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16. Abstract:

The objective of this project was to determine the resilient moduli for common Missouri subgrade soils and typical unbound granular base materials in accordance with the AASHTO T 307 test method. The results allow Missouri Department of Transportation pavement engineers to calibrate software included with the National Cooperative Highway Research Program Project 1-37A Mechanistic-Empirical Pavement Design Guide according to Missouri's conditions and materials.

The test results included resilient moduli data from 27 common subgrade soils out of the 99 Missouri soil associations and from five unbound granular base materials. The subgrade soils, selected and provided by MoDOT, were tested at their optimum water content (as determined from AASHTO T 99 testing (AASHTO, 2001)) and at an elevated water content. The five unbound granular base materials, again selected and provided by MoDOT and representing a typical range in geologic source, were tested at two different gradations (typical as-delivered percent minus #200 sieve size and at an elevated amount of fines). All testing included three replications for all materials. Data are provided in the form of tables and graphs.

As a part of the granular base material resilient moduli (M_r) specimen preparation deliberation, MDD and OMC were determined for each of the 10 material/gradation combinations. The M_r testing program results indicate that both the material source and fines content are highly significant in the level of attained resilient modulus. In regard to material source, the range between the highest and lowest M_r values was more than two-fold. Also, two of the five aggregate sources suffered a 15 to 20% loss in M_r with the addition of five percent fines.

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Resilient Moduli of Typical Missouri Soils and Unbound Granular Base Materials

Prepared for the
Missouri Department of Transportation
Organizational Results

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The opinions, findings, and conclusions expressed in this report are those of the principal investigator and the Missouri Department of Transportation. This report does not constitute a standard, specification, or regulation.

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EXECUTIVE SUMMARY

At the time of writing, MoDOT was in the process of implementing the National Cooperative Highway Research Program (NCHRP) Project 1-37A, Mechanistic-Empirical Pavement Design Guide (M-E PDG). To do so, calibration efforts required input of material characteristics that was specific to materials encountered and utilized by MoDOT. In particular, the test protocol American Association of State Highway and Transportation Officials (AASHTO) T 307 has been utilized to obtain the resilient modulus (M_r) values, which can be used with structural response analysis models to calculate the pavement structural response to wheel loads, and with pavement design procedures to design pavement structures.

The objective of this project is to determine the resilient moduli for common Missouri subgrade soils and typical unbound granular base materials in accordance with the AASHTO T 307 test method.

The results of this project allow MoDOT pavement engineers to calibrate the M-E PDG according to Missouri's conditions and materials. The results of this project also allow MoDOT pavement engineers to reliably model subgrade and base support in all pavement designs for optimum performance. The results of this effort provide a knowledge base of resilient moduli for Missouri soils and granular bases, as well as evaluation of moisture activity devices for use in evaluating subgrades.

The test results included resilient moduli data from 27 common subgrade soils out of the 99 Missouri soil associations and from five unbound granular base materials. The subgrade soils, selected and provided by MoDOT, were tested at their optimum water content (as determined from AASHTO T 99 testing) and at an elevated water content, which would normally occur as a worse case scenario during the life of a pavement. The five unbound granular base materials, again selected and provided by MoDOT and representing a typical range in geologic source, were tested at two different gradations (typical as-delivered percent minus #200 sieve size and at an elevated amount of fines). Data are provided in the form of tables and graphs.

As a part of the granular base material M_r specimen preparation deliberation, maximum dry density (MDD) and optimum moisture content (OMC) were determined for each of the 10 material/gradation combinations. The M_r testing program results indicate that both the material source and fines content are highly significant in the level of attained M_r. In regard to material source, the range between the highest and lowest M_r values was more than two-fold. Also, two of the five aggregate sources suffered a 15 to 20% loss in M_r when specimens were prepared with an elevated fines content using a 95-5% blend of as-delivered and minus #200 materials, respectively.

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INTRODUCTION

With the Missouri Department of Transportation (MoDOT) beginning to implement the National Cooperative Highway Research Program (NCHRP) Project 1-37A, Mechanistic-Empirical Pavement Design Guide (M-E PDG) (*1*), the need exists for determination of resilient modulus (M_r) of subgrade soils and unbound granular bases materials used by MoDOT in its flexible pavements. In particular, the American Association of State Highway and Transportation Officials (AASHTO) test protocol T 307 (*2*) is utilized to obtain M_r values, which can be used with structural response analysis models to calculate the pavement structural response to wheel loads, and with pavement design procedures to design pavement structures. MoDOT contracted with Missouri S&T to perform the T 307 testing on numerous subgrade soils and several typical base materials utilized throughout the state. M_r for subgrade soils and unbound granular bases is a critical input for the M-E PDG models for predicting various distresses. Therefore, it is necessary to accurately determine this property to calibrate the M-E PDG according to Missouri's conditions and materials.

The M_r test provides a basic relationship between stress and deformation of pavement materials for structural analysis of layered pavement systems. It also provides a means of characterizing pavement construction materials under a variety of conditions such as moisture, density, and stress states that simulate the conditions in a pavement subjected to moving wheel loads.

OBJECTIVES

The objective of this project is to determine the resilient moduli for common Missouri subgrade soils and unbound granular base materials in accordance with the AASHTO T 307 test method.

The test results will include resilient moduli data from 27 common subgrade soils out of the 99 Missouri soil associations and from five unbound granular base materials. The subgrade soils, selected and provided by MoDOT, will be tested at their optimum water content (as determined from AASHTO T 99 (*3*) testing) and at an elevated water content, which would normally occur as a worse case scenario during the life of a pavement. The five unbound granular base materials, again selected and provided by MoDOT and representing a typical range in geologic source, will be tested at two different gradations (typical as-delivered percent minus #200 sieve size and at an elevated amount of fines).

TECHNICAL APPROACH

MATERIALS

Granular Base Materials

MoDOT sampled and delivered to the Missouri S&T Construction Materials Laboratory five materials of differing geologic formations, but all within MoDOT Section 1007 Type 5 specification limits. The samples were in the as-delivered gradation condition. Additionally, fines (minus #200 sieve) that were specific to each formation were delivered to be used for gradation modification for the high-fines specimens. The five material types all had a nominal maximum size (NMS) of ¾ in. and minus #200 sieve values from 10.7 to 13.8%. Table 1 shows the list of project materials.

Table 1: Project Unbound Granular Materials

Name	Designation
Plattin Limestone, As-Delivered	Plattin A-D
Plattin Limestone, With added Fines	Plattin W-F
Bethany Falls Limestone, As-Delivered	Bethany Falls A-D
Bethany Falls Limestone, With added Fines	Bethany Falls W-F
Winterset Limestone As-Delivered	Winterset A-D
Winterset Limestone, With added Fines	Winterset W-F
Jefferson City Dolomite As-Delivered	Jefferson City A-D
Jefferson City Dolomite, With added Fines	Jefferson City W-F
Gasconade Dolomite As-Delivered	Gasconade A-D
Gasconade Dolomite, With added Fines	Gasconade W-F

Subgrade Soils

The soils for the resilient modulus tests were selected by MODOT which represented material throughout the state of Missouri. Soils were selected by MoDOT's 10 districts, based on current projects and considerations. Loose samples were collected by MoDOT personnel and shipped to MoDOT's Central Laboratory. Basic properties and compaction tests were conducted. The soils were then shipped to the geotechnical engineering laboratory at Missouri S&T, along with their test results. Tables 2-7 give MoDOT's information for each tested soil, including its district number, soil series, Atterberg limits, AASHTO soil classification, particle size distribution, and maximum dry density (MDD) and optimum moisture content (OMC) from compaction tests. With that, the locations of soil sites were identified and marked in the map shown in Figure 1. The soils consisted of 15 A-7-6's, 5 A-6's, and one each of A-7-5, A-4, A-2-4, and A-2-6. Two soils were not classified because of a lack of data. However, published information on them indicates that one was probably an A-4 and the other an A-2-6. The group index of the 27 soils ranged from zero to 43.

Table 2: Soil Information on Tested Soils

MoDOT ID	6MKWM011	6MKWM012	6MKWM013	6MKWM014	6MKWM015
District	9	9	9	10	10
Soil Series	Clarksville	Poynor/ Clarksville	Hobson-Lebanon	Lintonia	Waverly
Liquid Limit	50	30	23	[18]	32
Plastic Limit	21	17	13	[17]	18
Plasticity Index	29	13	10	NP [1]	14
ASTM D 2487	CH	SC	SC		CL
AASHO M145-49	A-7-6 (14)	A-2-6 (0)	A-4 (0)		A-6 (10)
AASHTO M145-87	A-7-6 (14)	A-2-6 (0)	A-4 (0)	[A-2-4 (0)]	A-6 (10)
3”	100	100	100	100	100
2”	100	100	100	100	100
1½”	100	98	100	100	100
1”	96	92	97	100	100
¾”	95	89	96	100	100
3/8”	92	80	93	100	100
#4	88	70	91	100	100
#10	86	63	89	100	100
#40	74	48	75	67	100
#200	59	24	37	10	82
Compaction Method	T99 C	T99 C	T99 C	T99 A	T99 A
MDD (pcf)	101	120	121	110	112
OMC (%)	20	11	11	12	15
Specfic Gravity	2.70	2.66	2.66	2.66	2.68

[ ] = Data from the literature

Table 3: Soil Information on Tested Soils (cont.)

MoDOT ID	6MKWM016	6MKWM017	6MKWM018	6MKWM019	6MKWM020
District	10	6	8	2	2
Soil Series	Sharkey	Sonsac	Wilderness-Viration	Darwin-Dockery-Chequest	Carlow-Dockery
Liquid Limit	63	65	62	48	35
Plastic Limit	21	23	28	17	22
Plasticity Index	42	42	34	31	13
ASTM D 2487	CH	CH	CH	CL	CL
AASHO M145-49	A-7-6 (20)	A-7-6 (18)	A-7-6 (20)	A-7-6 (17)	A-6 (9)
AASHTO M145-87	A-7-6 (43)	A-7-6 (27)	A-7-6 (28)	A-7-6 (22)	A-6 (13)
3”	100	100	100	100	100
2”	100	100	100	100	100
1½”	100	100	100	100	100
1”	100	100	100	100	100
¾”	100	100	100	100	100
3/8”	100	96	97	100	100
#4	100	91	93	99	100
#10	100	89	90	99	100
#40	98	83	82	93	99
#200	92	67	77	74	97
Compaction Method	T99 A	T99 C	T99 C	T99 A	T99 A
MDD (pcf)	96	97	91	108	102
OMC (%)	21	20	27	16	20
Specific Gravity	2.70	2.70	2.70	2.68	2.68

Table 4: Soil Information on Tested Soils (cont.)

MoDOT ID	6MKWM021	6MKWM022	6MKWM023	6MKWM024	6MKWM025
District	2	7	7	7	8
Soil Series	Mexico-Leonard Putnam	Nixa-Clarksville	Cliquot-Bolivar	Eldorado-Newtonia	Rueter-Clarksville-Hailey
Liquid Limit	37	61	46	49	44
Plastic Limit	23	33	24	24	19
Plasticity Index	14	28	22	25	25
ASTM D 2487	CL	MH	CL	CL	SC
AASHO M145-49	A-6 (10)	A-7-5 (19)	A-7-6 (14)	A-7-6 (16)	A-7-6 (7)
AASHTO M145-87	A-6 (11)	A-7-5 (23)	A-7-6 (22)	A-7-6 (25)	A-7-6 (7)
3”	100	100	100	100	100
2”	100	98	100	100	100
1½”	100	97	100	100	100
1”	100	94	100	100	100
¾”	100	91	100	100	100
3/8”	100	88	100	100	96
#4	100	87	100	99	86
#10	100	85	99	98	72
#40	96	80	97	95	56
#200	82	76	90	91	46
Compaction Method	T99 A	T99 C	T99 A	T99 A	T99 C
MDD (pcf)	101	80	100	96	112
OMC (%)	18	32	20	21	13
Specific Gravity	2.68	2.68	2.68	2.68	2.66

Table 5: Soil Information on Tested Soils (cont.)

MoDOT ID	6MKWM026	6MKWM027	6MKWM028	6MKWM029	6MKWM030
District	6	3	3	3	5
Soil Series	Glacial-residual	Belknap-Okaw-Twomile	Mexico-Armstrong	Vesser-Klum-Wakefiled	Hunington
Liquid Limit	57	27	52	34	38
Plastic Limit	18	20	22	20	23
Plasticity Index	39	7	30	14	15
ASTM D 2487	CH	SM	CH	CL	SC
AASHO M145-49	A-7-6 (19)	A-2-4 (0)	A-7-6 (18)	A-6 (10)	A-6 (3)
AASHTO M145-87	A-7-6 (29)	A-2-4 (0)	A-7-6 (32)	A-6 (9)	A-6 (1)
3”	100	100	100	100	100
2”	100	100	100	100	100
1½”	100	98	100	100	94
1”	100	91	100	100	85
¾”	100	83	100	100	77
3/8”	100	65	100	98	64
#4	100	54	100	96	56
#10	98	46	100	94	51
#40	94	33	99	88	44
#200	75	25	96	75	36
Compaction Method	T99 A	T99 C	T99 A	T99 A	T99 C
MDD (pcf)	99	126	97	109	118
OMC (%)	22	9	22	15	12
Specific Gravity	2.70	2.66	2.70	2.68	2.66

Table 6: Soil Information on Tested Soils (cont.)

MoDOT ID	6MKWM031	6MKWM032	6MKWM033	6MKWM034	6MKWM035
District	1	4	4	4	4
Soil Series	Knox	Sampsel-Snead-Polo	Mandeville-Norris-Bolivar	Knox-Sibley-Urban Land	Snead-Menfro-Oska
Liquid Limit	[34]	60	43	48	36
Plastic Limit	[21]	20	17	19	21
Plasticity Index	[13]	40	26	29	15
ASTM D 2487		CH	CL	CL	CL
AASHO M145-49		A-7-6 (20)	A-7-6 (15)	A-7-6 (17)	A-6 (10)
AASHTO M145-87	[A-4 (10)]	A-7-6 (43)	A-7-6 (24)	A-7-6 (31)	A-6 (14)
3”		100	100	100	100
2”		100	100	100	100
1½”		100	100	100	100
1”		100	100	100	100
¾”		100	100	100	100
3/8”		100	100	100	99
#4		100	100	100	99
#10		100	100	100	98
#40		99	98	99	96
#200	[82]	97	90	98	93
Compaction Method	T99 A	T99 A	T99 A	T99 A	T99 A
MDD (pcf)	108	94	103	101	100
OMC (%)	17	24	18	19	18
Specific Gravity	2.68	2.70	2.68	2.68	2.68

[ ] = Data from the literature

Table 7: Soil Information on Tested Soils (cont.)

MoDOT ID	6MKWM036	6MKWM037
District	4	6
Soil Series	Marksburg-Sharpsburg-Sampsel	Useful
Liquid Limit	55	48
Plastic Limit	24	19
Plasticity Index	31	29
ASTM D 2487	CH	CL
AASHO M145-49	A-7-6 (19)	A-7-6 (17)
AASHTO M145-87	A-7-6 (34)	A-7-6 (27)
3”	100	100
2”	100	100
1½”	100	100
1”	100	100
¾”	100	100
3/8”	100	100
#4	100	100
#10	100	99
#40	98	98
#200	96	88
Compaction Method	T99 A	T99 A
MDD (pcf)	94	105
OMC (%)	23	19
Specfic Gravity	2.70	2.70

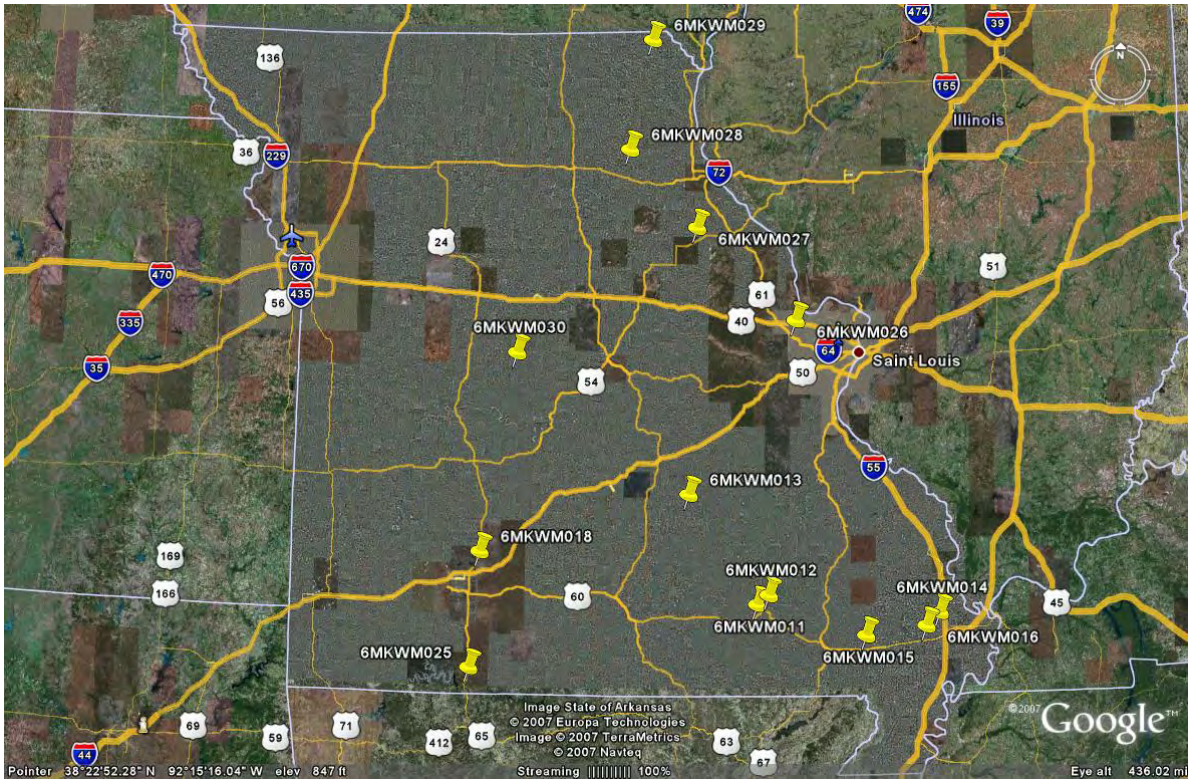


Figure 1: Selected Locations of Soil Sites for This Project

LABORATORY TEST METHODS

Granular Base Materials

Moisture-Density Relationships, Gradations, and Moisture Contents

For the granular base materials, moisture-density relationships (AASHTO T 99) were determined both by MoDOT and Missouri S&T in order to ascertain the required compaction condition for the M_r specimens. Missouri S&T determined gradations for the as-delivered and as-tested condition. As-tested moisture contents were also determined. Results of these tests are given in the Results and Discussion section.

Before M_r testing could commence, several issues needed to be resolved. The compaction level, moisture content, and method of degree of saturation determination needed to be decided upon.

The desired compaction level and moisture content was chosen by MoDOT to be 100% of the standard proctor (T 99) MDD and at OMC. The issue at hand was the possible disparity of specimen preparation between T 99 and that required for T 307.

An analysis of current industry approaches (AASHTO, ASTM, Corps of Engineers) necessary to determine moisture-density relationships of coarse-grained materials was completed and forwarded to MoDOT; details are included in Appendix A. It was concluded that for moisture-density relationship determination (proctors), the industry trends are:

- 6 in. diameter mold for coarse materials
- Scalping but no replacement of (+ ¾ in.) material
- four to five data points per proctor curve
- For materials with > five % (+ ¾ in.) material, adjustment of MDD and OMC for field control is necessary; e.g. using AASHTO T 224 (*4*)
- 4 in. and 6 in. molds may not always be interchangeable

For specimen fabrication, the following conclusions were drawn:

1) AASHTO T 307 limits maximum particle size to 1/5 of mold diameter, thus a 4 in. diameter specimen is limited to ¾ in. maximum size, while a 6 in. diameter specimen can accommodate up to 1.2 in. particles.

2) All five aggregate types in the study had some (+ ¾ in.) material, but no (+ 1.2 in.) material, thus a 6 in. diameter specimen is appropriate.

3) Because there may be some differences in the effect of mold size, the moisture-density relationship should be determined in the same size mold as the M_r specimen (6 in.).

4) Because the M_r tests are to be determined on as-delivered material, and a 6 in. mold can accommodate (+ ¾ in.) material, and there is less than 10% (+ ¾ in.) (five % in most cases) material, the samples should not be scalped.

5) Because MoDOT's central lab scalps and uses a 4 in. diameter mold, and the M_r tests were to be run in a 6 in. mold, it was decided that the MDD and OMC needed to be re-determined. Missouri S&T researchers performed T 99 tests at Missouri S&T on all ten materials (two gradations each, five aggregate types, with a minimum of four points per curve) using a mechanical compactor, a 6 in. diameter mold, with no scalping or replacement of material. A summary of the results and comparisons between the Missouri S&T and MoDOT compaction data is given in Table 8 and Figures 2 and 3.

Table 8: Missouri S&T and MoDOT Compaction Data (T 99)

Material	Missouri S&T		MoDOT	
	MDD (pcf)	OMC (%)	MDD (pcf)	OMC (%)
Jefferson City A-D	133.6	9.0	133	10
Jefferson City W-F	136.2	8.9	136	9
Gasconade A-D	133.7	9.4	132	10
Gasconade W-F	133.4	9.1	134	10
Bethany Falls A-D	138.0	7.4	138	7
Bethany Falls W-F	139.3	7.0	139	9
Winterset A-D	133.6	8.6	128	12
Winterset W-F	134.4	8.0	133	10
Plattin A-D	133.9	8.0	135	8
Plattin W-F	134.4	7.9	134	9
Average	135.2	8.3	134.2	9.4
Maximum	139.3	9.4	139.0	12.0
Minimum	133.6	7.0	128.0	7.0

Note: A-D = As-Delivered; W-F = With added Fines

The moisture-density curves developed at Missouri S&T are given in Appendix B. A statistical analysis across all five materials showed no significant difference in MDD (at a 95% confidence level) but OMC's were significantly lower with the larger material. However, three of the 10 materials had a 2 pcf or greater difference between methods, so on an individual basis, the differences could be important. Upon review of the new information, MoDOT decided to use Missouri S&T's results in establishing the moisture-density curves for said materials.

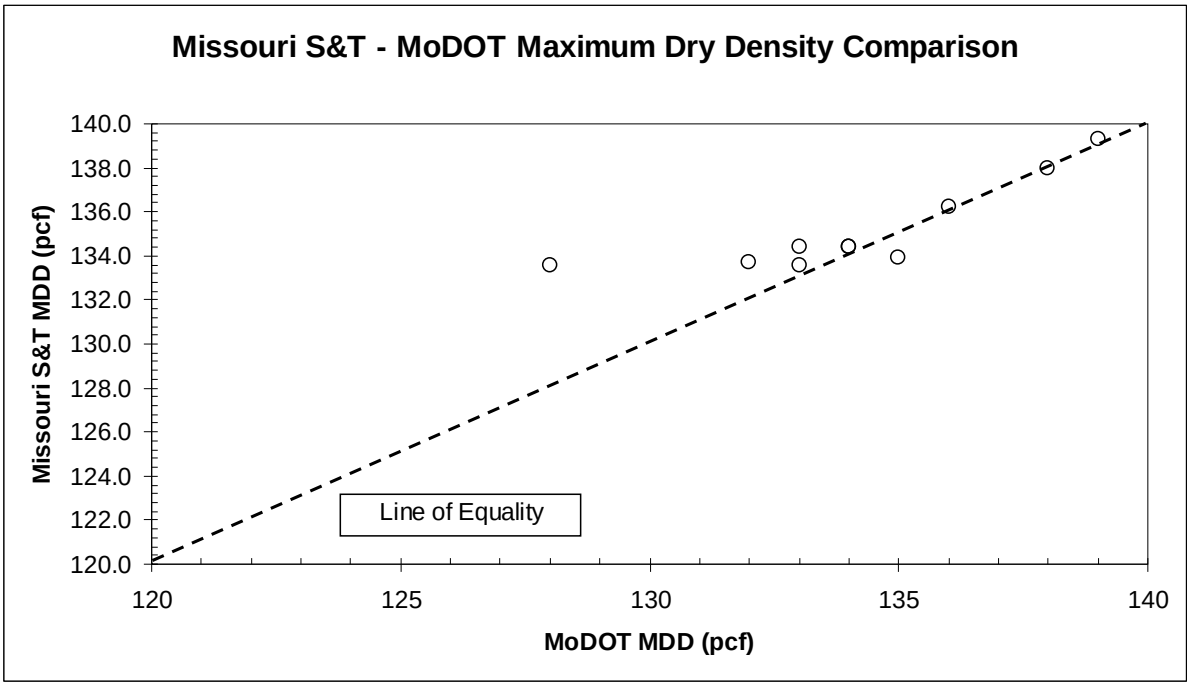


Figure 2: Missouri S&T and MoDOT MDD Comparison

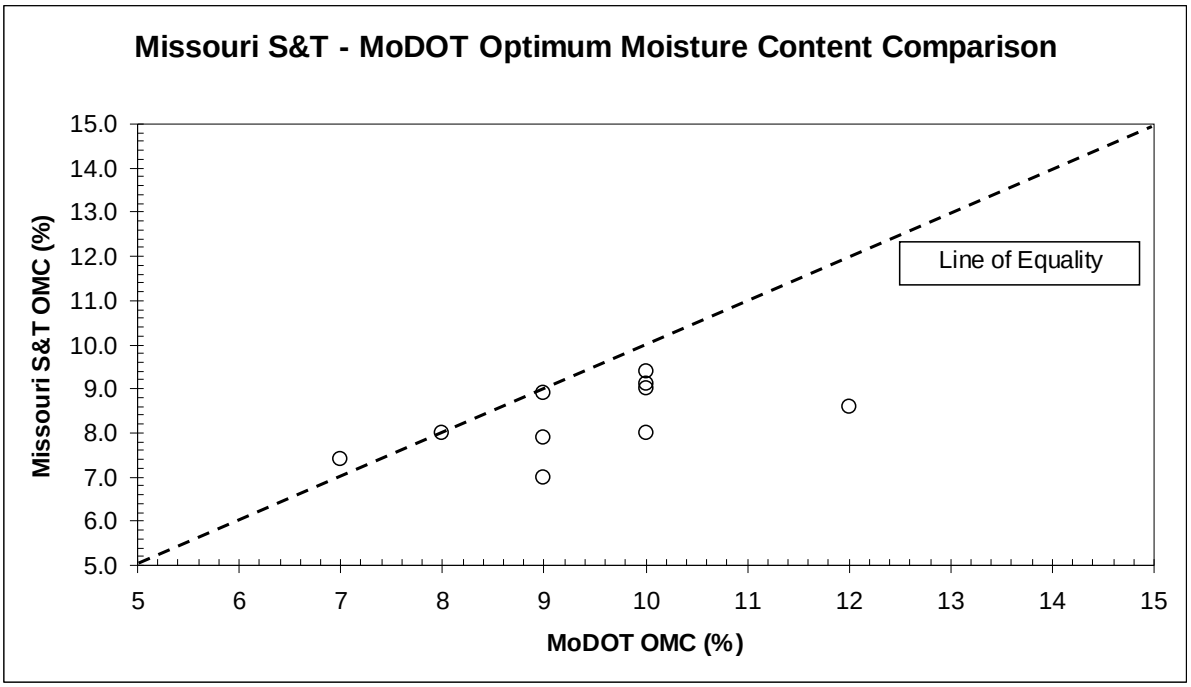


Figure 3: Missouri S&T and MoDOT OMC Comparison

Specific Gravity

Specific gravity tests were performed on the 10 different materials (two gradations, five aggregate types). Specific gravities were determined using three methods: AASHTO T 84 (*5*), T 85 (*6*), and the CoreLok® method (*7*). The purpose of determining specific gravities using all three of these methods was to give MoDOT the choice of using calculated degree of saturation (SAT) values based on: 1) weighted averages of fine and coarse specific gravity results using the AASHTO methods (T 84 and T 85) or 2) the CoreLok® method which MoDOT now allows for aggregate specific gravity determinations. Further reporting of this is in the Results and Discussion section.

Resilient Modulus

Resilient modulus (M_r) is defined as cyclic axial stress, S_{cyclic}, (resilient stress) divided by the resilient (recovered) axial strain, ε_r, due to cyclic axial stress, i.e. $M_r = S_{cyclic}/\varepsilon_r$ (*1*). In the T 307 test, a repeated axial cyclic stress of fixed magnitude, load duration (0.1 sec), and cyclic duration (1.0 to 3.1 sec) is applied to a cylindrical test specimen. During testing, the specimen is subjected to a dynamic cyclic stress and a static confining stress provided by means of a triaxial pressure chamber. The total resilient (recoverable) axial deformation response of the specimen is measured and used to calculate the resilient modulus.

The M_r testing equipment was in conformance with AASHTO T 307 for Type I materials (granular bases), which specifies that test specimens shall be 6 in.

diameter. The equipment consisted of a Geotechnical Consulting and Testing Systems (GCTS) control system, an MTS 858 closed-loop servo-hydraulic load system, a GCTS triaxial chamber capable of housing a 6 in. diameter specimen while subjected to cyclic loads, and a GCTS data acquisition system. Load was measured with an external 2200 lb load cell located between the actuator and the chamber piston rod.

Deformation was measured using two Schaevitz MHR-250 linear variable differential transducers (LVDTs) mounted externally to the cell. The range of the LVDTs was ± 6.35 mm.

Air was used as the confining fluid. Triaxial cell pressure was controlled manually via a pressure regulator, and measured with a pressure transducer linked to the GCTS data acquisition system. The test setup is shown in Figure 4.

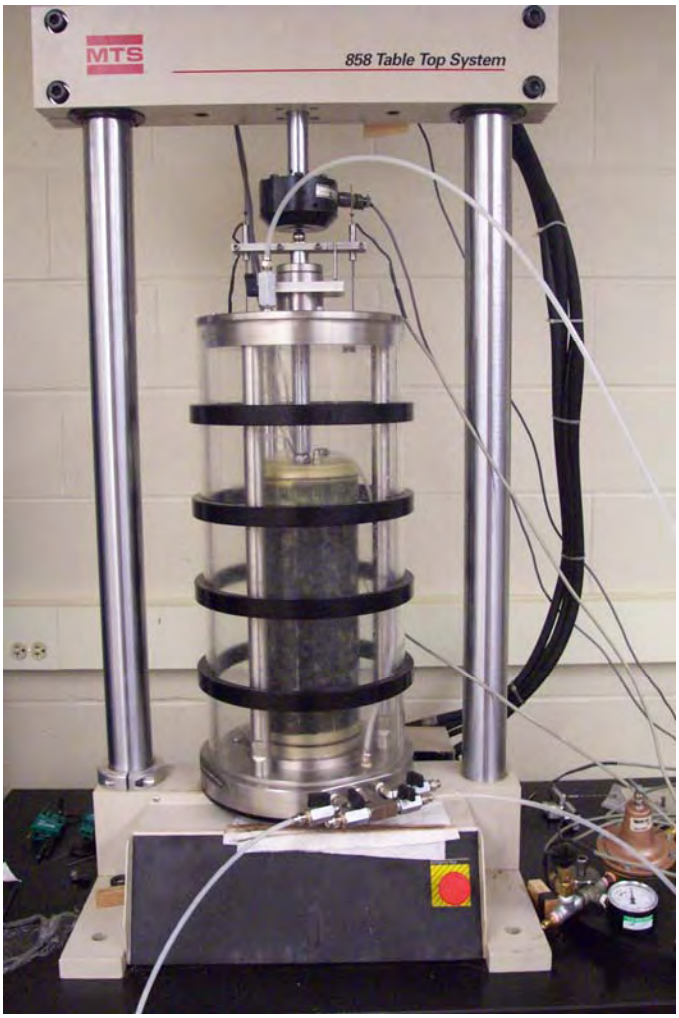


Figure 4: Triaxial Chamber and Measurement Devices

Initial Sample Preparation. The as-delivered samples were introduced into a Quartermaster splitting device and split at least once into the appropriate test specimen size.

The W-F blends were built using 95% A-D material and five % fines (minus #200 material). The amount required for a W-F specimen was determined, then the A-D material was weighed out based on 95% of the required air-dry W-F weight; the appropriate amount of minus #200 material was then added to achieve the proper total weight.

As-tested gradations were determined post-M_r testing. The results are presented in the Results and Discussion section.

Specimen Fabrication. Mr specimens were fabricated in the following manner. Knowing the target dry densities and moisture contents, the existing moisture content of the material, and the target compacted volume of the specimen, enough air-dry material was obtained to produce seven “lifts”; six to be compacted into the mold and one to be used for the as-compacted moisture content determination (as-tested moisture content testing is discussed in the Results and Discussion section). The air-dry material was placed into a five gallon bucket mixer and water was added to bring the material to the OMC plus a small amount to allow for moisture loss. After mixing, the material was returned to a large pan, covered, and allowed to cure for at least 15 minutes (usually longer). After curing, a square point scoop was used to systematically remove the calculated amount of moist material from the pan and place it into the mold to be compacted as a lift. After compaction of the six lifts, the remaining material was used for as-compacted moisture content determination.

The specimen mold was 6 in. nominal diameter. The actual compacted specimen diameter was 5.82 in. This met the requirement that the diameter be equal to or greater than five times the maximum particle size, which was 1 in. for all gradations. The material was compacted into the mold using a hand-held mechanical hammer-drill (meeting T 307 specifications) and bearing on a steel plate. An under-compaction principle was utilized to assure uniform compacted density throughout the height of the specimen. This principle requires that the first or bottom lift be under-compacted to some degree (between one % and five % for the material in this study) and each successive lift be decreasingly under-compacted resulting in the top lift thickness being exactly 1/6 of the specimen height. The mold was an aluminum vacuum split mold mounted directly on the triaxial cell pedestal. The specimens were compacted to a height of approximately 11.70 in., which met the requirement of at least two times the diameter.

A 6 in. diameter, 0.025 in. thick latex rubber membrane was placed onto the triaxial cell pedestal and secured with an O-ring. The split mold was then secured onto the pedestal. Sufficient vacuum was applied to the membrane to hold it against the interior mold wall. Prior to adding material to the mold, the membrane was protected from damage during compaction by securing a series of 0.08 in. thick, approximately

2 in. wide, and 12 in. long nitrile rubber strips against the membrane using a small amount of vacuum grease. T 307 specifies membrane thickness between 0.25 and 0.79 mm (0.0098 in. to 0.0311 in.). Because the protective nitrile rubber was cut into strips and placed side-by-side around the interior perimeter of the membrane, it was reasoned that although the combined thickness of the membrane and the rubber nitrile strips exceeded the T 307 specifications, the rubber nitrile strips did not add any confining pressures to the specimen; only the rubber membrane could supply any confining pressure and it met T 307 thickness specifications.

Stress States/Testing Sequence. Stress state is considered the most important variable that affects the modulus of granular materials. The three principal stresses are σ_1, σ_2, and σ_3, where σ_1 is the major principal stress, σ_2 is the intermediate principal stress, and σ_3 is the minor principal stress. In a triaxial type test, σ_1 is provided by the total vertical stress, and σ_2 equals σ_3 for a cylindrical specimen. In the triaxial state, the difference between the total vertical stress (σ_1) and the confining pressure (σ_3) is called the deviator stress or stress difference (σ_d). A small static load ($0.1\sigma_d$) provides the "overburden" pressure while the cyclic deviator stress ($0.9\sigma_d$) provides the "vehicle" momentary stress. The sum of the three principal stresses is known as the bulk stress (θ).

M_r is calculated as $(0.9\sigma_d)/\varepsilon_r$, where ε_r is the resilient (recovered) axial strain. For each specimen, resilient modulus was determined at fifteen stress states where confining pressure ranged from 3 to 20 psi and σ_d varied from 3 to 40 psi. This resulted in a range of bulk stress from 12 to 100 psi, which is considered adequate to represent the range in stress states likely to be encountered under field conditions. The testing sequence and stress state schedule is shown in Table 9.

Table 9: Testing Sequence for Granular Base Material

Sequence No.	σ_3 (psi)	σ_d (psi)	0.9 σ_d (psi)	0.1 σ_d (psi)	Θ (psi)	No. load applications
0	15	15	13.5	1.5	60	500
1	3	3	2.7	0.3	12	100
2	3	6	5.4	0.6	15	100
3	3	9	8.1	0.9	18	100
4	5	5	4.5	0.5	20	100
5	5	10	9.0	1.0	25	100
6	5	15	13.5	1.5	30	100
7	10	10	9.0	1.0	40	100
8	10	20	18.0	2.0	50	100
9	10	30	27.0	3.0	60	100
10	15	10	9.0	1.0	55	100
11	15	15	13.5	1.5	60	100
12	15	30	27.0	3.0	75	100
13	20	15	13.5	1.5	75	100
14	20	20	18.0	2.0	80	100
15	20	40	36.0	4.0	100	100

Testing Procedure. The resilient modulus testing procedure involved the following steps: specimen compaction, assembly of the triaxial cell, application of confining pressure, stress conditioning at a given stress state (see stress sequence “zero” in Table 9), and load application through 15 additional stress states. Conditioning was used to eliminate the effects of any specimen disturbance due to specimen preparation procedures. It also aided in minimizing the effects of initially imperfect contact between end platens and the test specimen. In this study, conditioning load applications were limited to 500 because the decrease in specimen height had ceased by then.

Load and deformation data were taken for every load application over the entire sequence, but only the last five applications were used for calculation of M_r.

The load duration for each repetition was 0.1 sec followed by 0.9 sec rest. The stress pulse shape was haversine in nature. The drainage valves were left open. Repeated load equipment deflection was determined through the use of an aluminum dummy specimen and was subtracted from total deflections for each stress state. The change in specimen height was continuously monitored. None of the specimens approached the maximum allowable permanent strain of five %.

To verify that each of the three replicates tested per treatment combination were substantially the same, moisture contents were obtained on each specimen after the M_r test had been completed. M_r test specimens were divided into three approximately equal portions (top, middle, and bottom 4 in.) and moisture contents were determined on each third. Also, moisture contents used for calculation of reported actual (as-tested) dry densities were based on the entire specimen. As mentioned previously, for every M_r specimen, enough material was prepared to produce seven layers or lifts; six to be compacted in the vacuum split mold and one to be used as a check on the as-compacted moisture content. A summary of the target, as-compacted, and actual (post-M_r test) moisture contents, and target and actual dry densities are given in the Results and Discussion section.

An additional check on similarity between the replicates per treatment combination was made. Gradation analyses were performed on each M_r specimen. After obtaining the moisture contents of the top, middle, and bottom 4 in. of the specimen, these same “thirds” were then tested per AASHTO T 11 (*8*) and T 27 (*9*). A total of 83 gradation analyses were performed, three per specimen (except for the JCD A-D specimens in which a sieve analysis was not performed on the first specimen and the other two specimens were analyzed for gradation purposes but not in “thirds” as were all others). This information could also be used to track any fines migration in the specimen. Gradation plots are given in Appendix C.

Subgrade Soils

Moisture-Density Relationships

MoDOT supplied the T 99 moisture-density relationships. These are shown in Appendix D. Both Methods A (scalping all plus #4) and C (scalping the plus 3/4 in.) were used.

Soil Suction

In 1960's, the idea of resilient modulus tests was first proposed (*10*) and provided a tool for evaluating the dynamic response and fatigue behavior under vehicle loading. Its results can be analyzed and used in the mechanistic-empirical based pavement design model. The M_r test method has been utilized and accepted as a standard approach, so that the next issue is how to mimic different environmental effects. Among these environmental effects, change in the moisture content (or more precisely, the degree of saturation) has a strong effect on subgrade performance. It is very important and necessary to investigate this performance by testing subgrade under different moisture conditions. But it is not feasible to simulate every moisture condition. The common practice is to prepare specimens under two conditions: MDD and OMC, and MDD (or 95% MDD) in a fully saturated condition. The first case simulates the condition immediately after construction, while the second case represents the worst-case scenario.

Through better understanding of subgrade soil physico-chemical phenomena and new developments of field moisture content monitoring techniques, engineers started to realize that it is very difficult for soil to reach 100% saturation in the field under normal conditions. Actually, 100% saturation would only happen under submerged conditions and using numbers from 100% saturation could result in an unreasonable pavement structure design. Lately, the information obtained and experience accumulated from the soil-water characteristic curves, including soil suction (total suction), has gained more and more attention from pavement engineers and researchers (*1, 11, 12, 13*). Soil suction is related to three phenomena; capillary rise (this directly links to soil's pore size distribution), the physical-chemical need of clay minerals and the physico-chemical need of cations within the soil. Based on these phenomena, it is understandable that soil suction could provide more details about soil behavior under different moisture contents. In other words, it could be used as an indicator whether soil can or cannot take on more water in the field.

Other than the "immediately after construction" condition, tests under the "wet side" conditions were also required to be performed. In order to determine a more reasonable "wet side" condition in the field, the total soil suction was used as the main factor for engineers to decide which moisture content to be used in the laboratory M_r tests.

Generally speaking, soil suction decreases as moisture content increases. Once the soil reaches certain level, the soil does not have enough energy differential to continue to “pull” water into the soil mass. This level of moisture is commonly defined as the soil’s “field capacity”.

The definition of unit of suction level (pF) used here is:

$$pF = \log_{10} \frac{\text{suction, cm water}}{1\,\text{cm}} \tag{1}$$

Soil suction was used in this study to help determine the elevated moisture content at which to test resilient modulus specimens. It was reasoned that the moisture content at the highest level of suction could help define a realistic upper bound of moisture content achieved in the field.

Soil suction samples were prepared by using only minus #4 sieve materials at this stage. The relationship of soil suction-moisture content was established in the following manner. A range in moisture contents was calculated. The low end of the range was the optimum moisture content from the T 99 test results. The high end was the estimated moisture content at 100% saturation (this moisture content was determined using weight-volume relationships). Two more moisture contents were chosen in between the low and the high ends. About 100 g of natural state or air-dried soils were mixed with the water needed to reach pre-selected moisture contents and sealed in a Ziploc® bags. After storage in the moisture room for at least 24 hours, three loose samples were taken into the standard plastic cup from the Decagon Devices, Inc. Potentiometer equipment manufacturer. Capped and sealed samples were placed into a cooler and allowed to equilibrate for another 24 hours. This process ensures the air within each plastic cup reaches an equilibrium condition with the soil samples stored in the sample container.

The standard procedure requires a period of at least 30 minutes of warming up before daily calibration can be performed. Standard fluid provided by equipment manufacturer is tested first and the readings were compared with reference numbers. If the readings did not fall within the acceptable range, the offset was adjusted and the calibration rechecked. The completed and detailed procedure can be found the operator’s manual. Three readings were taken and recorded for each specimen and the average pF was determined. After the suction test, each soil was dried and moisture contents were calculated the next day. Then, the soil-water characteristic curves were developed based on the measured total suctions and moisture content determinations. An example curve is shown in Figure 5. Tables 2-7 contain the soil classification, Atterberg Limits, MDD, OMC, and compaction test data for the soil. Based on the test results, Table 10 gives the moisture contents that were targeted to simulate wet side of compaction curves. The target moisture contents were based on the point where the 95% MDD value was on the T 99 curve on the wet side, as long as this point was wet of the breakpoint in the pF-MC curve. Each soil’s soil-water characteristic curve is shown in Appendix E.

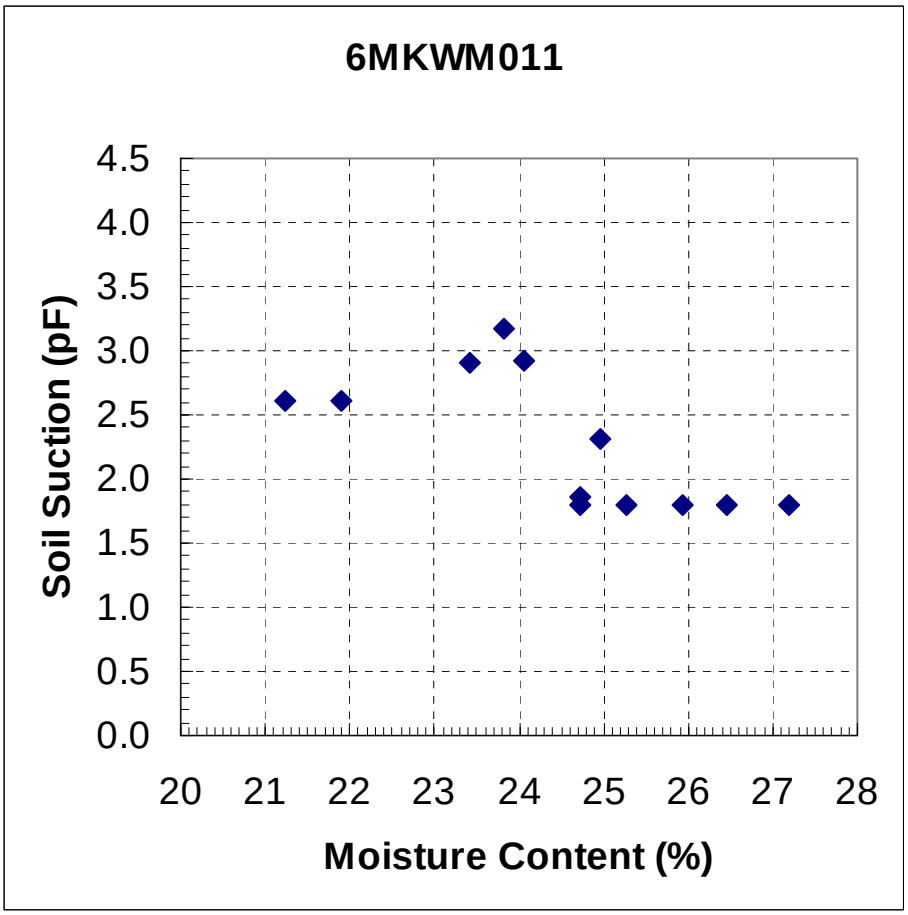


Figure 5: Total Suction versus Moisture Content for Soil 6MKWM011

Resilient Modulus

Initial Sample Preparation. All soils were screened over a ¾ in. sieve, and the percent of plus ¾ in. material was replaced with an equal amount of #4 to ¾ in. material. This allowed the use of a 4 in. diameter specimen.

Target Compaction Points. Two types of specimens we prepared: 1) At MDD and OMC, and 2) at 95% MDD and the wet-side moisture content as determined by the previously described soil suction method.

Specimen fabrication. Mr specimens were prepared by hand-mixing the desired amount of moisture into the soil, then allowing the material to cure overnight in a sealed plastic bag. A pre-weighed amount of soil was then placed into a Pine gyratory shear compactor 4 in. diameter mold in three lifts. Each lift was compacted to a pre-determined height until the proper specimen height was achieved. The gyratory compactor ram pressure was 600 kPa. After compaction, the specimen was extracted from the gyratory mold and wrapped in plastic wrap to retain moisture until

M_r testing was performed. Prior to performing M_r testing, the plastic wrap was removed from the specimen and a membrane stretcher was used to encase the specimen in a latex membrane.

Table 10: Wet-Side Dry Density and Moisture Content

Soil No.	MDD (lb/ft^3)	OMC (%)	95% MDD (lb/ft^3)	MC @ S=100% and 95% MDD (%)	Target Moisture Content (%)
6MKWM011	101	20	96	28	24.5
6MKWM012	120	11	114	17	14
6MKWM013	121	11	115	17	14
6MKWM014	110	12	108	22	15
6MKWM015	112	15	107	21	18
6MKWM016	96	21	91.5	31	27
6MKWM017	97	20	92	31	24
6MKWM018	91	27	86.5	35	31
6MKWM019	108	16	102.5	24	20.5
6MKWM020	102	20	97	27	24
6MKWM021	101	18	99	28	23
6MKWM022	80	32	76	45	36
6MKWM023	100	20	95 or 97	28	24
6MKWM024	96	21	92 or 94	31	24 or 26
6MKWM025	112	13	107	21	17
6MKWM026	99	22	94	29	26
6MKWM027	126	9	120	14	12
6MKWM028	97	22	92	31	27
6MKWM029	109	15	104	23	19.5
6MKWM030	118	12	112	18	17
6MKWM031	108	17	102.5	24	20
6MKWM032	94	24	89.5	33	29
6MKWM033	103	18	98	26	23
6MKWM034	101	19	96	28	24
6MKWM035	100	18	95	28	23
6MKWM036	94	23	89.5	33	27.5
6MKWM037	105	19	100	26	22

Stress States/Testing Sequence. For each specimen, resilient modulus was determined at fifteen stress states where confining pressure ranged from 2 to 6 psi and σ_d varied from 2 to 10 psi, which is considered adequate to represent the range in stress states likely to be encountered under field conditions. The testing sequence and stress state schedule is shown in Table 11.

Testing Procedure. The resilient modulus testing procedure was similar to the granular base material testing, and involved the following steps: specimen compaction, assembly of the triaxial cell, application of confining pressure, stress conditioning at a given stress state (see stress sequence “zero” in Table 11), and load application through 15 additional stress states. Conditioning was used to eliminate the effects of any specimen disturbance due to specimen preparation procedures. It also aided in minimizing the effects of initially imperfect contact between end platens and the test specimen.

Load and deformation data were taken for every load application over the entire sequence, but only the last five applications were used for calculation of M_r.

The load duration for each repetition was 0.1 sec followed by 0.9 sec rest. The stress pulse shape was haversine in nature. The drainage valves were left open. The change in specimen height was continuously monitored. Several of the specimens exceeded the maximum allowable permanent strain of five percent, thus the results were discarded.

Table 11: Testing Sequence for Subgrade Soil

Sequence No.	σ_3 (psi)	σ_d (psi)	0.9 σ_d (psi)	0.1 σ_d (psi)	No. load applications
0	6	4	3.6	0.4	500
1	6	2	1.8	0.2	100
2	6	4	3.6	0.4	100
3	6	6	5.4	0.6	100
4	6	8	7.2	0.8	100
5	6	10	9.0	1.0	100
6	4	2	1.8	0.2	100
7	4	4	3.6	0.4	100
8	4	6	5.4	0.6	100
9	4	8	7.2	0.8	100
10	4	10	9.0	1.0	100
11	2	2	1.8	0.2	100
12	2	4	3.6	0.4	100
13	2	6	5.4	0.6	100
14	2	8	7.2	0.8	100
15	2	10	9.0	1.0	100

Equipment

Resilient Modulus. The test equipment for the Mr testing of subgrade soils was essentially the same as that which was used for the granular base materials, except a 4 in. triaxial cell was used.

Soil Suction. Several methods have been developed for measuring soil suction. They include the pressure plate method (*14*) and filter paper method (*15*). These two methods have their advantages but are very time consuming. With new techniques of measuring soil suction proposed and their standard practices developed, new equipment was developed by different companies. One of these devices is the WP4 Potentiometer (as seen in Figure 6). The design philosophy of the WP4 Potentiometer is the use of a chilled mirror dewpoint technique which can be found in ASTM D6836 Method D (*16*).

Figure 6: WP4 Potentiometer (Courtesy of Decagon Devices, Inc.)

The basic idea of this technique is that a sample is equilibrated with a sealed chamber's headspace. Within the chamber, there is a mirror and device of detecting condensation on the mirror. As described in the WP4 operator's manual (*17*):

"At equilibrium, the water potential of the air in the chamber is the same as the water potential of the sample. In the WP4, the mirror temperature is precisely controlled by a thermoelectric (Peltier) cooler. Detection of the exact point at which condensation first appears on the mirror is observed with a photoelectric cell. A beam of light is directed onto the mirror and reflected into a photodetector cell. The photodetector senses the change in reflectance when condensation occurs on the mirror. A thermocouple attached to the mirror then records the temperature at which condensation occurs"

Published research (*18, 19*) has provided the authors enough experience and proof that the WP4 is easy to use and is a reliable laboratory tool for measuring total soil suction. At the same time, it has provided consistent readings of total suction. Based on these considerations, a WP4 potentiometer was selected for this research project. The specimen preparation used was as described by Petry and Jiang (*18*).

RESULTS AND DISCUSSION

GRANULAR BASE MATERIALS

General

Five types of test results were generated during the course of this study: moisture-density relationships (AASHTO T 99), moisture distribution, gradation and fines distribution, specific gravity and degree of saturation, and resilient modulus. T 99 results were presented in the Technical Approach section.

Testing at Elevated Moisture

A series of four M_r tests were performed on MoDOT-supplied granular pavement base material to determine the feasibility of running M_r tests at an elevated moisture content (i.e. wet of OMC) when the material is compacted to 95% of MDD determined using T 99.

The material used for these tests was the Jefferson City Dolomite W-F (With added Fines). The W-F gradation (95% as-delivered material blended with five % minus #200) was used assuming that it would be the worse-case scenario for running M_r tests on high moisture content specimens. Figure 7 shows the target densities and moisture contents for the W-F gradation. The target of interest for purposes of this discussion is the intersection of the 95% MDD line and the extrapolated wet side of the proctor curve.

Drained Testing Conditions

The first two specimens were compacted at the target density and moisture content: 95% MDD or 129.4 pcf, and 11.5%, respectively. The M_r tests were performed according to T 307 which specifies that all drainage valves leading into the specimen be open to atmospheric pressure, simulating drained conditions.

These two initial M_r tests were successful in that the entire set of stress sequences was completed without the specimen failing (i.e. experiencing five % or more vertical strain). However, approximately 200 ml of water were expelled from the drainage ports during the cyclic loading resulting in a final moisture content of 9.6% for both specimens. Figure 8 graphically depicts the results of this scenario. Although bulk volume changes of the specimens were not actually determined, one could assume that the density increased slightly during the test (as noted by the thick dashed arrow).

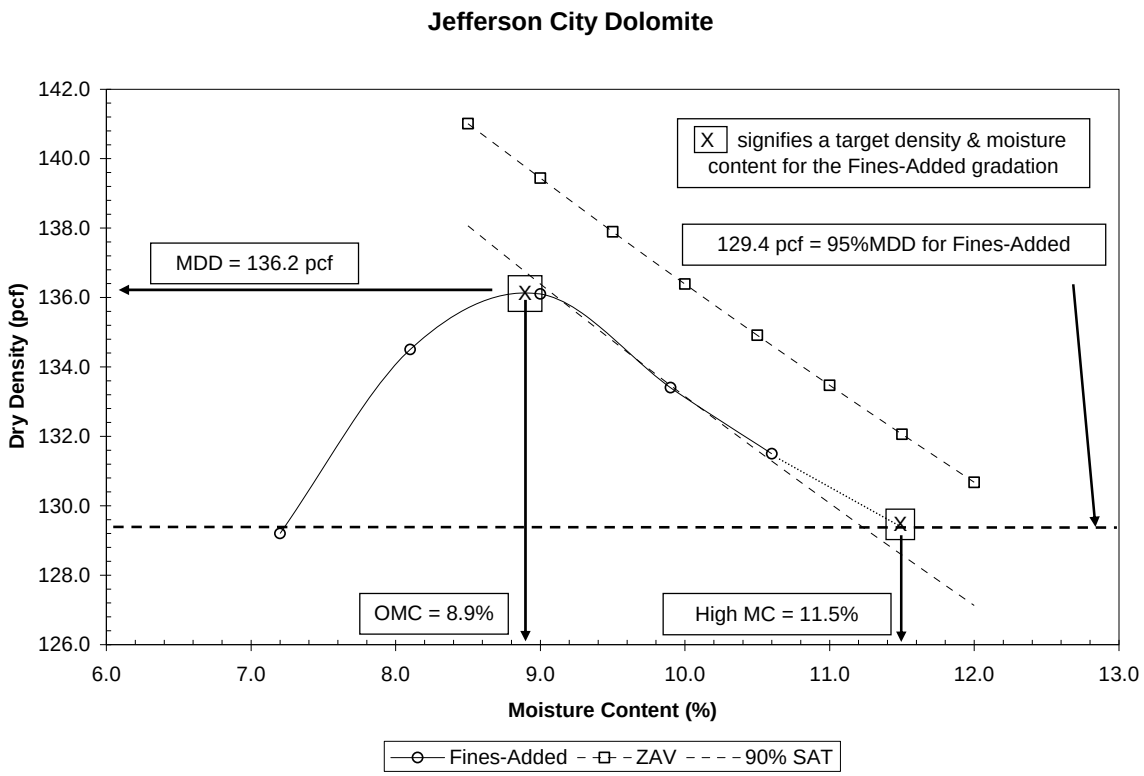


Figure 7: Target Densities and Moisture Contents for W-F Gradation

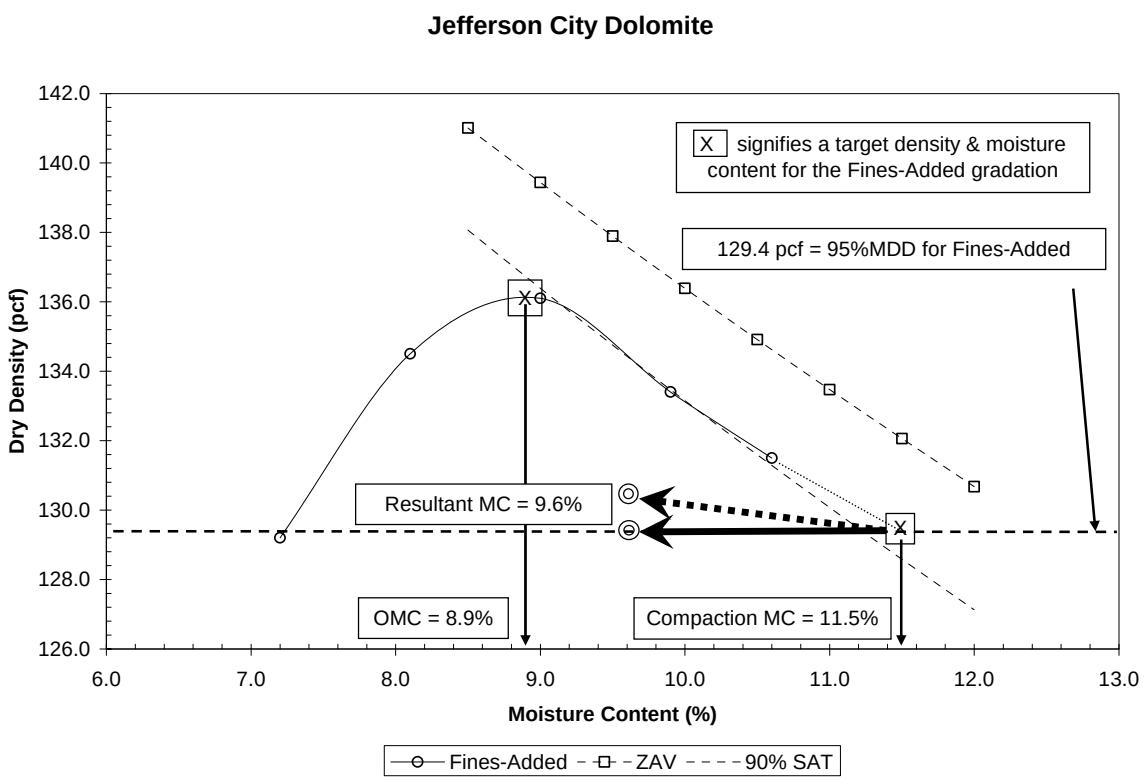


Figure 8: Drained M_r Test Results

Undrained Testing Conditions

Having brought this loss of moisture issue to the attention of MoDOT, the decision was made to attempt performing the M_r tests at 95% MDD and at an elevated moisture content but with the drainage valves closed, simulating undrained conditions.

Two different methods were used in producing an elevated moisture level in the specimens to be tested in the undrained condition. The first method began by compaction of the specimen using five % under-compaction on the first layer, and at a moisture content dry-of-optimum (7.2%). Water was then allowed to percolate upward through the compacted specimen under a small head of approximately 6 in. until water was observed coming out of the upper drainage line. The thought was that compacting dry-of-optimum would not only assist the percolation of water due to capillary action, but would also minimize the potential over-compaction of the lower layers of the specimen. The second method of producing an elevated moisture level was the same used for those specimens tested in the drained condition, i.e. compaction of the sample at the target elevated moisture content.

As with all of the preliminary tests, a small vacuum (approximately 1.5 psi) was applied to the specimen to check for leaks in the membrane and to help stabilize the specimen during placement and setup in the load frame. When testing the specimen that had been soaked-by-percolation, consolidation of the specimen before the conditioning sequence (15 psi confining pressure) was not performed. A confining pressure of approximately three psi was first applied to the specimen already under vacuum (a total confining pressure of approximately 4.5 psi), the 1.5 psi vacuum was removed then the drainage valves were closed. The confining pressure was then increased to 15 psi, the level required during the conditioning sequence.

This particular specimen held up during the conditioning sequence but failed due to excessive strain halfway through the remaining stress sequences. Failure was evident in that the bottom 2/3 of the specimen bulged outward noticeably. Post-failure moisture content tests on the upper 1/3 and the bottom 2/3 of the specimen resulted in values of 7.7% and 10.7%, respectively. It is not clear if the moisture content gradient was a result of the percolation procedure, the cyclic loading and subsequent failure/bulging, or a combination of both. Because the specimen was not consolidated prior to closing the drainage valves, one could assume the dry density as tested was the same as that obtained during compaction.

The second undrained specimen was compacted at the target moisture content of 11.5% and five % under-compaction on the first layer. In addition, this specimen was consolidated at 15 psi *before* closing the drainage valves. The valves were left open for approximately 10 minutes while the 15 psi confining pressure was applied to the specimen. It was observed that air and a small amount of water was expelled from the upper drainage line during this 10 minute period. The drainage valves were then closed and the conditioning sequence was initiated.

This specimen failed before the conditioning sequence was completed. Excessive strain occurred quickly and the bulging of the specimen was most pronounced at mid-height with the diameter decreasing in an approximately symmetric manner toward the top and bottom of the specimen. Post-failure moisture content tests on the top, middle, and bottom 4 in. resulted in 10.1%, 10.6%, and 11.4%, respectively. Because this specimen was consolidated prior to closing the drainage valves, one could assume the dry density as tested was greater than that obtained during compaction.

Conclusion

Performing undrained M_r tests at 95% MDD and at some elevated moisture content is problematic, at best. It seems that to achieve a wet-of-optimum M_r test result at the 95% MDD level requires performing the test in the drained condition (per T 307) and living with the final moisture content, as generally depicted in Figure 8. Attempts at testing at an elevated moisture condition and a relatively low dry density were discontinued, as the data was not necessary for input into the M-E PDG.

Moisture Content and Distribution

As presented in the Technical Approach section, moisture content was determined for the "7th lift" (initial as-compacted moisture content), and the top, middle, and bottom portions of each M_r specimen (as-tested). In all but one M_r test (Plattin W-F2), the as-tested moisture content was somewhat lower than the target despite the fact that the as-compacted moisture (7th lift) contents were, on average, in agreement with the targets (See Table 12). The dry density of the M_r specimens as-tested was, on average, only slightly larger than the average target density. The reduction of the post-M_r test moisture content relative to the as-compacted (7th lift) moisture content is most likely due to 1) drying of the aggregate during vibratory compaction (heat generation due to high energy input), 2) moisture loss during handling, and most significantly, 3) testing in the drained condition.

After the first four specimens were subjected to cyclic testing, measures were taken to capture the water that was forced through the bottom drainage valve, although on several occasions water was also forced through the upper drainage system. Prior to compaction of a specimen, the bottom drainage system, including the porous bronze disk, was saturated with water. Therefore, the volume of any water that existed in the bottom drainage line (downstream of the bottom drainage valve) was captured in a bottle and the amount was recorded (varied from 5 to 35 ml). One could assume that this same volume of water had been expelled from the specimen during the M_r test. Thus, it is clear that there is an upper limit to the amount of moisture a specimen can hold when subjected to cyclic testing in the drained condition.

Table 12: Dry Densities & Moisture Contents

Specimen & Statistics	Target Dry Density (pcf)	Target Moisture (%)	As-Compacted Moisture [7th lift] (%)	Actual Dry Density (pcf)	Actual Moisture (%)
JCD A-D2	133.6	9.0	9.1	133.7	8.6
JCD A-D3	133.6	9.0	9.0	133.8	8.7
JCD A-D4	133.6	9.0	9.0	133.7	8.7
Average				133.8	8.7
St Dev.				0.0452	0.0572
Coeff. Var				0.0338	0.6594
JCD W-F1	136.2	8.9	9.0	136.3	8.6
JCD W-F2	136.2	8.9	8.8	136.3	8.7
JCD W-F3	136.2	8.9	8.7	136.4	8.5
Average				136.3	8.6
St Dev.				0.0336	0.0867
Coeff. Var				0.0246	1.0046
Gasc A-D1	133.7	9.4	9.8	133.9	8.9
Gasc A-D2	133.7	9.4	9.9	133.8	8.8
Gasc A-D3	133.7	9.4	9.8	133.7	8.9
Average				133.8	8.9
St Dev.				0.0647	0.0491
Coeff. Var				0.0484	0.5511
Gasc W-F1	134.4	9.1	9.2	134.4	8.8
Gasc W-F2	134.4	9.1	9.4	134.6	8.7
Gasc W-F3	134.4	9.1	9.5	134.6	8.8
Average				134.5	8.8
St Dev.				0.1183	0.0188
Coeff. Var				0.0879	0.2149
Plat A-D1	133.9	8.0	8.1	133.9	7.6
Plat A-D2	133.9	8.0	7.8	134.1	7.3
Plat A-D3	133.9	8.0	7.9	134.2	7.4
Average				134.1	7.4
St Dev.				0.1472	0.1703
Coeff. Var				0.1098	2.2869
Plat W-F1	134.4	7.9	6.8	135.6	6.9
Plat W-F2	134.4	7.9	8.2	134.2	7.9
Plat W-F3	134.4	7.9	8.0	134.6	7.6
Average				134.8	7.5
St Dev.				0.7367	0.4908
Coeff. Var				0.5466	6.5681
Win A-D1	133.6	8.6	8.1	133.7	8.0
Win A-D2	133.6	8.6	8.5	133.9	8.0
Win A-D3	133.6	8.6	8.5	133.8	7.9
Average				133.8	8.0
St Dev.				0.0809	0.0730
Coeff. Var				0.0605	0.9183
Win W-F1	134.4	8.0	7.9	134.5	7.9
Win W-F2	134.4	8.0	7.8	134.6	7.9
Win W-F3	134.4	8.0	8.2	134.5	7.9
Average				134.5	7.9
St Dev.				0.0719	0.0164
Coeff. Var				0.0534	0.2069
BF A-D1	138.0	7.4	7.2	138.2	6.8
BF A-D2	138.0	7.4	7.3	138.3	6.8
BF A-D3	138.0	7.4	7.3	138.3	6.7
Average				138.3	6.8
St Dev.				0.0779	0.0223
Coeff. Var				0.0564	0.3291
BF W-F1	139.3	7.0	7.2	139.6	6.6
BF W-F2	139.3	7.0	7.1	139.5	6.6
BF W-F3	139.3	7.0	6.9	139.5	6.6
Average				139.5	6.6
St Dev.				0.0329	0.0467
Coeff. Var				0.0236	0.7079
Average	135.15	8.330	8.331	135.34	7.911

An analysis of the moisture within the M_r specimens, post-test, was performed. Using the moisture content determinations performed on the top, middle, and bottom thirds of the specimens, average values of moisture content were calculated across three groups of specimens: the A-D group, the W-F group, and “All” specimens. Figure 9 shows the results of this analysis.

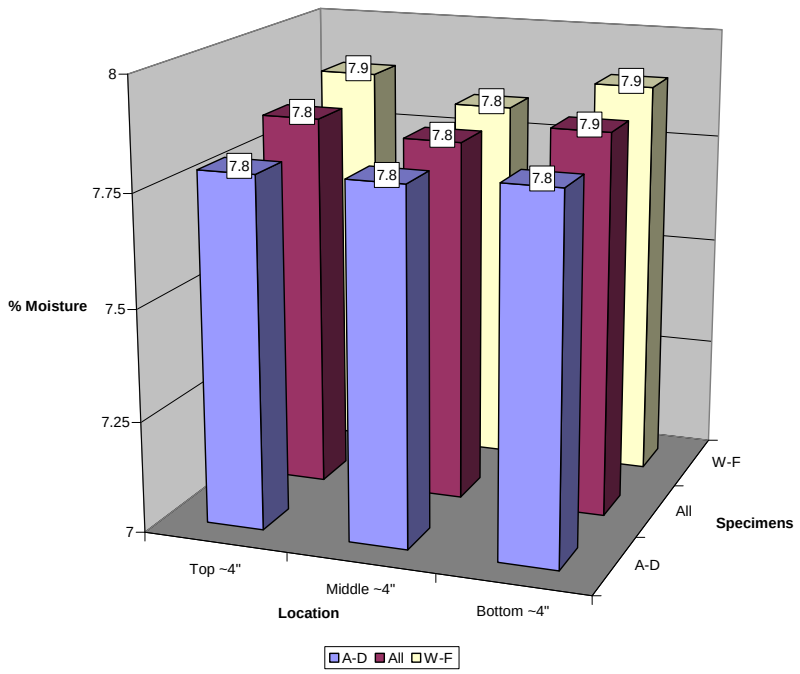


Figure 9: Average Moisture Distribution Within Specimens

As shown in Figure 9, the specimens have a slight tendency to be drier, on average, in the center third, possibly because the center third of the specimen experiences the greatest stress during cyclic testing, on a per unit volume basis, thereby forcing water downward (and assisting gravity) and upward where the fines, if present in a sufficient quantity, then hold onto the water.

Gradation and Fines Distribution

Gradations were determined for the as-delivered condition as well as the with-fines added materials. Additionally, like the moisture content distribution study, the gradations of the top, middle, and bottom thirds of each M_r specimen were determined post-M_r testing.

Combining the data from each replicate allowed for an overall gradation of all of the material used in all three replicates (except for the JCD A-D specimens in which only two specimens were subjected to sieve analyses). Summary gradation results are shown below in Table 13 and Figures 10 and 11.

Table 13: Gradation Data Summary

Sieve Size		Aggregate Types and Gradations									
(mm)	Standard	JCD A-D	JCD W-F	Gasc A-D	Gasc W-F	Plat A-D	Plat W-F	Win A-D	Win W-F	BF A-D	BF W-F
25	1"	100	100	100	100	100	100	100	100	100	100
19	3/4"	98	99	97	97	89	90	96	96	96	96
12.5	1/2"	87	87	83	82	67	70	80	81	80	80
9.5	3/8"	76	76	71	70	56	59	66	70	69	69
4.75	#4	57	58	52	51	39	42	43	50	47	49
2.36	#8	40	42	39	40	30	33	31	38	33	36
1.18	#16	30	33	32	33	25	28	23	30	25	29
0.6	#30	25	28	27	28	22	25	19	25	21	24
0.3	#50	21	24	21	23	19	22	16	22	18	21
0.15	#100	18	21	15	18	16	19	14	19	15	19
0.075	#200	13.6	17.1	10.7	14.2	12.6	16.2	12.2	17.7	13.8	17.6

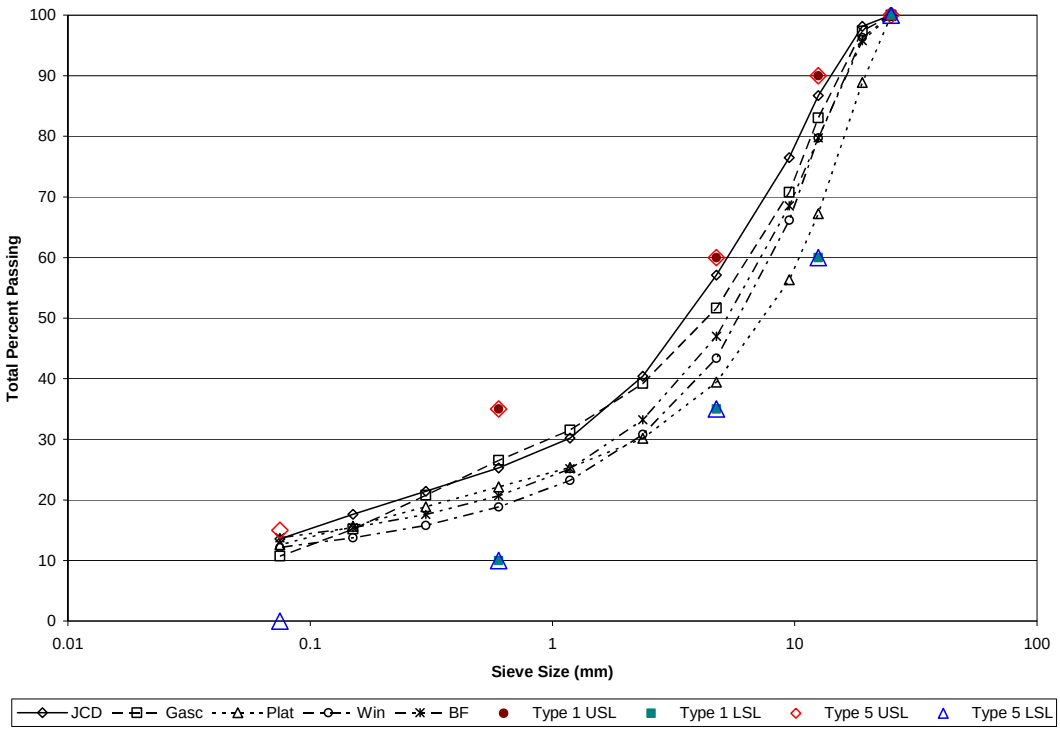


Figure 10: A-D Gradation Comparison: All 5 Aggregate Types

As can be seen, all A-D gradations met Type 5 specifications, although the % minus #200 sieve material was close to the high side of the specification. As shown in Figure 11, blending five % minus #200 fines to the materials resulted in four of the five gradations moving out of specification on the #200 sieve, with the fifth gradation (Gasconade Dolomite) being barely in on the high side of the #200 sieve control point. However, the W-F gradations for all five aggregate types met MoDOT's Type 1 base aggregate specifications.

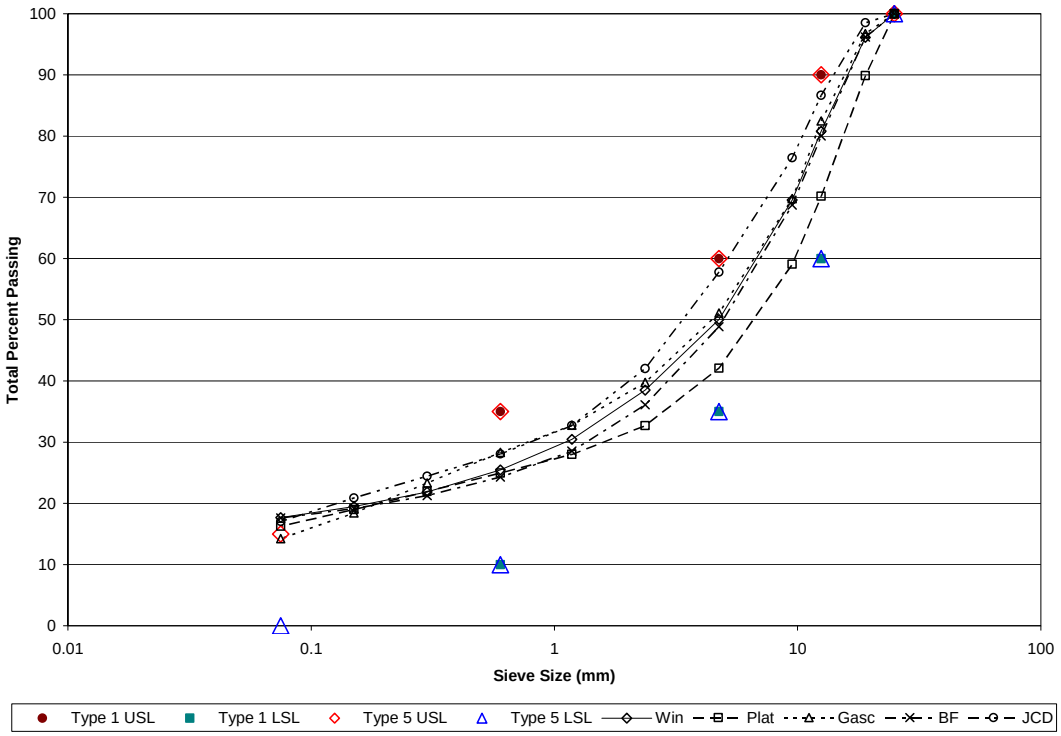


Figure 11: W-F Gradation Comparison: All 5 Aggregate Types

Comparisons of the gradations of the top, middle, and lower portions of each specimen were plotted and those plots are included in Appendix C. A summary of the results is shown in Figure 12.

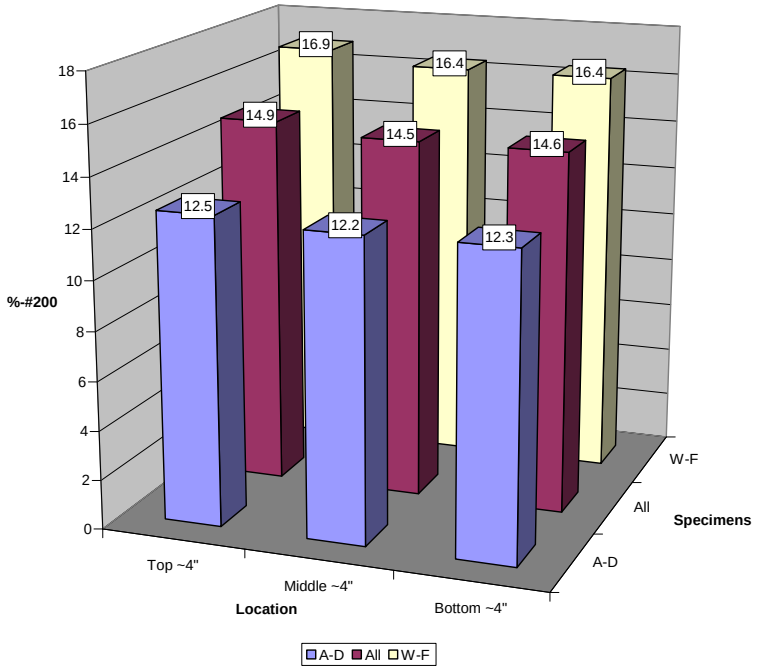


Figure 12: Average Fines Distribution Within Specimens

Figure 12 indicates slight fines migration to the top of the specimen. It is assumed that the majority of the movement of the fines occurred during compaction. It was not unusual to see fines pump around the outside of the compaction disk, especially during compaction of the W-F specimens. It is also possible that some movement occurred during cyclic testing; the fines could have been transported with the water during its downward and upward movement out of the middle third of the specimen.

Specific Gravity and Degree of Saturation

As previously introduced, specific gravity tests were performed on the 10 different gradations. Specific gravities were determined using T 84 and T 85 methods plus the CoreLok method. This gives MoDOT the choice of using calculated degree of saturation (SAT) values based on 1) weighted averages of fine and coarse specific gravity results using the AASHTO methods (T 84 and T 85) or 2) the CoreLok method.

Within the Mechanistic-Empirical Pavement Design Guide (M-E PDG) software, one can either input degree of saturation (SAT) directly or let the software calculate SAT based on material properties; i.e. the specimen moisture content and dry density, unit weight of water (a function of temperature), and the apparent specific gravity (G_{sa}) of the material.

Table 14 shows the aggregate specific gravities and absorption values determined for the 10 materials tested, and the SAT values for each M_r specimen. The raw CoreLok data has been corrected to T 84/85 values using a correlation equation developed at Missouri S&T and implemented by MoDOT in the CoreLok spreadsheet used for collection of data and calculation of aggregate bulk and apparent specific gravities, and absorption. As shown, SAT is fairly sensitive to G_{sa} . CoreLok $G_{sa(predicted)}$ values were lower in all 10 cases than the weighted average G_{sa} values. As G_{sa} decreases, SAT increases, everything else remaining constant. Therefore, using CoreLok $G_{sa(predicted)}$ values results in significantly higher SAT values.

Resilient Modulus

General

Fifteen M_r tests (five materials, three replications) were performed on the A-D gradation of all five aggregate types at 100% MDD and the OMC specimens, as well as 15 tests on the W-F gradation. The W-F blends were built using 95% A-D material and five % fines (-#200 material). All were compacted at 100% MDD and the OMC. There were five crushed aggregate types:

1. Jefferson City Dolomite (JCD)
2. Gasconade Dolomite (Gasc)
3. Plattin Limestone (Plat)

4. Winterset Limestone (Win)
5. Bethany Falls Limestone (BF)

Summary tables and plots of the M_r test results are included in Appendix F.

