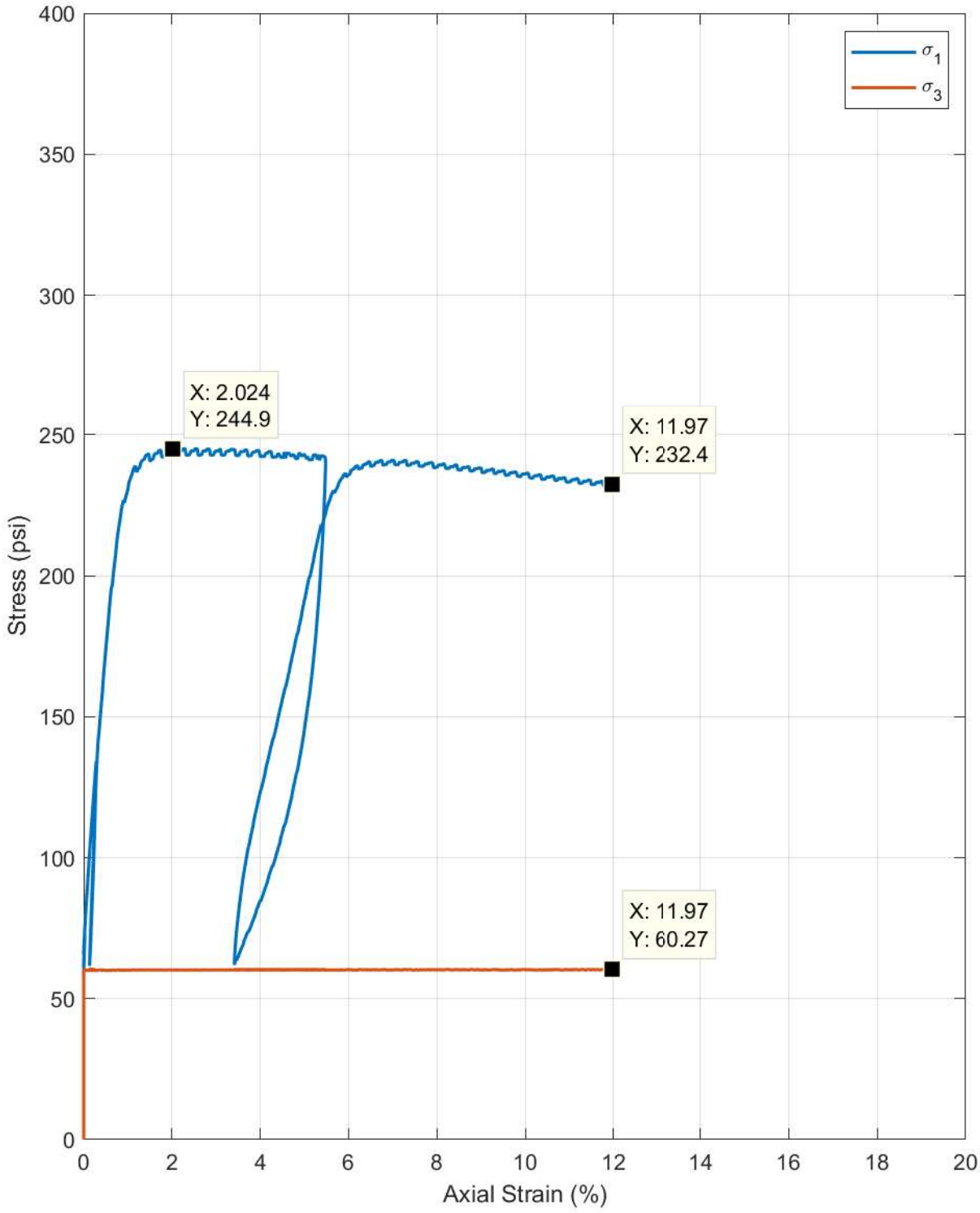

X: 1.341
Y: 266
X: 10.41
Y: 257.7
Deviator Stress (psi)
Axial Strain (%)
0
50
100
150
200
250
300
350
400
0
2
4
6
8
10
12
14
16
18
20

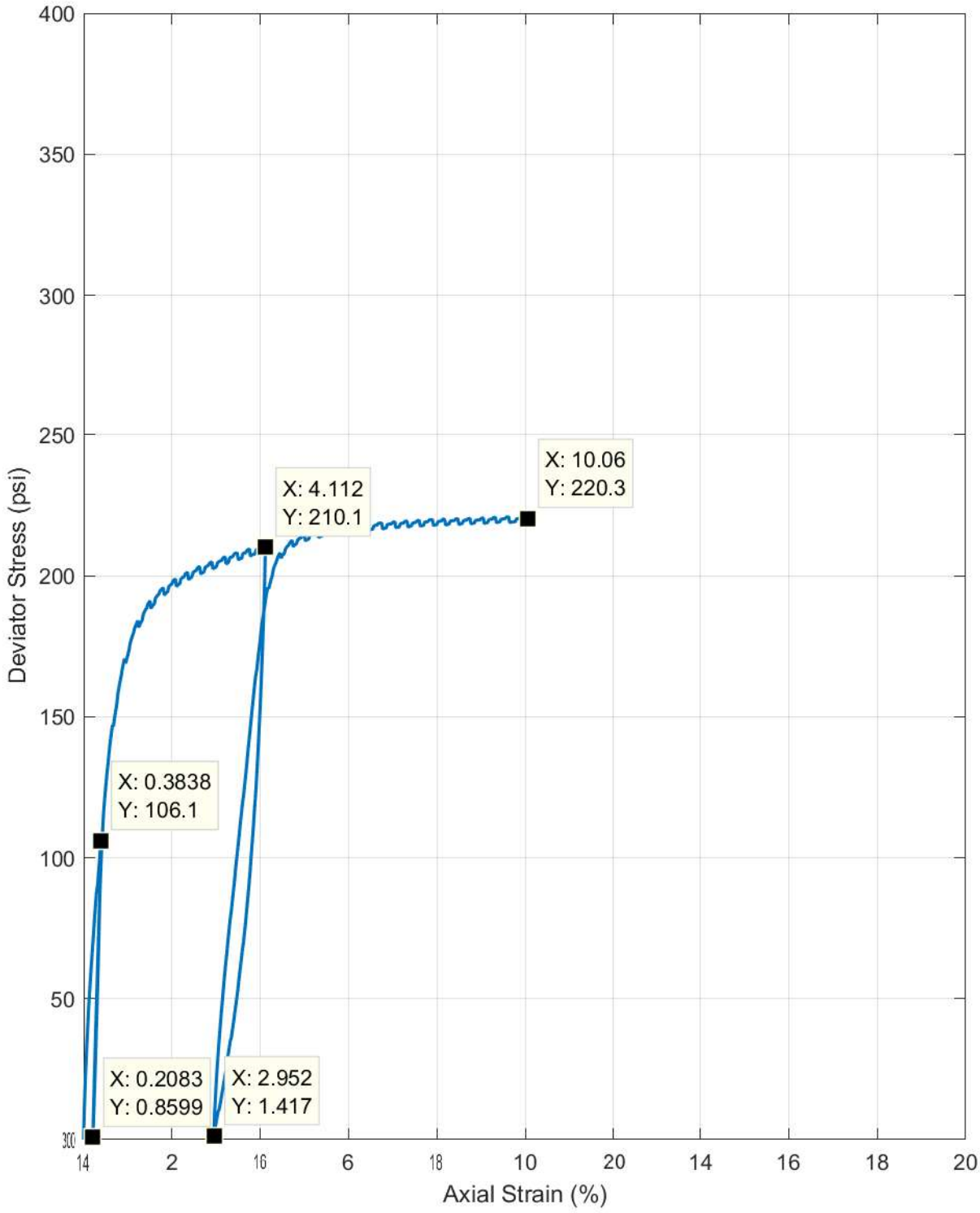

400
350
300
250
200
150
100
50
0
Stress (psi)
0
2
4
6
8
10
12
14
16
18
20
Axial Strain (%)
X: 1.316
Y: 385.8
X: 10.43
Y: 376.6
X: 10.43
Y: 120.1
σ_1
σ_3

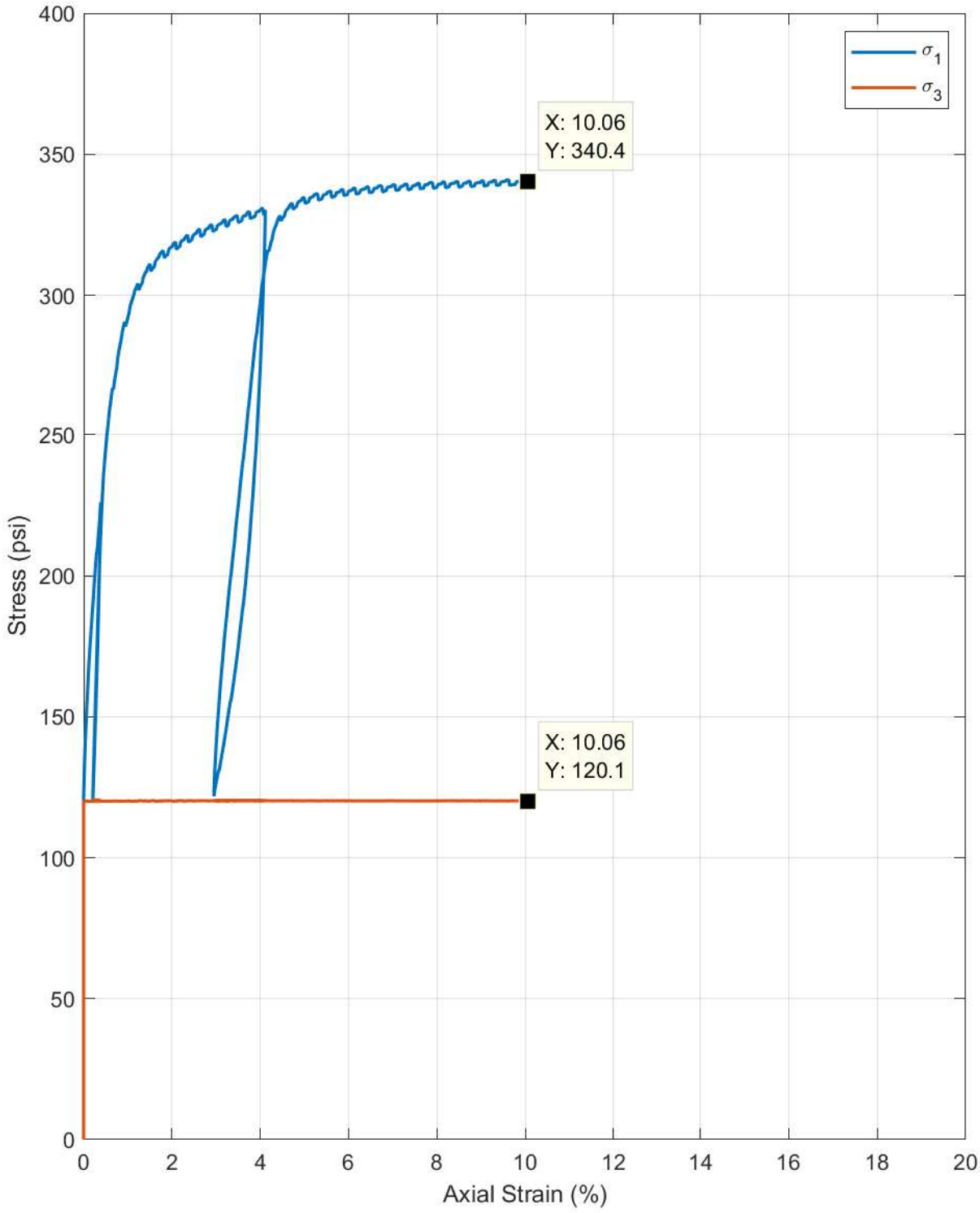

400
350
300
250
200
150
100
50
0
Deviator Stress (psi)
X: 3.219
Y: 158.3
X: 19.76
Y: 146.7
14
2
16
6
8
10
12
14
16
18
20
Axial Strain (%)

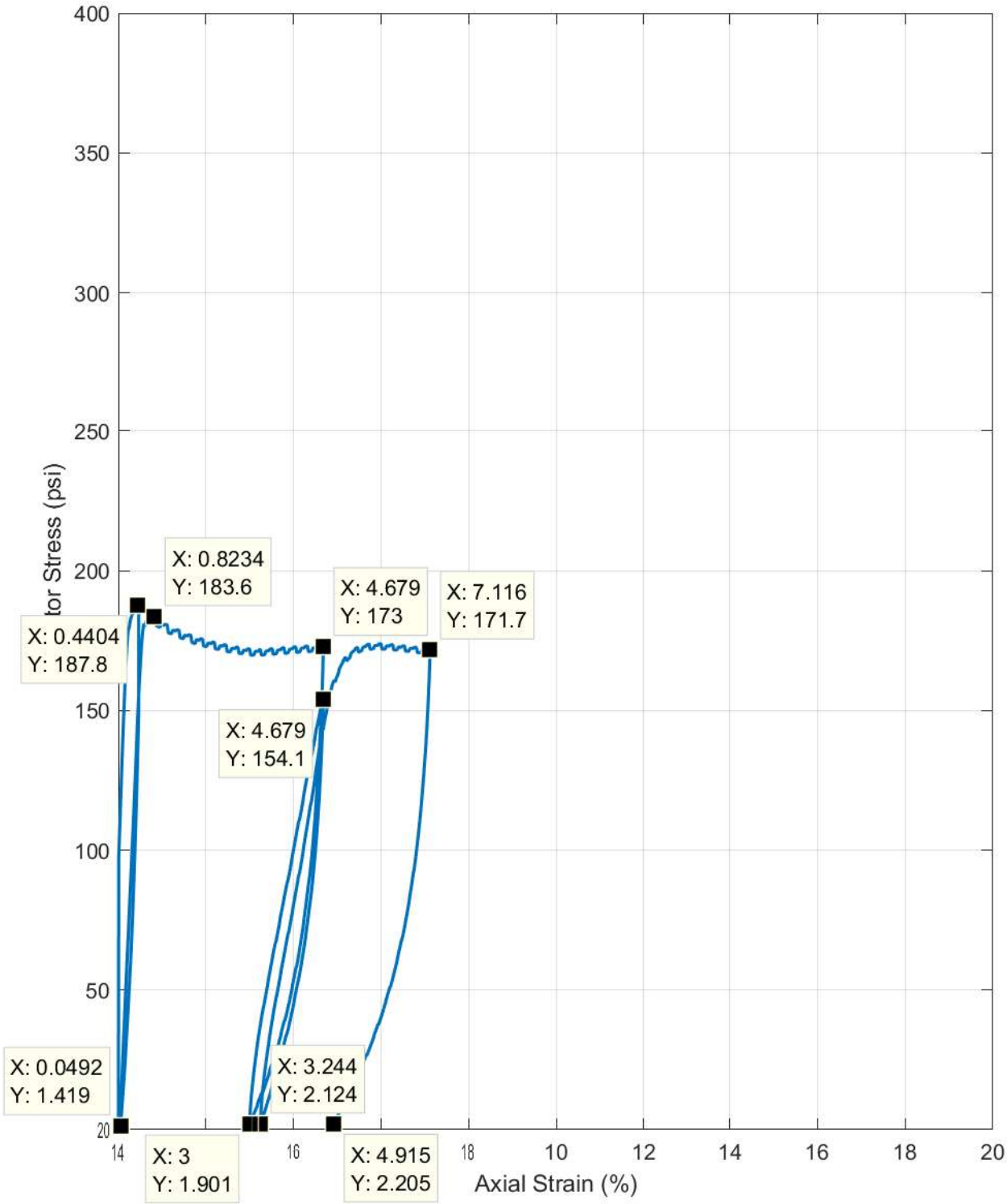

400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
14
16
18
20
Stress (psi)
Axial Strain (%)
σ_1
σ_3
X: 3.182
Y: 218.4
X: 19.76
Y: 207
X: 19.79
Y: 60.29

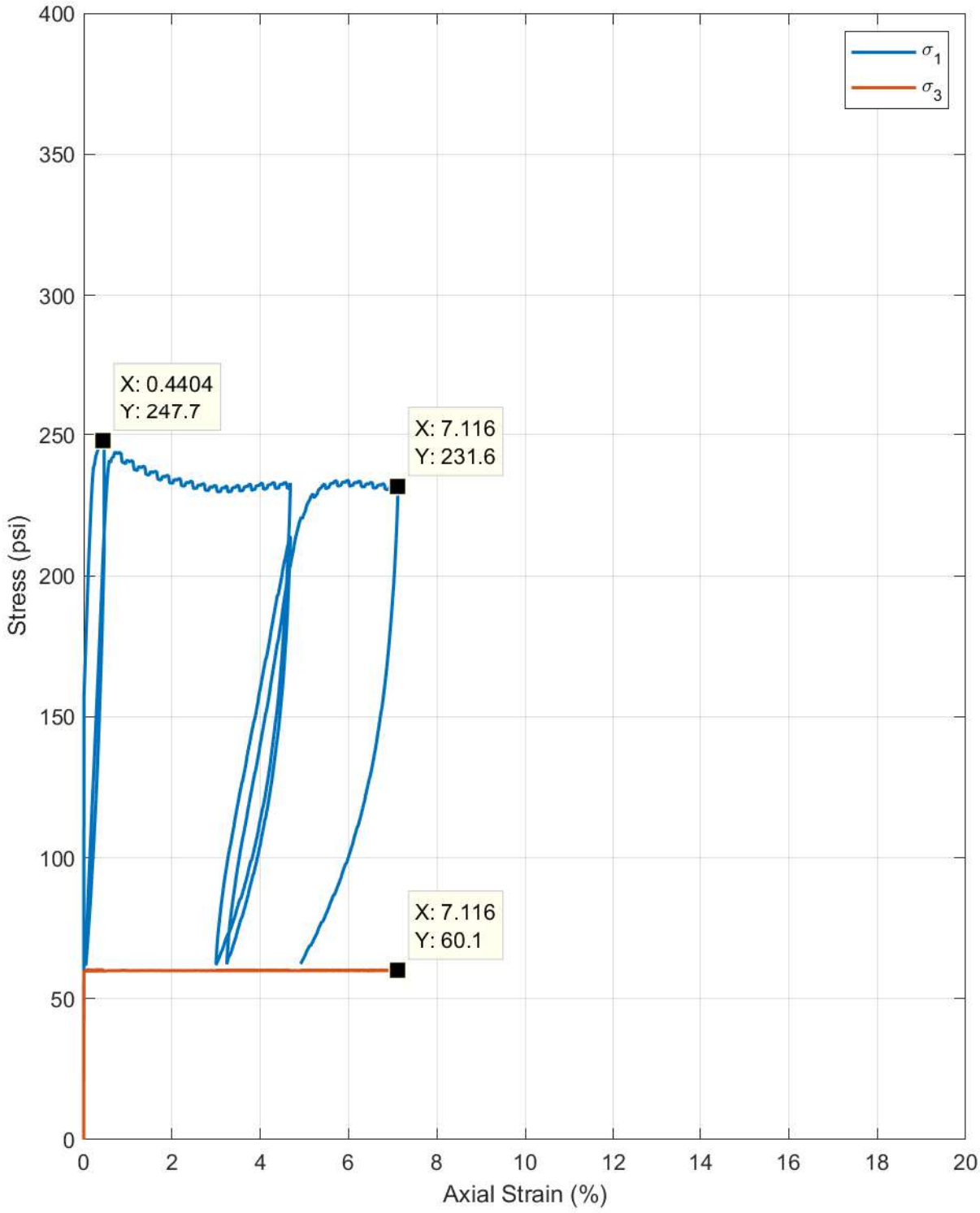

400
350
300
250
200
150
350
50
300
Deviator Stress (psi)
X: 2.024
Y: 184.8
X: 5.471
Y: 181.8
X: 11.95
Y: 172.4
X: 0.2833
Y: 74.09
X: 0.1334
Y: 1.093
X: 3.414
Y: 1.613
14
2
16
6
18
10
20
14
16
18
20
Axial Strain (%)