Table 14: Degree of Saturation, Specific Gravities & Absorptions

Specimen & Statistics	SAT CoreLok (%)	SAT Wt. Avg (%)	Specific Gravities and Absorptions	UMR T84 (-#4)	UMR T85 (+#4)	UMR Weighted Average	UMR CoreLok	MoDOT (T85?)
JCD A-D2	84.2	80.9	Gsb (Bulk Specific Gravity, Oven-Dry)	2.416	2.550	2.472	2.530	2.628
JCD A-D3	85.5	82.2	Gsb (Bulk Specific Gravity, SSD)	2.546	2.631	2.582		
JCD A-D4	84.7	81.4	Gsa (Apparent Specific Gravity)	2.779	2.774	2.777	2.745	2.797
Average	84.8	81.5	Pabs (Absorption) (%)	5.42	3.17	4.16	3.10	2.3
St Dev.	0.6809	0.6498						
Coeff. Var	0.8031	0.7974						
JCD W-F1	92.9	88.6	Gsb (Bulk Specific Gravity, Oven-Dry)	2.428	2.550	2.478	2.520	
JCD W-F2	93.8	89.5	Gsb (Bulk Specific Gravity, SSD)	2.553	2.631	2.585		
JCD W-F3	92.2	87.9	Gsa (Apparent Specific Gravity)	2.774	2.774	2.774	2.740	
Average	93.0	88.7	Pabs (Absorption) (%)	5.15	3.17	4.08	3.18	
St Dev.	0.8364	0.8022						
Coeff. Var	0.8996	0.9044						
Gasc A-D1	91.7	87.4	Gsb (Bulk Specific Gravity, Oven-Dry)	2.302	2.488	2.388	2.456	2.609
Gasc A-D2	90.7	86.4	Gsb (Bulk Specific Gravity, SSD)	2.464	2.583	2.520		
Gasc A-D3	91.5	87.2	Gsa (Apparent Specific Gravity)	2.746	2.748	2.747	2.711	2.768
Average	91.3	87.0	Pabs (Absorption) (%)	7.02	3.80	4.98	3.84	2.2
St Dev.	0.5361	0.5074						
Coeff. Var	0.5871	0.5833						
Gasc W-F1	91.8	87.0	Gsb (Bulk Specific Gravity, Oven-Dry)	2.337	2.488	2.408	2.457	
Gasc W-F2	92.2	87.3	Gsb (Bulk Specific Gravity, SSD)	2.489	2.583	2.534		
Gasc W-F3	92.6	87.7	Gsa (Apparent Specific Gravity)	2.754	2.748	2.751	2.711	
Average	92.2	87.3	Pabs (Absorption) (%)	6.47	3.80	4.82	3.82	
St Dev.	0.3879	0.3501						
Coeff. Var	0.4207	0.4011						
Plat A-D1	84.3	83.7	Gsb (Bulk Specific Gravity, Oven-Dry)	2.359	2.530	2.460	2.533	2.498
Plat A-D2	81.6	81.0	Gsb (Bulk Specific Gravity, SSD)	2.482	2.578	2.539		
Plat A-D3	82.0	81.4	Gsa (Apparent Specific Gravity)	2.689	2.658	2.670	2.665	2.700
Average	82.7	82.0	Pabs (Absorption) (%)	5.20	1.90	2.53	1.95	3.0
St Dev.	1.4807	1.4722						
Coeff. Var	1.7914	1.7951						
Plat W-F1	81.4	79.6	Gsb (Bulk Specific Gravity, Oven-Dry)	2.312	2.530	2.433	2.527	
Plat W-F2	87.5	85.7	Gsb (Bulk Specific Gravity, SSD)	2.459	2.578	2.527		
Plat W-F3	85.9	84.1	Gsa (Apparent Specific Gravity)	2.711	2.658	2.680	2.666	
Average	84.9	83.1	Pabs (Absorption) (%)	6.36	1.90	2.70	2.07	
St Dev.	3.1799	3.1628						
Coeff. Var	3.7451	3.8057						
Win A-D1	84.6	79.4	Gsb (Bulk Specific Gravity, Oven-Dry)	2.346	2.498	2.430	2.465	2.515
Win A-D2	85.1	79.8	Gsb (Bulk Specific Gravity, SSD)	2.490	2.582	2.541		
Win A-D3	83.5	78.4	Gsa (Apparent Specific Gravity)	2.739	2.728	2.733	2.688	2.698
Average	84.4	79.2	Pabs (Absorption) (%)	6.11	3.37	4.18	3.35	2.7
St Dev.	0.7827	0.7319						
Coeff. Var	0.9273	0.9239						
Win W-F1	86.0	80.6	Gsb (Bulk Specific Gravity, Oven-Dry)	2.316	2.498	2.404	2.461	
Win W-F2	86.1	80.7	Gsb (Bulk Specific Gravity, SSD)	2.471	2.582	2.525		
Win W-F3	85.9	80.5	Gsa (Apparent Specific Gravity)	2.740	2.728	2.734	2.689	
Average	86.0	80.6	Pabs (Absorption) (%)	6.68	3.37	4.48	3.44	
St Dev.	0.1019	0.0867						
Coeff. Var	0.1185	0.1075						
BF A-D1	85.1	81.3	Gsb (Bulk Specific Gravity, Oven-Dry)	2.402	2.578	2.492	2.560	2.611
BF A-D2	85.4	81.6	Gsb (Bulk Specific Gravity, SSD)	2.520	2.627	2.576		
BF A-D3	84.9	81.1	Gsa (Apparent Specific Gravity)	2.724	2.711	2.717	2.690	2.710
Average	85.1	81.3	Pabs (Absorption) (%)	4.93	1.91	2.68	1.89	1.4
St Dev.	0.2723	0.2548						
Coeff. Var	0.3199	0.3133						
BF W-F1	86.9	82.7	Gsb (Bulk Specific Gravity, Oven-Dry)	2.414	2.578	2.495	2.553	
BF W-F2	87.5	83.3	Gsb (Bulk Specific Gravity, SSD)	2.529	2.627	2.578		
BF W-F3	87.9	83.7	Gsa (Apparent Specific Gravity)	2.726	2.711	2.718	2.690	
Average	87.4	83.2	Pabs (Absorption) (%)	4.75	1.91	2.70	1.99	
St Dev.	0.4978	0.4794						
Coeff. Var	0.5693	0.5759						

Regression Coefficients (k_1, k_2, and k_3)

The constitutive model as described in Part 2 Chapter 2 of the M-E PDG is given by

$$Mr = k_1 p_a \left(\frac{\theta}{p_a}\right)^{k_2} \left(\frac{\tau_{oct}}{p_a} + 1\right)^{k_3} \tag{2}$$

Where

M_r = resilient modulus, psi
θ = bulk stress = $\sigma_1 + \sigma_2 + \sigma_3$, psi
σ_1 = major principal stress, psi
σ_2 = intermediate principal stress = σ_3 for M_r test on cylindrical specimen, psi
σ_3 = minor principal stress/confining pressure, psi
τ_{oct} = octahedral shear stress = $\frac{1}{3}\sqrt{(\sigma_1-\sigma_2)^2+(\sigma_1-\sigma_3)^2+(\sigma_2-\sigma_3)^2}$, psi
p_a = normalizing stress (atmospheric pressure; in this case, 14.7 psi)
k_1, k_2, k_3 = regression constants (obtained by fitting resilient modulus test data to equation)
k_1 = model intercept; greater k_1's indicate a stiffer material
k_2 = slope of the line; a greater slope indicates a stiffer material as bulk stress increases
k_3 = effect of deviator stress; typically negative, indicating a stress-softening effect, even for granular materials (however, there is multicollinearity between k_2 and k_3 in this model)

In other words, a given specimen is tested at 15 different stress states. θ, $\tau_{oct,}$ and M_r are calculated from the data. Using the above model (Equation 2), the regression constants k_1, k_2, k_3 can be determined for that specimen. These are shown in Table 15.

Model Data Fit

The fit of the data to the model for each replicate is rated with an R^2. The M-E PDG states in Part 2 Chapter 2 "The constitutive model coefficients determined for each test specimen should be such that the multiple correlation coefficient, R^2, exceeds 0.90. Constitutive model coefficients from similar soils and test specimen conditions can be combined to obtain a "pooled" k_1, k_2, and k_3. If the R^2 for a particular test specimen is less that 0.90, the test results and equipment should be checked for possible errors and/or test specimen disturbance." (*1*) In other words, this is a form of an outlier recognition test.

Table 15: Granular Base Regression Coefficients – k's

Specimen & Statistics	k_1	k_2	k_3	R^2	Se/Sy
JCD A-D2	1818.332	0.635	-0.303	0.992	0.098
JCD A-D3	1509.215	0.652	-0.236	0.990	0.107
JCD A-D4	1556.384	0.667	-0.227	0.989	0.113
Pooled	1627.558	0.651	-0.257	0.963	0.197
JCD W-F1	1130.693	0.683	-0.231	0.986	0.130
JCD W-F2	1434.249	0.642	-0.327	0.981	0.148
JCD W-F3	1378.216	0.670	-0.396	0.987	0.124
Pooled	1313.939	0.664	-0.322	0.954	0.219
Gasc A-D1	1456.506	0.783	-0.353	0.998	0.050
Gasc A-D2	1429.921	0.752	-0.323	0.997	0.058
Gasc A-D3	1298.257	0.796	-0.325	0.996	0.068
Pooled	1394.519	0.777	-0.334	0.989	0.110
Gasc W-F1	1505.352	0.690	-0.406	0.989	0.112
Gasc W-F2	1461.368	0.689	-0.354	0.992	0.094
Gasc W-F3	1211.002	0.769	-0.344	0.993	0.089
Pooled	1390.806	0.714	-0.367	0.979	0.149
Plat A-D1	2449.920	0.583	-0.279	0.988	0.121
Plat A-D2	3173.793	0.557	-0.289	0.988	0.120
Plat A-D3	2687.857	0.594	-0.273	0.989	0.114
Pooled	2769.219	0.577	-0.280	0.901	0.321
Plat W-F1	3081.705	0.478	-0.135	0.985	0.133
Plat W-F2	2410.360	0.520	-0.214	0.986	0.129
Plat W-F3	2896.399	0.454	-0.281	0.974	0.173
Pooled	2794.575	0.483	-0.207	0.850	0.396
Win A-D1	2103.090	0.581	-0.232	0.992	0.096
Win A-D2	2014.575	0.595	-0.266	0.984	0.137
Win A-D3	1722.742	0.650	-0.308	0.991	0.103
Pooled	1946.593	0.607	-0.266	0.952	0.224
Win W-F1	2087.403	0.508	-0.268	0.965	0.201
Win W-F2	2025.851	0.547	-0.262	0.977	0.162
Win W-F3	2052.418	0.506	-0.215	0.969	0.189
Pooled	2054.856	0.520	-0.248	0.968	0.182
BF A-D1	2044.140	0.632	-0.320	0.994	0.086
BF A-D2	2281.441	0.541	-0.321	0.987	0.122
BF A-D3	2098.281	0.610	-0.328	0.988	0.120
Pooled	2139.855	0.594	-0.322	0.985	0.125
BF W-F1	1887.359	0.685	-0.377	0.993	0.093
BF W-F2	1738.195	0.686	-0.368	0.993	0.093
BF W-F3	1876.223	0.640	-0.316	0.985	0.132
Pooled	1833.686	0.670	-0.354	0.981	0.143

So, although not specified as part of the contracted work or in T 307, regression analyses were performed per the statements in the M-E PDG on the M_r test results for each specimen to obtain each individual replicates' R^2.and for each set of three replicates in order to obtain a "pooled" set of k's. The results of the regression analyses are given in Table 15. As can be seen, all individual replications R^2

exceeded 0.90, indicating good precision of replicates. The data represents all stress states and all replicates, e.g. there were no outliers identified and removed.

Additionally, variability among replicates per the ten treatment combinations was analyzed using a one-way analysis of variance (ANOVA). Three parameters were analyzed relative to the effect that differences among the replicate specimens may have on them: M_r, deviator stress (σ_d), and confining pressure (σ_3). Table 16 shows the results of the basic ANOVA.

Table 16: Replicate One-way Anova

Aggregate & Gradation	M_r vs. Replicate		σ_d vs. Replicate		σ_3 vs. Replicate	
	p-value	R^2	p-value	R^2	p-value	R^2
JCD A-D	0.587	0.0250	1.000	0.0000	1.000	0.0000
JCD W-F	0.540	0.0289	1.000	0.0000	1.000	0.0000
Gasc A-D	0.858	0.0073	1.000	0.0000	1.000	0.0000
Gasc W-F	0.770	0.0123	1.000	0.0000	1.000	0.0000
Plat A-D	0.164	0.0826	1.000	0.0000	1.000	0.0000
Plat W-F	0.068	0.1200	1.000	0.0000	1.000	0.0000
Win A-D	0.462	0.0361	1.000	0.0000	1.000	0.0000
Win W-F	0.982	0.0009	1.000	0.0000	1.000	0.0000
BF A-D	0.999	0.0000	1.000	0.0000	1.000	0.0000
BF W-F	0.839	0.0083	1.000	0.0000	1.000	0.0000

The higher the p-value is (or the lower the R^2 value is), the lower the probability that the replicates are different. In other words, a high p-value and a low R^2 indicate that replicates specimens themselves are similar, σ_d's are similar, and σ_3's are similar. To verify that any differences between the M_r values (per stress state, per replicate) are strictly a function of the replicate specimen material conditions, the stress parameters were analyzed in regard to the replicates. In all cases, the differences in the σ_d and σ_3 values were so small as to be completely insignificant, which makes sense, as these parameters are not really responses but computer-controlled inputs. Based on the p-values and R^2 values, the Plattin aggregate possessed the most variability between replicate specimens within each gradation. However, the variability was insignificant at an $\alpha = 0.05$ level; i.e. the p-values for both the Plattin A-D and W-F analyses were greater than 0.05. The source of this increased variability is probably due to the fact that the Plattin aggregate has a higher percentage of material retained on the ¾" sieve than the other aggregates (see Table 13).

Effect of Added Fines

Having confirmed (by using the one-way ANOVA) that the replicates were similar within all 10 treatment combinations present during M_r testing, the M_r data was once again analyzed for the five aggregate types using a one-way ANOVA to determine the significance of the effect on M_r by adding fines to the A-D materials. Table 17 gives the results of the analysis across all 15 stress states.

Table 17: Gradation One-way Anova

Aggregate	p-value	R^2
Jeff City Dolomite	0.003	0.0930
Gasconade Dolomite	0.253	0.0148
Bethany Falls	0.272	0.0137
Plattin	0.280	0.0132
Winterset	0.538	0.0043

The effect on M_r due to the increased fines content is most significant in the Jefferson City Dolomite (JCD) material. The gradation p-value for the JCD is highly significant at an α = 0.05 level, while the other four aggregates experienced an insignificant effect of increased fines on the M_r at the same α level. The aggregates are ranked in order from most significantly affected at the top (JCD) to the least significantly affected at the bottom (Winterset). To graphically show the difference between the A-D and W-F gradations for these two materials, plots of the pooled M_r values versus the two stress parameters in Equation 2 are given below in Figures. 13-16 (θ vs. M_r and τ_{oct} vs M_r). Similar plots of the other materials are included in Appendix F. The greater the offset of best-fit lines, the greater the effect of fines addition.

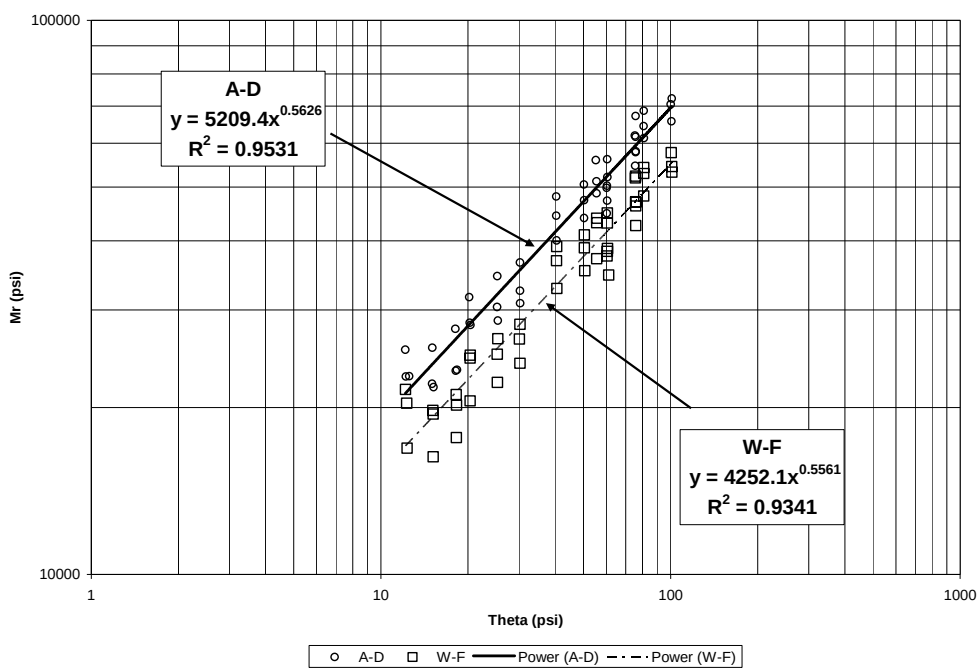


Figure 13: JCD Pooled A-D vs W-F, Theta (Bulk Stress) Parameter

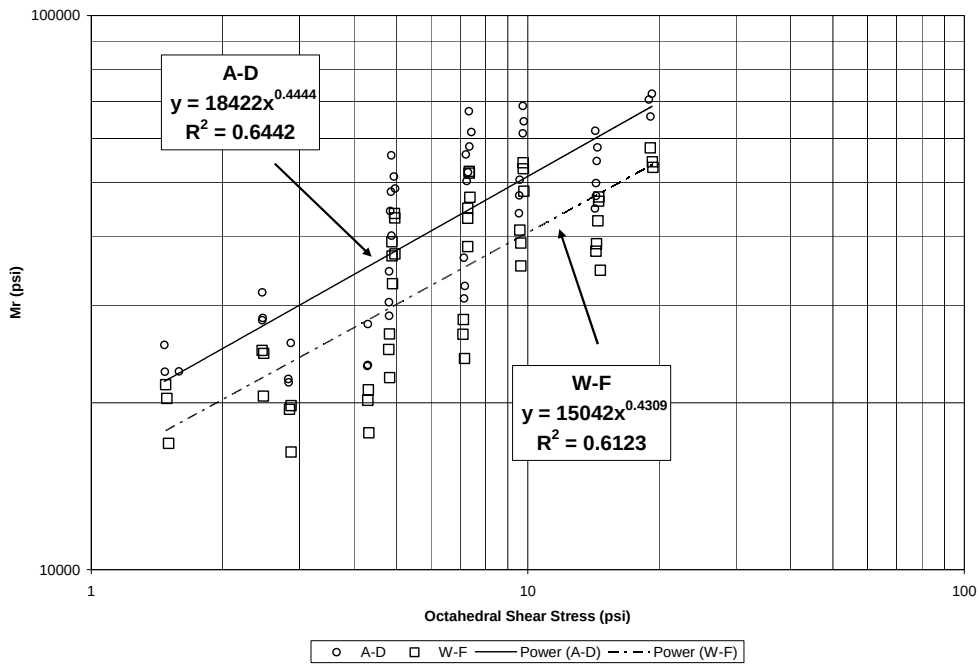


Figure 14: JCD Pooled A-D vs W-F, Octahedral Shear Stress Parameter

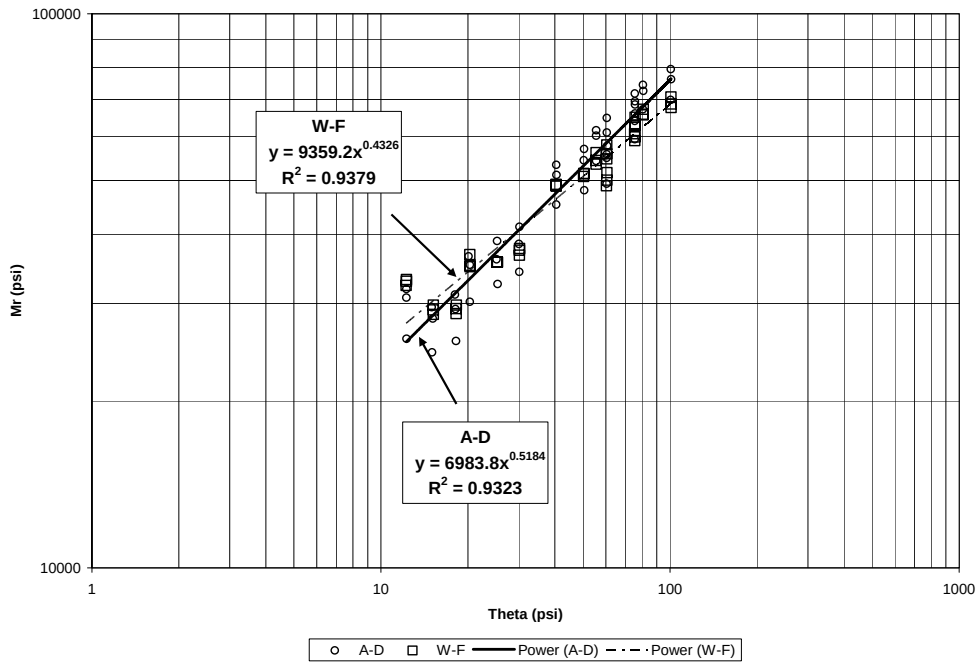


Figure 15: Winterset Pooled A-D vs W-F, Theta (Bulk Stress) Parameter

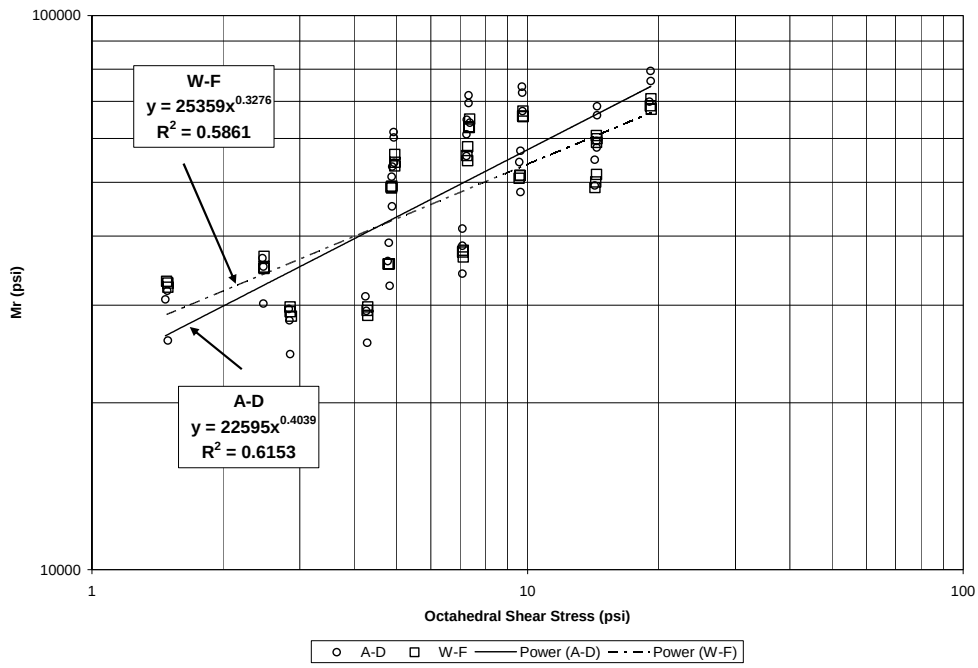


Figure 16: Winterset Pooled A-D vs W-F, Octahedral Shear Stress Parameter

However, when looking at specific stress states (Appendix F), several of the aggregate types' curves diverge, such as the Bethany Falls, Winterset, and the Gasconade. For instance, to examine the effect of fines at lower stress states, Table 18 shows a ranking of the five materials in regard to M_r (as calculated by Equation 2) for a stress state of θ = 12 psi (σ_1= 6 psi, σ_2 and σ_3 =3 psi each). Several of the aggregate types suffered considerable losses when the gradation was changed from the A-D to the W-F. Thus, with certain pavement designs (which give unique stress states), higher fines content in base materials may lower base stiffness significantly.

Table 18: Resilient Moduli at θ = 12 psi

Material	M_r A-D (psi)	M_r W-F (psi)	Δ M_r (%)
Plattin	35290	36543	+0.7
Bethany Falls	27071	22776	-15.9
Winterset	24688	26569	+7.6
Jeff. City	20475	16388	-20.0
Gasconade	16980	17101	+0.7

In Table 19 it can be seen that as fines were added, the compacted dry density (DD) increased. As compacted M_r specimen DD increased, the specimens tended to become more highly saturated (as the point of position of a compacted specimen on a moisture-density plot changes, the saturation level changes in most cases). There seems to be a rough correlation between the change in % saturation and the % change in M_r (at θ = 12 psi), that is, as the change in % saturation increases, the % change (loss) in M_r increases. Obviously, other factors are in play which shade or obscure this relationship.

Table 19: Change in Compaction Variables of M_r Specimens

Material	Δ M_r (psi)	Δ M_r (%)	Δ Dry Density (pcf)	Δ OMC (%)	Δ Sat (%)
JCD	-4087	-20.0	2.5	-0.1	+8.2
BF	-4295	-15.9	1.2	-0.2	+2.3
Gasc	+121	+0.7	0.7	-0.1	+0.9
Plat	+1253	+3.6	0.7	+0.1	+3.6
Win	+1881	+7.6	0.7	-0.1	+1.6

Effect of Material Type

As can be seen from Table18, at a low level of stress state, the range between the highest and the lowest M_r was more than twofold between material types. Although gradation may have some interactive effect, these are as-delivered gradations, so it would be realistic to expect differences in materials' M_r behavior from different quarries.

SUBGRADE SOILS

Resilient Modulus

The results from resilient modulus tests are presented in Appendix G. An example table and figure (Table 20 and Figure 17) are presented below. The resilient modulus at a given deviator stress and confining stress is calculated as the average of the last five cycles in a testing sequence. Each test result table and figure are labeled as 6MKWM0XX_Y, where 0XX corresponds to the soil number in Table 20, and Y represents the test number (1, 2, 3 are tests at optimum moisture contents and 4, 5, 6 are tests at elevated moisture contents). The optimum moisture contents were determined from the compaction curves (see Appendix D) that were provided by MODOT, while the elevated moisture contents were selected based on a series of soil suction tests (see Technical Approach section). Figure 17 exhibits the classic shape of the M_r vs deviator stress curve, where there is a "knee" at a deviator stress of about 6 psi. The M_r at the knee can be useful in a variety of analyses.

As with the granular base material, the M-E PDG constitutive model (Equation 2) was used to determine the regression constants k_1, k_2, and k_3 for each specimen, and then for each pooled set of three replicates. Some of the individual model fits exhibited low R^2. The results of the determination of the R^2 for each subgrade soil replicate specimen led to an effort to identify outlying stress states and replicate specimens.

Table 20: Resilient Modulus Test Results for 6MKWM016_4

Sequence	CS=σ_d (psi)	DS=σ_3 (psi)	M_r 1 (psi)	M_r 2 (psi)	M_r 3 (psi)	M_r 4 (psi)	M_r 5 (psi)	M_r AVG (psi)
1	6	2.68	8849	8896	8850	8808	8928	8866
2	6	4.76	7047	7135	7063	7015	7033	7059
3	6	6.44	4881	4843	4907	4922	4869	4885
4	6	8.47	3561	3573	3561	3568	3549	3562
5	6	10.5	2763	2764	2762	2770	2784	2768
6	4	2.72	9085	9377	9060	9052	9018	9118
7	4	4.67	5381	5389	5445	5451	5389	5411
8	4	6.48	3835	3828	3806	3811	3832	3822
9	4	8.49	3057	3031	3037	3066	3015	3041
10	4	10.56	2631	2626	2626	2613	2610	2621
11	2	2.74	7765	7731	7738	7735	7702	7734
12	2	4.66	4948	4960	4961	4972	5003	4969
13	2	6.45	3531	3552	3545	3539	3537	3541
14	2	8.46	2823	2860	2864	2877	2875	2860
15	2	10.53	2501	2500	2517	2522	2506	2509

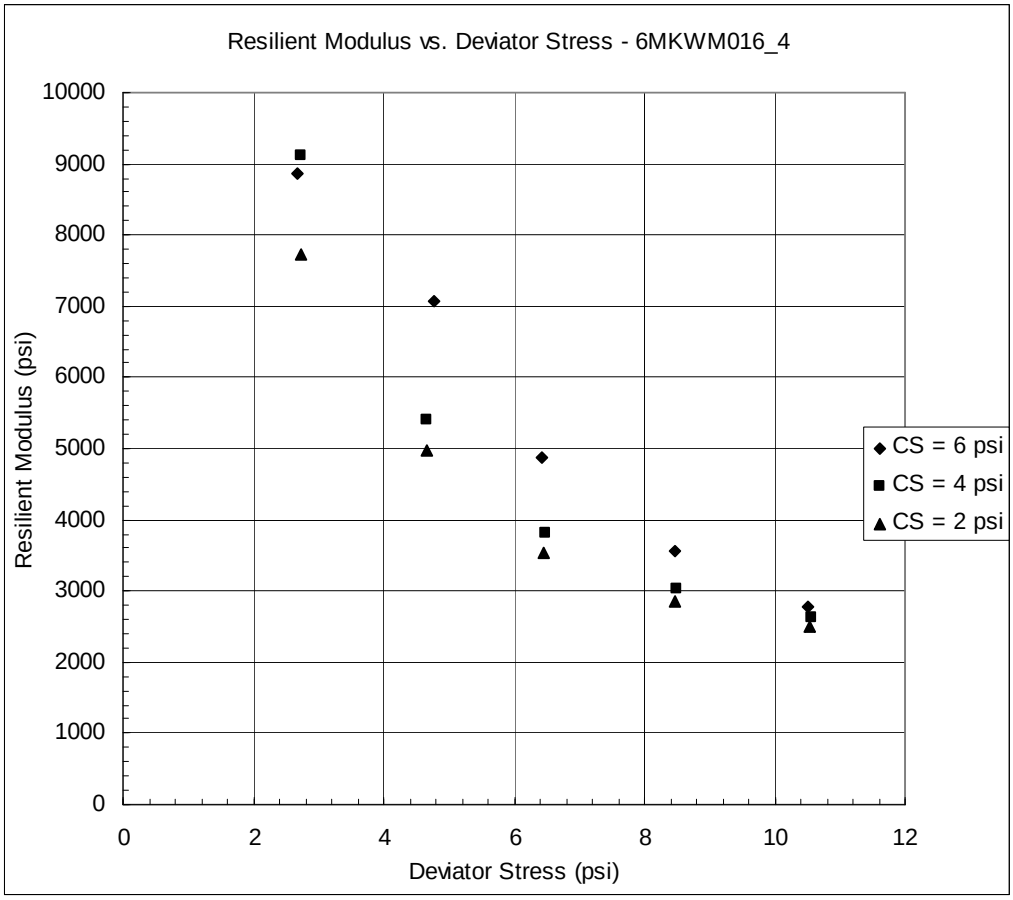


Figure 17: Resilient Modulus Test Results for 6MKWM016_4

First, each individual replicate's results were examined for outlying stress states which were excessively affecting the regression results. Outliers were removed. Next, for each set of three replicates, outlying replicates were identified using ANOVA analysis to examine the effect of σ_d. Then, ANOVA was run again to look at the similarity of the three replicates themselves. Non-similar replicate data was removed. The results of the ANOVA analysis are shown in Table 21.

Table 21: Replicate One-way Anova

Soil No. & Moisture Condition	M_r vs. Replicate		σ_d vs. Replicate	
	p-value	R^2	p-value	R^2
6MKWM011 (Dry)	0.000	0.7704	0.990	0.0500
6MKWM012 (Dry)	0.031	0.1550	0.977	0.0000
6MKWM013 (Dry)	0.269	0.0434	0.994	0.0000
6MKWM014 (Dry)	0.666	0.0192	1.000	0.0000
6MKWM014 (Wet)	0.457	0.0384	0.955	0.0023
6MKWM015 (Dry)	0.162	0.0711	0.814	0.0021
6MKWM016 (Dry)	0.091	0.0988	0.976	0.0000
6MKWM016 (Wet)	0.923	0.0038	1.000	0.0000
6MKWM017 (Dry)	0.000	0.7771	0.625	0.0251
6MKWM019 (Dry)	0.869	0.0010	0.942	0.0002
6MKWM020 (Dry)	0.734	0.0042	0.948	0.0002
6MKWM020 (Wet)	0.980	0.0000	0.956	0.0001
6MKWM021 (Dry)	0.231	0.0706	0.826	0.0095
6MKWM021 (Wet)	0.320	0.0396	0.425	0.0257
6MKWM022 (Dry)	0.415	0.0278	0.424	0.0268
6MKWM023 (Dry)	0.394	0.0260	0.983	0.0000
6MKWM023 (Wet)	0.356	0.0480	0.999	0.0000
6MKWM024 (Dry)	0.398	0.0256	0.989	0.0000
6MKWM024 (Wet)	0.879	0.0061	1.000	0.0000
6MKWM025 (Dry)	0.103	0.0923	0.965	0.0001
6MKWM026 (Dry)	0.176	0.0794	0.999	0.0001
6MKWM027 (Dry)	0.662	0.0194	0.999	0.0000
6MKWM028 (Dry)	0.565	0.0268	1.000	0.0000
6MKWM029 (Dry)	0.449	0.0206	0.991	0.0000
6MKWM030 (Dry)	0.000	0.4356	0.946	0.0002
6MKWM031 (Dry)	0.414	0.0258	0.589	0.0114
6MKWM031 (Wet)	0.509	0.0157	0.956	0.0001
6MKWM032 (Dry)	0.259	0.0623	0.999	0.0000
6MKWM032 (Wet)	0.709	0.0170	0.813	0.0103
6MKWM033 (Dry)	0.000	0.6458	0.991	0.0000
6MKWM033 (Wet)	0.850	0.0013	0.972	0.0000
6MKWM034 (Dry)	0.242	0.0486	0.995	0.0000
6MKWM034 (Wet)	0.366	0.0467	0.999	0.0001
6MKWM035 (Dry)	0.000	0.5477	0.700	0.0169
6MKWM035 (Wet)	0.559	0.0294	0.626	0.0237
6MKWM036 (Dry)	0.054	0.1262	0.985	0.0000
6MKWM036 (Wet)	0.716	0.0170	0.881	0.0064
6MKWM037 (Dry)	0.896	0.0052	0.999	0.0000

Finally, the pooled statistics were determined. The results are shown in Tables 22 and 23.

Table 22: Soils Regression Coefficients – k's

Specimen & Statistics	k_1	k_2	k_3	R^2	Se/Sy	n
6MKWM011-1 (Dry)	1811.206	0.345	-0.988	0.922	0.301	15
6MKWM011-2 (Dry)	1791.535	0.302	-1.942	0.939	0.267	15
6MKWM011-3 (Dry)	1398.467	0.130	-3.480	0.984	0.135	15
Pooled	1627.136	0.280	-1.773	0.156	0.940	45
6MKWM012-1 (Dry)	2137.965	0.396	-1.499	0.970	0.186	15
6MKWM012-2 (Dry)	2237.049	0.244	-1.069	0.941	0.263	15
Pooled	2185.389	0.316	-1.268	0.785	0.481	30
6MKWM013-2 (Dry)	2441.827	0.292	-2.502	0.898	0.345	15
6MKWM013-3 (Dry)	2046.962	0.290	-1.820	0.984	0.136	15
Pooled	2241.259	0.291	-2.170	0.850	0.401	30
6MKWM014-1 (Dry)	980.191	0.518	-2.788	0.892	0.354	15
6MKWM014-2 (Dry)	958.127	0.531	-2.551	0.896	0.349	15
6MKWM014-3 (Dry)	1014.203	0.567	-2.633	0.923	0.300	15
Pooled	984.137	0.539	-2.656	0.884	0.349	45
6MKWM014-4 (Wet)	915.330	0.451	-2.544	0.825	0.452	15
6MKWM014-5 (Wet)	886.903	0.464	-2.502	0.951	0.240	14
6MKWM014-6 (Wet)	1319.740	0.450	-3.998	0.769	0.522	14
Pooled	1007.165	0.417	-2.885	0.708	0.554	43
6MKWM015-1 (Dry)	524.861	0.361	-1.873	0.749	0.545	14
6MKWM015-2 (Dry)	708.949	0.595	-3.246	0.912	0.320	15
Pooled	613.969	0.488	-2.583	0.732	0.537	29
6MKWM015-5 (Wet)	529.082	0.173	-1.294	0.652	0.646	13
6MKWM016-1 (Dry)	1016.848	0.126	-3.112	0.997	0.058	15
6MKWM016-3 (Dry)	1102.631	0.192	-2.833	0.993	0.093	15
Pooled	1059.397	0.160	-2.962	0.890	0.343	30
6MKWM016-4 (Wet)	1023.645	0.266	-6.827	0.965	0.202	15
6MKWM016-5 (Wet)	865.624	0.239	-6.125	0.981	0.150	15
6MKWM016-6 (Wet)	913.100	0.277	-6.374	0.972	0.180	15
Pooled	933.345	0.261	-6.449	0.963	0.196	45
6MKWM017-2 (Dry)	1116.441	0.359	-4.319	0.992	0.101	13
6MKWM017-3 (Dry)	1618.261	0.429	-5.895	0.974	0.178	12
Pooled	1261.694	0.404	-4.793	0.910	0.314	25
6MKWM018-3 (Dry)	1106.368	-0.983	-4.415	0.992	0.097	12
6MKWM019-1 (Dry)	1023.818	0.261	-1.844	0.680	0.611	15
6MKWM019-2 (Dry)	1442.470	0.142	-3.787	0.967	0.195	15
Pooled	1218.840	0.200	-2.817	0.741	0.528	30
6MKWM020-1 (Dry)	778.345	0.074	-5.773	0.891	0.356	15
6MKWM020-2 (Dry)	637.213	0.282	-4.768	0.894	0.352	15
Pooled	706.376	0.173	-5.268	0.859	0.389	30
6MKWM020-5 (Wet)	929.323	0.279	-6.182	0.970	0.186	15
6MKWM020-6 (Wet)	989.296	0.262	-6.497	0.963	0.208	15
Pooled	958.765	0.271	-6.339	0.965	0.194	30
6MKWM021-1 (Dry)	1021.577	0.230	-2.531	0.927	0.291	15
6MKWM021-2 (Dry)	1188.794	0.263	-3.034	0.961	0.217	13
6MKWM021-3 (Dry)	923.577	0.342	-2.500	0.983	0.142	15
Pooled	1018.252	0.302	-2.616	0.838	0.412	43
6MKWM021-4 (Wet)	1228.259	0.447	-6.072	0.964	0.210	12
6MKWM021-5 (Wet)	808.614	0.517	-5.366	0.955	0.229	15
Pooled	845.067	0.492	-4.936	0.798	0.468	27
6MKWM022-2 (Dry)	1102.722	-0.069	-0.228	0.960	0.224	11
6MKWM022-3 (Dry)	1813.073	0.346	-3.264	0.971	0.183	15
Pooled	1667.392	0.281	-2.611	0.800	0.466	26
6MKWM023-2 (Dry)	1534.786	0.212	-1.958	0.986	0.128	15
6MKWM023-3 (Dry)	1604.534	0.317	-2.645	0.993	0.091	15
Pooled	1567.669	0.263	-2.290	0.947	0.240	30
6MKWM023-4 (Wet)	1036.759	-0.018	-5.446	0.969	0.190	15
6MKWM023-5 (Wet)	1308.025	0.049	-5.599	0.977	0.162	15
6MKWM023-6 (Wet)	1202.293	0.072	-5.471	0.971	0.185	15
Pooled	1182.524	0.037	-5.509	0.919	0.290	45
6MKWM024-2 (Dry)	1188.155	0.291	-1.834	0.989	0.115	15
6MKWM024-3 (Dry)	1411.058	0.344	-2.618	0.895	0.350	15
Pooled	1297.864	0.317	-2.237	0.863	0.383	30
6MKWM024-4 (Wet)	1036.234	0.243	-5.530	0.979	0.156	15
6MKWM024-5 (Wet)	1125.568	0.445	-6.641	0.967	0.197	15
6MKWM024-6 (Wet)	2530.930	-0.023	-11.404	0.958	0.222	15
Pooled	1452.823	0.202	-7.737	0.822	0.432	45
6MKWM025-1 (Dry)	1127.100	0.178	-2.197	0.759	0.530	15
6MKWM025-3 (Dry)	1249.064	0.239	-2.226	0.758	0.532	15
Pooled	1187.348	0.209	-2.208	0.680	0.586	30
6MKWM025-5 (Wet)	2274.837	0.348	-4.249	0.849	0.419	15

Table 23: Soils Regression Coefficients – k's (cont.)

Specimen & Statistics	k_1	k_2	k_3	R^2	Se/Sy	n
6MKWM026-1 (Dry)	868.308	0.066	-4.470	0.991	0.101	15
6MKWM026-2 (Dry)	842.356	0.166	-6.159	0.989	0.113	15
6MKWM026-3 (Dry)	841.556	0.109	-5.190	0.991	0.105	15
Pooled	847.251	0.110	-5.197	0.908	0.310	45
6MKWM027-1 (Dry)	965.069	0.358	-2.585	0.746	0.544	15
6MKWM027-2 (Dry)	995.544	0.512	-3.427	0.687	0.604	15
6MKWM027-3 (Dry)	967.402	0.488	-3.002	0.812	0.469	15
Pooled	973.961	0.449	-2.982	0.721	0.540	45
6MKWM028-1 (Dry)	1700.478	0.120	-4.476	0.858	0.407	15
6MKWM028-2 (Dry)	1295.439	0.223	-2.657	0.983	0.142	15
6MKWM028-3 (Dry)	1982.106	-0.130	-4.614	0.867	0.395	15
Pooled	1635.313	0.065	-3.864	0.742	0.519	45
6MKWM028-6 (Wet)	1574.337	-0.459	-7.748	0.985	0.135	14
6MKWM029-2 (Dry)	807.677	0.367	-4.720	0.935	0.329	15
6MKWM029-3 (Dry)	856.830	0.379	-4.515	0.958	0.263	15
Pooled	832.125	0.373	-4.613	0.926	0.282	30
6MKWM030-1 (Dry)	1440.221	0.102	-2.010	0.925	0.313	15
6MKWM030-2 (Dry)	1629.757	0.188	-1.524	0.977	0.195	15
Pooled	1529.010	0.150	-1.720	0.505	0.729	30
6MKWM031-2 (Dry)	667.298	0.709	-4.415	0.834	0.447	13
6MKWM031-3 (Dry)	628.439	0.735	-3.544	0.924	0.362	15
Pooled	644.573	0.721	-3.940	0.851	0.401	28
6MKWM031-4 (Wet)	574.318	0.234	-2.283	0.681	0.729	15
6MKWM031-5 (Wet)	538.246	0.016	-1.959	0.489	0.771	15
Pooled	556.493	0.125	-2.121	0.540	0.703	30
6MKWM032-1 (Dry)	1425.320	0.223	-2.362	0.988	0.139	15
6MKWM032-2 (Dry)	1223.437	0.254	-2.021	0.984	0.157	15
6MKWM032-3 (Dry)	1241.199	0.238	-1.924	0.998	0.057	15
Pooled	1295.895	0.238	-2.107	0.911	0.305	45
6MKWM032-4 (Wet)	918.557	0.090	-5.798	0.983	0.139	15
6MKWM032-5 (Wet)	872.751	0.300	-5.652	0.970	0.190	13
6MKWM032-6 (Wet)	929.004	0.222	-5.635	0.977	0.162	15
Pooled	921.130	0.179	-5.735	0.969	0.179	43
6MKWM033-2 (Dry)	1354.436	0.350	-1.857	0.985	0.154	15
6MKWM033-3 (Dry)	1969.245	0.321	-1.893	0.968	0.243	15
Pooled	1664.567	0.334	-1.887	0.336	0.844	30
6MKWM033-5 (Wet)	966.481	0.171	-5.684	0.964	0.233	15
6MKWM033-6 (Wet)	914.647	0.060	-5.411	0.969	0.205	15
Pooled	940.733	0.116	-5.549	0.963	0.200	30
6MKWM034-2 (Dry)	1353.159	0.283	-1.713	0.983	0.164	15
6MKWM034-3 (Dry)	1291.873	0.223	-1.699	0.960	0.232	15
Pooled	1322.398	0.254	-1.706	0.916	0.300	30
6MKWM034-4 (Wet)	1100.862	0.112	-4.838	0.983	0.151	15
6MKWM034-5 (Wet)	953.248	0.016	-5.089	0.978	0.172	15
6MKWM034-6 (Wet)	1049.800	0.156	-5.296	0.979	0.179	15
Pooled	1033.328	0.096	-5.057	0.927	0.276	45
6MKWM035-1 (Dry)	1476.520	0.377	-1.421	0.983	0.157	15
6MKWM035-2 (Dry)	1932.451	0.225	-1.660	0.930	0.398	15
6MKWM035-3 (Dry)	2538.527	0.097	-2.063	0.954	0.265	15
Pooled	1881.928	0.223	-1.509	0.271	0.874	45
6MKWM035-4 (Wet)	1822.987	0.292	-6.719	0.968	0.198	12
6MKWM035-5 (Wet)	1058.044	0.150	-5.279	0.974	0.194	15
6MKWM035-6 (Wet)	1037.308	0.092	-5.025	0.982	0.159	15
Pooled	1071.235	0.160	-4.845	0.814	0.442	42
6MKWM036-1 (Dry)	1264.089	0.188	-2.585	0.994	0.095	15
6MKWM036-3 (Dry)	1108.140	0.162	-2.582	0.990	0.110	15
Pooled	1185.517	0.176	-2.58	0.861	0.386	30
6MKWM036-4 (Wet)	1807.722	0.102	-5.816	0.991	0.102	14
6MKWM036-5 (Wet)	1809.167	0.304	-6.970	0.959	0.220	15
6MKWM036-6 (Wet)	3158.334	-0.065	-8.309	0.964	0.209	13
Pooled	1980.370	0.236	-6.661	0.873	0.365	42
6MKWM037-1 (Dry)	1088.443	0.256	-4.752	0.955	0.230	15
6MKWM037-2 (Dry)	1059.737	0.210	-4.456	0.957	0.225	15
6MKWM037-3 (Dry)	991.596	0.334	-4.506	0.965	0.201	15
Pooled	1046.232	0.265	-4.569	0.949	0.232	45
6MKWM037-4 (Wet)	847.498	-0.080	-5.091	0.879	0.379	14

CONCLUSIONS

GRANULAR BASE MATERIALS

Based on the results of this study, the following conclusions are drawn:

1. The effect of the method of establishing a moisture-density relationship, such as AASHTO T 99, can be important to the value of MDD (sometimes) and OMC (more often). In this study, compaction in a 6 in. mold with no scalping or replacement resulted in lower OMC values in almost all cases and a greater MDD in four cases.
2. The effect of the method of specific gravity determination can be significant to the calculated degree of saturation. MoDOT historic data vs. weighted average of T 85 and T 84 (determined on job materials) vs Corelok method results can be quite different. In this study, degrees of saturation calculated from Corelok-determined specific gravities were greater.
3. Attempts to perform T 307 tests on high moisture-low density materials led to excessive strain during testing. If the effects of high degrees of saturation on resilient modulus is desired, the dry density most likely needs to be greater than 95% of T 99 maximum for the materials in this study.
4. All five materials' as-delivered gradations exhibited minus #200 sieve levels that approached the maximum allowable. Additional amounts of fines put them out of specification.
5. Elevated fines content can occur in as-compacted base material from a variety of reasons. The effect of high fines content can be deleterious to M_r. One of the five materials lost a significant amount of stiffness (lower M_r) across all stress states. And, several of the materials lost stiffness at specific stress state levels.
6. The effect of materials quarry source (geologic formation/ produced gradation) on M_r can be large at specific stress states.

All of the individual specimens' R^2 values resulting from fitting the M_r data to Equation 2 were greater than 0.90, thus satisfying recommendations of the M-E PDG. Because of the high R^2 values of the replicate sets and analyses showing that the replicates were uniform in regard to their properties, the reported regression coefficients, k's, from the pooled replicate data can be used as Level 1 inputs to the M-E PDG.

SUBGRADE SOILS

The results of this project allow MoDOT pavement engineers to calibrate the design guide according to Missouri's conditions and materials. The results of this project also allow MoDOT pavement engineers to reliably model subgrade and base support under all pavement design for optimum performance. The results of this effort provide knowledge base of resilient modulus for Missouri soils, as well as evaluation of moisture activity devices for use in evaluating subgrades. Some stress state results in certain replicate data and certain replicate specimens were removed

from the data set. Most of the remaining individual specimens' R^2 values resulting from fitting the M_r data to Equation 2 were greater than 0.90, thus recommendations of the M-E PDG were satisfied in most cases. Because of the high R^2 values of the majority of the replicate sets and analyses showing that the replicates were uniform in regard to their properties, the reported regression coefficients, k's, from the pooled replicate data can be used as Level 1 inputs to the M-E PDG.

RECOMMENDATIONS

It is recommended that MoDOT use the results of this study for input into the M-E PDG models for calibration purposes.

FURTHER RESEARCH

The potential for future research includes:

1. The prediction of resilient modulus and moisture content using other properties of soil and unbound bases.
2. Extension of known resilient modulus and moisture content to prediction for untested materials.
3. Evaluation of moisture activity devices to be used in future field evaluation of subgrades in determining needed properties for new M-E pavement designs.
4. It has been shown that material type, gradation, degree of saturation, and compacted dry density have a significant effect on granular base material resilient modulus. Only five granular base materials were tested in this project. If MoDOT is contemplating using significantly different materials for granular base aggregate, future research should explore the effects of these materials.

REFERENCES

1. ARA, Inc., ERES Consultants Division. *NCHRP 1-37A Guides for Mechanistic-Empirical of New and Rehabilitated Pavement Structures*. Final Report, ARA, Champaign, Illinois, 2004.
2. *Determining the Resilient Modulus of Soils and Aggregate Materials*, in AASHTO T 307-99 (2003). American Association of State Highway and Transportation Officials, Washington, D.C. 2003.
3. *Moisture Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop,* in AASHTO T 99-01. American Association of State Highway and Transportation Officials, Washington, D.C. 2001.
4. *Correction for Coarse Particles in the Soil Compaction Test,* in AASHTO T 224-01. American Association of State Highway and Transportation Officials, Washington, D.C. 2001.
5. *Specific Gravity and Absorption of Fine Aggregate,* in AASHTO T 84-00. American Association of State Highway and Transportation Officials, Washington, D.C. 2000.
6. *Specific Gravity and Absorption of Coarse Aggregate,* in AASHTO T 85-91 (2000). American Association of State Highway and Transportation Officials, Washington, D.C. 2000.
7. *Specific Gravity and Absorption of Aggregate Using Automatic Vacuum Sealing Method,* MoDOT Test Method (TM)-81 adapted from the CoreLok® Manual, in Missouri Department of Transportation (MoDOT) Engineering Policy Guide Section 106.7.81. Missouri Department of Transportation. 2007.
8. *Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing,* in AASHTO T 11-97 (2000). American Association of State Highway and Transportation Officials, Washington, D.C. 2000.
9. *Sieve Analysis of Fine and Coarse Aggregates,* in AASHTO T 27-99. American Association of State Highway and Transportation Officials, Washington, D.C. 1999.
10. Seed, H. B., C. K. Chan, and C. E. Lee. Resilience Characteristics of Subgrade Soils and Their Relation to Fatigue Failure in Asphalt Pavements. *Proceedings., 1st International Conference on Structural Design of Asphalt Pavement*, University of Michigan, Ann Arbor, 1962, pp. 667-679.
11. Mitchell, J. K. *Fundamentals of Soil Behaviors*. 2nd Edition, John Wiley & Sons, Inc., New York, 1993.
12. Fredlund, D. G., and Xing, A. Equation of the Soil-Water Characteristics Curve. *Canadian Geotechnical Journal*, Vol. 32, No. 4, 1994, pp. 521-532.
13. Perea, Y. Y., Zapata, C. E., Houston, W. N., and Houston, S. L. Prediction of the Soil-Water Characteristic Curve Based on Grain-Size-Distribution and Index Properties. *Proceedings, GeoFrontier 2005*, American Society of Civil Engineers, 2005.
14. *ASTM Standard Test Method for Capillary-Moisture Relationship for Fine-Textured Soils by Pressure-Membrane Apparatus*, D 3152-72, American Society of Testing Materials, 2000.

15. *ASTM Standard Test Method for Measurement of Soil Potential (Suction) Using Filter Paper, D 5298-03*, American Society of Testing Materials, 2003.
16. *ASTM Standard Test Method for Determination of the Soil Water Characteristic Curve for Desorption Using a Hanging Column, Pressure Extractor, Chilled Mirror Hygrometer, and/or Centriguge, D 6836-02*, American Society of Testing Materials, 2002.
17. Decagon Devices, Inc. *WP4 Dewpoint Potentiameter Operator's Manual*, Version 2.2, 2003.
18. Petry, T. M. and Jiang, C. P. *Evaluation and Utilization of the WP4 Dewpoint Potentiameter Phase I and II*, University Transportation Center Report No. R91-R126, University of Missouri – Rolla, 2003.
19. Petry, T. M. and Jiang, C. P. Round-Robin Testing of a Dewpoint Potentiameter versus Filter Paper to Determine Total Suction, *Proceedings, GeoDenver 2007*, American Society of Civil Engineers, 2007.

APPENDIX A: ANALYSIS OF CURRENT INDUSTRIAL APPROACHES

MOISTURE-DENSITY RELATIONSHIP

AASHTO T 99-01 ("Standard Proctor")

According to T 99-01 (current method):

Table A-1: T 99 Specimen Information

Method	Material size	Mold diameter (in.)	Scalp	T 224 correction*
A	≤ 40% (+#4)	4	+#4 (all)	If > 5% (+#4)
B	≤ 40% (+#4)	6	+#4 (all)	If > 5% (+#4)
C	> 40% (+#4) & ≤ 30% (+3/4")	4	+3/4" (all)	If > 5% (+3/4")
D	> 40% (+#4) & ≤ 30% (+3/4")	6	+3/4" (all)	If > 5% (+3/4")

*****Use T 224-01 to calculate an adjusted maximum dry density (MDD) and optimum moisture content (OMC) to allow for the % of (+ ¾") material
*****As % (+3/4") material increases, the adjusted MDD increases and the OMC decreases (larger solid particles have a greater specific gravity than an equal volume of smaller particles with voids between them)

No replacement of scalped material

ASTM D 698-00a$^{\varepsilon 1}$ ("Standard Proctor")

ASTM D 698-00 dictates a 6" mold if the sample has greater than 20% (+3/8") material. It does not allow a choice of 4" or 6" for a given gradation; it is one or the other. Other test parameters are similar to T 99 (scalping all oversize, necessity for adjustment, and no replacement). At least four (five preferred) points per curve.

Corps of Engineers Compaction a-VI and a-VIA (1986) (in reference to "Standard Proctor")

Table A-2: Corps of Engineers Specimen Information

Material size	Mold diameter (in)	Scalp	Replacement
100% (-#4)	4	NA	No
100% (-3/4") & ≤ 5% (+#4)	4	+#4 (all)	No
100% (-3/4") & > 5% (+#4)	6	NA	No
≤ 5% (+3/4")	6	+3/4" (all)	No
> 5-10% (+3/4")	12	+ 2" (all)	No: ≤ 10% (+2") Yes: > 10% (+2")

At least 5 points per curve

Across all materials sampling and testing, in general, as the nominal maximum size (NMS) of a material increases, larger samples are required. Additionally, as sample mold size decreases, the influence of particle size increases. Thus, the specification of a 6” mold for granular material by ASTM and Corps of Engineers seems justified.

In general, it is easier to characterize or define the moisture-density (proctor) curve if more data points are available; i.e. software programs used for plotting can better define the peak of a proctor curve given more data. It is difficult for certain programs to define peaks based on three data points.

NOTE: 6” diameter molds can be used for T 99 or T 180; however, the focus of this discussion is T 99.

UMR (Missouri S&T) Study

The moisture-density relationships of the five materials in the resilient modulus (M_r) study were determined in two ways:

1. MoDOT: 4” mold, mechanical hammer, (+3/4”) scalped ***and replaced***. In regard to the scalping and replacing, the Central Lab’s method (as per conversations with several technicians in the geotechnical section) is as follows:

    - If (+3/4”) is ≤ 5%, scalp only
    - If (+3/4”) is > 5%, scalp and replace the %(+3/4”) with an equivalent percentage of (+#4, -3/4”) material to maintain the original percentage of coarse material.

NOTE: MoDOT Standard Specification for Aggregate Base Course, Section 304.3.4.2, states the following; “*The Standard Compaction Test will be conducted in accordance with AASHTO T 99, Method C, replacing any material retained on the ¾-inch (19.0 mm) sieve, as provided therein*.” However, the use of the replacement method is discontinued under T 99-01; see Section 8.2, Note 9; “*The use of the replacement method previously specified, where the oversized particles are replaced with finer particles, to maintain the same percentage of coarse material, is not considered appropriate to compute the maximum density.*” It seems the current MoDOT specification is based on an earlier version of T 99. This disconnect is a possible source of error that could lead to unfavorable comparisons between laboratories.

2. UMR: 6” mold, mechanical hammer, no scalping and no replacing, (however, 4 of the 5 aggregate types had ≤ 5% (+3/4”), the fifth ≤ 10%)

Results: A statistical analysis across all 5 materials showed no significant difference in MDD (at a 95% confidence level) but OMC’s were significantly lower with the larger material.

Addition of 5% -#200 material study:

MDD's increased, OMC's decreased. This seemingly contradicts the T 224 predicted outcome (more coarse materials, MDD up, OMC down).

Explanation: Effect of coarse aggregate replacement is a function of the gradation of the sample. It has been documented that for a certain gradation, an increase in finer material will merely fill in voids and not displace large particles, thus density would increase. As % finer material increases past a threshold, it begins to displace the large particles and the density decreases.

Thus, the effect of scalping and replacement is material-specific: it could decrease the MDD (make it easier to achieve in the field) or vice-versa.

Summary

It appears that the industry has moved or is moving toward:

- 6" mold for coarse materials
- Scalping but no replacement of (+3/4") material
- 4 to 5 data points per proctor curve
- For materials with > 5% (+3/4") material, adjustment of MDD and OMC for field control is necessary; e.g. using T 224.
- 4" and 6" molds may not always be interchangeable.

RESILIENT MODULUS TESTING

AASHTO T 307 limits maximum particle size to 1/5 of mold diameter, thus a 4" diameter specimen is limited to ¾" maximum size, while a 6" diameter specimen can accommodate up to 1.2" particles.

All 5 aggregate types in the study have some (+3/4") material, but no (+1.2") material, thus a 6" specimen is appropriate.

Because there may be some differences in the effect of mold size, the moisture-density relationship should be determined in the same size mold as the M_r specimen (6").

Because the M_r tests are to be determined on as-delivered material, and a 6" mold can accommodate (+3/4") material, and there is less than 10% (+3/4") (5% in most cases) material, the samples should not be scalped.

Mechanistic-Empirical Pavement Design Guide (MEPDG)

Regarding the target densities and moisture contents for M_r testing, the MEPDG (version 0.910) states the following in Section 2.1.3.3; "*The density used in the resilient modulus test program should be the in situ density after construction*." Later in that same paragraph is the statement, "*The Enhanced Integrated Climatic Model (EICM) estimates the seasonal variation in moisture content of the subgrade soil, as well as in an unbound pavement layer (6). Thus, the moisture content to be used in the resilient modulus test should be representative of the moisture condition at construction.*" This implies that M_r testing should be performed at T 99 MDD (i.e. the lowest expected density immediately following construction) and OMC. Within the software is another example of the recommended moisture content during M_r testing.

Target Moisture Contents for M_r Testing

Based on the UMR T 99 proctor results and aggregate properties obtained from MoDOT data (i.e. bulk dry specific gravity and absorption), the degree of saturation values at OMC for all ten materials to be tested (two gradations for each of the five aggregate types) ranged from 82.2% to 89.2% with an average of 86.8%. Therefore, one may assume worse-case moisture conditions to be associated with degree of saturation values ranging from 95-100%.

To investigate whether these high levels of saturation occur in-situ after construction, the Long-Term Pavement Performance (LTPP) Database (Version 20.0) was utilized. In-situ property data was extracted from the database for highway projects in Missouri. Seventeen sets of data for granular base materials were analyzed. Using average values of dry density and moisture content within the granular layer sampled, and assumed apparent specific gravity (G_a) values of 2.7 and 2.8, degree of saturation values were calculated for the seventeen datasets. For G_a = 2.7 (a representative value for the majority of the five aggregates to be tested), degree of saturation values ranged from 54% to 100% with an average of 84%. For G_a = 2.8, degree of saturation values ranged from 48% to 94% with an average of 74%. As this was a quick analysis, seasonal conditions at the time of sampling were not investigated and are not known. Nevertheless, the data indicates that high levels of saturation are possible in the long-term for in-situ granular base material.

This conclusion is not unexpected and simply brings to mind the purpose of the EICM in the MEPDG: to adjust as-constructed moisture contents throughout the lifetime of the pavement supporting layers as a function of seasonal variations.

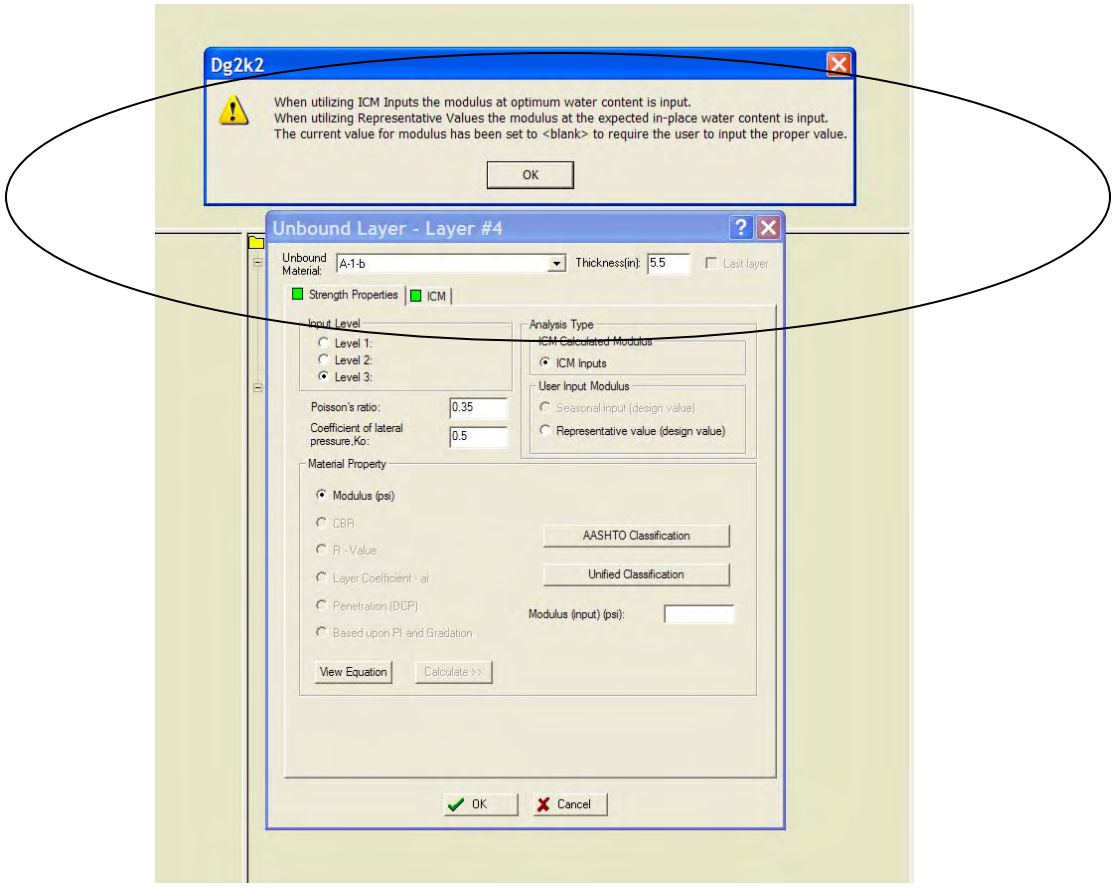


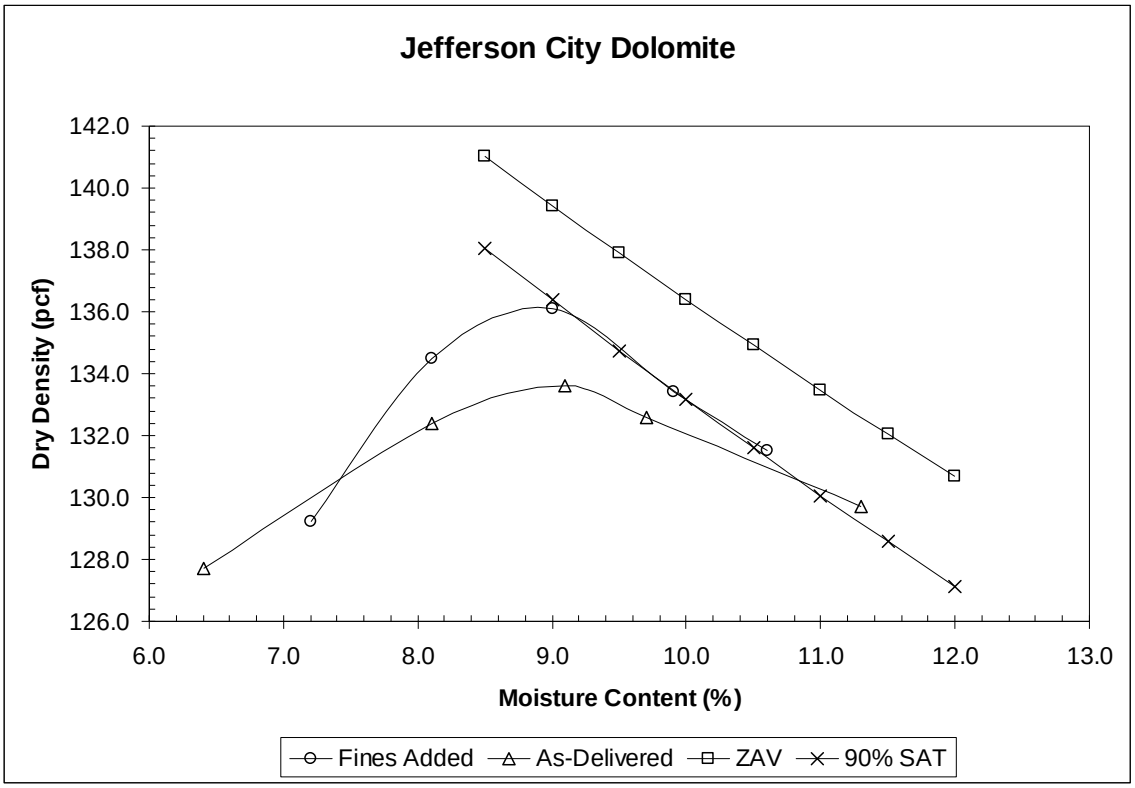
Figure A-1- OMC if EICM utilized

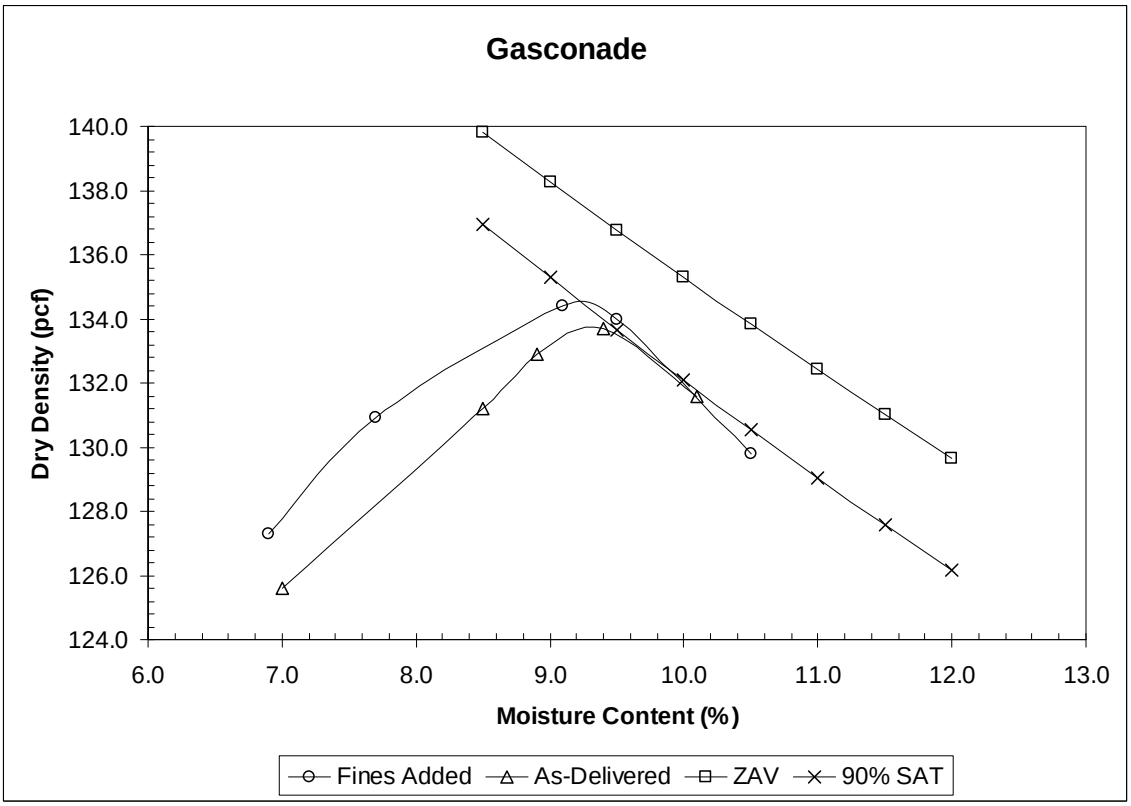
In view of the preceding discussions regarding recommendations of the MEPDG and potential problems with M_r testing at a "worse-case", it seems that OMC is the only ***necessary*** moisture level at which M_r testing should occur.

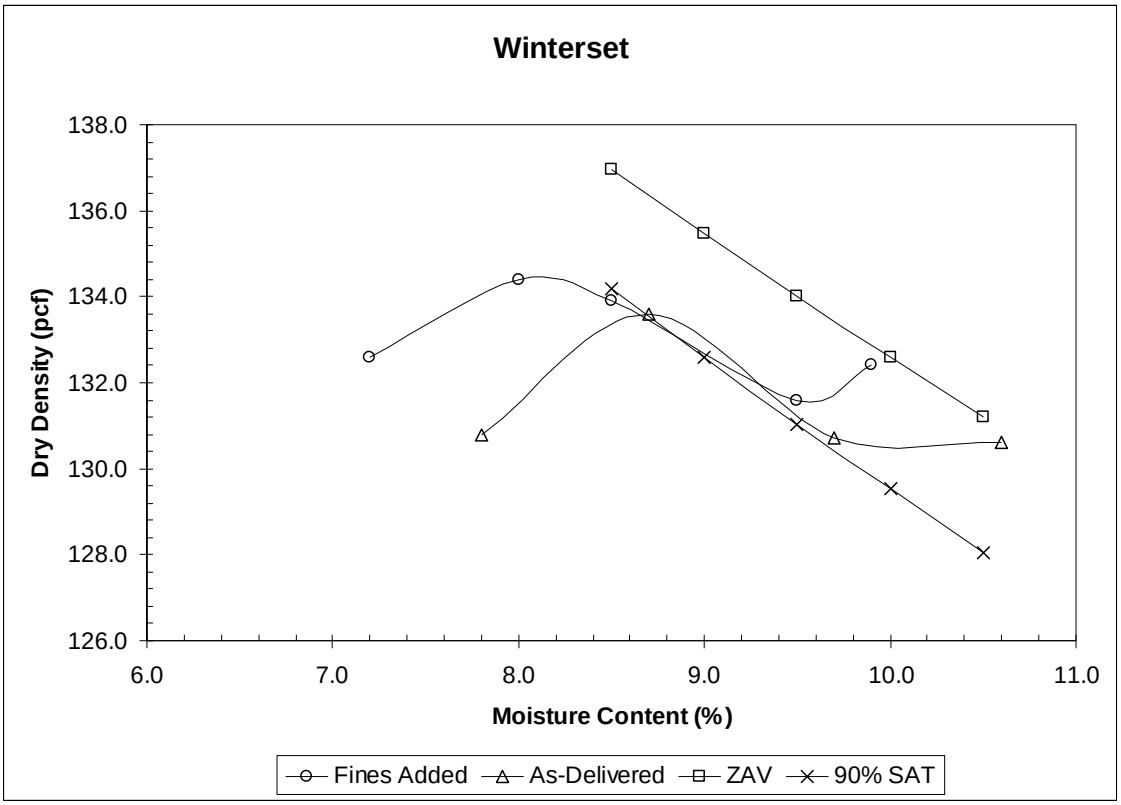
Summary

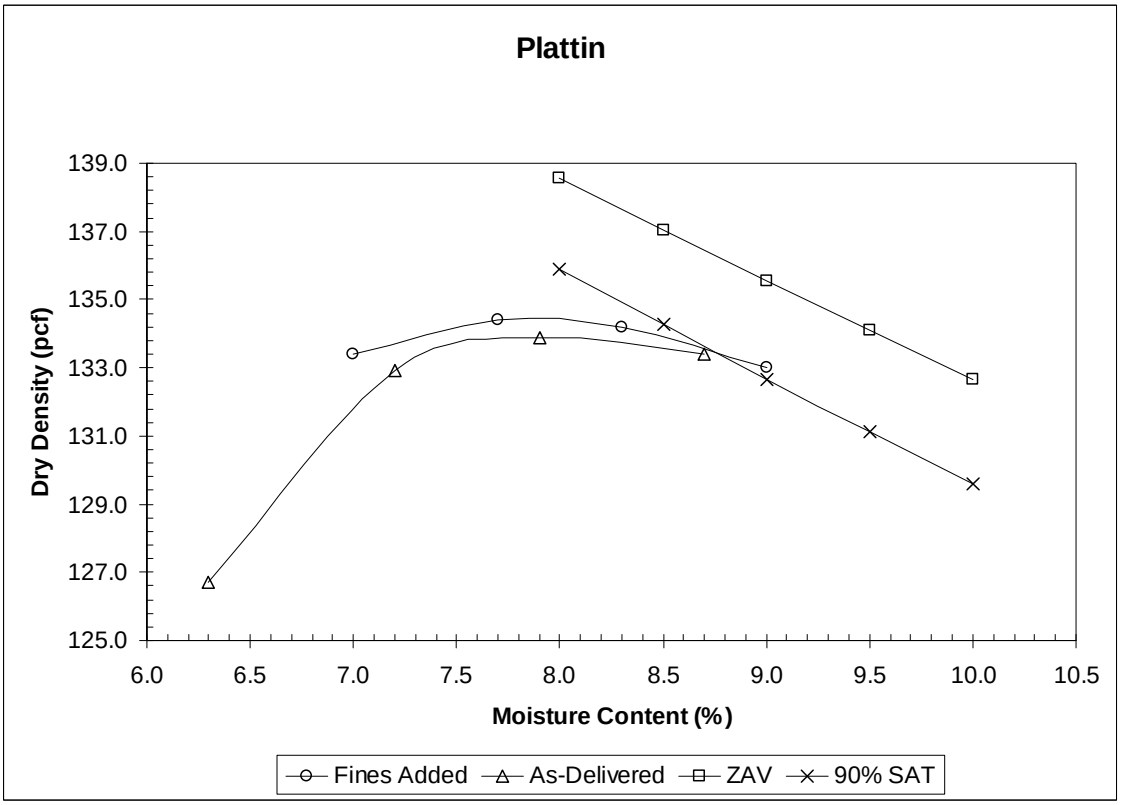
- In determining the sample conditions for M_r testing, proctor results using a 6" mold are more appropriate than a 4" mold
- MEPDG and T 307 indicate OMC as the only required moisture content for M_r testing, provided the EICM feature of the MEPDG is utilized
- Degree of saturation levels at OMC for the aggregates to be tested are already surprisingly high and are comparable to average long-term in-situ saturation levels of existing Missouri pavement bases

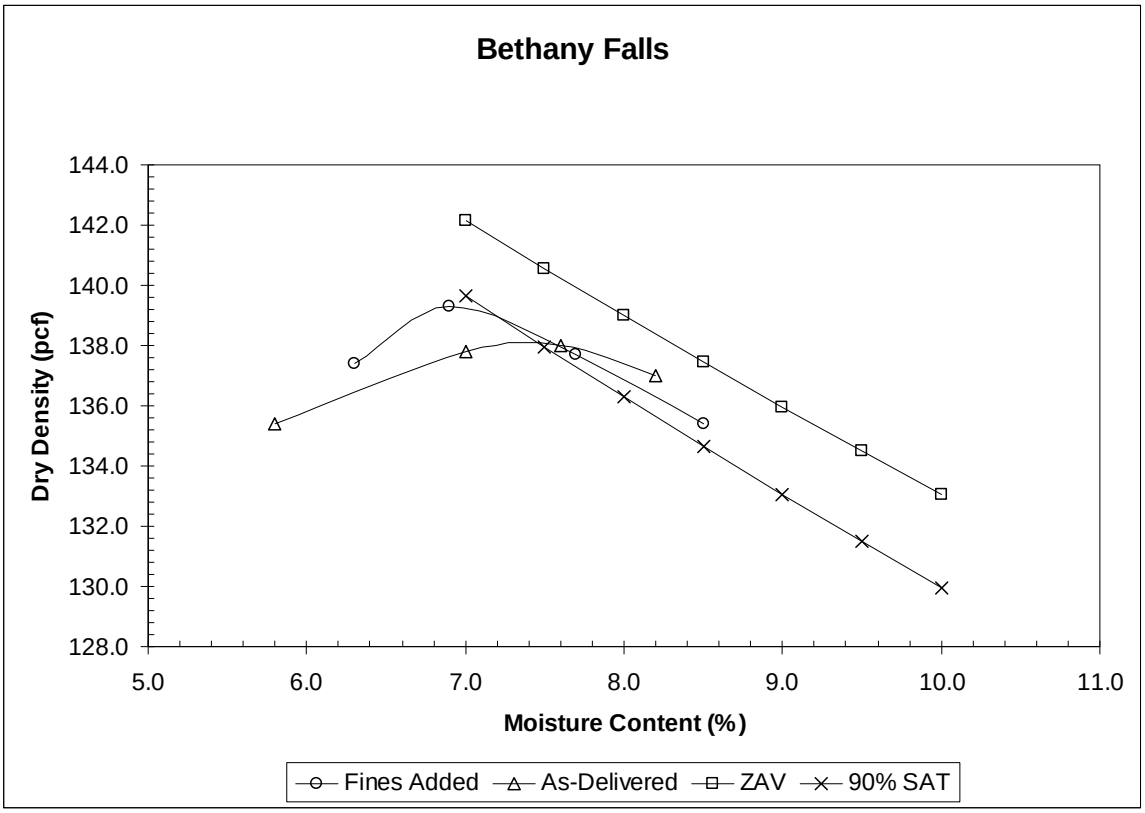
APPENDIX B: GRANULAR BASE T 99 CURVES


Jefferson City Dolomite
Dry Density (pcf)
142.0
140.0
138.0
136.0
134.0
132.0
130.0
128.0
126.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
Moisture Content (%)
Fines Added
As-Delivered
ZAV
90% SAT


Gasconade
Dry Density (pcf)
140.0
138.0
136.0
134.0
132.0
130.0
128.0
126.0
124.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
Moisture Content (%)
Fines Added
As-Delivered
ZAV
90% SAT


Winterset
138.0
136.0
134.0
132.0
130.0
128.0
126.0
Dry Density (pcf)
6.0
7.0
8.0
9.0
10.0
11.0
Moisture Content (%)
Fines Added
As-Delivered
ZAV
90% SAT


Plattin
139.0
137.0
135.0
133.0
131.0
129.0
127.0
125.0
Dry Density (pcf)
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
Moisture Content (%)
Fines Added
As-Delivered
ZAV
90% SAT


Bethany Falls
144.0
142.0
140.0
138.0
136.0
134.0
132.0
130.0
128.0
Dry Density (pcf)
5.0
6.0
7.0
8.0
9.0
10.0
11.0
Moisture Content (%)
Fines Added
As-Delivered
ZAV
90% SAT