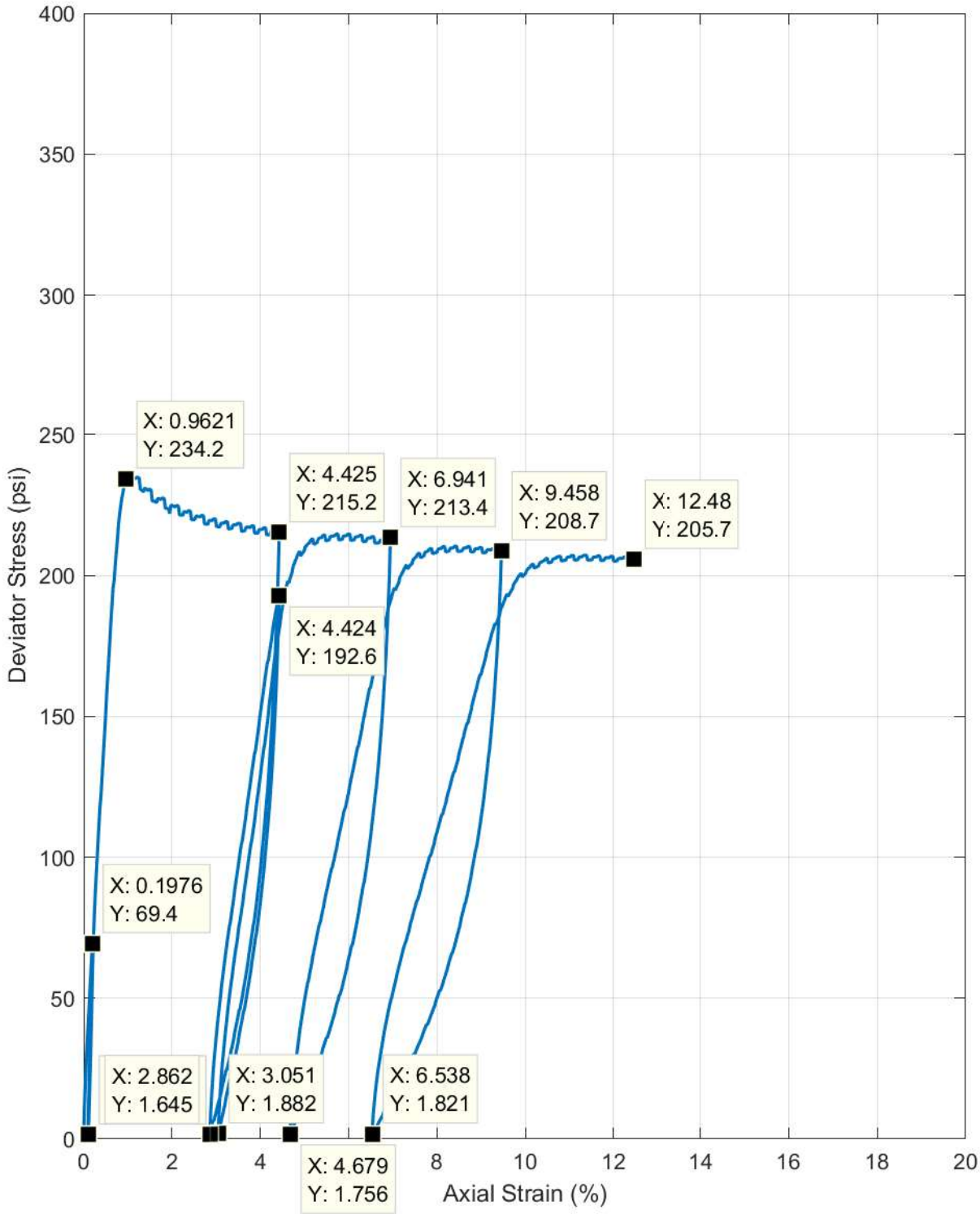

400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
14
16
18
20
Stress (psi)
Axial Strain (%)
σ_1
σ_3
X: 2.024
Y: 244.9
X: 11.97
Y: 232.4
X: 11.97
Y: 60.27

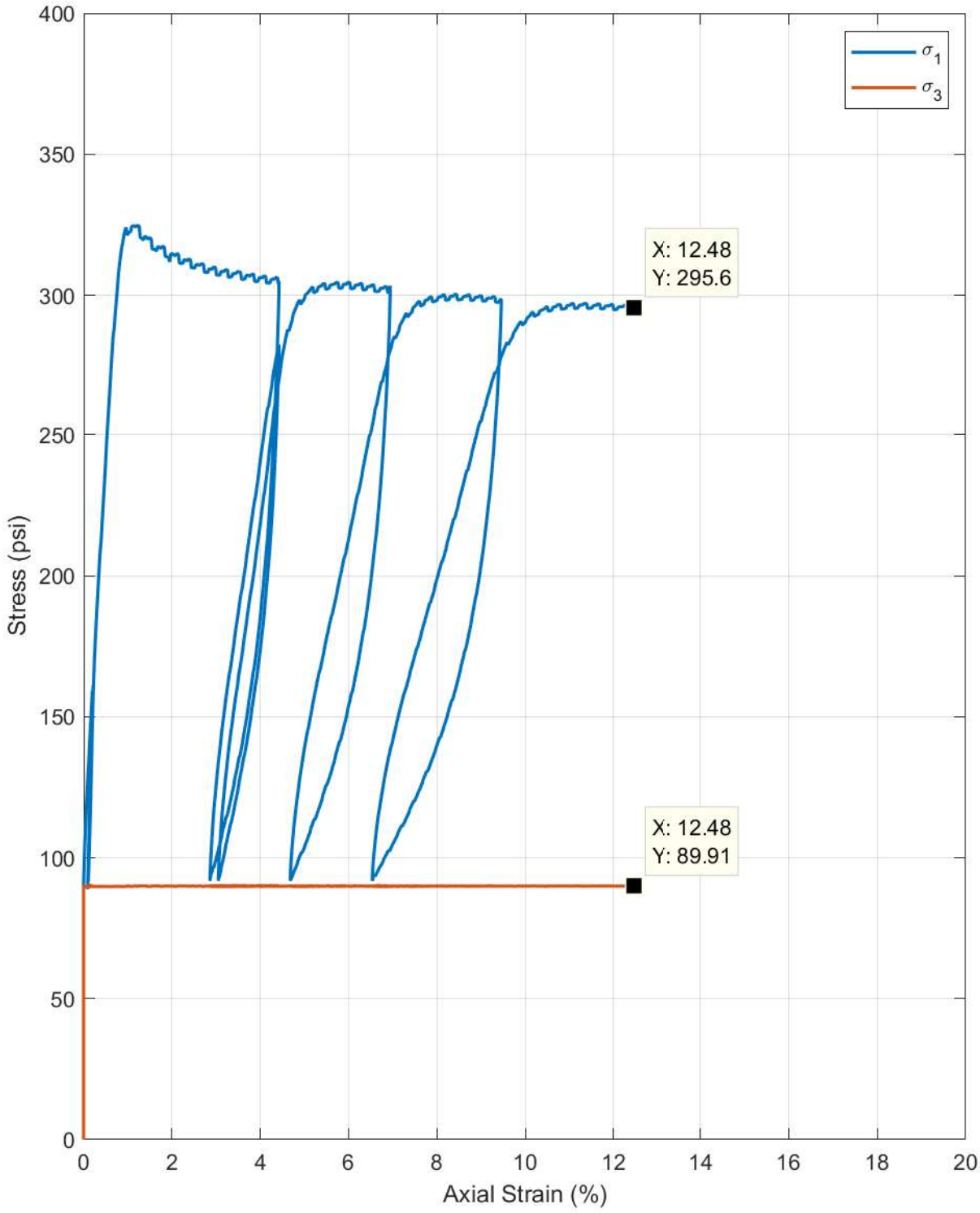

Deviator Stress (psi)
Axial Strain (%)
X: 4.112
Y: 210.1
X: 10.06
Y: 220.3
X: 0.3838
Y: 106.1
X: 0.2083
Y: 0.8599
X: 2.952
Y: 1.417

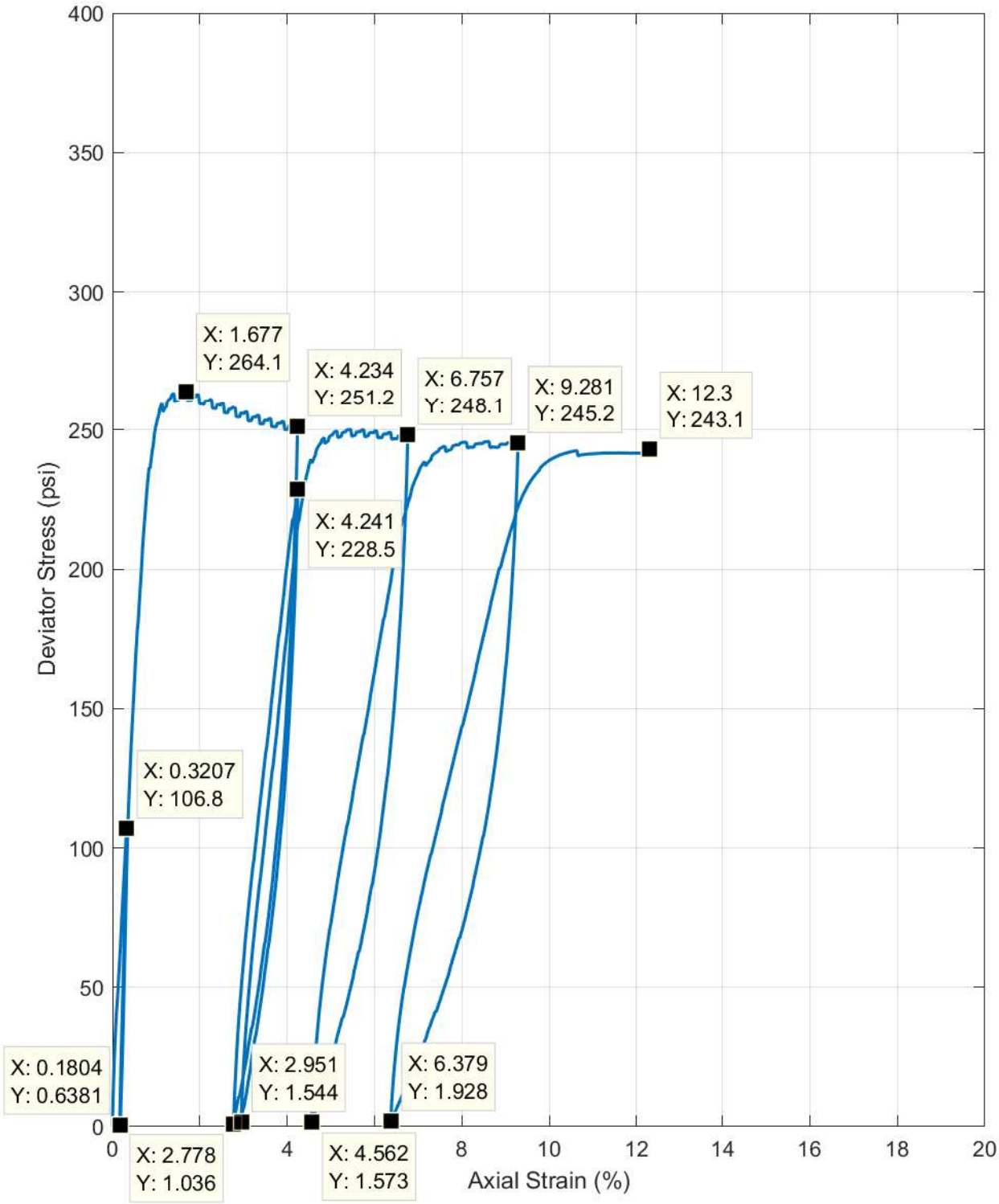

400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
14
16
18
20
Stress (psi)
Axial Strain (%)
σ_1
σ_3
X: 10.06
Y: 340.4
X: 10.06
Y: 120.1

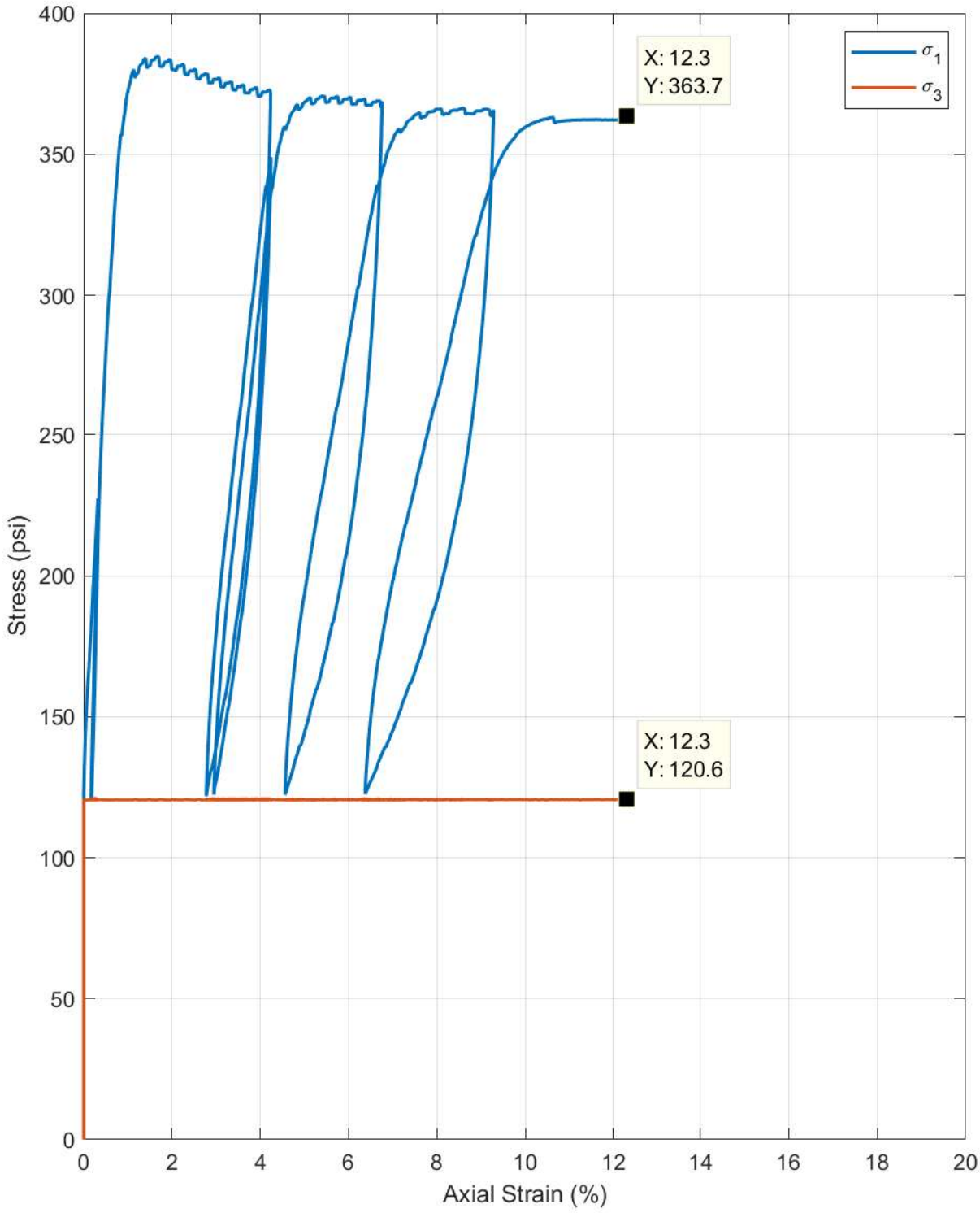

400
350
300
250
200
150
100
50
20
tor Stress (psi)
X: 0.8234
Y: 183.6
X: 4.679
Y: 173
X: 7.116
Y: 171.7
X: 0.4404
Y: 187.8
X: 4.679
Y: 154.1
X: 0.0492
Y: 1.419
X: 3.244
Y: 2.124
X: 3
Y: 1.901
X: 4.915
Y: 2.205
14
16
18
10
12
14
16
18
20
Axial Strain (%)


σ_1
σ_3
X: 0.4404
Y: 247.7
X: 7.116
Y: 231.6
X: 7.116
Y: 60.1
Stress (psi)
Axial Strain (%)
0
50
100
150
200
250
300
350
400
0
2
4
6
8
10
12
14
16
18
20


Deviator Stress (psi)
Axial Strain (%)
X: 0.9621
Y: 234.2
X: 4.425
Y: 215.2
X: 6.941
Y: 213.4
X: 9.458
Y: 208.7
X: 12.48
Y: 205.7
X: 4.424
Y: 192.6
X: 0.1976
Y: 69.4
X: 2.862
Y: 1.645
X: 3.051
Y: 1.882
X: 6.538
Y: 1.821
X: 4.679
Y: 1.756


σ_1
σ_3
X: 12.48
Y: 295.6
X: 12.48
Y: 89.91
Stress (psi)
Axial Strain (%)
0
50
100
150
200
250
300
350
400
0
2
4
6
8
10
12
14
16
18
20


Deviator Stress (psi)
Axial Strain (%)
X: 1.677
Y: 264.1
X: 4.234
Y: 251.2
X: 6.757
Y: 248.1
X: 9.281
Y: 245.2
X: 12.3
Y: 243.1
X: 4.241
Y: 228.5
X: 0.3207
Y: 106.8
X: 0.1804
Y: 0.6381
X: 2.951
Y: 1.544
X: 6.379
Y: 1.928
X: 2.778
Y: 1.036
X: 4.562
Y: 1.573


X: 12.3
Y: 363.7
X: 12.3
Y: 120.6
σ_1
σ_3
Stress (psi)
Axial Strain (%)
0
50
100
150
200
250
300
350
400
0
2
4
6
8
10
12
14
16
18
20

Appendix C

Bender Element Test Report

www.gdsinstruments.com	Travel time [ms]		
Filename	Frequency domain (FFT)	Time domain (Cross-correlation)	User-specified travel time
Batch 2_29 days_60 psi specimen_5 psi stress_s-wave.bes	0.247	0.181	0.164
Batch 2_29 days_60 psi specimen_15 psi stress_s-wave.bes	0.216	0.151	0.146
Batch 2_29 days_60 psi specimen_30 psi stress_s-wave.bes	0.213	0.129	0.128
Batch 2_29 days_60 psi specimen_60 psi stress_s-wave.bes	0.213	0.118	0.115
Batch 2_29 days_90 psi specimen_5 psi stress_s-wave.bes	0.225	0.177	0.163
Batch 2_29 days_90 psi specimen_15 psi stress_s-wave.bes	0.216	0.161	0.150
Batch 2_29 days_90 psi specimen_45 psi stress_s-wave.bes	0.225	0.132	0.130
Batch 2_29 days_90 psi specimen_90 psi stress_s-wave.bes	0.186	0.116	0.114
Batch 2_30 days_120 psi specimen_ 0 psi stress_s-wave.bes	0.194	0.187	0.168
Batch 2_30 days_120 psi specimen_ 5 psi stress_s-wave.bes	0.274	0.183	0.168
Batch 2_30 days_120 psi specimen_ 15 psi stress_s-wave.bes	0.276	0.405	0.156
Batch 2_30 days_120 psi specimen_ 30 psi stress_s-wave.bes	0.267	0.364	0.148
Batch 2_30 days_120 psi specimen_ 60 psi stress_s-wave.bes	0.220	0.323	0.123
Batch 2_30 days_120 psi specimen_ 120 psi stress_s-wave.bes	0.198	0.107	0.108
Batch 2_31 days_90 psi specimen_5 psi stress_s-wave.bes	0.228	0.183	0.165
Batch 2_31 days_90 psi specimen_15 psi stress_s-wave.bes	0.259	0.412	0.149
Batch 2_31 days_90 psi specimen_45 psi stress_s-wave.bes	0.270	0.356	0.144
Batch 2_31 days_90 psi specimen_90 psi stress_s-wave.bes	0.233	0.326	0.129

Test and specimen measurements				
Confining Pressure (kPa)	**Initial Moist Specimen Mass (kg)**	**Initial Speciment Height (mm)**	**Initial Specimen Diameter (mm)**	**Axial Displ. (mm)**
34.5	0.2350	101.981	51.985	0.8769
103.4	0.2350	101.981	51.985	0.9925
206.8	0.2350	101.981	51.985	1.1025
413.7	0.2350	101.981	51.985	1.2612
34.5	0.2261	102.218	52.002	0.1192
103.4	0.2261	102.218	52.002	0.2571
310.3	0.2261	102.218	52.002	0.5337
620.5	0.2261	102.218	52.002	0.7998
0.0	0.2215	102.218	51.909	0.0000
34.5	0.2215	102.218	51.909	0.1371
103.4	0.2215	102.218	51.909	0.2896
206.8	0.2215	102.218	51.909	0.4273
413.7	0.2215	102.218	51.909	0.6317
827.4	0.2215	102.218	51.909	0.9461
34.5	0.2275	102.080	51.680	0.0792
103.4	0.2275	102.080	51.680	0.1996
310.3	0.2275	102.080	51.680	0.4085
620.5	0.2275	102.080	51.680	0.6500