APPENDIX C: GRANULAR BASE GRADATIONS

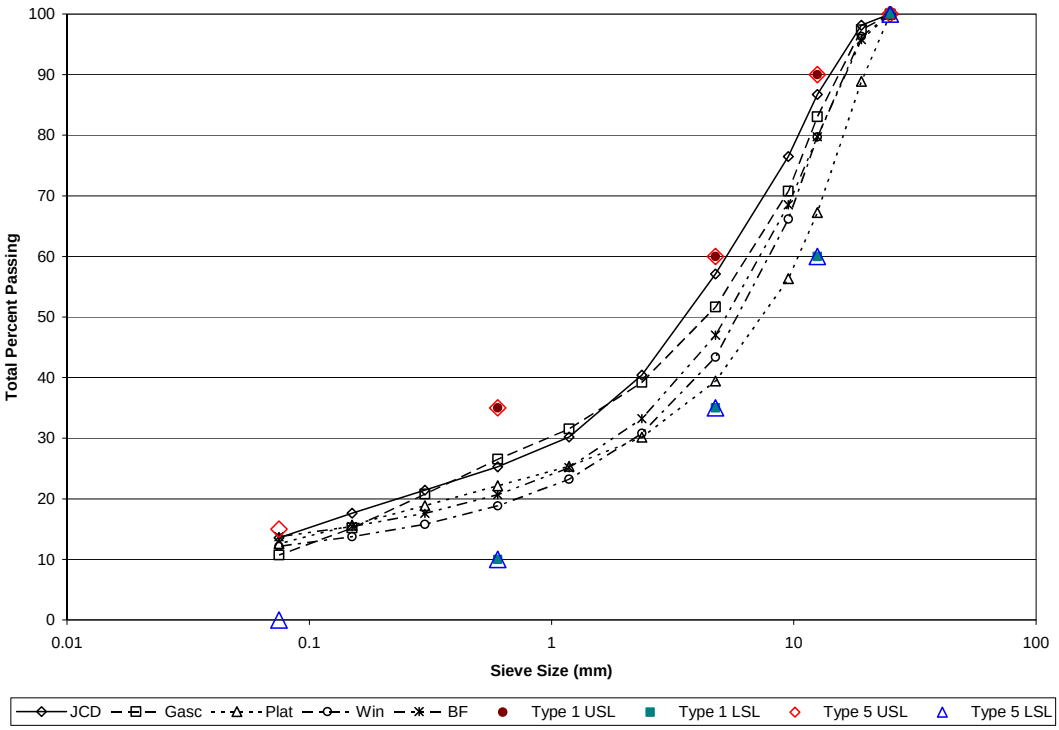


Figure C-1: A-D Comparison: All 5 Aggregate Types

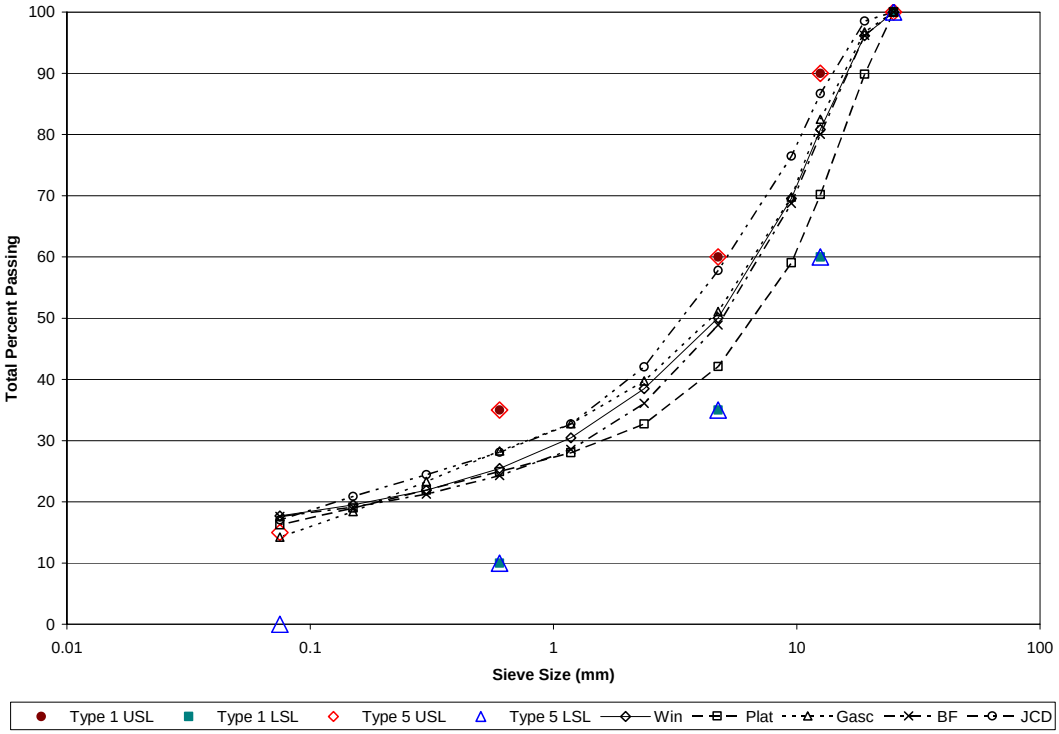


Figure C-2: W-F Comparison: All 5 Aggregate Types

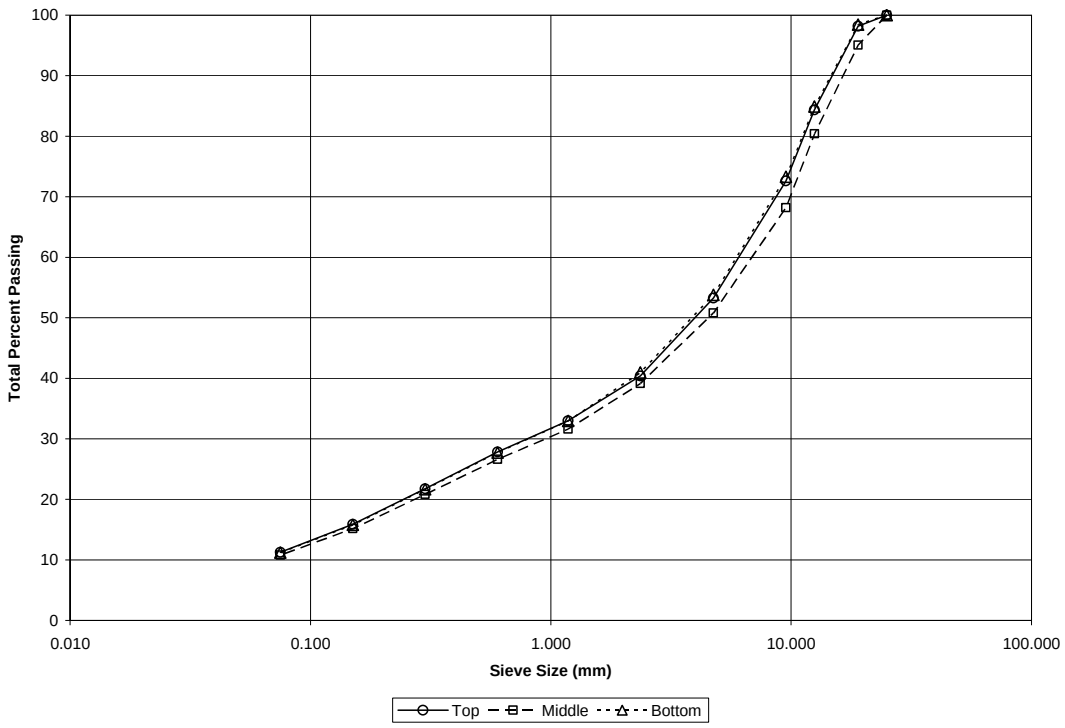


Figure C-3: Gasconade A-D Replicate #1

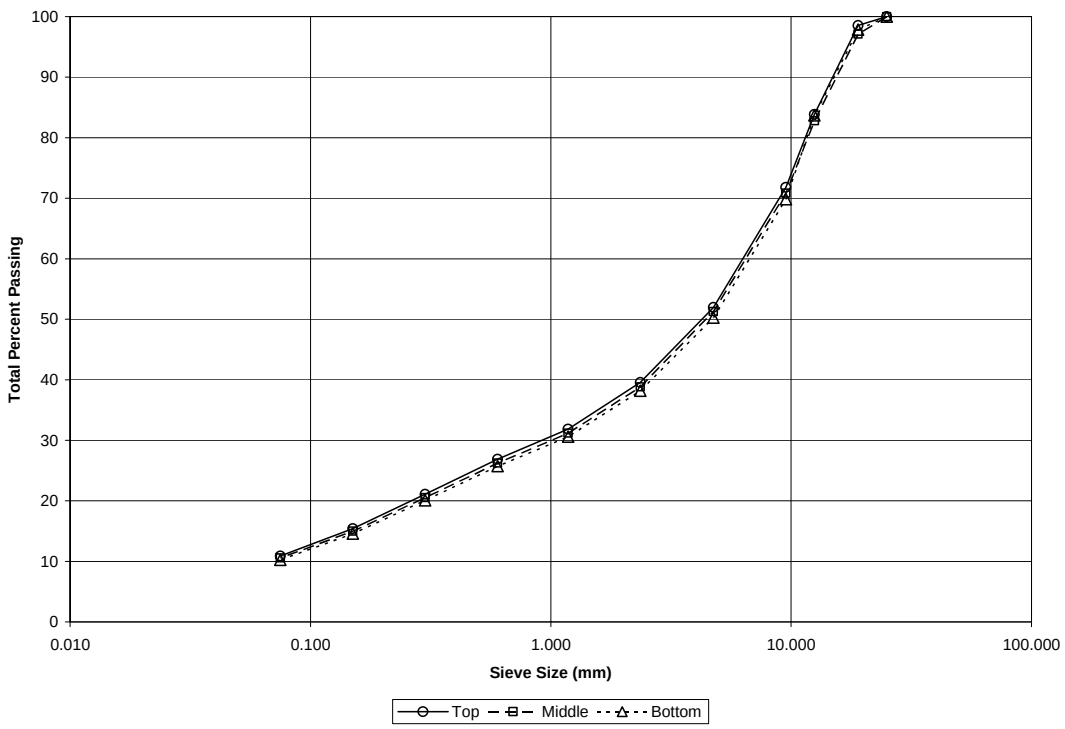


Figure C-4: Gasconade A-D Replicate #2

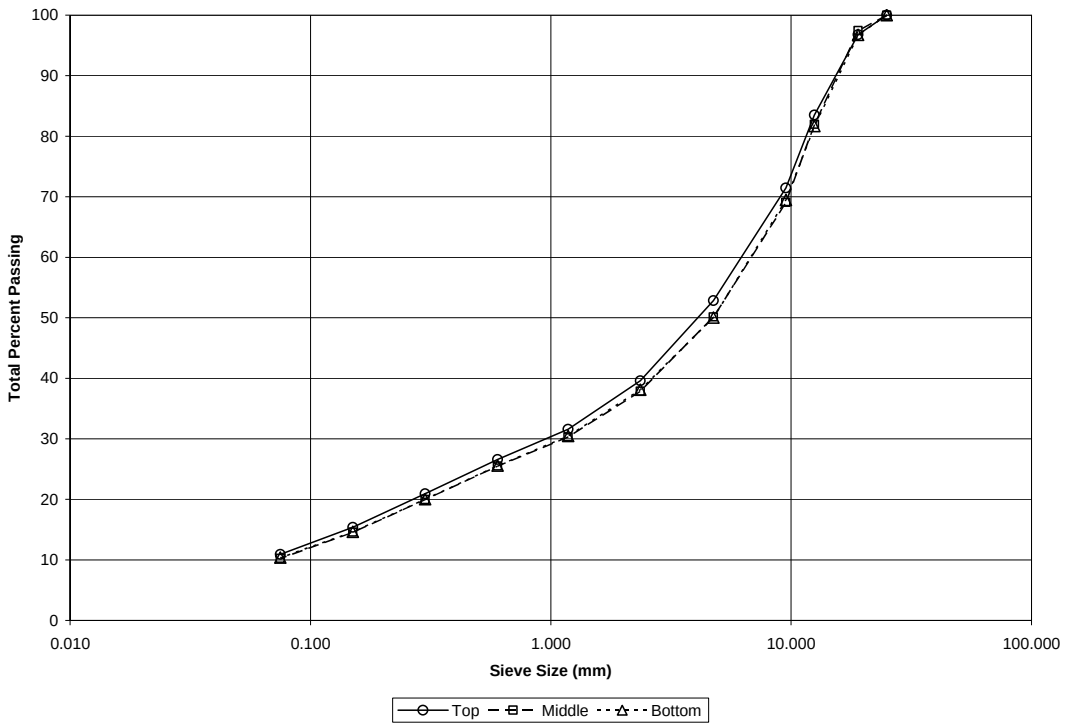


Figure C-5: Gasconade A-D Replicate #3

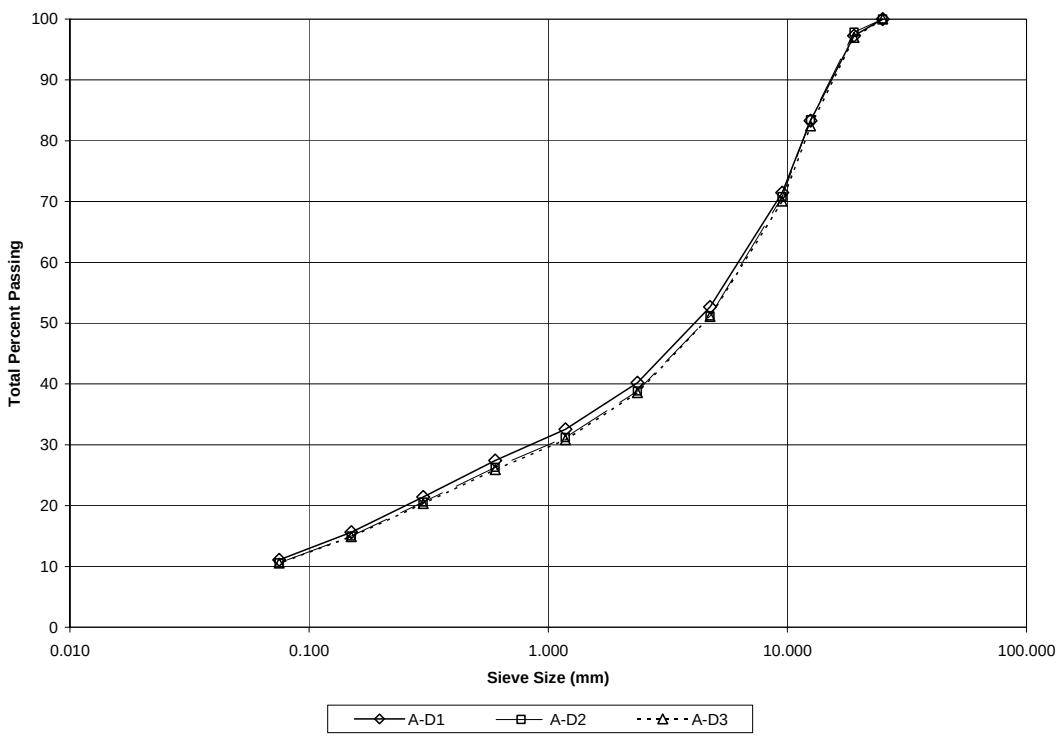


Figure C-6: Gasconade A-D: Between Replicate Comparison

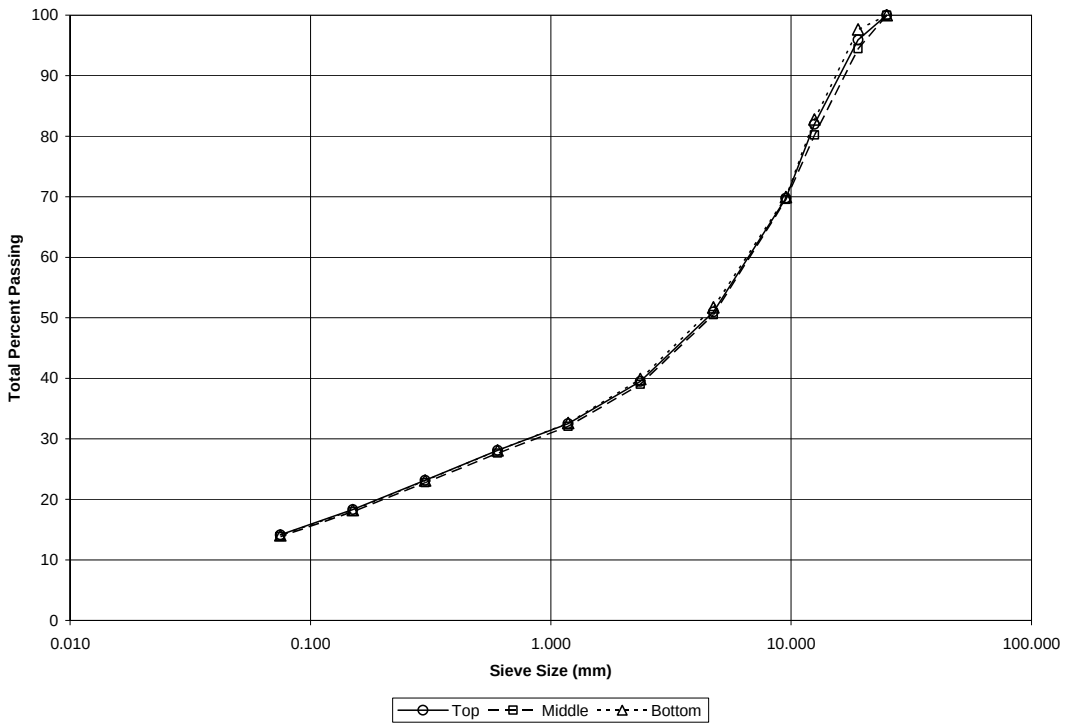


Figure C-7: Gasconade W-F Replicate #1

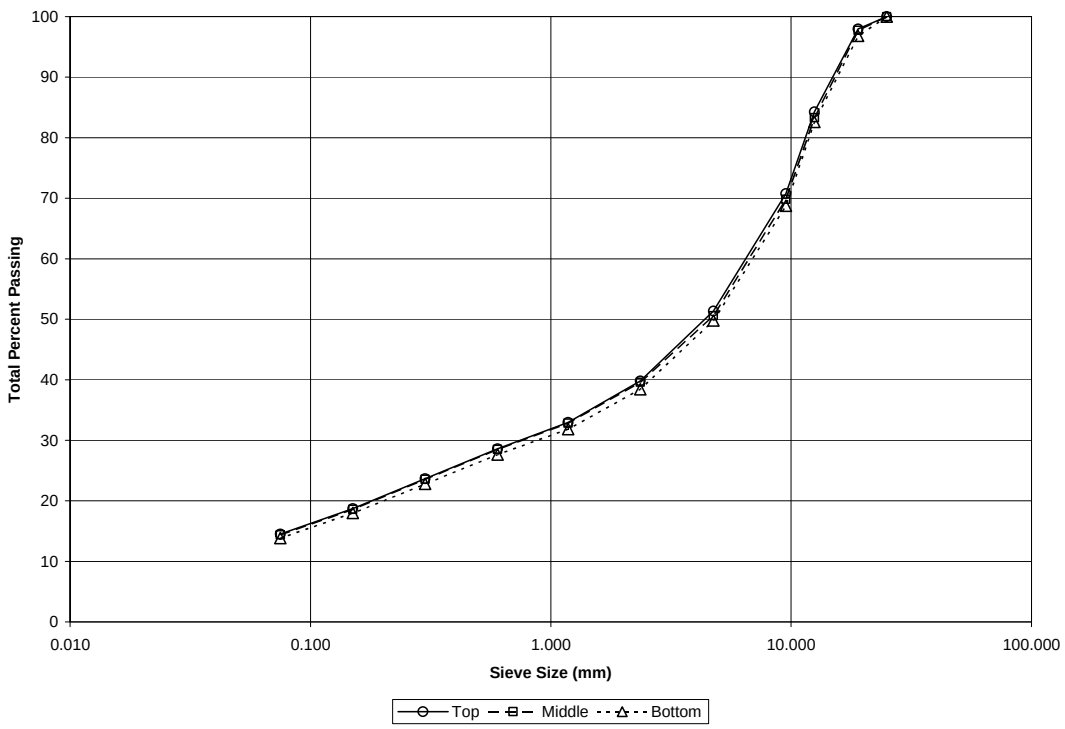


Figure C-8: Gasconade W-F Replicate #2

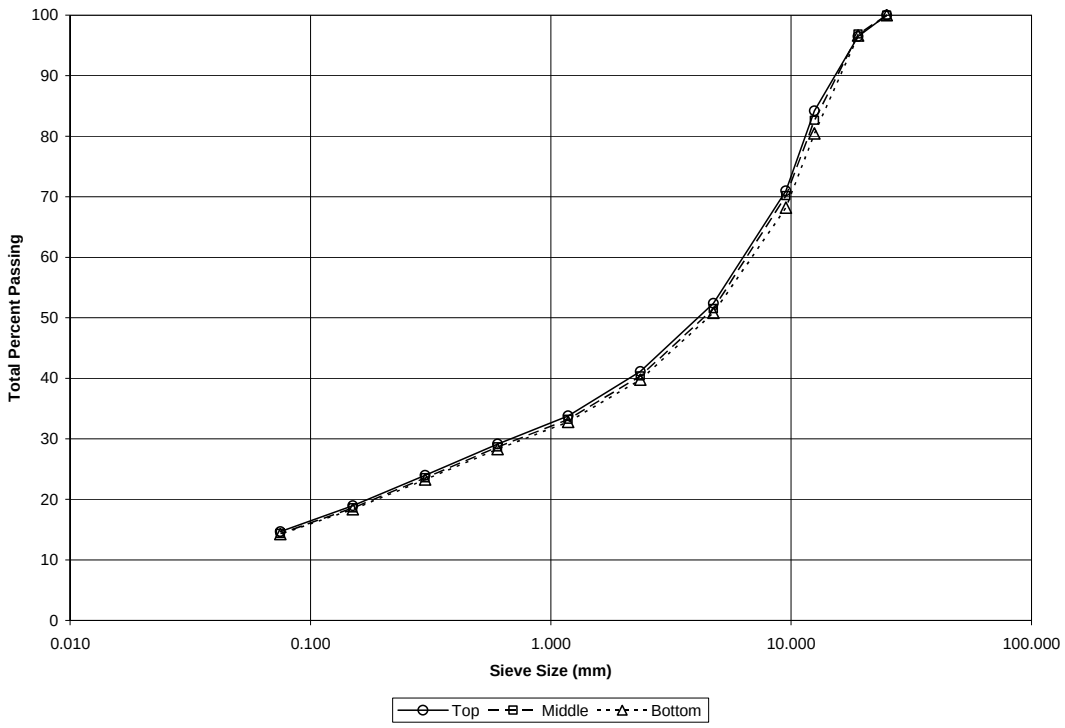


Figure C-9: Gasconade W-F Replicate #3

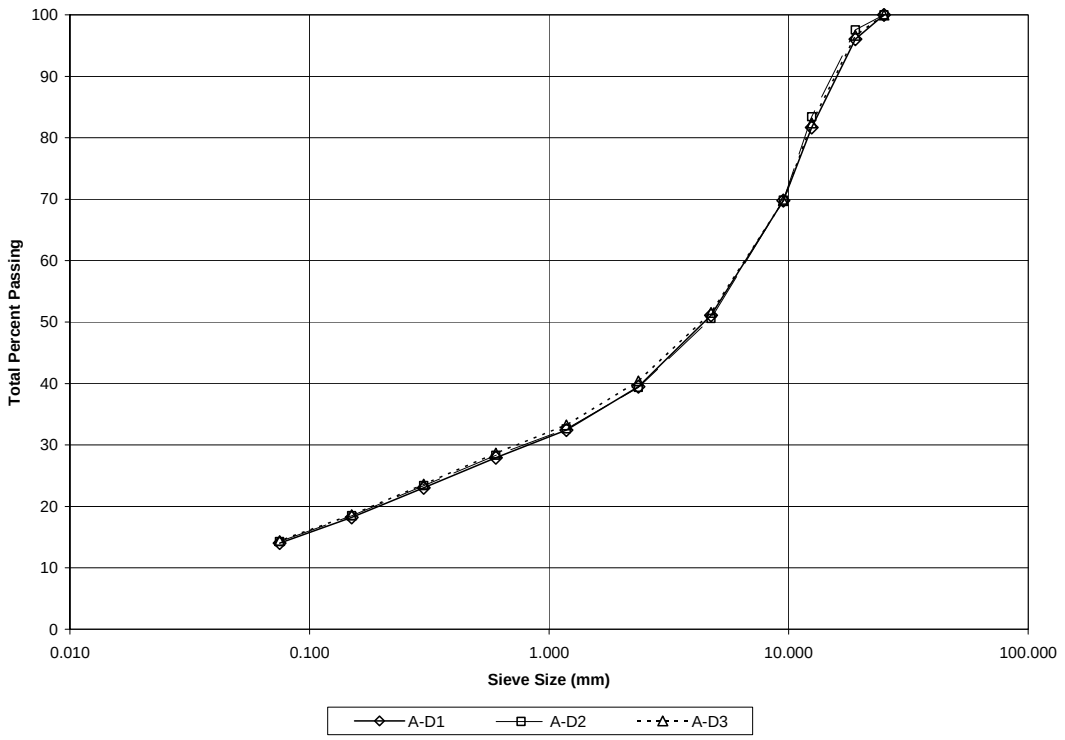


Figure C-10: Gasconade W-F: Between Replicate Comparison

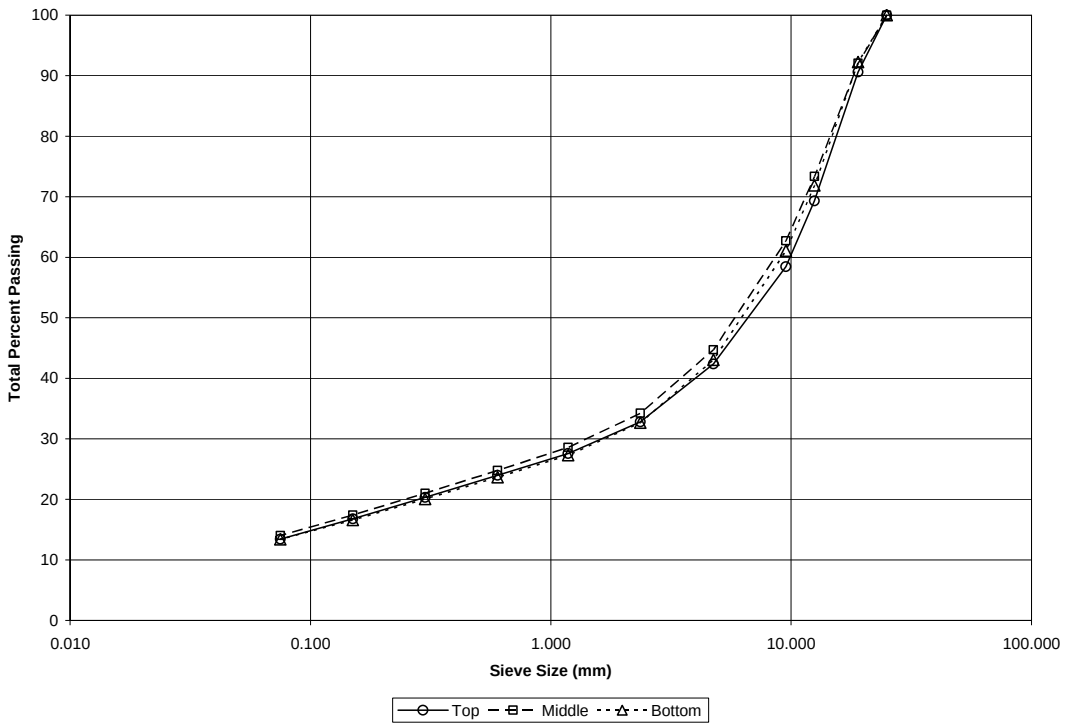


Figure C-11: Plattin A-D Replicate #1

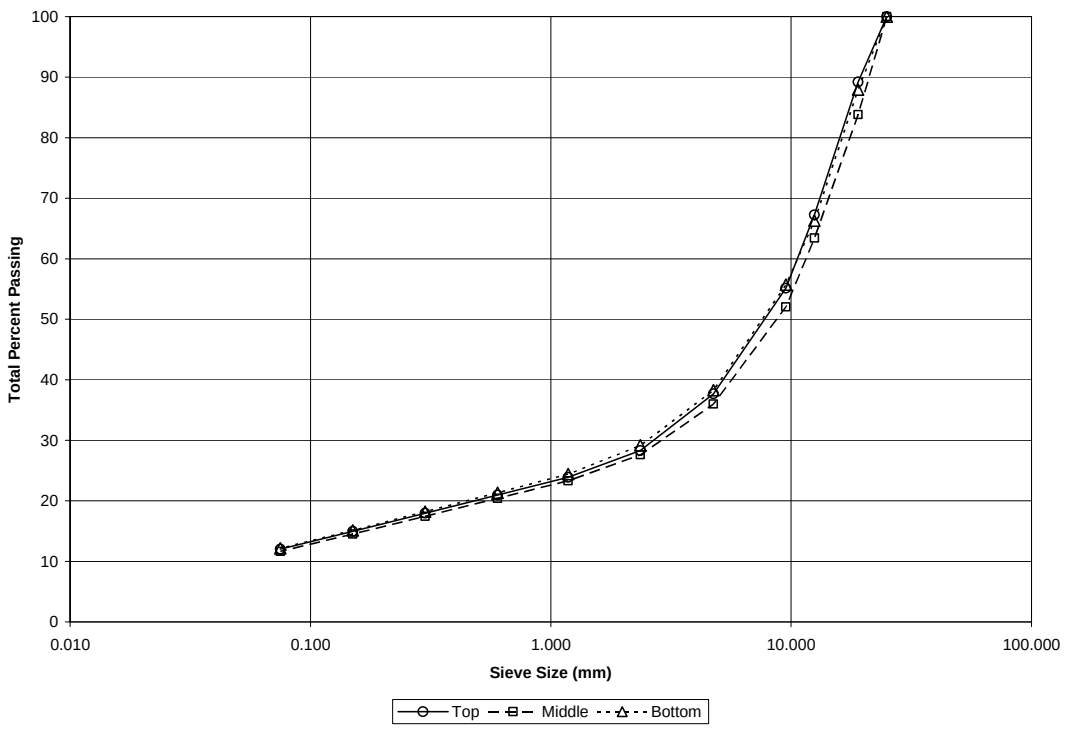


Figure C-12: Plattin A-D Replicate #2

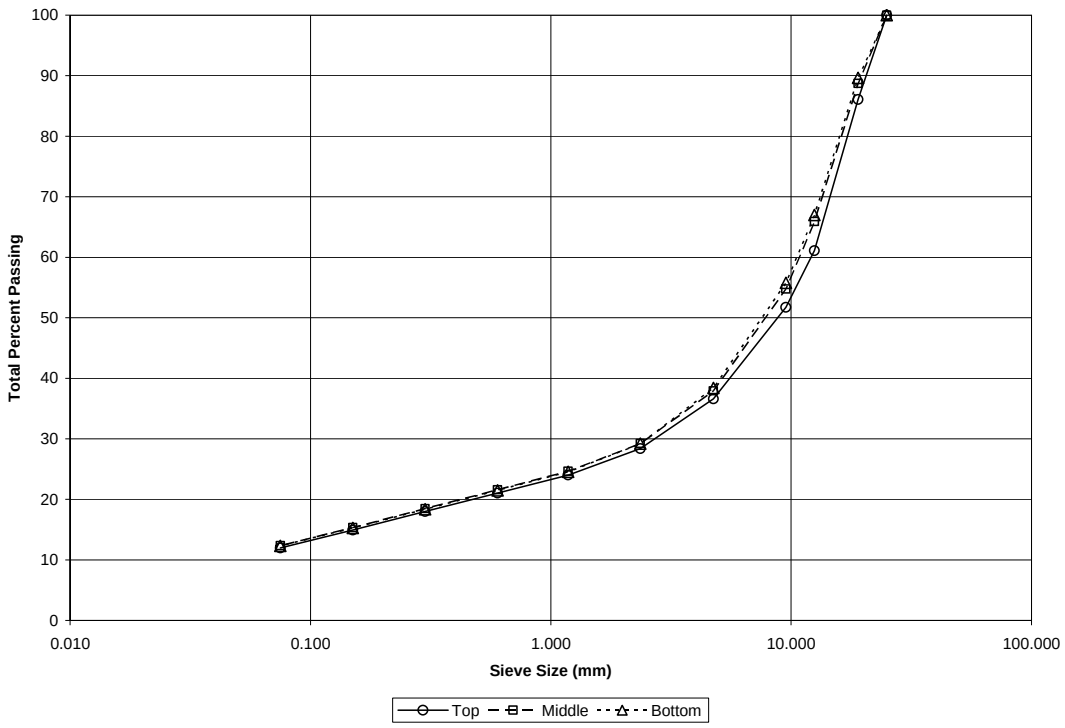


Figure C-13: Plattin A-D Replicate #3

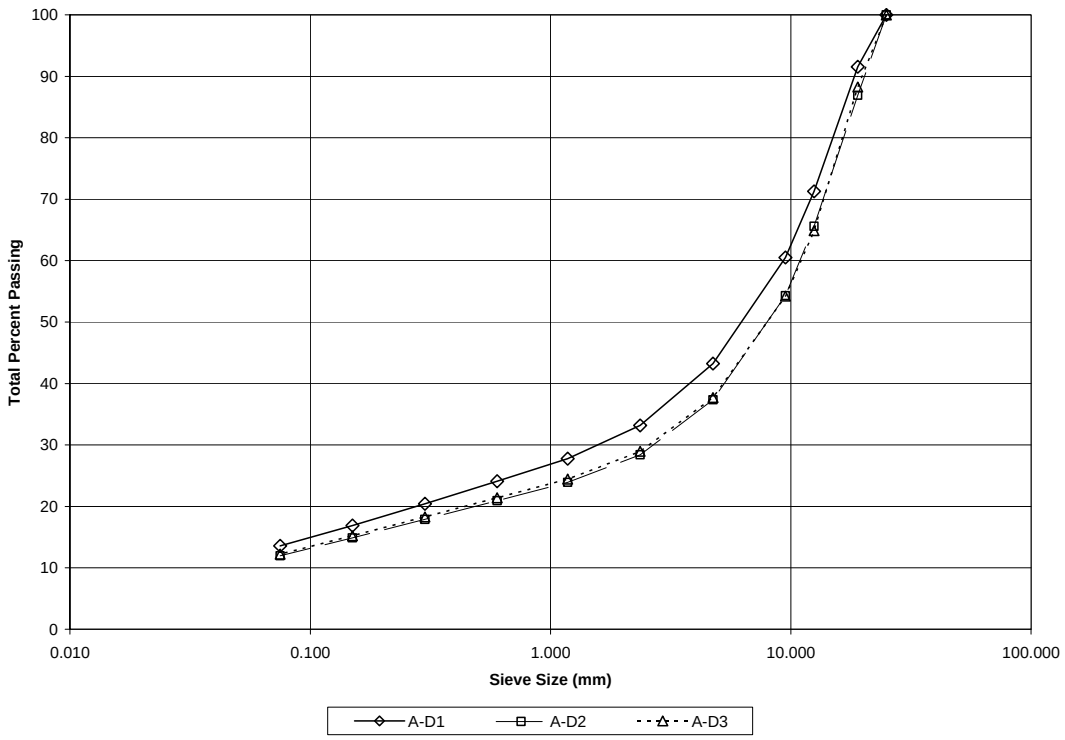


Figure C-14: Plattin A-D: Between Replicate Comparison

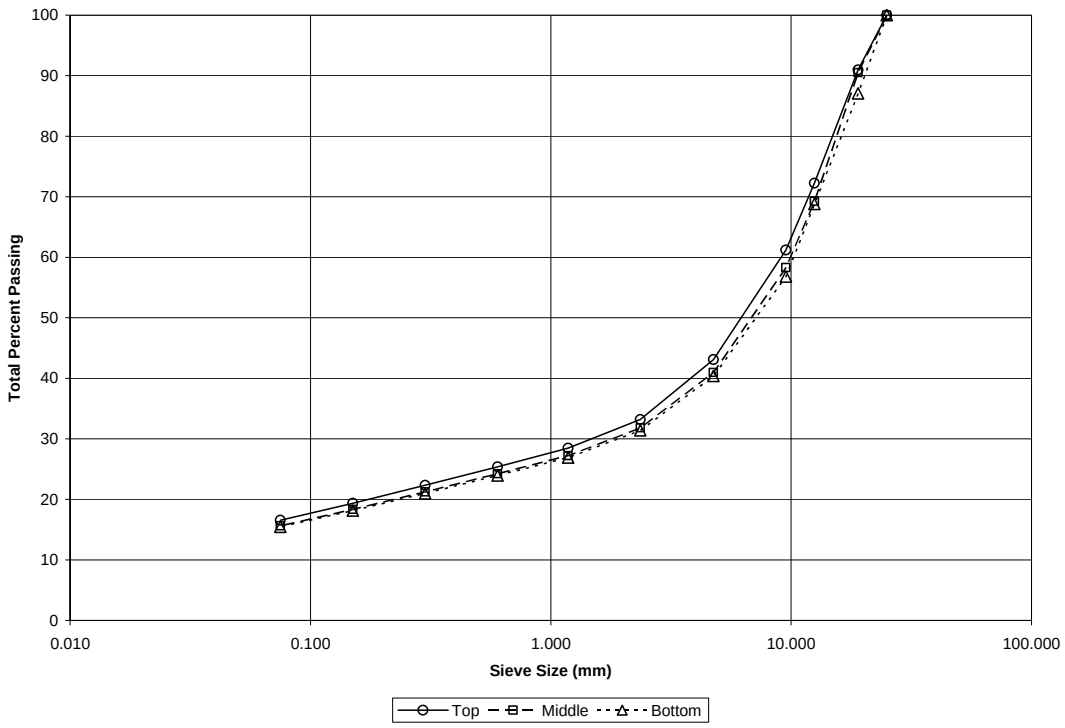


Figure C-15: Plattin W-F Replicate #1

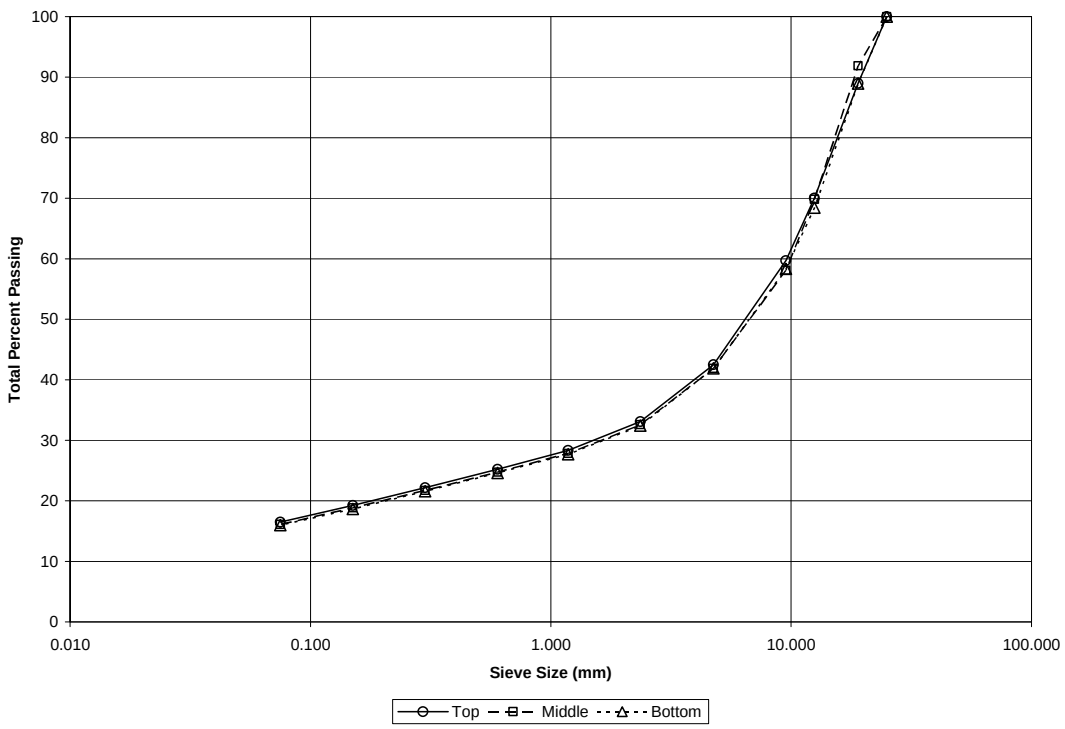


Figure C-16: Plattin W-F Replicate #2

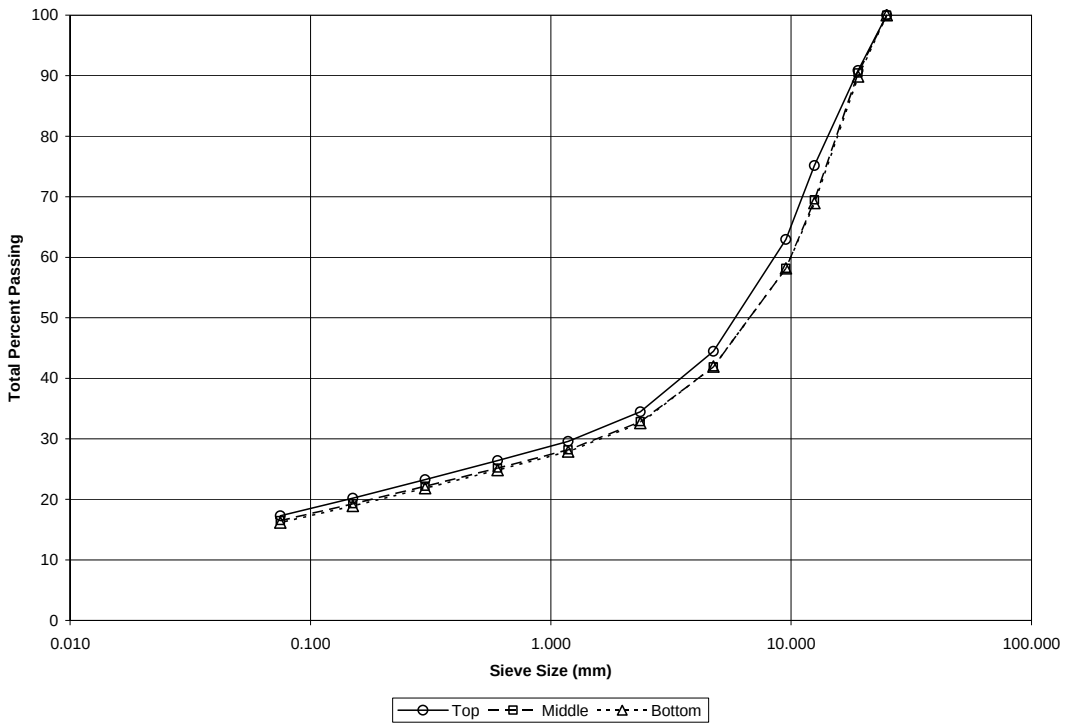


Figure C-17: Plattin W-F Replicate #3

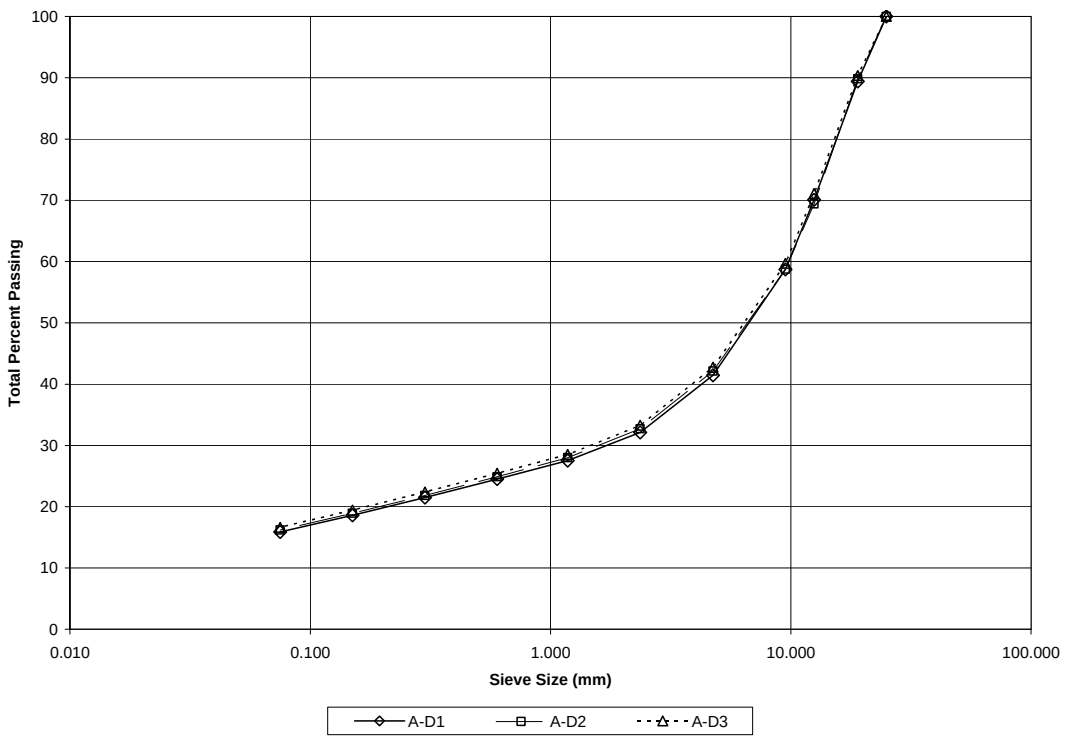


Figure C-18: Plattin W-F: Between Replicate Comparison

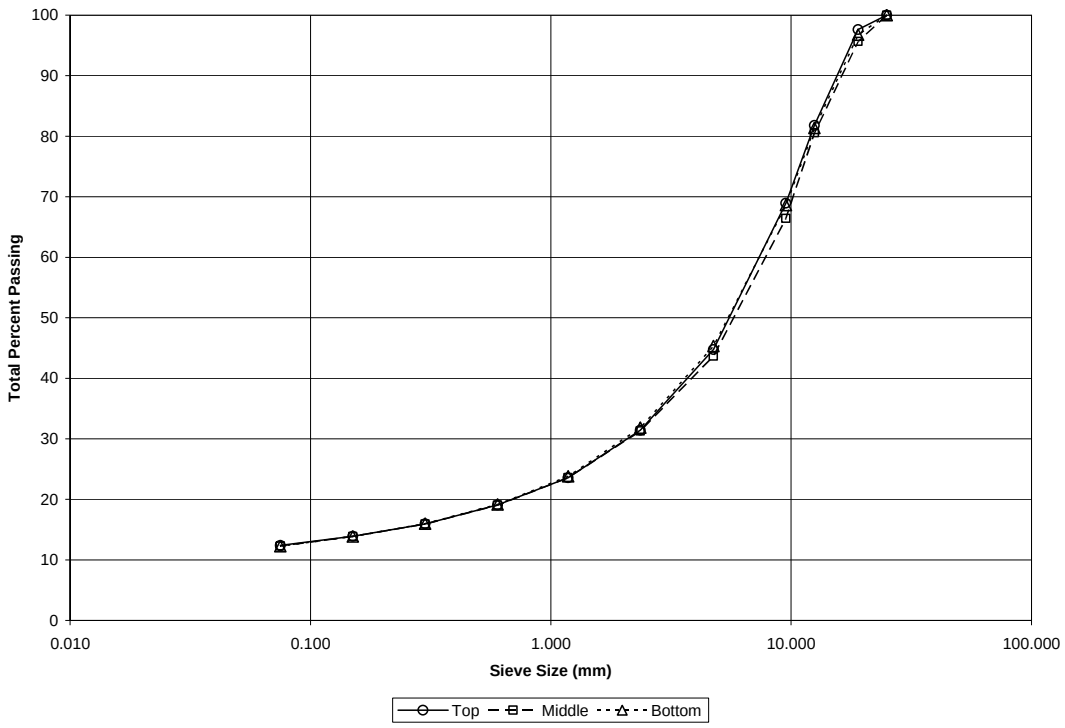


Figure C-19: Winterset A-D Replicate #1

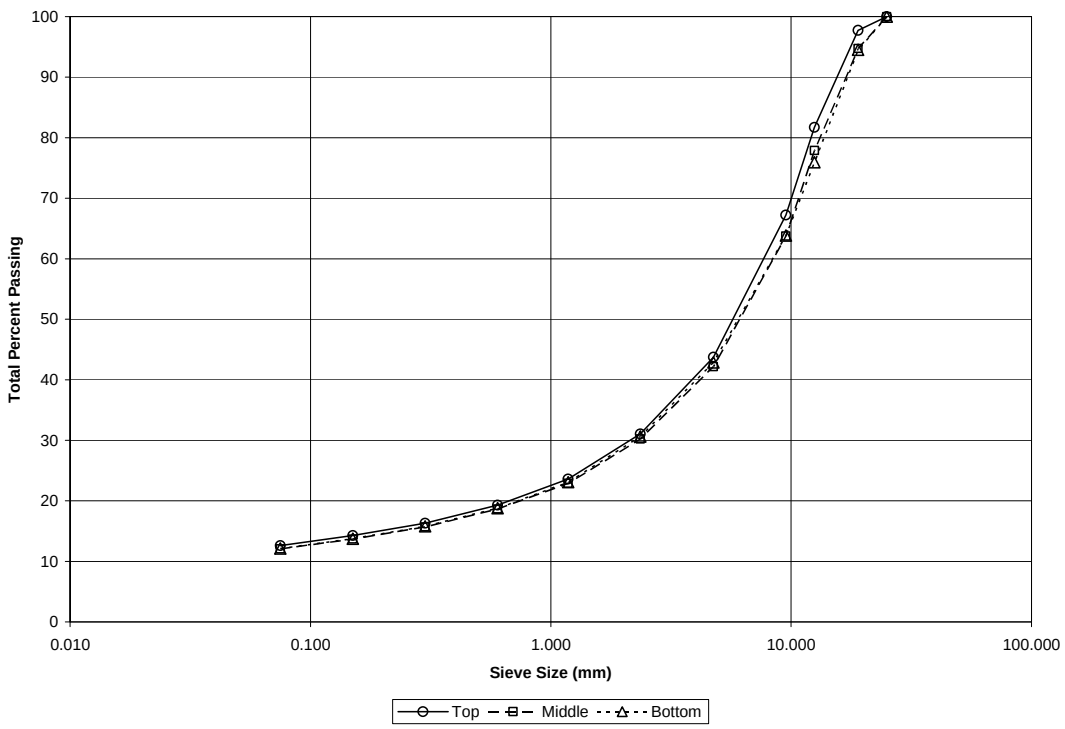


Figure C-20: Winterset A-D Replicate #2

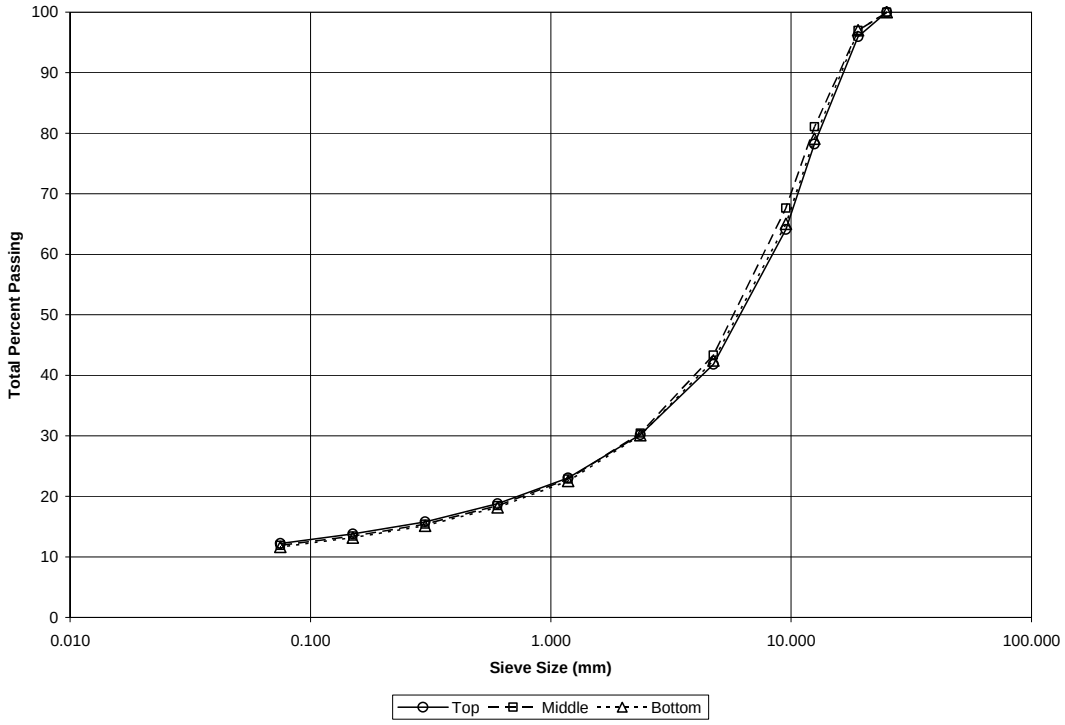


Figure C-21: Winterset A-D Replicate #3

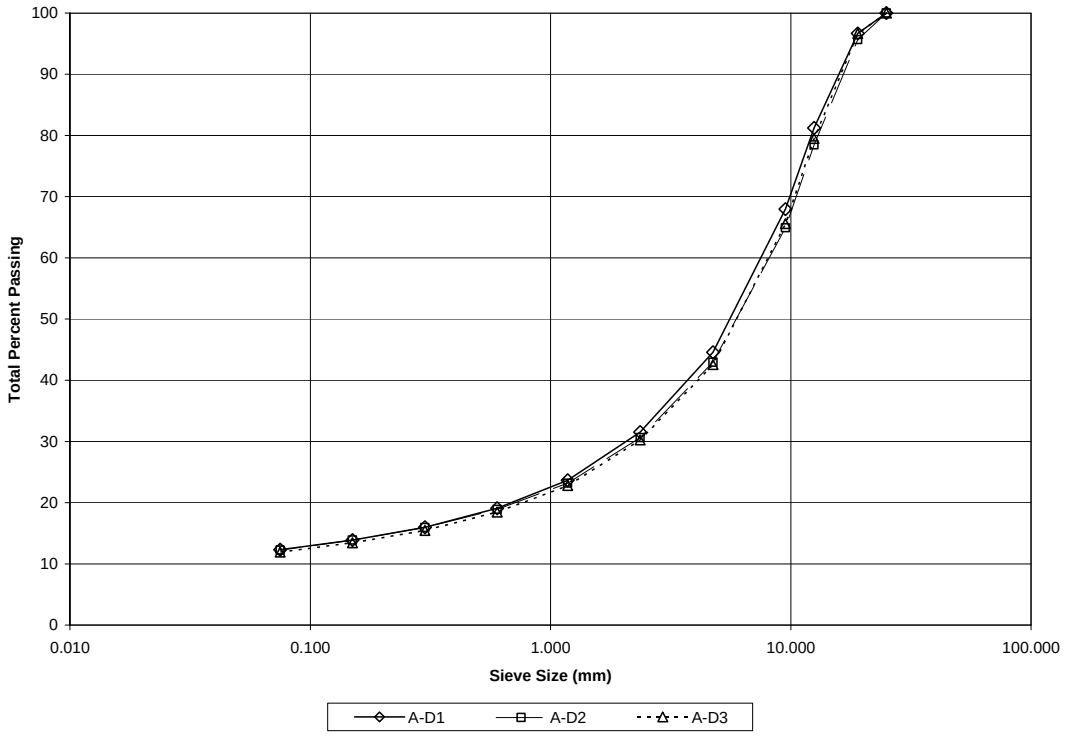


Figure C-22: Winterset A-D: Between Replicate Comparison

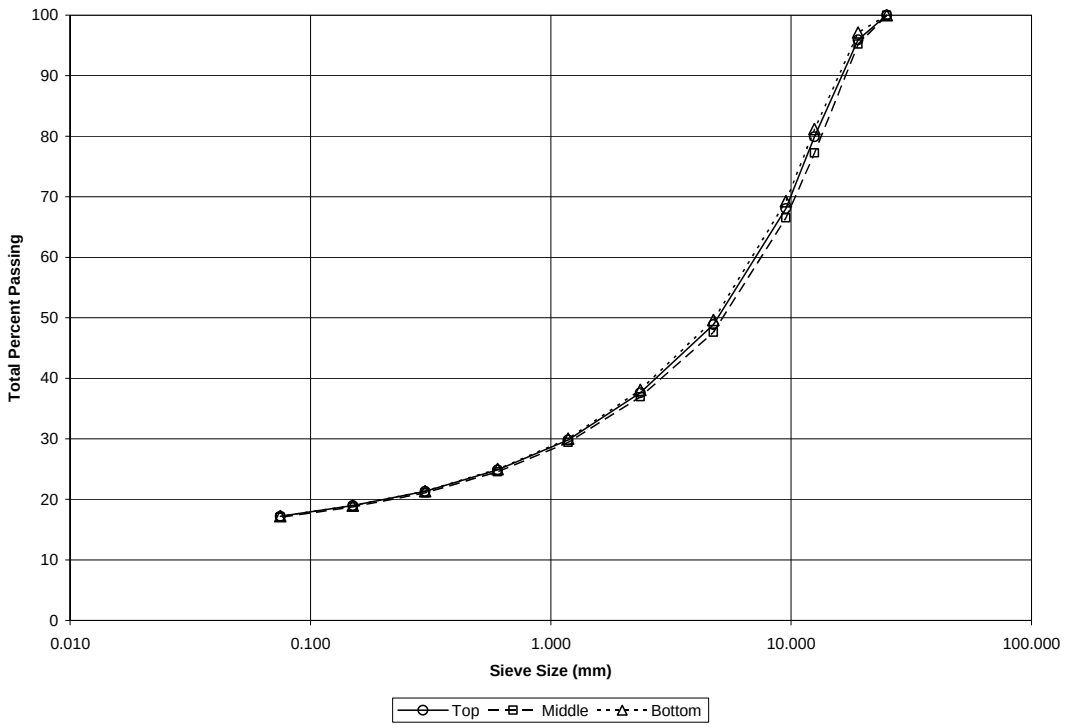


Figure C-23: Winterset W-F Replicate #1

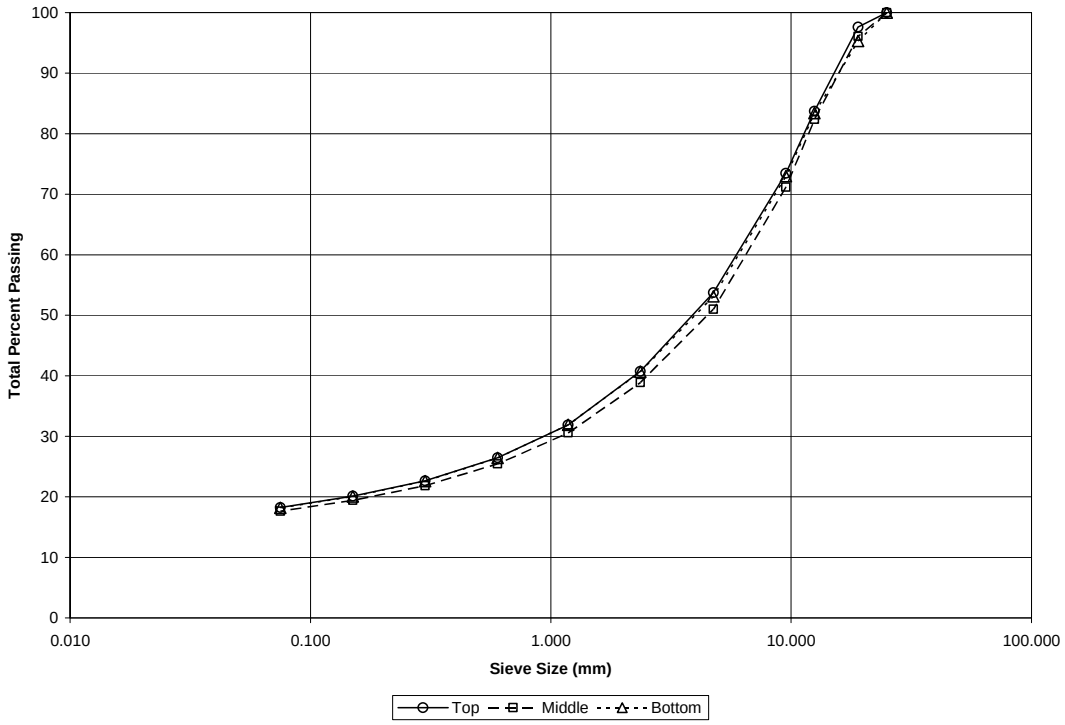


Figure C-24 Winterset W-F Replicate #2

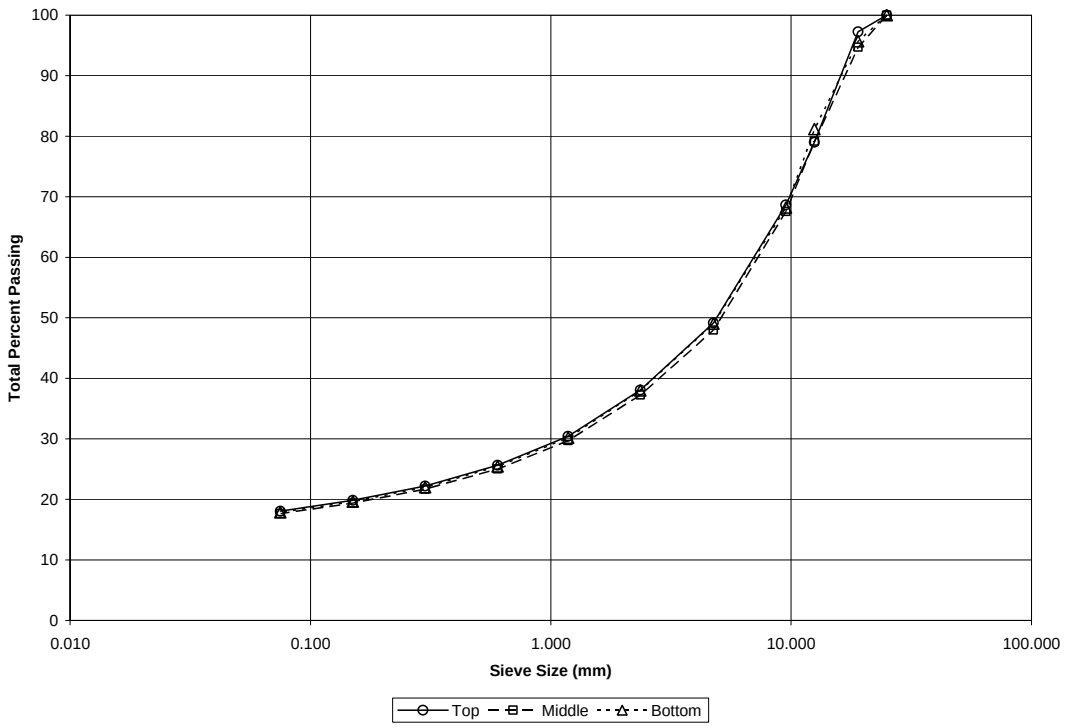


Figure C-25: Winterset W-F Replicate #3

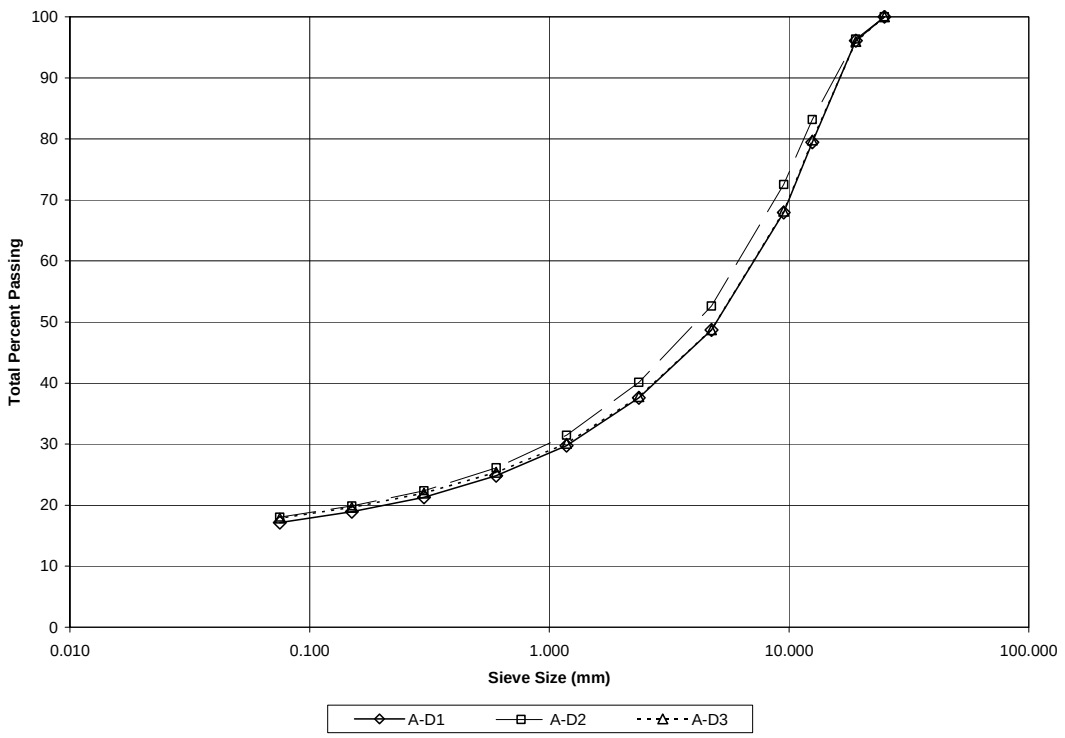


Figure C-26: Winterset W-F: Between Replicate Comparison

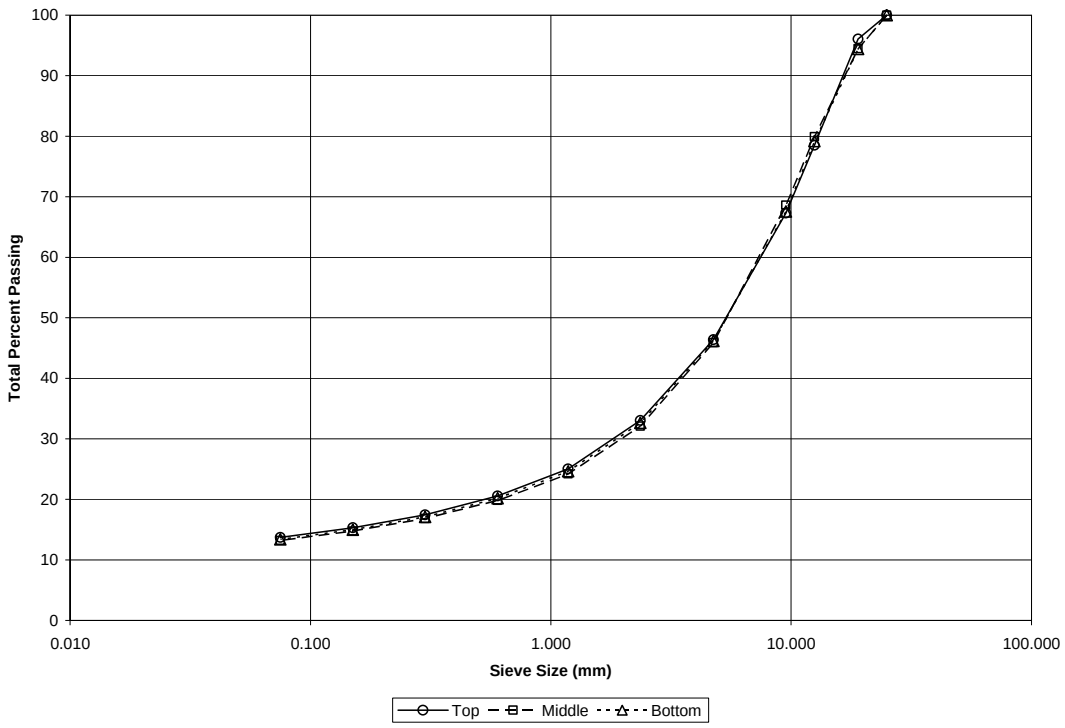


Figure C-27: Bethany Falls A-D Replicate #1

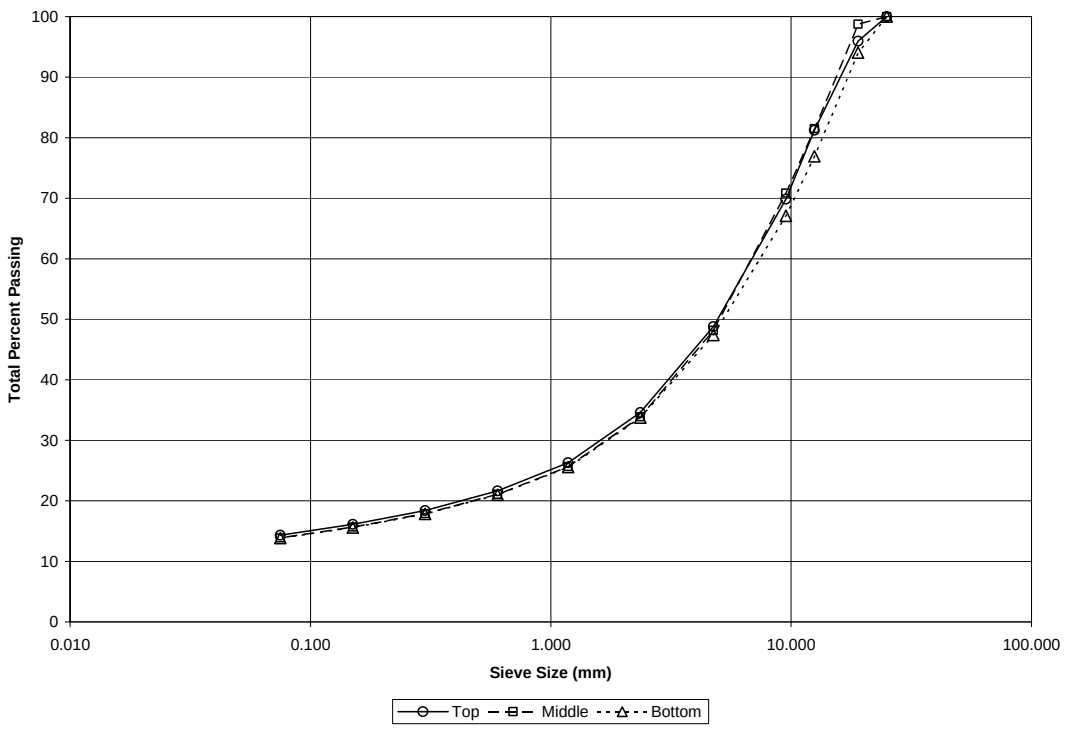


Figure C-28: Bethany Falls A-D Replicate #2

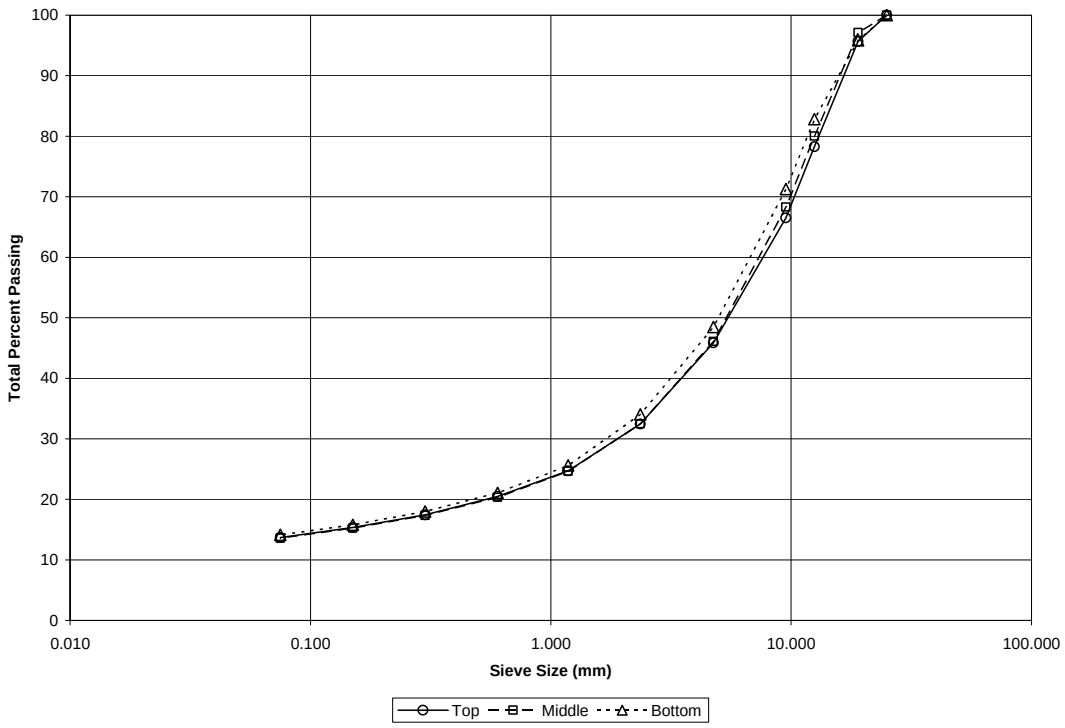


Figure C-29: Bethany Falls A-D Replicate #3

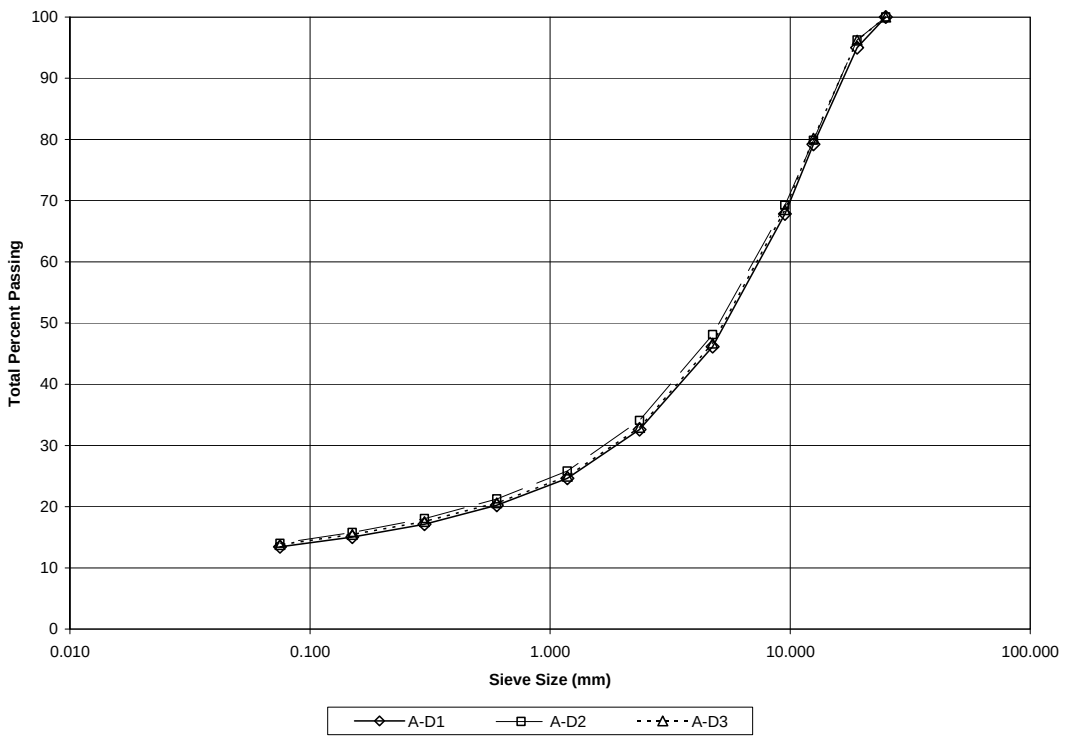


Figure C-30: Bethany Falls A-D: Between Replicate Comparison

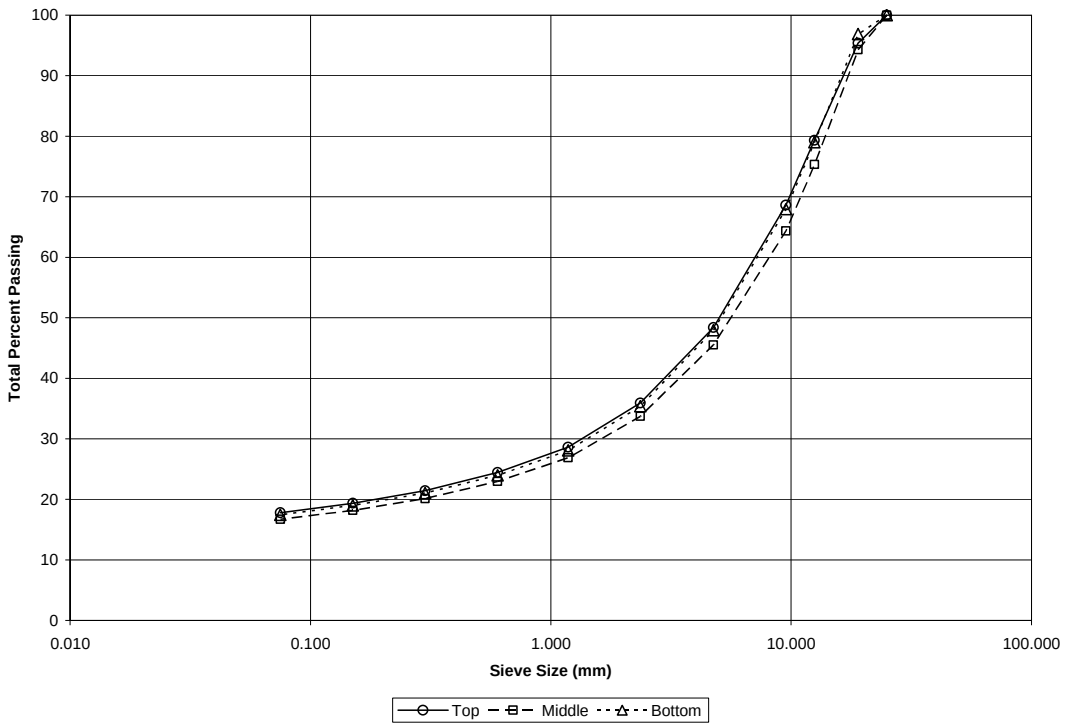


Figure C-31: Bethany Falls W-F Replicate #1

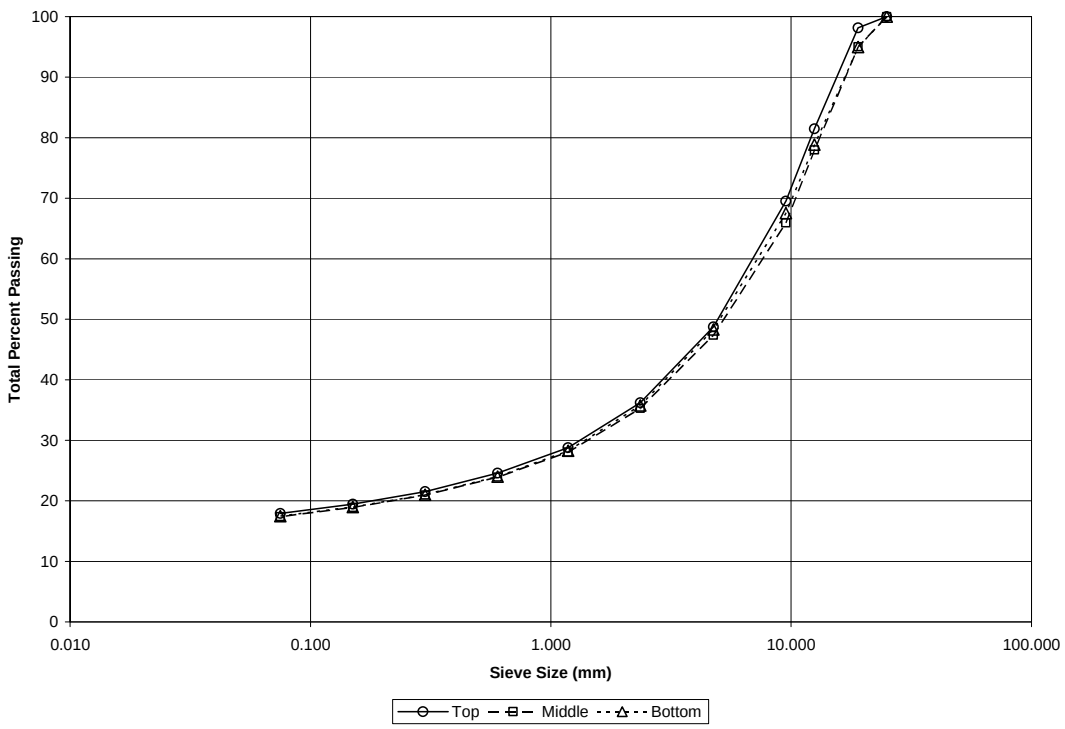


Figure C-32: Bethany Falls W-F Replicate #2

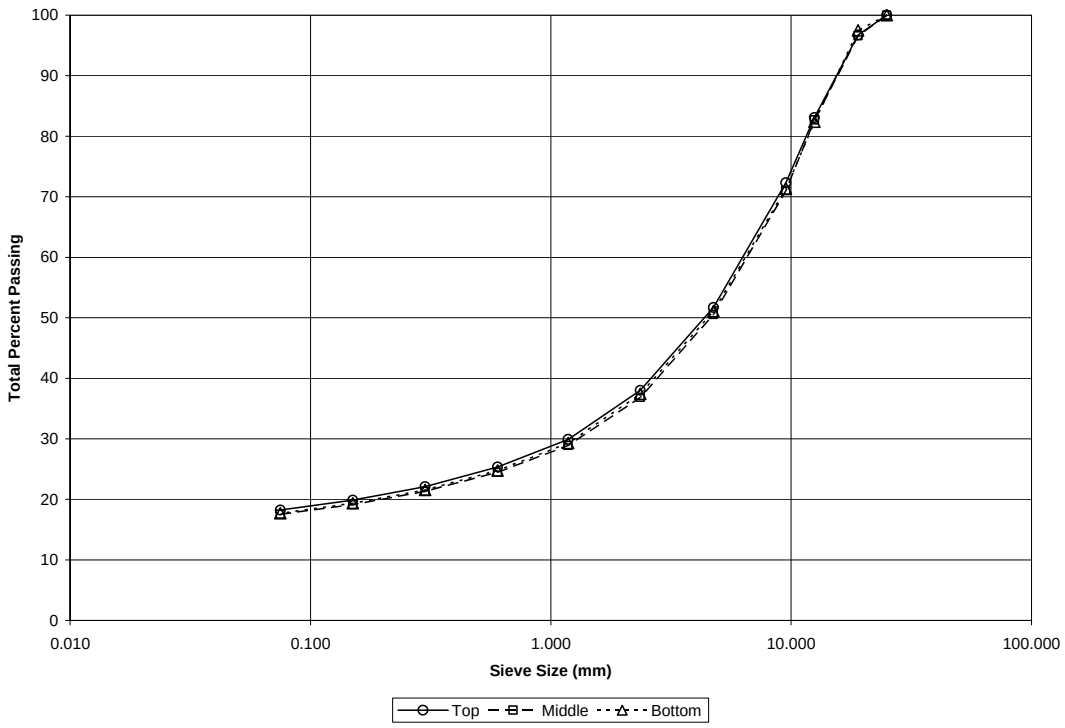


Figure C-33: Bethany Falls W-F Replicate #3

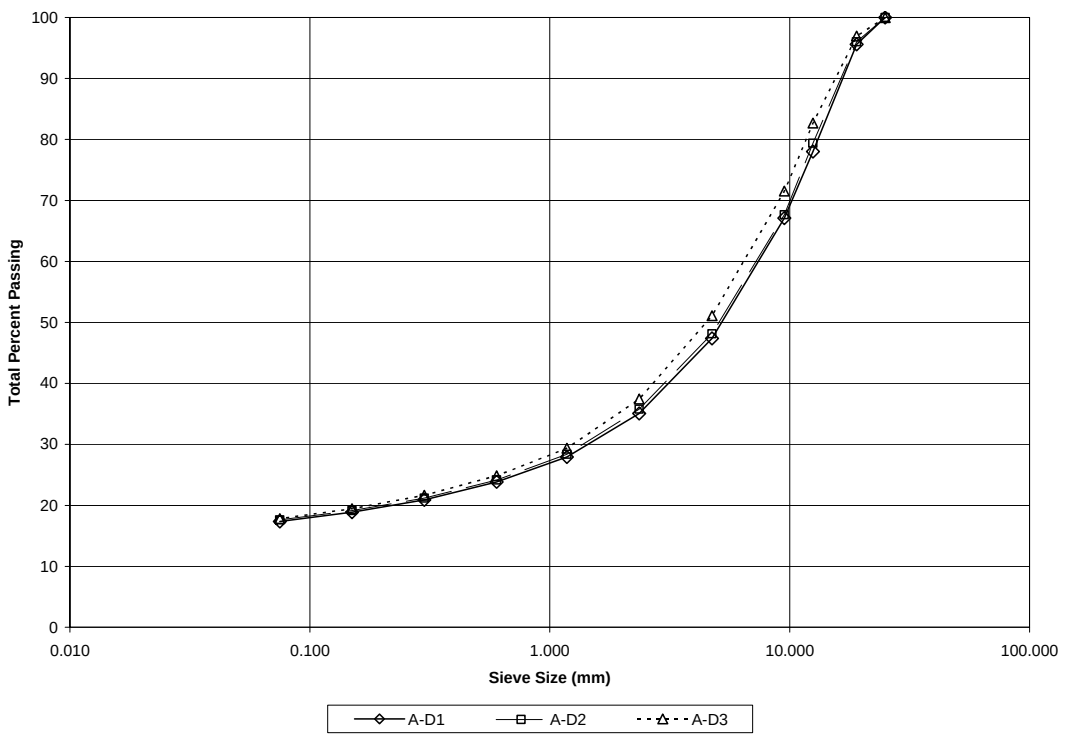


Figure C-34: Bethany Falls W-F: Between Replicate Comparison

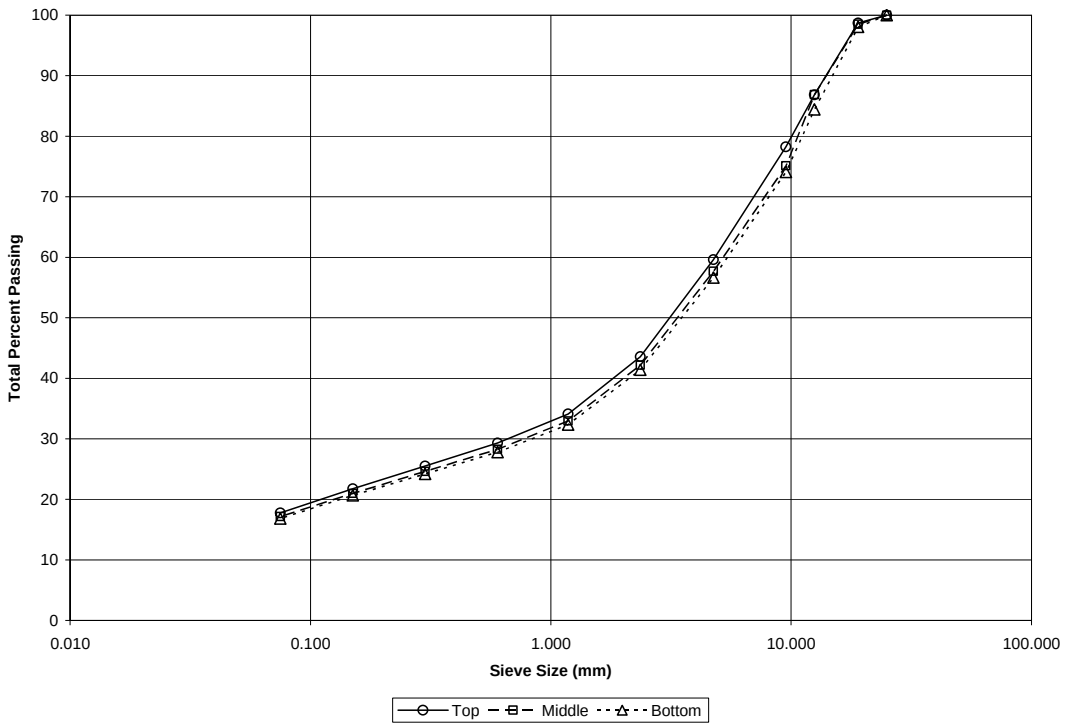


Figure C-35: Jefferson City Dolomite W-F Replicate #1

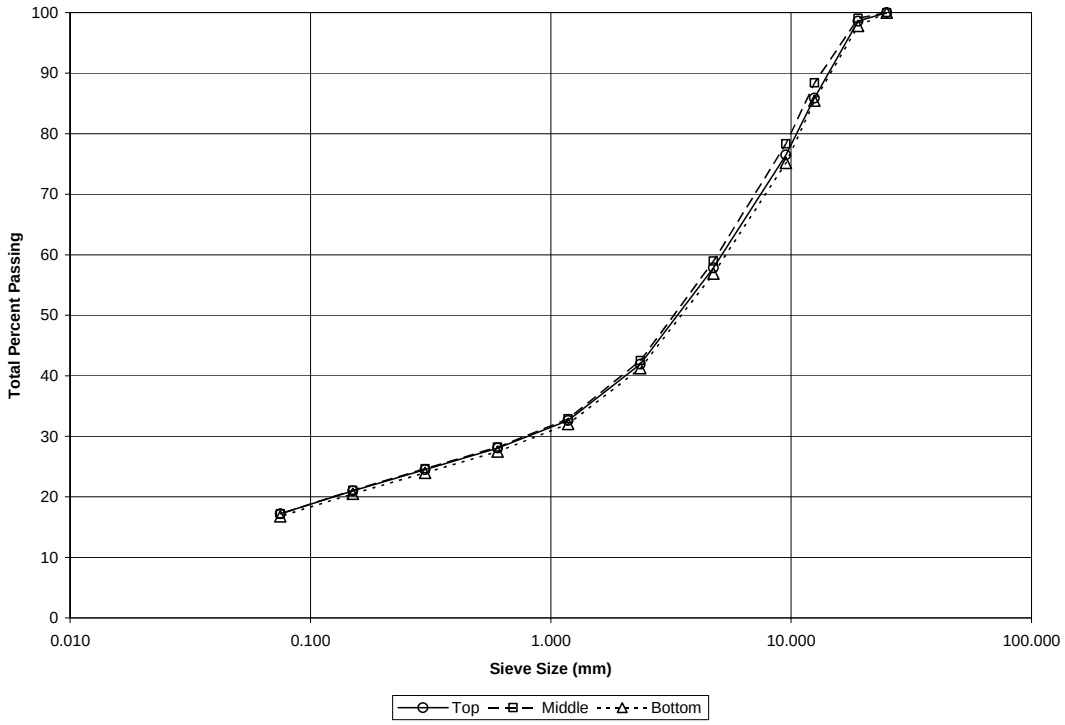


Figure C-36: Jefferson City Dolomite W-F Replicate #2

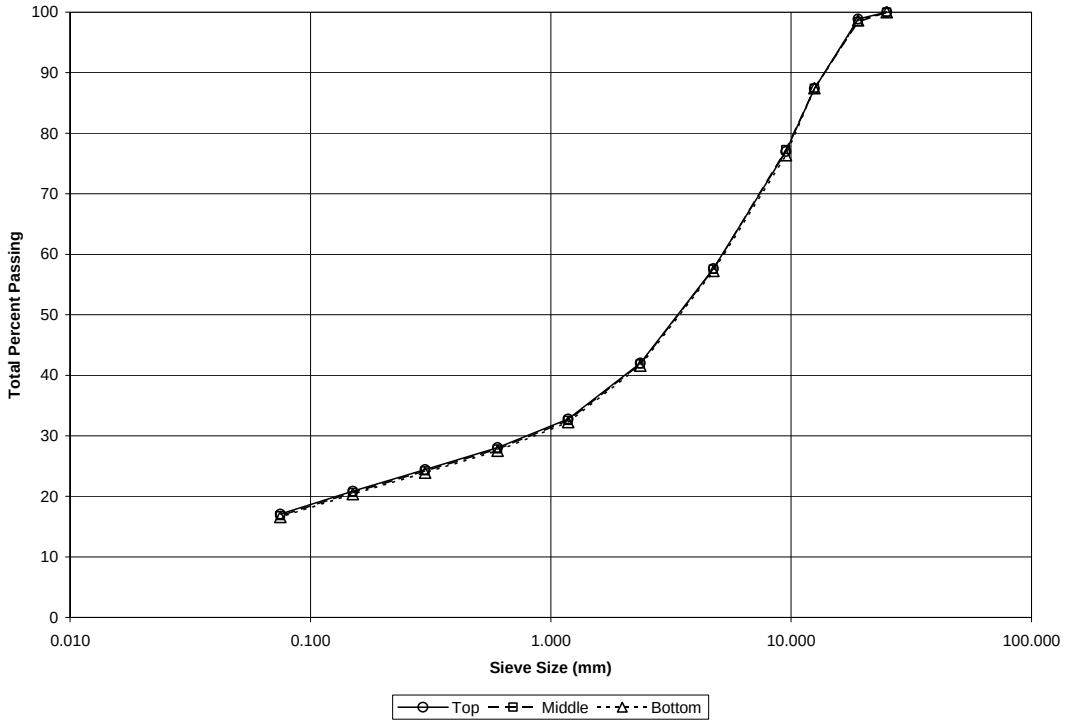


Figure C-37: Jefferson City Dolomite W-F Replicate #3

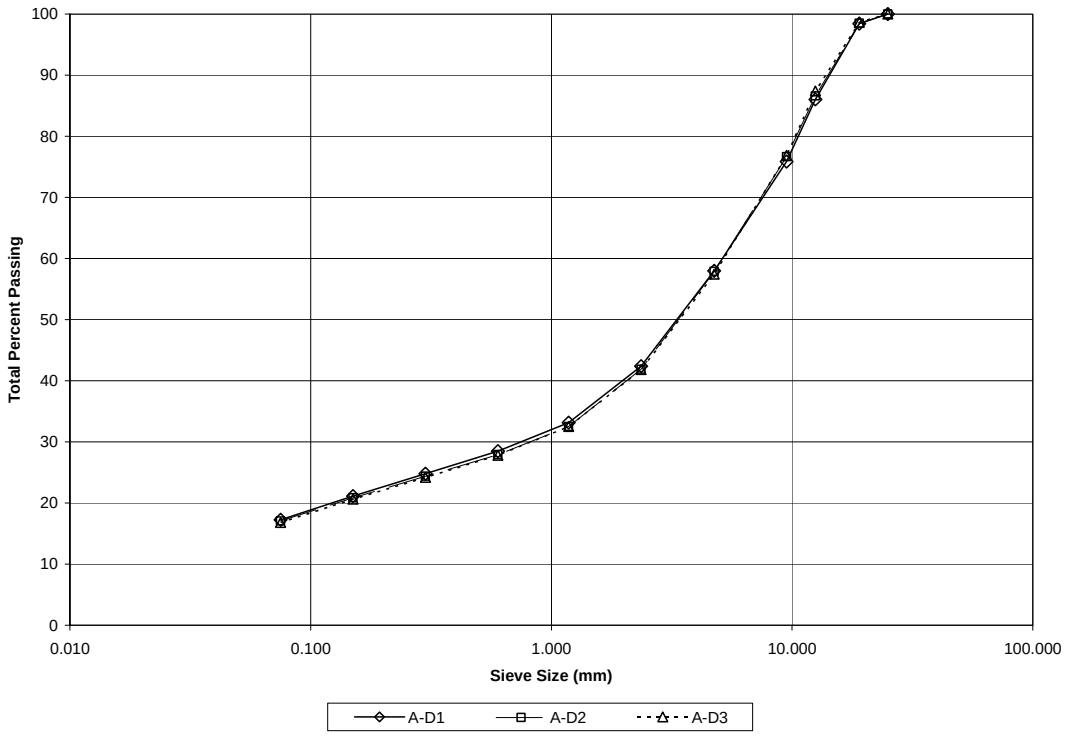


Figure C-38: Jefferson City Dolomite W-F: Between Replicate Comparison

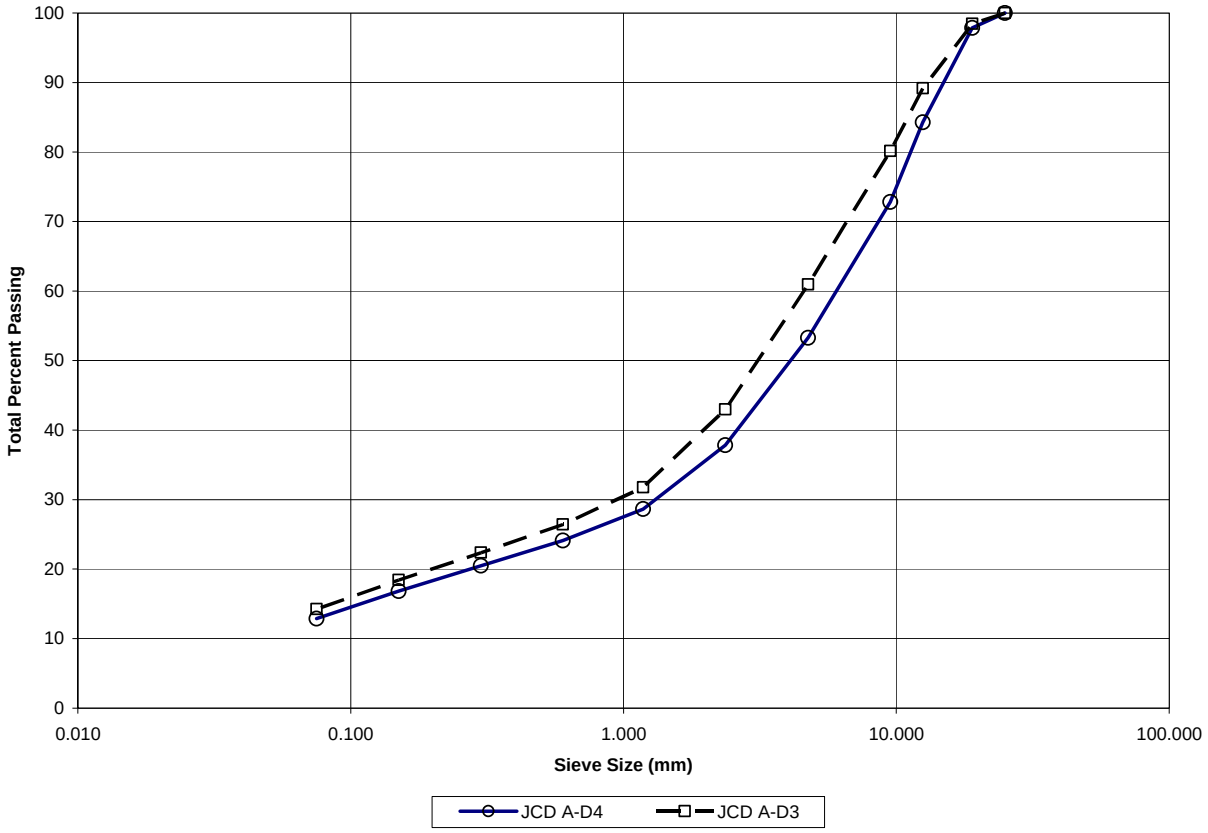


Figure C-39: Jefferson City Dolomite A-D: Between Replicate Comparison: Only Two Gradations were Performed

APPENDIX D: SUBGRADE SOILS T 99 CURVES

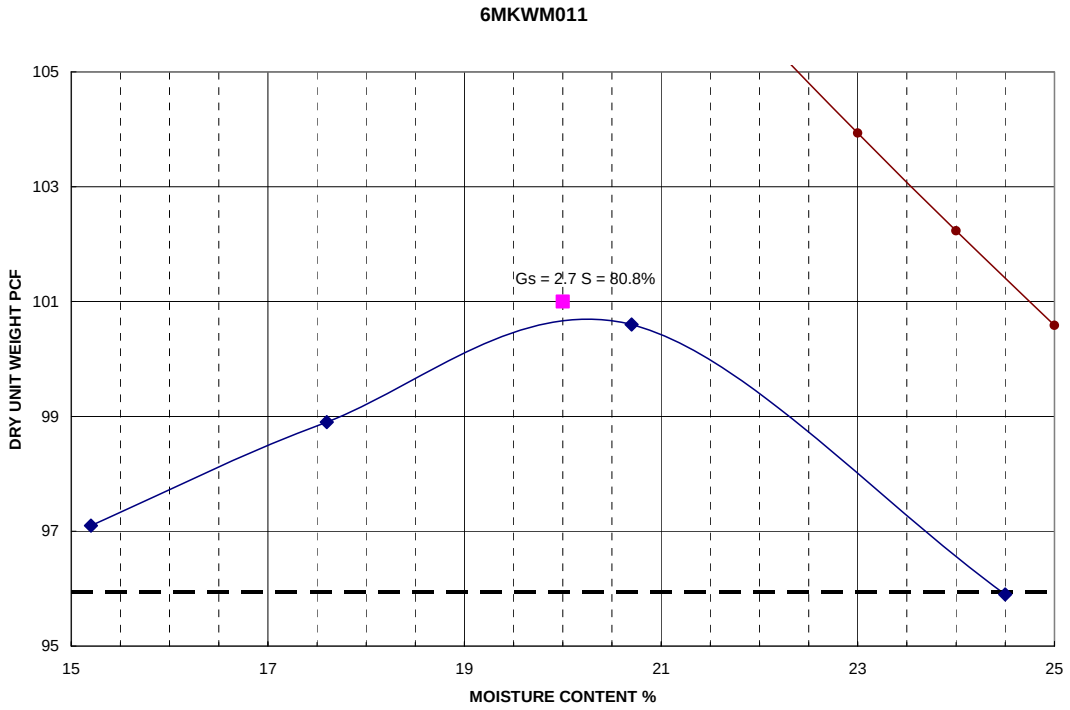


Figure D. 1 – Compaction Curve for Soil 6MKWM011

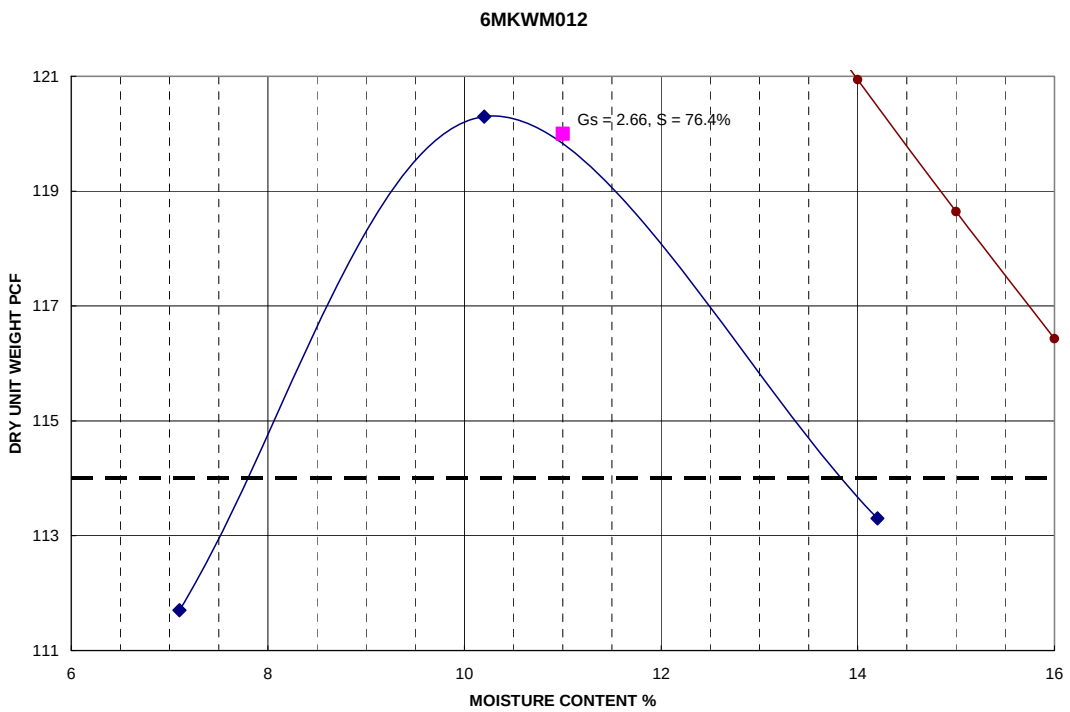


Figure D. 2 – Compaction Curve for Soil 6MKWM012

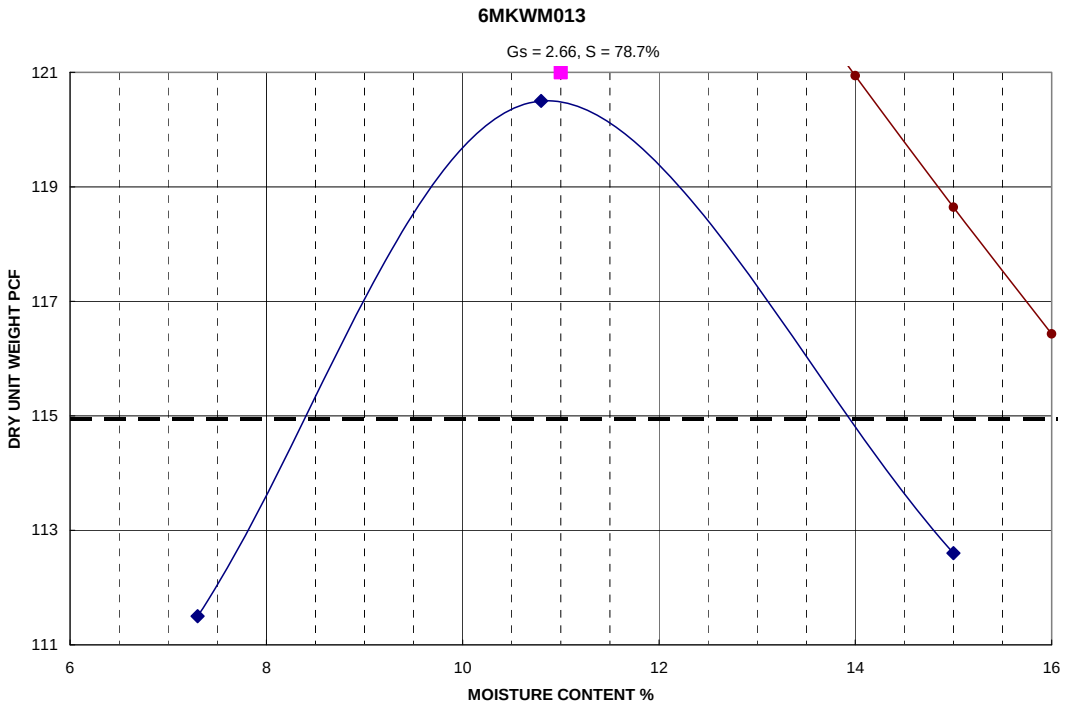


Figure D. 3 – Compaction Curve for Soil 6MKWM013

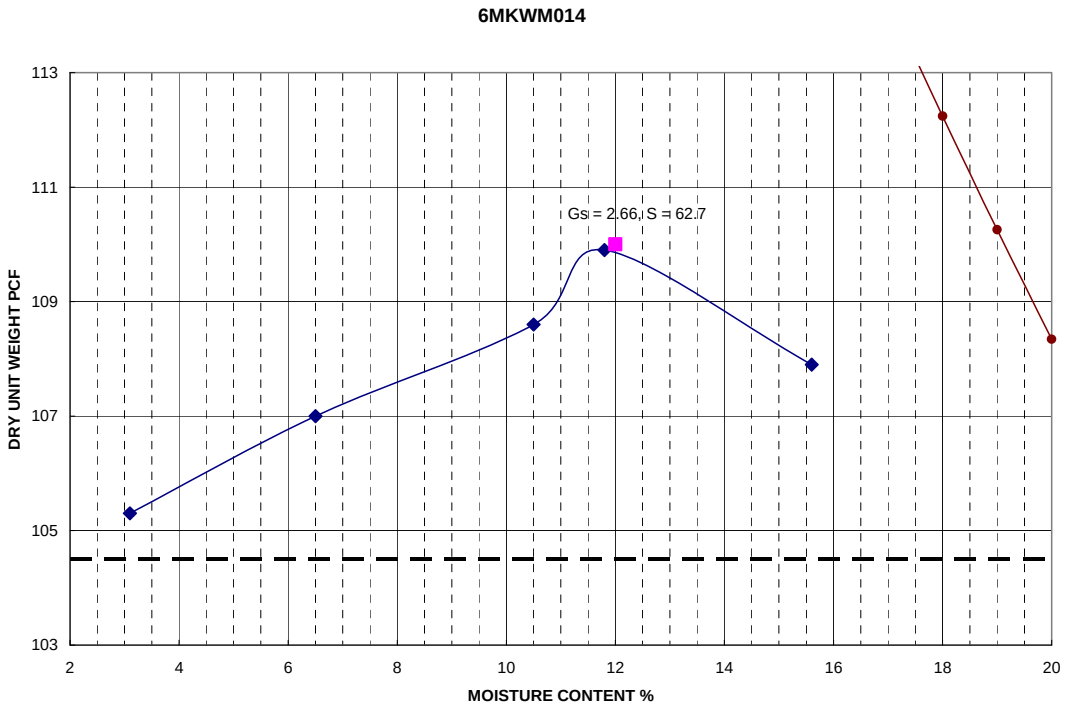


Figure D. 4 – Compaction Curve for Soil 6MKWM014

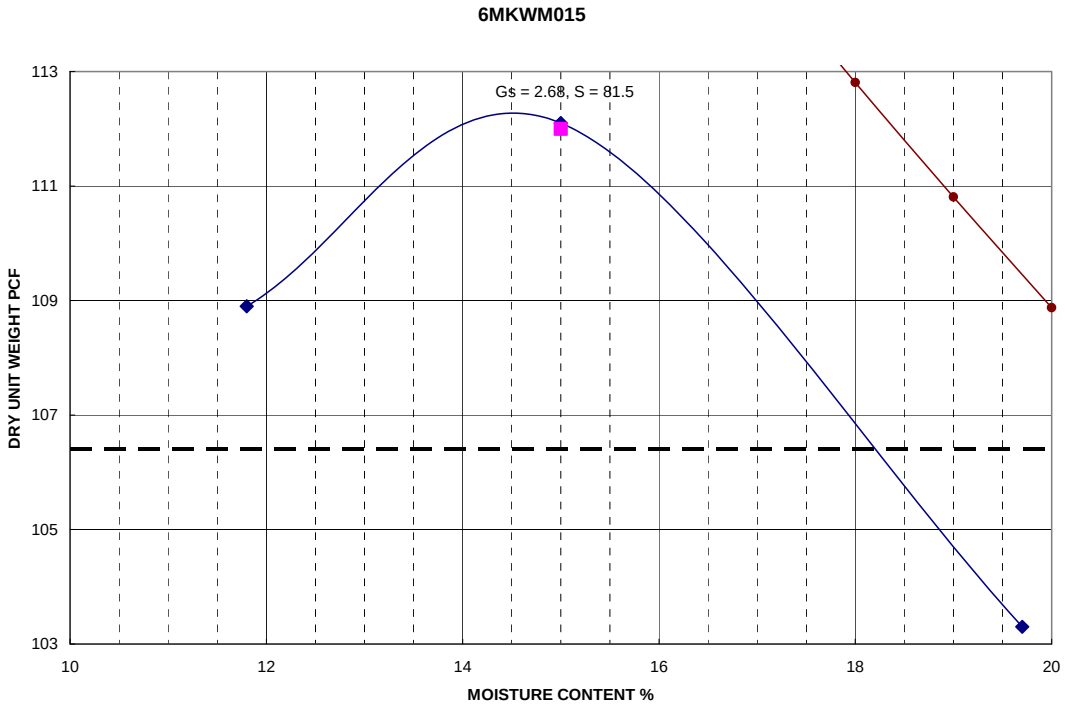


Figure D. 5 – Compaction Curve for Soil 6MKWM015

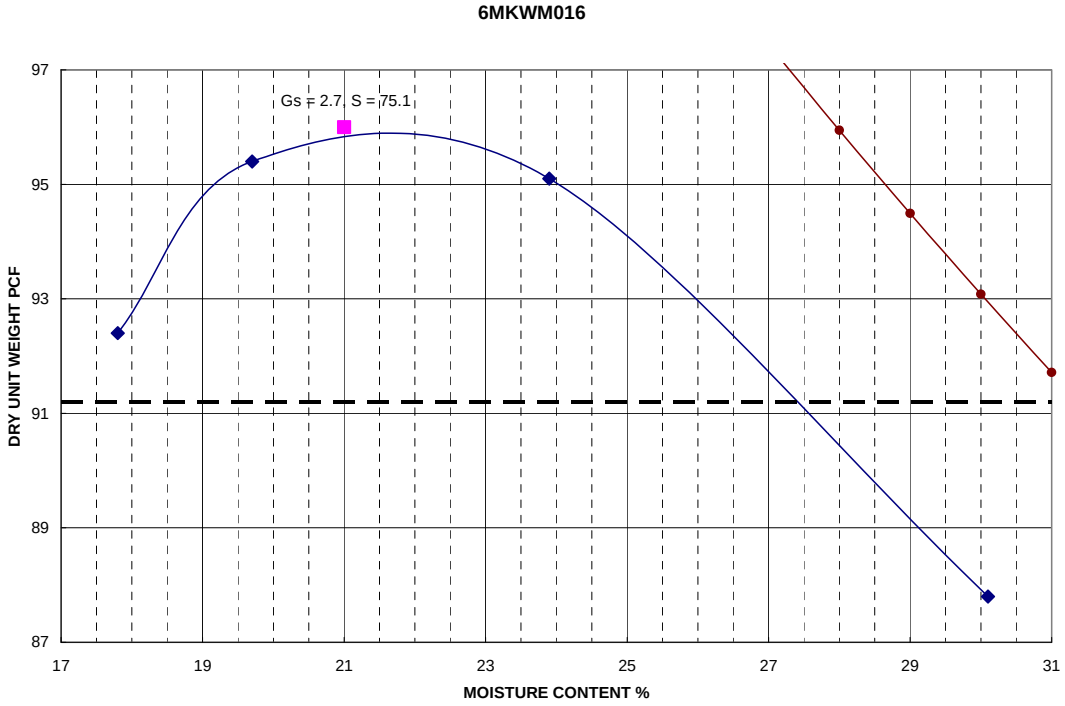


Figure D. 6 – Compaction Curve for Soil 6MKWM016

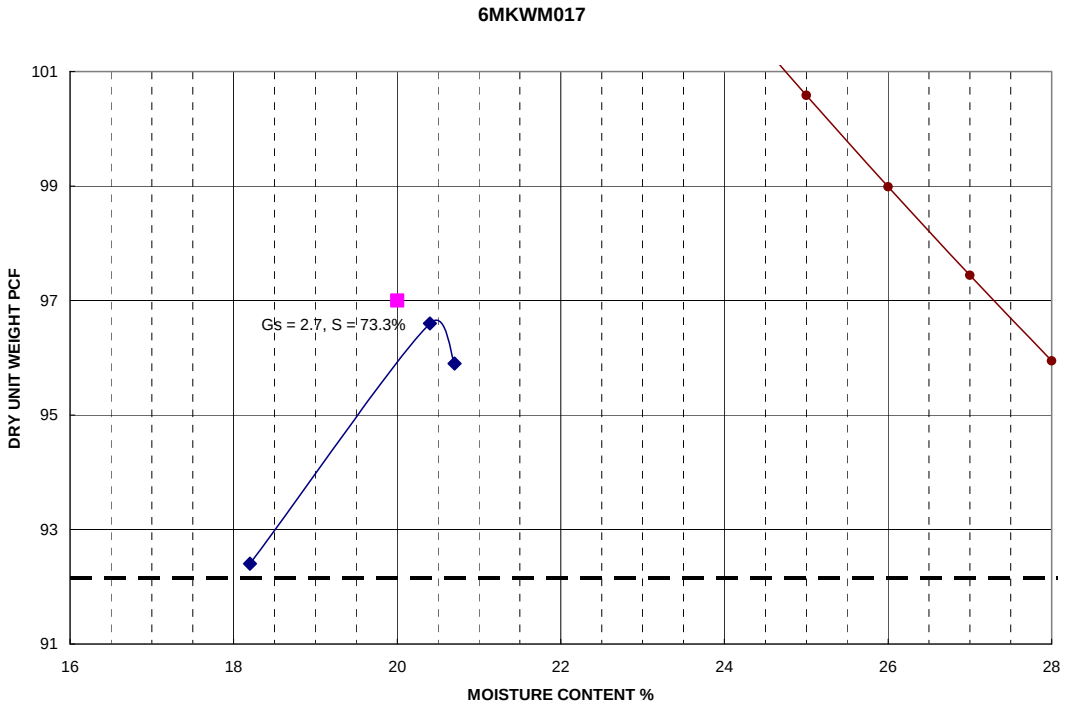


Figure D. 7 – Compaction Curve for Soil 6MKWM017

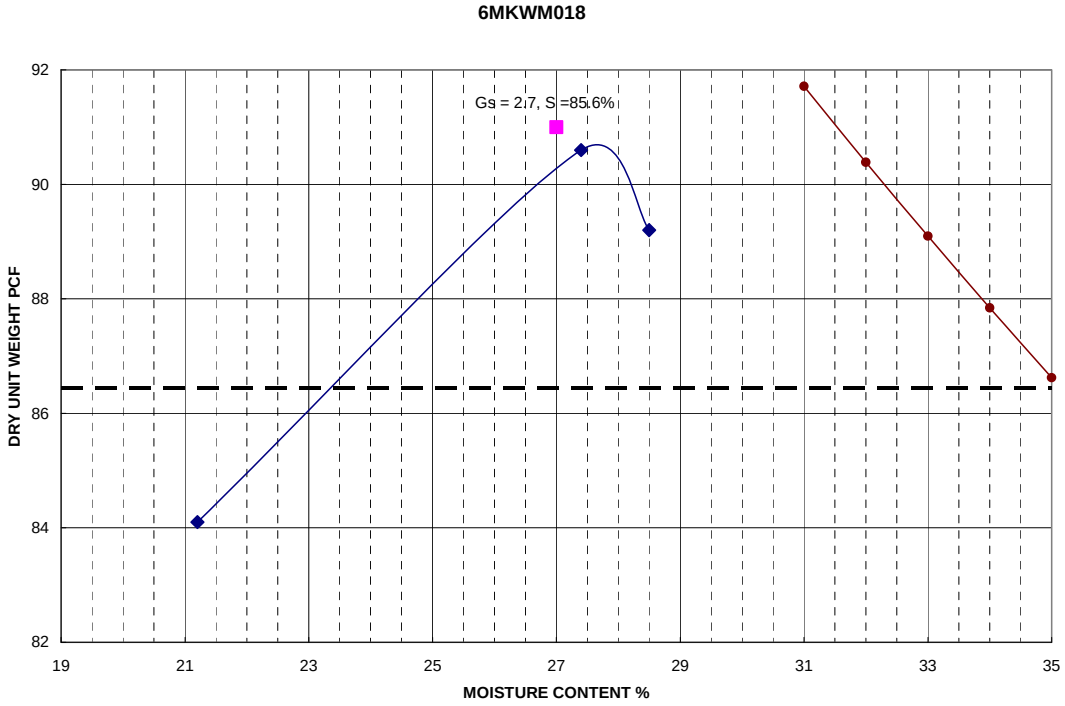


Figure D. 8 – Compaction Curve for Soil 6MKWM018

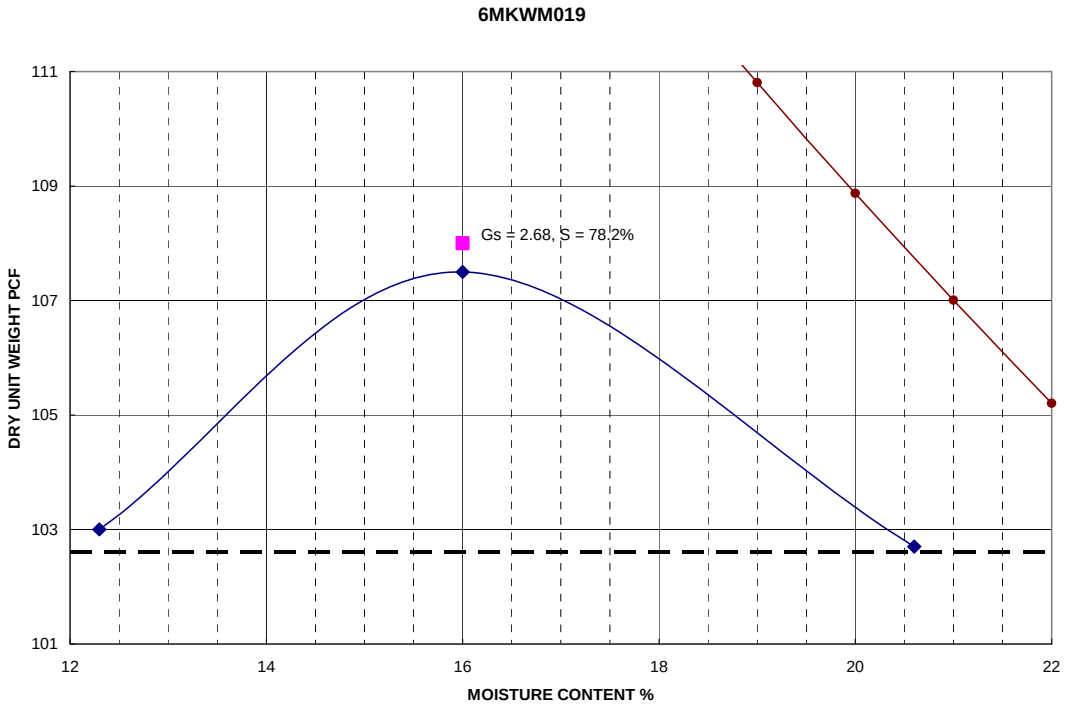


Figure D. 9 – Compaction Curve for Soil 6MKWM019

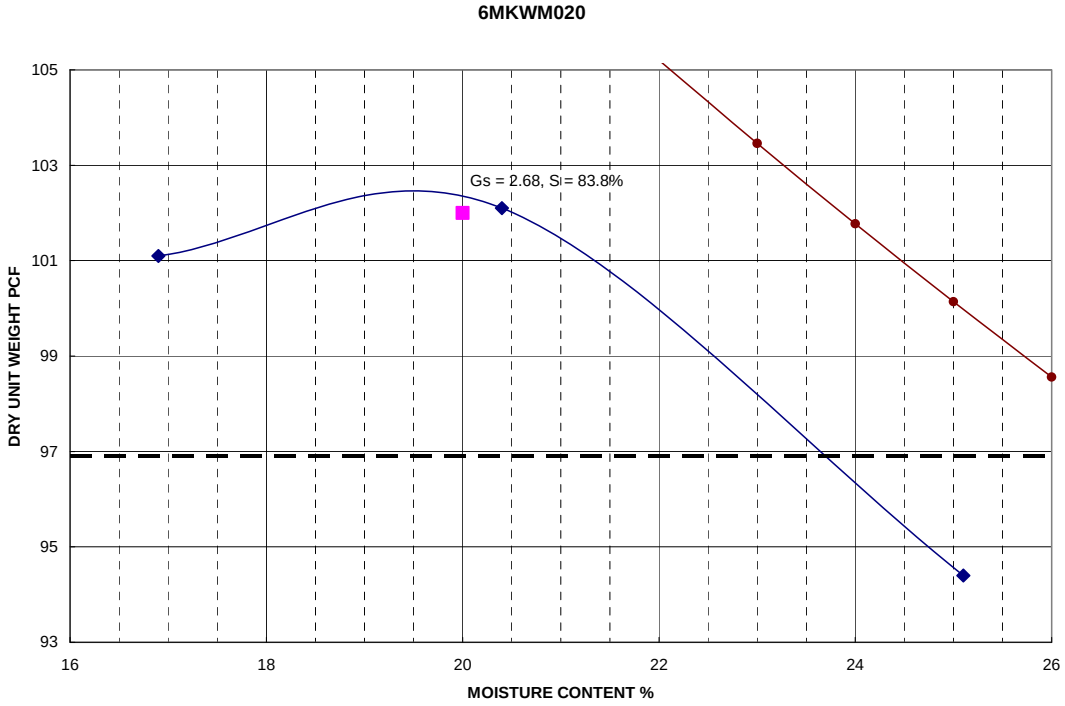


Figure D. 10 – Compaction Curve for Soil 6MKWM020

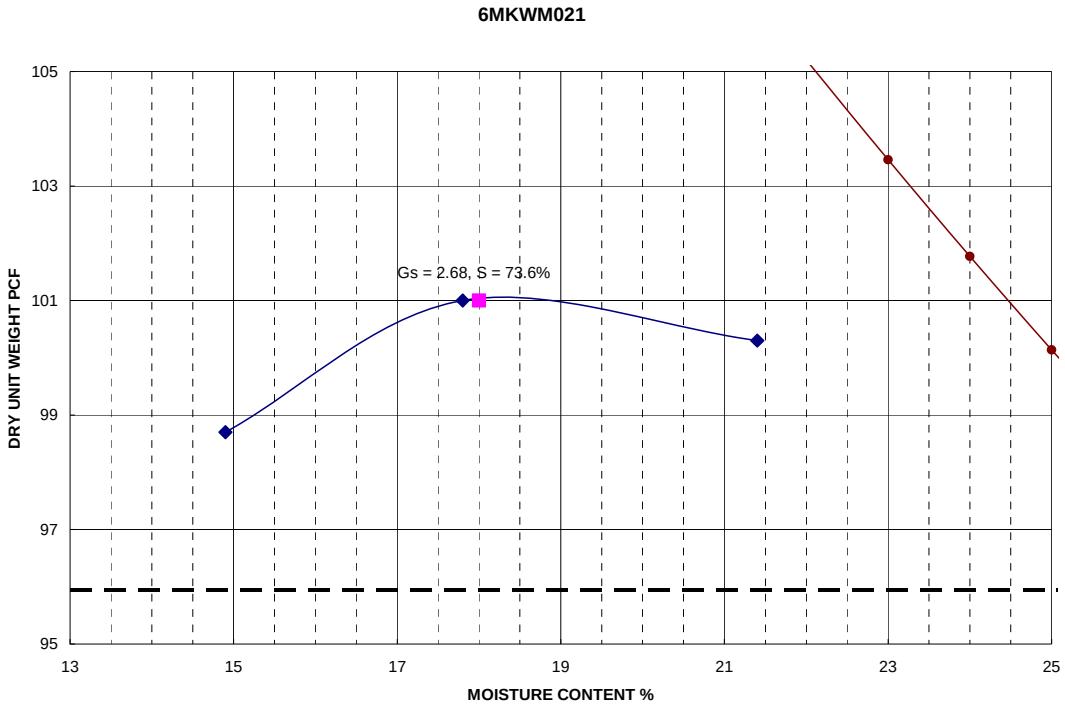


Figure D. 11 – Compaction Curve for Soil 6MKWM021

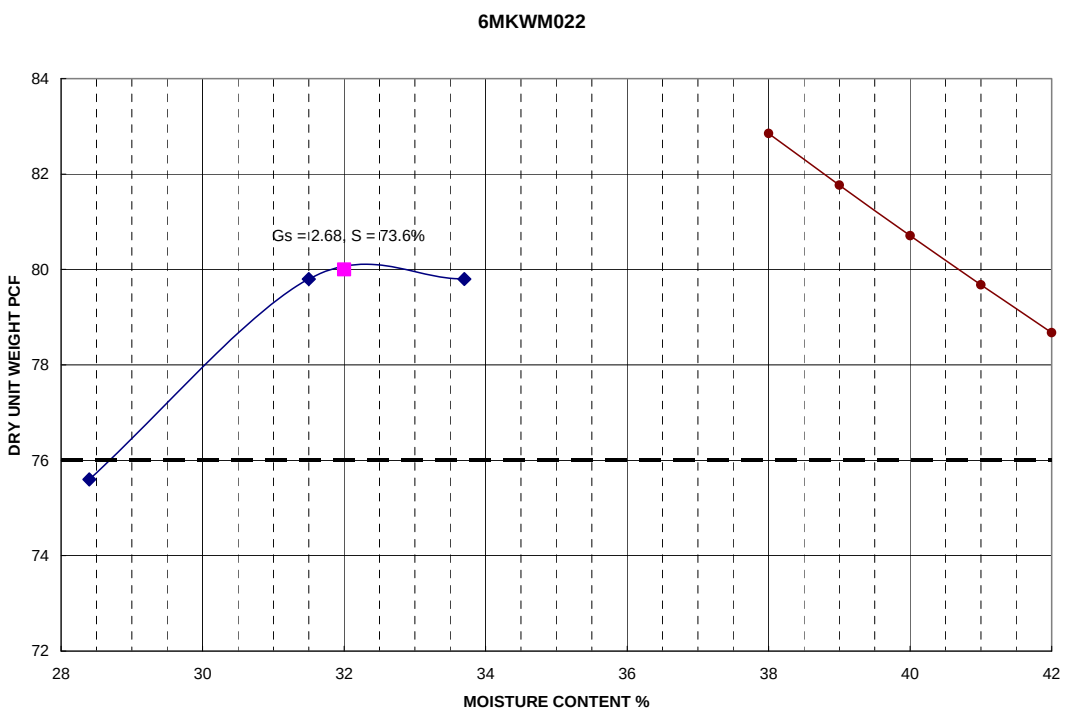


Figure D. 12 – Compaction Curve for Soil 6MKWM022

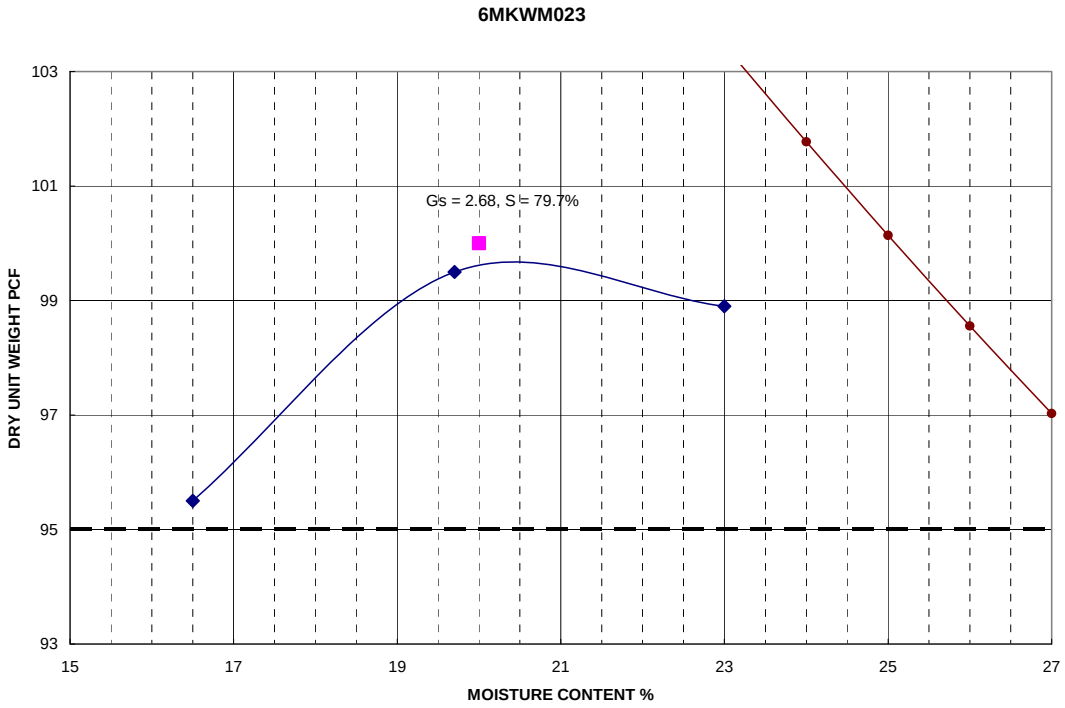


Figure D. 13 – Compaction Curve for Soil 6MKWM023

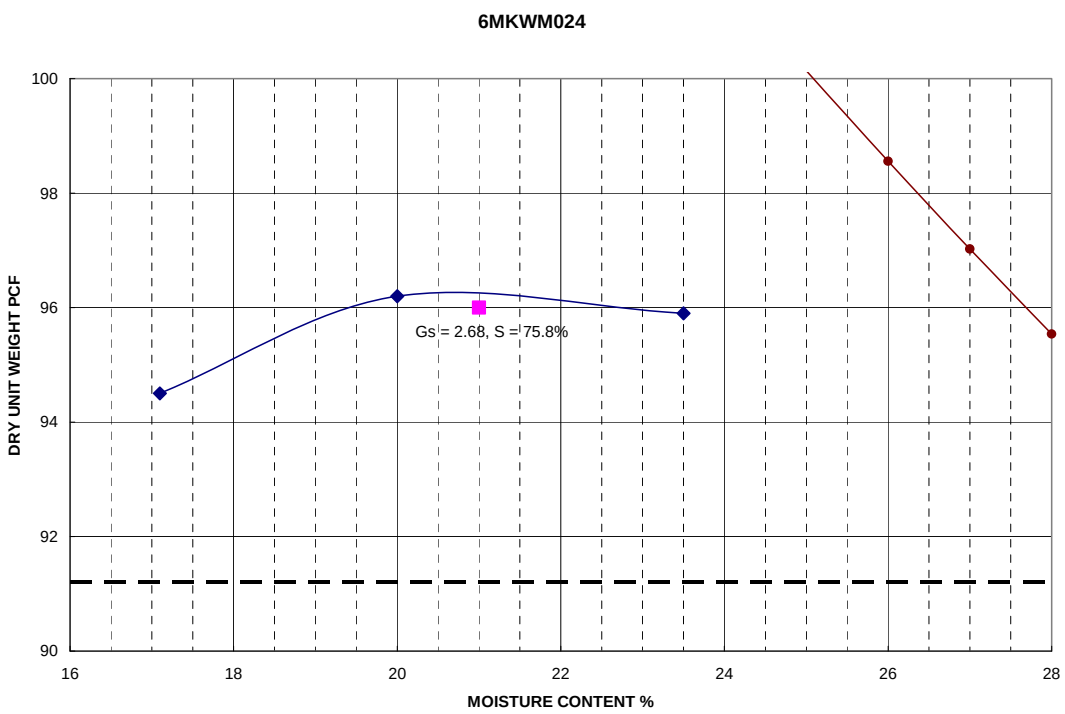


Figure D. 14 – Compaction Curve for Soil 6MKWM024

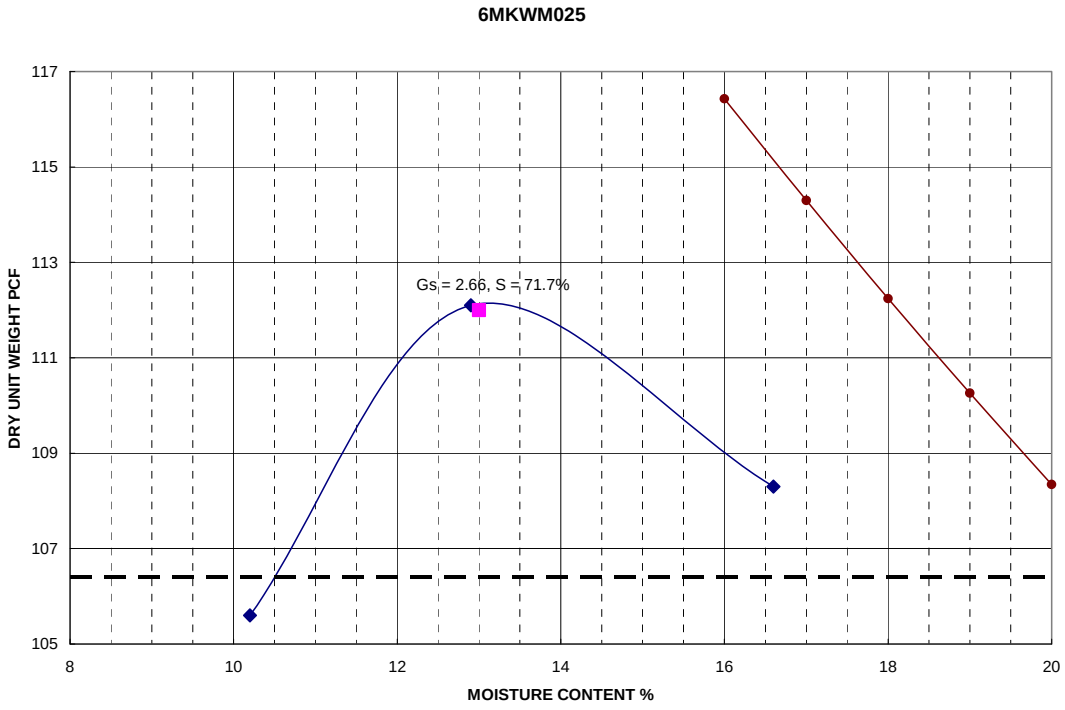


Figure D. 15 – Compaction Curve for Soil 6MKWM025

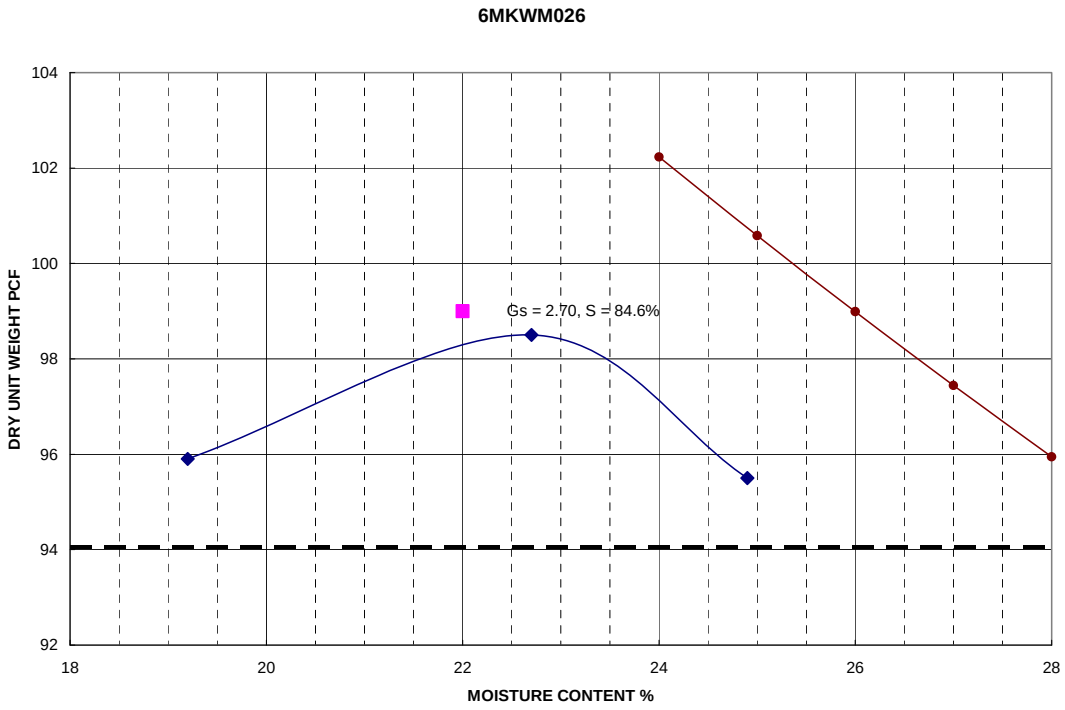


Figure D. 16 – Compaction Curve for Soil 6MKWM026

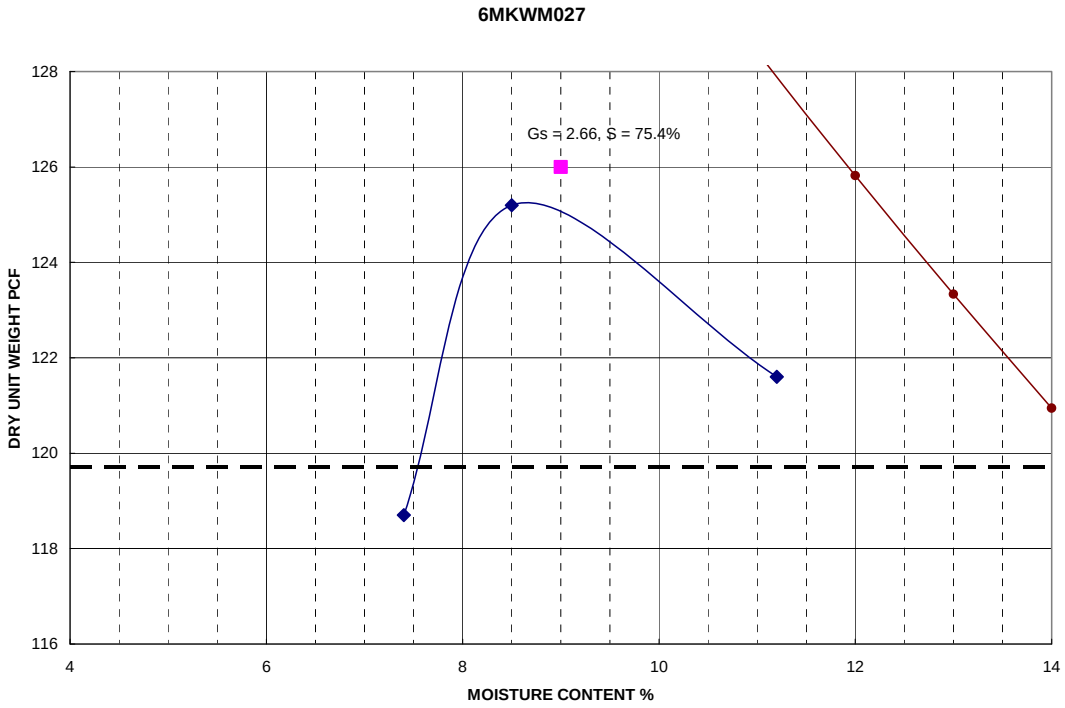


Figure D. 17 – Compaction Curve for Soil 6MKWM027

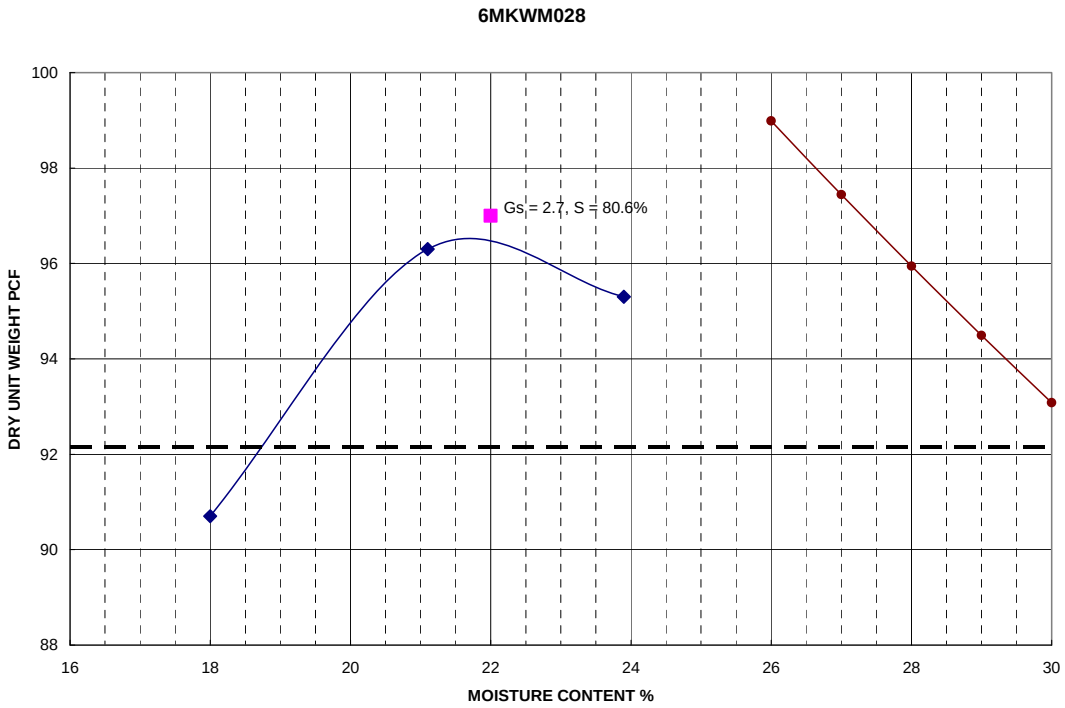


Figure D. 18 – Compaction Curve for Soil 6MKWM028

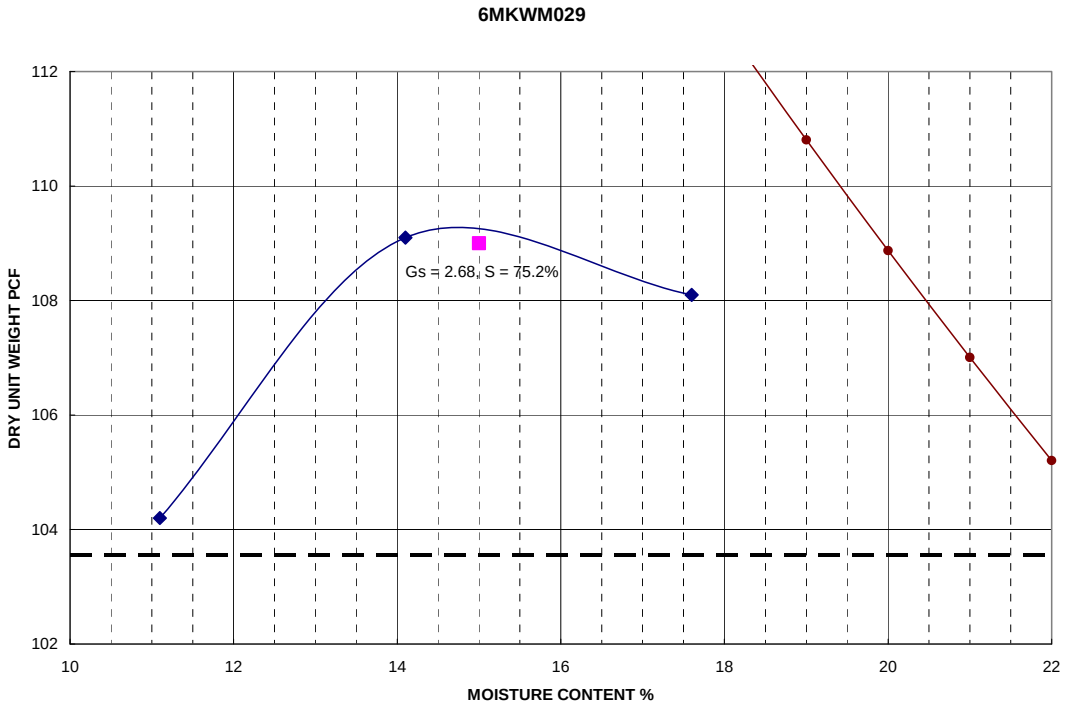


Figure D. 19 – Compaction Curve for Soil 6MKWM029

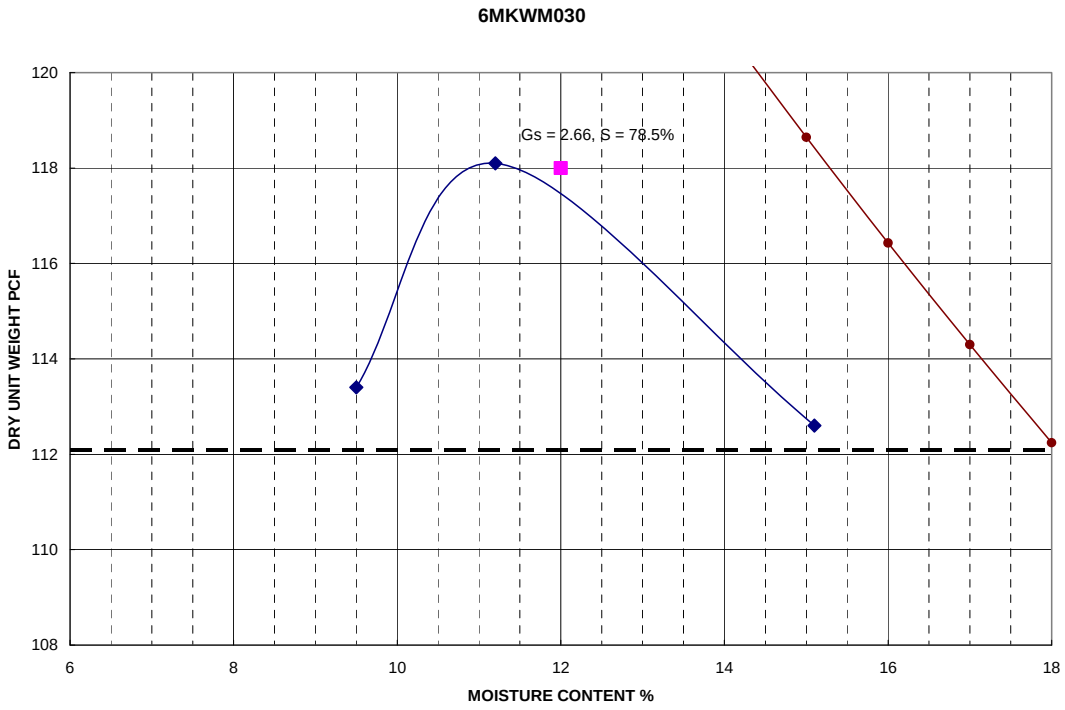


Figure D. 20 – Compaction Curve for Soil 6MKWM030

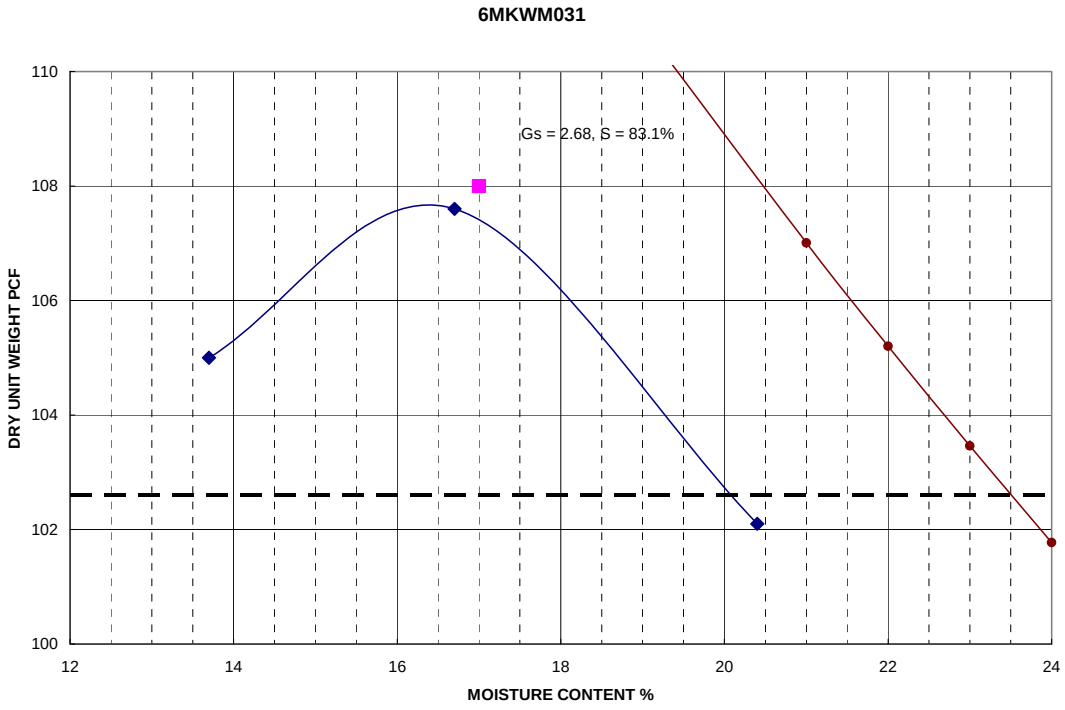


Figure D. 21 – Compaction Curve for Soil 6MKWM031

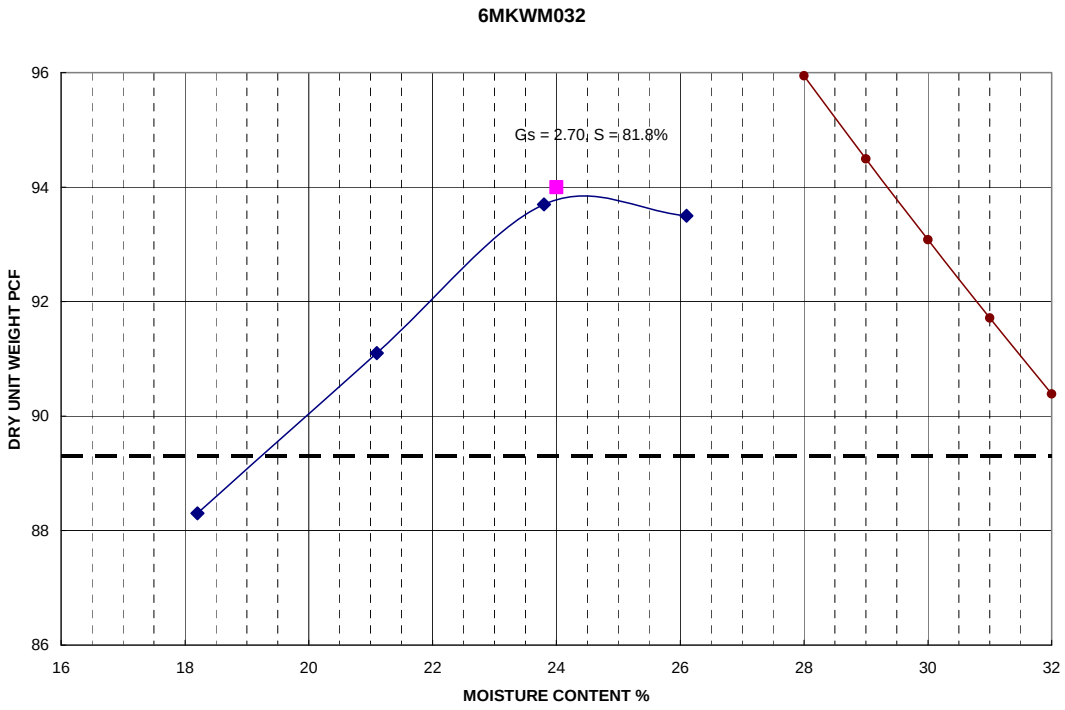


Figure D. 22 – Compaction Curve for Soil 6MKWM032

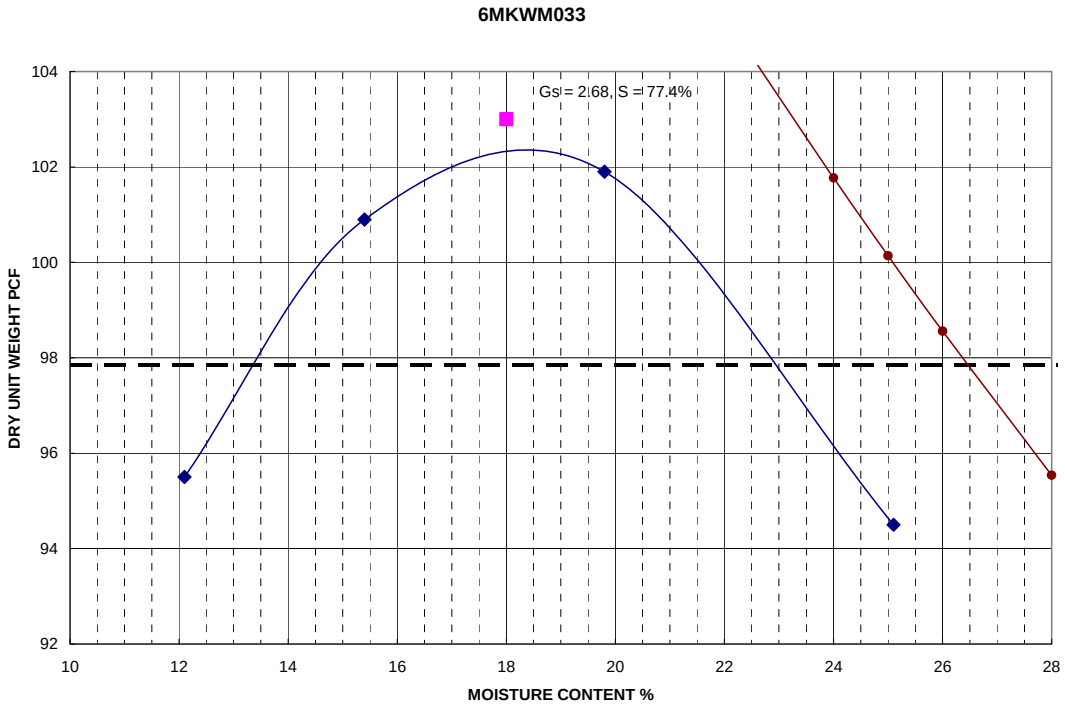


Figure D. 23 – Compaction Curve for Soil 6MKWM033

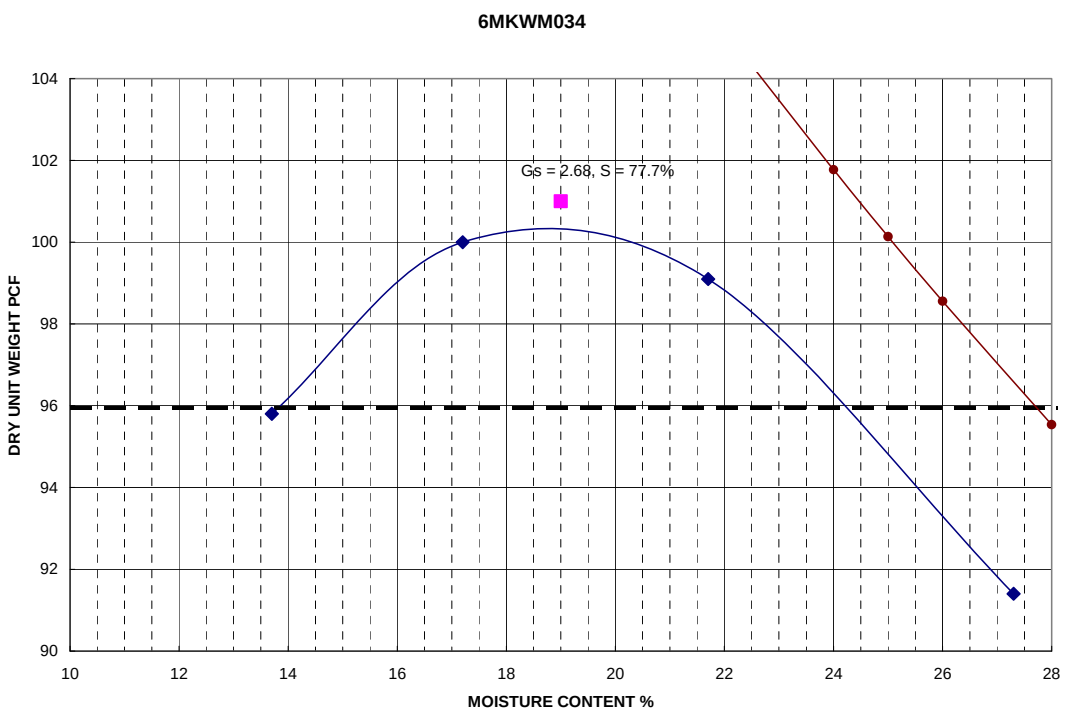


Figure D. 24 – Compaction Curve for Soil 6MKWM034

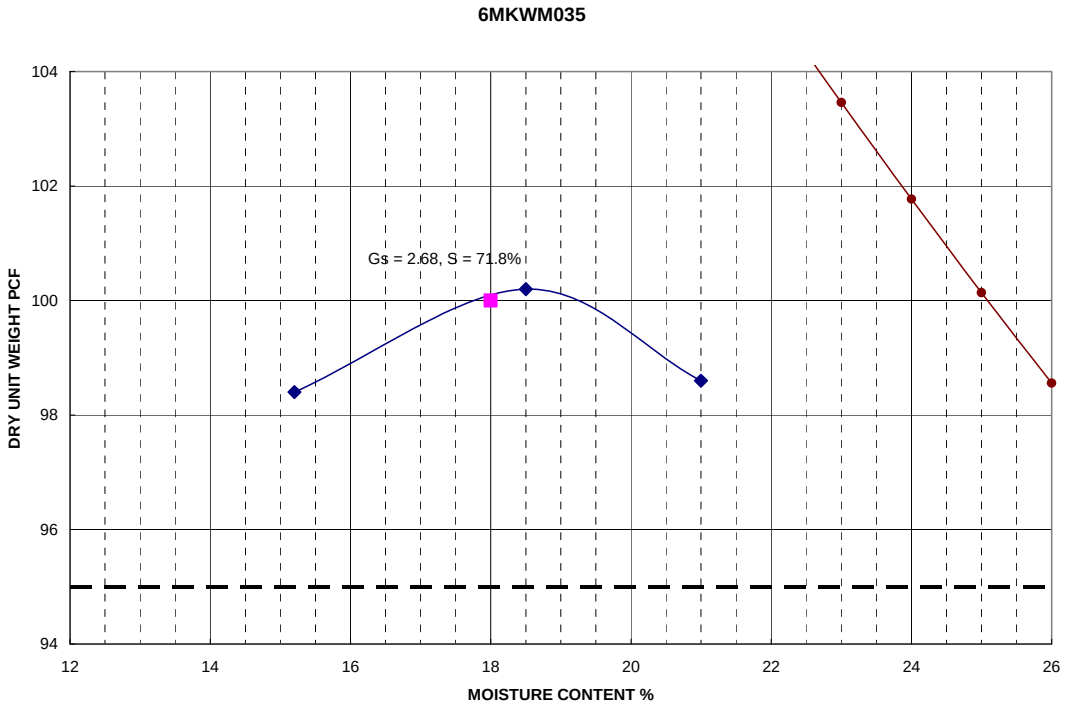


Figure D. 25 – Compaction Curve for Soil 6MKWM035

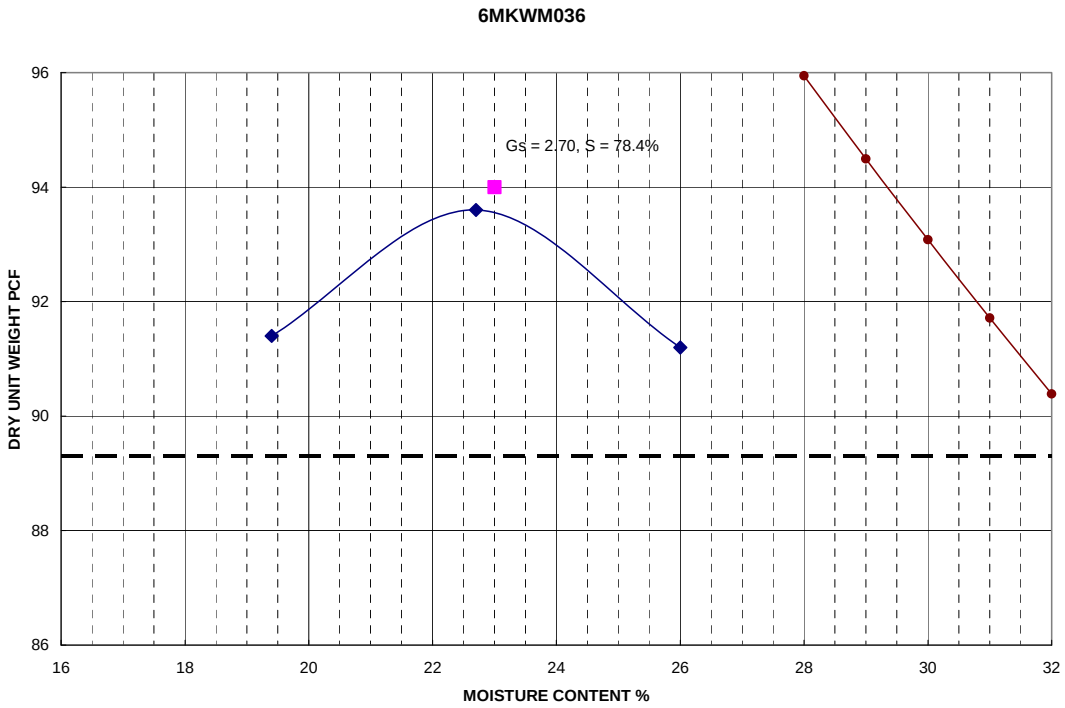


Figure D. 26 – Compaction Curve for Soil 6MKWM036

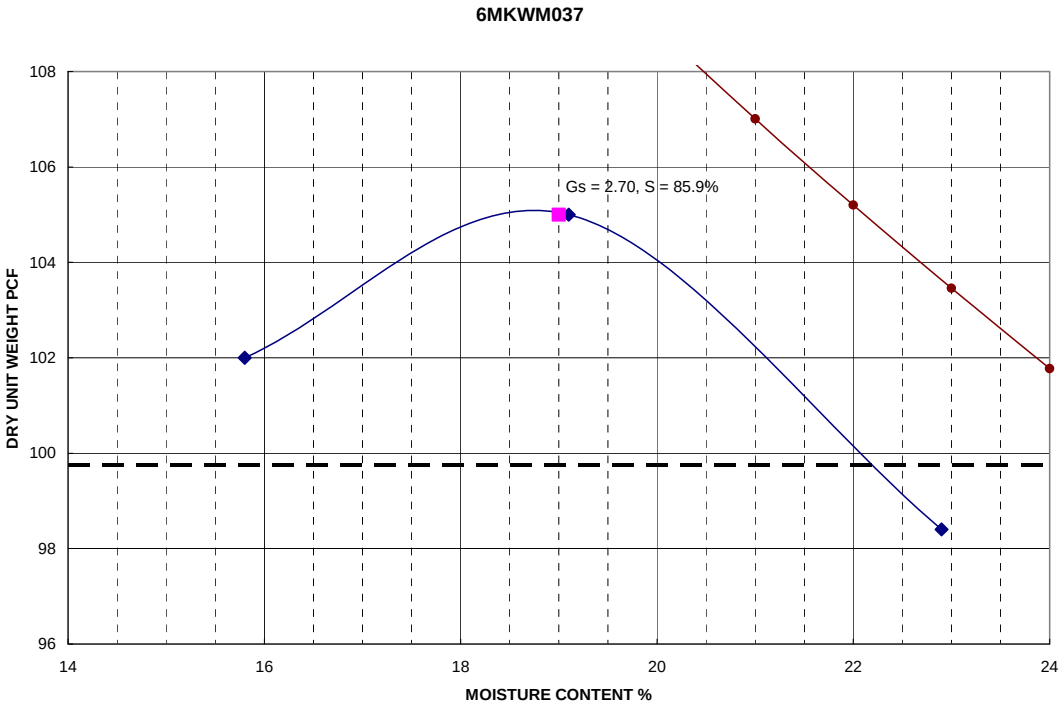


Figure D. 27 – Compaction Curve for Soil 6MKWM037

APPENDIX E: SUBGRADE SOILS SUCTION CURVES

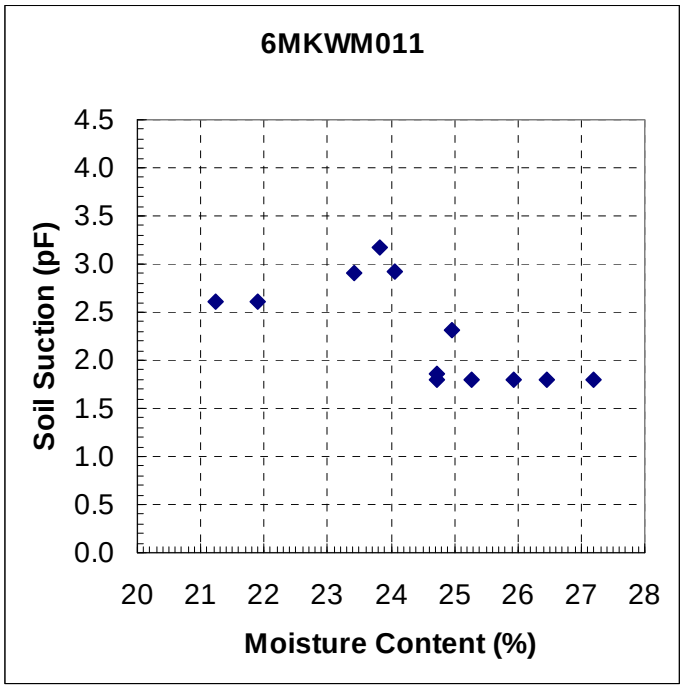


Figure E.1 – Total Suction versus Moisture Content for Soil 6MKWM011

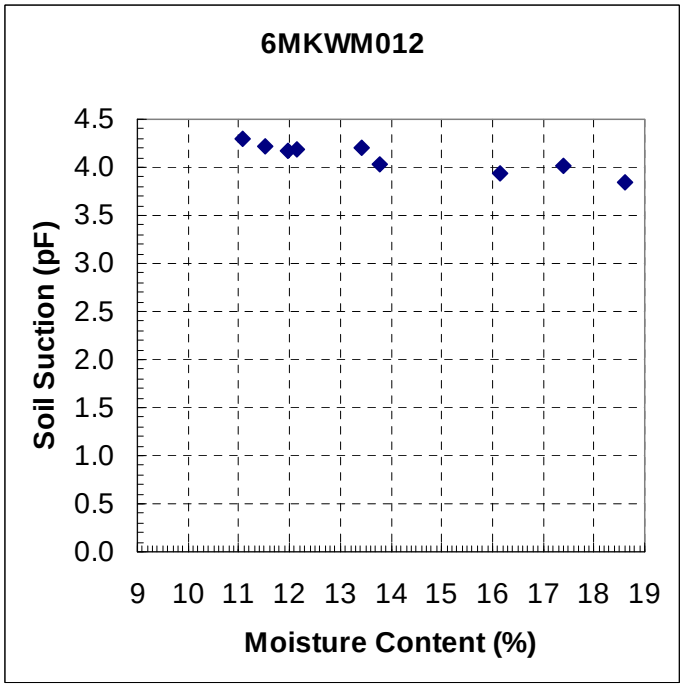


Figure E.2 – Total Suction versus Moisture Content for Soil 6MKWM012

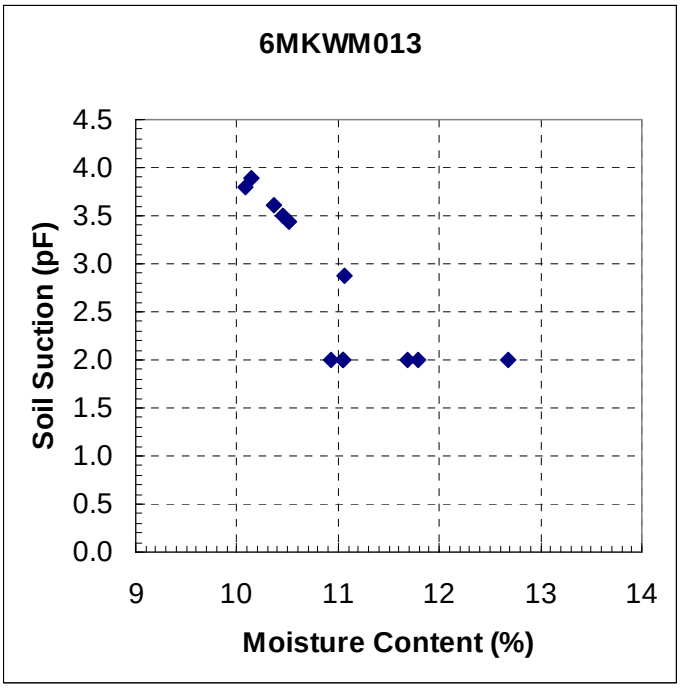


Figure E.3 – Total Suction versus Moisture Content for Soil 6MKWM013

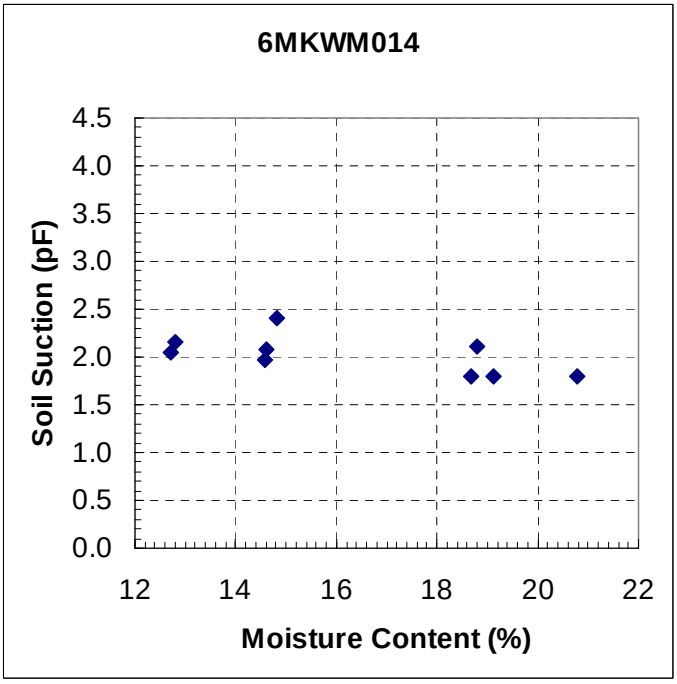


Figure E.4 – Total Suction versus Moisture Content for Soil 6MKWM014

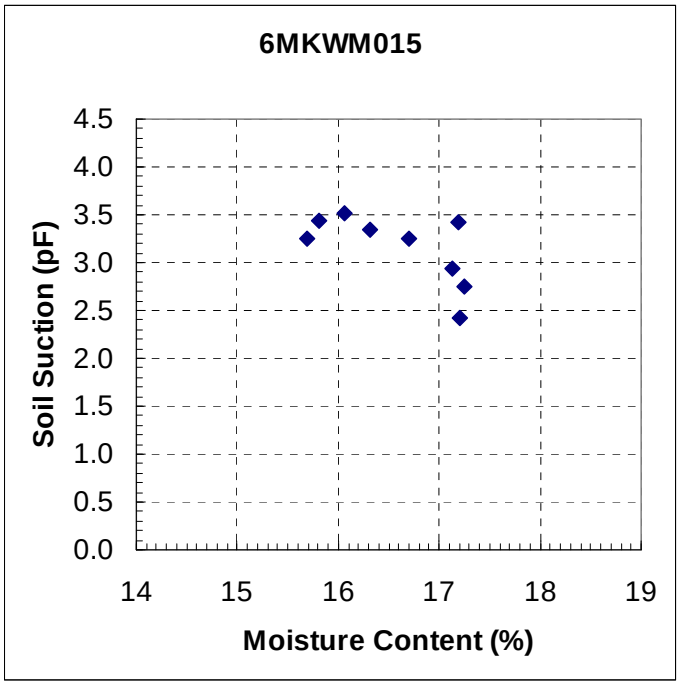


Figure E.5 – Total Suction versus Moisture Content for Soil 6MKWM015

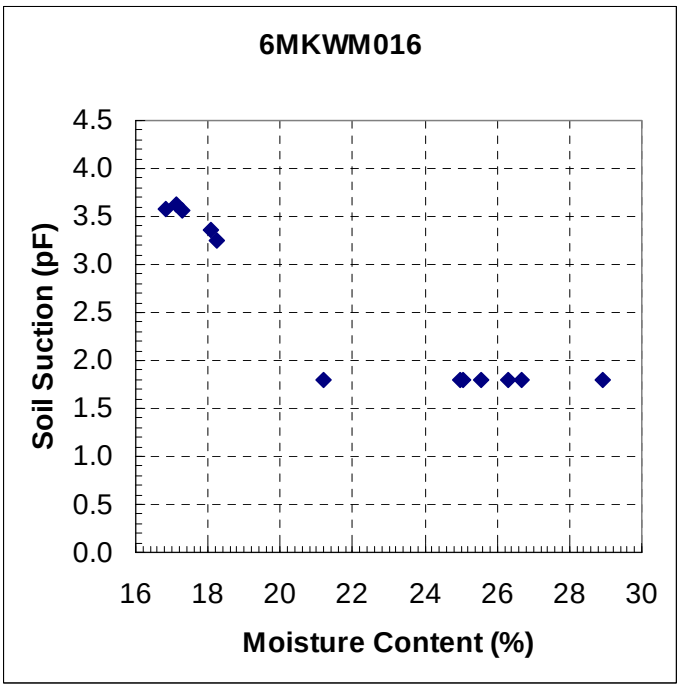


Figure E.6 – Total Suction versus Moisture Content for Soil 6MKWM016

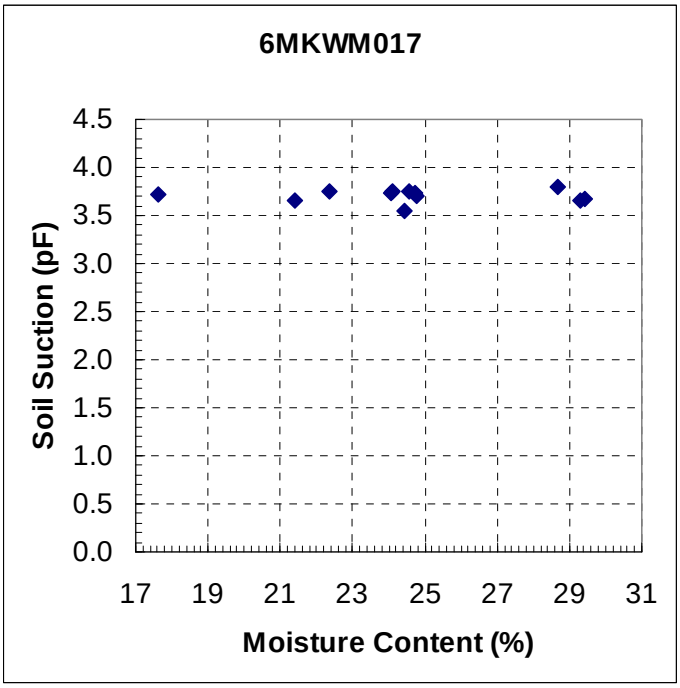


Figure E.7 – Total Suction versus Moisture Content for Soil 6MKWM017

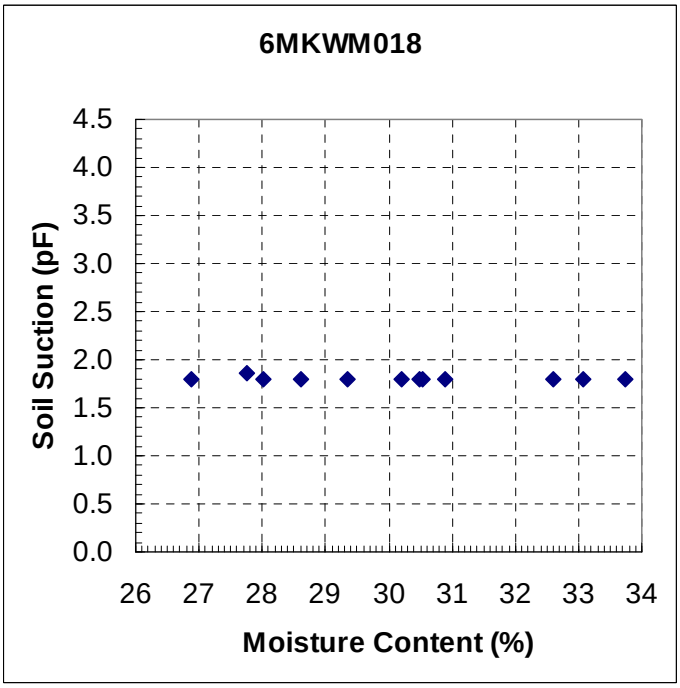


Figure E.8 – Total Suction versus Moisture Content for Soil 6MKWM018

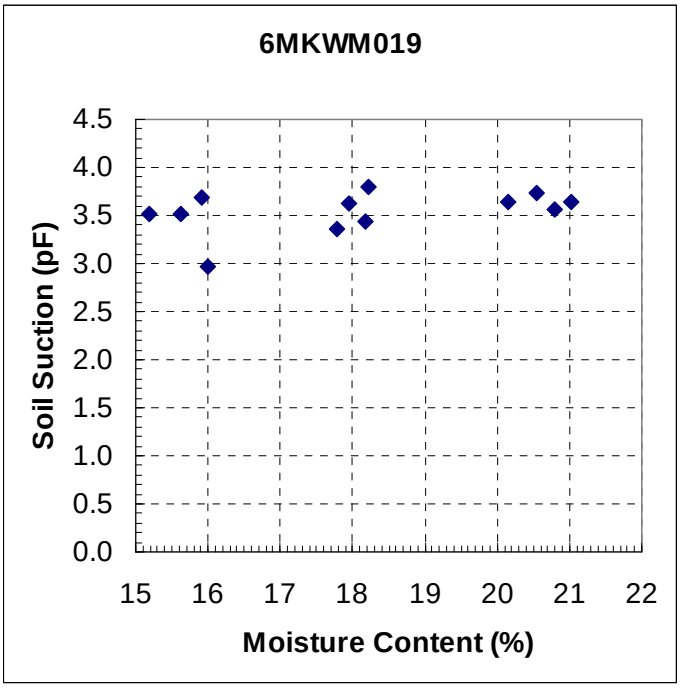


Figure E.9 – Total Suction versus Moisture Content for Soil 6MKWM019

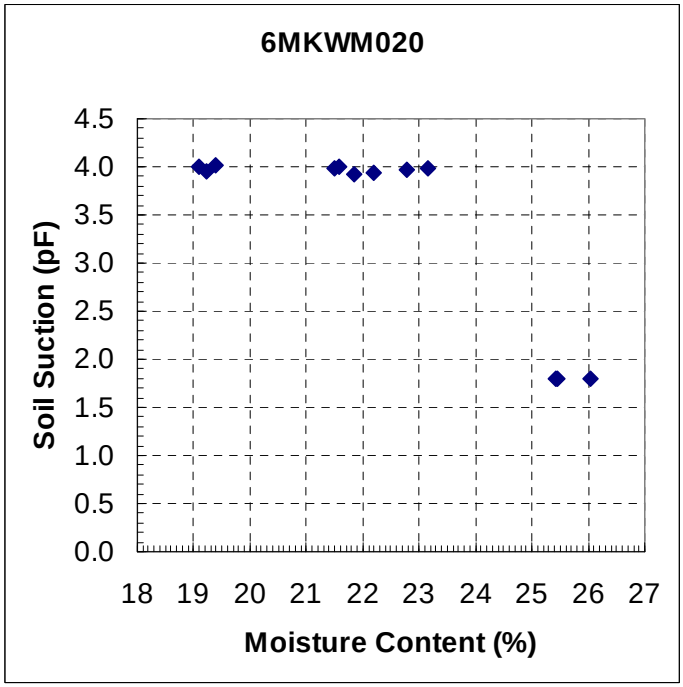


Figure E.10 – Total Suction versus Moisture Content for Soil 6MKWM020

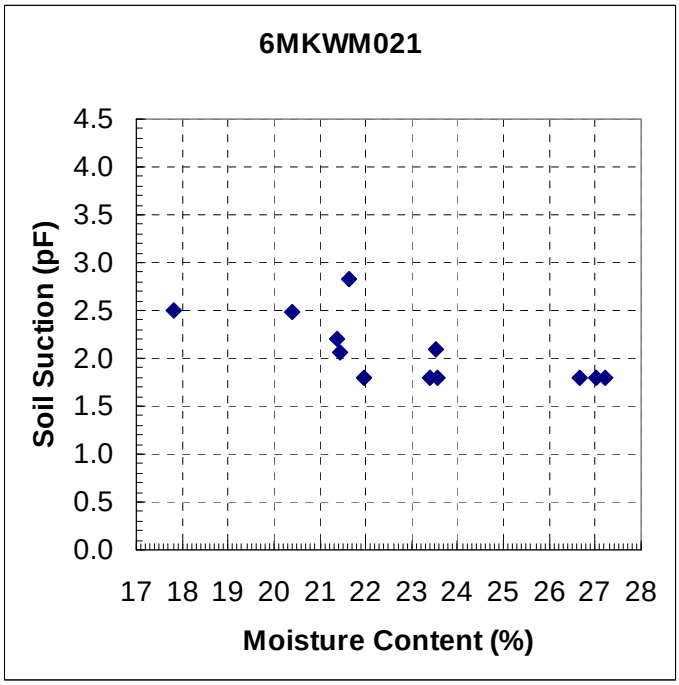


Figure E.11 – Total Suction versus Moisture Content for Soil 6MKWM021

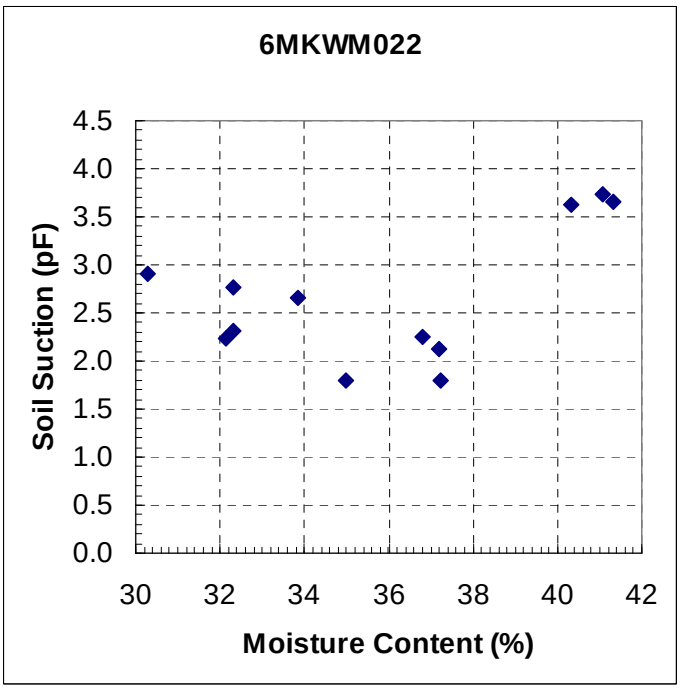


Figure E.12 – Total Suction versus Moisture Content for Soil 6MKWM022

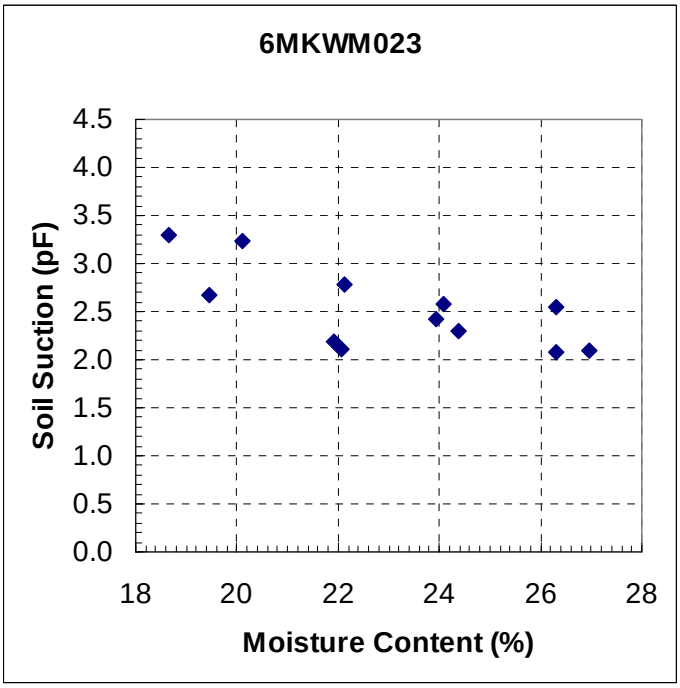


Figure E.13 – Total Suction versus Moisture Content for Soil 6MKWM023

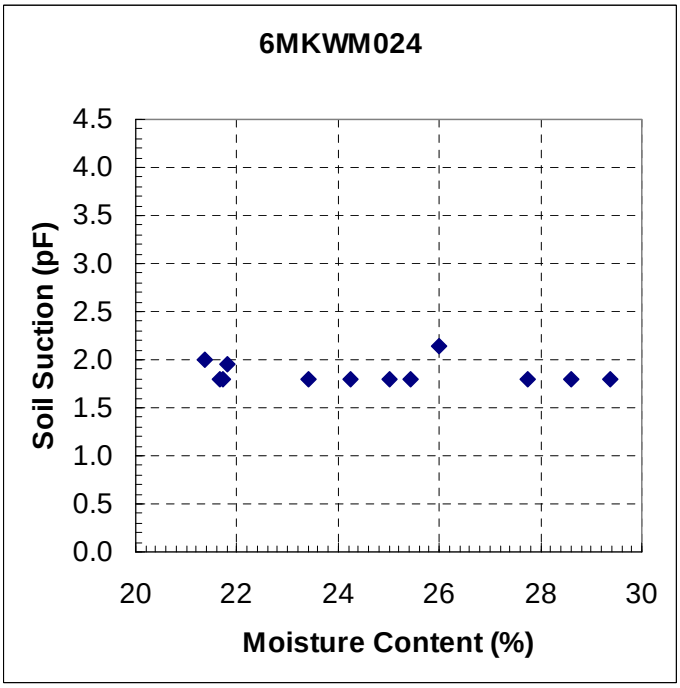


Figure E.14 – Total Suction versus Moisture Content for Soil 6MKWM024

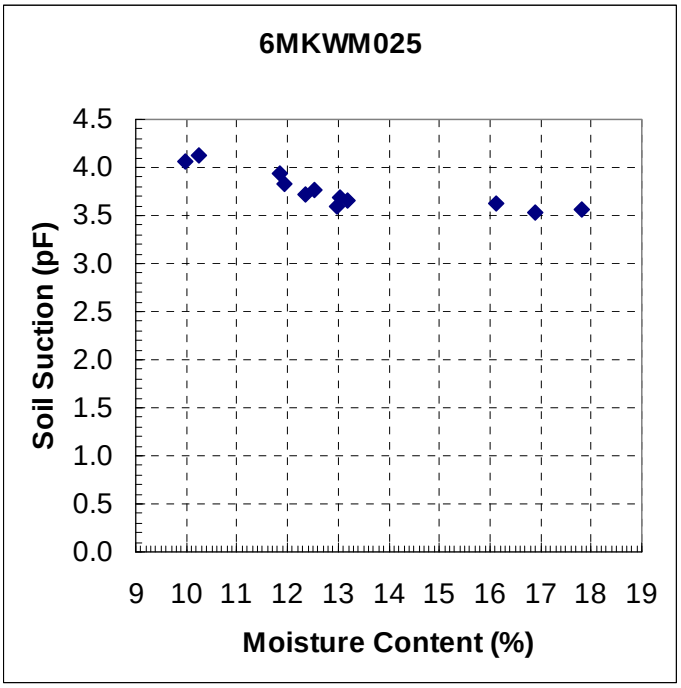


Figure E.15 – Total Suction versus Moisture Content for Soil 6MKWM025

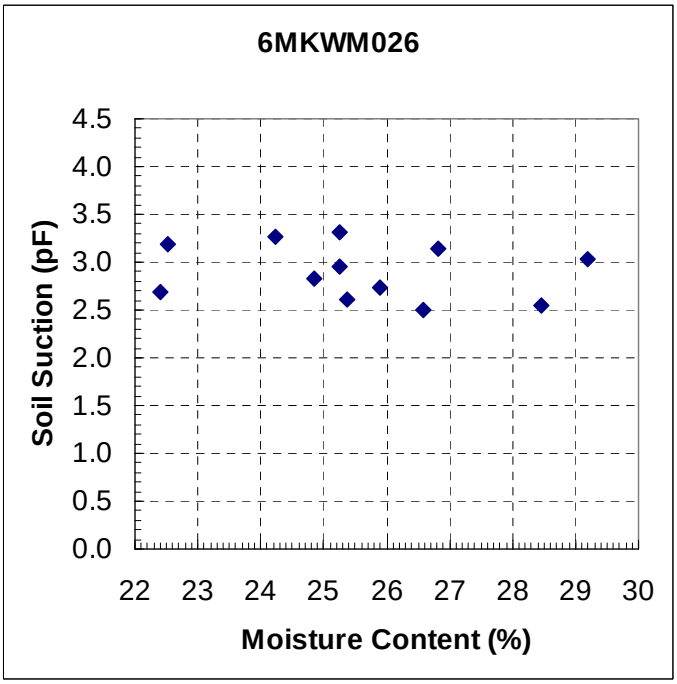


Figure E.16 – Total Suction versus Moisture Content for Soil 6MKWM026

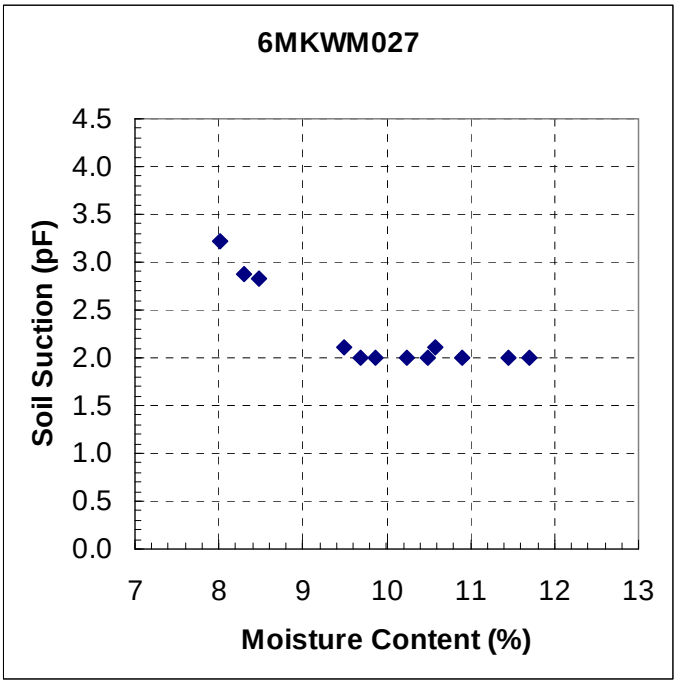


Figure E.17 – Total Suction versus Moisture Content for Soil 6MKWM027

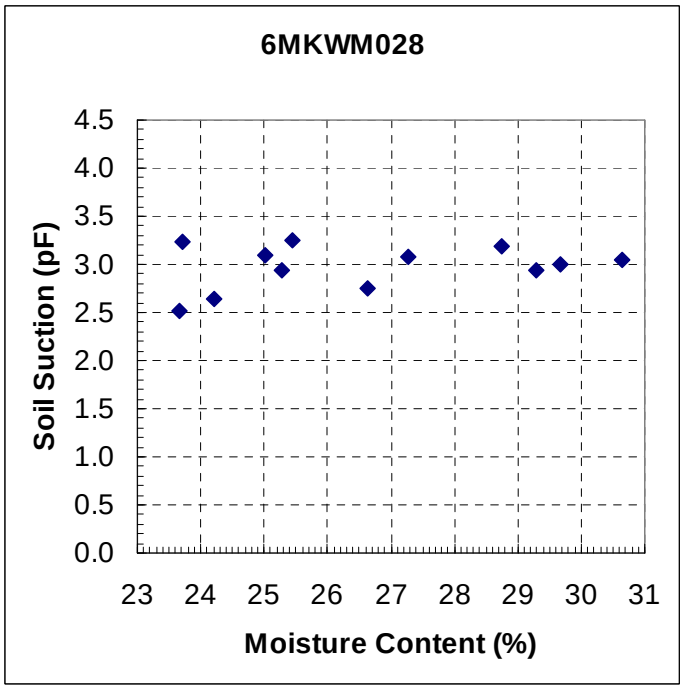


Figure E.18 – Total Suction versus Moisture Content for Soil 6MKWM028

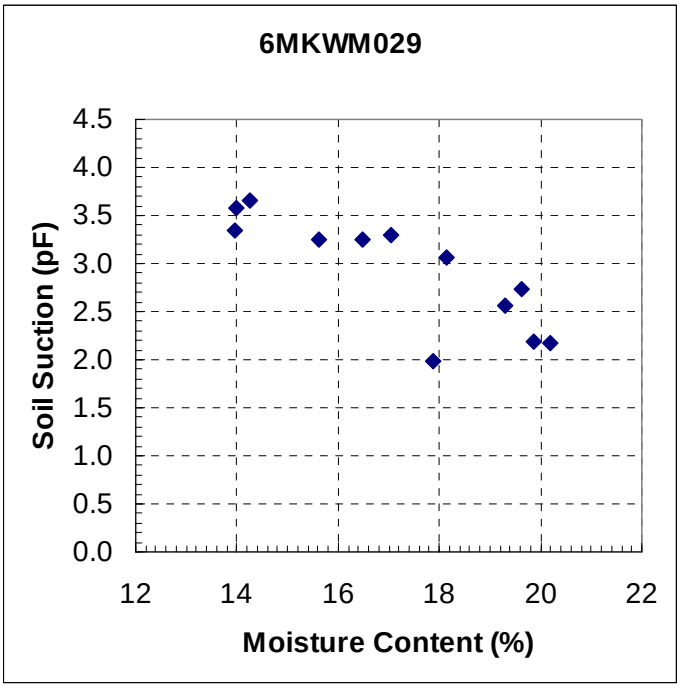


Figure E.19 – Total Suction versus Moisture Content for Soil 6MKWM029

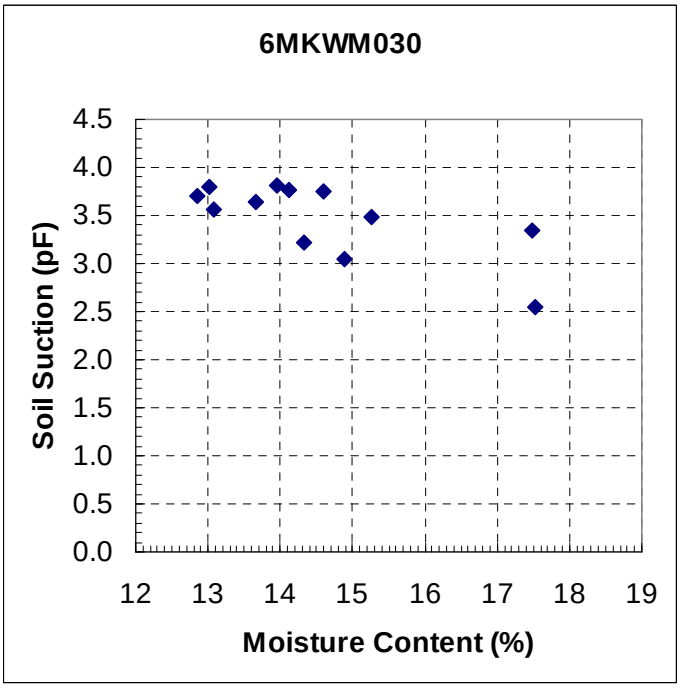


Figure E.20 – Total Suction versus Moisture Content for Soil 6MKWM030

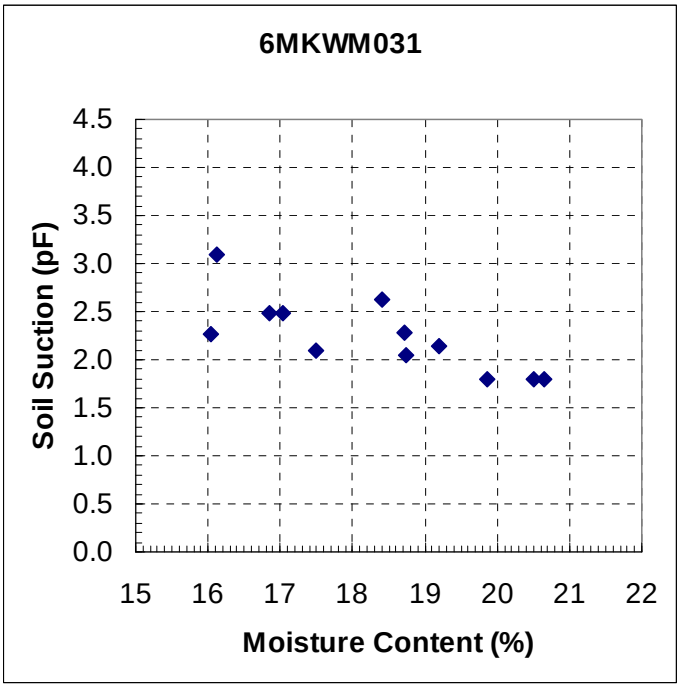


Figure E.21 – Total Suction versus Moisture Content for Soil 6MKWM031

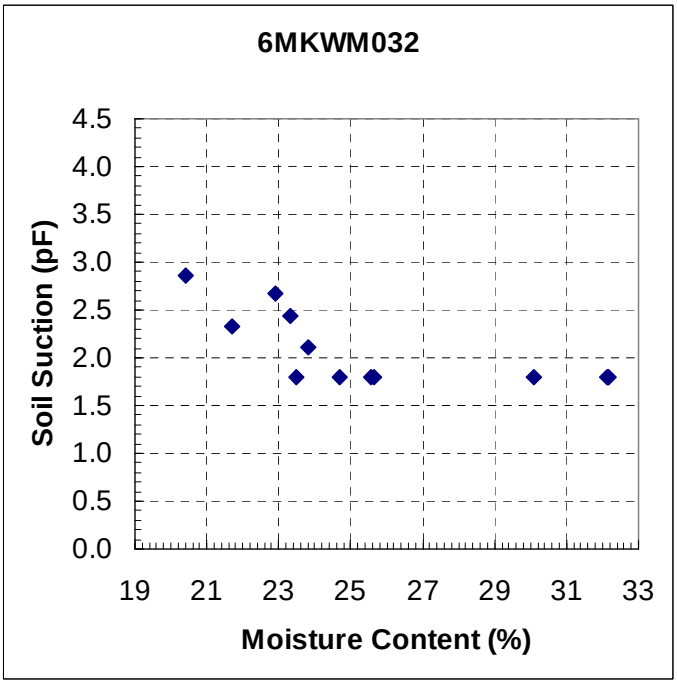


Figure E.22 – Total Suction versus Moisture Content for Soil 6MKWM032

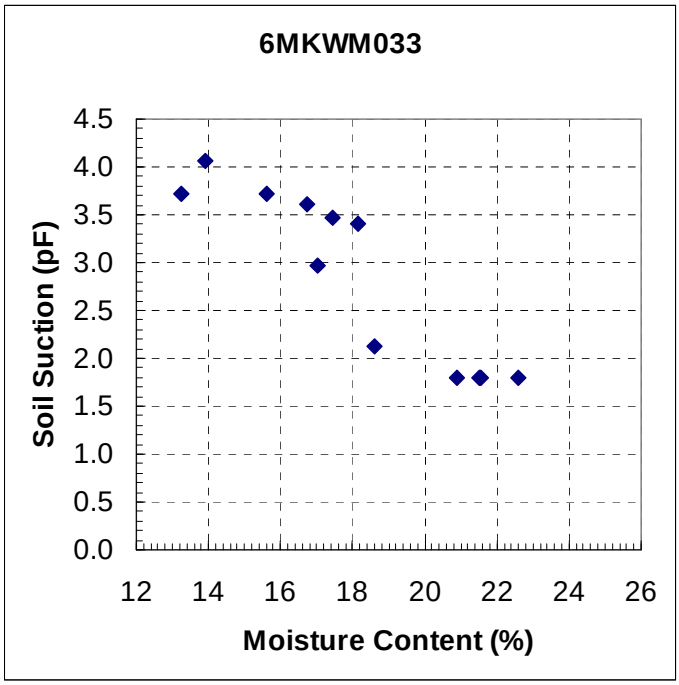


Figure E.23– Total Suction versus Moisture Content for Soil 6MKWM033

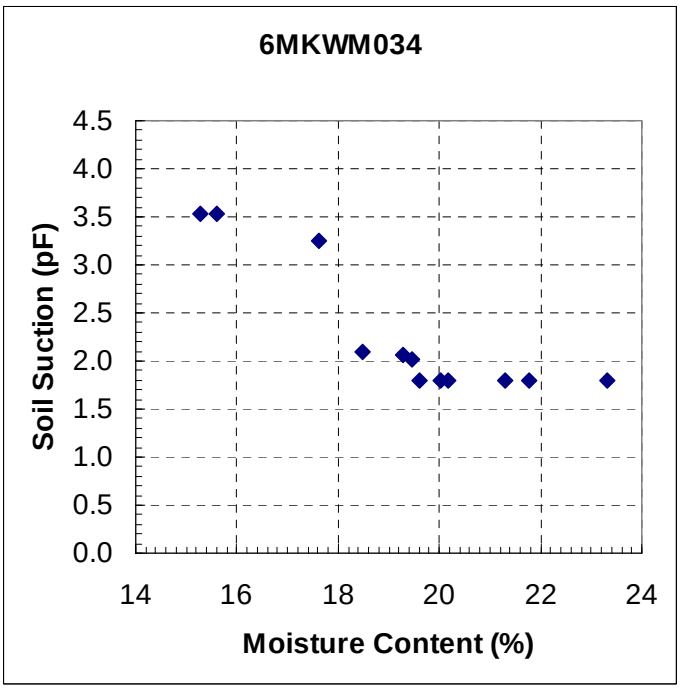


Figure E.24 – Total Suction versus Moisture Content for Soil 6MKWM034

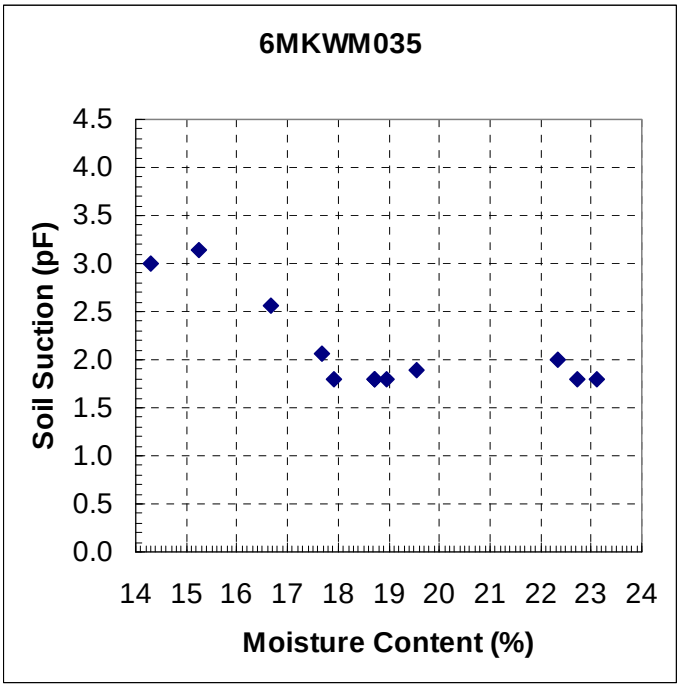


Figure E.25 – Total Suction versus Moisture Content for Soil 6MKWM035

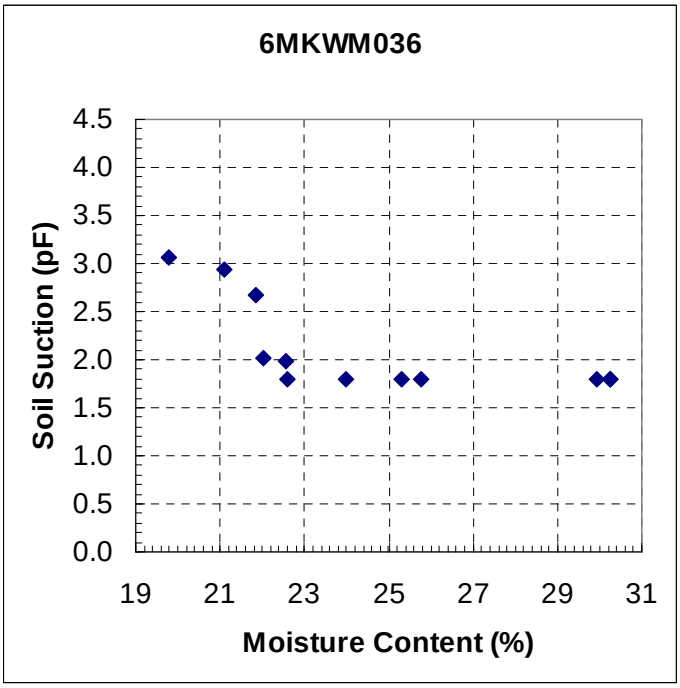


Figure E.26 – Total Suction versus Moisture Content for Soil 6MKWM036

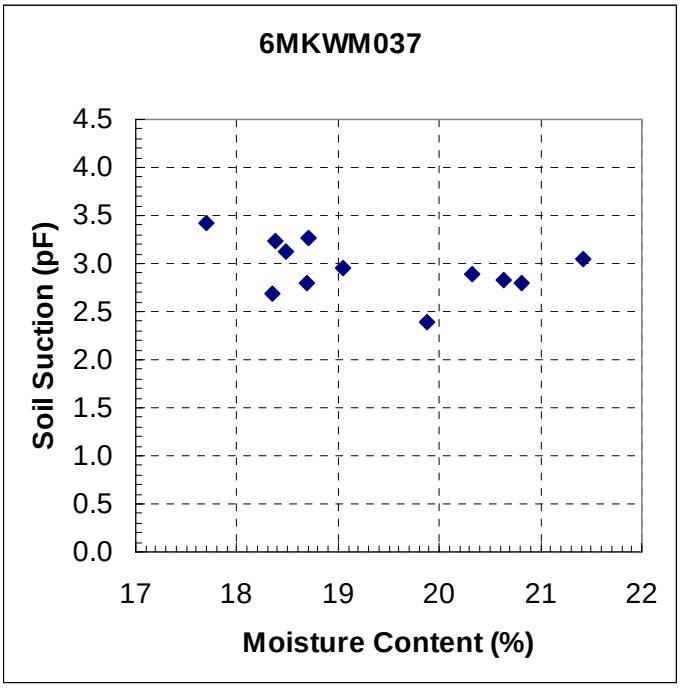


Figure E.27 – Total Suction versus Moisture Content for Soil 6MKWM037

APPENDIX F: GRANULAR BASE M_R TESTS AND EFFECT OF FINES

Table F-1: Jefferson City Dolomite M_r Test Data

Gradation			A-D					W-F		
Replicate	Mr	Sig3	SigD	Theta	Oct	Mr	Sig3	SigD	Theta	Oct
1	25446	3.01	3.12	12.15	1.47	16897	3.04	3.19	12.31	1.50
1	25646	2.99	6.08	15.05	2.87	16297	3.02	6.09	15.15	2.87
1	27735	2.98	9.13	18.07	4.30	17661	3.02	9.18	18.24	4.33
1	31658	4.99	5.23	20.20	2.47	20562	5.02	5.26	20.32	2.48
1	34548	5.01	10.21	25.24	4.81	22220	5.01	10.24	25.27	4.83
1	36547	5.02	15.15	30.21	7.14	24042	5.01	15.21	30.24	7.17
1	48098	10.00	10.31	40.31	4.86	32818	10.05	10.40	40.55	4.90
1	50534	9.97	20.33	50.24	9.58	35317	10.05	20.46	50.61	9.64
1	49867	9.93	30.42	60.21	14.34	34698	10.04	31.12	61.24	14.67
1	55919	14.97	10.33	55.24	4.87	37119	15.03	10.53	55.62	4.96
1	56129	15.04	15.30	60.42	7.21	38270	15.03	15.46	60.55	7.29
1	61952	15.02	30.30	75.36	14.28	42597	15.03	30.73	75.82	14.49
1	67187	20.08	15.55	75.79	7.33	46965	20.04	15.64	75.76	7.37
1	68677	20.07	20.67	80.88	9.74	48198	20.03	20.79	80.88	9.80
1	72268	20.07	40.85	101.06	19.26	53220	20.03	41.07	101.16	19.36
2	22783	3.05	3.37	12.52	1.59	21573	3.01	3.14	12.17	1.48
2	21771	3.06	6.01	15.19	2.83	19765	3.01	6.09	15.12	2.87
2	23399	3.06	9.13	18.31	4.30	21113	3.02	9.15	18.21	4.31
2	28189	5.05	5.23	20.38	2.47	24867	5.04	5.23	20.35	2.47
2	28723	5.04	10.21	25.33	4.81	26619	5.04	10.23	25.35	4.82
2	30851	5.04	15.16	30.28	7.15	28270	5.04	15.10	30.22	7.12
2	40055	10.02	10.34	40.40	4.87	39052	10.03	10.37	40.46	4.89
2	43986	10.01	20.26	50.29	9.55	40988	10.03	20.34	50.43	9.59
2	44864	10.01	30.25	60.28	14.26	38746	10.03	30.49	60.58	14.37
2	48740	15.01	10.53	55.56	4.96	43955	15.03	10.50	55.59	4.95
2	50281	15.00	15.38	60.38	7.25	44907	15.03	15.46	60.55	7.29
2	54651	15.00	30.53	75.53	14.39	47054	15.03	30.87	75.96	14.55
2	58032	20.08	15.60	75.84	7.35	52325	20.04	15.60	75.72	7.35
2	61324	20.08	20.67	80.91	9.74	54238	20.03	20.71	80.80	9.76
2	65717	20.08	40.54	100.78	19.11	57678	20.04	40.50	100.62	19.09
3	22758	3.02	3.13	12.19	1.48	20376	3.04	3.16	12.28	1.49
3	22085	3.01	6.00	15.03	2.83	19464	3.04	6.04	15.16	2.85
3	23318	3.01	9.10	18.13	4.29	20202	3.04	9.13	18.25	4.30
3	28464	5.01	5.24	20.27	2.47	24567	5.02	5.27	20.33	2.48
3	30383	5.00	10.20	25.20	4.81	24952	5.01	10.19	25.22	4.80
3	32507	5.00	15.22	30.22	7.17	26580	5.01	15.08	30.11	7.11
3	44394	10.02	10.27	40.33	4.84	36814	10.01	10.38	40.41	4.89
3	47361	10.01	20.29	50.32	9.56	38853	10.01	20.46	50.49	9.64
3	47258	10.01	30.42	60.45	14.34	37562	10.01	30.40	60.43	14.33
3	51209	15.03	10.47	55.56	4.94	43119	15.03	10.52	55.61	4.96
3	52123	15.03	15.48	60.57	7.30	43064	15.02	15.47	60.53	7.29
3	57798	15.03	30.64	75.73	14.44	46232	15.02	30.84	75.90	14.54
3	61609	20.00	15.76	75.76	7.43	51950	20.03	15.60	75.69	7.35
3	64428	20.00	20.77	80.77	9.79	52887	20.03	20.73	80.82	9.77
3	70512	20.00	40.21	100.21	18.96	54423	20.03	40.96	101.05	19.31

NOTE: All values have units of psi

Table F-2: Gasconade Dolomite M_r Test Data

Gradation			A-D					W-F		
Replicate	Mr	Sig3	SigD	Theta	Oct	Mr	Sig3	SigD	Theta	Oct
1	18164	3.00	3.12	12.12	1.47	20189	3.03	3.14	12.23	1.48
1	19475	3.00	6.01	15.01	2.83	20058	3.03	6.10	15.19	2.88
1	22222	3.00	9.13	18.13	4.30	21517	3.03	9.18	18.27	4.33
1	25974	4.98	5.18	20.12	2.44	27900	5.03	5.25	20.34	2.47
1	29066	4.99	10.24	25.21	4.83	27875	5.02	10.26	25.32	4.84
1	32324	5.00	15.14	30.14	7.14	29550	5.02	15.11	30.17	7.12
1	44375	10.04	10.30	40.42	4.86	42756	10.03	10.31	40.40	4.86
1	48794	10.03	20.42	50.51	9.63	43559	10.02	20.45	50.51	9.64
1	50543	10.03	30.51	60.60	14.38	42770	10.01	30.62	60.65	14.43
1	55420	15.03	10.44	55.53	4.92	48691	15.01	10.52	55.55	4.96
1	56076	15.03	15.44	60.53	7.28	48519	15.01	15.41	60.44	7.26
1	60307	15.03	30.67	75.76	14.46	52034	15.00	30.70	75.70	14.47
1	65540	20.01	15.44	75.47	7.28	57442	20.04	15.63	75.75	7.37
1	67854	20.05	20.74	80.89	9.78	58194	20.04	20.68	80.80	9.75
1	72501	20.05	41.18	101.33	19.41	60846	20.03	40.74	100.83	19.21
2	18238	2.96	3.11	11.99	1.47	21284	3.02	3.13	12.19	1.48
2	19796	3.03	6.02	15.11	2.84	20096	3.02	6.06	15.12	2.86
2	21832	3.02	9.04	18.10	4.26	21914	3.02	9.10	18.16	4.29
2	25805	5.04	5.27	20.39	2.48	25838	5.02	5.21	20.27	2.46
2	28422	4.98	10.23	25.17	4.82	27357	5.01	10.14	25.17	4.78
2	31249	4.98	15.02	29.96	7.08	29421	5.01	15.06	30.09	7.10