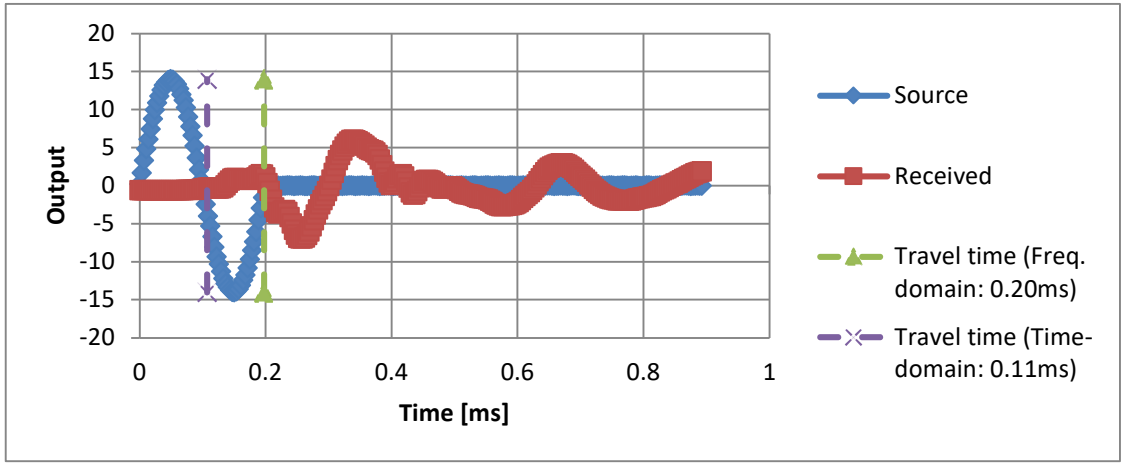
Test and specimen measurements				
Adjusted Specimen Height (mm)	Initial Volume of Cylindrical Specimen (m^3)	Volume Change of Cylindrical Specimen (m^3)	Total (Moist) Density (kg/m^3)	Adjusted Travel Length (mm)
101.1041	0.00021645	0.00000186	1086.4251	94.8841
100.9885	0.00021645	0.00000211	1086.5240	94.7685
100.8785	0.00021645	0.00000234	1086.6184	94.6585
100.7198	0.00021645	0.00000268	1086.7548	94.4998
102.0988	0.00021710	0.00000025	1041.5099	95.8788
101.9609	0.00021710	0.00000055	1041.5660	95.7409
101.6843	0.00021710	0.00000113	1041.6791	95.4643
101.4182	0.00021710	0.00000170	1041.7884	95.1982
102.2180	0.00021632	0.00000000	1023.9321	95.9980
102.0809	0.00021632	0.00000029	1023.9642	95.8609
101.9284	0.00021632	0.00000061	1024.0001	95.7084
101.7907	0.00021632	0.00000090	1024.0325	95.5707
101.5863	0.00021632	0.00000134	1024.0809	95.3663
101.2719	0.00021632	0.00000200	1024.1556	95.0519
102.0008	0.00021413	0.00000017	1062.4920	95.7808
101.8804	0.00021413	0.00000042	1062.5658	95.6604
101.6715	0.00021413	0.00000086	1062.6944	95.4515
101.4300	0.00021413	0.00000136	1062.8437	95.2100

Velocity (m/s)		
Velocity (m/s)	**Velocity (m/s)**	**Velocity (m/s)**
384.744	524.222	580.331
438.997	627.606	651.330
444.046	733.787	742.420
442.922	800.846	821.737
426.844	541.688	588.213
443.022	594.664	638.273
425.151	723.214	734.341
511.363	824.227	838.751
495.472	513.358	571.417
350.190	523.830	572.304
346.834	236.609	615.488
357.896	262.918	647.937
432.796	295.252	775.336
481.228	888.336	884.204
419.312	523.392	582.254
369.673	232.468	642.016
353.022	268.122	665.167
409.083	292.504	738.062

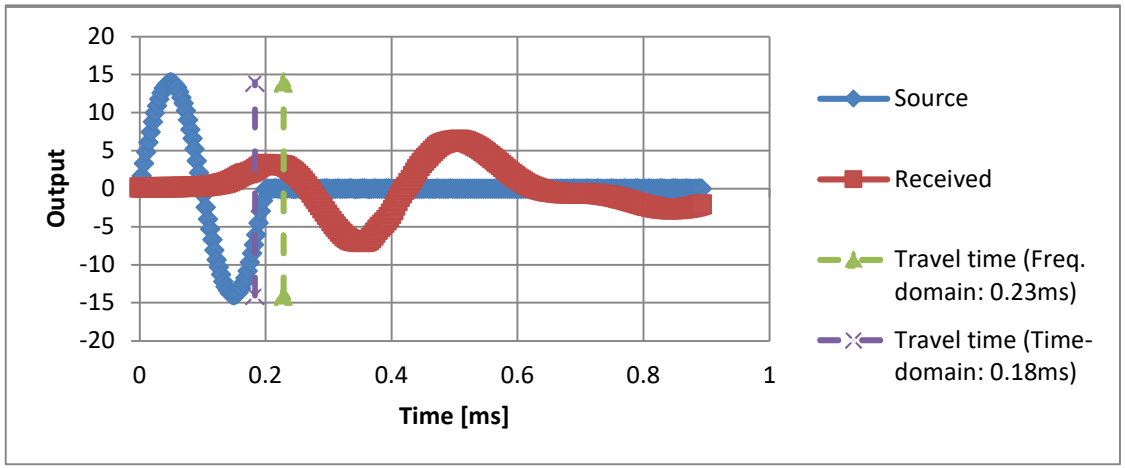
G_{max}		
G_{max} (Mpa)	G_{max} (Mpa)	G_{max} (Mpa)
160.821	298.559	365.891
209.393	427.970	460.937
214.256	585.082	598.930
213.200	696.994	733.834
189.758	305.606	360.357
204.427	368.324	424.326
188.287	544.839	561.732
272.419	707.739	732.901
251.368	269.844	334.331
125.571	280.974	335.381
123.181	57.328	387.917
131.168	70.787	429.912
191.823	89.273	615.622
237.174	808.202	800.701
186.810	291.059	360.206
145.208	57.422	437.973
132.438	76.397	470.186
177.866	90.935	578.969

Filename

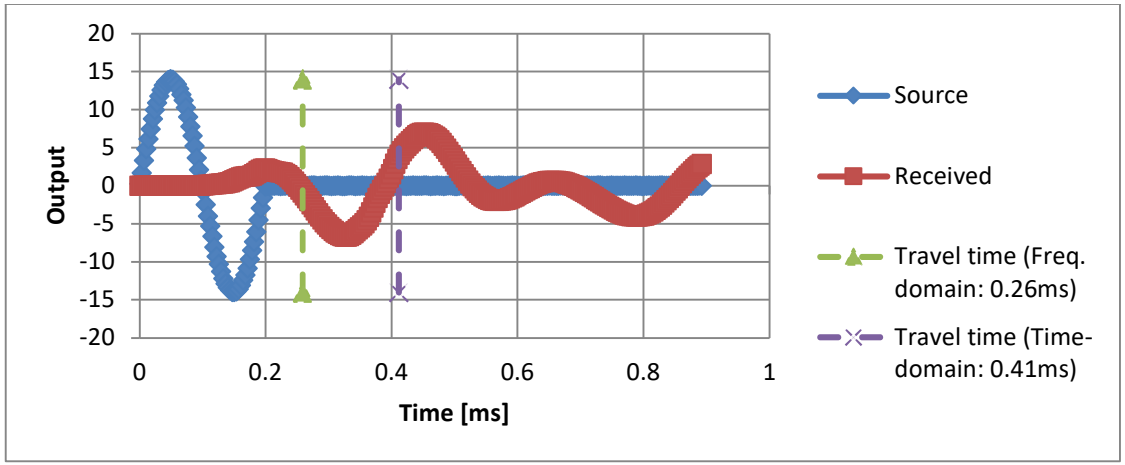
Batch 2_30 days_120 psi specimen_ 120 psi stress_s-wave.bes



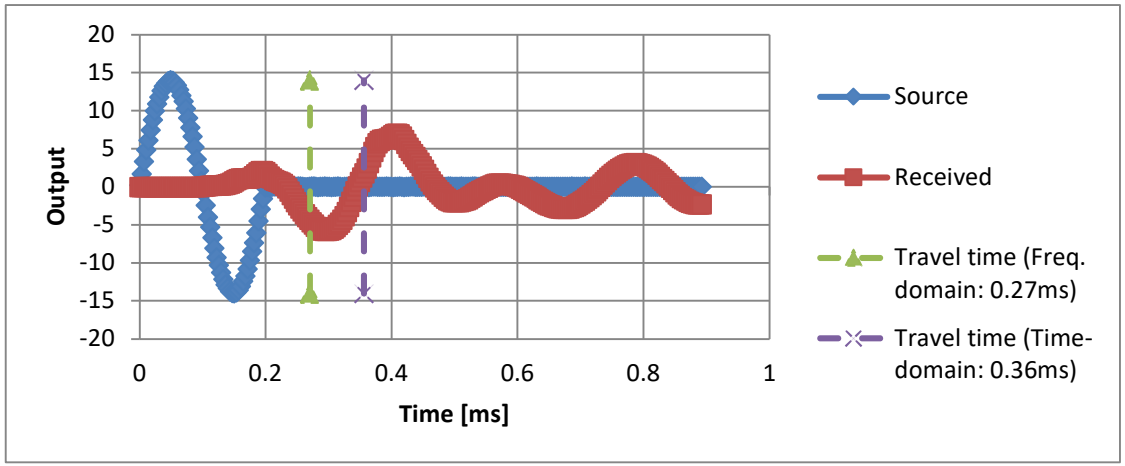
Batch 2_31 days_90 psi specimen_5 psi stress_s-wave.bes



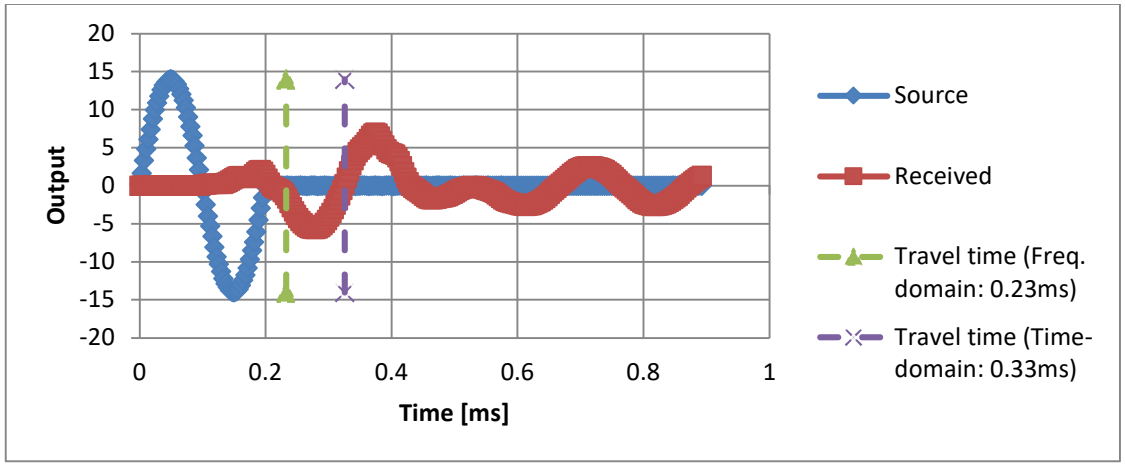
Batch 2_31 days_90 psi specimen_15 psi stress_s-wave.bes



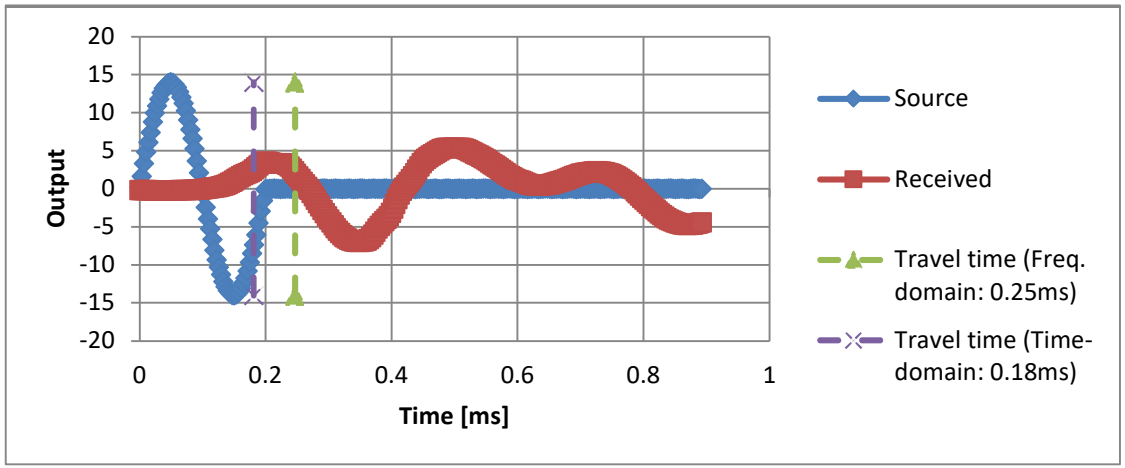
Batch 2_31 days_90 psi specimen_45 psi stress_s-wave.bes



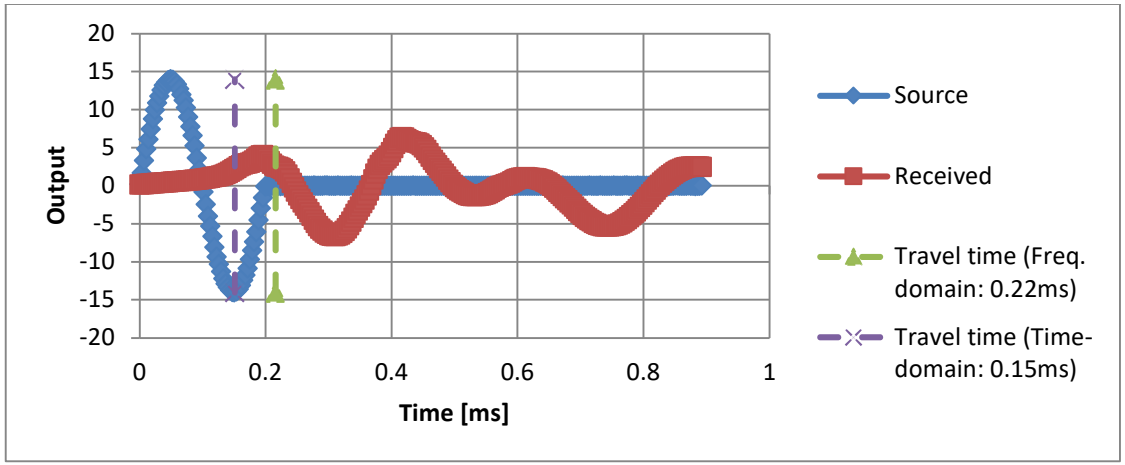
Batch 2_31 days_90 psi specimen_90 psi stress_s-wave.bes



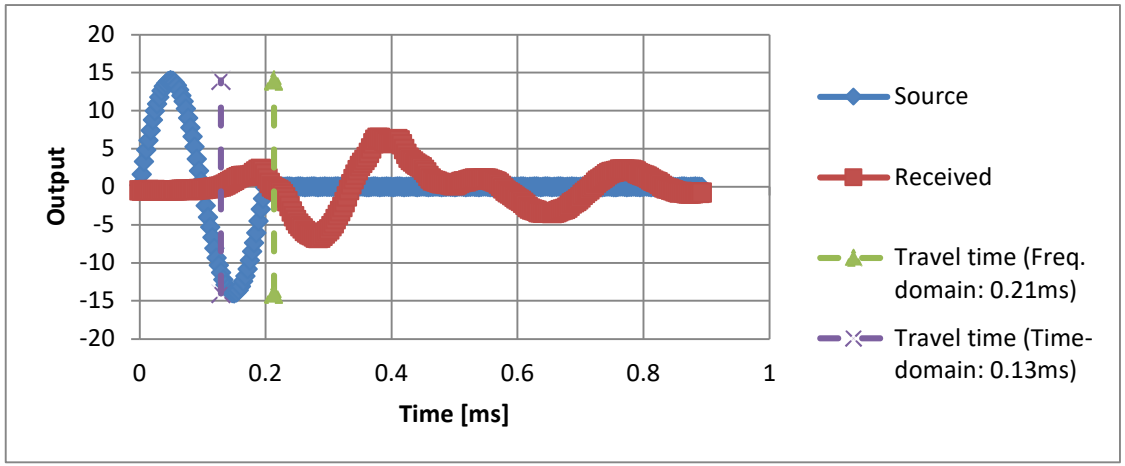
Batch 2_29 days_60 psi specimen_5 psi stress_s-wave.bes



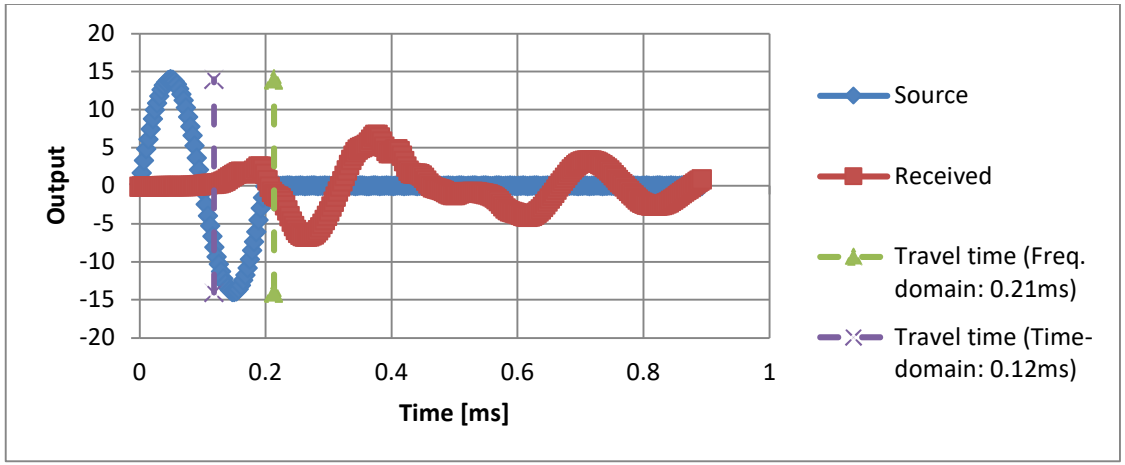
Batch 2_29 days_60 psi specimen_15 psi stress_s-wave.bes



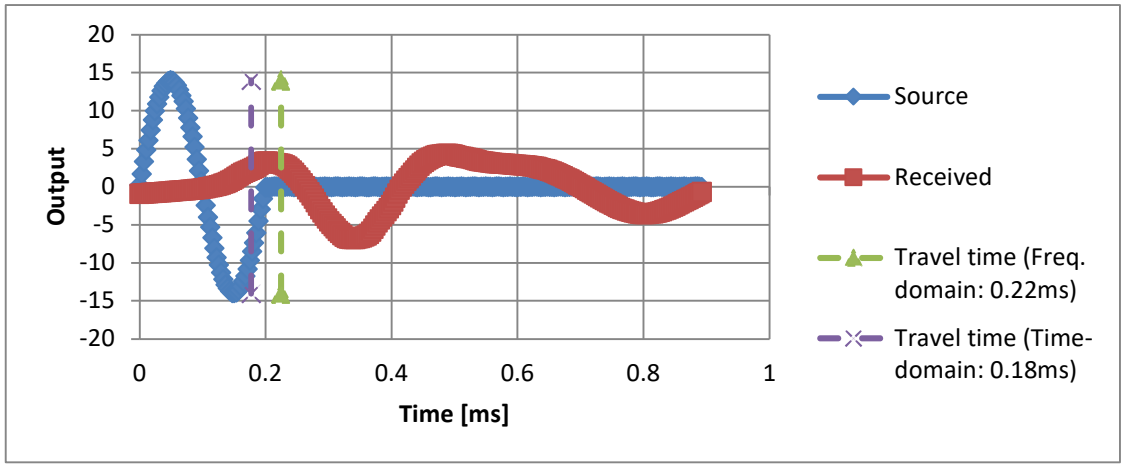
Batch 2_29 days_60 psi specimen_30 psi stress_s-wave.bes



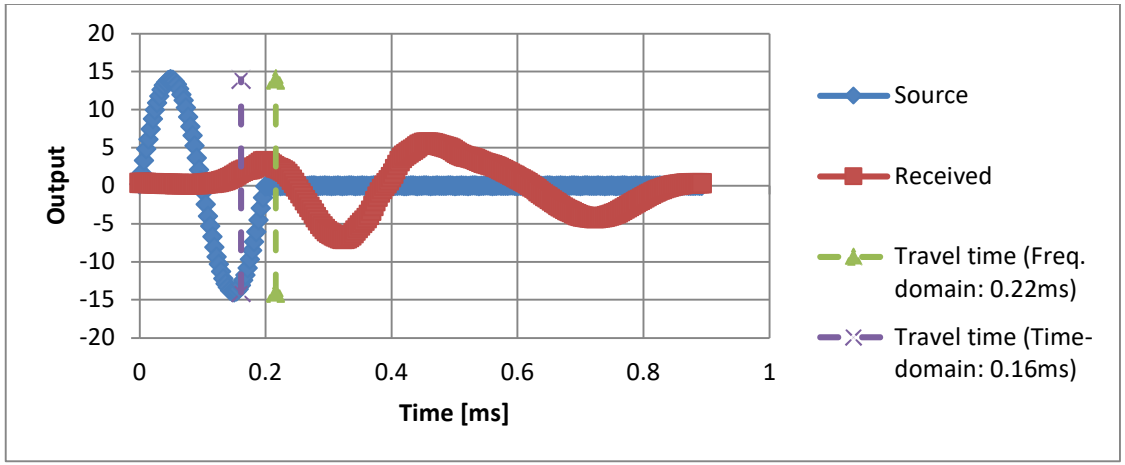
Batch 2_29 days_60 psi specimen_60 psi stress_s-wave.bes



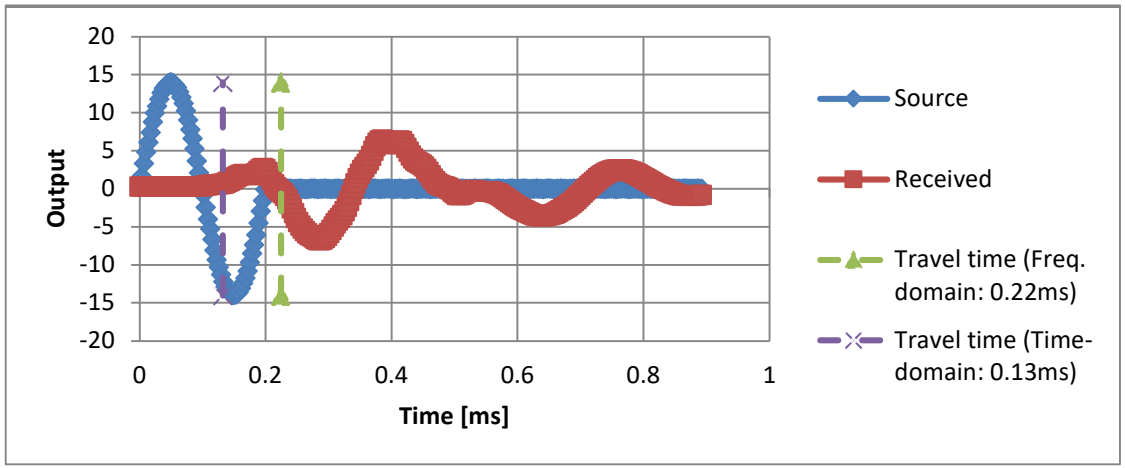
Batch 2_29 days_90 psi specimen_5 psi stress_s-wave.bes



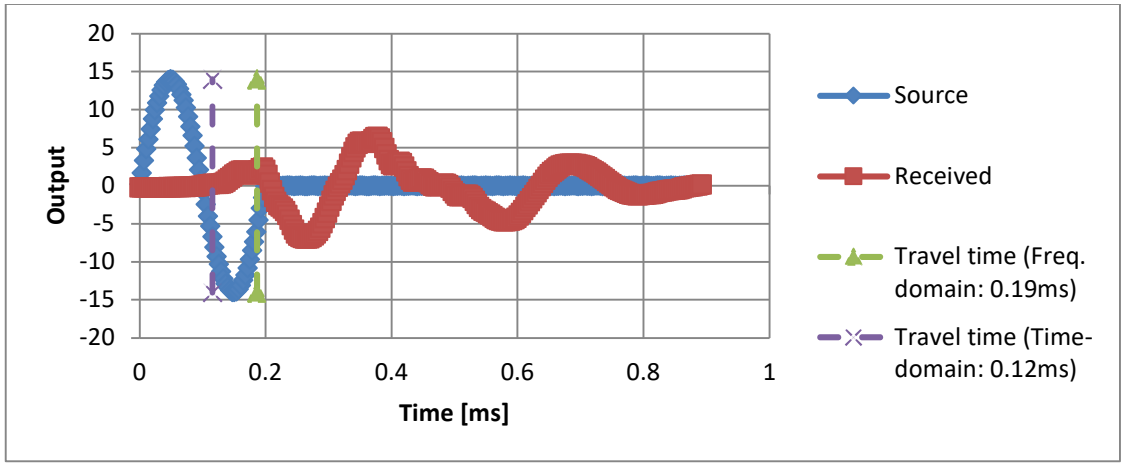
Batch 2_29 days_90 psi specimen_15 psi stress_s-wave.bes



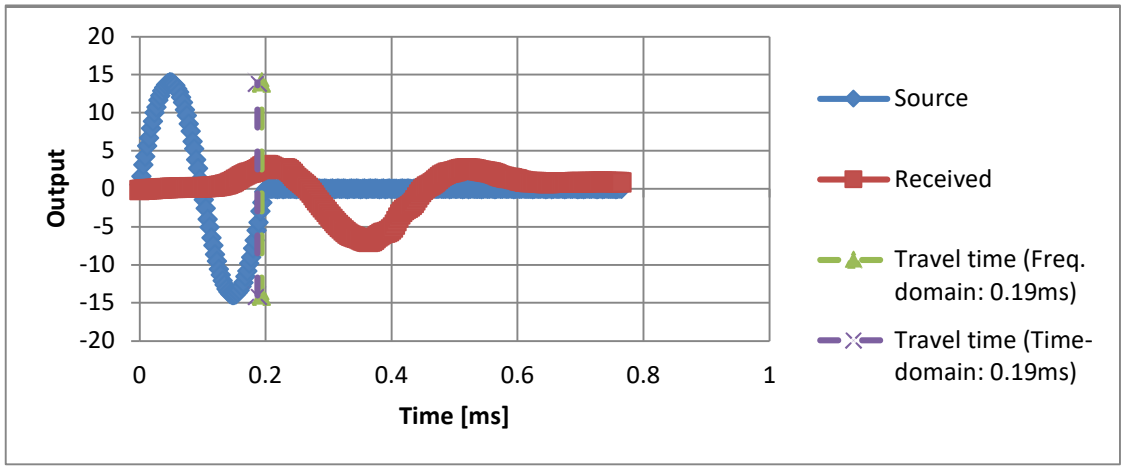
Batch 2_29 days_90 psi specimen_45 psi stress_s-wave.bes



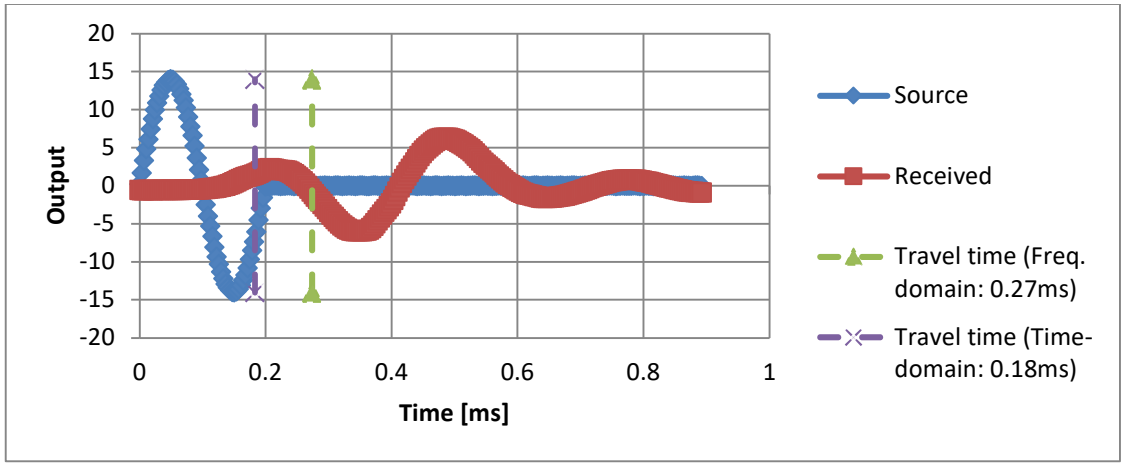
Batch 2_29 days_90 psi specimen_90 psi stress_s-wave.bes



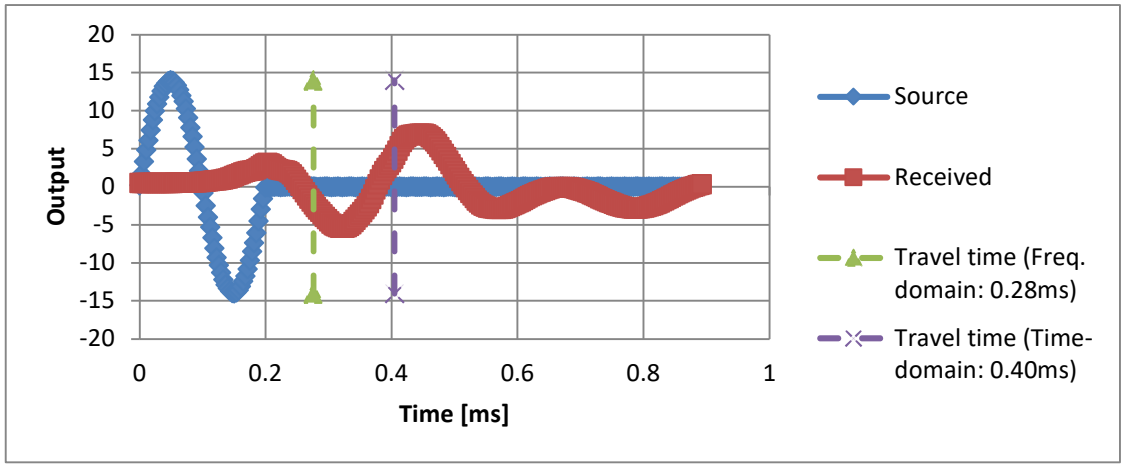
Batch 2_30 days_120 psi specimen_ 0 psi stress_s-wave.bes



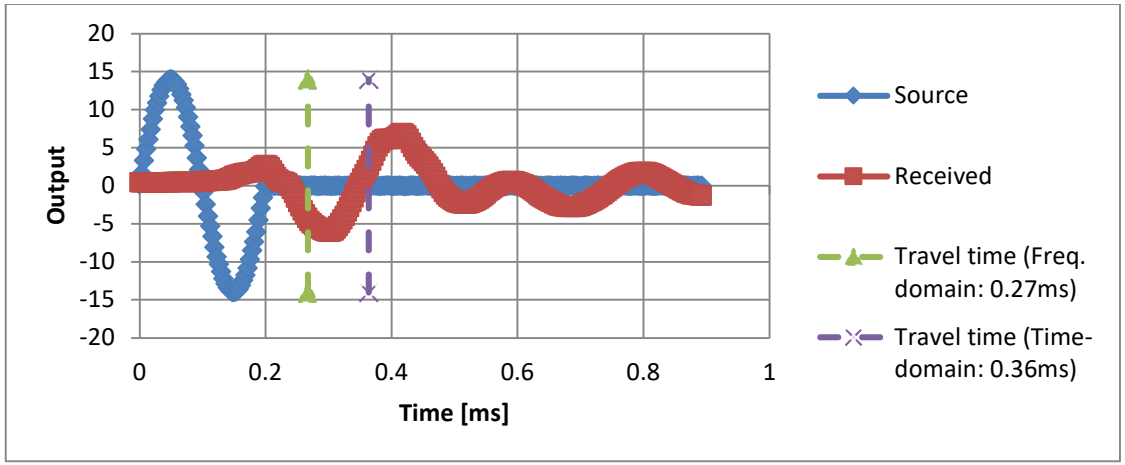
Batch 2_30 days_120 psi specimen_ 5 psi stress_s-wave.bes



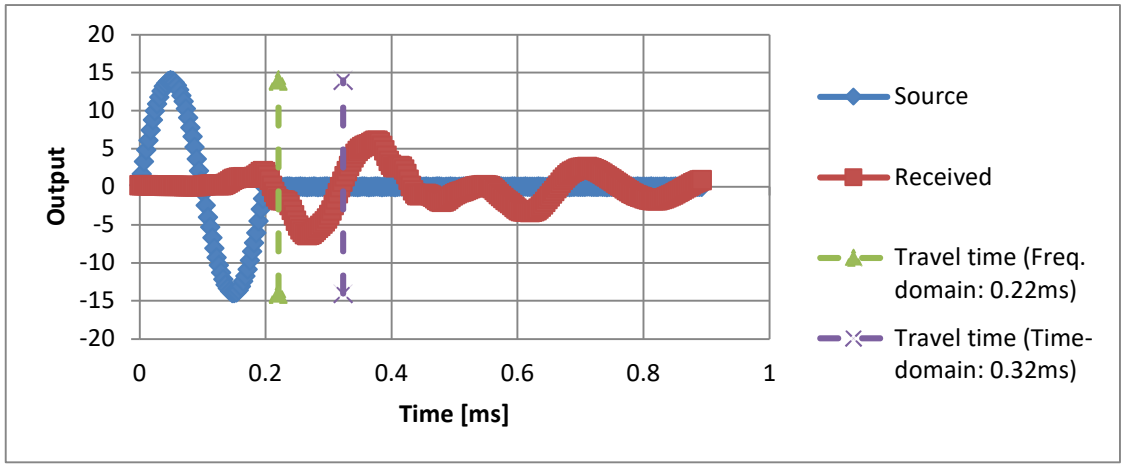
Batch 2_30 days_120 psi specimen_ 15 psi stress_s-wave.bes



Batch 2_30 days_120 psi specimen_ 30 psi stress_s-wave.bes



Batch 2_30 days_120 psi specimen_ 60 psi stress_s-wave.bes



www.gdsinstruments.com	Travel time [ms]		
Filename	Frequency domain (FFT)	Time domain (Cross-correlation)	User-specified travel time
Batch 3_28 days_60 psi specimen_ 0 psi stress_s-wave.bes	0.163	0.202	0.184
Batch 3_28 days_60 psi specimen_ 5 psi stress_s-wave.bes	0.284	0.195	0.177
Batch 3_28 days_60 psi specimen_ 15 psi stress_s-wave.bes	0.274	0.183	0.176
Batch 3_28 days_60 psi specimen_ 30 psi stress_s-wave.bes	0.259	0.170	0.170
Batch 3_28 days_60 psi specimen_ 60 psi stress_s-wave.bes	0.229	0.151	0.155
Batch 3_29 days_60 psi unloadreload_ 0 psi stress_s-wave.bes	0.113	0.207	0.177
Batch 3_29 days_60 psi unloadreload_ 5 psi stress_s-wave.bes	0.287	0.192	0.176
Batch 3_29 days_60 psi unloadreload_ 15 psi stress_s-wave.bes	0.266	0.173	0.168
Batch 3_29 days_60 psi unloadreload_ 30 psi stress_s-wave.bes	0.271	0.385	0.161
Batch 3_29 days_60 psi unloadreload_ 60 psi stress_s-wave.bes	0.178	0.114	0.120
Batch 3_29 days_90 psi unloadreload_ 0 psi stress_s-wave.bes	0.256	0.202	0.187
Batch 3_29 days_90 psi unloadreload_ 5 psi stress_s-wave.bes	0.236	0.186	0.176
Batch 3_29 days_90 psi unloadreload_ 15 psi stress_s-wave.bes	0.242	0.173	0.167
Batch 3_29 days_90 psi unloadreload_ 45 psi stress_s-wave.bes	0.201	0.140	0.149
Batch 3_29 days_90 psi unloadreload_90 psi stress_s-wave.bes	0.190	0.116	0.115
Batch 3_29 days_120 psi unloadreload_0 psi stress_s-wave.bes	0.226	0.203	0.177
Batch 3_29 days_120 psi unloadreload_5 psi stress_s-wave.bes	0.271	0.194	0.173
Batch 3_29 days_120 psi unloadreload_15 psi stress_s-wave.bes	0.237	0.174	0.166
Batch 3_29 days_120 psi unloadreload_30 psi stress_s-wave.bes	0.210	0.151	0.156
Batch 3_29 days_120 psi unloadreload_60 psi stress_s-wave.bes	0.203	0.129	0.130
Batch 3_29 days_120 psi unloadreload_120 psi stress_s-wave.bes	0.192	0.111	0.108

Test and specimen measurements				
Confining Pressure (kPa)	**Initial Moist Specimen Mass (kg)**	**Initial Speciment Height (mm)**	**Initial Specimen Diameter (mm)**	**Axial Displ. (mm)**
0.0	0.2396	101.956	51.867	0.0000
34.5	0.2396	101.956	51.867	0.4187
103.4	0.2396	101.956	51.867	0.5819
206.8	0.2396	101.956	51.867	0.7456
413.7	0.2396	101.956	51.867	0.9804
0.0	0.2336	102.006	51.840	0.0000
34.5	0.2336	102.006	51.840	0.0960
103.4	0.2336	102.006	51.840	0.1965
206.8	0.2336	102.006	51.840	0.3117
413.7	0.2336	102.006	51.840	0.5246
0.0	0.2275	101.900	51.900	0.0000
34.5	0.2275	101.900	51.900	0.1398
103.4	0.2275	101.900	51.900	0.3260
310.3	0.2275	101.900	51.900	0.6369
620.5	0.2275	101.900	51.900	0.9415
0.0	0.2275	102.060	51.890	0.0000
34.5	0.2275	102.060	51.890	0.1408
103.4	0.2275	102.060	51.890	0.3271
206.8	0.2400	102.060	51.890	0.4779
413.7	0.2400	102.060	51.890	0.6546
827.4	0.2400	102.060	51.890	0.9506

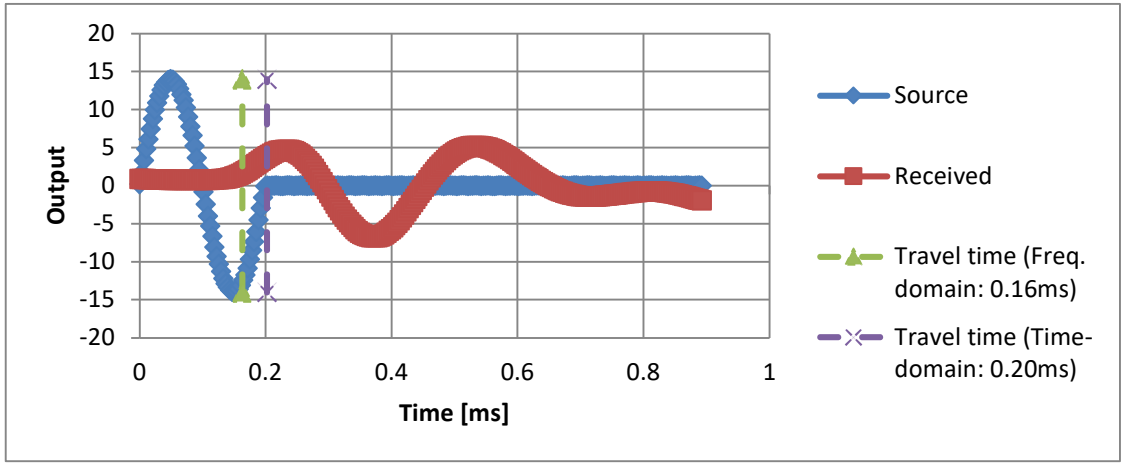
Test and specimen measurements				
Adjusted Specimen Height (mm)	Initial Volume of Cylindrical Specimen (m^3)	Volume Change of Cylindrical Specimen (m^3)	Total (Moist) Density (kg/m^3)	Adjusted Travel Length (mm)
101.9560	0.00021542	0.00000000	1112.2486	95.7360
101.5373	0.00021542	0.00000088	1112.7115	95.3173
101.3741	0.00021542	0.00000123	1112.8930	95.1541
101.2104	0.00021542	0.00000158	1113.0756	94.9904
100.9756	0.00021542	0.00000207	1113.3385	94.7556
102.0060	0.00021530	0.00000000	1084.9938	95.7860
101.9100	0.00021530	0.00000020	1085.0739	95.6900
101.8095	0.00021530	0.00000041	1085.1578	95.5895
101.6943	0.00021530	0.00000066	1085.2543	95.4743
101.4814	0.00021530	0.00000111	1085.4332	95.2614
101.9000	0.00021558	0.00000000	1055.3162	95.6800
101.7602	0.00021558	0.00000030	1055.3922	95.5402
101.5740	0.00021558	0.00000069	1055.4938	95.3540
101.2631	0.00021558	0.00000135	1055.6642	95.0431
100.9585	0.00021558	0.00000199	1055.8321	94.7385
102.0600	0.00021583	0.00000000	1054.0680	95.8400
101.9192	0.00021583	0.00000030	1054.1427	95.6992
101.7329	0.00021583	0.00000069	1054.2418	95.5129
101.5821	0.00021583	0.00000101	1112.3710	95.3621
101.4054	0.00021583	0.00000138	1112.5668	95.1854
101.1094	0.00021583	0.00000201	1112.8963	94.8894