2	42807	10.04	10.39	40.51	4.90	40176	10.04	10.39	40.51	4.90
2	46558	10.04	20.52	50.64	9.67	43178	10.04	20.38	50.50	9.61
2	46966	10.04	30.40	60.52	14.33	42858	10.03	30.53	60.62	14.39
2	52104	15.02	10.53	55.59	4.96	46995	15.04	10.46	55.58	4.93
2	53294	15.01	15.55	60.58	7.33	48839	15.04	15.39	60.51	7.25
2	58041	15.01	30.85	75.88	14.54	52022	15.04	30.65	75.77	14.45
2	62145	20.04	15.61	75.73	7.36	57795	20.04	15.58	75.70	7.34
2	64164	20.04	20.42	80.54	9.63	58606	20.04	20.64	80.76	9.73
2	69200	20.04	41.15	101.27	19.40	61182	20.04	40.89	101.01	19.28
3	16801	3.01	3.15	12.18	1.48	16081	3.03	3.12	12.21	1.47
3	18021	3.04	6.01	15.13	2.83	16383	3.04	6.07	15.19	2.86
3	20183	3.05	9.11	18.26	4.29	18391	3.04	9.15	18.27	4.31
3	23428	5.02	5.21	20.27	2.46	21703	5.01	5.25	20.28	2.47
3	26757	5.03	10.15	25.24	4.78	24049	5.01	10.25	25.28	4.83
3	28755	5.04	15.10	30.22	7.12	26333	5.01	15.06	30.09	7.10
3	40975	9.98	10.36	40.30	4.88	37707	10.03	10.36	40.45	4.88
3	45312	9.99	20.61	50.58	9.72	40638	10.03	20.39	50.48	9.61
3	45244	9.99	30.59	60.56	14.42	40109	10.03	30.33	60.42	14.30
3	49483	15.02	10.43	55.49	4.92	44215	15.04	10.52	55.64	4.96
3	51113	15.01	15.40	60.43	7.26	44805	15.04	15.41	60.53	7.26
3	56277	15.00	30.74	75.74	14.49	49906	15.04	30.70	75.82	14.47
3	60847	20.03	15.54	75.63	7.33	53495	20.04	15.64	75.76	7.37
3	63111	20.03	20.68	80.77	9.75	56577	20.04	20.68	80.80	9.75
3	68120	20.02	40.60	100.66	19.14	59068	20.04	40.60	100.72	19.14

NOTE: All values have units of psi

Table F-3: Plattin M_r Test Results

Gradation			A-D					W-F		
Replicate	Mr	Sig3	SigD	Theta	Oct	Mr	Sig3	SigD	Theta	Oct
1	35408	3.05	3.18	12.33	1.50	45749	3.02	3.11	12.17	1.47
1	34869	3.00	6.06	15.06	2.86	44330	3.03	5.84	14.93	2.75
1	36477	3.02	9.11	18.17	4.29	45887	3.03	9.13	18.22	4.30
1	43083	5.02	5.25	20.31	2.47	54972	5.01	5.14	20.17	2.42
1	45589	5.04	10.13	25.25	4.78	56384	5.04	10.28	25.40	4.85
1	47571	5.04	15.24	30.36	7.18	57770	5.04	15.08	30.20	7.11
1	60623	10.02	10.26	40.32	4.84	71116	10.00	10.30	40.30	4.86
1	65492	10.03	20.34	50.43	9.59	75351	9.98	20.22	50.16	9.53
1	64046	10.02	30.33	60.39	14.30	78232	9.99	30.40	60.37	14.33
1	68119	15.01	10.47	55.50	4.94	79827	15.04	10.45	55.57	4.93
1	72448	15.00	15.35	60.35	7.24	83172	15.03	15.39	60.48	7.25
1	77641	15.00	30.52	75.52	14.39	90748	15.02	30.41	75.47	14.34
1	84378	20.00	15.59	75.59	7.35	93147	20.05	15.56	75.71	7.34
1	87057	20.00	20.64	80.64	9.73	99225	20.04	20.61	80.73	9.72
1	88832	20.00	40.64	100.64	19.16	103546	20.03	40.49	100.58	19.09
2	45839	3.01	3.16	12.19	1.49	34925	3.02	3.17	12.23	1.49
2	43950	3.03	6.04	15.13	2.85	33264	3.02	6.12	15.18	2.88
2	44744	3.00	9.07	18.07	4.28	34911	3.02	9.07	18.13	4.28
2	57508	4.99	5.24	20.21	2.47	42638	5.03	5.22	20.31	2.46
2	56188	5.02	10.22	25.28	4.82	43839	5.03	10.21	25.30	4.81
2	59777	5.04	15.06	30.18	7.10	45505	5.03	15.17	30.26	7.15
2	76448	10.03	10.31	40.40	4.86	58529	10.03	10.32	40.41	4.86
2	80486	10.02	20.39	50.45	9.61	62742	10.03	20.30	50.39	9.57
2	81471	10.03	30.53	60.62	14.39	61626	10.03	30.60	60.69	14.42
2	90122	15.02	10.51	55.57	4.95	64768	15.03	10.52	55.61	4.96
2	92342	15.02	15.37	60.43	7.25	66112	15.01	15.36	60.39	7.24
2	96097	15.03	30.76	75.85	14.50	72093	14.98	30.50	75.44	14.38
2	101730	20.02	15.66	75.72	7.38	75142	20.02	15.64	75.70	7.37
2	103325	20.02	20.58	80.64	9.70	79036	20.01	20.62	80.65	9.72
2	109979	20.02	40.53	100.59	19.11	81483	20.00	40.42	100.42	19.05
3	38616	3.00	3.19	12.19	1.50	42212	3.02	3.16	12.22	1.49
3	38017	3.04	6.07	15.19	2.86	40937	3.02	6.03	15.09	2.84
3	39068	3.04	9.07	18.19	4.28	40917	3.01	9.12	18.15	4.30
3	48694	5.01	5.25	20.28	2.47	49087	5.02	5.16	20.22	2.43
3	48606	4.99	10.18	25.15	4.80	48998	5.02	10.20	25.26	4.81
3	51577	5.02	15.09	30.15	7.11	49865	5.02	15.11	30.17	7.12
3	69766	10.01	10.35	40.38	4.88	65674	10.04	10.33	40.45	4.87
3	73065	10.03	20.54	50.63	9.68	65897	10.03	20.39	50.48	9.61
3	73228	10.04	30.53	60.65	14.39	63152	10.03	30.38	60.47	14.32
3	78234	15.04	10.46	55.58	4.93	68819	15.03	10.48	55.57	4.94
3	80573	15.03	15.39	60.48	7.25	71645	15.02	15.46	60.52	7.29
3	87949	15.02	30.72	75.78	14.48	74475	15.02	30.52	75.58	14.39
3	94228	20.04	15.55	75.67	7.33	79211	20.01	15.57	75.60	7.34
3	94713	20.03	20.61	80.70	9.72	81406	20.01	20.74	80.77	9.78
3	100455	20.03	40.52	100.61	19.10	82957	20.01	40.69	100.72	19.18

NOTE: All values have units of psi

Table F-4: Winterset M_r Test Data

Gradation			A-D					W-F		
Replicate	Mr	Sig3	SigD	Theta	Oct	Mr	Sig3	SigD	Theta	Oct
1	30748	3.04	3.13	12.25	1.48	32879	3.03	3.17	12.26	1.49
1	29548	2.99	6.01	14.98	2.83	29777	3.04	6.05	15.17	2.85
1	31123	3.01	9.01	18.04	4.25	29777	3.04	9.12	18.24	4.30
1	36502	4.96	5.23	20.11	2.47	36766	5.01	5.27	20.30	2.48
1	38910	5.01	10.19	25.22	4.80	35588	5.01	10.18	25.21	4.80
1	41264	5.03	15.03	30.12	7.09	36659	5.01	15.11	30.14	7.12
1	53368	10.01	10.38	40.41	4.89	48835	10.02	10.35	40.41	4.88
1	57025	10.01	20.44	50.47	9.64	50853	9.99	20.29	50.26	9.56
1	57763	10.03	30.59	60.68	14.42	48896	9.98	30.30	60.24	14.28
1	61637	15.02	10.45	55.51	4.93	54375	15.01	10.52	55.55	4.96
1	64891	15.01	15.39	60.42	7.25	54734	15.00	15.46	60.46	7.29
1	68568	15.00	30.65	75.65	14.45	59022	15.00	30.54	75.54	14.40
1	71780	20.02	15.54	75.60	7.33	62779	20.05	15.59	75.74	7.35
1	74427	20.02	20.59	80.65	9.71	65859	20.04	20.68	80.80	9.75
1	79441	20.01	40.64	100.67	19.16	67737	20.04	40.80	100.92	19.23
2	31861	3.03	3.16	12.25	1.49	32339	3.02	3.17	12.23	1.49
2	28180	3.03	6.03	15.12	2.84	28672	3.03	6.09	15.18	2.87
2	29319	3.02	9.05	18.11	4.27	28758	3.03	9.12	18.21	4.30
2	35243	5.02	5.25	20.31	2.47	34947	5.02	5.27	20.33	2.48
2	36055	5.00	10.14	25.14	4.78	35630	5.03	10.22	25.31	4.82
2	38427	4.99	15.03	30.00	7.09	37425	5.03	15.07	30.16	7.10
2	51184	10.04	10.35	40.47	4.88	49245	10.00	10.36	40.36	4.88
2	54402	10.00	20.31	50.31	9.57	51492	9.98	20.39	50.33	9.61
2	54915	10.02	30.26	60.32	14.26	51692	10.00	30.54	60.54	14.40
2	60218	15.02	10.46	55.52	4.93	56131	15.01	10.52	55.55	4.96
2	61027	15.02	15.37	60.43	7.25	57999	15.00	15.47	60.47	7.29
2	66070	15.01	30.63	75.66	14.44	60707	14.99	30.51	75.48	14.38
2	69485	20.05	15.54	75.69	7.33	65033	20.05	15.63	75.78	7.37
2	72578	20.05	20.64	80.79	9.73	67262	20.04	20.71	80.83	9.76
2	76151	20.05	40.69	100.84	19.18	70811	20.02	40.72	100.78	19.20
3	25921	3.03	3.17	12.26	1.49	33137	3.04	3.15	12.27	1.48
3	24491	2.99	6.05	15.02	2.85	29197	3.04	6.05	15.17	2.85
3	25667	3.03	9.09	18.18	4.29	29347	3.04	9.09	18.21	4.29
3	30216	5.02	5.25	20.31	2.47	35169	5.03	5.27	20.36	2.48
3	32537	5.03	10.24	25.33	4.83	35588	5.03	10.16	25.25	4.79
3	34225	5.02	15.03	30.09	7.09	37684	5.03	15.10	30.19	7.12
3	45263	10.02	10.37	40.43	4.89	49007	10.01	10.32	40.35	4.86
3	48037	10.02	20.45	50.51	9.64	51400	10.01	20.39	50.42	9.61
3	49357	10.02	30.27	60.33	14.27	50082	10.01	30.43	60.46	14.34
3	54237	15.02	10.48	55.54	4.94	53533	15.01	10.52	55.55	4.96
3	55761	15.02	15.37	60.43	7.25	55888	15.00	15.40	60.40	7.26
3	59372	15.01	30.55	75.58	14.40	59949	14.99	30.60	75.57	14.42
3	64075	19.98	15.64	75.58	7.37	62990	20.00	15.57	75.57	7.34
3	67267	20.00	20.65	80.65	9.73	65692	19.98	20.74	80.68	9.78
3	69895	20.00	40.44	100.44	19.06	68758	19.99	40.63	100.60	19.15

NOTE: All values have units of psi

Table F-5: Bethany Falls M_r Test Data

Gradation			A-D					W-F		
Replicate	Mr	Sig3	SigD	Theta	Oct	Mr	Sig3	SigD	Theta	Oct
1	29568	3.01	3.11	12.14	1.47	26486	3.00	3.14	12.14	1.48
1	29096	3.00	6.05	15.05	2.85	25579	3.00	6.07	15.07	2.86
1	30329	2.99	9.06	18.03	4.27	26972	3.01	9.11	18.14	4.29
1	35598	5.01	5.23	20.26	2.47	33150	5.01	5.26	20.29	2.48
1	37872	5.01	10.20	25.23	4.81	35491	5.03	10.18	25.27	4.80
1	40362	5.01	15.08	30.11	7.11	37611	5.03	15.07	30.16	7.10
1	51660	10.01	10.38	40.41	4.89	51403	10.01	10.37	40.40	4.89
1	56223	10.01	20.34	50.37	9.59	56027	10.03	20.29	50.38	9.56
1	56674	10.00	30.34	60.34	14.30	54678	10.03	30.57	60.66	14.41
1	62369	15.02	10.50	55.56	4.95	61879	15.02	10.48	55.54	4.94
1	64129	15.02	15.40	60.46	7.26	61717	15.00	15.43	60.43	7.27
1	68998	15.01	30.38	75.41	14.32	66162	15.00	30.74	75.74	14.49
1	74531	19.99	15.56	75.53	7.34	71882	20.02	15.68	75.74	7.39
1	76013	19.99	20.60	80.57	9.71	74076	19.99	20.70	80.67	9.76
1	78430	20.00	40.90	100.90	19.28	76389	19.98	40.55	100.49	19.12
2	32047	2.96	3.00	11.88	1.41	24680	2.99	3.13	12.10	1.48
2	32198	3.04	5.98	15.10	2.82	24529	3.03	6.04	15.13	2.85
2	33597	2.99	9.13	18.10	4.30	26031	3.00	9.07	18.07	4.28
2	40635	5.01	5.28	20.31	2.49	30723	5.01	5.27	20.30	2.48
2	39845	5.01	10.26	25.29	4.84	32658	5.02	10.17	25.23	4.79
2	41081	5.01	15.15	30.18	7.14	34605	5.02	15.01	30.07	7.08
2	52935	10.01	10.35	40.38	4.88	46998	10.02	10.35	40.41	4.88
2	56580	10.00	20.32	50.32	9.58	50449	10.00	20.45	50.45	9.64
2	55012	10.00	30.36	60.36	14.31	49649	9.99	30.36	60.33	14.31
2	61880	15.04	10.49	55.61	4.95	55805	15.03	10.52	55.61	4.96
2	62280	15.04	15.44	60.56	7.28	57879	15.02	15.42	60.48	7.27
2	65618	15.04	30.51	75.63	14.38	60959	15.01	30.69	75.72	14.47
2	71503	19.98	15.56	75.50	7.34	66925	19.98	15.67	75.61	7.39
2	72617	19.98	20.72	80.66	9.77	69789	20.02	20.68	80.74	9.75
2	74694	19.98	40.66	100.60	19.17	71689	20.01	40.63	100.66	19.15
3	32364	3.04	3.18	12.30	1.50	28501	3.00	3.16	12.16	1.49
3	29845	3.00	6.07	15.07	2.86	26547	3.03	6.06	15.15	2.86
3	30404	3.00	9.10	18.10	4.29	27286	3.03	9.11	18.20	4.29
3	35627	5.00	5.24	20.24	2.47	34415	5.02	5.26	20.32	2.48
3	38375	4.99	10.18	25.15	4.80	34735	5.02	10.21	25.27	4.81
3	40138	5.00	15.04	30.04	7.09	36133	5.03	15.13	30.22	7.13
3	51940	10.05	10.32	40.47	4.86	48534	10.02	10.32	40.38	4.86
3	55617	10.04	20.44	50.56	9.64	52768	9.99	20.42	50.39	9.63
3	55902	10.03	30.43	60.52	14.34	51872	9.98	30.37	60.31	14.32
3	62027	15.04	10.49	55.61	4.95	56516	15.02	10.53	55.59	4.96
3	63872	15.03	15.45	60.54	7.28	59446	15.00	15.43	60.43	7.27
3	67456	15.03	30.52	75.61	14.39	64005	15.02	30.63	75.69	14.44
3	73504	20.03	15.62	75.71	7.36	70083	20.05	15.60	75.75	7.35
3	75192	20.02	20.71	80.77	9.76	71096	20.03	20.77	80.86	9.79
3	77459	20.02	40.58	100.64	19.13	74175	20.03	40.80	100.89	19.23

NOTE: All values have units of psi

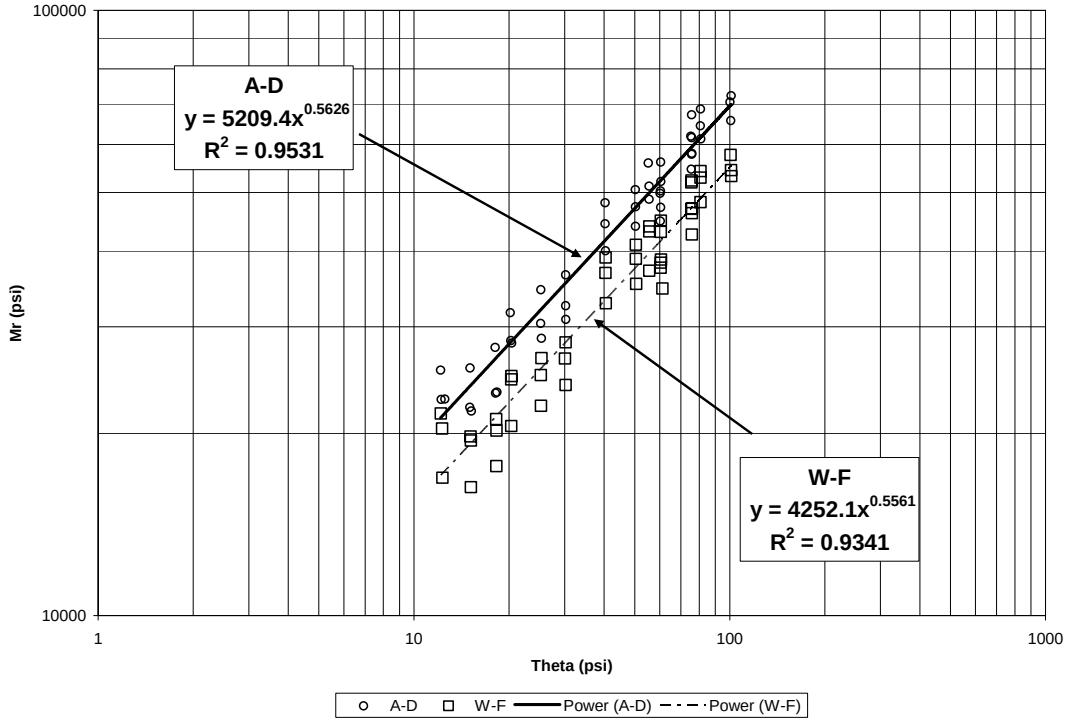


Figure F-1- Jefferson City Dolomite

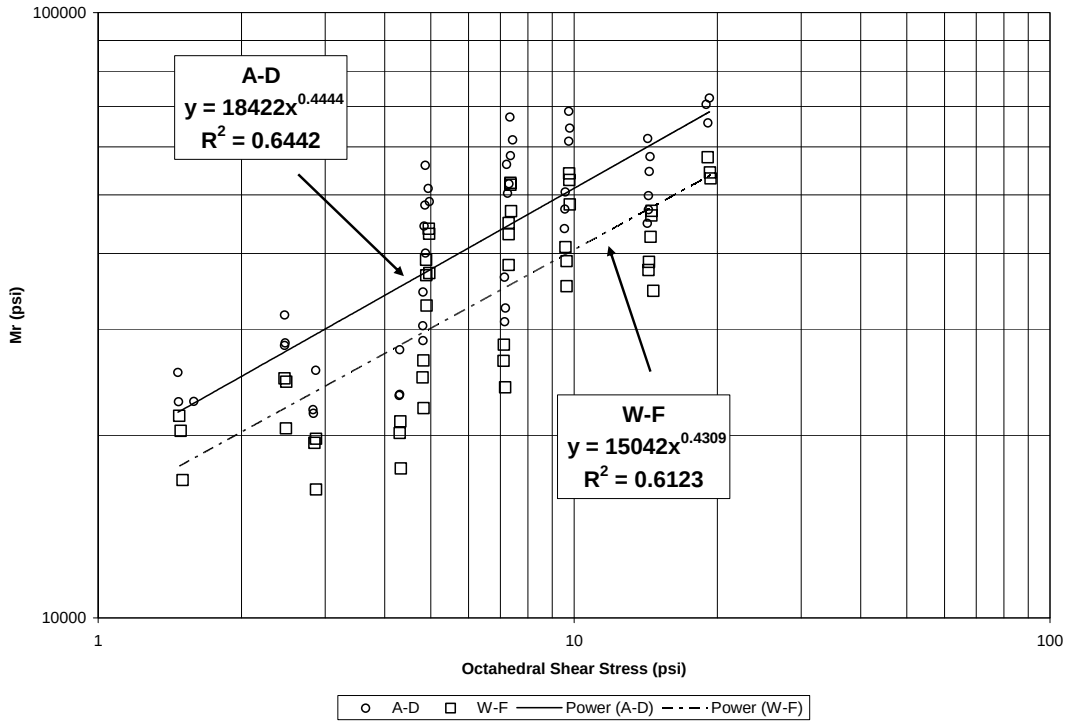


Figure F-2- Jefferson City Dolomite

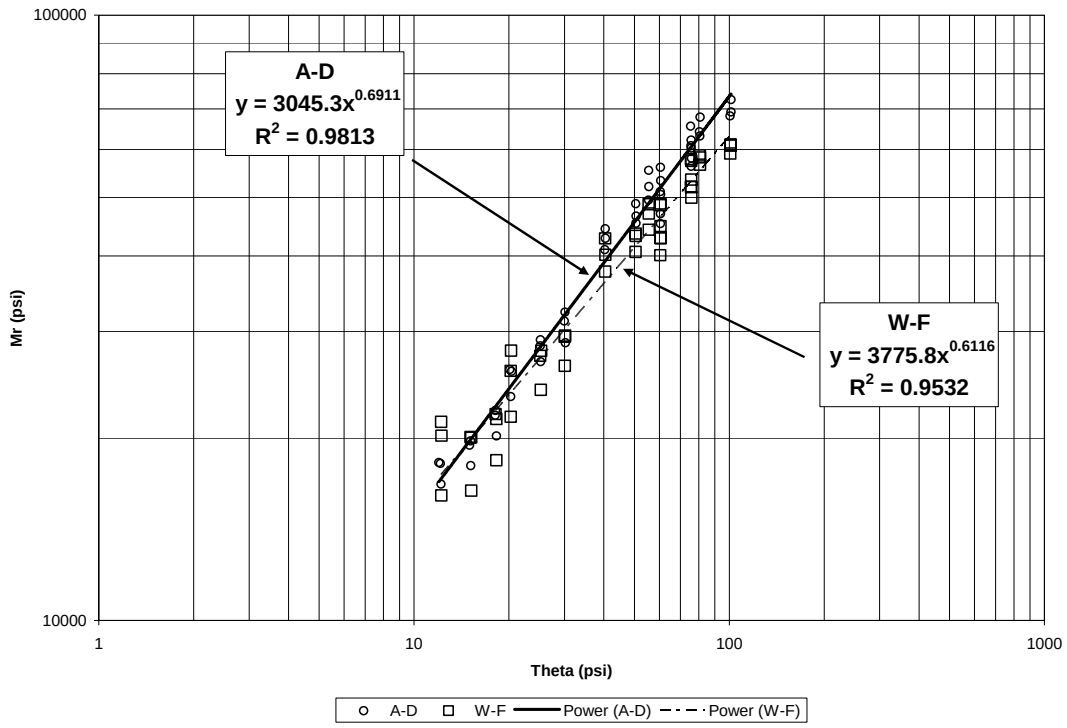


Figure F-3- Gasconade Dolomite

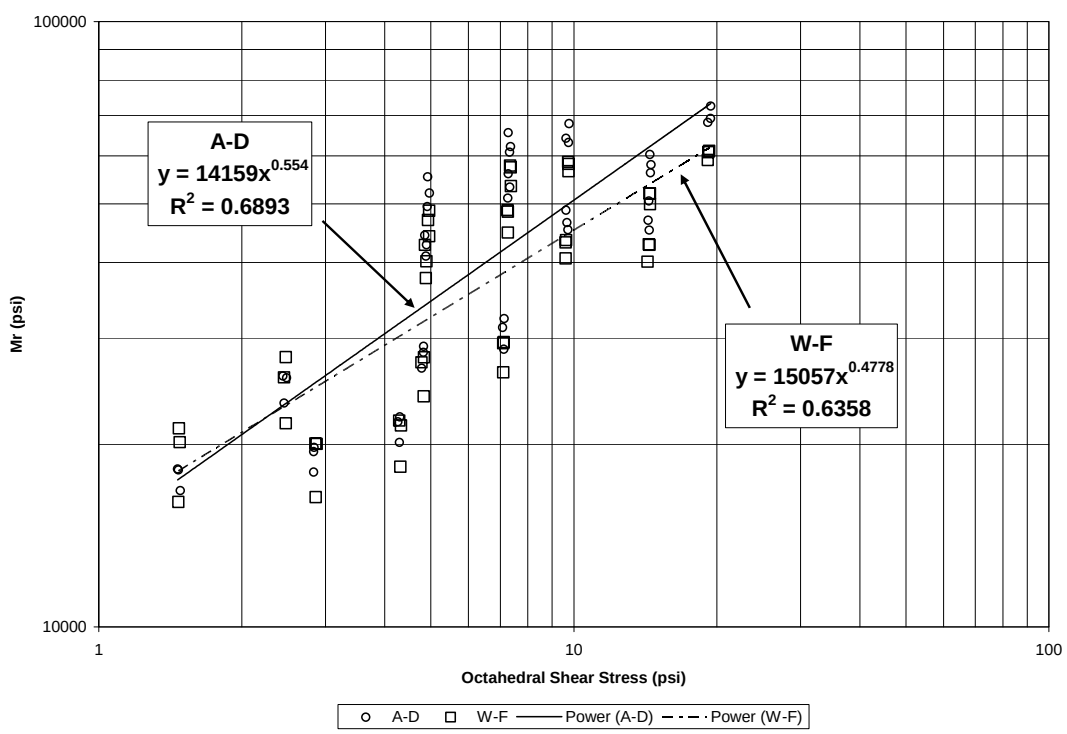


Figure F-4- Gasconade Dolomite

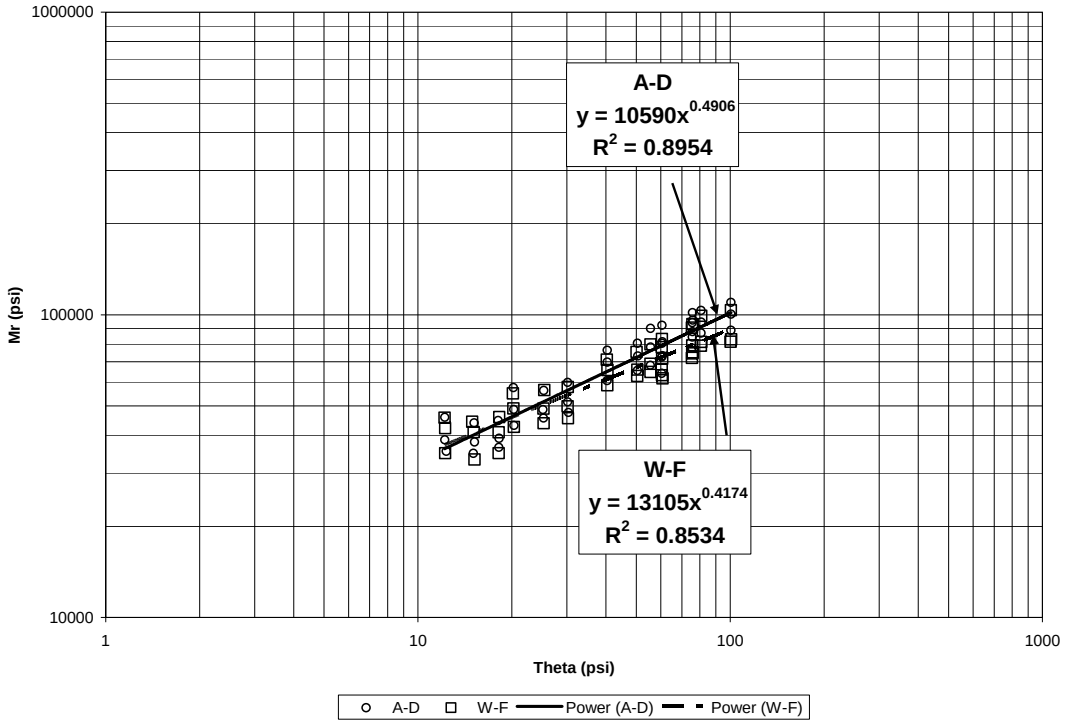


Figure F-5- Plattin

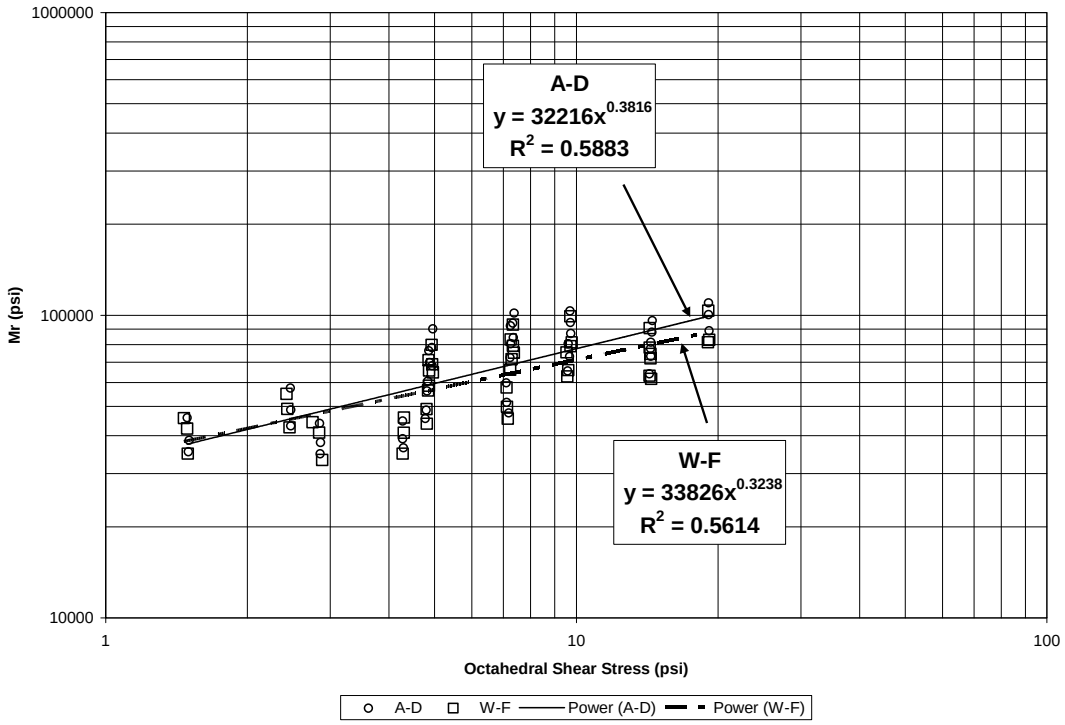


Figure F-6- Plattin

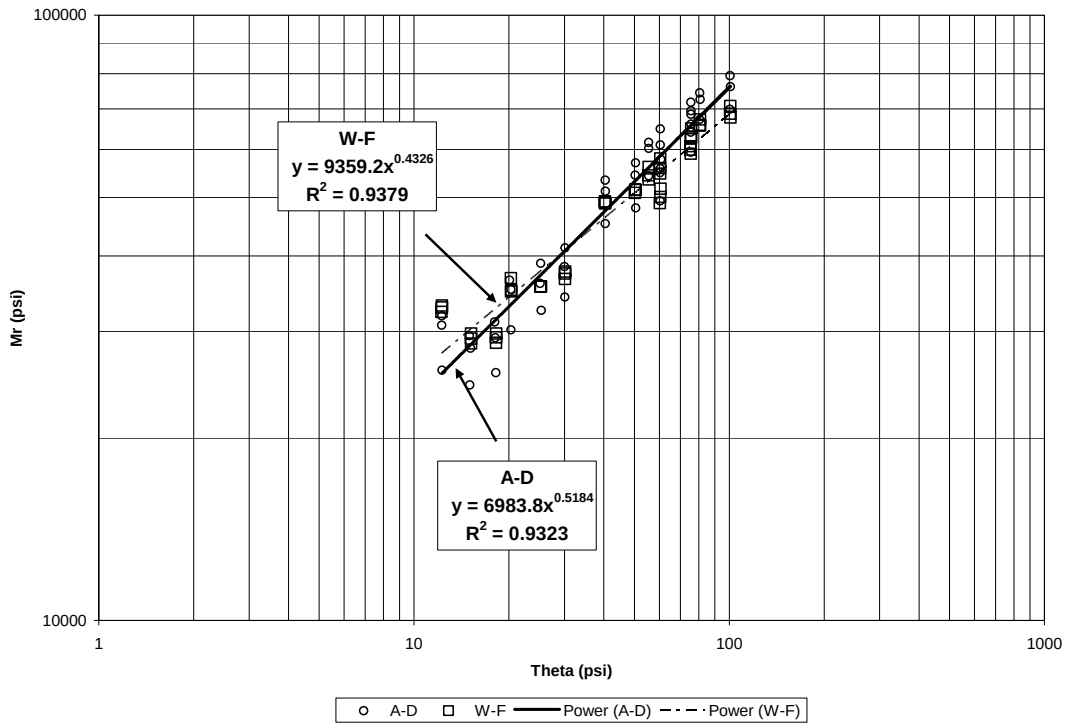


Figure F-7- Winterset

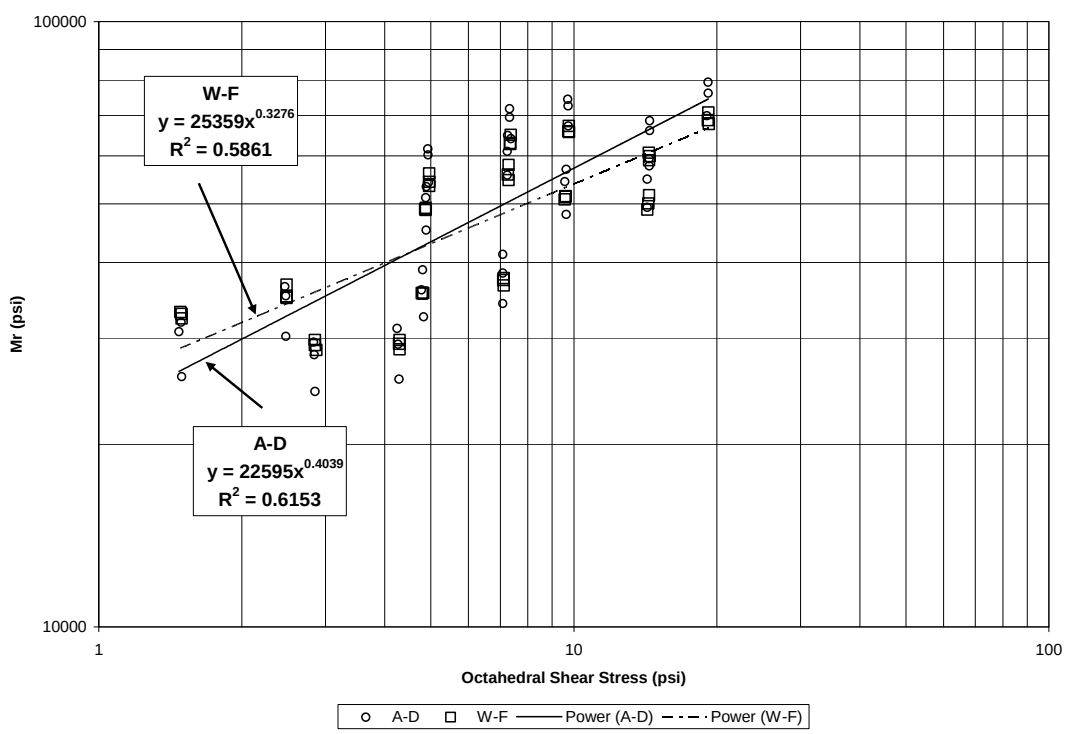


Figure F-8- Winterset

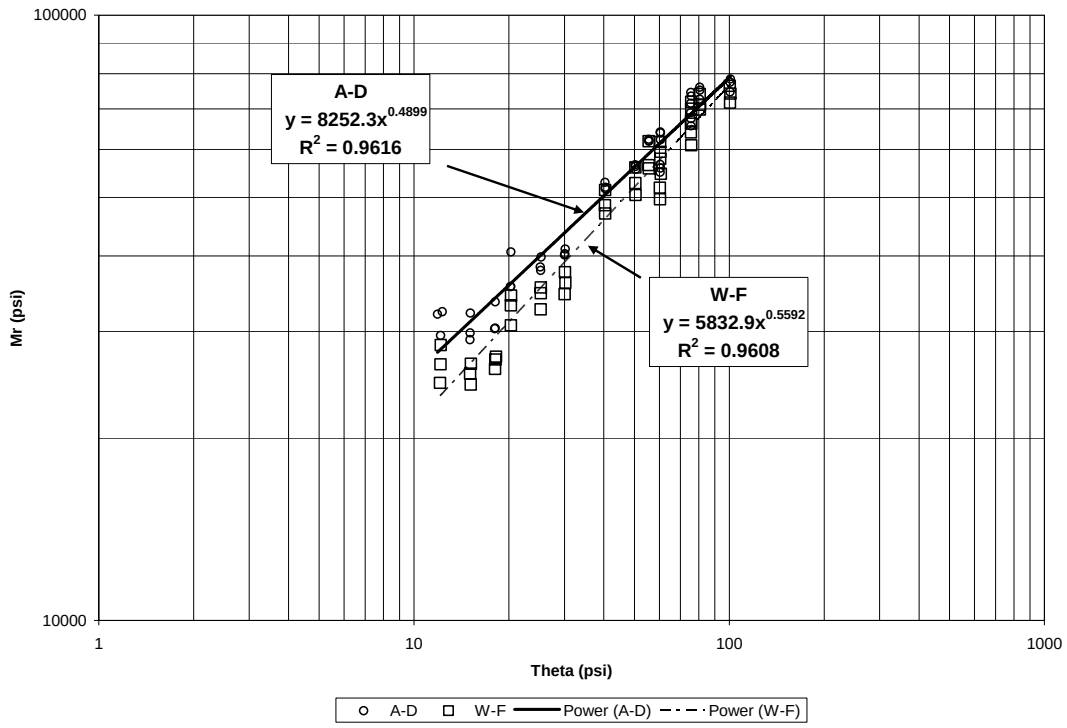


Figure F-9- Bethany Falls

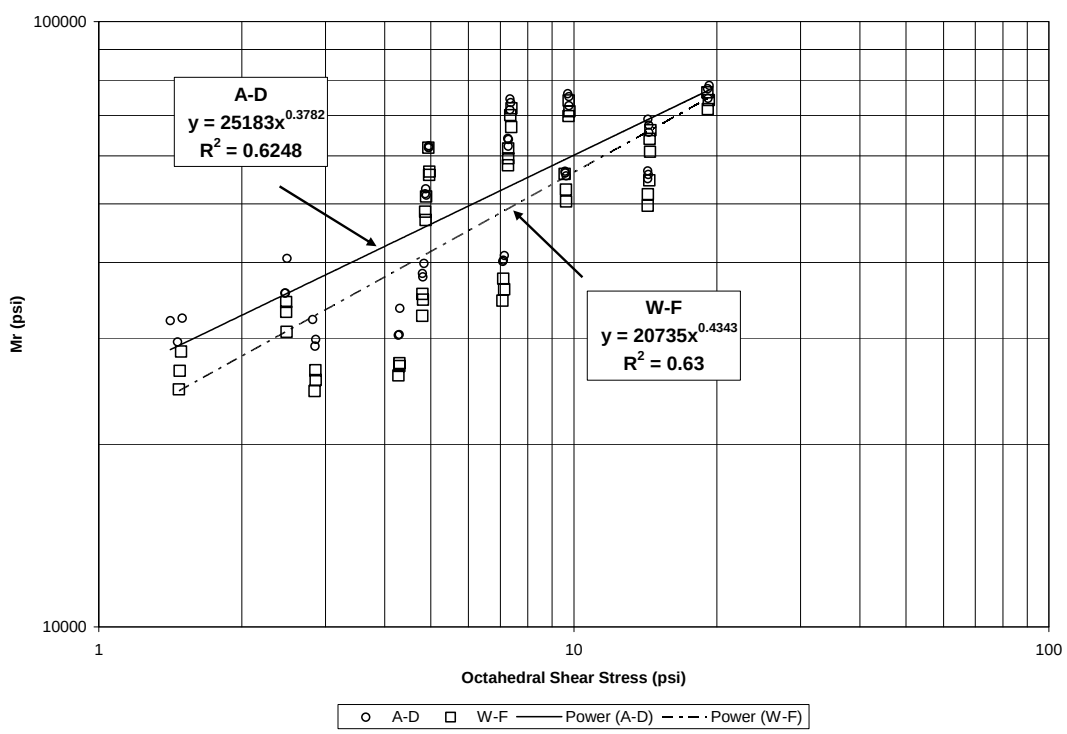
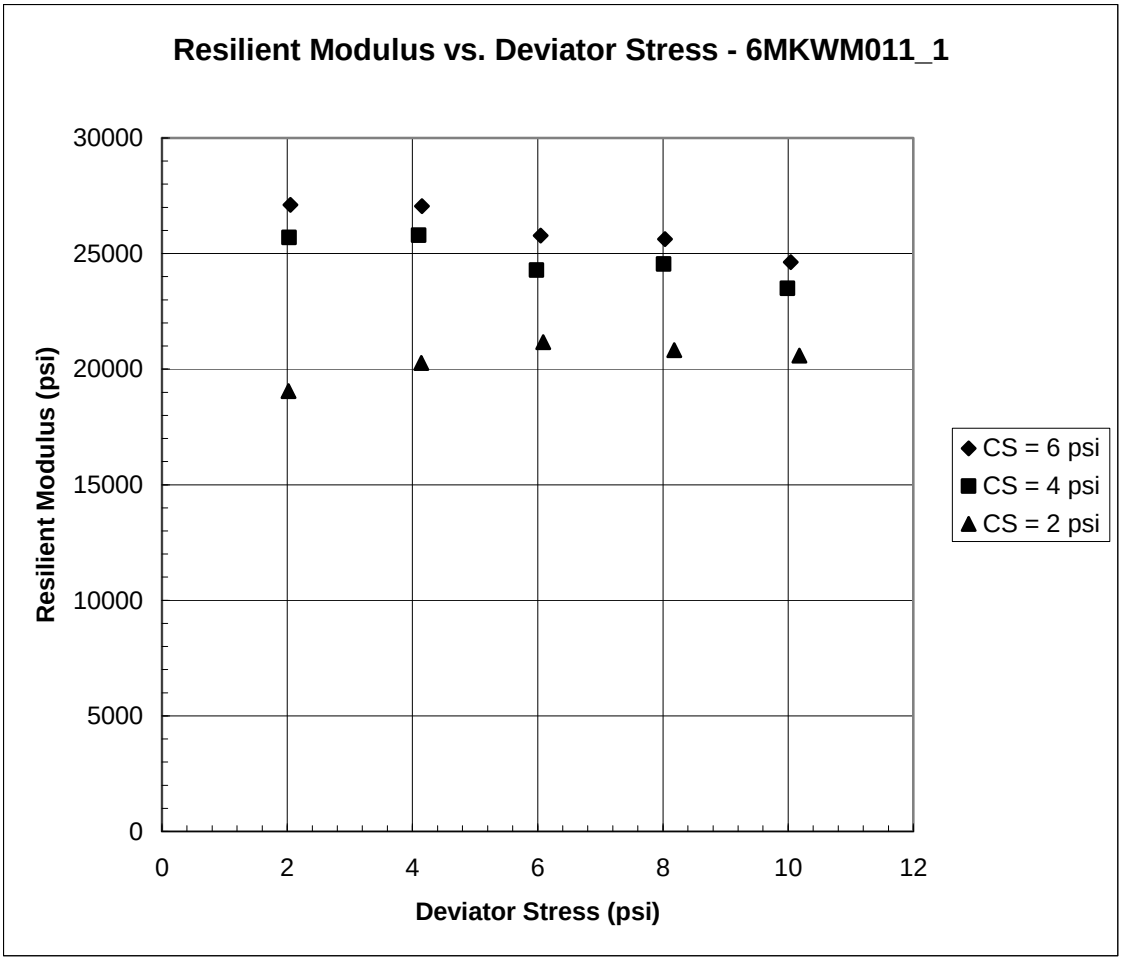
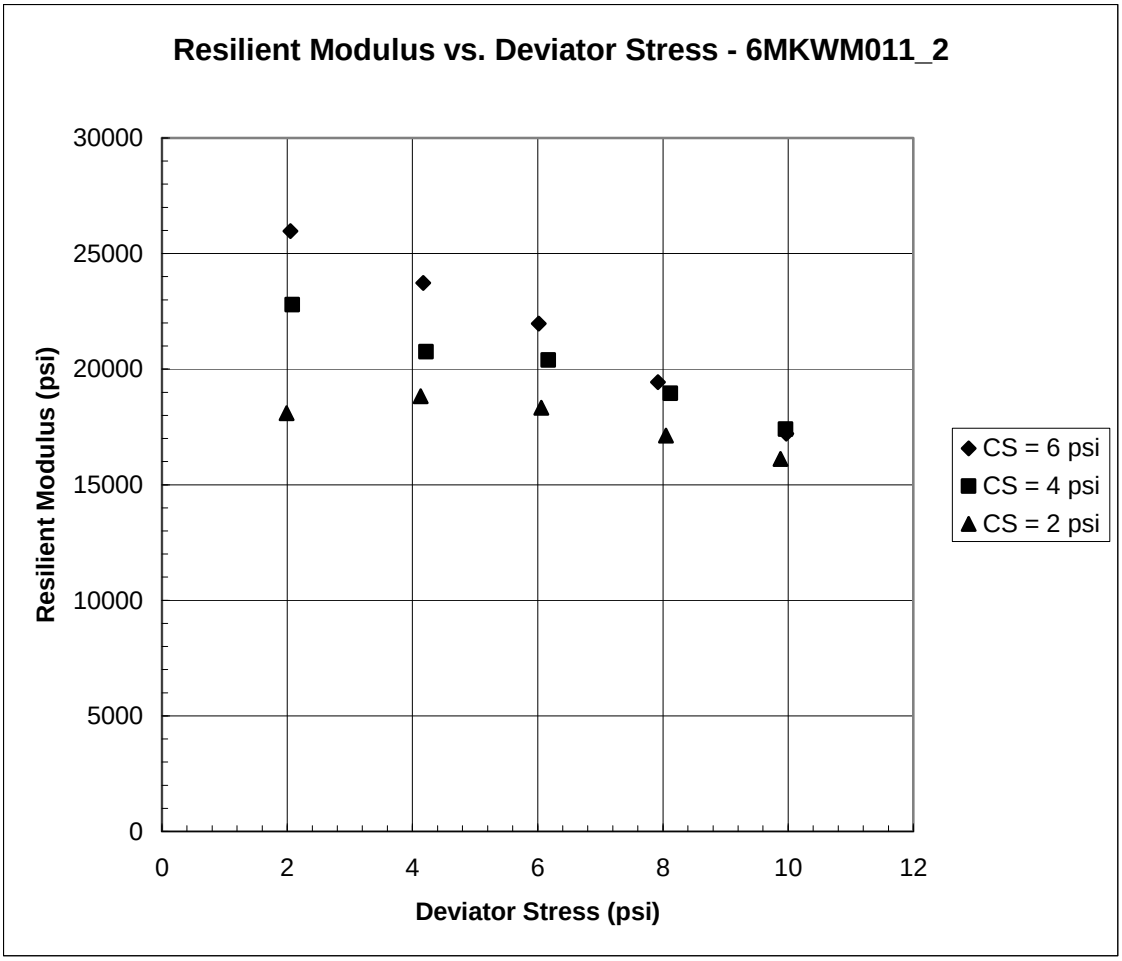


Figure F-10- Bethany Falls

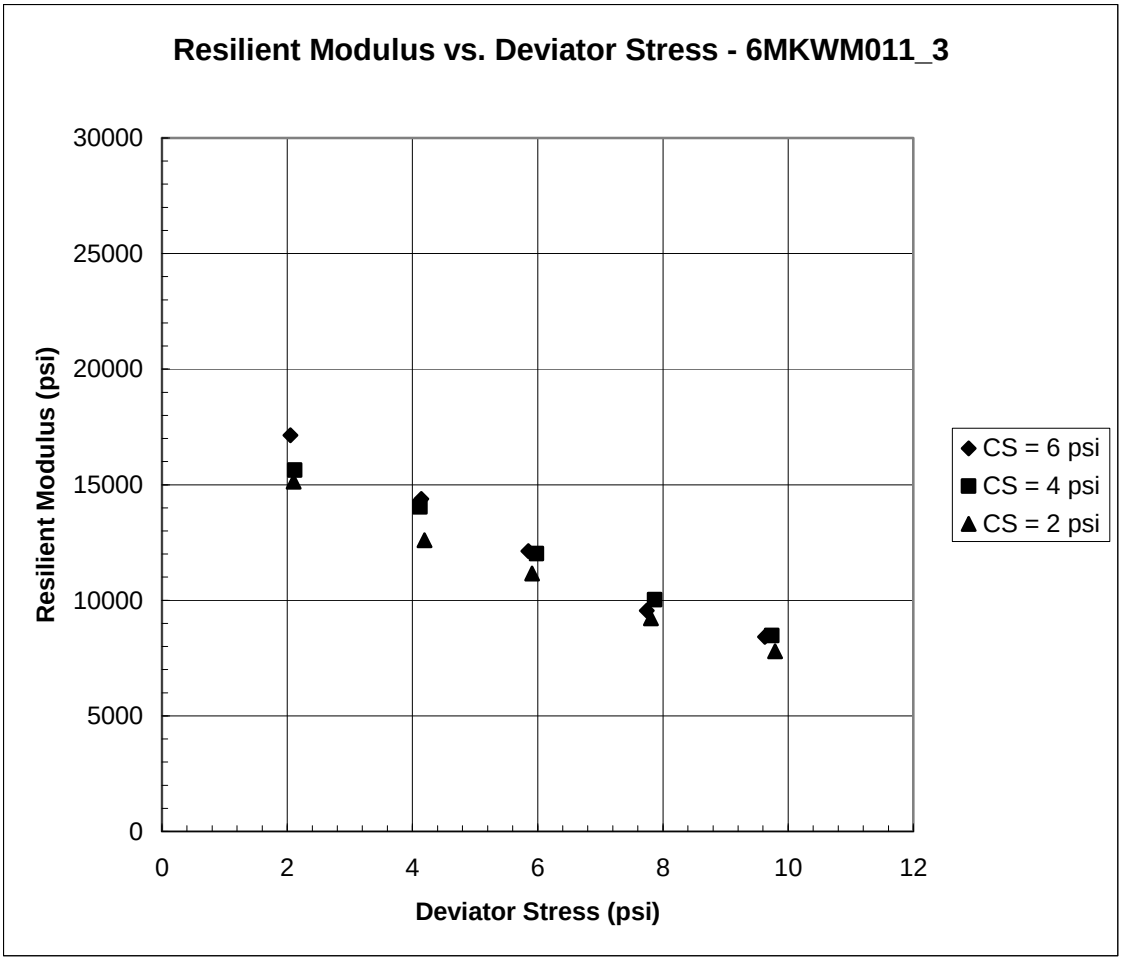
APPENDIX G: SUBGRADE SOILS M_R TESTS



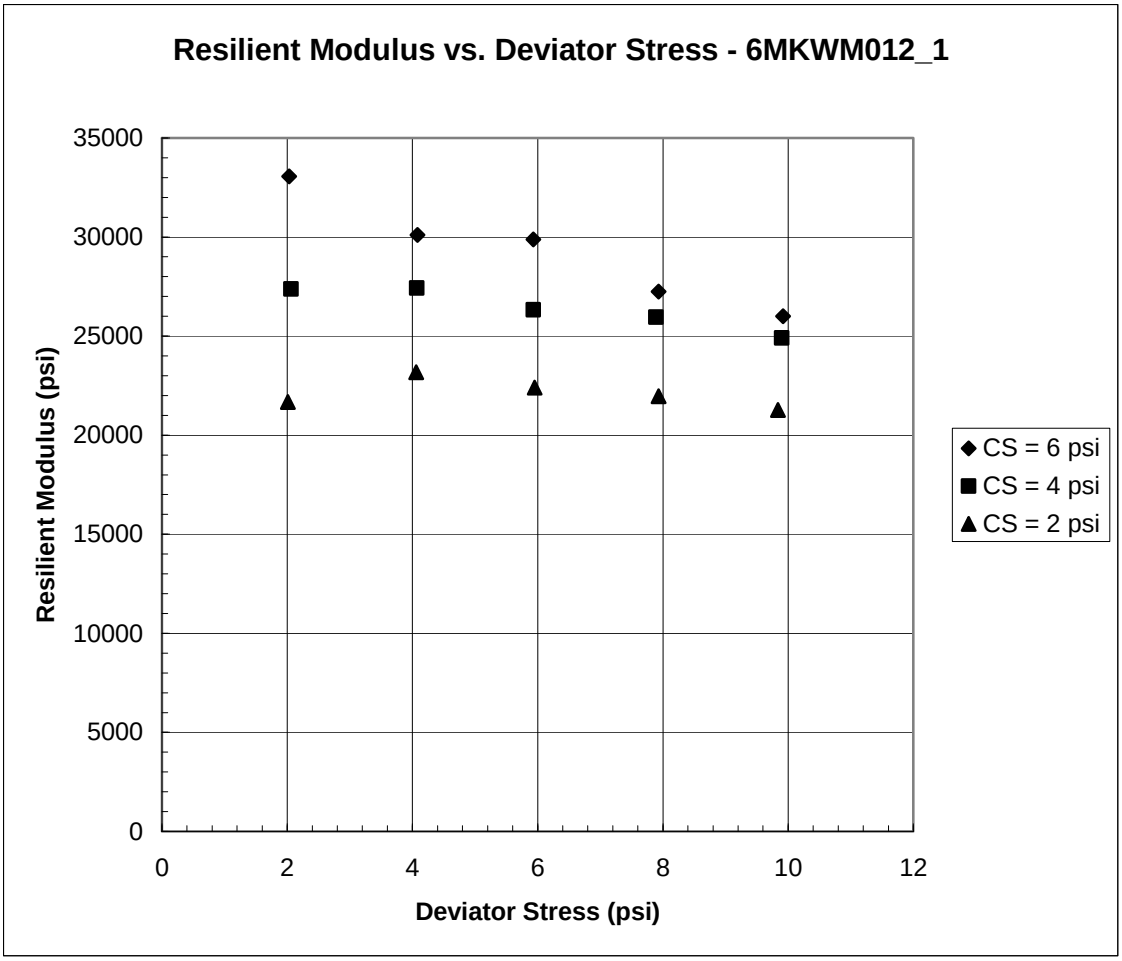
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.05	29084	24244	28933	24142	29121	27105
2	6	4.15	26745	26836	26740	28118	26805	27049
3	6	6.05	25302	26890	25345	25297	26071	25781
4	6	8.03	26555	25415	25408	25381	25372	25626
5	6	10.04	24209	25024	24638	24621	24623	24623
6	4	2.03	23896	26087	26181	26082	26193	25688
7	4	4.1	26454	25316	26399	24255	26511	25787
8	4	5.98	24257	24260	24315	24299	24314	24289
9	4	8.01	24721	24222	24785	24220	24782	24546
10	4	9.99	23634	23659	23631	23635	22891	23490
11	2	2.02	19016	19040	19111	19068	19022	19052
12	2	4.14	20268	20272	20273	20277	20265	20271
13	2	6.09	21155	21153	21713	21153	20643	21163
14	2	8.18	20827	20819	20817	20828	20824	20823
15	2	10.18	20442	20392	20727	20683	20691	20587



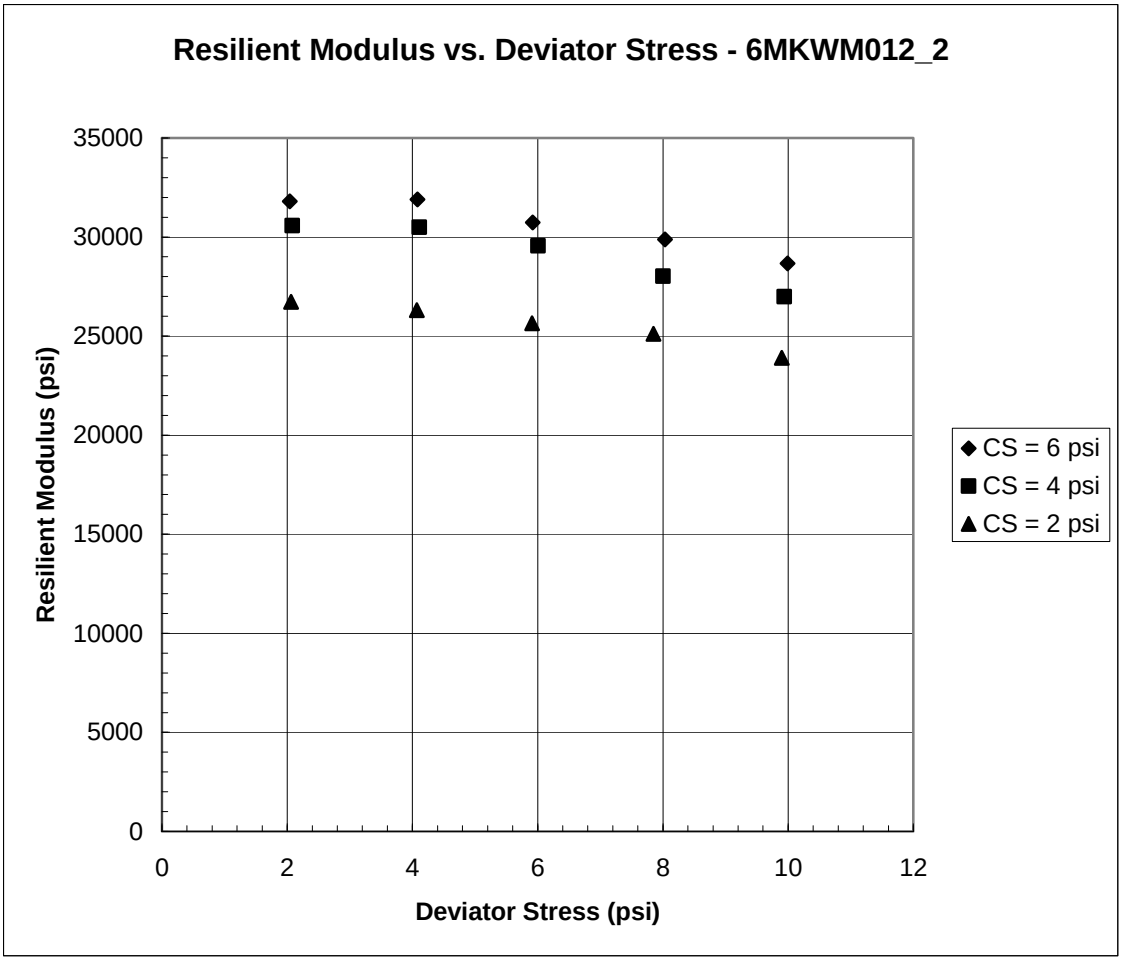
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.05	24066	26381	26510	26370	26501	25966
2	6	4.17	23659	23723	23789	23670	23786	23725
3	6	6.02	21964	22002	21991	21936	21929	21965
4	6	7.92	19735	19047	19357	19337	19696	19434
5	6	9.97	17238	17255	17047	17272	17230	17209
6	4	2.08	22691	22788	22790	22880	22791	22788
7	4	4.22	20806	20734	20758	20724	20754	20755
8	4	6.17	20465	20493	20032	20472	20470	20386
9	4	8.12	18981	18936	18960	18917	18960	18951
10	4	9.96	17437	17436	17652	17015	17465	17401
11	2	1.99	18793	18765	17734	17554	17654	18100
12	2	4.13	18959	18322	18960	18919	18958	18824
13	2	6.06	18319	18326	18380	18327	18324	18335
14	2	8.05	17089	17092	17086	17071	17306	17129
15	2	9.88	16101	16117	16117	16088	16128	16110



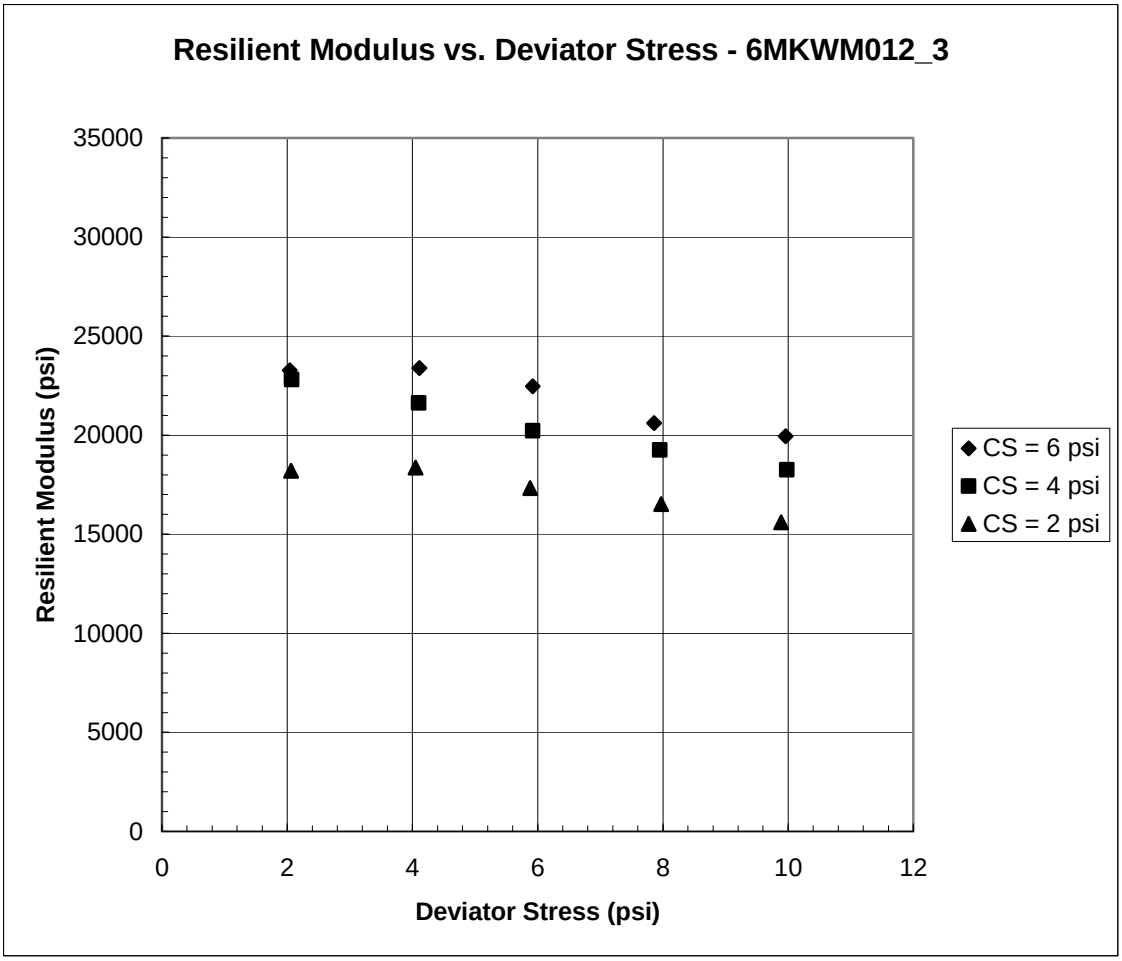
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.05	17132	17211	17067	17211	17065	17137
2	6	4.14	14057	14717	14404	14326	14437	14388
3	6	5.85	12215	11808	12233	12172	12193	12124
4	6	7.74	9483	9547	9585	9628	9509	9550
5	6	9.63	8402	8387	8463	8379	8469	8420
6	4	2.12	15961	15040	16032	15168	15915	15623
7	4	4.12	14340	13599	14337	13600	14308	14037
8	4	5.98	12129	12202	11775	12206	11762	12015
9	4	7.87	10027	10049	9949	10028	10074	10025
10	4	9.74	8480	8424	8481	8430	8530	8469
11	2	2.1	14955	14948	15014	14934	15776	15125
12	2	4.19	12759	12429	12689	12425	12687	12598
13	2	5.91	11127	11233	11000	11234	11179	11155
14	2	7.81	9190	9213	9211	9202	9301	9223
15	2	9.79	7728	7907	7688	7892	7788	7800



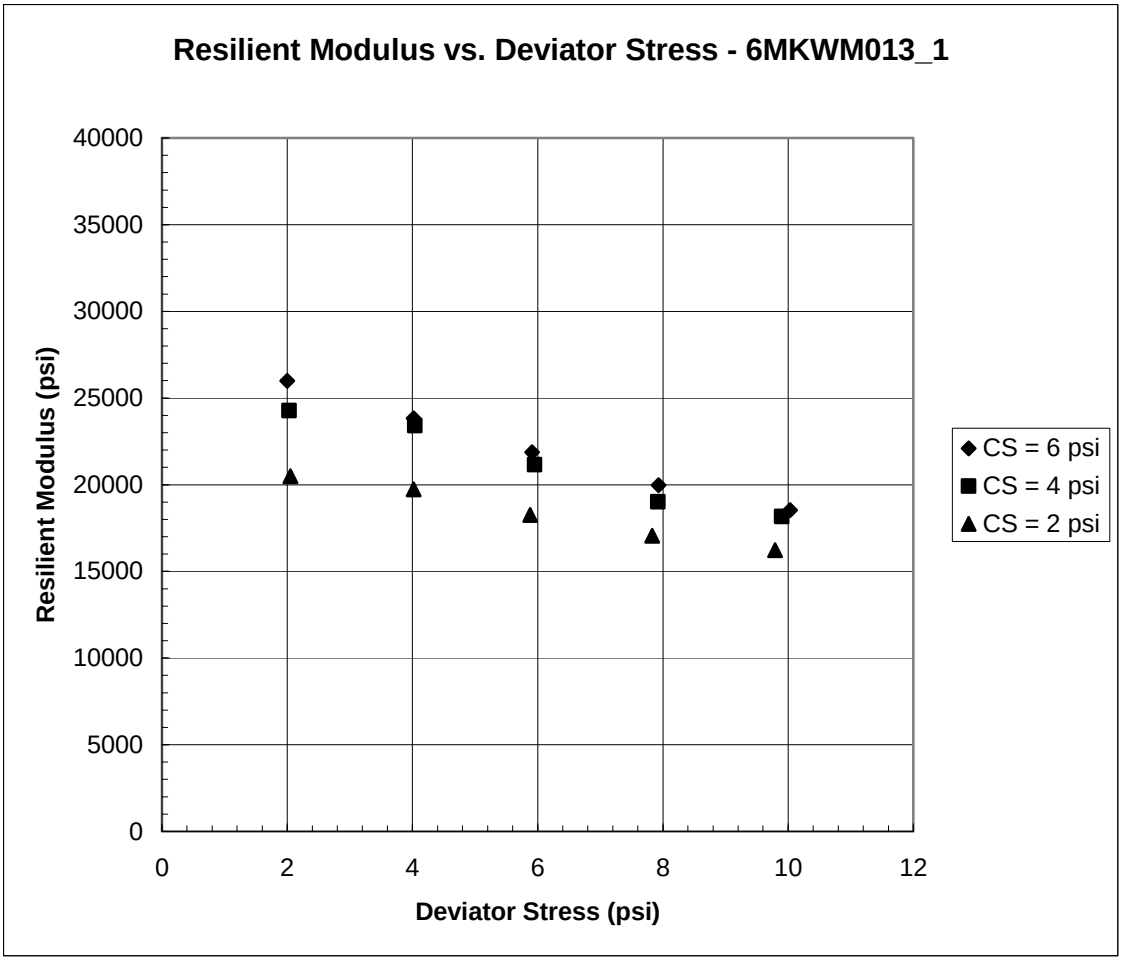
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.03	32137	28702	35978	32306	36169	33058
2	6	4.08	29111	30739	30784	30659	29257	30110
3	6	5.93	30390	29167	30296	29214	30296	29872
4	6	7.93	26960	27713	26957	26992	27644	27253
5	6	9.92	25784	25863	25786	25819	26765	26003
6	4	2.06	24338	26931	29388	29600	26590	27370
7	4	4.07	26486	27557	27798	27600	27678	27424
8	4	5.93	26425	26511	26470	25708	26479	26319
9	4	7.89	25014	26174	26238	26215	26144	25957
10	4	9.9	25267	24826	24823	24824	24823	24913
11	2	2.01	21972	21987	22076	21975	20369	21676
12	2	4.06	23144	23207	23093	23255	23197	23179
13	2	5.95	21783	22381	22362	23070	22392	22398
14	2	7.93	22678	21810	21770	21767	21779	21961
15	2	9.84	21307	21296	21311	21310	21155	21276



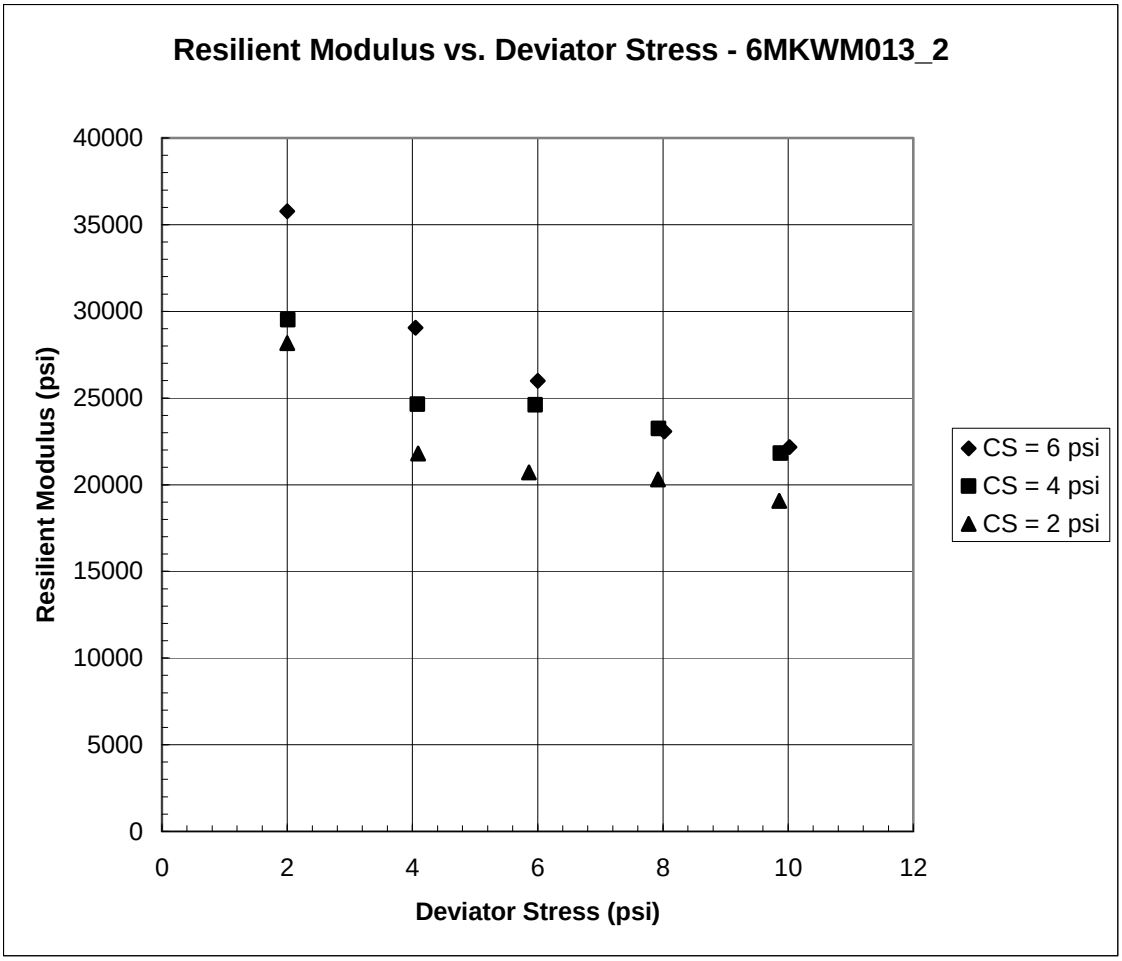
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.04	32492	32622	32348	32332	29256	31810
2	6	4.08	32567	30765	30842	30763	34554	31898
3	6	5.92	31432	30266	31463	30307	30248	30743
4	6	8.03	29563	29534	29529	30338	30415	29876
5	6	9.99	28667	28649	28669	28722	28675	28676
6	4	2.08	29829	29941	29833	29795	33441	30568
7	4	4.11	31054	29573	29564	31112	31125	30486
8	4	6.01	29845	29679	28761	30741	28781	29562
9	4	8	28692	27333	28725	27356	28003	28022
10	4	9.94	26864	27424	26402	27371	26907	26994
11	2	2.06	26675	26818	26803	26703	26682	26736
12	2	4.07	26451	25372	26555	26577	26562	26304
13	2	5.91	25606	26452	25677	25645	24886	25653
14	2	7.85	24991	24987	25023	24983	25586	25114
15	2	9.9	24033	24072	24033	23694	23666	23899



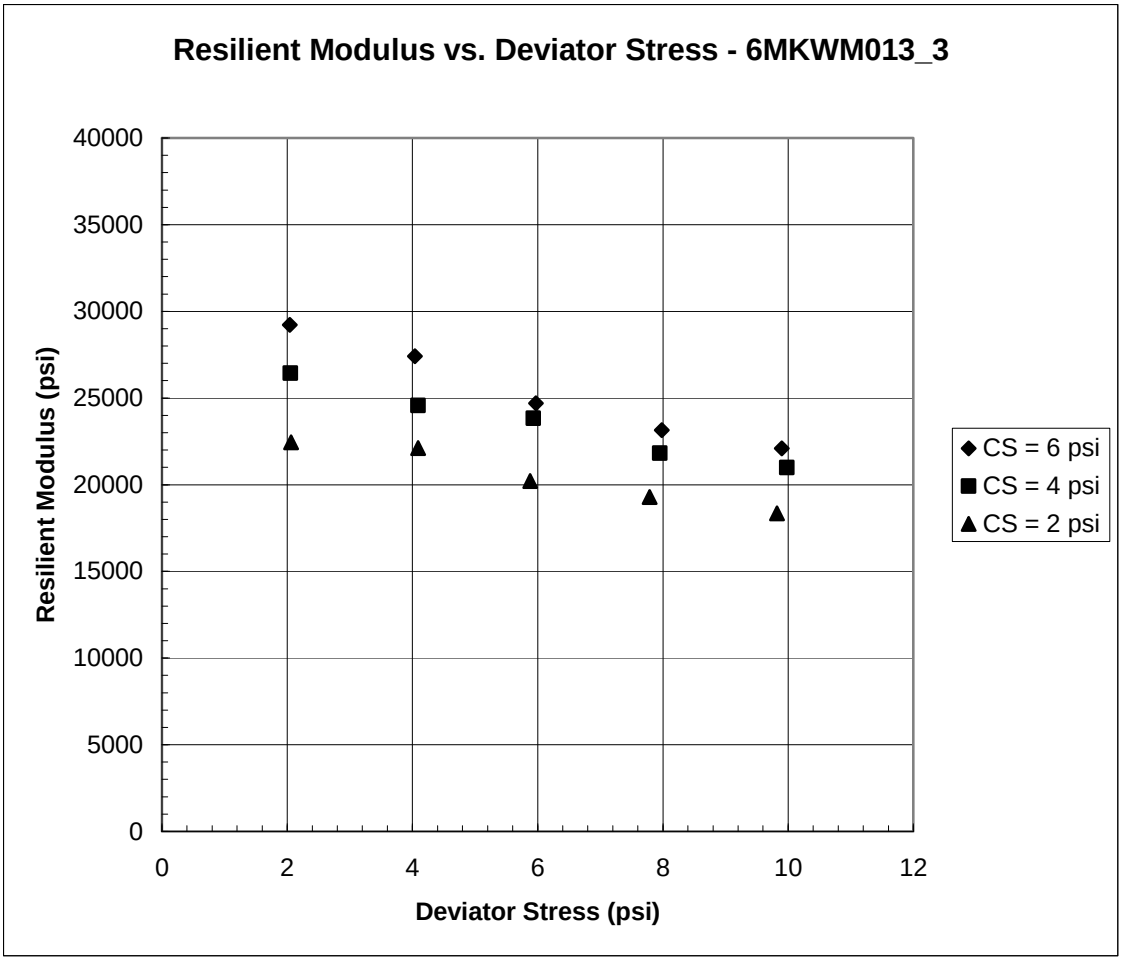
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.04	24317	22631	22461	24405	22535	23270
2	6	4.11	22670	23573	23582	23570	23574	23394
3	6	5.92	22957	21807	22956	21740	22906	22473
4	6	7.86	20815	20836	20448	20827	20088	20603
5	6	9.96	19839	19800	19858	20090	20133	19944
6	4	2.07	22824	22744	22718	22774	22932	22798
7	4	4.1	21783	21015	21784	21835	21690	21621
8	4	5.92	20195	20230	19752	20719	20222	20223
9	4	7.95	19300	19347	19301	19015	19300	19253
10	4	9.98	18362	18360	18097	18360	18112	18258
11	2	2.06	18496	18364	18488	17232	18406	18197
12	2	4.05	18724	18095	18724	18134	18138	18363
13	2	5.88	17181	17539	17230	17536	17181	17333
14	2	7.97	16576	16804	16819	16101	16325	16525
15	2	9.89	15565	15574	15734	15560	15565	15600



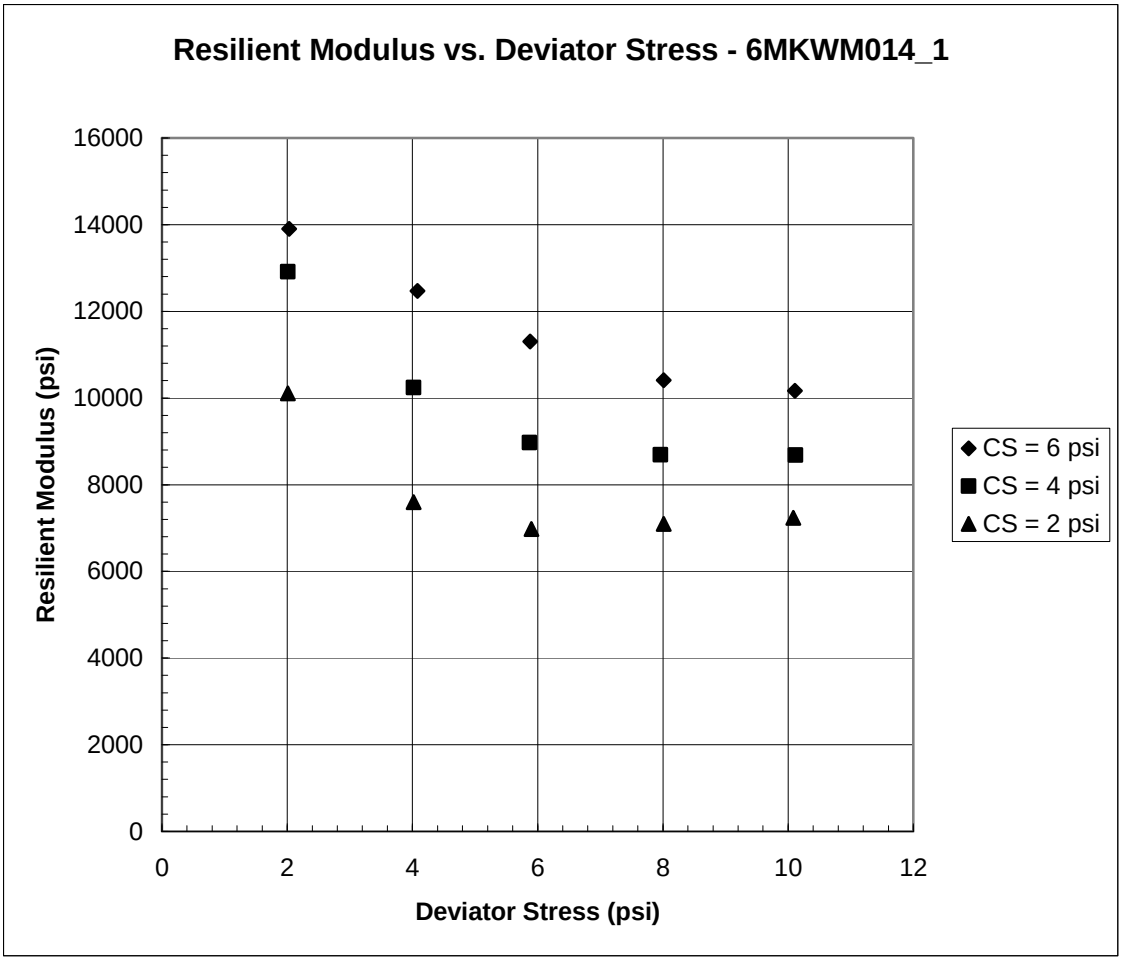
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2	25901	26070	26055	25962	25946	25987
2	6	4.02	23972	25049	23040	23043	24051	23831
3	6	5.91	22329	21212	21756	22362	21754	21882
4	6	7.93	19980	19969	19988	19964	19983	19977
5	6	10.03	18464	18262	18720	18489	18710	18529
6	4	2.03	24244	24272	24250	24248	24374	24278
7	4	4.04	22254	23217	24178	23201	24187	23407
8	4	5.95	20792	20819	21360	20827	21935	21146
9	4	7.92	19259	18942	18936	18969	18987	19019
10	4	9.9	18225	18195	18226	18004	18212	18172
11	2	2.05	21013	21076	20996	19695	19704	20497
12	2	4.02	19216	19791	19215	20544	19924	19738
13	2	5.88	18354	17955	18347	18326	18324	18261
14	2	7.83	17277	17036	16992	16999	17012	17063
15	2	9.79	16325	16329	16156	16141	16140	16218



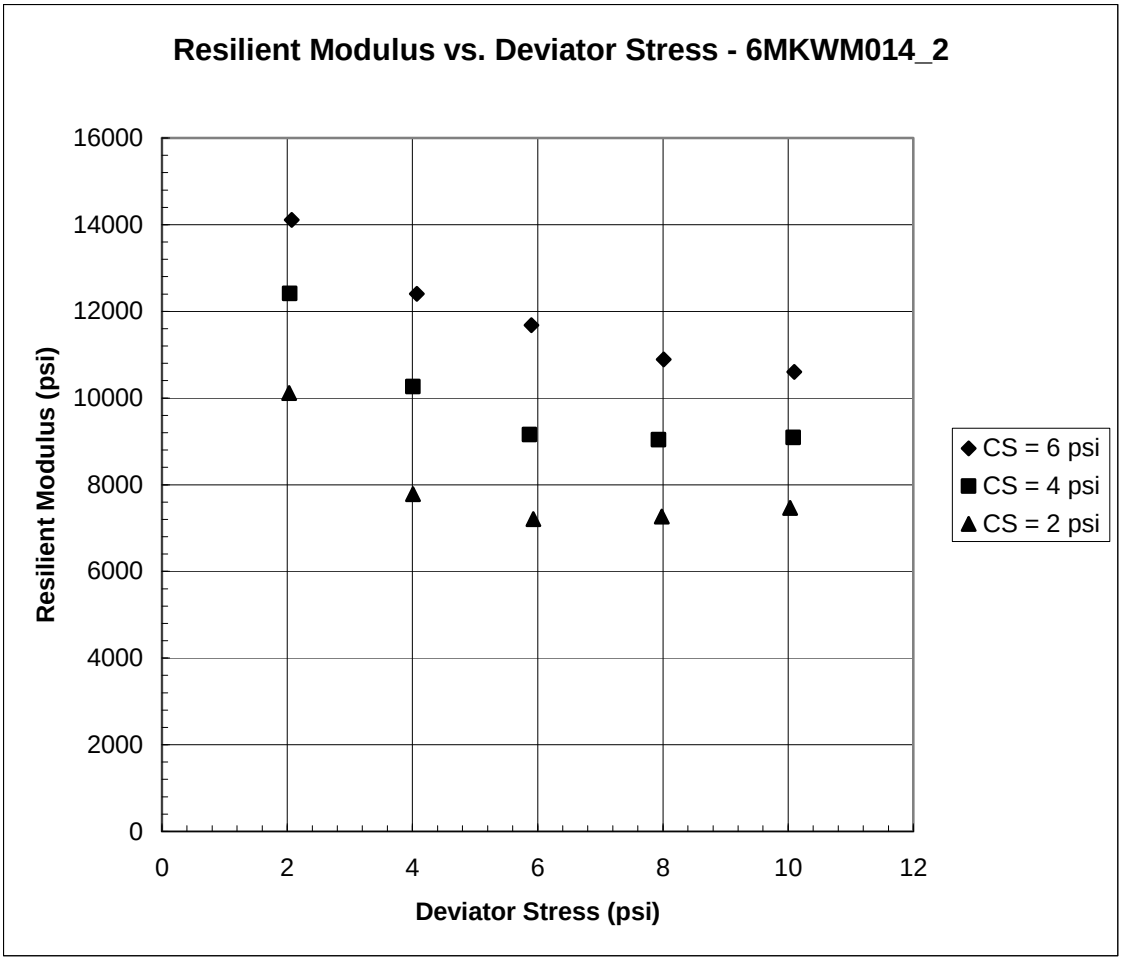
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2	35631	35942	35788	35776	35771	35782
2	6	4.05	29091	29014	29097	28956	29103	29052
3	6	6	25428	26185	26106	26182	26095	25999
4	6	8.02	23007	23113	23038	23087	23091	23067
5	6	10.02	22203	22116	22504	22175	21833	22166
6	4	2.01	32145	28908	28659	29055	28795	29512
7	4	4.08	25413	24455	24410	24528	24406	24642
8	4	5.96	24509	25149	24472	24394	24507	24606
9	4	7.93	23255	23248	23199	23275	23225	23240
10	4	9.88	21797	21822	21817	21789	21825	21810
11	2	2	28758	26024	28763	28663	28646	28171
12	2	4.09	21836	21776	21819	21784	21815	21806
13	2	5.86	20477	20537	20464	21594	20473	20709
14	2	7.92	20307	20242	20347	20289	20309	20299
15	2	9.86	19079	19164	18817	19187	19072	19064



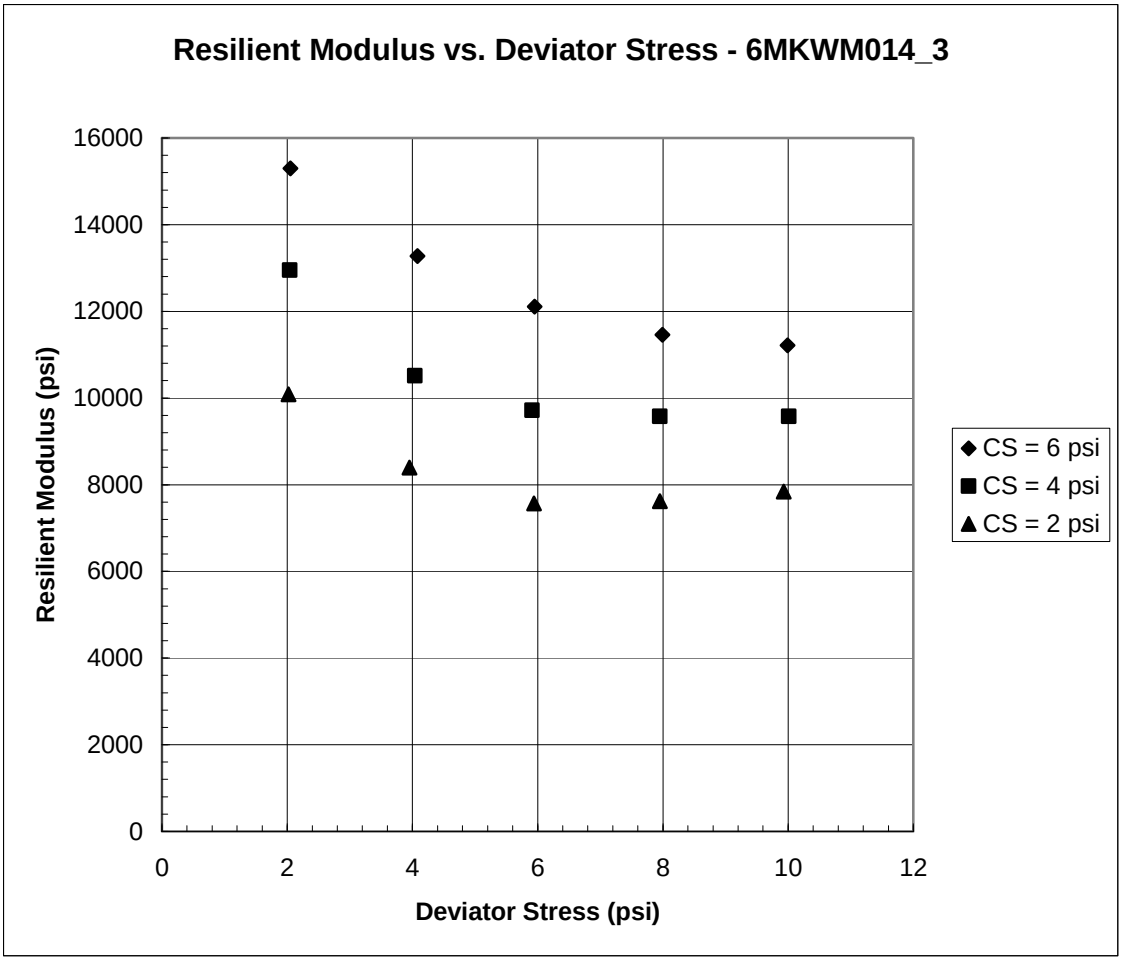
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.04	29172	29280	29280	29176	29157	29213
2	6	4.04	27661	26450	27632	27654	27639	27407
3	6	5.97	24500	24532	23857	25300	25257	24689
4	6	7.98	23442	22945	23415	22494	23438	23147
5	6	9.9	21543	22231	21876	22606	22237	22098
6	4	2.05	26733	26876	24489	29542	24496	26427
7	4	4.09	23502	23559	25597	24543	25600	24560
8	4	5.93	23679	23712	23680	24399	23711	23837
9	4	7.95	21601	21976	21985	21993	21572	21825
10	4	9.98	21104	21115	21113	20810	20787	20986
11	2	2.06	24572	22707	21072	22795	21110	22451
12	2	4.09	22613	21770	21816	22611	21779	22118
13	2	5.88	20602	20106	20144	20108	20144	20221
14	2	7.79	19296	19253	19279	19299	19278	19281
15	2	9.82	18285	18325	18279	18563	18279	18346



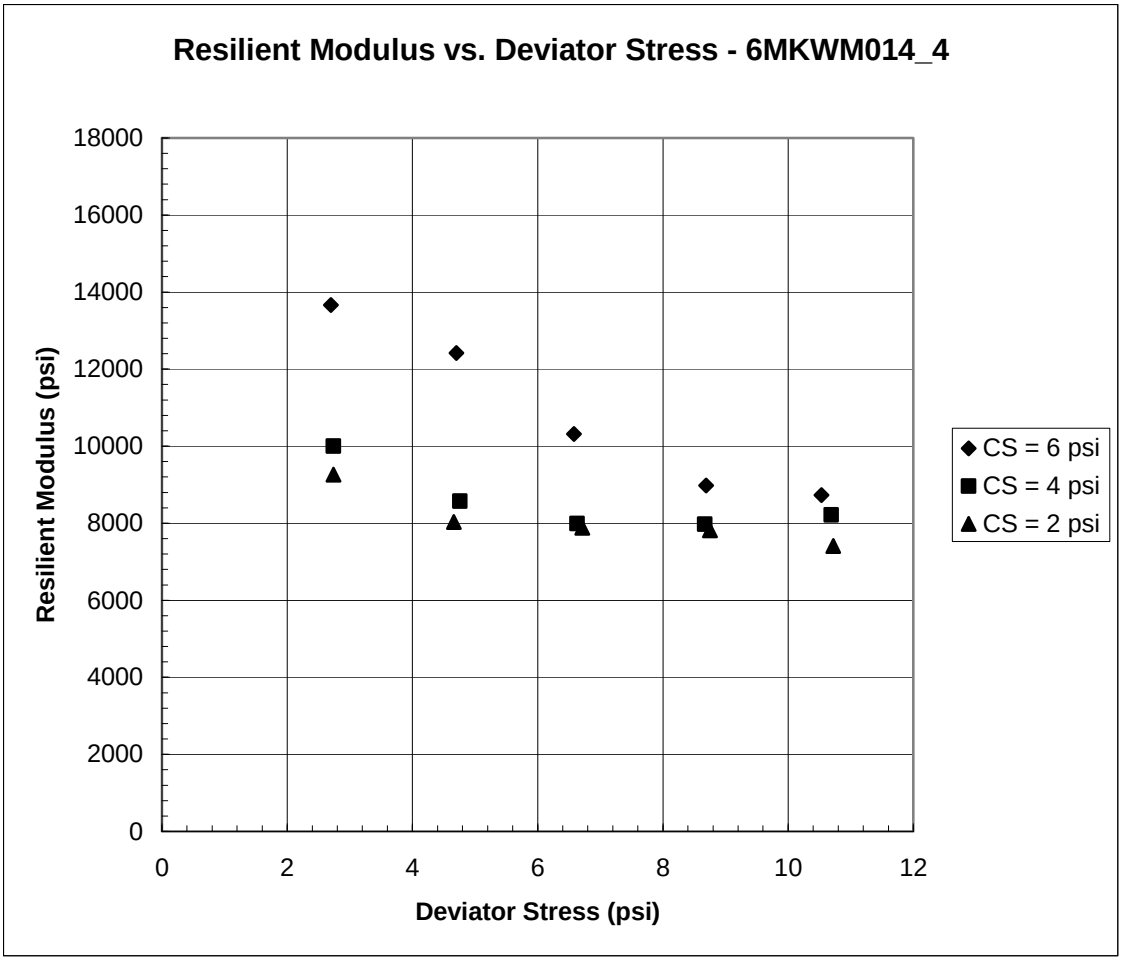
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.03	13849	13679	13796	13748	14457	13906
2	6	4.08	12459	12351	12457	12647	12428	12468
3	6	5.88	11473	11339	11166	11088	11450	11303
4	6	8.01	10484	10405	10375	10388	10398	10410
5	6	10.11	10190	10134	10182	10076	10253	10167
6	4	2.01	13071	12392	13075	13011	13006	12911
7	4	4.02	10438	10071	10228	10275	10200	10243
8	4	5.87	8868	9037	8959	9124	8871	8972
9	4	7.96	8675	8636	8685	8703	8761	8692
10	4	10.12	8709	8682	8652	8726	8636	8681
11	2	2.01	10221	10218	9914	9870	10316	10108
12	2	4.02	7569	7688	7672	7485	7586	7600
13	2	5.9	7038	6891	7016	7018	6936	6980
14	2	8.01	7093	7127	7084	7031	7137	7094
15	2	10.08	7264	7248	7193	7284	7198	7237



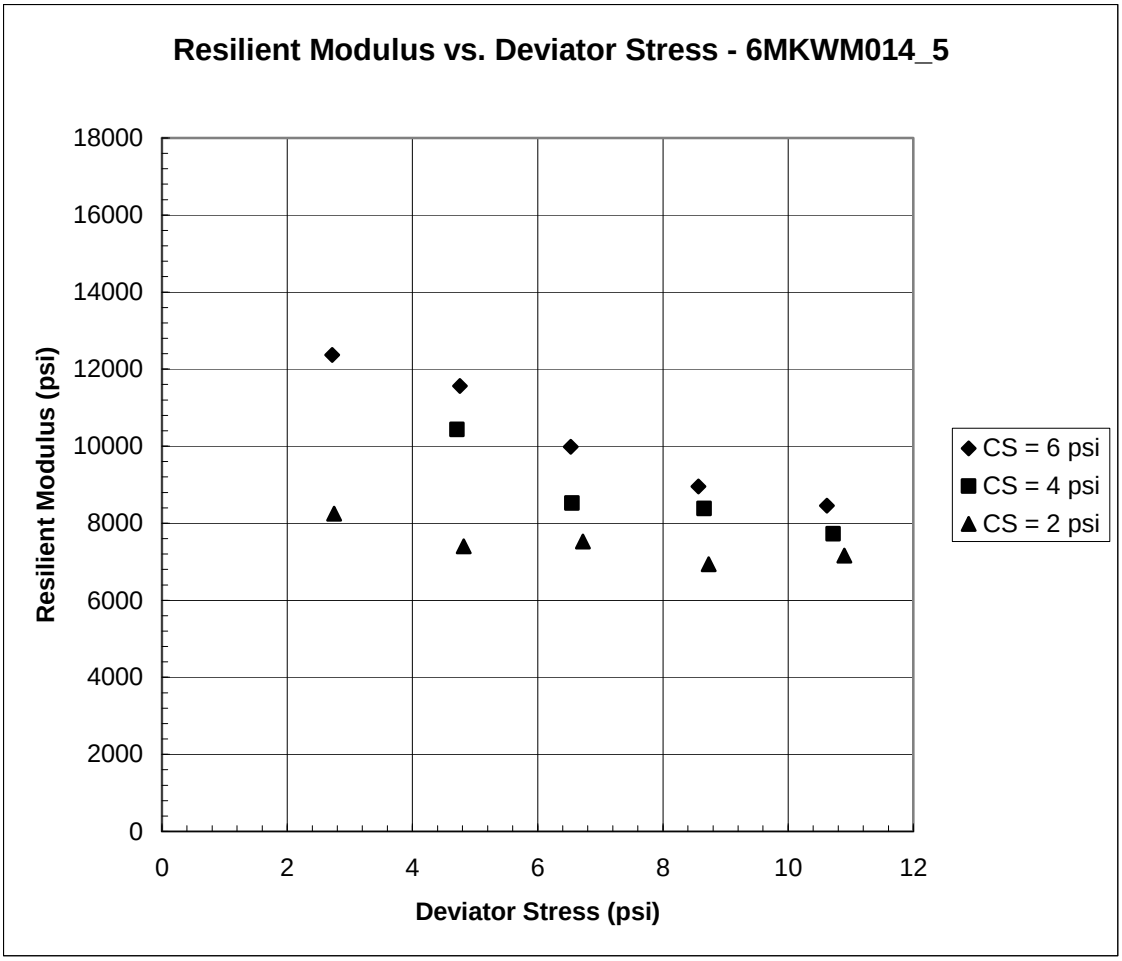
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.07	14107	14127	14171	14071	14080	14111
2	6	4.07	12369	12419	12397	12446	12396	12406
3	6	5.9	11724	11715	11718	11695	11562	11683
4	6	8.01	10933	10925	10927	10845	10819	10890
5	6	10.1	10646	10647	10559	10598	10569	10604
6	4	2.04	12214	12208	12174	12765	12709	12414
7	4	4.01	10251	10295	10250	10276	10226	10260
8	4	5.87	9236	9134	9125	9046	9231	9154
9	4	7.93	9021	9060	8999	9010	9082	9034
10	4	10.08	9083	9089	9082	9105	9073	9086
11	2	2.03	10059	10010	10047	10406	10047	10114
12	2	4.01	7675	7861	7883	7741	7758	7784
13	2	5.93	7193	7217	7193	7217	7203	7205
14	2	7.98	7283	7191	7282	7274	7291	7264
15	2	10.03	7442	7487	7483	7444	7475	7466



Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.05	15289	15276	15268	15385	15292	15302
2	6	4.08	13530	13525	13225	12892	13219	13278
3	6	5.95	12115	11918	12286	11936	12281	12107
4	6	7.99	11415	11415	11417	11646	11401	11459
5	6	9.99	11222	11232	11153	11223	11234	11213
6	4	2.04	13198	13210	12625	13138	12573	12949
7	4	4.04	10473	10481	10455	10499	10654	10512
8	4	5.91	9699	9931	9685	9575	9703	9718
9	4	7.95	9606	9437	9610	9608	9607	9574
10	4	10.01	9589	9656	9451	9721	9463	9576
11	2	2.02	10254	9864	9906	10207	10213	10089
12	2	3.95	8499	8374	8371	8372	8373	8398
13	2	5.94	7568	7637	7501	7637	7503	7569
14	2	7.95	7608	7612	7619	7620	7628	7617
15	2	9.93	7822	7815	7780	7955	7824	7839



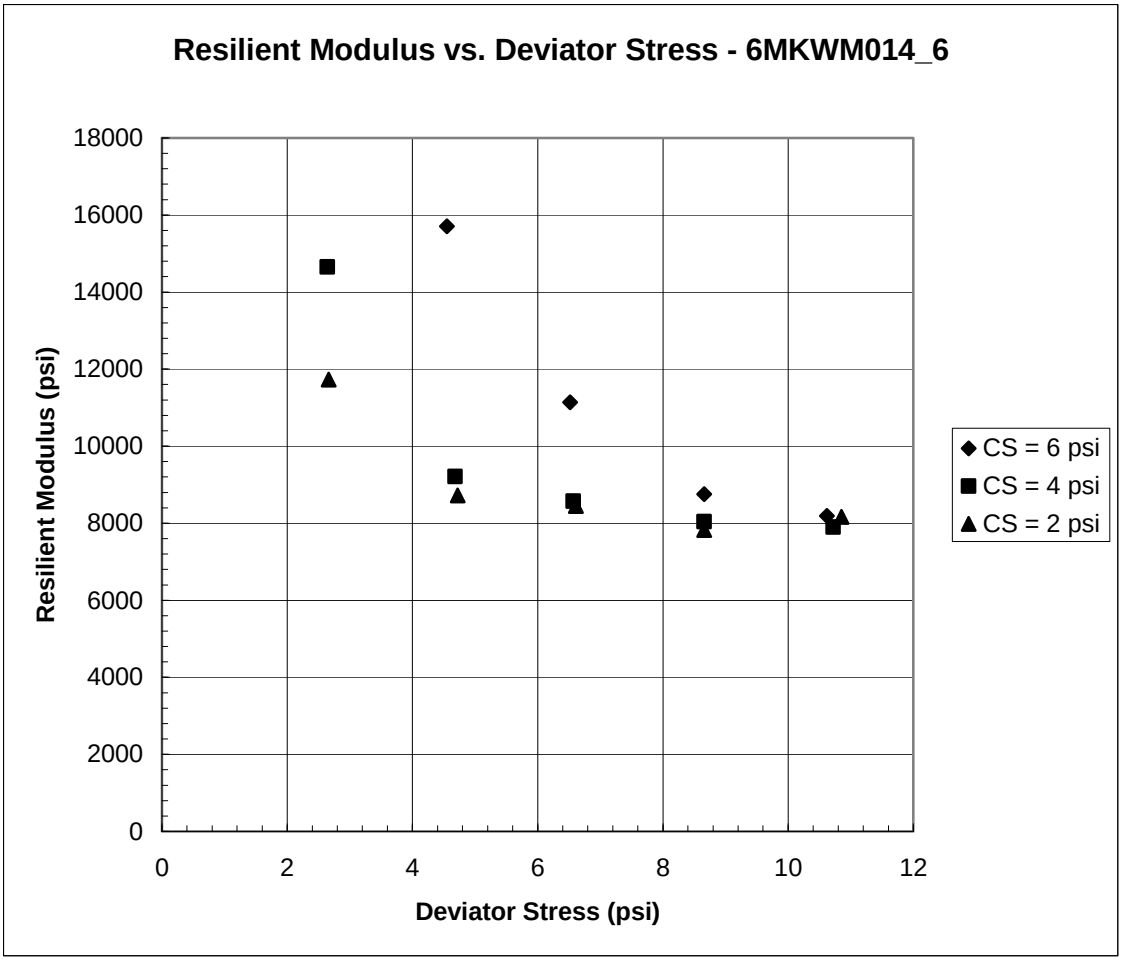
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.7	13261	14028	13509	13499	14039	13667
2	6	4.7	12330	12335	12358	12355	12694	12414
3	6	6.58	10410	10392	10218	10359	10224	10320
4	6	8.69	8979	8996	8914	8945	9081	8983
5	6	10.53	8744	8817	8746	8669	8674	8730
6	4	2.74	9913	9954	9973	10269	9908	10003
7	4	4.76	8488	8479	8628	8622	8645	8573
8	4	6.63	7981	7991	7940	8069	7967	7990
9	4	8.67	7921	7914	8042	7993	8011	7976
10	4	10.69	8127	8236	8253	8224	8214	8211
11	2	2.74	9250	9258	9266	9254	9269	9259
12	2	4.66	8010	8013	8032	8031	8076	8032
13	2	6.71	7991	7907	7791	7784	7955	7886
14	2	8.75	7716	7770	7840	7869	7877	7814
15	2	10.72	7401	7402	7427	7389	7438	7411



Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.72	12390	12336	12404	12344	12349	12365
2	6	4.76	11564	11570	11582	11576	11540	11566
3	6	6.53	9877	10013	10030	10011	10000	9986
4	6	8.57	8932	8924	9005	8982	8943	8957
5	6	10.62	8446	8454	8451	8444	8494	8458
6	4	2.71	17597	17545	17583	17594	17700	17603.8
7	4	4.71	10510	10365	10415	10344	10535	10434
8	4	6.55	8602	8485	8413	8501	8600	8520
9	4	8.66	8424	8372	8365	8365	8374	8380
10	4	10.72	7693	7692	7750	7754	7754	7729
11	2	2.75	8276	8271	8002	8234	8478	8252
12	2	4.82	7424	7419	7330	7437	7403	7403
13	2	6.72	7549	7457	7534	7536	7561	7527
14	2	8.73	6952	6909	6942	6943	6951	6940
15	2	10.9	7106	7174	7180	7180	7179	7164

Calculated

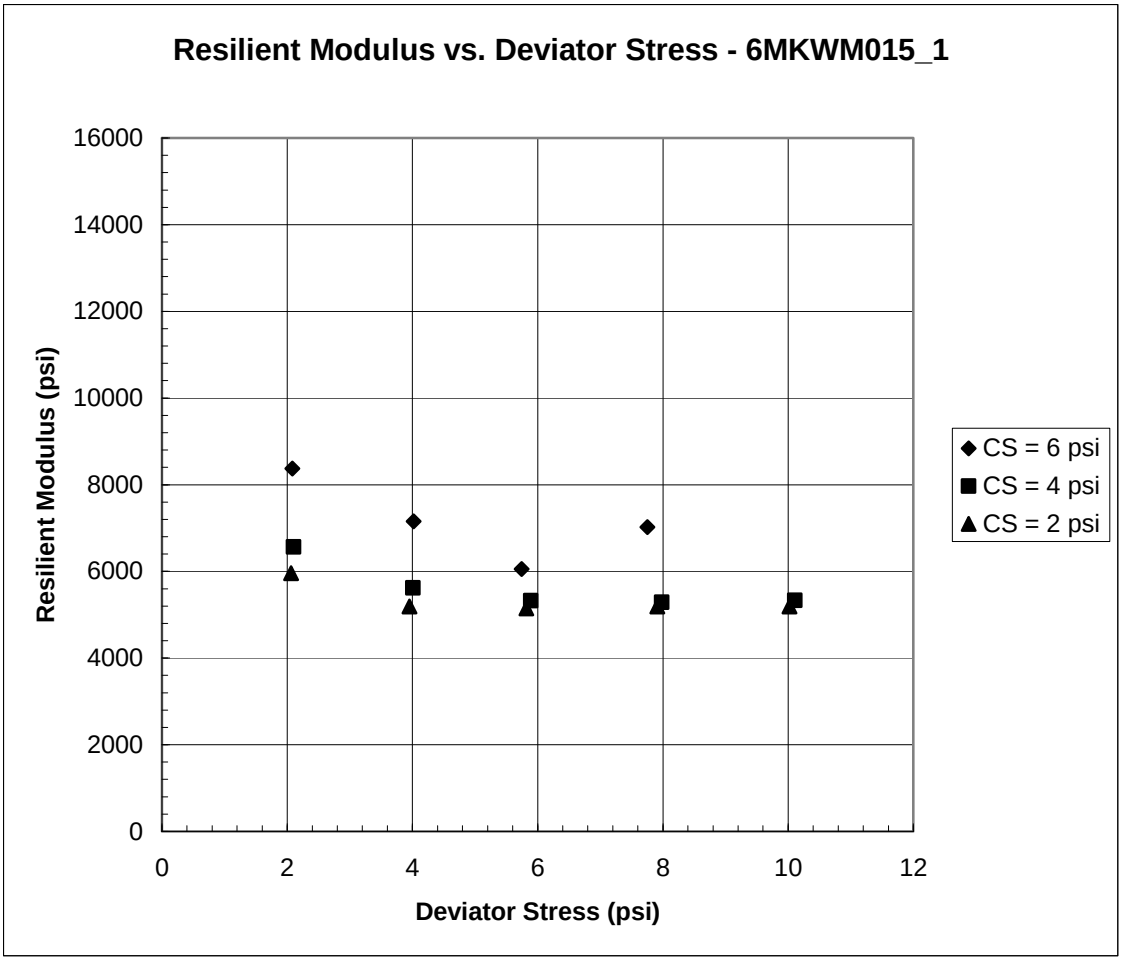
Not used in re-analysis



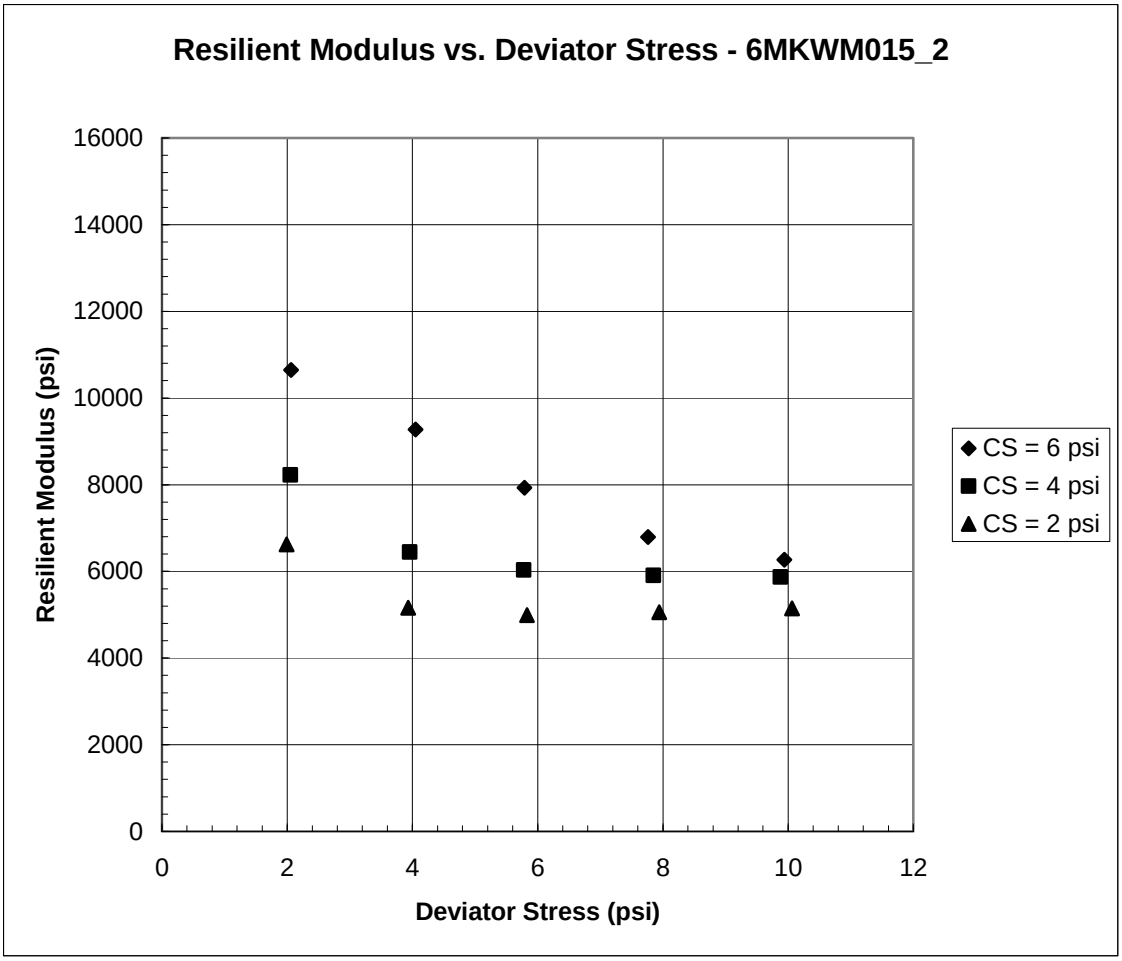
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.62	26236	27273	27305	26417	27273	26900.8
2	6	4.55	16140	15592	15581	15731	15484	15706
3	6	6.52	11143	11263	11097	11088	11093	11137
4	6	8.66	8700	8780	8718	8795	8786	8756
5	6	10.62	8198	8143	8232	8169	8221	8192
6	4	2.64	15260	15137	15166	12800	14905	14653
7	4	4.68	9271	9130	9167	9179	9308	9211
8	4	6.57	8495	8615	8570	8543	8633	8571
9	4	8.66	8007	8074	7993	8080	8037	8038
10	4	10.72	7916	7947	7876	7853	7902	7899
11	2	2.66	11440	11392	13660	10791	11375	11731
12	2	4.72	8759	8753	8685	8723	8687	8722
13	2	6.61	8517	8519	8462	8427	8322	8450
14	2	8.66	7843	7795	7764	7872	7868	7828
15	2	10.85	7328	7536	8056	8624	9301	8169