Velocity (m/s)		
Velocity (m/s)	**Velocity (m/s)**	**Velocity (m/s)**
587.642	473.941	520.304
335.928	488.807	538.516
346.856	521.392	540.648
366.980	560.415	558.767
414.679	629.605	613.305
846.795	463.855	542.697
333.148	498.385	545.242
359.418	552.540	568.985
352.518	248.308	593.008
534.881	839.307	797.167
374.450	474.839	511.658
405.242	513.657	544.389
394.510	551.179	570.982
471.869	678.879	637.873
499.114	820.247	823.813
424.110	473.284	541.469
353.470	493.295	554.778
402.517	548.925	577.117
454.173	633.635	613.261
469.440	740.742	732.195
495.421	858.728	878.606

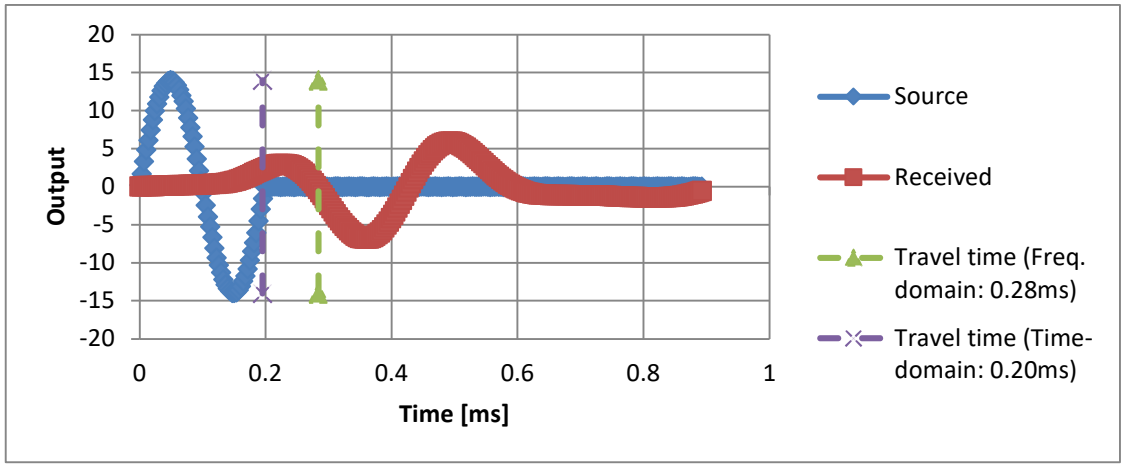
G_{max}		
G_{max} (Mpa)	G_{max} (Mpa)	G_{max} (Mpa)
384.086	249.833	301.104
125.567	265.862	322.686
133.891	302.540	325.299
149.902	349.578	347.525
191.448	441.331	418.774
778.008	233.449	319.552
120.429	269.519	322.581
140.182	331.300	351.313
134.863	66.913	381.639
310.540	764.619	689.765
147.969	237.944	276.275
173.317	278.458	312.775
164.275	320.657	344.113
235.054	486.531	429.531
263.023	710.369	716.559
189.594	236.109	309.041
131.706	256.515	324.443
170.808	317.662	351.130
229.452	446.610	418.351
245.180	610.465	596.458
273.152	820.664	859.098

Filename

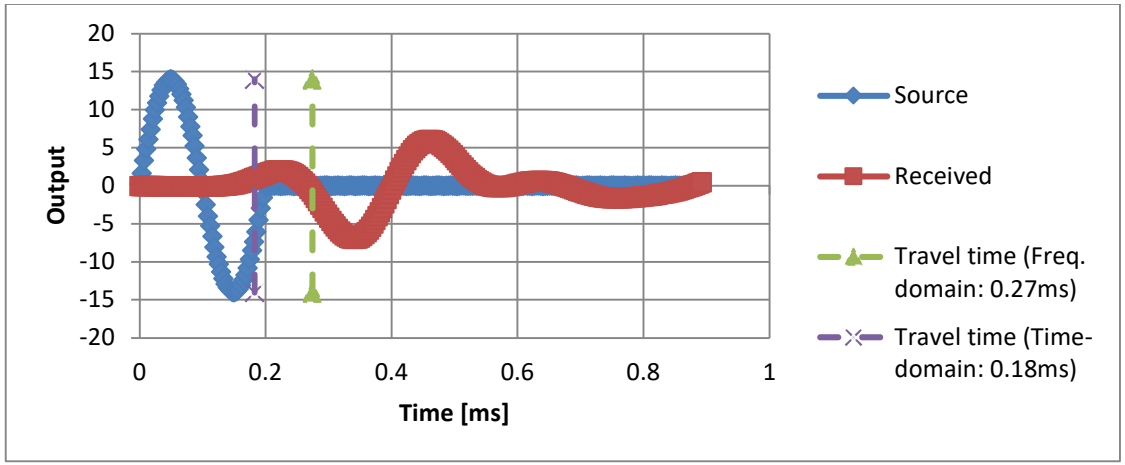
Batch 3_28 days_60 psi specimen_ 0 psi stress_s-wave.bes



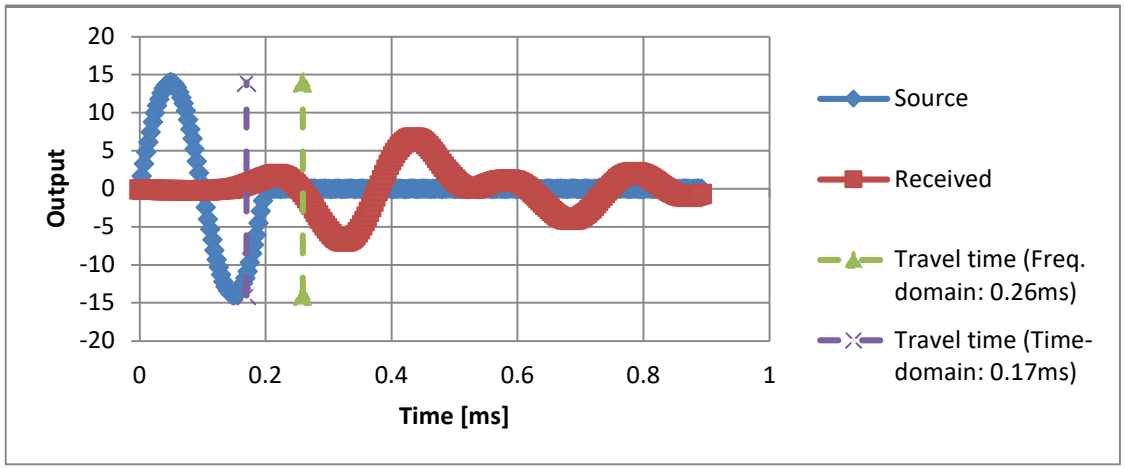
Batch 3_28 days_60 psi specimen_ 5 psi stress_s-wave.bes



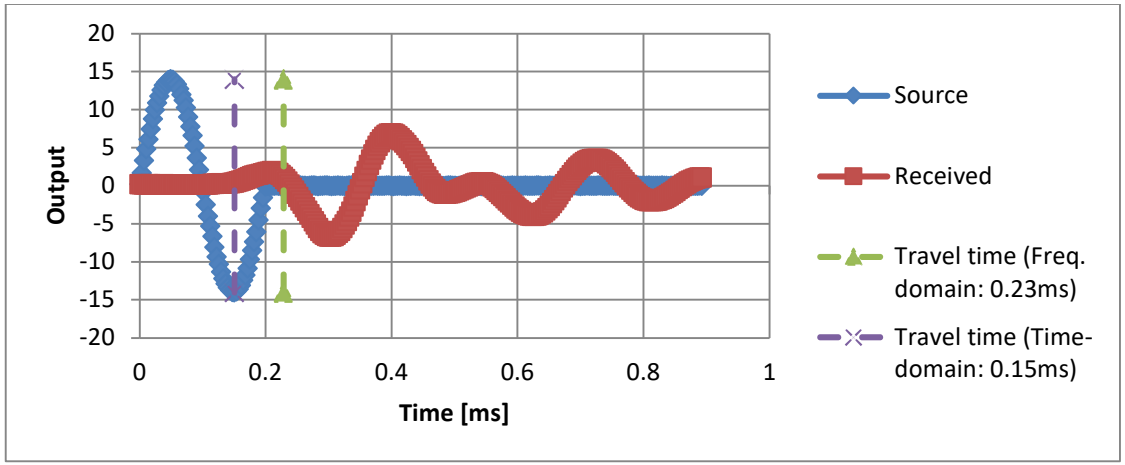
Batch 3_28 days_60 psi specimen_ 15 psi stress_s-wave.bes



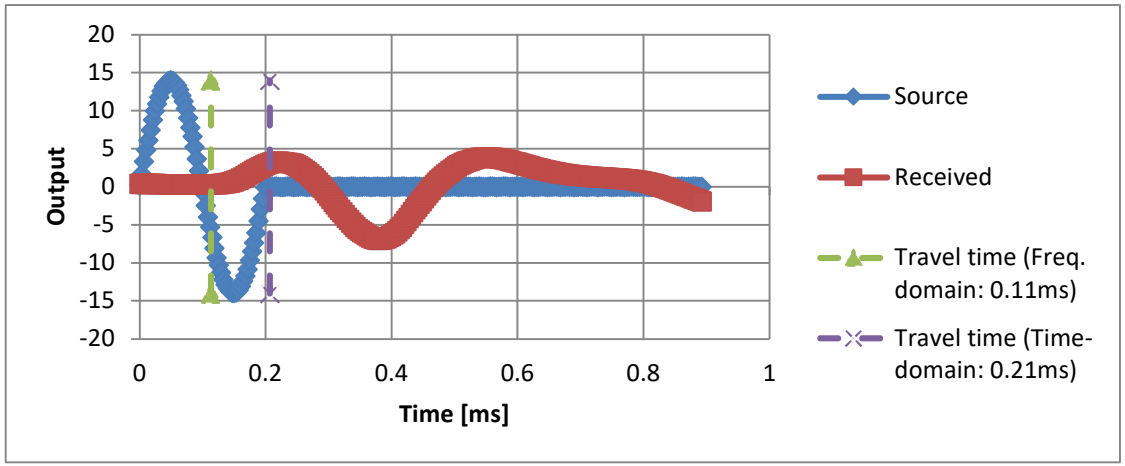
Batch 3_28 days_60 psi specimen_ 30 psi stress_s-wave.bes



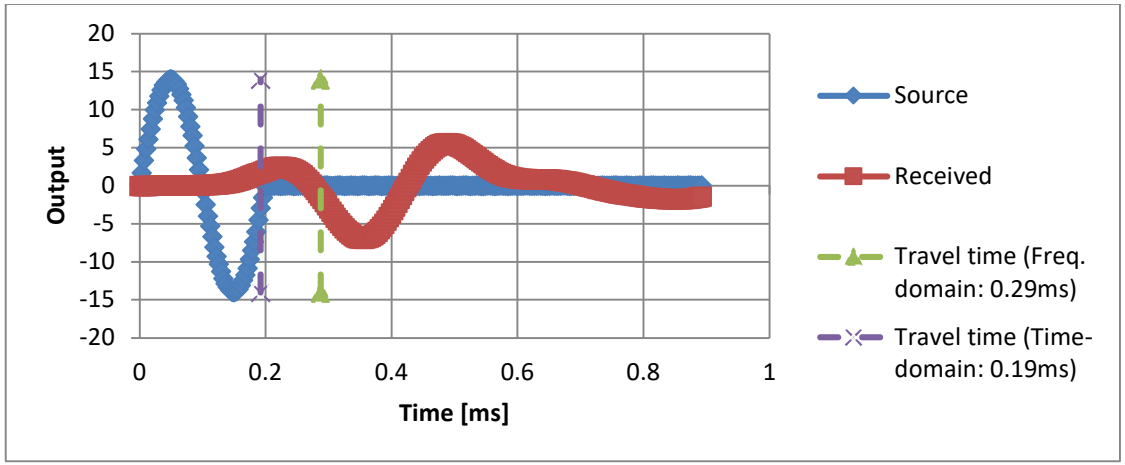
Batch 3_28 days_60 psi specimen_ 60 psi stress_s-wave.bes



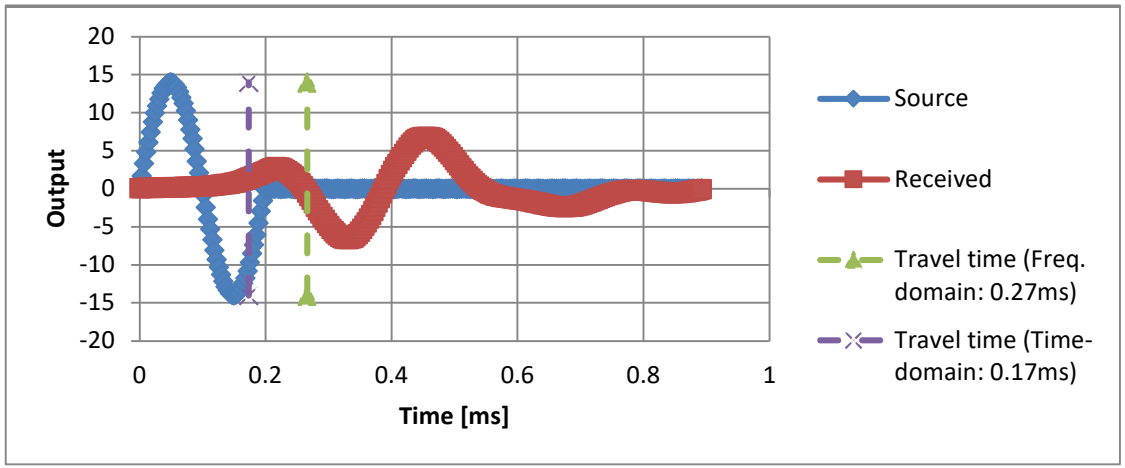
Batch 3_29 days_60 psi unloadreload_ 0 psi stress_s-wave.bes



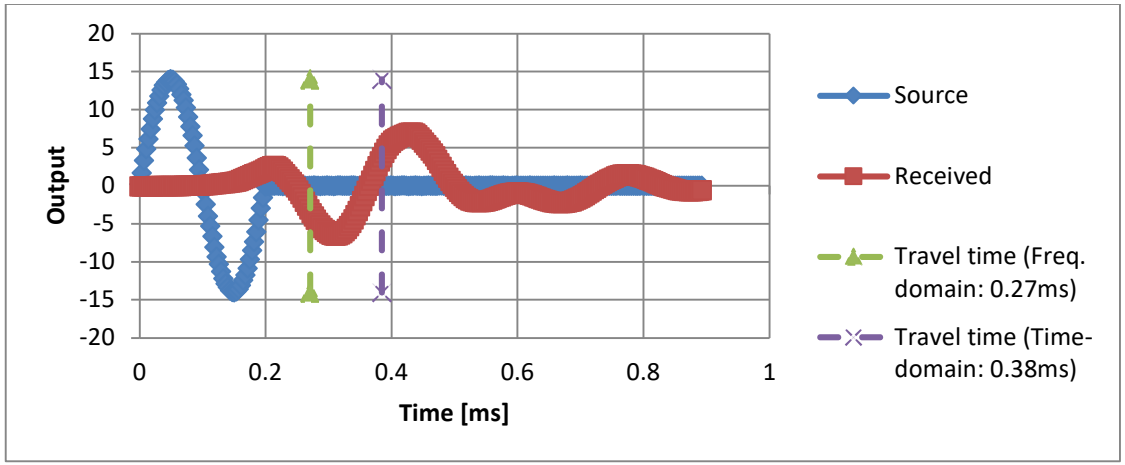
Batch 3_29 days_60 psi unloadreload_ 5 psi stress_s-wave.bes



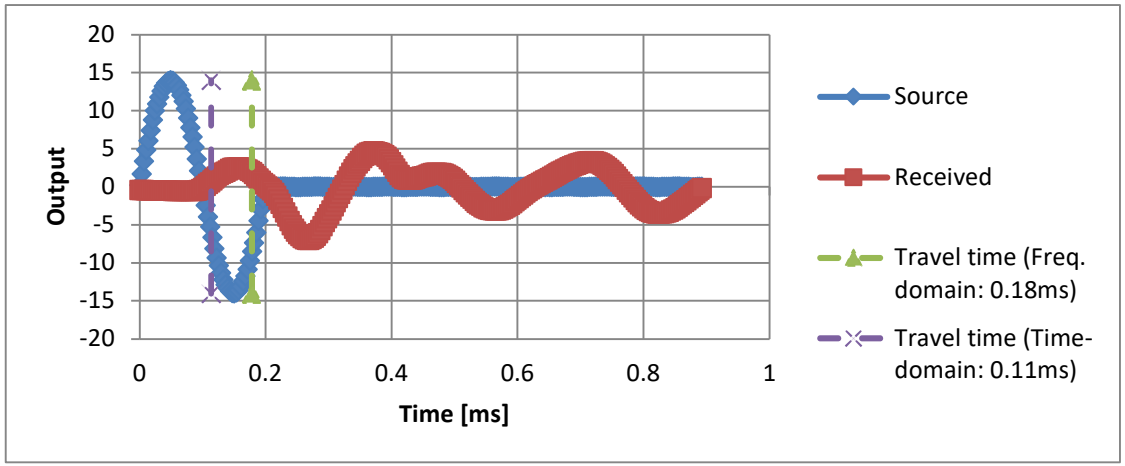
Batch 3_29 days_60 psi unloadreload_ 15 psi stress_s-wave.bes



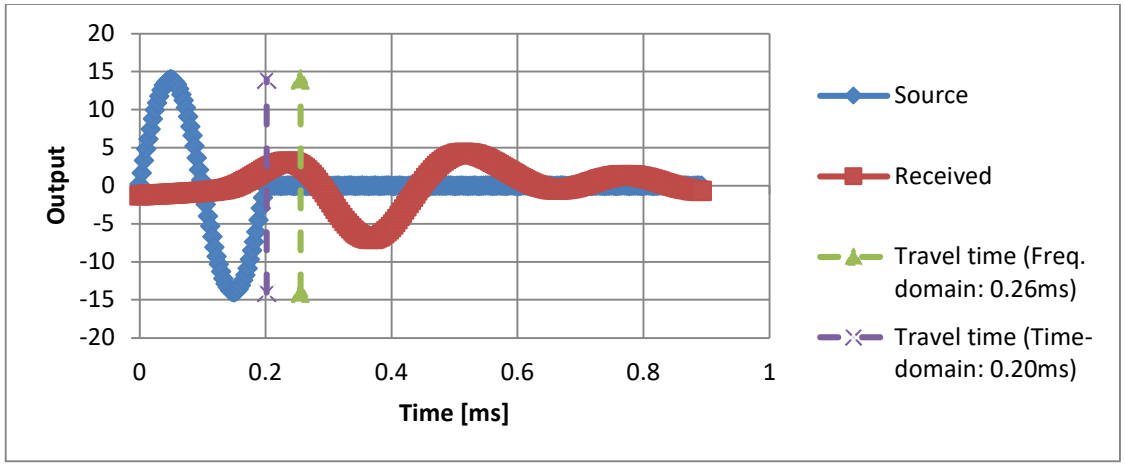
Batch 3_29 days_60 psi unloadreload_ 30 psi stress_s-wave.bes



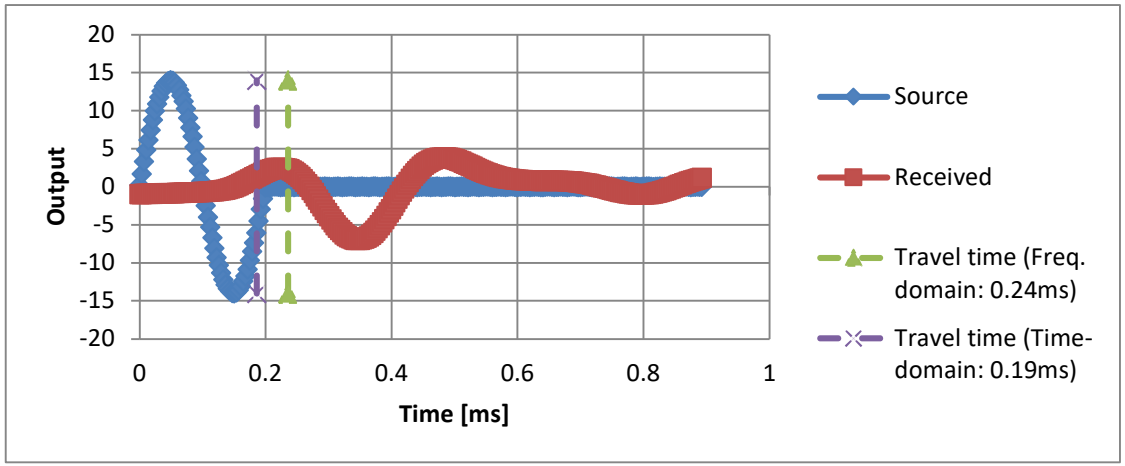
Batch 3_29 days_60 psi unloadreload_ 60 psi stress_s-wave.bes



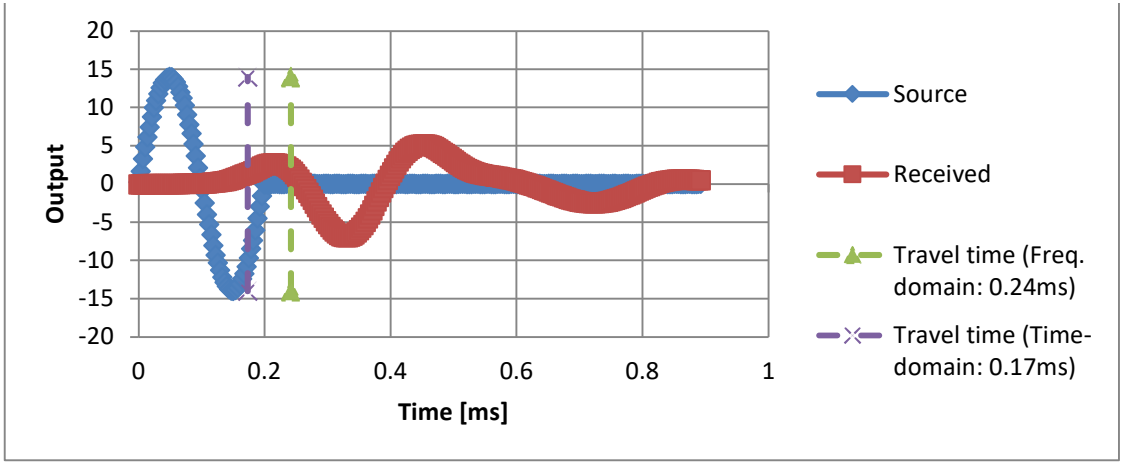
Batch 3_29 days_90 psi unloadreload_ 0 psi stress_s-wave.bes



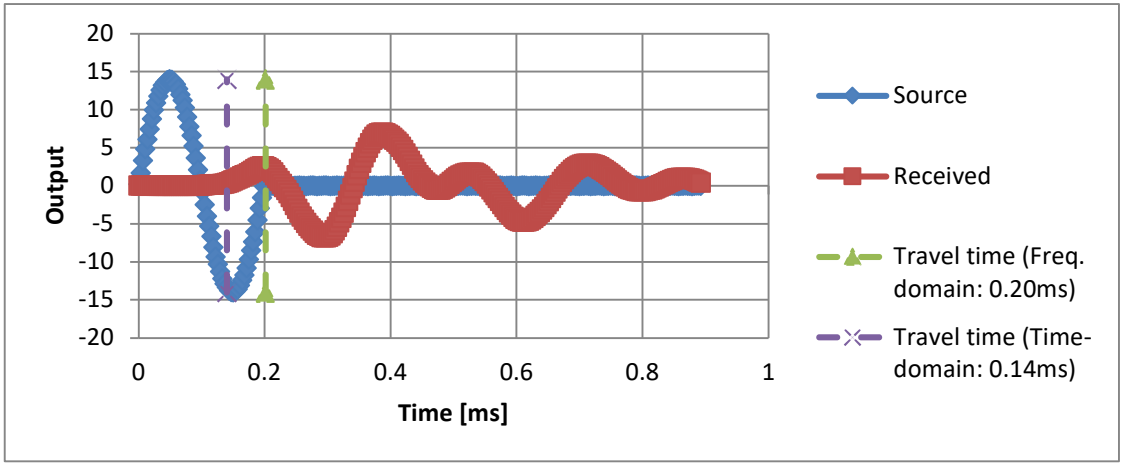
Batch 3_29 days_90 psi unloadreload_ 5 psi stress_s-wave.bes



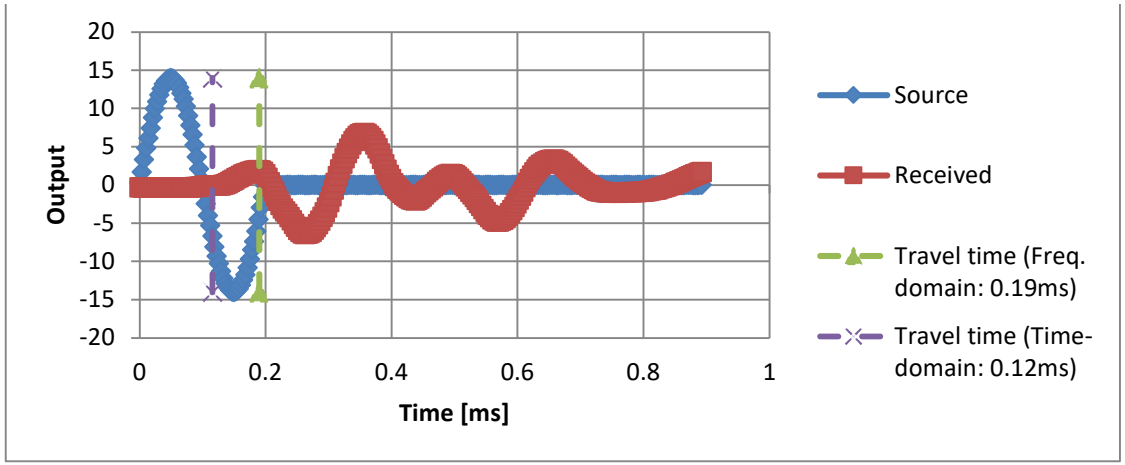
Batch 3_29 days_90 psi unloadreload_ 15 psi stress_s-wave.bes



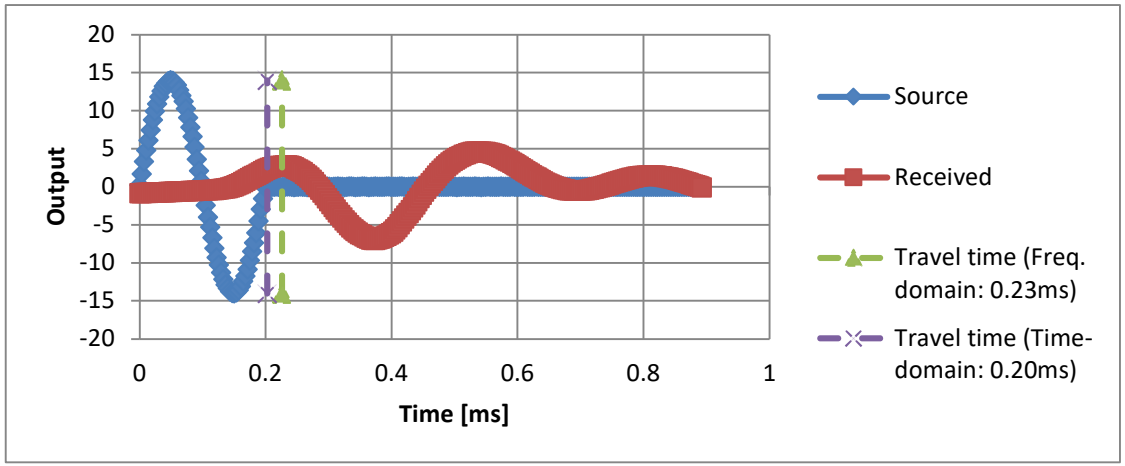
Batch 3_29 days_90 psi unloadreload_ 45 psi stress_s-wave.bes



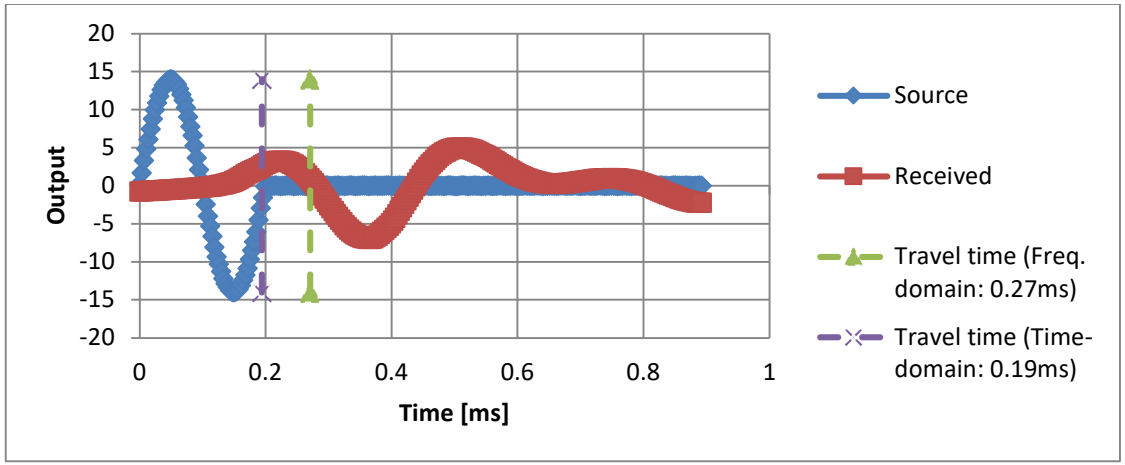
Batch 3_29 days_90 psi unloadreload_90 psi stress_s-wave.bes



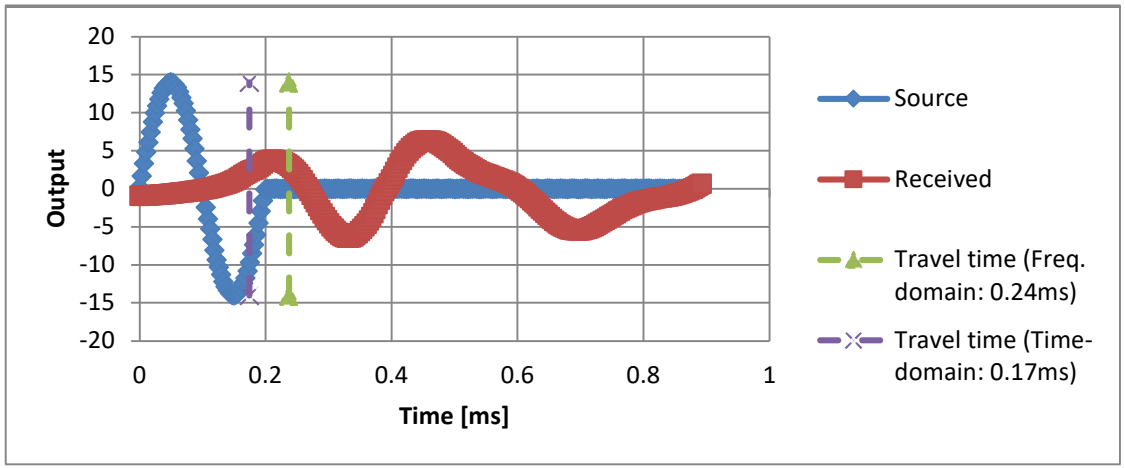
Batch 3_29 days_120 psi unloadreload_0 psi stress_s-wave.bes



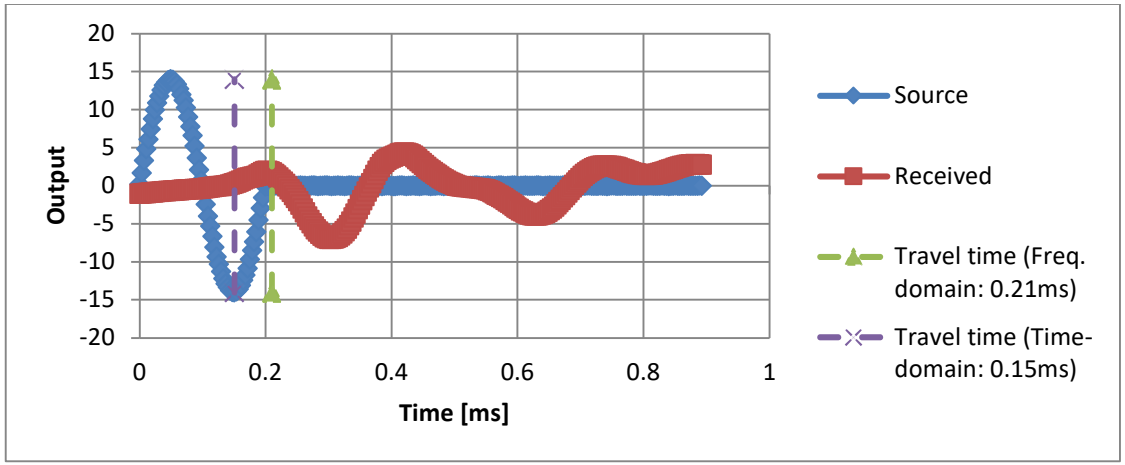
Batch 3_29 days_120 psi unloadreload_5 psi stress_s-wave.bes



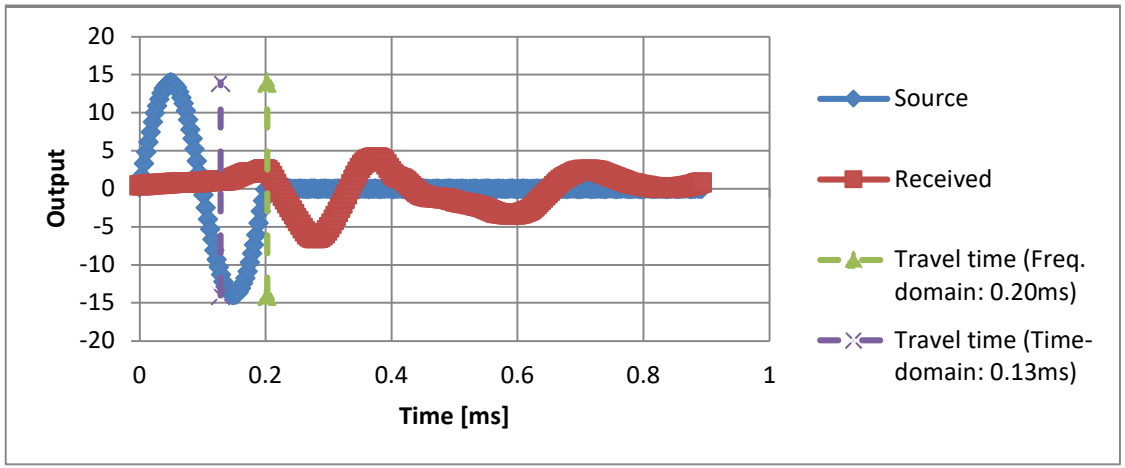
Batch 3_29 days_120 psi unloadreload_15 psi stress_s-wave.bes



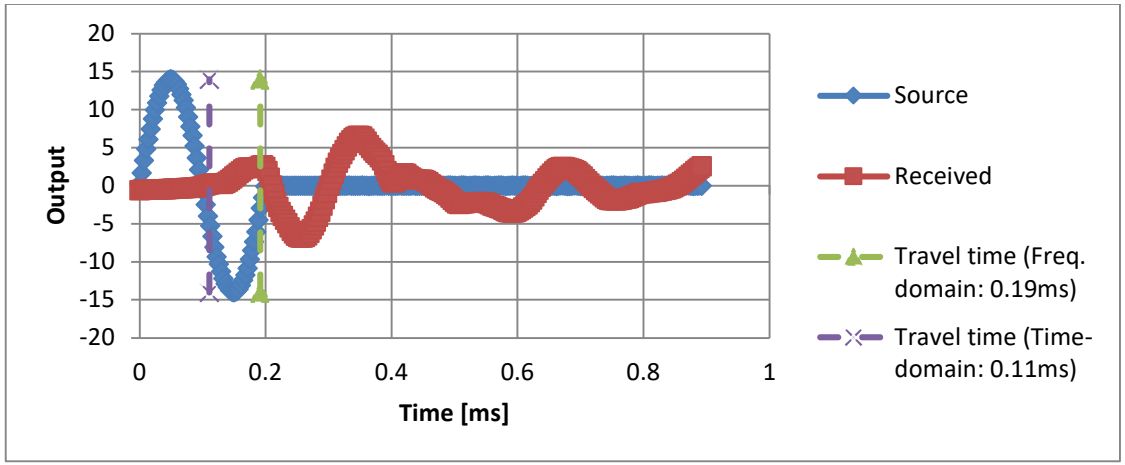
Batch 3_29 days_120 psi unloadreload_30 psi stress_s-wave.bes



Batch 3_29 days_120 psi unloadreload_60 psi stress_s-wave.bes



Batch 3_29 days_120 psi unloadreload_120 psi stress_s-wave.bes



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Filename	Travel time [ms]		
	Frequency domain (FFT)	Time domain (Cross-correlation)	User-specified travel time
Batch 4_28 days_60 psi specimen_ 0 psi stress_s-wave.bes	0.269	0.223	0.196
Batch 4_28 days_60 psi specimen_ 5 psi stress_s-wave.bes	0.280	0.196	0.178
Batch 4_28 days_60 psi specimen_ 15 psi stress_s-wave.bes	0.268	0.173	0.168
Batch 4_28 days_60 psi specimen_ 30 psi stress_s-wave.bes	0.251	0.152	0.158
Batch 4_28 days_60 psi specimen_ 60 psi stress_s-wave.bes	0.235	0.329	0.142
Batch 4_28 days_90 psi specimen_ 0 psi stress_s-wave.bes	0.257	0.185	0.168
Batch 4_28 days_90 psi specimen_ 5 psi stress_s-wave.bes	0.270	0.412	0.157
Batch 4_28 days_90 psi specimen_ 15 psi stress_s-wave.bes	0.249	0.153	0.153
Batch 4_28 days_90 psi specimen_ 45 psi stress_s-wave.bes	0.220	0.331	0.143
Batch 4_28 days_90 psi specimen_ 90 psi stress_s-wave.bes	0.202	0.117	0.135
Batch 4_29 days_120 psi specimen_ 0 psi stress_s-wave.bes	0.275	0.204	0.192
Batch 4_29 days_120 psi specimen_ 5 psi stress_s-wave.bes	0.293	0.197	0.186
Batch 4_29 days_120 psi specimen_ 15 psi stress_s-wave.bes	0.263	0.176	0.173
Batch 4_29 days_120 psi specimen_ 30 psi stress_s-wave.bes	0.236	0.156	0.163
Batch 4_29 days_120 psi specimen_ 60 psi stress_s-wave.bes	0.218	0.140	0.154
Batch 4_29 days_120 psi specimen_ 120 psi stress_s-wave.bes	0.206	0.310	0.146
Batch 4_30 days_120 psi specimen_ 0 psi stress_s-wave.bes	0.255	0.196	0.179
Batch 4_30 days_120 psi specimen_ 5 psi stress_s-wave.bes	0.088	0.128	0.124
Batch 4_30 days_120 psi specimen_ 15 psi stress_s-wave.bes	0.257	0.161	0.155
Batch 4_30 days_120 psi specimen_ 30 psi stress_s-wave.bes	0.251	0.360	0.151
Batch 4_30 days_120 psi specimen_ 60 psi stress_s-wave.bes	0.222	0.323	0.141
Batch 4_30 days_120 psi specimen_ 120 psi stress_s-wave.bes	0.193	0.110	0.134

Test and specimen measurements				
Confining Pressure (kPa)	**Initial Moist Specimen Mass (kg)**	**Initial Speciment Height (mm)**	**Initial Specimen Diameter (mm)**	**Axial Displ. (mm)**
0.0	0.2396	102.447	51.863	0.0000
34.5	0.2396	102.447	51.863	1.7316
103.4	0.2396	102.447	51.863	1.9093
206.8	0.2396	102.447	51.863	2.0591
413.7	0.2396	102.447	51.863	2.2912
0.0	0.2336	101.930	51.780	0.0000
34.5	0.2336	101.930	51.780	0.1077
103.4	0.2336	101.930	51.780	0.2079
310.3	0.2336	101.930	51.780	0.3931
620.5	0.2336	101.930	51.780	0.6171
0.0	0.2275	102.167	51.820	0.0000
34.5	0.2275	102.167	51.820	0.1300
103.4	0.2275	102.167	51.820	0.2767
206.8	0.2275	102.167	51.820	0.4196
413.7	0.2275	102.167	51.820	0.5902
827.4	0.2275	102.167	51.820	0.8419
0.0	0.2400	102.180	51.820	0.0000
34.5	0.2400	102.180	51.820	0.1302
103.4	0.2400	102.180	51.820	0.2365
206.8	0.2400	102.180	51.820	0.3521
413.7	0.2400	102.180	51.820	0.5422
827.4	0.2400	102.180	51.820	0.8177