Calculated

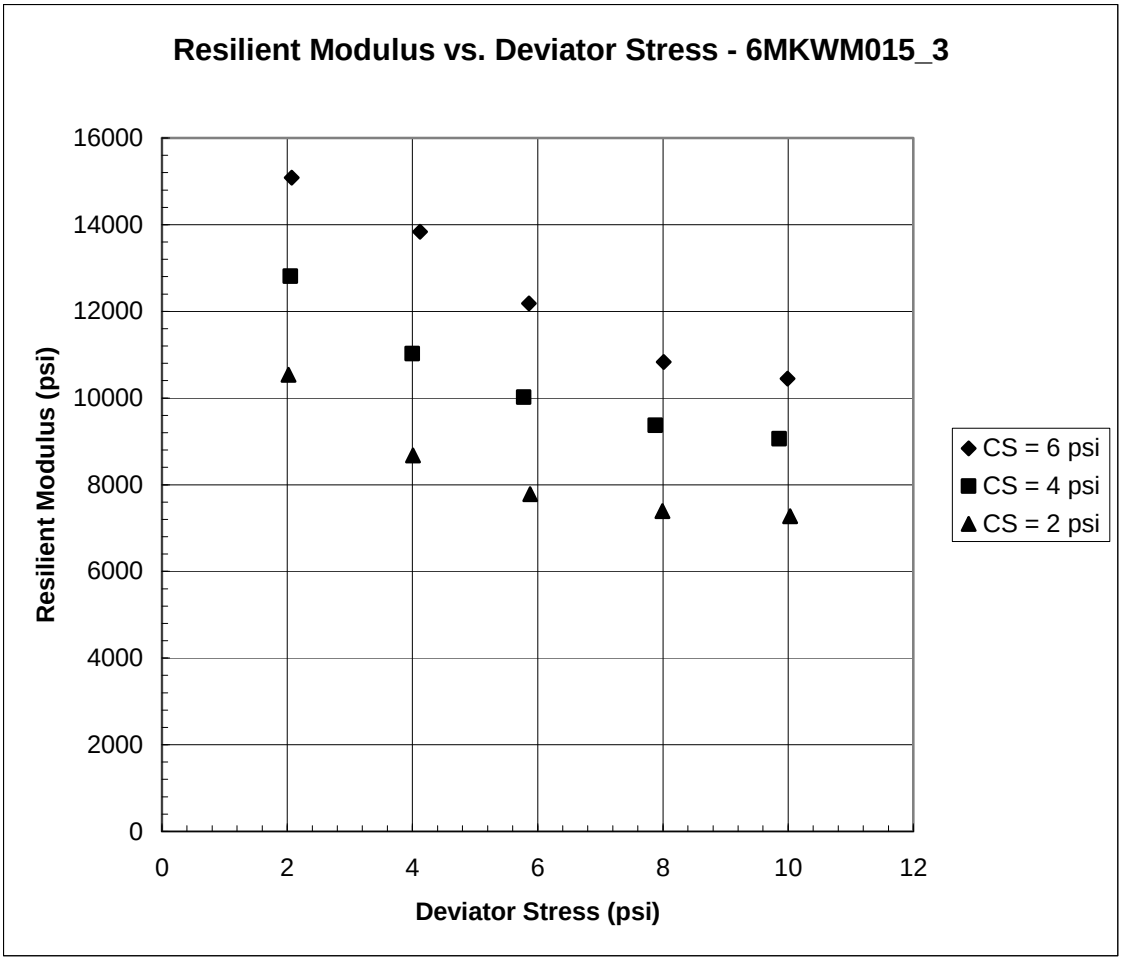
Not used in re-analysis



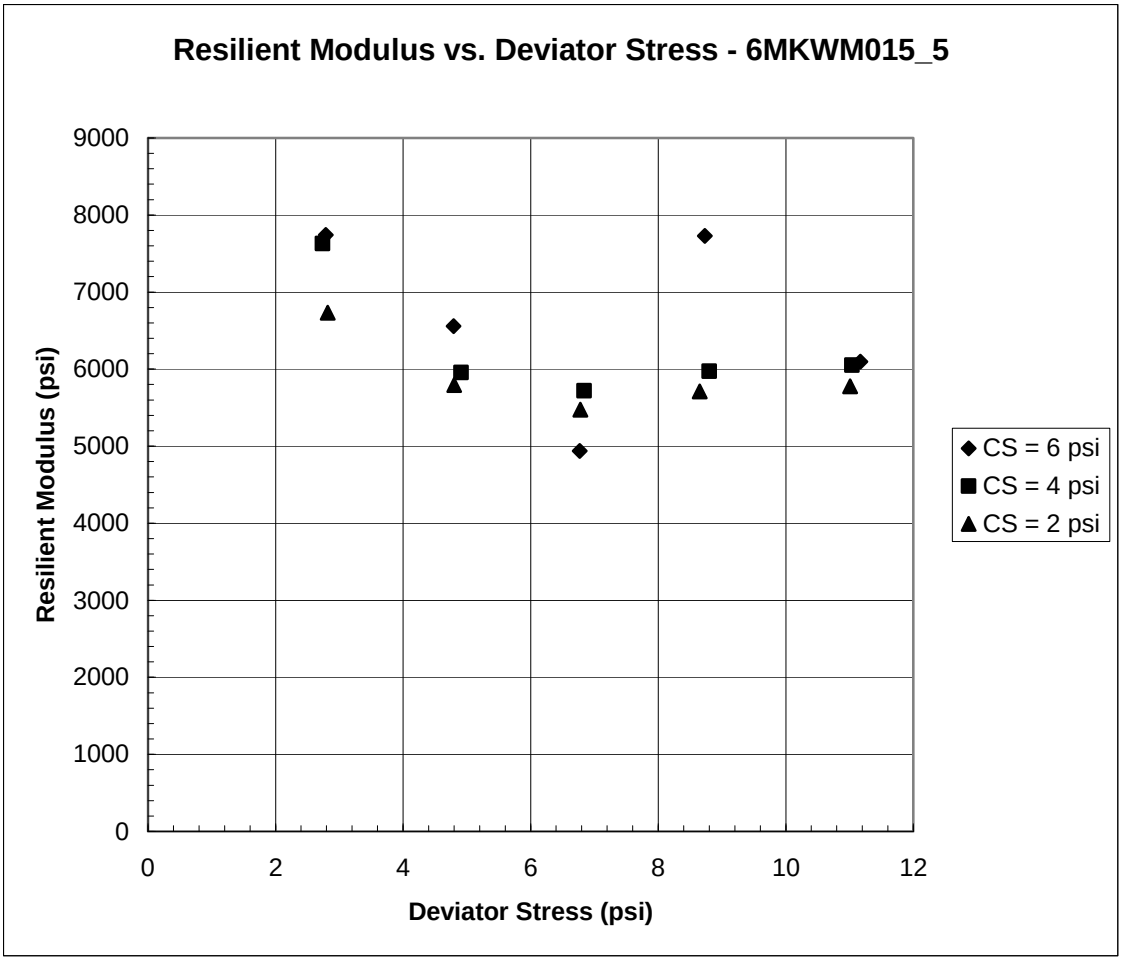
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.08	8254	8522	8289	8527	8288	8376
2	6	4.02	7214	7197	7109	7021	7214	7151
3	6	5.74	6035	6089	6033	6088	6044	6058
4	6	7.75	6850	6928	7034	7070	7218	7020
5	6							
6	4	2.1	6407	6713	6543	6718	6433	6563
7	4	4.01	5563	5674	5632	5619	5590	5616
8	4	5.89	5336	5302	5343	5312	5344	5327
9	4	7.98	5326	5259	5247	5358	5260	5290
10	4	10.11	5346	5322	5327	5346	5327	5333
11	2	2.06	5910	5908	5911	6029	6030	5958
12	2	3.95	5176	5258	5188	5174	5175	5194
13	2	5.82	5100	5142	5198	5142	5134	5143
14	2	7.91	5181	5182	5211	5199	5188	5192
15	2	10.02	5154	5249	5160	5216	5165	5189



Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.06	11013	10958	10673	9925	10671	10648
2	6	4.05	9402	9238	9210	9291	9220	9272
3	6	5.79	7881	7914	7892	8004	7968	7932
4	6	7.76	6822	6811	6788	6781	6756	6791
5	6	9.94	6281	6252	6287	6264	6276	6272
6	4	2.05	8228	8232	8192	8266	8195	8223
7	4	3.96	6499	6466	6426	6485	6354	6446
8	4	5.78	5993	6045	6045	6037	6056	6035
9	4	7.85	5903	5882	5947	5829	5971	5906
10	4	9.88	5854	5895	5859	5876	5870	5871
11	2	1.99	6512	6485	6823	6652	6640	6622
12	2	3.93	5191	5154	5166	5156	5153	5164
13	2	5.83	5011	4959	5012	4974	5011	4993
14	2	7.94	5049	5041	5061	5042	5087	5056
15	2	10.06	5133	5161	5153	5157	5131	5147

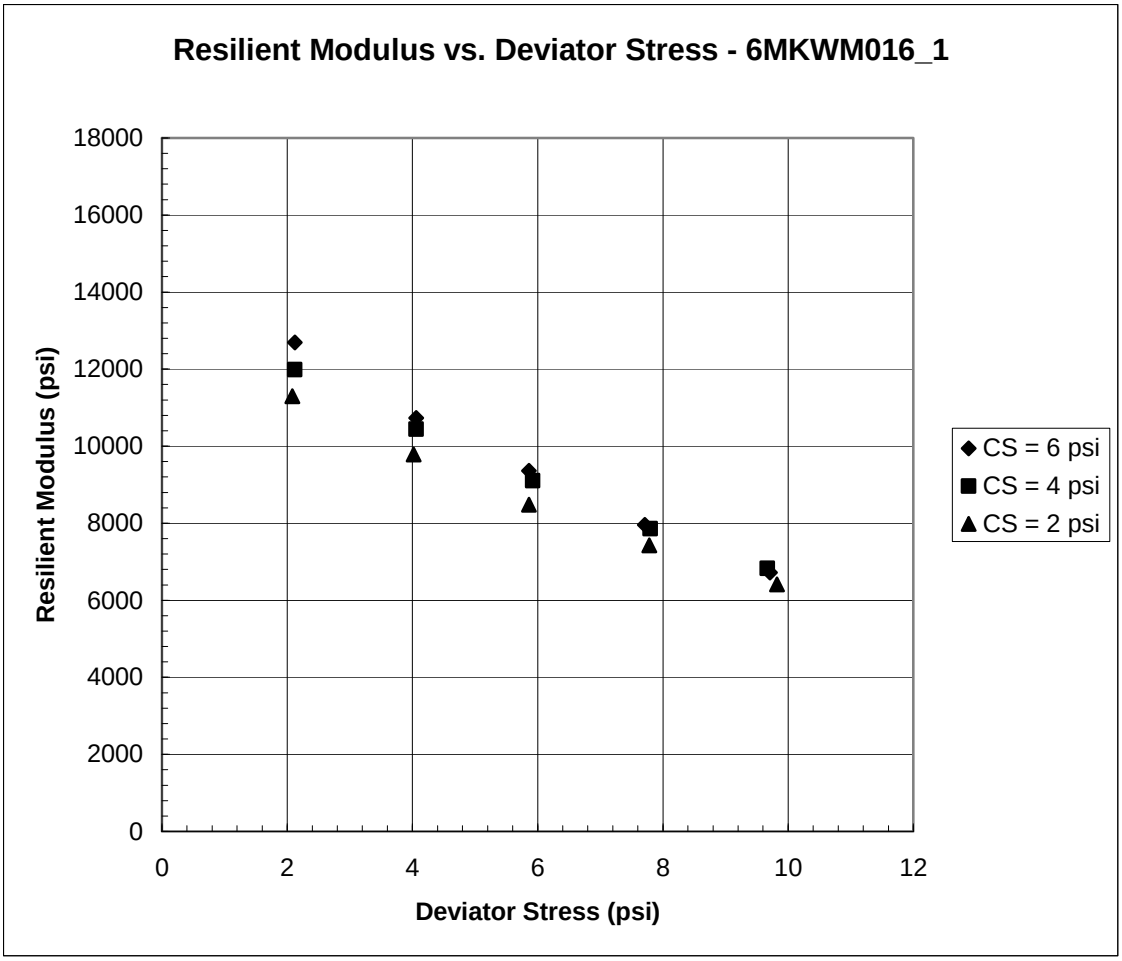


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.07	14685	15341	14750	15299	15361	15087
2	6	4.12	13964	13965	13650	13905	13681	13833
3	6	5.86	12109	12063	12262	12256	12233	12185
4	6	8.01	10886	10848	10692	10939	10799	10833
5	6	9.99	10536	10359	10378	10431	10543	10449
6	4	2.05	13248	12748	12692	12742	12640	12814
7	4	4	11185	10792	10746	11232	11160	11023
8	4	5.78	10079	10088	9713	10063	10168	10022
9	4	7.88	9364	9323	9376	9419	9367	9370
10	4	9.86	8956	9037	9133	9046	9142	9063
11	2	2.02	10748	10794	10370	10425	10351	10537
12	2	4.01	8599	8654	8707	8802	8597	8672
13	2	5.88	7776	7857	7788	7774	7729	7785
14	2	7.99	7391	7466	7391	7320	7373	7388
15	2	10.03	7371	7254	7221	7282	7228	7271

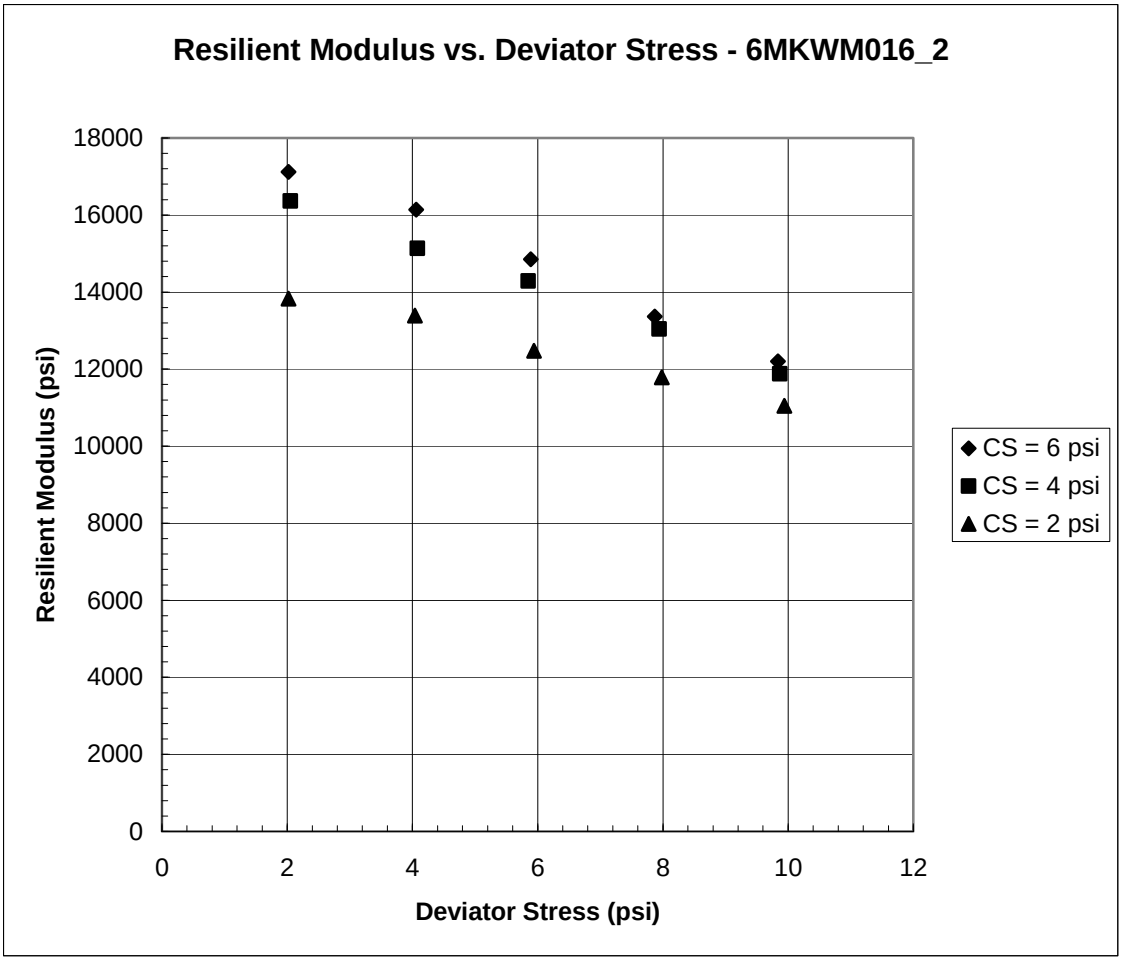


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.79	7717	7743	7746	7785	7720	7742
2	6	4.79	6533	6605	6537	6591	6519	6557
3	6	6.77	4927	4920	4954	4952	4944	4939
4	6	8.73	9247	9815	4870	4963	9761	7731
5	6	11.17	6076	6056	6085	6116	6150	6097
6	4	2.74	7493	7727	7759	7689	7485	7630
7	4	4.91	5920	5929	5956	5962	6014	5956
8	4	6.84	5715	5752	5763	5675	5700	5721
9	4	8.8	6004	6012	5937	5967	5950	5974
10	4	11.04	5993	6051	6086	6080	6051	6052
11	2	2.82	6817	6704	6730	6613	6793	6732
12	2	4.8	5695	5818	5759	5844	5859	5795
13	2	6.78	5473	5517	5492	5473	5423	5476
14	2	8.65	5741	5714	5724	5686	5679	5709
15	2	11.01	5752	5763	5797	5807	5768	5777

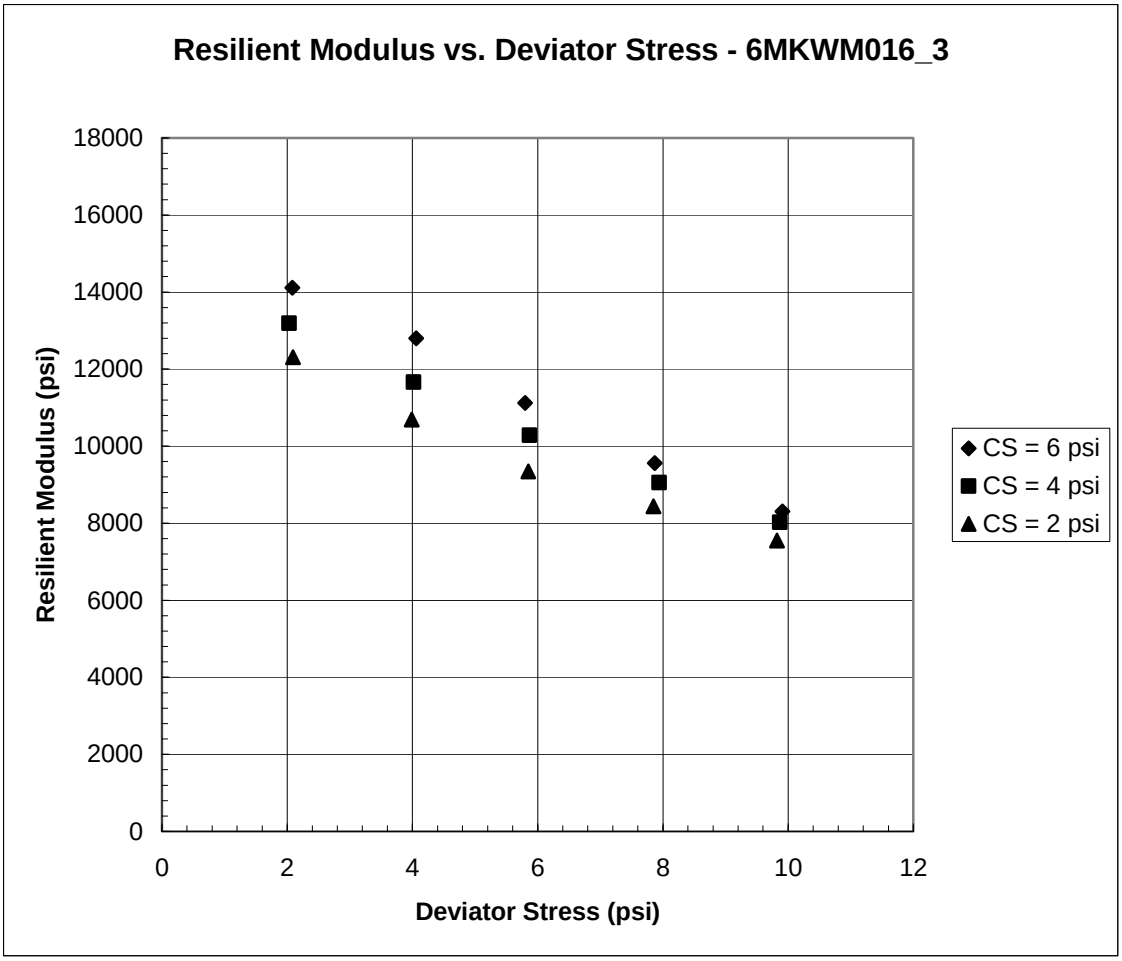
Not used in re-analysis



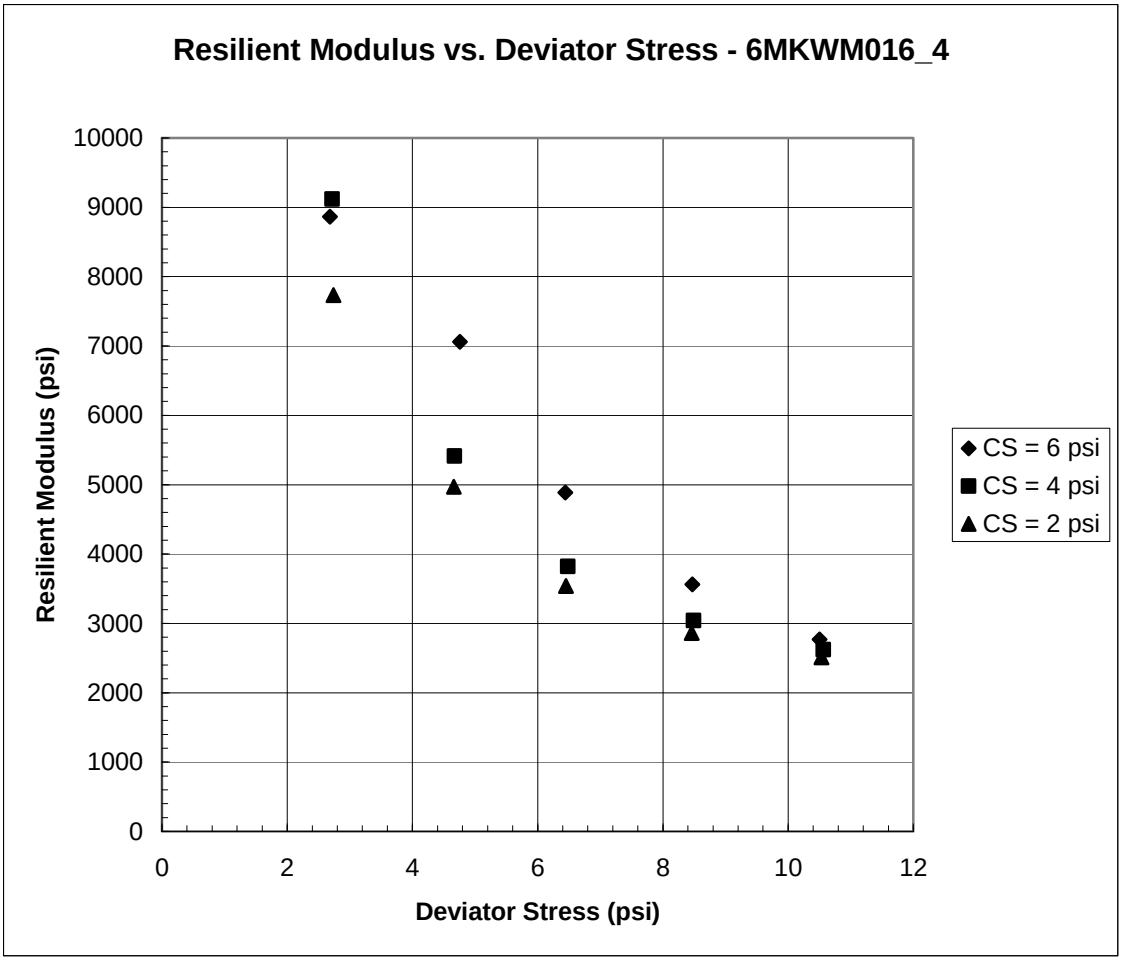
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.12	12653	12701	12677	12705	12731	12693
2	6	4.06	10618	10812	10853	10784	10614	10736
3	6	5.86	9259	9436	9455	9231	9439	9364
4	6	7.71	8004	7898	7880	8010	7992	7957
5	6	9.71	6720	6714	6663	6785	6725	6721
6	4	2.12	11771	11815	11769	12812	11781	11990
7	4	4.06	10255	10419	10650	10633	10259	10443
8	4	5.92	9041	9041	9238	9057	9123	9100
9	4	7.8	7809	7838	7819	7885	7932	7857
10	4	9.67	6833	6818	6866	6788	6836	6828
11	2	2.08	11126	11148	11577	11101	11522	11295
12	2	4.02	9935	9806	9599	9979	9591	9782
13	2	5.86	8495	8572	8410	8400	8510	8477
14	2	7.78	7438	7422	7430	7431	7430	7430
15	2	9.82	6400	6448	6398	6414	6404	6413



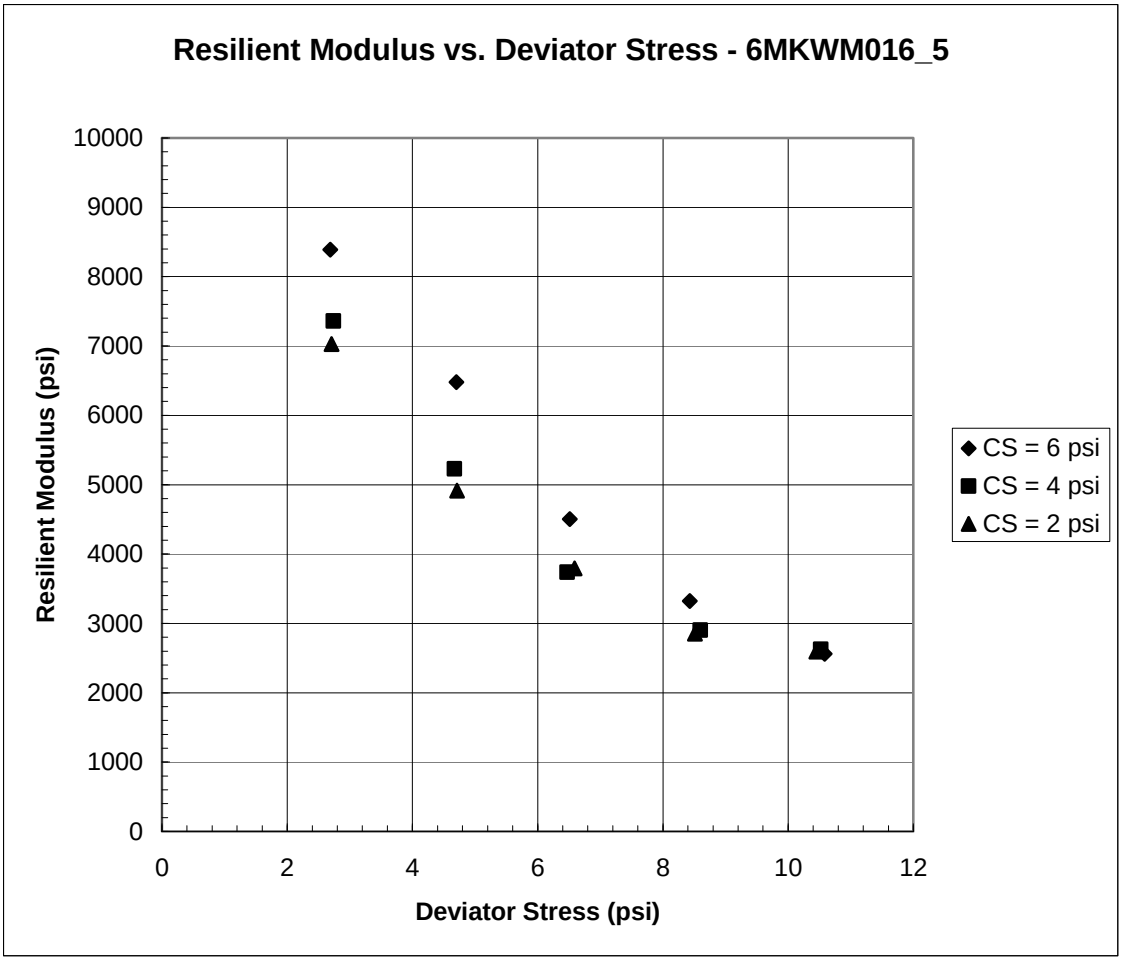
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.02	17117	17172	17117	17091	17090	17118
2	6	4.06	15813	16673	16216	15772	16210	16137
3	6	5.89	14655	14873	14910	14908	14910	14851
4	6	7.87	13486	13464	13191	13304	13362	13361
5	6	9.84	12223	12234	12225	12120	12205	12202
6	4	2.05	16412	16376	16354	16333	16324	16360
7	4	4.08	15850	15067	15430	14723	14621	15138
8	4	5.85	14276	14517	14036	14537	14055	14284
9	4	7.94	13016	12999	13166	13016	13002	13040
10	4	9.87	11831	11842	11852	11929	11957	11882
11	2	2.02	13806	13871	13855	13818	13807	13831
12	2	4.04	13274	13577	13572	12968	13566	13391
13	2	5.94	12399	12561	12583	12599	12221	12473
14	2	7.98	11740	11738	11740	11873	11861	11790
15	2	9.94	11024	11040	10937	11020	11211	11046



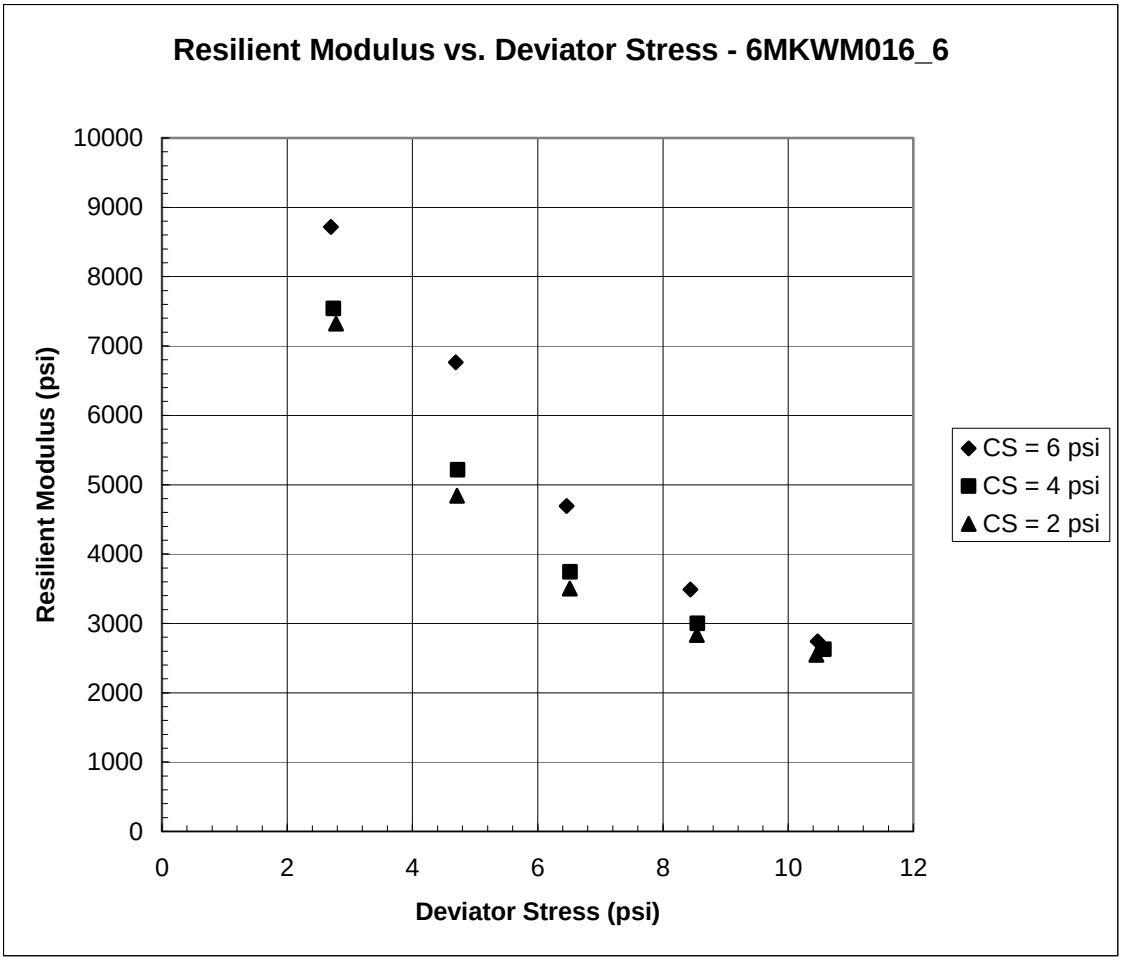
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.08	14257	14256	13562	14197	14275	14109
2	6	4.06	12683	12955	12680	12736	12956	12802
3	6	5.8	10962	11076	11066	11233	11259	11119
4	6	7.87	9575	9586	9515	9680	9446	9560
5	6	9.91	8294	8303	8343	8290	8295	8305
6	4	2.03	13337	12701	13326	13270	13334	13194
7	4	4.02	11564	11774	11590	11803	11564	11659
8	4	5.87	10398	10288	10287	10148	10285	10281
9	4	7.94	9145	8932	9137	9065	9001	9056
10	4	9.87	8022	8124	8015	7933	8012	8021
11	2	2.09	13041	11995	12500	11537	12490	12312
12	2	3.99	10587	10835	10584	10835	10607	10690
13	2	5.85	9464	9342	9342	9244	9342	9347
14	2	7.85	8424	8478	8416	8480	8408	8441
15	2	9.82	7554	7552	7554	7554	7547	7552



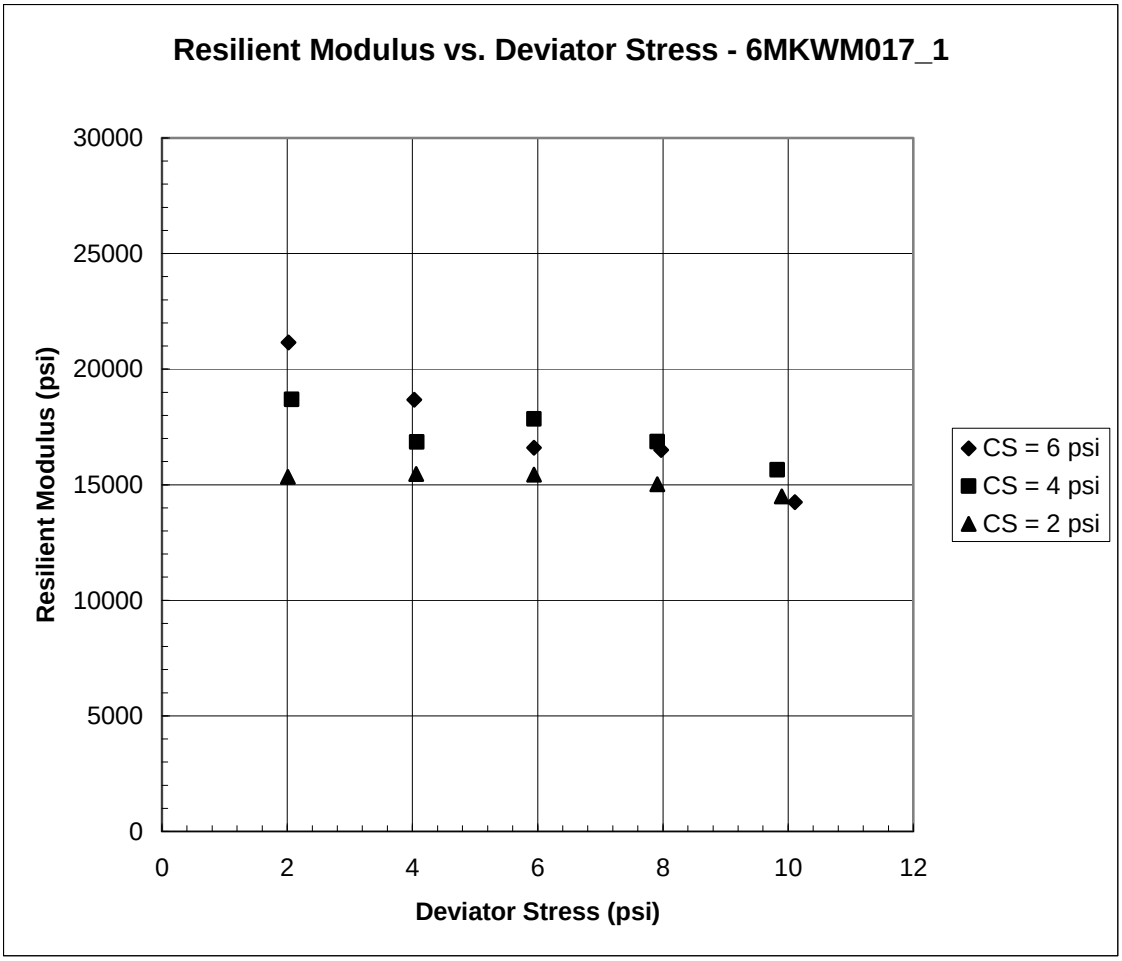
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.68	8849	8896	8850	8808	8928	8866
2	6	4.76	7047	7135	7063	7015	7033	7059
3	6	6.44	4881	4843	4907	4922	4869	4885
4	6	8.47	3561	3573	3561	3568	3549	3562
5	6	10.5	2763	2764	2762	2770	2784	2768
6	4	2.72	9085	9377	9060	9052	9018	9118
7	4	4.67	5381	5389	5445	5451	5389	5411
8	4	6.48	3835	3828	3806	3811	3832	3822
9	4	8.49	3057	3031	3037	3066	3015	3041
10	4	10.56	2631	2626	2626	2613	2610	2621
11	2	2.74	7765	7731	7738	7735	7702	7734
12	2	4.66	4948	4960	4961	4972	5003	4969
13	2	6.45	3531	3552	3545	3539	3537	3541
14	2	8.46	2823	2860	2864	2877	2875	2860
15	2	10.53	2501	2500	2517	2522	2506	2509



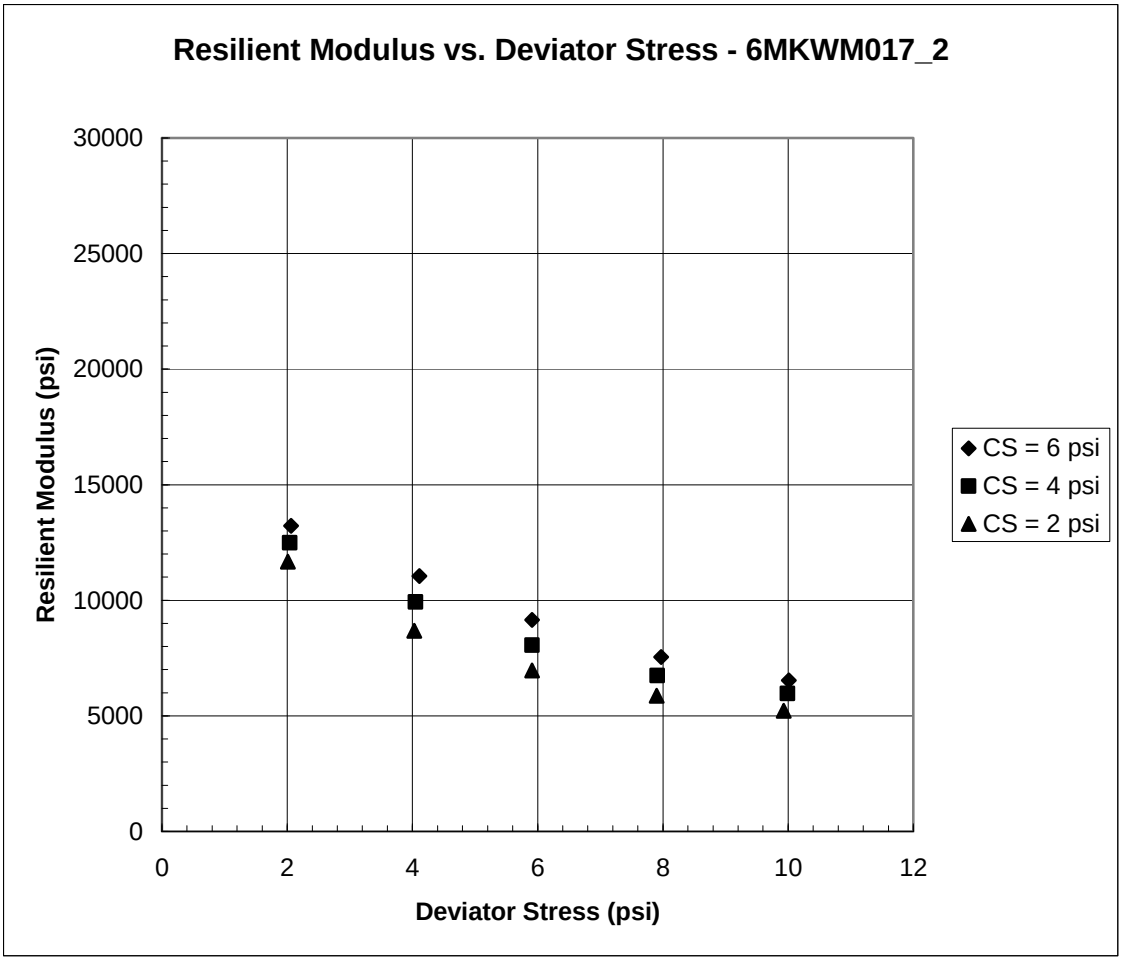
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.69	8374	8331	8457	8371	8413	8389
2	6	4.7	6481	6478	6435	6470	6541	6481
3	6	6.51	4502	4533	4484	4528	4484	4506
4	6	8.43	3332	3331	3324	3308	3327	3324
5	6	10.58	2541	2558	2569	2580	2557	2561
6	4	2.74	7382	7354	7348	7340	7378	7360
7	4	4.67	5244	5252	5250	5239	5155	5228
8	4	6.47	3771	3731	3721	3739	3738	3740
9	4	8.6	2877	2909	2897	2931	2907	2904
10	4	10.52	2630	2626	2622	2632	2611	2624
11	2	2.71	7027	7037	6999	7030	7057	7030
12	2	4.71	4907	4952	4949	4882	4886	4915
13	2	6.59	3779	3790	3780	3809	3811	3794
14	2	8.51	2851	2856	2866	2853	2836	2852
15	2	10.45	2603	2616	2592	2565	2585	2592



Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.7	8746	8750	8705	8674	8704	8716
2	6	4.69	6739	6744	6738	6773	6842	6767
3	6	6.46	4684	4717	4720	4655	4680	4691
4	6	8.44	3483	3489	3469	3485	3513	3488
5	6	10.47	2747	2744	2754	2734	2729	2742
6	4	2.74	7541	7546	7542	7548	7516	7539
7	4	4.72	5163	5183	5222	5281	5223	5215
8	4	6.52	3755	3750	3726	3737	3742	3742
9	4	8.55	2963	2987	2999	3040	3006	2999
10	4	10.57	2634	2649	2622	2593	2634	2626
11	2	2.78	7287	7322	7327	7331	7356	7325
12	2	4.71	4866	4865	4813	4852	4814	4842
13	2	6.51	3480	3495	3520	3517	3505	3503
14	2	8.54	2849	2846	2844	2808	2827	2835
15	2	10.45	2550	2541	2535	2545	2557	2546

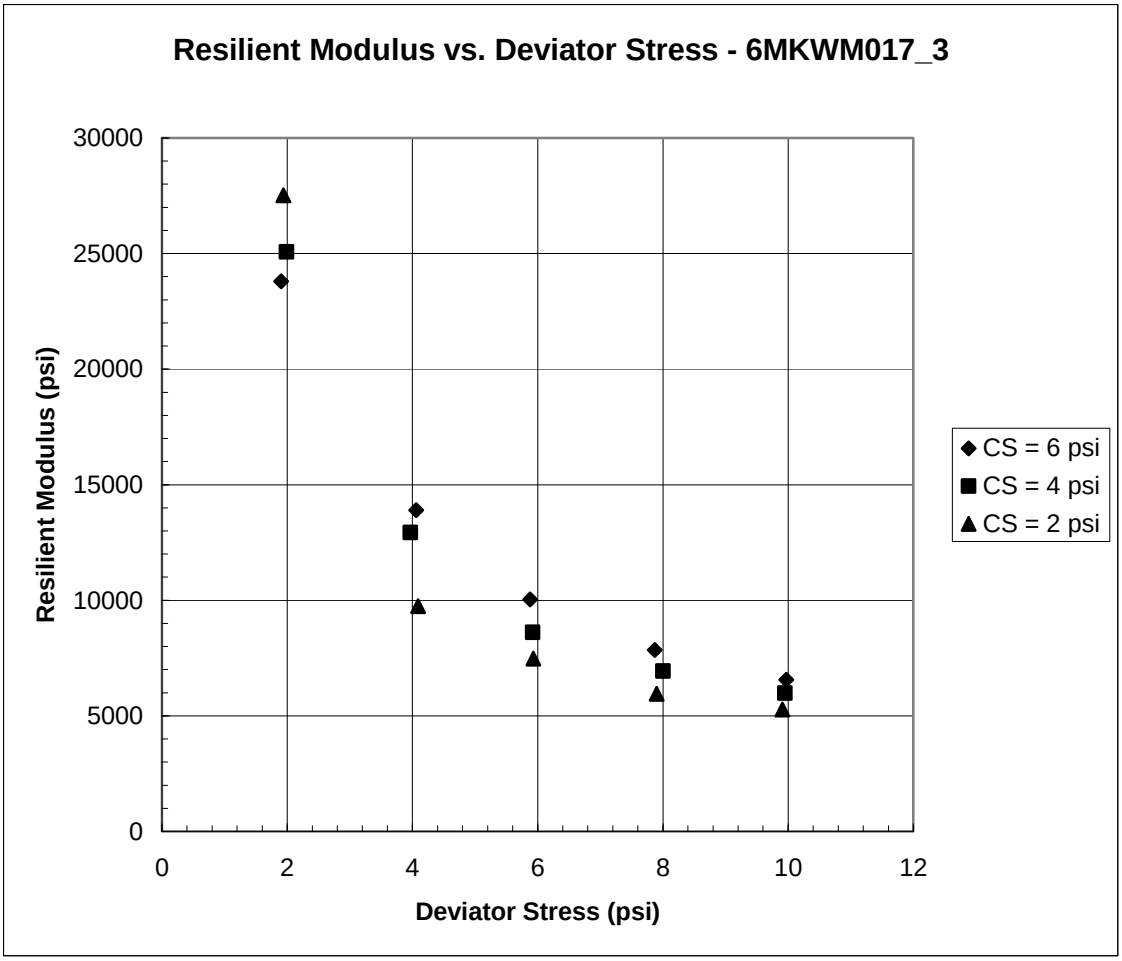


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.02	21987	20589	20496	22126	20545	21148
2	6	4.03	18909	18954	18311	18263	18939	18675
3	6	5.94	16696	16710	16482	16345	16765	16600
4	6	7.97	16476	16506	16502	16532	16492	16502
5	6	10.11	14226	14545	14236	14090	14110	14241
6	4	2.07	18156	19486	19433	18062	18340	18695
7	4	4.07	16809	16881	16851	16854	16861	16851
8	4	5.94	17765	17744	17788	17741	18211	17850
9	4	7.91	16839	16626	17096	16630	17100	16858
10	4	9.83	15501	15688	15694	15668	15696	15649
11	2	2.01	15530	15761	14916	14867	15610	15337
12	2	4.06	15445	15484	15523	15418	15463	15466
13	2	5.94	15489	15217	15491	15518	15437	15431
14	2	7.91	15435	14842	15007	14822	15018	15025
15	2	9.9	14489	14504	14490	14499	14502	14497



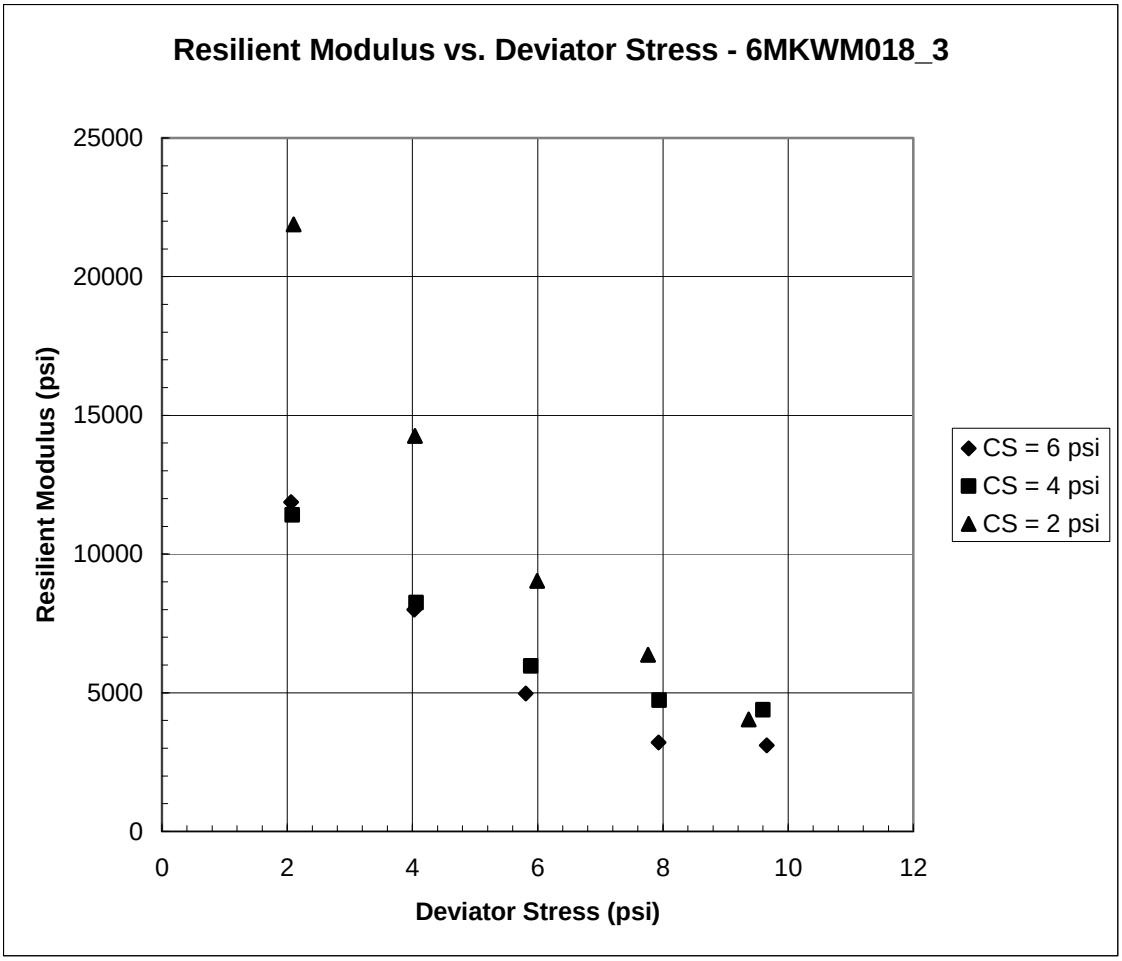
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.06	13859	13265	12641	13131	13218	13223
2	6	4.11	10893	11104	11077	11098	11074	11049
3	6	5.91	9089	9103	9217	9131	9204	9149
4	6	7.97	7608	7552	7486	7545	7551	7549
5	6	10.01	6506	6524	6591	6541	6528	6538
6	4	2.04	12516	12446	12465	12530	12507	12493
7	4	4.05	9926	9778	9960	9981	9998	9929
8	4	5.91	8040	8064	8122	8018	8044	8058
9	4	7.91	6747	6714	6750	6763	6762	6747
10	4	9.99	5954	5990	5980	5961	5955	5968
11	2	2.01	11874	11339	11766	11723	11667	11674
12	2	4.03	8673	8693	8708	8588	8731	8678
13	2	5.91	6971	6974	6975	6922	6953	6959
14	2	7.9	5889	5840	5876	5857	5888	5870
15	2	9.93	5227	5235	5239	5196	5184	5216

Not used in re-analysis



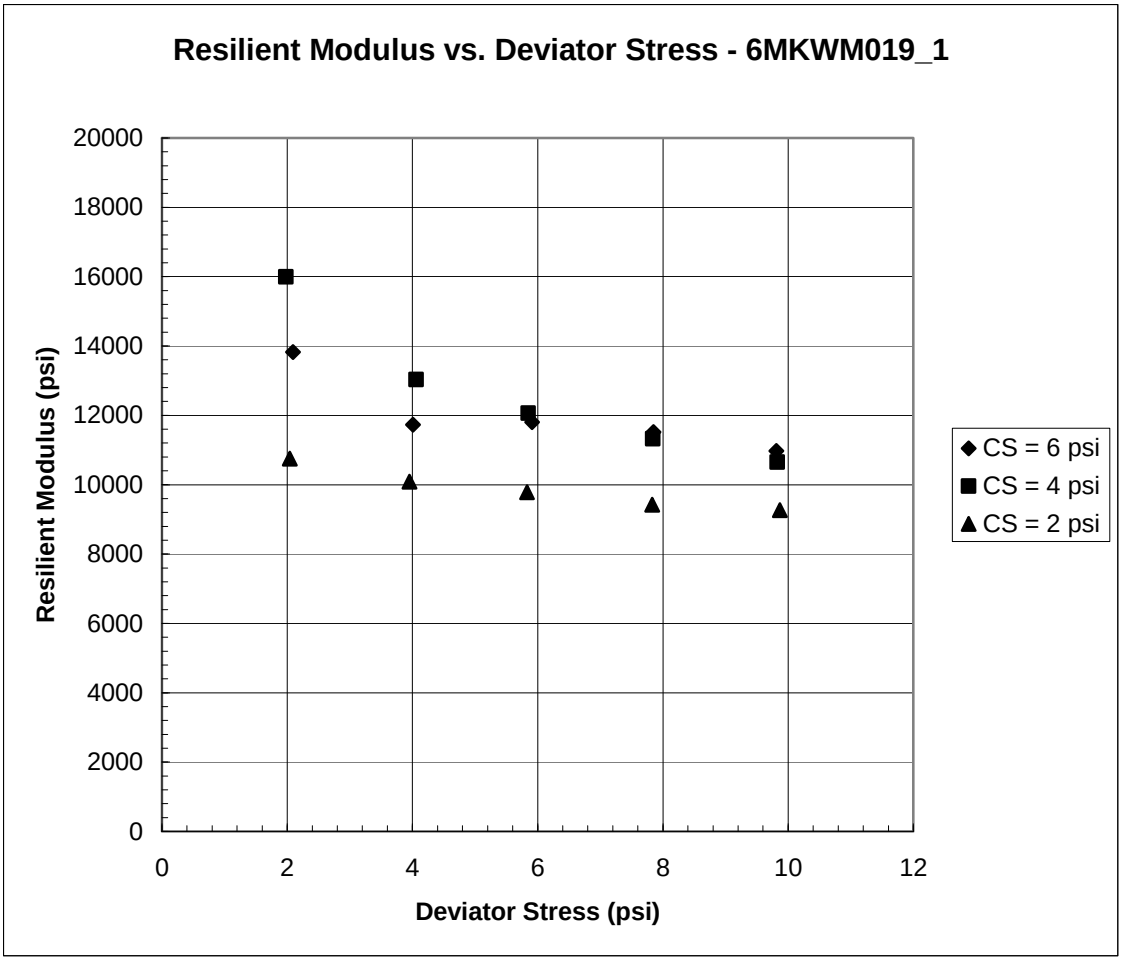
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	1.9	23364	20258	26384	21976	27031	23803
2	6	4.06	13603	14084	14057	13651	14074	13894
3	6	5.88	10019	10007	10055	10009	10124	10043
4	6	7.87	7838	7839	7870	7850	7876	7854
5	6	9.97	6557	6572	6544	6532	6586	6558
6	4	1.99	26151	23185	22736	23924	29385	25076
7	4	3.97	12969	12520	13058	12526	13594	12933
8	4	5.92	8474	8525	8565	8625	8834	8605
9	4	8	6991	6911	6946	6942	6886	6935
10	4	9.95	5998	5977	5957	5992	5971	5979
11	2	1.94	25608	27840	28145	30244	25786	27525
12	2	4.09	9720	9801	9832	9596	9770	9744
13	2	5.93	7387	7327	7528	7551	7598	7478
14	2	7.9	5928	5954	5967	5967	5966	5957
15	2	9.91	5275	5252	5259	5258	5305	5270

Not used in re-analysis

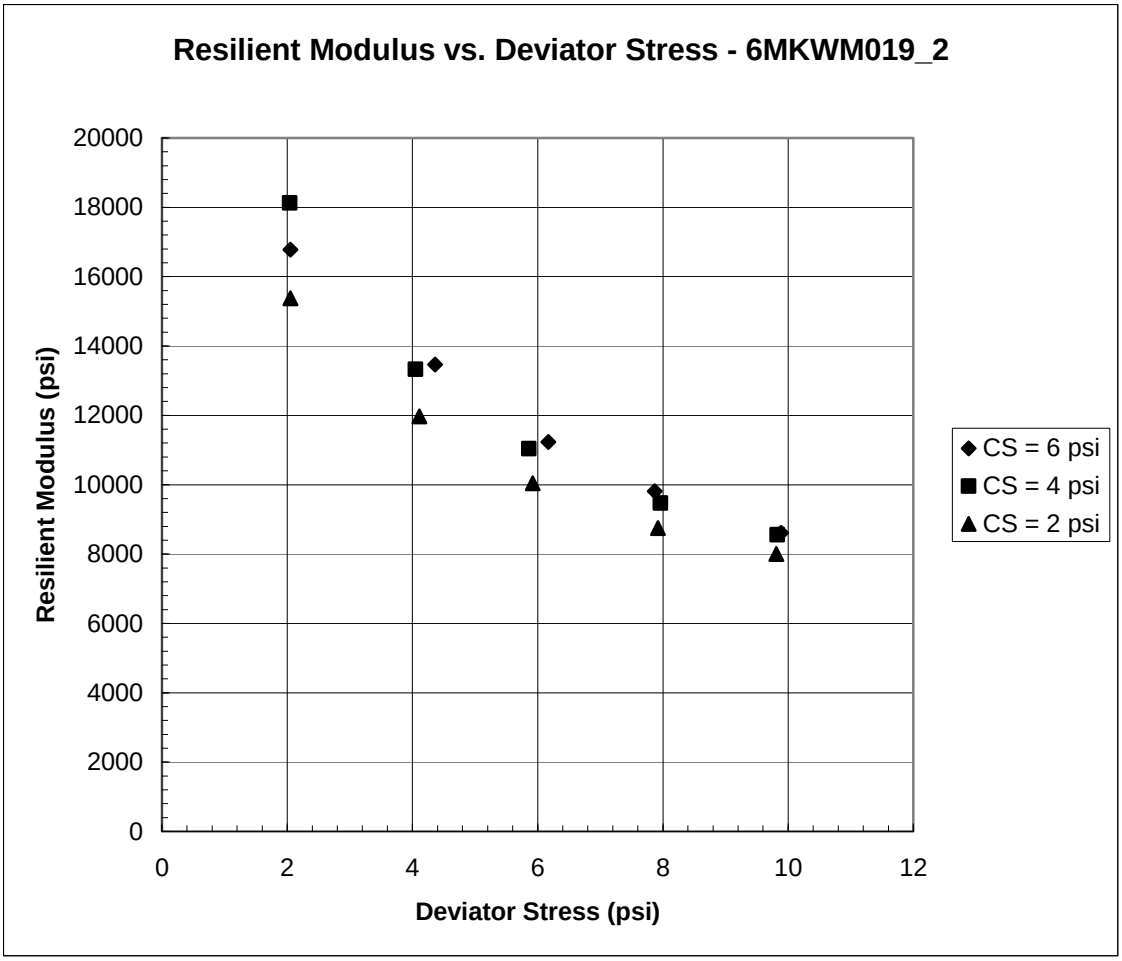


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.06	11857	11843	11903	11906	11847	11871
2	6	4.03	7998	7927	7928	8018	8109	7996
3	6	5.81	5002	4930	5084	4918	4940	4975
4	6	7.93	3267	3213	3182	3196	3157	3203
5	6	9.66	3174	3159	3097	3078	3030	3108
6	4	2.08	11252	11474	11147	11576	11573	11405
7	4	4.06	8111	8405	8210	8292	8238	8251
8	4	5.89	5960	5952	5996	5929	6006	5969
9	4	7.94	4756	4665	4785	4681	4739	4725
10	4	9.6	4319	4412	4409	4410	4377	4385
11	2	2.1	25240	18942	23496	21531	20201	21882
12	2	4.04	14149	14183	14533	13907	14536	14262
13	2	5.99	8987	8998	8907	9290	9001	9036
14	2	7.76	6323	6357	6442	6353	6349	6365
15	2	9.37	4029	4009	4054	4017	4099	4042

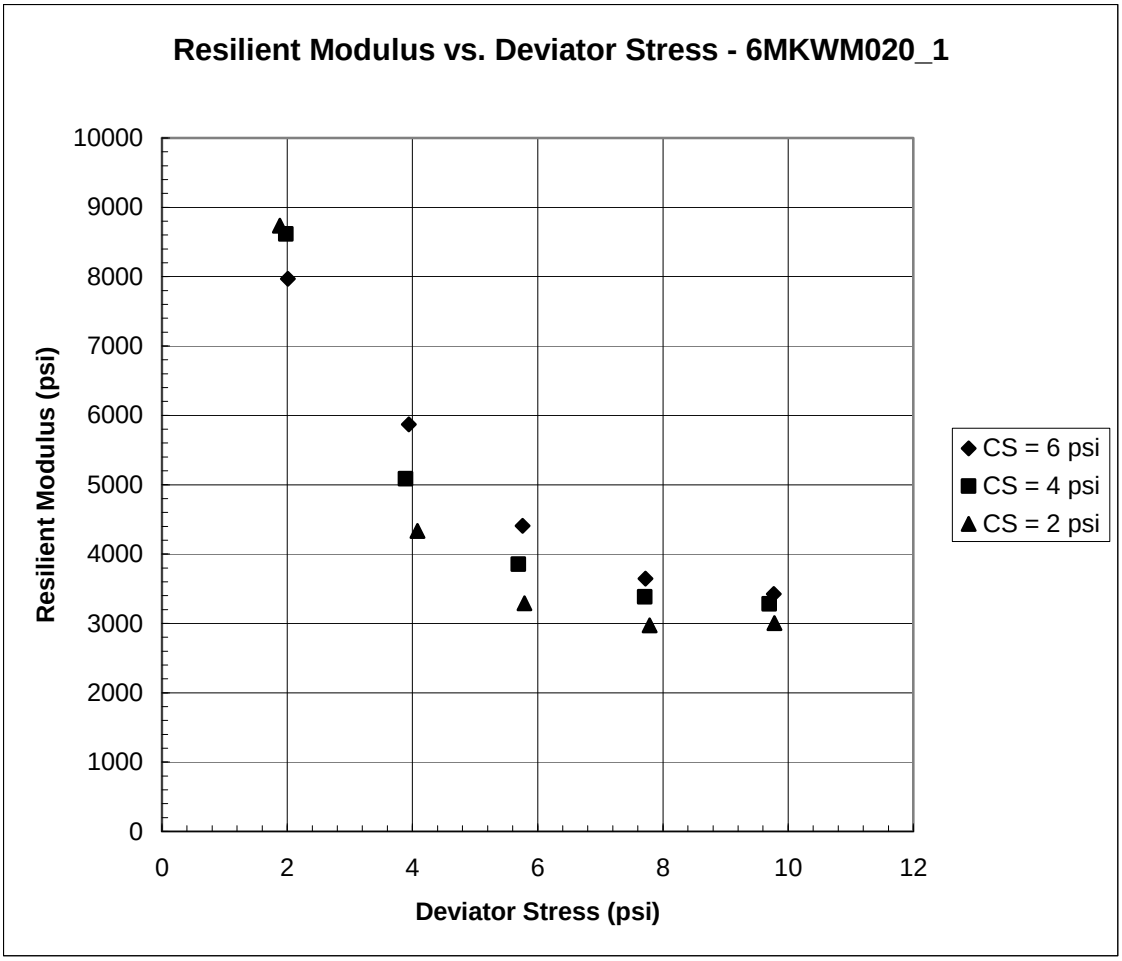
Not used in re-analysis



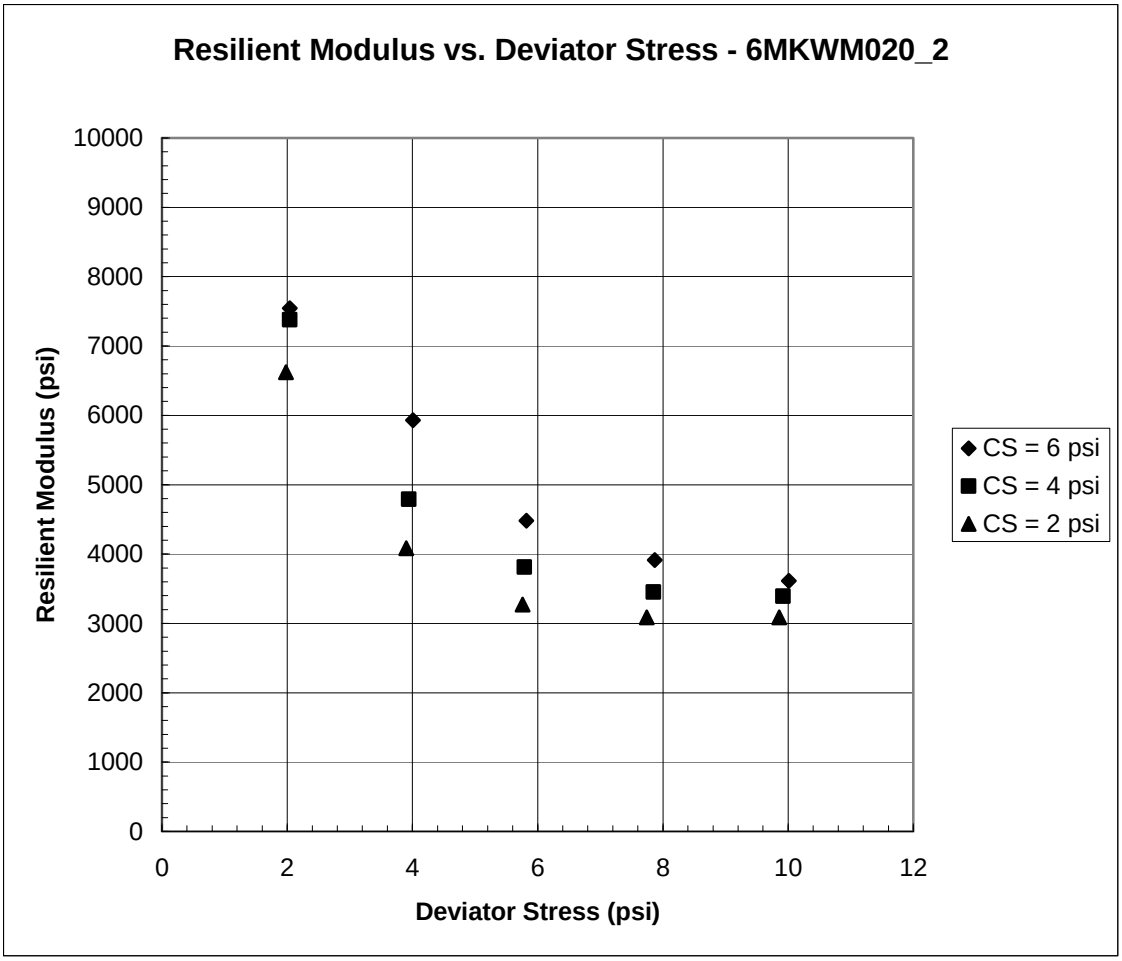
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.09	13449	13367	14561	13770	13987	13827
2	6	4.01	11583	12047	11589	11581	11851	11730
3	6	5.91	11948	11830	11796	11868	11597	11808
4	6	7.85	11605	11606	11485	11360	11512	11514
5	6	9.81	10912	10827	10965	11033	11133	10974
6	4	1.98	16455	15399	15397	15472	17238	15992
7	4	4.06	13406	12484	13086	12796	13394	13033
8	4	5.85	12006	12085	12006	12025	12181	12060
9	4	7.84	11363	11220	11261	11352	11403	11320
10	4	9.83	10653	10726	10634	10675	10553	10648
11	2	2.04	11604	10706	10322	11118	9998	10750
12	2	3.95	10176	10135	10005	10149	9975	10088
13	2	5.83	9868	9739	9722	9755	9822	9781
14	2	7.83	9343	9469	9404	9504	9415	9427
15	2	9.87	9251	9262	9312	9210	9287	9264



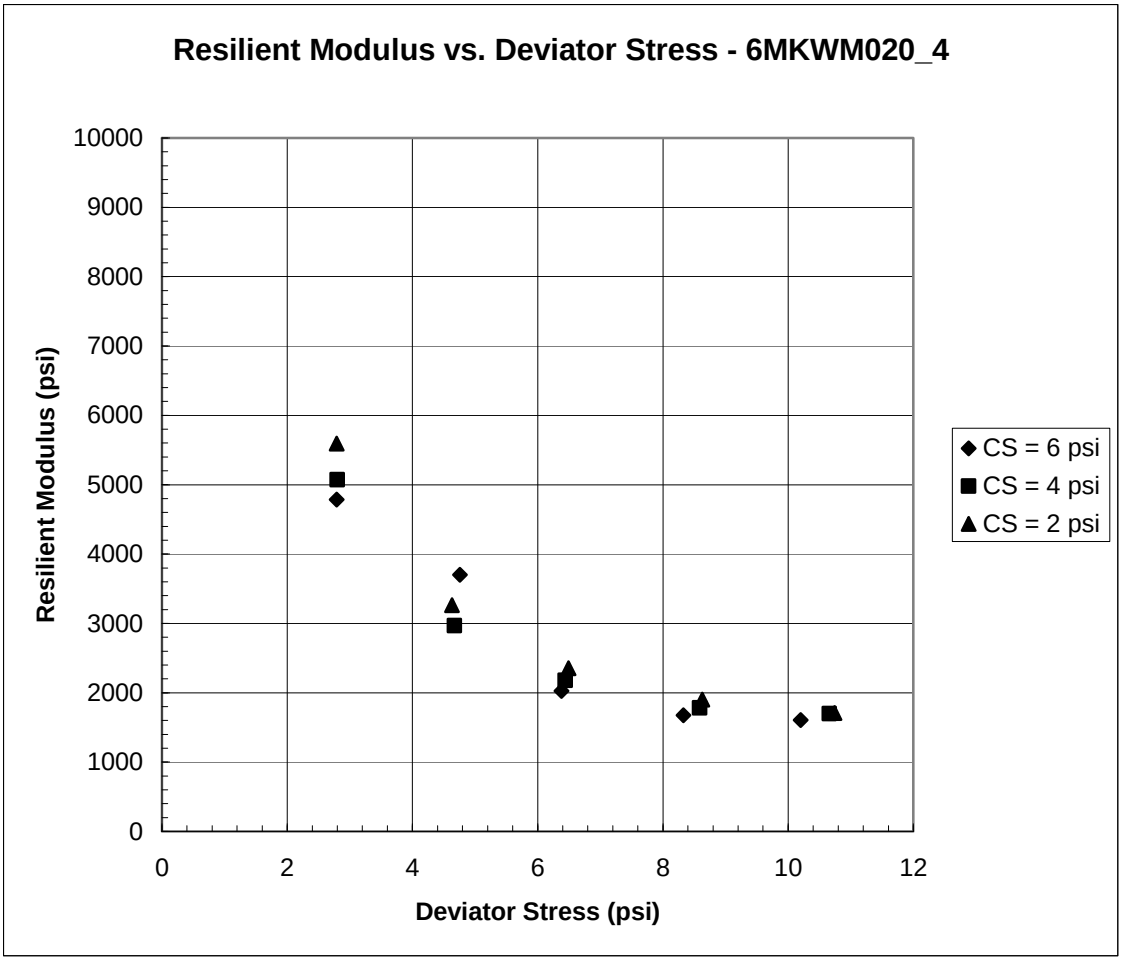
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.05	16082	17250	16152	17244	17178	16782
2	6	4.36	13690	13530	13301	13501	13301	13464
3	6	6.17	11451	11252	11127	11092	11234	11231
4	6	7.87	9835	9855	9749	9793	9823	9811
5	6	9.89	8564	8633	8580	8678	8604	8612
6	4	2.04	18196	18162	18080	18097	18089	18125
7	4	4.05	13415	13383	13352	13386	13078	13323
8	4	5.86	11037	11106	11036	11117	10893	11038
9	4	7.96	9498	9443	9509	9376	9509	9467
10	4	9.83	8604	8484	8580	8536	8566	8554
11	2	2.05	15385	14528	15515	15235	16225	15378
12	2	4.11	11909	11931	12157	11668	12207	11975
13	2	5.92	10260	9975	10009	9977	9977	10039
14	2	7.92	8674	8797	8732	8781	8741	8745
15	2	9.81	8060	8041	7952	8058	7910	8004



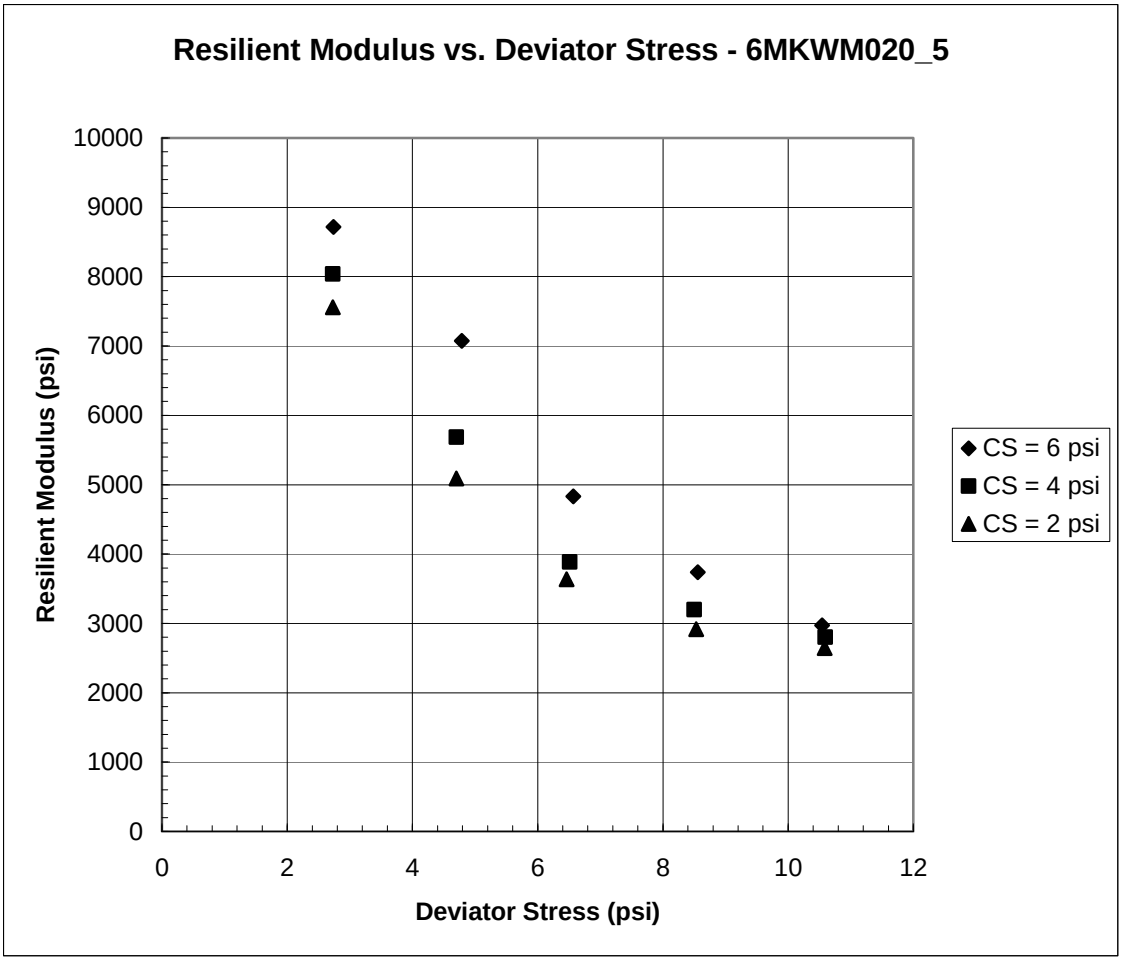
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.01	7809	8023	8022	8012	7991	7971
2	6	3.94	5849	5963	5802	5922	5819	5871
3	6	5.76	4391	4356	4423	4434	4422	4405
4	6	7.72	3660	3613	3651	3657	3648	3646
5	6	9.77	3399	3430	3412	3477	3402	3424
6	4	1.98	8589	8544	8584	8762	8592	8614
7	4	3.89	5027	5181	5097	5017	5108	5086
8	4	5.69	3885	3788	3885	3793	3916	3854
9	4	7.71	3387	3366	3446	3338	3385	3384
10	4	9.7	3276	3277	3262	3313	3273	3280
11	2	1.88	8613	8611	8938	8568	8938	8734
12	2	4.08	4193	4389	4203	4500	4390	4335
13	2	5.79	3324	3299	3306	3252	3275	3291
14	2	7.79	2983	2966	2977	2969	2977	2974
15	2	9.78	3015	2999	2981	3003	3024	3004



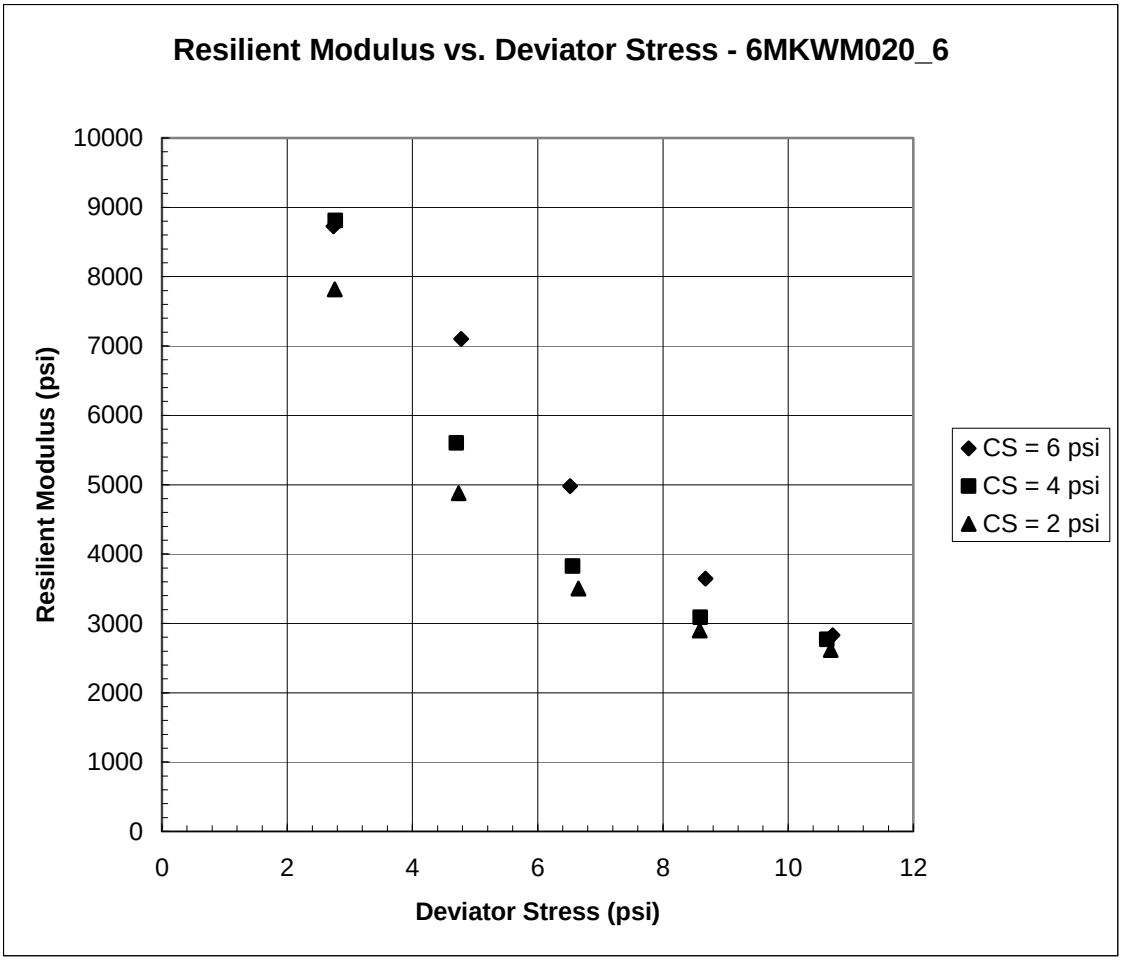
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.04	7518	7552	7508	7552	7600	7546
2	6	4.01	6023	5939	5839	6014	5839	5931
3	6	5.82	4433	4529	4471	4498	4471	4481
4	6	7.87	3936	3892	3927	3896	3914	3913
5	6	10.01	3611	3614	3605	3624	3602	3611
6	4	2.04	7507	7542	7317	7204	7323	7379
7	4	3.94	4824	4757	4760	4838	4782	4792
8	4	5.79	3838	3874	3786	3816	3751	3813
9	4	7.85	3425	3469	3450	3476	3447	3453
10	4	9.92	3395	3389	3397	3378	3394	3390
11	2	1.98	6624	6567	6753	6596	6562	6620
12	2	3.9	4084	4085	4083	4124	4045	4084
13	2	5.76	3303	3289	3258	3273	3233	3271
14	2	7.74	3072	3119	3075	3096	3074	3087
15	2	9.86	3100	3074	3096	3113	3052	3087