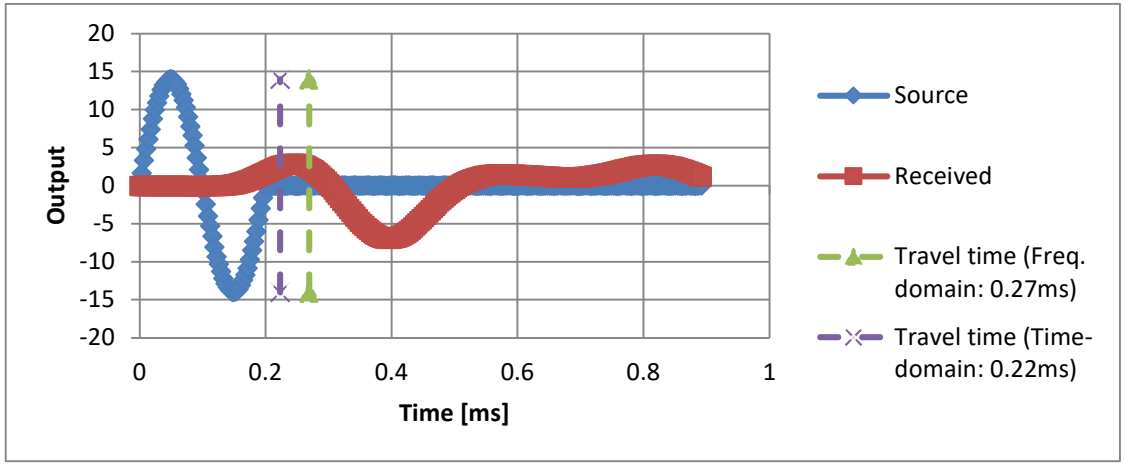
Test and specimen measurements				
Adjusted Specimen Height (mm)	Initial Volume of Cylindrical Specimen (m^3)	Volume Change of Cylindrical Specimen (m^3)	Total (Moist) Density (kg/m^3)	Adjusted Travel Length (mm)
102.4470	0.00021642	0.00000000	1107.0887	96.2270
100.7154	0.00021642	0.00000366	1108.9299	94.4954
100.5377	0.00021642	0.00000403	1109.1224	94.3177
100.3879	0.00021642	0.00000435	1109.2852	94.1679
100.1558	0.00021642	0.00000484	1109.5385	93.9358
101.9300	0.00021464	0.00000000	1088.3206	95.7100
101.8223	0.00021464	0.00000023	1088.4140	95.6023
101.7221	0.00021464	0.00000044	1088.5011	95.5021
101.5369	0.00021464	0.00000083	1088.6625	95.3169
101.3129	0.00021464	0.00000130	1088.8585	95.0929
102.1670	0.00021547	0.00000000	1055.8107	95.9470
102.0370	0.00021547	0.00000027	1055.8818	95.8170
101.8903	0.00021547	0.00000058	1055.9623	95.6703
101.7474	0.00021547	0.00000088	1056.0409	95.5274
101.5768	0.00021547	0.00000124	1056.1350	95.3568
101.3251	0.00021547	0.00000178	1056.2744	95.1051
102.1800	0.00021550	0.00000000	1113.5414	95.9600
102.0498	0.00021550	0.00000027	1113.6862	95.8298
101.9435	0.00021550	0.00000050	1113.8048	95.7235
101.8279	0.00021550	0.00000074	1113.9340	95.6079
101.6378	0.00021550	0.00000114	1114.1471	95.4178
101.3623	0.00021550	0.00000172	1114.4573	95.1423

Velocity (m/s)		
Velocity (m/s)	**Velocity (m/s)**	**Velocity (m/s)**
357.596	431.511	490.954
337.784	483.352	532.368
351.662	545.189	563.091
375.296	619.526	595.999
399.995	285.954	661.520
373.043	518.753	571.403
353.625	232.326	610.877
383.632	624.197	624.197
433.936	287.966	668.891
469.815	816.248	707.010
348.465	471.484	499.724
327.060	487.618	516.534
364.048	545.130	554.610
404.058	614.324	587.861
436.546	683.561	621.217
461.749	307.286	653.643
376.762	490.844	537.591
1087.097	748.670	775.950
372.093	594.556	619.570
380.447	265.578	635.268
430.309	295.869	676.722
492.941	868.879	712.676

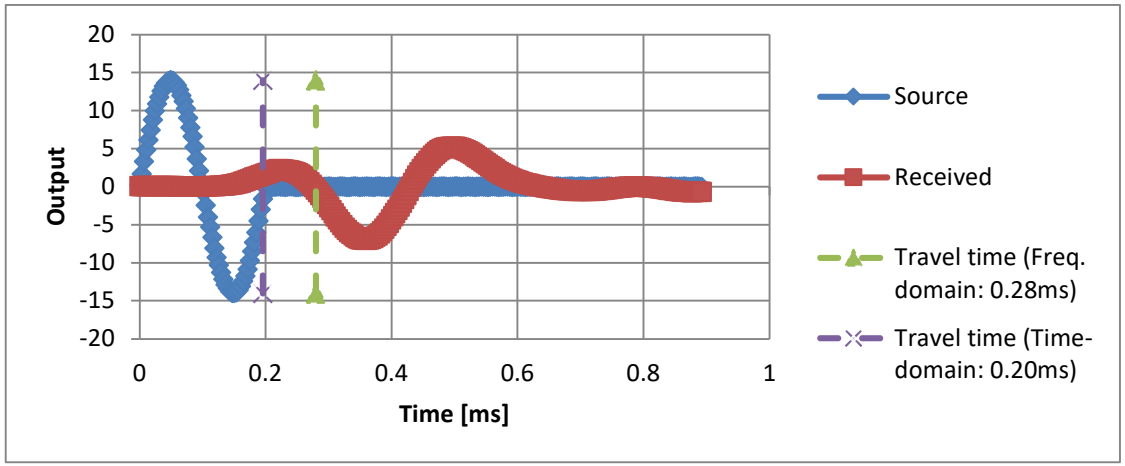
G_{max}		
G_{max} (Mpa)	G_{max} (Mpa)	G_{max} (Mpa)
141.569	206.142	266.848
126.527	259.079	314.289
137.161	329.666	351.671
156.239	425.757	394.035
177.522	90.726	485.543
151.451	292.873	355.338
136.107	58.748	406.165
160.198	424.103	424.103
204.996	90.277	487.083
240.340	725.464	544.281
128.205	234.704	263.661
112.946	251.059	281.717
139.948	313.797	324.806
172.412	398.544	364.947
201.270	493.485	407.574
225.210	99.739	451.293
158.067	268.283	321.818
1316.132	624.229	670.548
154.210	393.726	427.552
161.231	78.567	449.546
206.302	97.531	510.227
270.803	841.361	566.041

Filename

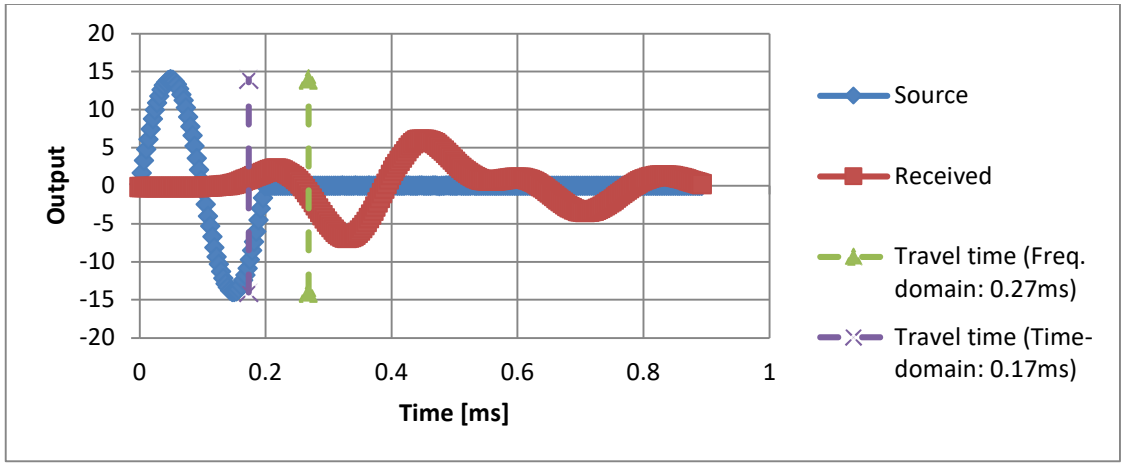
Batch 4_28 days_60 psi specimen_ 0 psi stress_s-wave.bes



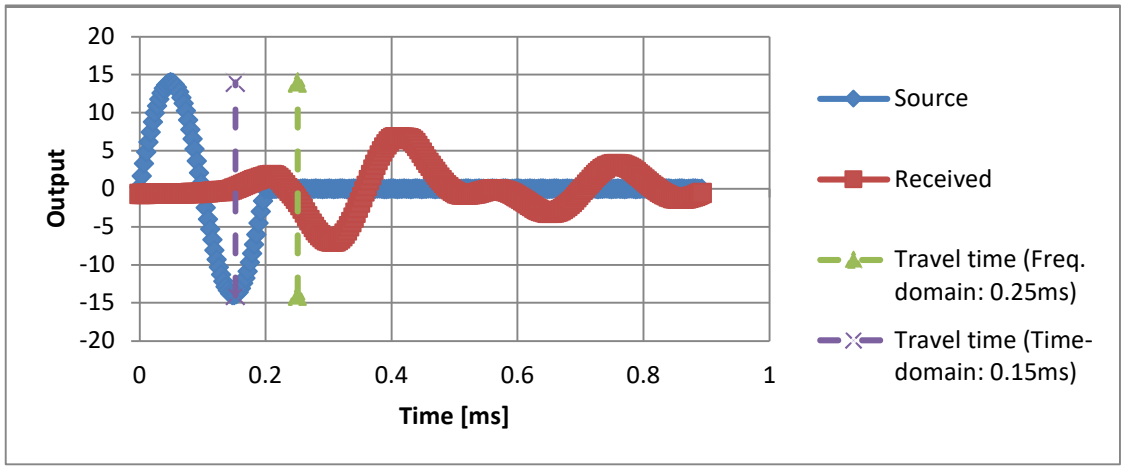
Batch 4_28 days_60 psi specimen_ 5 psi stress_s-wave.bes



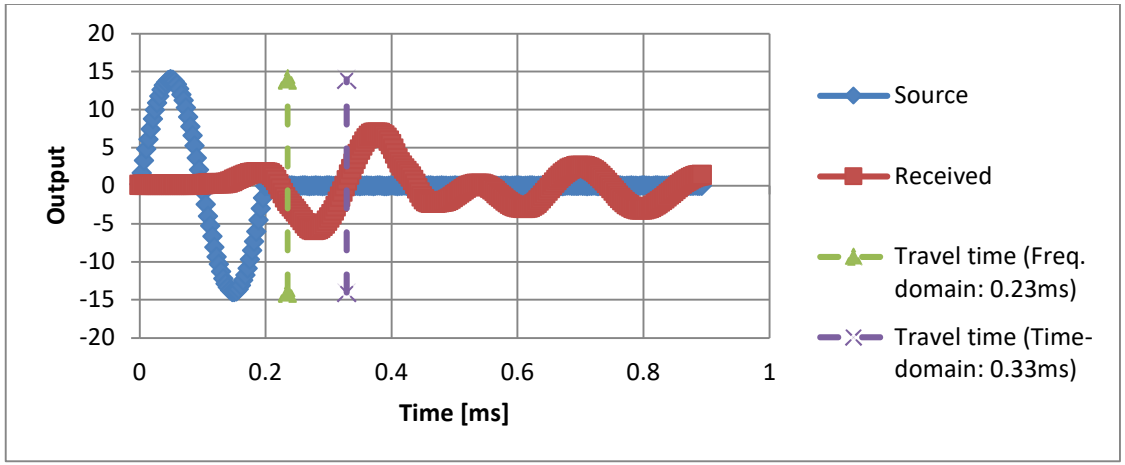
Batch 4_28 days_60 psi specimen_ 15 psi stress_s-wave.bes



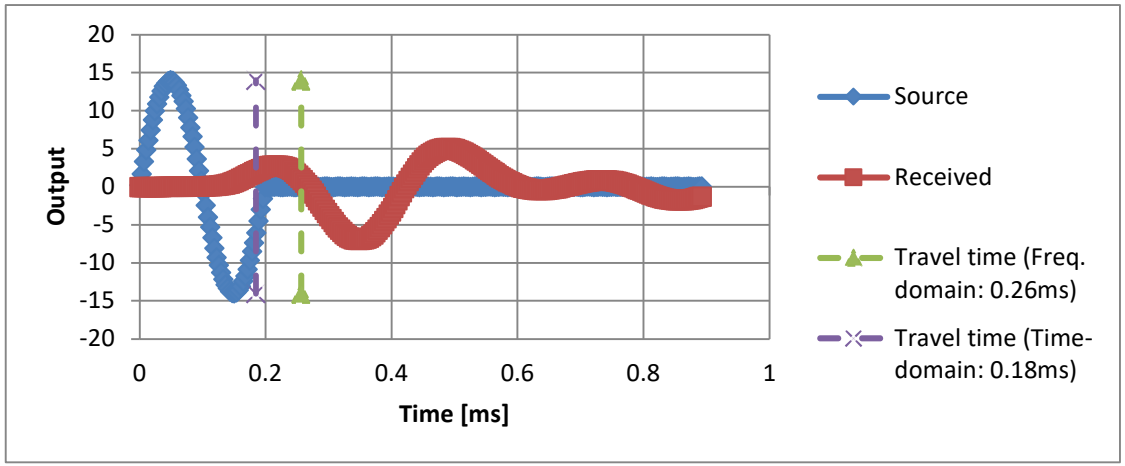
Batch 4_28 days_60 psi specimen_ 30 psi stress_s-wave.bes



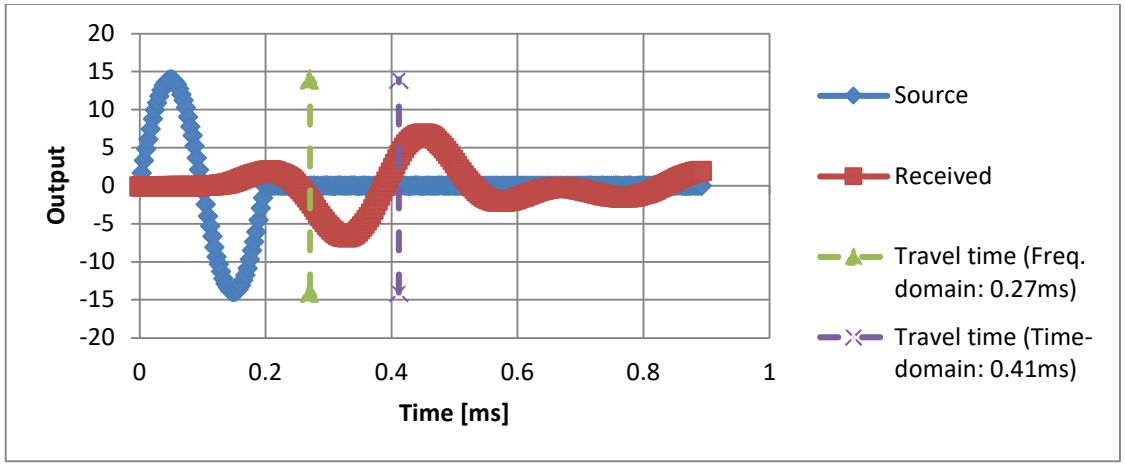
Batch 4_28 days_60 psi specimen_ 60 psi stress_s-wave.bes



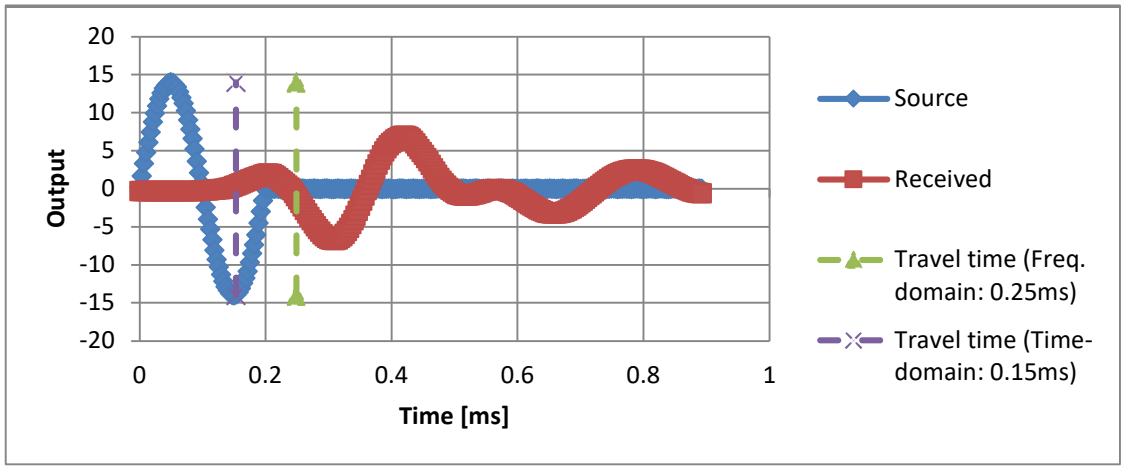
Batch 4_28 days_90 psi specimen_ 0 psi stress_s-wave.bes



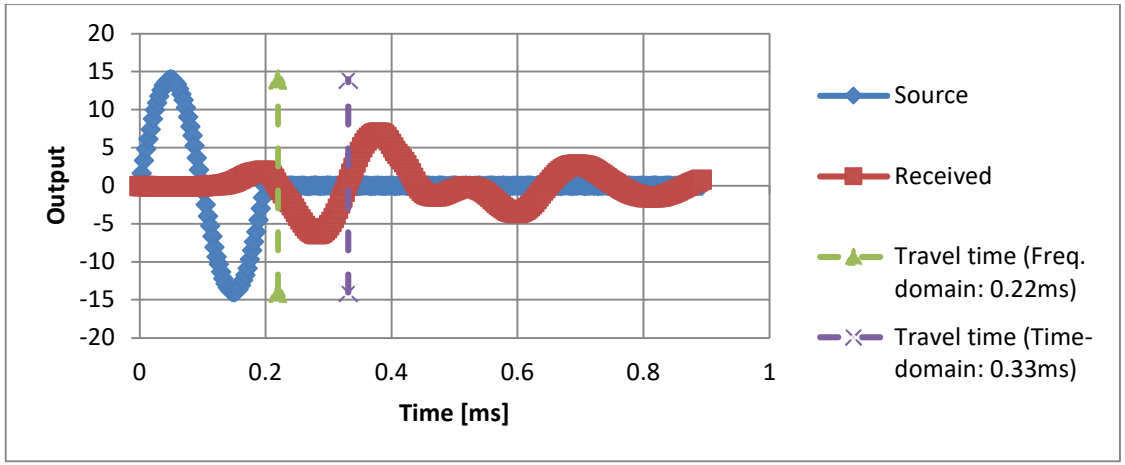
Batch 4_28 days_90 psi specimen_ 5 psi stress_s-wave.bes



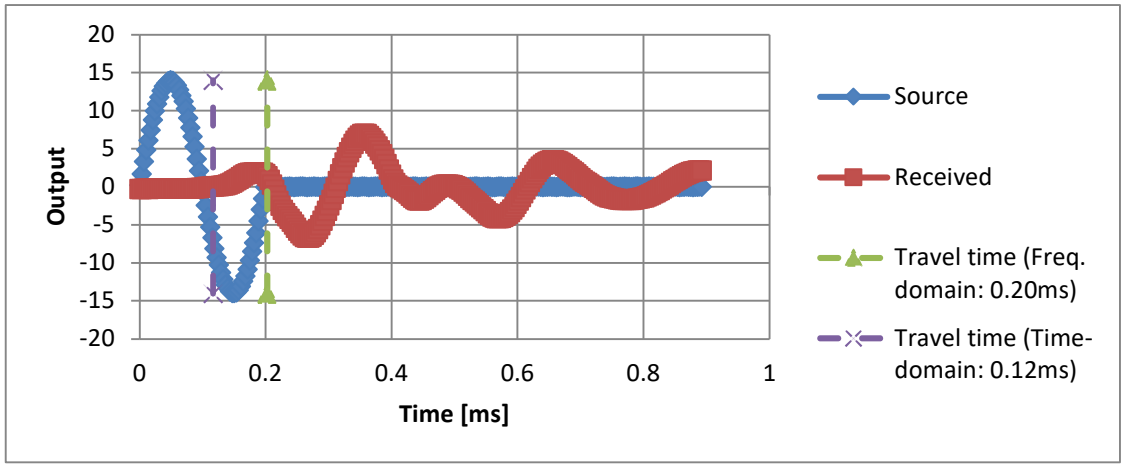
Batch 4_28 days_90 psi specimen_ 15 psi stress_s-wave.bes



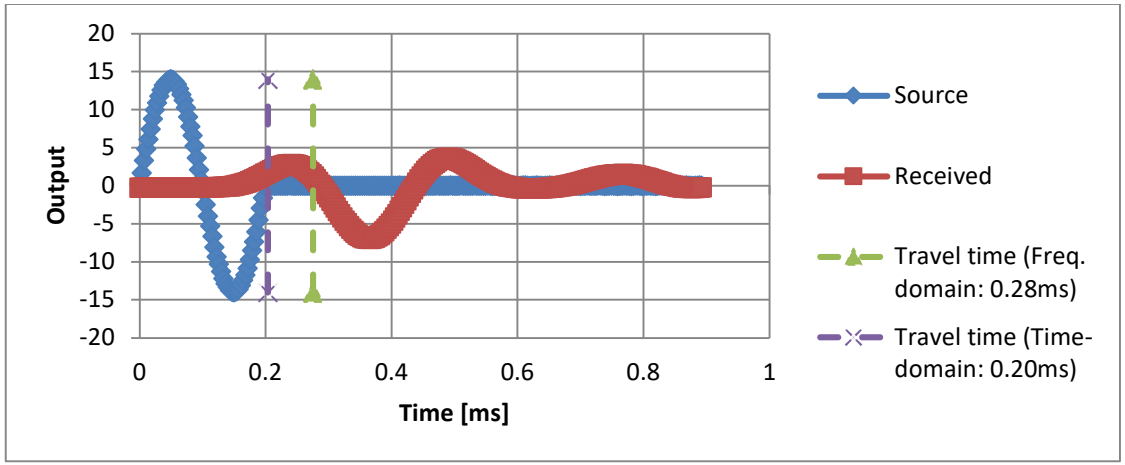
Batch 4_28 days_90 psi specimen_ 45 psi stress_s-wave.bes



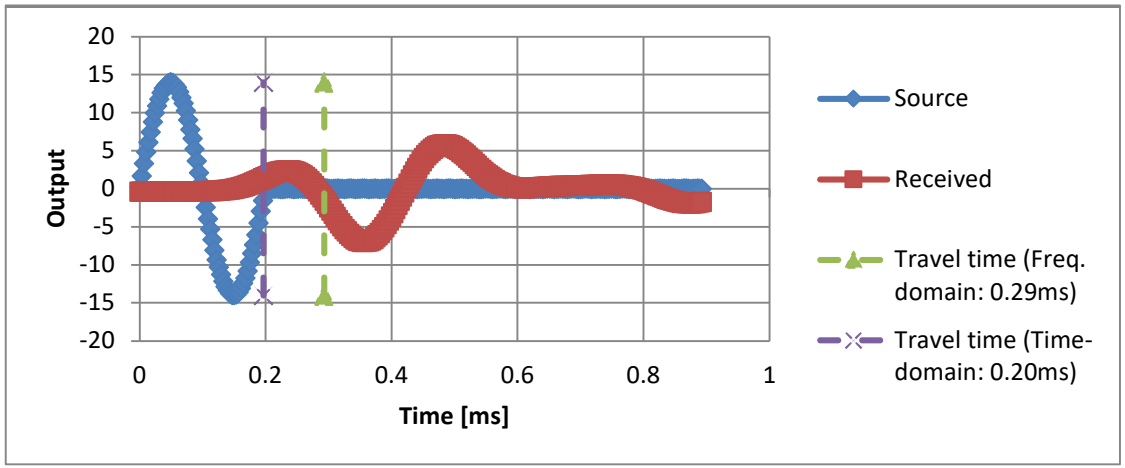
Batch 4_28 days_90 psi specimen_ 90 psi stress_s-wave.bes



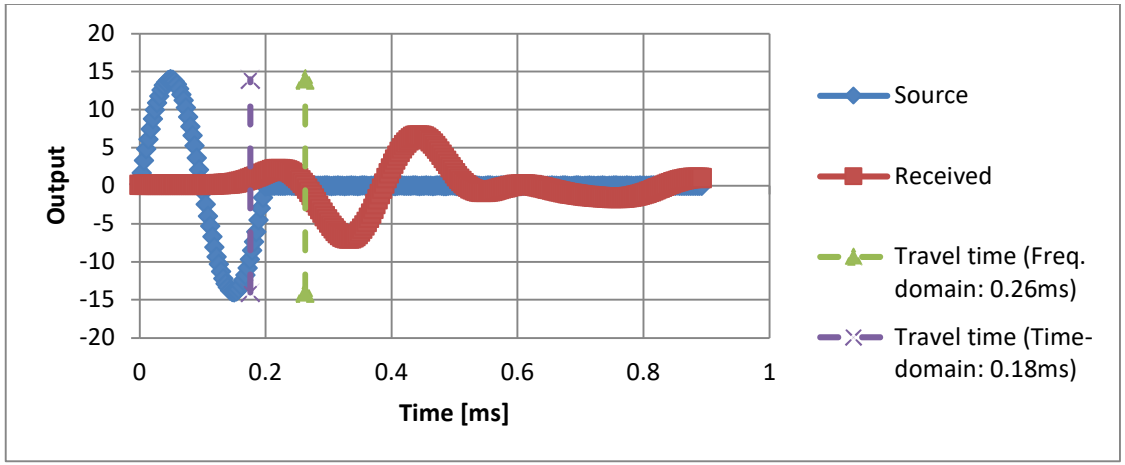
Batch 4_29 days_120 psi specimen_ 0 psi stress_s-wave.bes



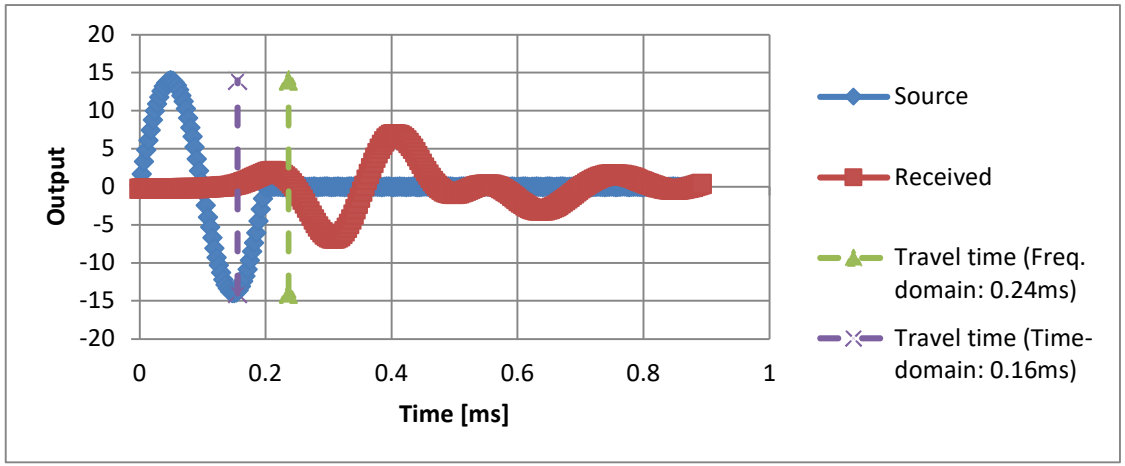
Batch 4_29 days_120 psi specimen_ 5 psi stress_s-wave.bes



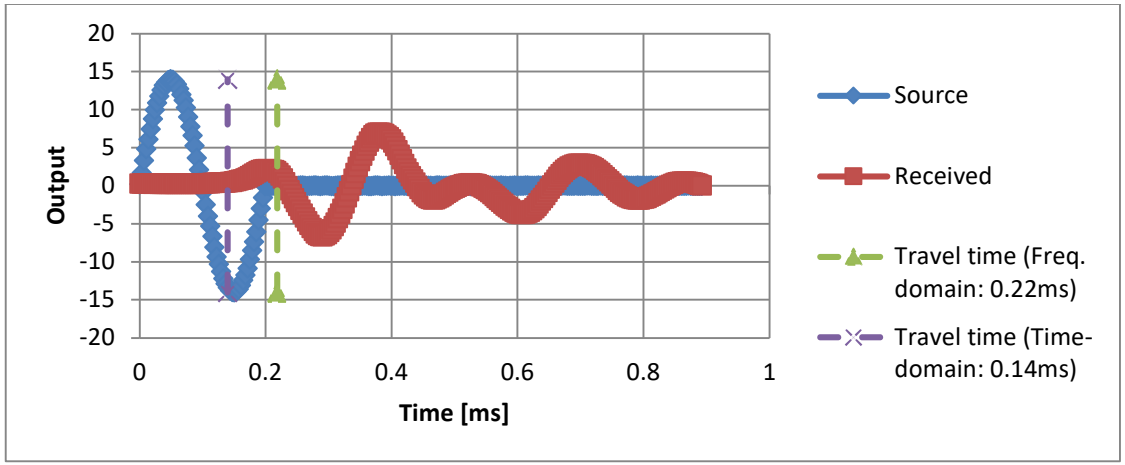
Batch 4_29 days_120 psi specimen_ 15 psi stress_s-wave.bes



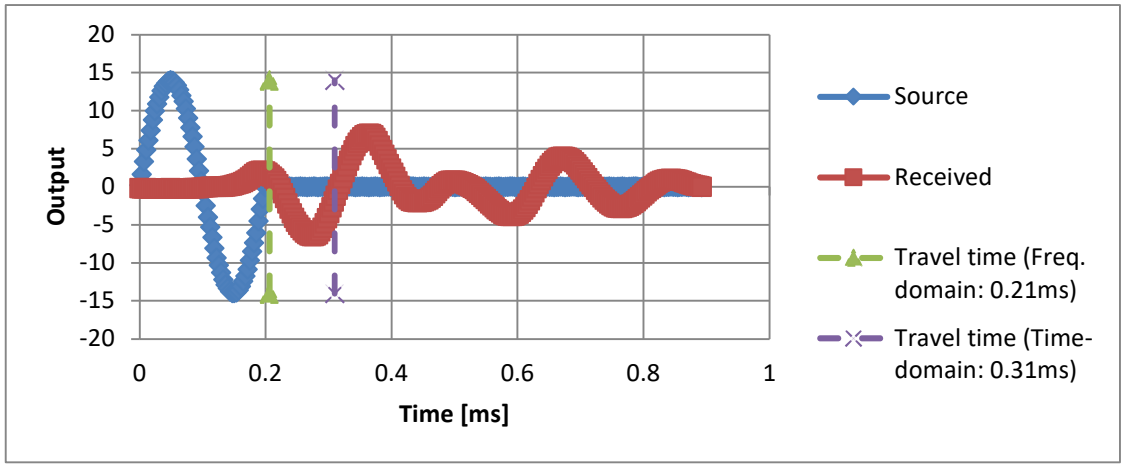
Batch 4_29 days_120 psi specimen_ 30 psi stress_s-wave.bes



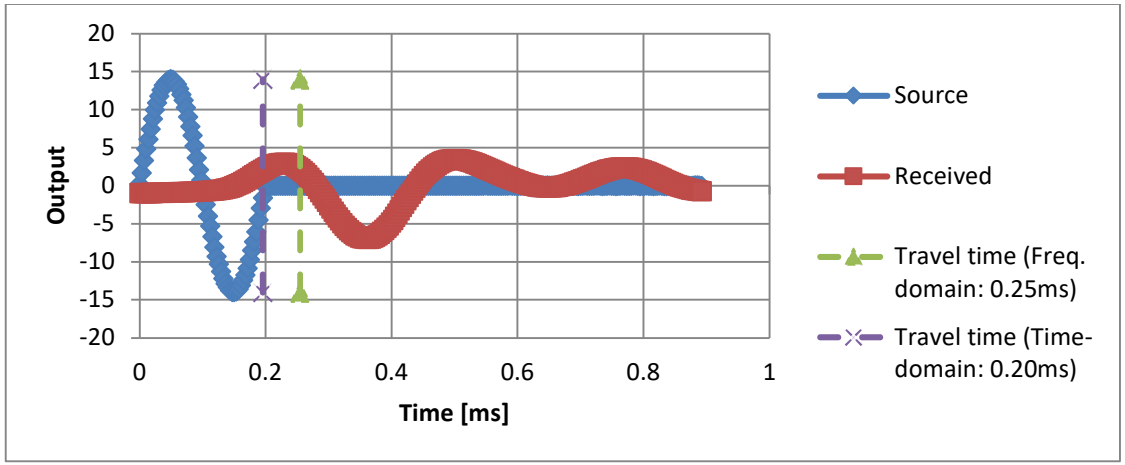
Batch 4_29 days_120 psi specimen_ 60 psi stress_s-wave.bes



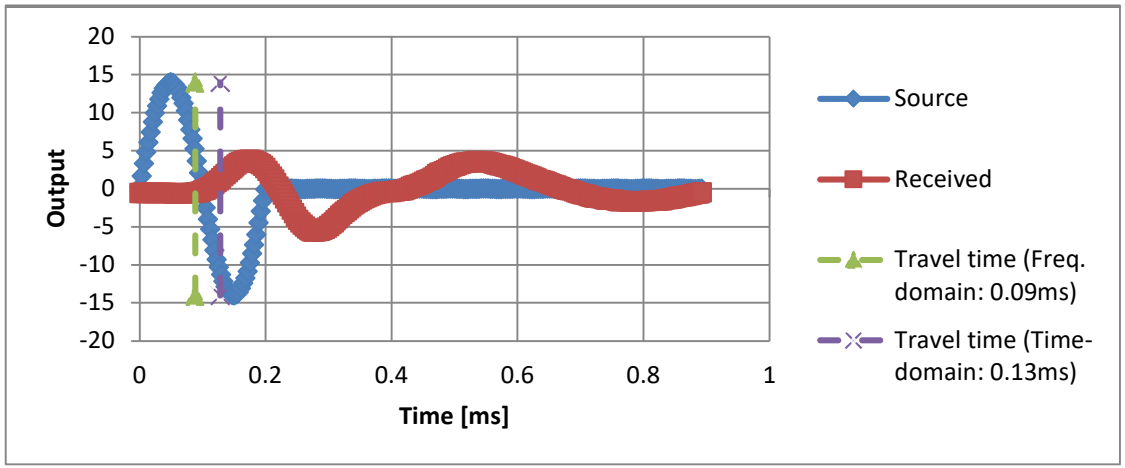
Batch 4_29 days_120 psi specimen_ 120 psi stress_s-wave.bes



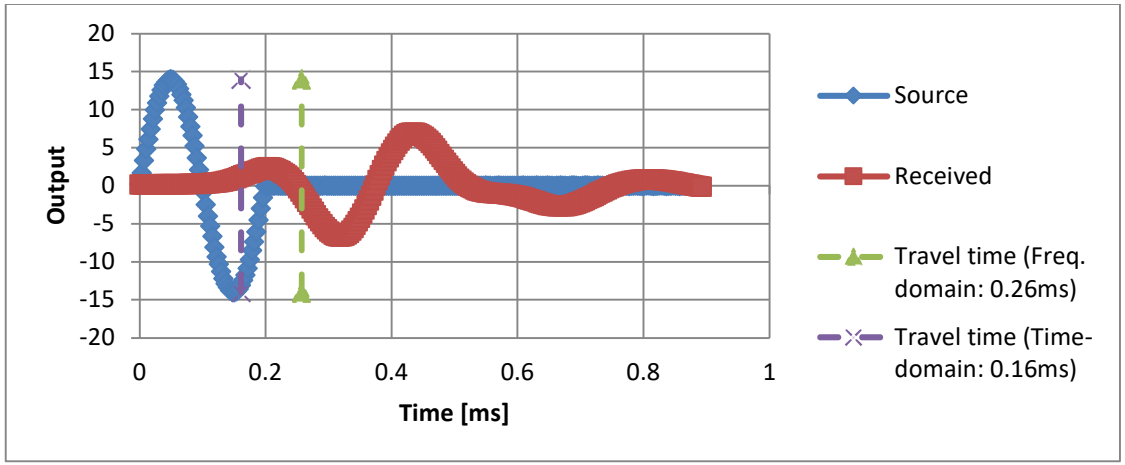
Batch 4_30 days_120 psi specimen_ 0 psi stress_s-wave.bes



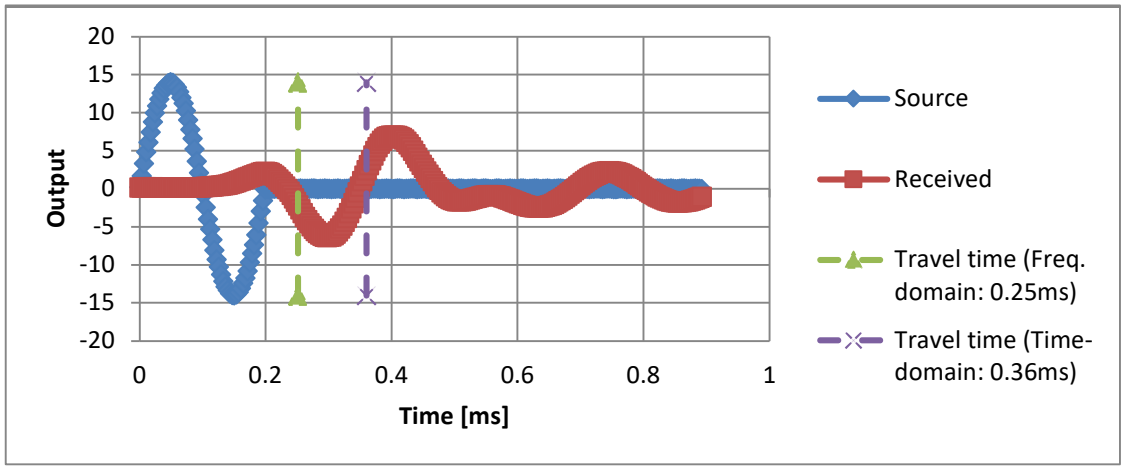
Batch 4_30 days_120 psi specimen_ 5 psi stress_s-wave.bes



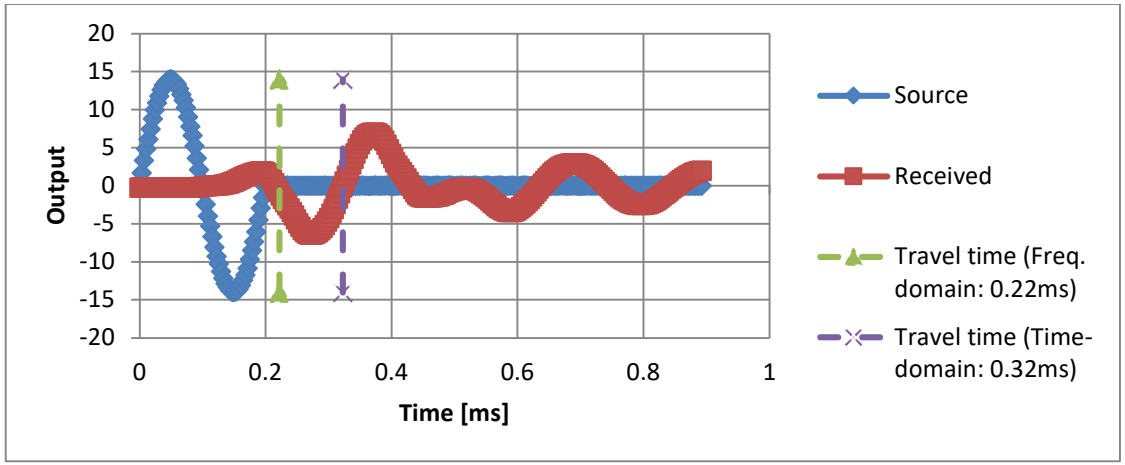
Batch 4_30 days_120 psi specimen_ 15 psi stress_s-wave.bes



Batch 4_30 days_120 psi specimen_ 30 psi stress_s-wave.bes



Batch 4_30 days_120 psi specimen_ 60 psi stress_s-wave.bes



Batch 4_30 days_120 psi specimen_ 120 psi stress_s-wave.bes