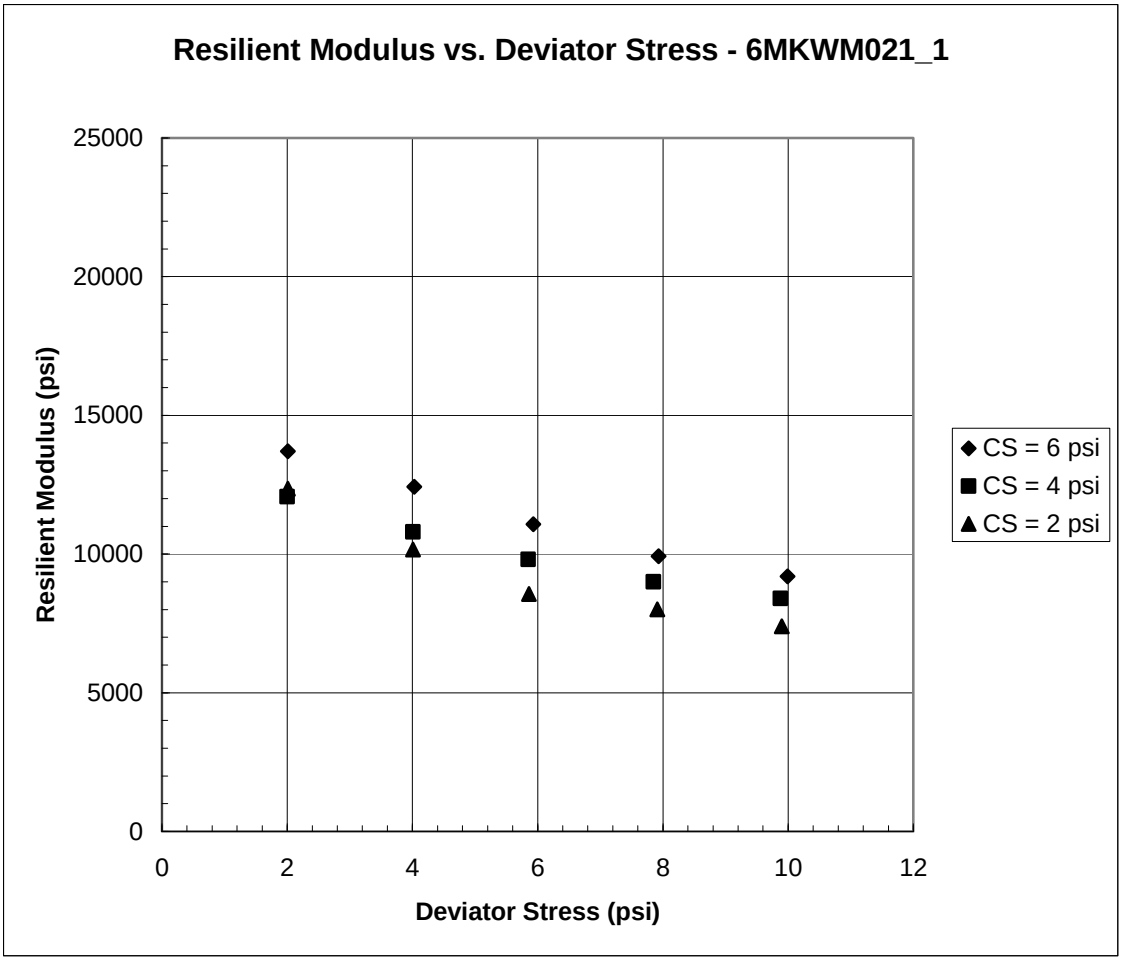
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.79	4757	4775	4777	4853	4758	4784
2	6	4.76	3720	3718	3655	3682	3729	3701
3	6	6.38	2010	2021	2025	2042	2032	2026
4	6	8.33	1670	1661	1682	1683	1682	1676
5	6	10.2	1589	1606	1604	1603	1618	1604
6	4	2.8	5054	5020	5101	5109	5076	5072
7	4	4.67	2947	2962	2959	2978	2979	2965
8	4	6.44	2211	2203	2163	2160	2158	2179
9	4	8.59	1780	1772	1794	1792	1774	1783
10	4	10.66	1696	1699	1697	1707	1696	1699
11	2	2.79	5508	5718	5602	5527	5620	5595
12	2	4.63	3233	3259	3285	3265	3274	3263
13	2	6.49	2337	2377	2321	2362	2363	2352
14	2	8.63	1896	1890	1909	1911	1899	1901
15	2	10.74	1706	1715	1713	1697	1710	1708



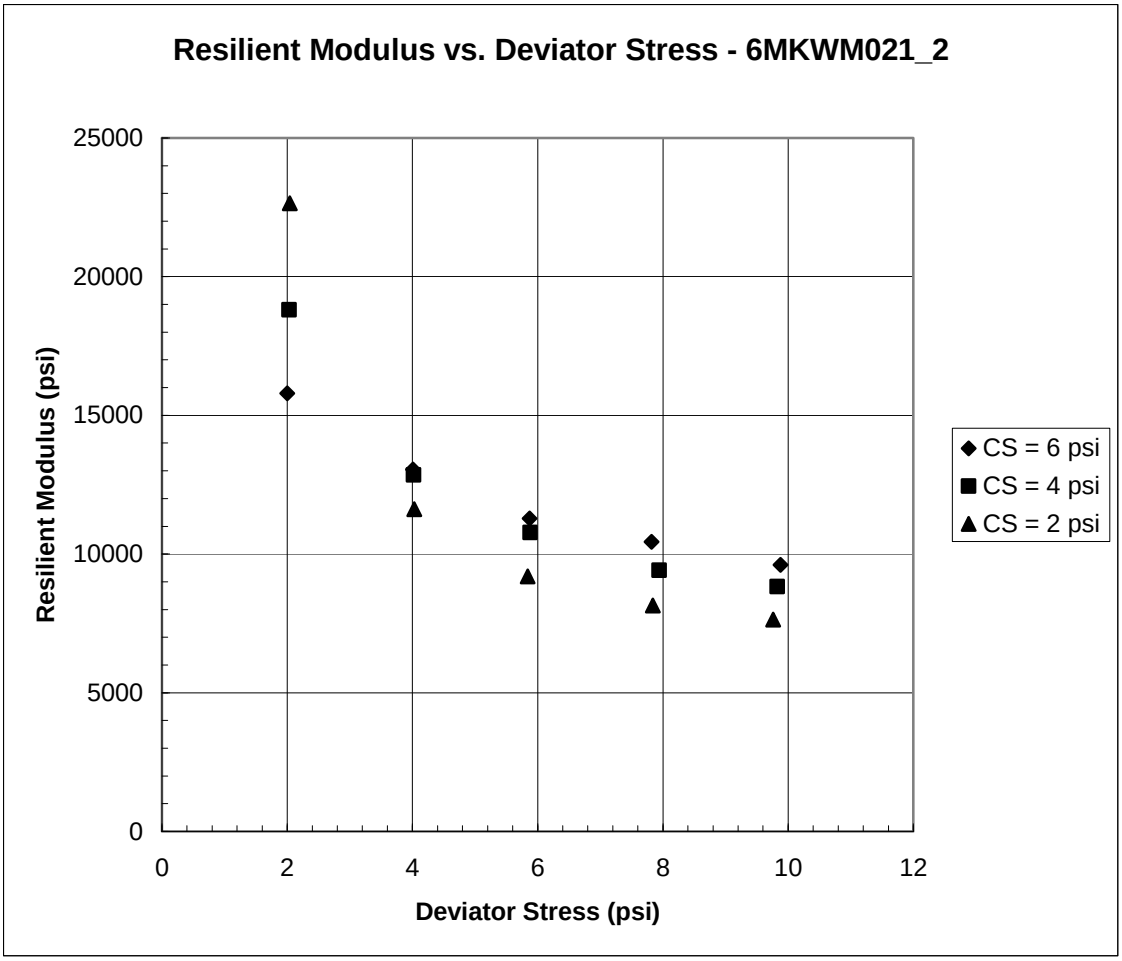
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.74	8678	8678	8711	8763	8755	8717
2	6	4.79	7068	7114	7091	7062	7046	7076
3	6	6.57	4808	4809	4815	4858	4861	4830
4	6	8.56	3738	3752	3752	3738	3719	3740
5	6	10.54	2972	2976	2966	2973	2969	2971
6	4	2.73	8181	7967	7924	8194	7937	8041
7	4	4.7	5663	5674	5701	5687	5701	5685
8	4	6.51	3878	3883	3918	3869	3871	3884
9	4	8.5	3205	3159	3201	3207	3217	3198
10	4	10.59	2794	2790	2810	2809	2806	2802
11	2	2.73	7556	7559	7598	7557	7524	7558
12	2	4.7	5098	5087	5076	5091	5090	5088
13	2	6.46	3633	3627	3658	3629	3625	3635
14	2	8.53	2910	2918	2908	2904	2937	2916
15	2	10.58	2645	2634	2637	2632	2660	2642



Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.74	8742	8771	8724	8699	8693	8726
2	6	4.78	7062	7046	7076	7178	7159	7104
3	6	6.52	4984	5026	4948	4986	4953	4979
4	6	8.68	3647	3614	3649	3659	3663	3646
5	6	10.71	2838	2846	2836	2811	2805	2827
6	4	2.77	8889	8844	8841	8848	8625	8809
7	4	4.7	5585	5610	5612	5598	5596	5600
8	4	6.56	3846	3842	3835	3801	3813	3827
9	4	8.6	3122	3121	3055	3066	3078	3088
10	4	10.62	2758	2785	2755	2783	2753	2767
11	2	2.76	7872	7719	7661	7936	7904	7818
12	2	4.74	4865	4945	4844	4865	4865	4877
13	2	6.65	3482	3499	3498	3532	3499	3502
14	2	8.59	2932	2871	2869	2914	2914	2900
15	2	10.68	2601	2614	2624	2625	2621	2617

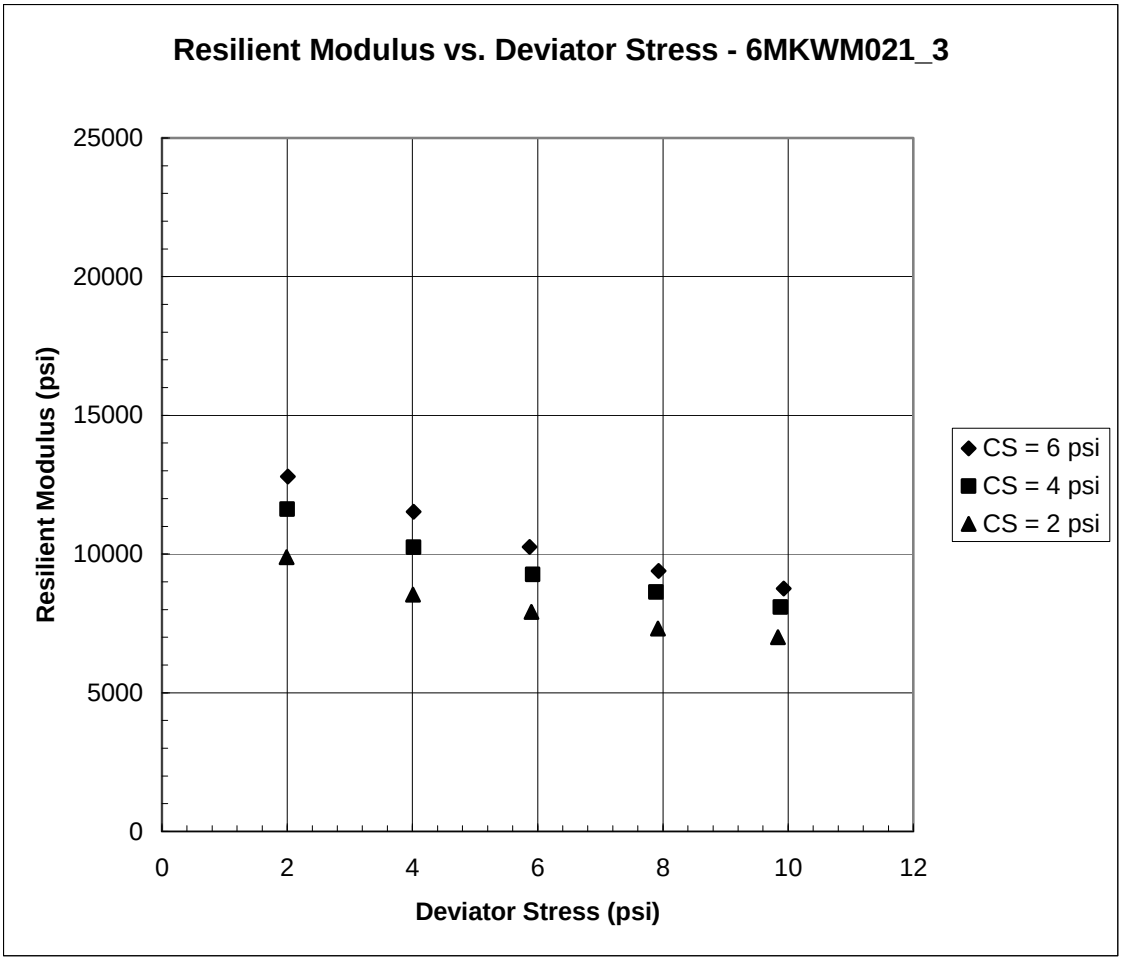


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.01	13699	13638	13766	13723	13708	13707
2	6	4.03	12592	12364	12576	12057	12549	12428
3	6	5.93	11051	10951	11051	11213	11093	11072
4	6	7.93	9906	9880	9908	9808	10083	9917
5	6	9.99	9240	9190	9116	9276	9167	9198
6	4	2	11921	11485	12479	11956	12480	12064
7	4	4.01	10649	10906	10649	10896	10875	10795
8	4	5.85	9771	9738	9769	9859	9914	9810
9	4	7.85	9010	9017	8985	8959	8999	8994
10	4	9.88	8325	8371	8333	8503	8438	8394
11	2	2.01	12585	13104	12005	12011	12061	12353
12	2	4.01	10285	10104	10280	9946	10232	10169
13	2	5.86	8634	8523	8478	8588	8566	8558
14	2	7.91	8006	7986	8014	8032	8013	8010
15	2	9.9	7411	7354	7373	7353	7463	7391

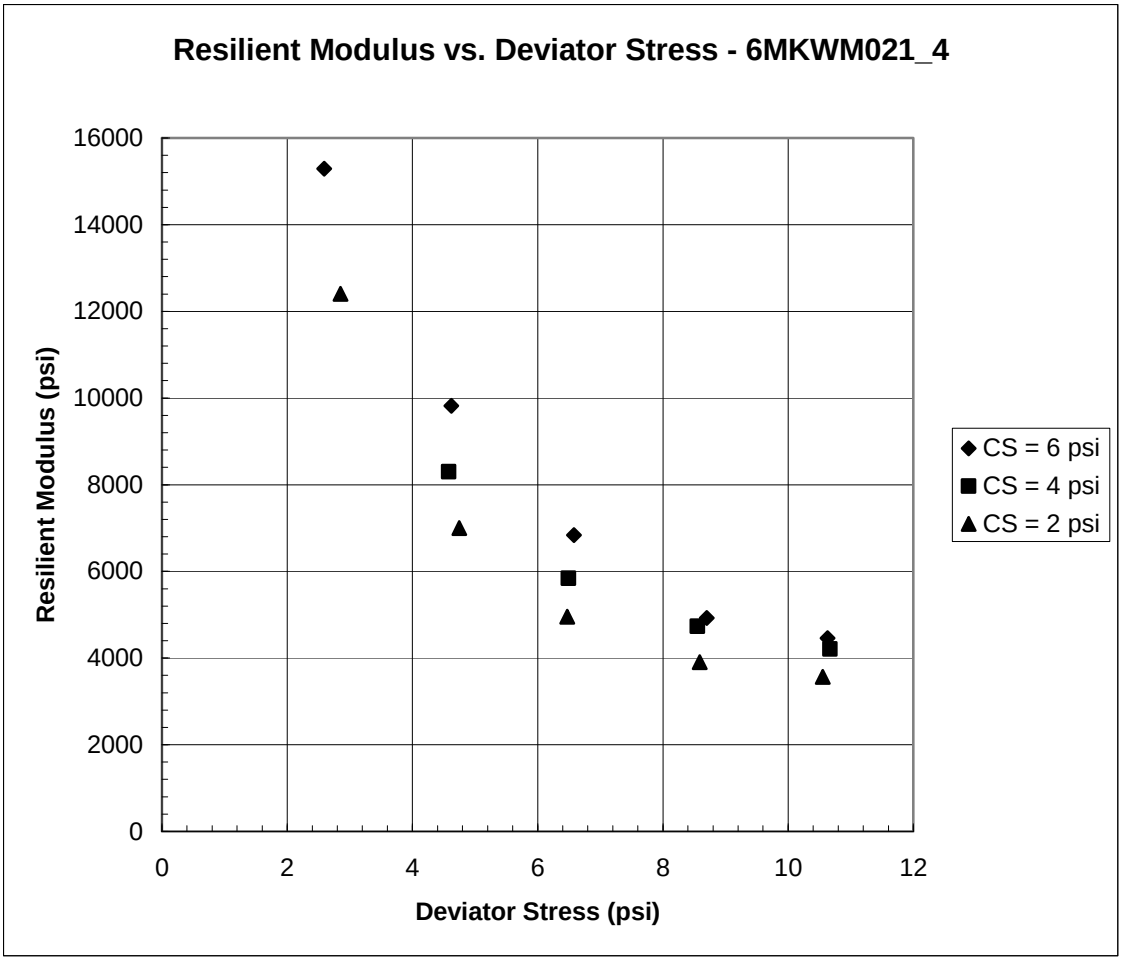


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2	16007	15163	15938	15927	15934	15794
2	6	4.01	13068	13469	12782	13134	12811	13053
3	6	5.87	11404	11236	11272	11236	11291	11288
4	6	7.82	10634	10363	10534	10277	10377	10437
5	6	9.88	9558	9716	9523	9640	9627	9613
6	4	2.03	18177	19664	18276	19562	18355	18807
7	4	4.02	12836	12841	12859	12900	12831	12853
8	4	5.88	10685	10874	10644	10999	10686	10778
9	4	7.94	9447	9327	9436	9305	9537	9410
10	4	9.83	8846	8813	8817	8874	8802	8830
11	2	2.04	22662	22659	22560	22657	22665	22641
12	2	4.03	11576	11572	11575	11520	11840	11617
13	2	5.84	9256	9082	9225	9173	9212	9190
14	2	7.84	8035	8262	8085	8260	8085	8145
15	2	9.76	7670	7519	7667	7667	7654	7635

Not used in re-analysis

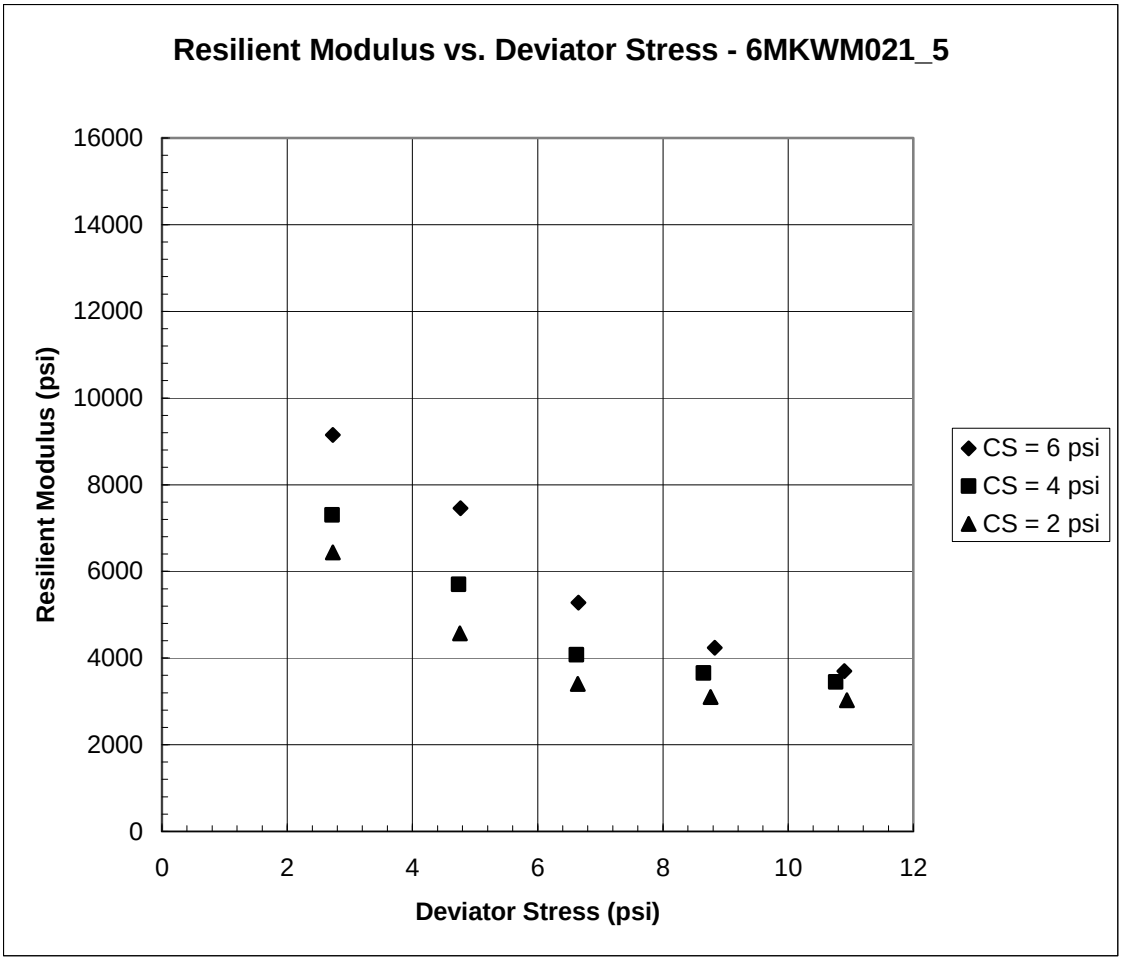


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.01	13062	12437	13012	12440	13015	12793
2	6	4.02	11281	11782	11516	11546	11527	11530
3	6	5.87	10262	10118	10263	10372	10262	10255
4	6	7.93	9474	9257	9412	9330	9484	9391
5	6	9.93	8734	8738	8800	8855	8639	8753
6	4	2	11473	11427	11889	11423	11889	11620
7	4	4.02	10258	10280	10099	10493	10076	10241
8	4	5.92	9248	9335	9249	9234	9248	9263
9	4	7.89	8635	8630	8635	8639	8629	8634
10	4	9.88	8103	8102	8062	8100	8064	8086
11	2	1.99	9790	9795	10183	9832	9829	9886
12	2	4.01	8554	8428	8576	8593	8556	8541
13	2	5.9	7772	8063	7901	7902	7914	7910
14	2	7.92	7279	7238	7285	7283	7485	7314
15	2	9.84	6951	6951	7022	7063	7020	7001

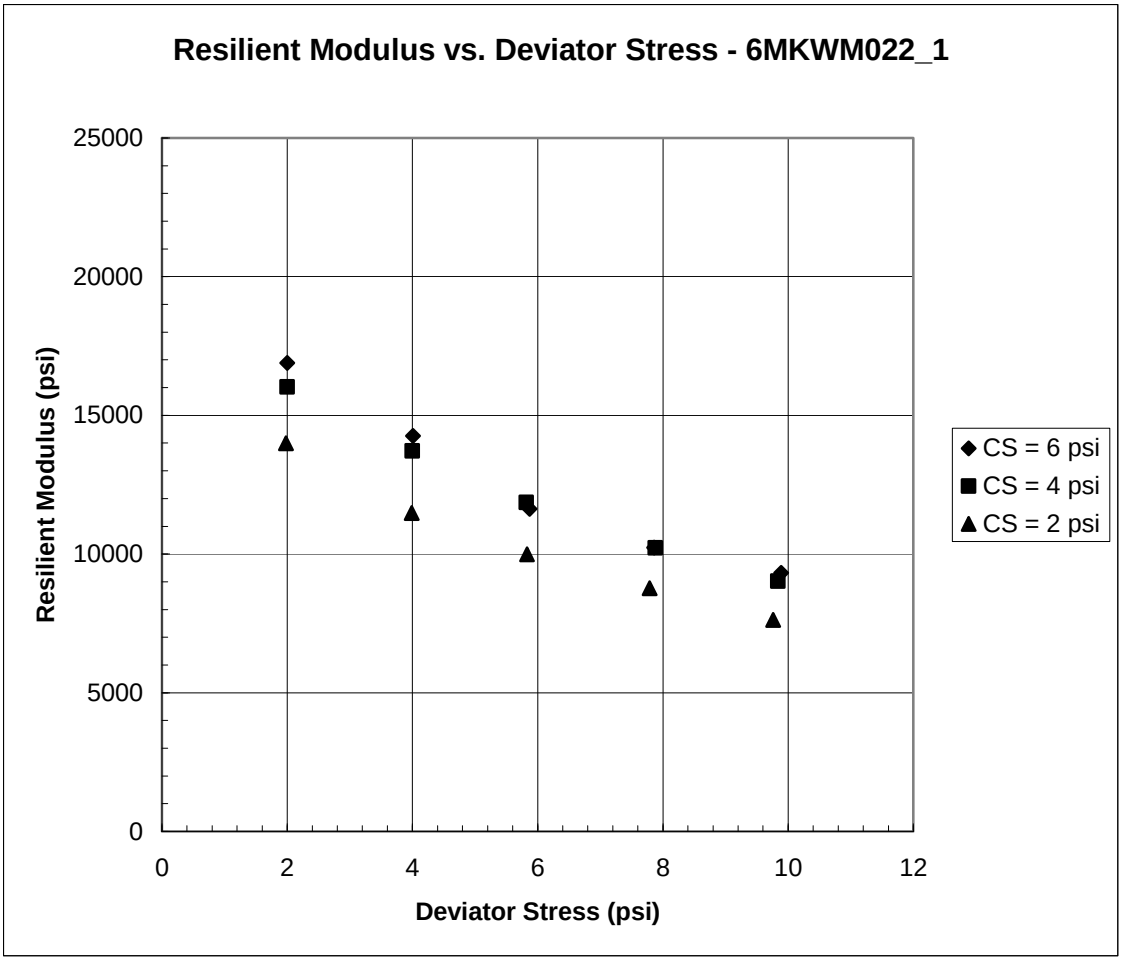


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.59	16909	15278	14247	14994	15035	15292
2	6	4.62	9776	9833	9739	9705	10045	9820
3	6	6.58	6736	6861	6805	6896	6871	6834
4	6	8.7	4882	4894	4957	4943	4936	4922
5	6	10.63	4480	4483	4442	4442	4447	4459
6	4	2.62	18002	28148	27324	24025	22848	24069.4
7	4	4.58	8277	8329	8281	8289	8316	8298
8	4	6.49	5812	5789	5825	5881	5894	5840
9	4	8.55	4664	4735	4747	4800	4720	4733
10	4	10.67	4212	4228	4214	4183	4223	4212
11	2	2.85	12422	12033	12915	11296	13359	12405
12	2	4.75	7030	6919	6971	7050	7023	6999
13	2	6.47	4938	4942	4949	4956	4999	4957
14	2	8.59	3867	3973	3929	3834	3911	3903
15	2	10.55	3555	3563	3565	3570	3580	3566

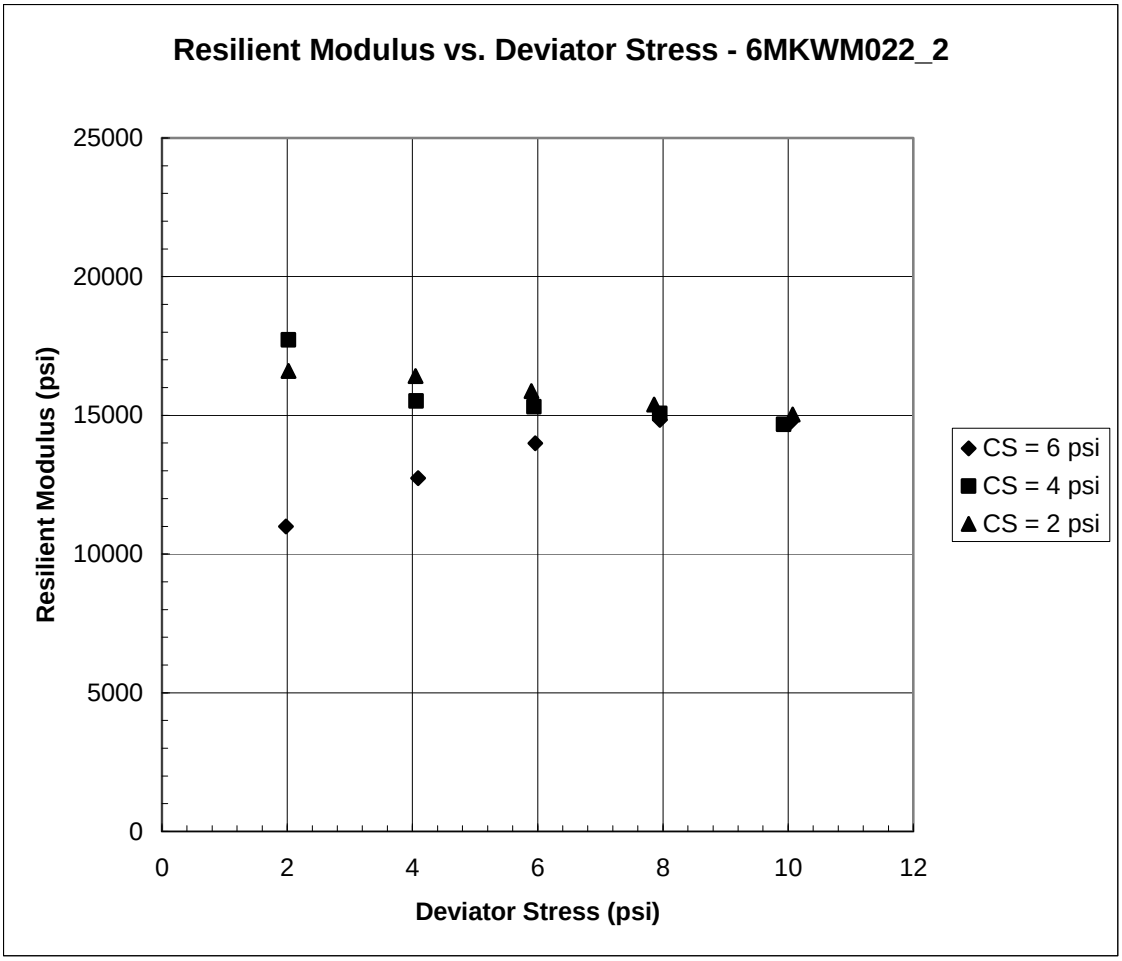
Not used in re-analysis
Calculated



Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.73	9131	9169	9168	9127	9160	9151
2	6	4.77	7563	7436	7416	7397	7465	7455
3	6	6.65	5254	5295	5300	5261	5272	5276
4	6	8.83	4238	4228	4227	4241	4256	4238
5	6	10.9	3687	3697	3718	3709	3699	3702
6	4	2.72	7334	7297	7260	7300	7327	7304
7	4	4.74	5707	5665	5690	5746	5678	5697
8	4	6.62	4095	4058	4066	4090	4075	4077
9	4	8.65	3632	3657	3656	3657	3691	3658
10	4	10.76	3450	3459	3454	3433	3428	3445
11	2	2.73	6353	6385	6381	6518	6555	6438
12	2	4.76	4564	4591	4574	4543	4561	4567
13	2	6.64	3388	3396	3401	3431	3417	3407
14	2	8.76	3090	3105	3104	3105	3090	3099
15	2	10.94	3000	3025	3031	3030	3048	3027

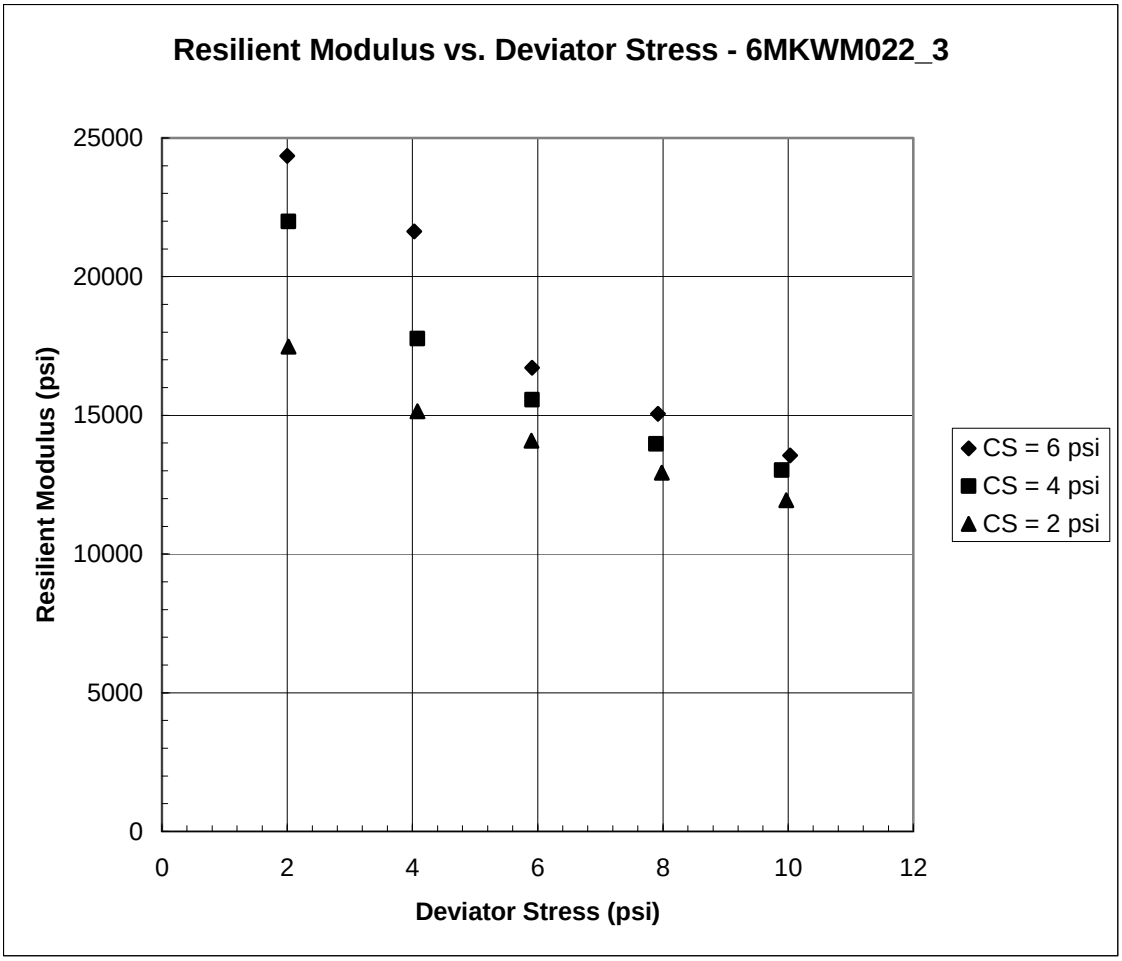


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2	16826	16901	16836	16916	16971	16890
2	6	4.01	14398	14055	14395	14042	14423	14263
3	6	5.87	11570	11594	11625	11736	11595	11624
4	6	7.86	10288	10279	10200	10192	10208	10234
5	6	9.89	9272	9264	9389	9382	9330	9327
6	4	2	16046	15976	15994	16053	16063	16026
7	4	4	13688	13754	13722	13723	13687	13715
8	4	5.82	11971	11625	11969	11790	11949	11860
9	4	7.88	10174	10381	10187	10196	10185	10225
10	4	9.84	9041	8910	9043	9042	9089	9025
11	2	1.98	14297	13533	14273	14252	13610	13993
12	2	3.99	11467	11483	11489	11484	11486	11482
13	2	5.83	10104	9981	9966	9956	9959	9993
14	2	7.79	8775	8757	8774	8773	8780	8772
15	2	9.76	7642	7649	7602	7600	7640	7627

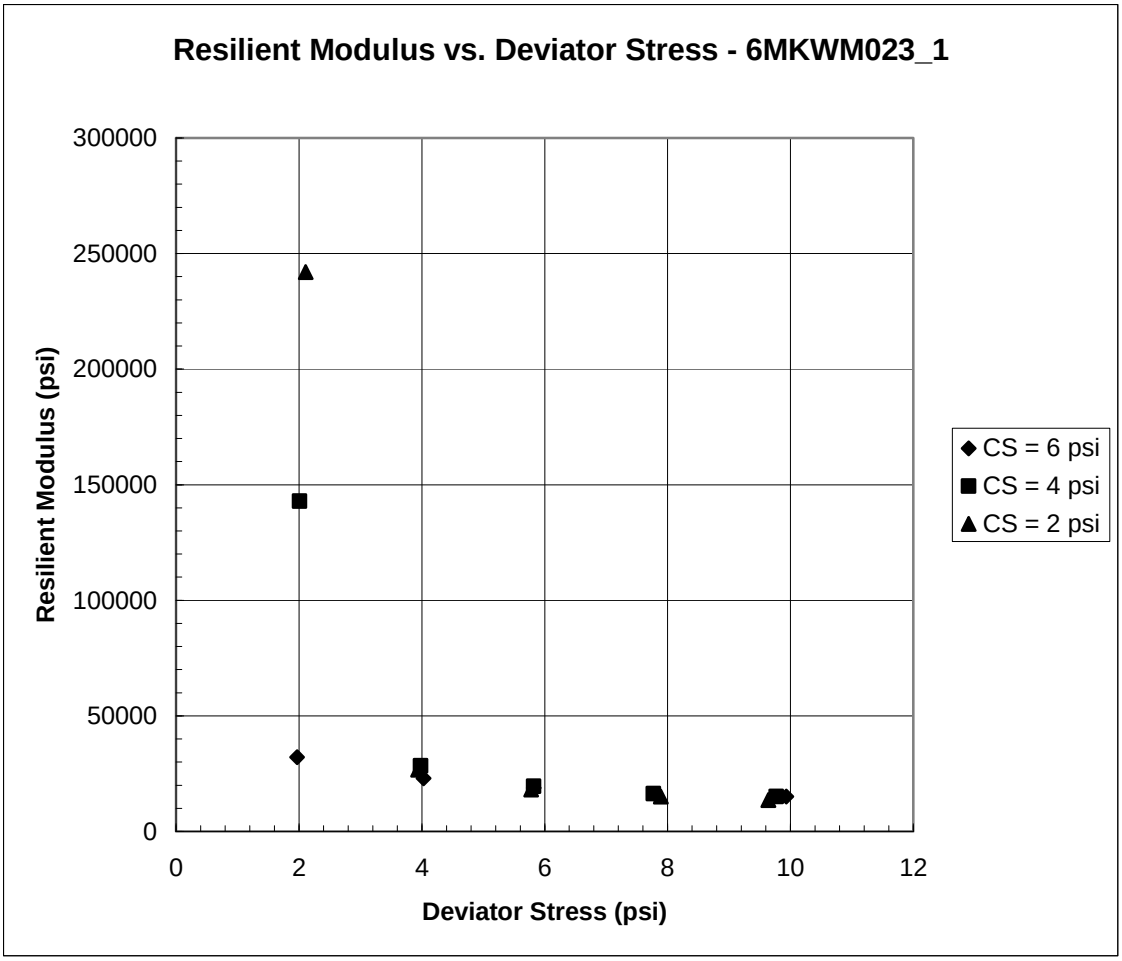


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	1.98	11329	10939	10886	10905	10893	10991
2	6	4.09	12769	12786	12797	12522	12782	12731
3	6	5.96	13810	14029	14034	14049	14035	13991
4	6	7.95	15007	14826	14834	14475	15027	14834
5	6	10.04	14726	14745	14741	14905	14738	14771
6	4	2.02	17087	17069	18203	18130	18108	17720
7	4	4.06	14922	15751	15759	15811	15330	15515
8	4	5.94	15007	15251	15524	15222	15535	15308
9	4	7.95	15208	15227	15239	14809	14846	15066
10	4	9.93	14559	14697	14546	15031	14561	14679
11	2	2.02	16876	16257	15907	16032	17939	16602
12	2	4.05	16157	16153	16598	16607	16594	16422
13	2	5.9	16005	15957	15706	15676	16007	15870
14	2	7.86	15257	15483	15256	15481	15468	15389
15	2	10.07	15077	14784	15114	15093	15090	15032

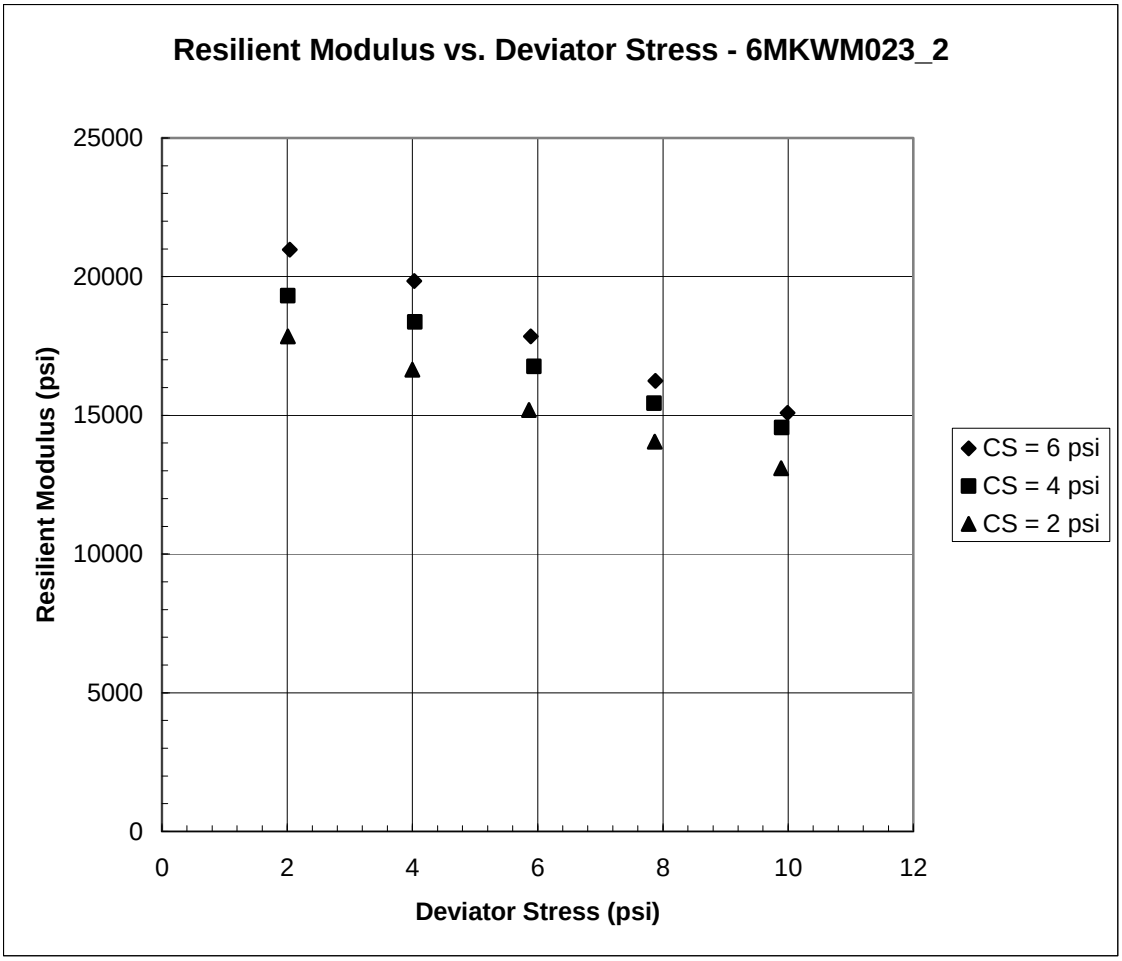
Not used in re-analysis



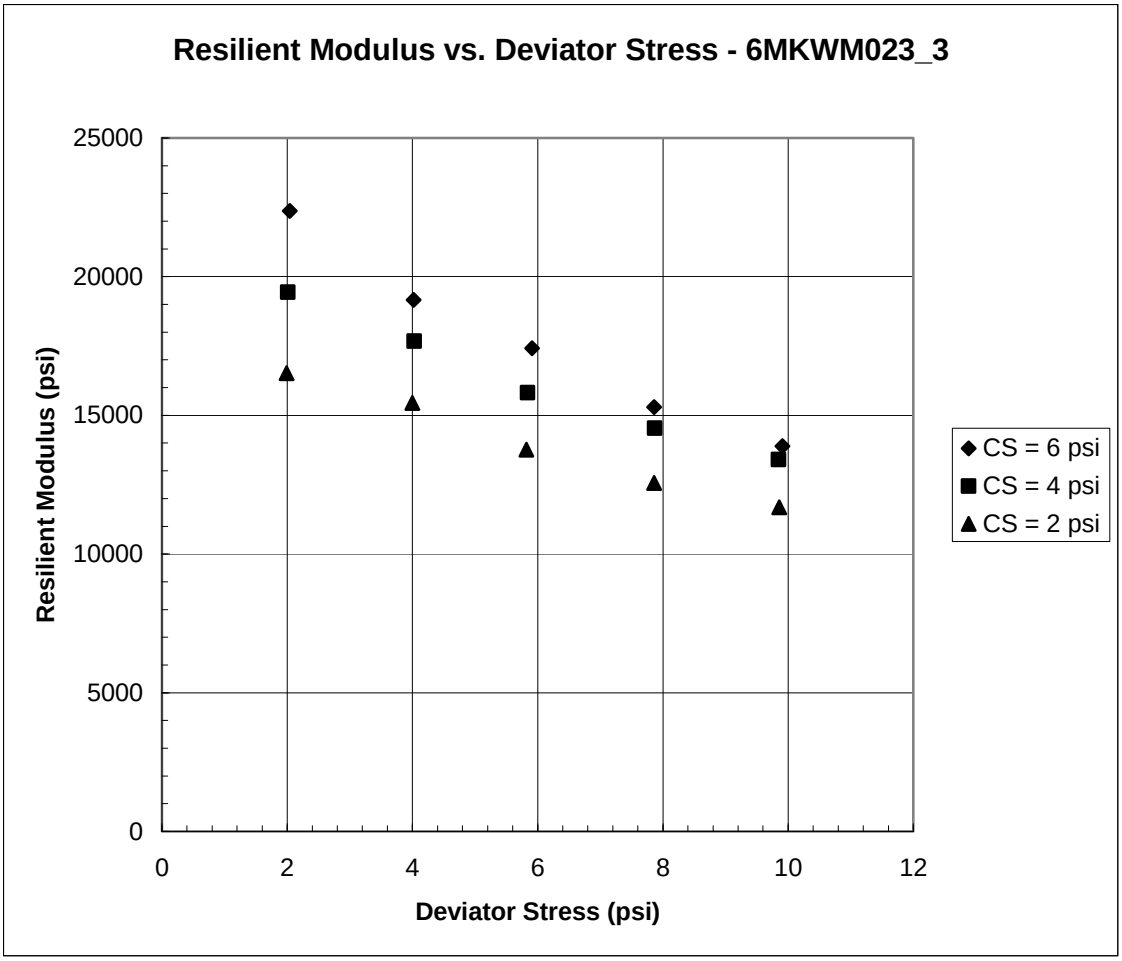
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2	26235	23710	23963	23936	23943	24358
2	6	4.03	19935	22282	22227	22280	21450	21635
3	6	5.91	16654	16994	16635	16630	16668	16716
4	6	7.92	15186	14947	15200	14965	14986	15057
5	6	10.03	13586	13772	13446	13504	13465	13555
6	4	2.02	24104	20751	22217	22252	20645	21994
7	4	4.08	17733	17262	17731	17800	18318	17769
8	4	5.91	15742	15429	15476	15698	15469	15563
9	4	7.89	13803	13966	13975	13975	14150	13974
10	4	9.9	12805	13187	12921	13174	13038	13025
11	2	2.02	17125	16989	18137	17049	18117	17483
12	2	4.08	15493	15448	15059	14672	15039	15142
13	2	5.9	13885	14411	13893	14113	14116	14084
14	2	7.98	12911	12850	13044	12836	13030	12934
15	2	9.97	11958	11933	12035	11947	11834	11941



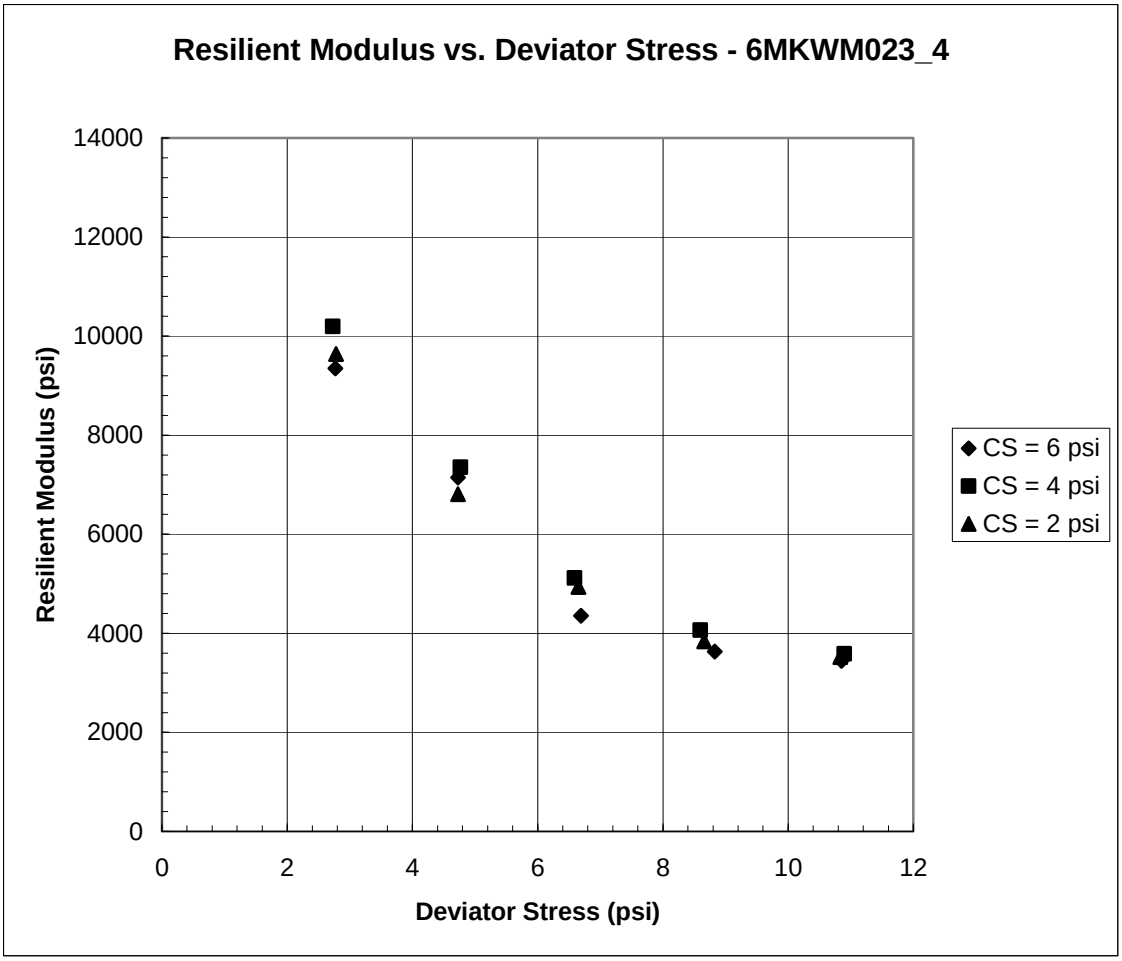
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	1.97	30992	34892	30836	35384	28156	32052
2	6	4.03	22983	23019	23091	23044	23004	23028
3	6	5.82	18892	18811	18889	18838	18830	18852
4	6	7.79	16299	16302	16265	16140	16254	16252
5	6	9.93	14899	15188	15054	15201	15067	15082
6	4	2.01	141756	143807	141601	143044	144189	142879
7	4	3.98	28361	28258	28487	28184	28427	28343
8	4	5.82	19251	19775	19281	19740	19759	19561
9	4	7.77	16270	16240	16525	16257	16572	16373
10	4	9.77	15253	14937	15266	14938	15281	15135
11	2	2.11	151939	302406	150691	300914	304104	242011
12	2	3.94	25390	26938	26465	26528	28044	26673
13	2	5.78	17869	18683	17863	18726	17486	18125
14	2	7.89	14998	15223	14815	15186	15222	15089
15	2	9.64	13537	13574	13527	13550	13534	13544



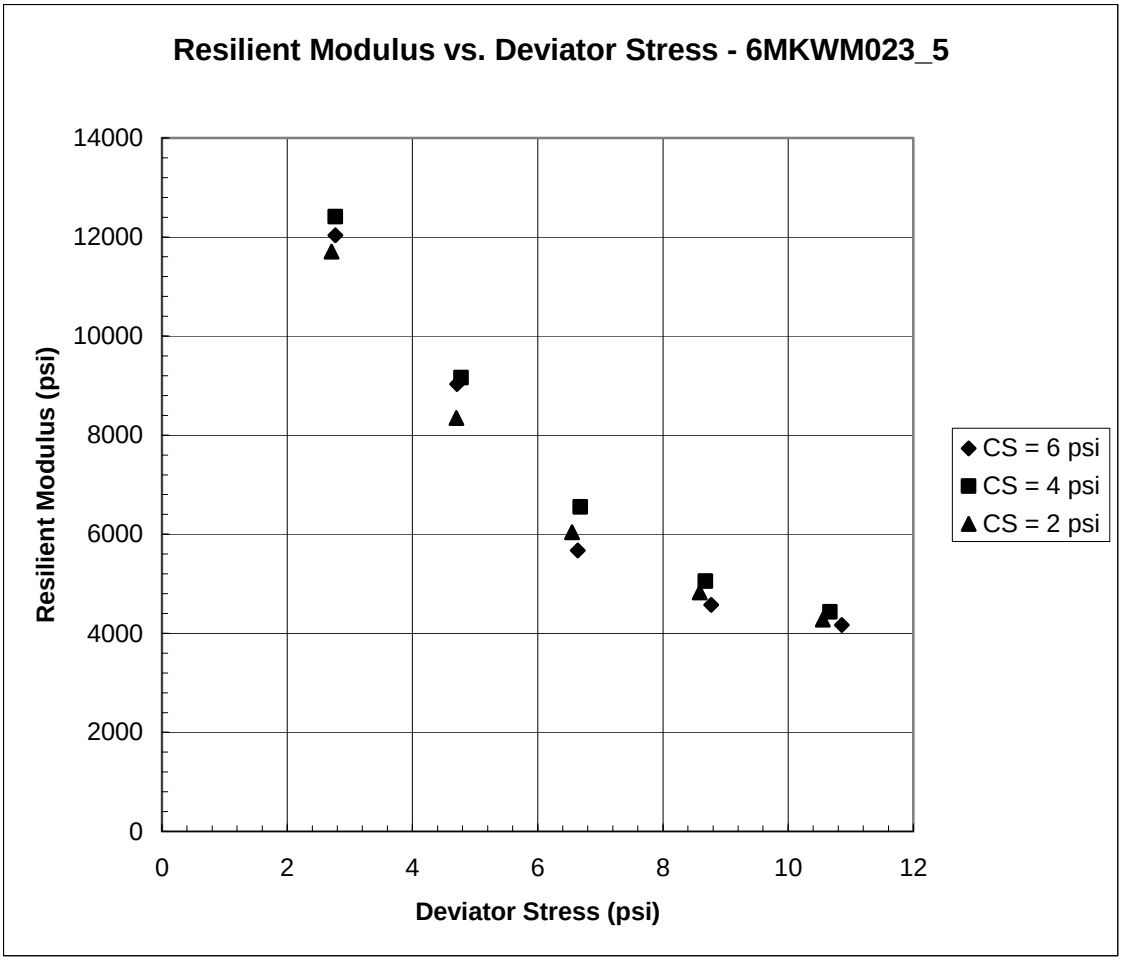
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.04	20645	20637	20562	20760	22258	20972
2	6	4.03	19866	19847	19810	19858	19822	19841
3	6	5.89	17829	18238	17483	17477	18233	17852
4	6	7.88	16301	16298	16264	16046	16281	16238
5	6	9.99	15186	15185	15026	15040	15026	15093
6	4	2.01	20410	19040	19035	19046	19041	19314
7	4	4.04	18621	18601	18033	18602	17982	18368
8	4	5.94	16629	16956	16650	16602	16956	16758
9	4	7.86	15558	15343	15345	15576	15363	15437
10	4	9.9	14549	14715	14245	14708	14565	14556
11	2	2.01	17850	17743	17852	17848	17927	17844
12	2	4	16277	16707	16760	16720	16770	16647
13	2	5.86	15210	14920	15194	15474	15194	15198
14	2	7.87	14039	13829	14358	14010	14036	14054
15	2	9.89	13055	13074	13179	12961	13177	13089



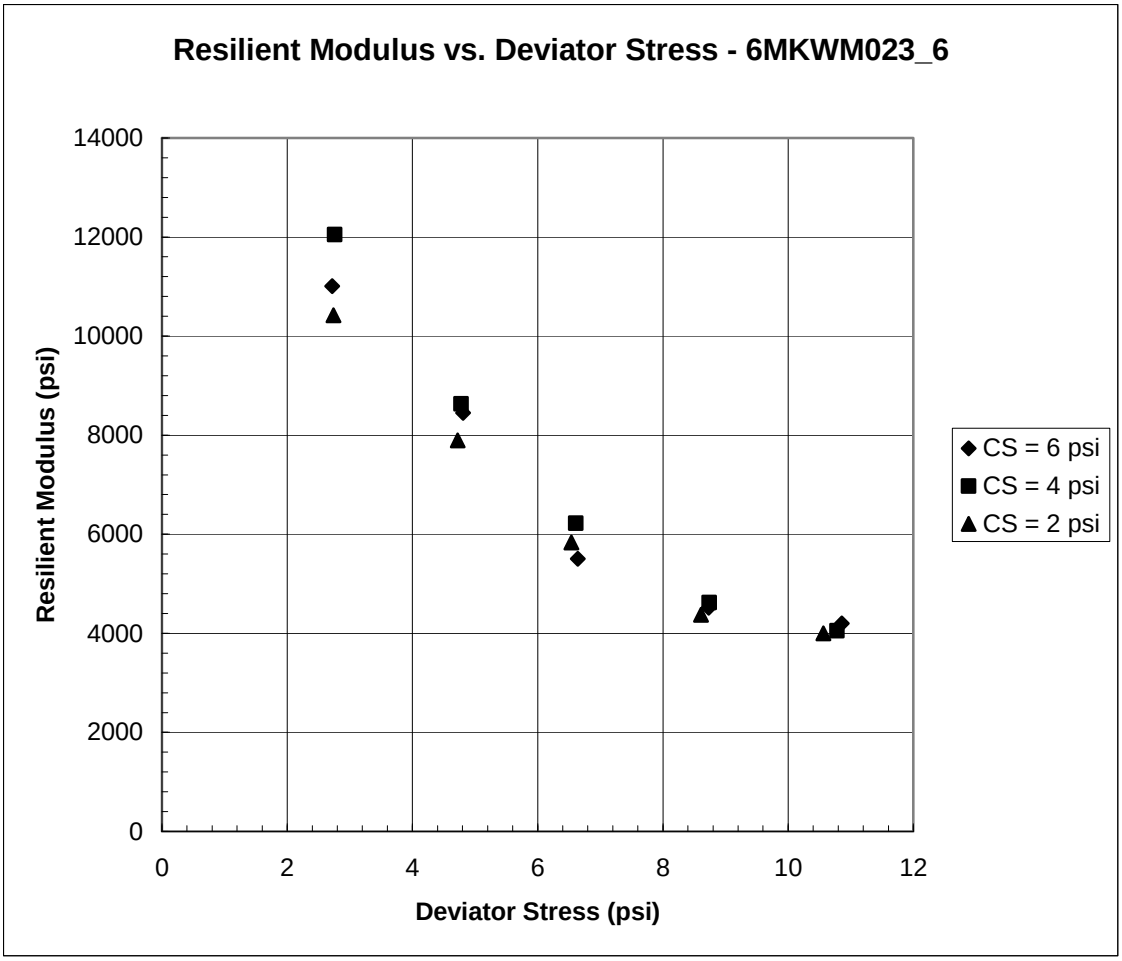
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.04	22303	20513	24258	20630	24161	22373
2	6	4.02	19676	19025	19011	19012	19068	19158
3	6	5.91	17476	17115	17508	17484	17520	17421
4	6	7.86	15293	15282	15298	15092	15500	15293
5	6	9.91	13963	13966	13840	13840	13826	13887
6	4	2.01	18892	18782	20247	18921	20342	19437
7	4	4.03	17865	17869	16795	17908	17927	17673
8	4	5.84	15635	15631	15636	16247	15937	15817
9	4	7.87	14541	14538	14557	14518	14524	14536
10	4	9.85	13104	13603	13218	13602	13479	13401
11	2	1.99	16500	16503	16498	16503	16570	16515
12	2	4	15370	15766	14933	15771	15369	15442
13	2	5.82	13996	13758	13773	13541	13743	13762
14	2	7.86	12548	12577	12562	12564	12562	12563
15	2	9.86	11603	11701	11694	11702	11715	11683



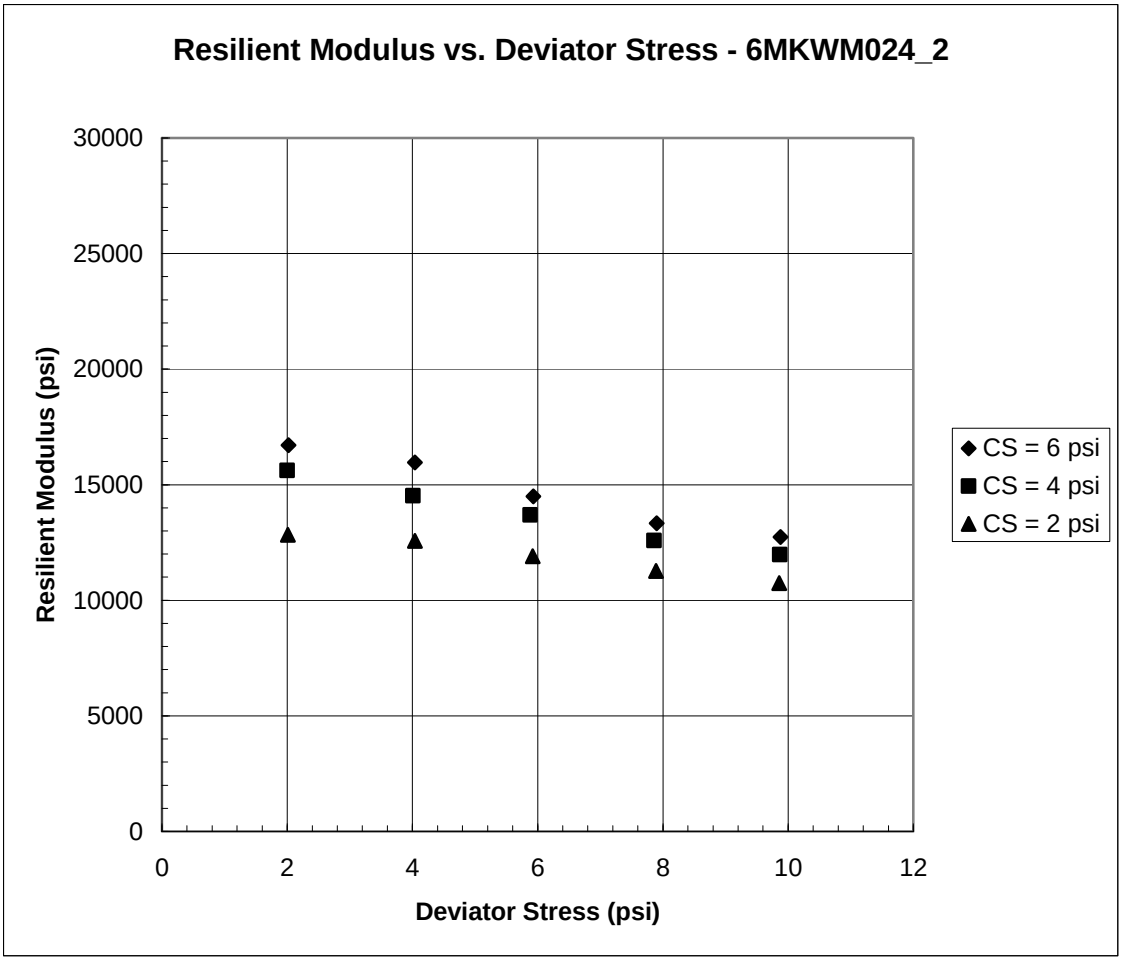
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.77	9604	9297	9249	9293	9293	9347
2	6	4.73	7092	7108	7116	7201	7196	7143
3	6	6.69	4330	4357	4338	4369	4370	4353
4	6	8.83	3620	3648	3640	3617	3615	3628
5	6	10.85	3442	3454	3430	3454	3448	3446
6	4	2.73	10032	10040	10027	10438	10430	10193
7	4	4.77	7376	7344	7343	7342	7371	7355
8	4	6.59	5077	5116	5123	5142	5116	5115
9	4	8.6	4044	4040	4088	4069	4068	4062
10	4	10.9	3570	3589	3587	3582	3603	3586
11	2	2.78	9595	9638	9647	9639	9669	9638
12	2	4.73	6782	6876	6749	6845	6797	6810
13	2	6.65	4906	4942	4950	4950	4934	4936
14	2	8.66	3908	3797	3842	3823	3826	3839
15	2	10.83	3543	3528	3524	3505	3521	3524



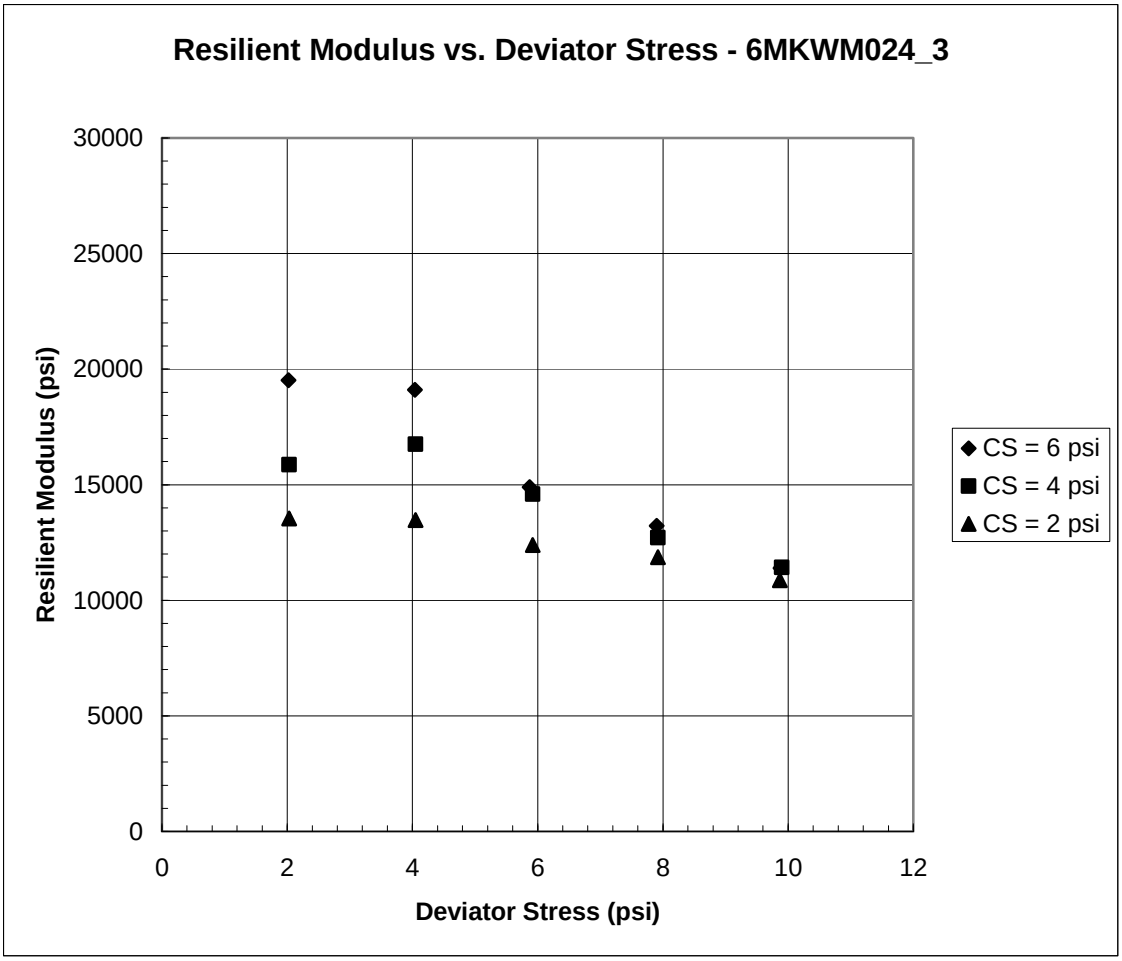
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.77	11398	12352	11830	12263	12344	12037
2	6	4.71	9124	8976	9018	9041	9006	9033
3	6	6.64	5692	5656	5664	5671	5686	5674
4	6	8.77	4560	4578	4599	4595	4539	4574
5	6	10.86	4171	4151	4155	4192	4170	4168
6	4	2.77	12282	12225	12871	12312	12351	12408
7	4	4.78	9145	9150	9180	9184	9149	9162
8	4	6.68	6538	6520	6573	6555	6560	6549
9	4	8.68	5054	5048	5039	5073	5032	5049
10	4	10.67	4446	4432	4409	4445	4442	4435
11	2	2.71	11449	11397	11382	11861	12434	11705
12	2	4.7	8284	8424	8307	8447	8289	8350
13	2	6.55	6041	6063	6036	6013	6054	6041
14	2	8.59	4828	4822	4833	4818	4819	4824
15	2	10.55	4285	4273	4266	4271	4278	4275



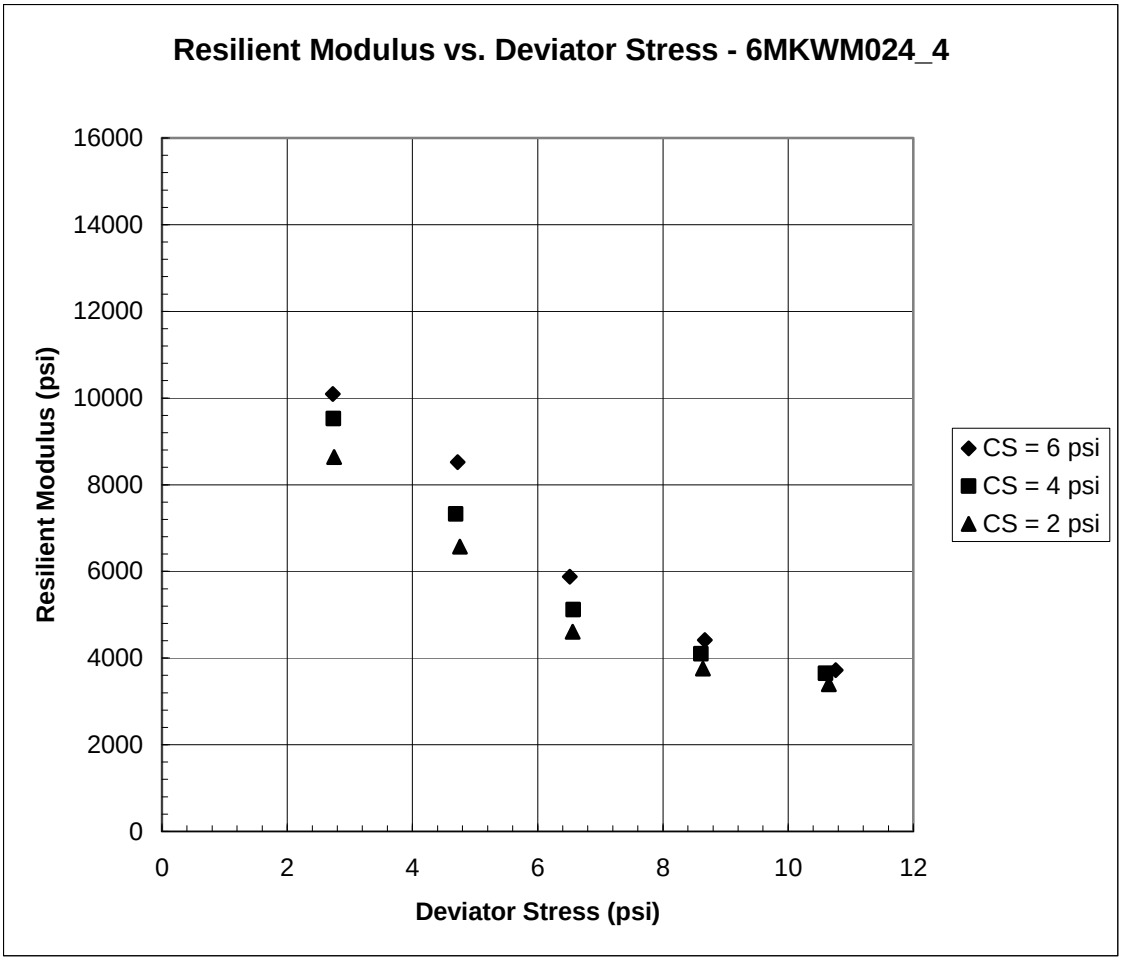
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.72	10998	10999	11000	10999	11052	11010
2	6	4.81	8409	8449	8455	8486	8452	8450
3	6	6.64	5520	5488	5488	5494	5528	5503
4	6	8.73	4472	4497	4542	4555	4513	4516
5	6	10.86	4186	4198	4203	4192	4212	4198
6	4	2.76	12241	11730	11742	12242	12291	12049
7	4	4.78	8593	8616	8628	8649	8675	8632
8	4	6.61	6221	6235	6216	6208	6216	6219
9	4	8.74	4582	4624	4634	4635	4627	4620
10	4	10.78	4011	4055	4089	4067	4033	4051
11	2	2.74	10386	10306	10348	10344	10730	10423
12	2	4.72	7971	7898	7809	7782	8013	7895
13	2	6.54	5838	5833	5835	5830	5834	5834
14	2	8.61	4345	4369	4400	4383	4380	4375
15	2	10.56	3981	3997	3987	4004	4019	3998



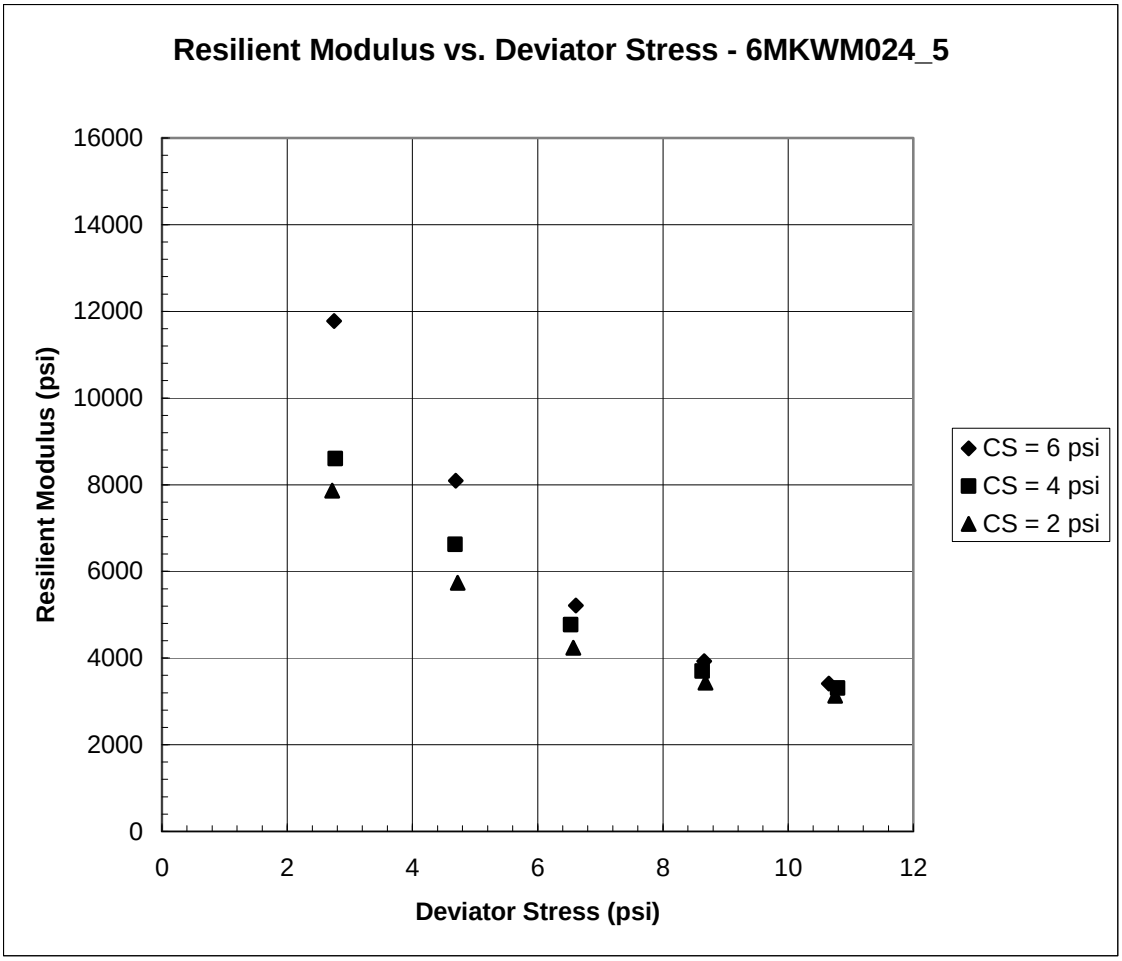
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.02	17676	16703	15703	17802	15698	16716
2	6	4.04	15767	16233	15772	16224	15825	15964
3	6	5.93	14414	14393	14644	14149	14890	14498
4	6	7.9	13237	13243	13398	13388	13400	13333
5	6	9.88	12623	12627	12844	12862	12732	12738
6	4	2	15628	16535	14670	15639	15622	15619
7	4	4.01	14461	14402	14468	14463	14785	14516
8	4	5.88	13552	13785	13778	13757	13568	13688
9	4	7.86	12729	12550	12552	12534	12539	12581
10	4	9.87	11967	11962	12062	11859	12055	11981
11	2	2.01	13471	12793	12804	12235	12853	12831
12	2	4.04	12629	12628	12628	12630	12327	12568
13	2	5.92	11737	12067	12072	12065	11567	11902
14	2	7.89	11317	11307	11309	11192	11194	11264
15	2	9.86	10745	10748	10842	10747	10653	10747



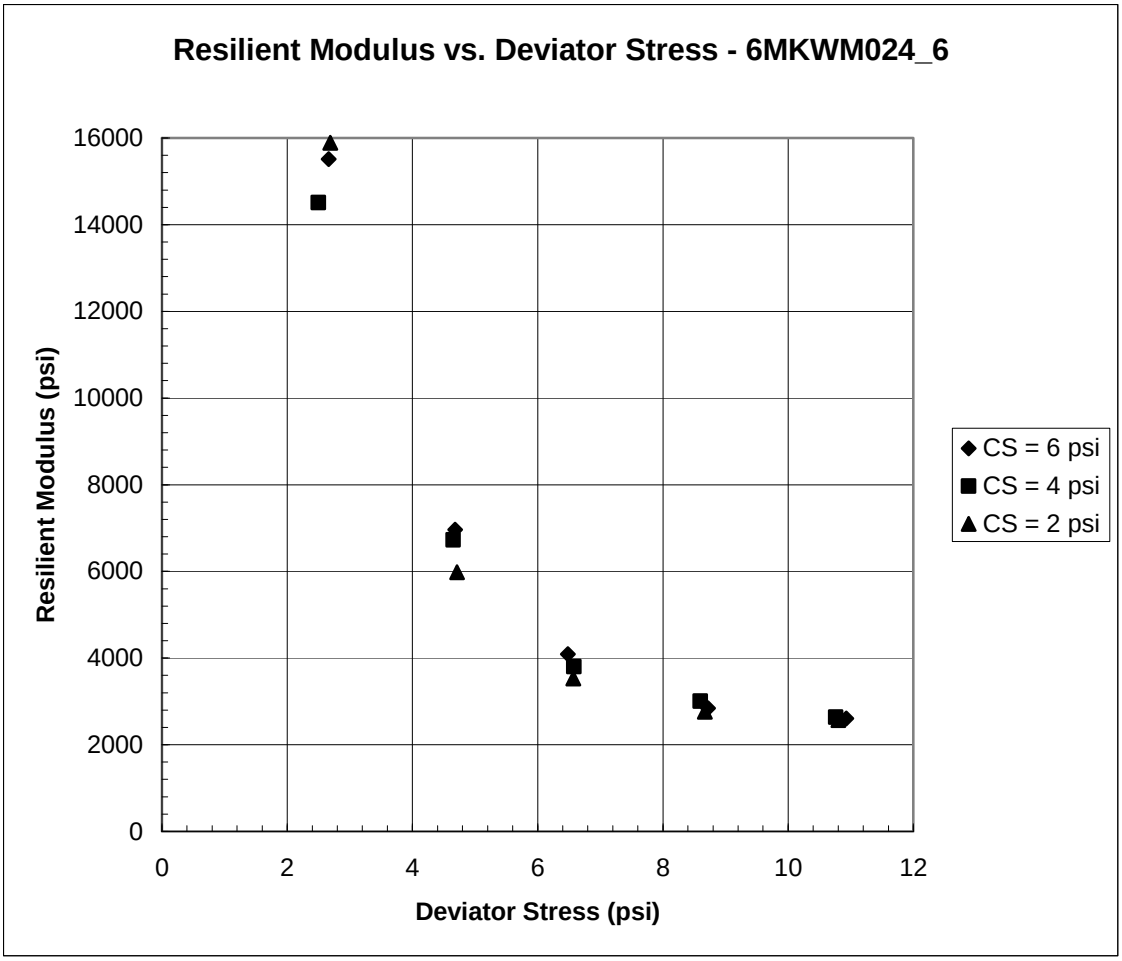
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.02	18955	18859	20221	21760	17808	19521
2	6	4.04	19592	21000	19517	18261	17168	19108
3	6	5.87	14174	15561	15552	14738	14471	14899
4	6	7.9	13217	13375	13061	13058	13390	13220
5	6	9.88	11353	11380	11483	11297	11475	11398
6	4	2.03	15009	15005	16770	15767	16771	15864
7	4	4.05	16242	16742	16263	16710	17769	16745
8	4	5.92	14593	14598	14325	14601	14857	14595
9	4	7.92	12942	12937	12513	12635	12483	12702
10	4	9.9	11306	11412	11501	11412	11502	11427
11	2	2.03	14320	12873	15828	11796	12902	13544
12	2	4.05	13524	13519	13556	13516	13240	13471
13	2	5.92	12607	12421	12443	12255	12255	12396
14	2	7.92	11818	11850	11834	11843	11976	11864
15	2	9.87	11102	10751	10749	10757	11013	10874



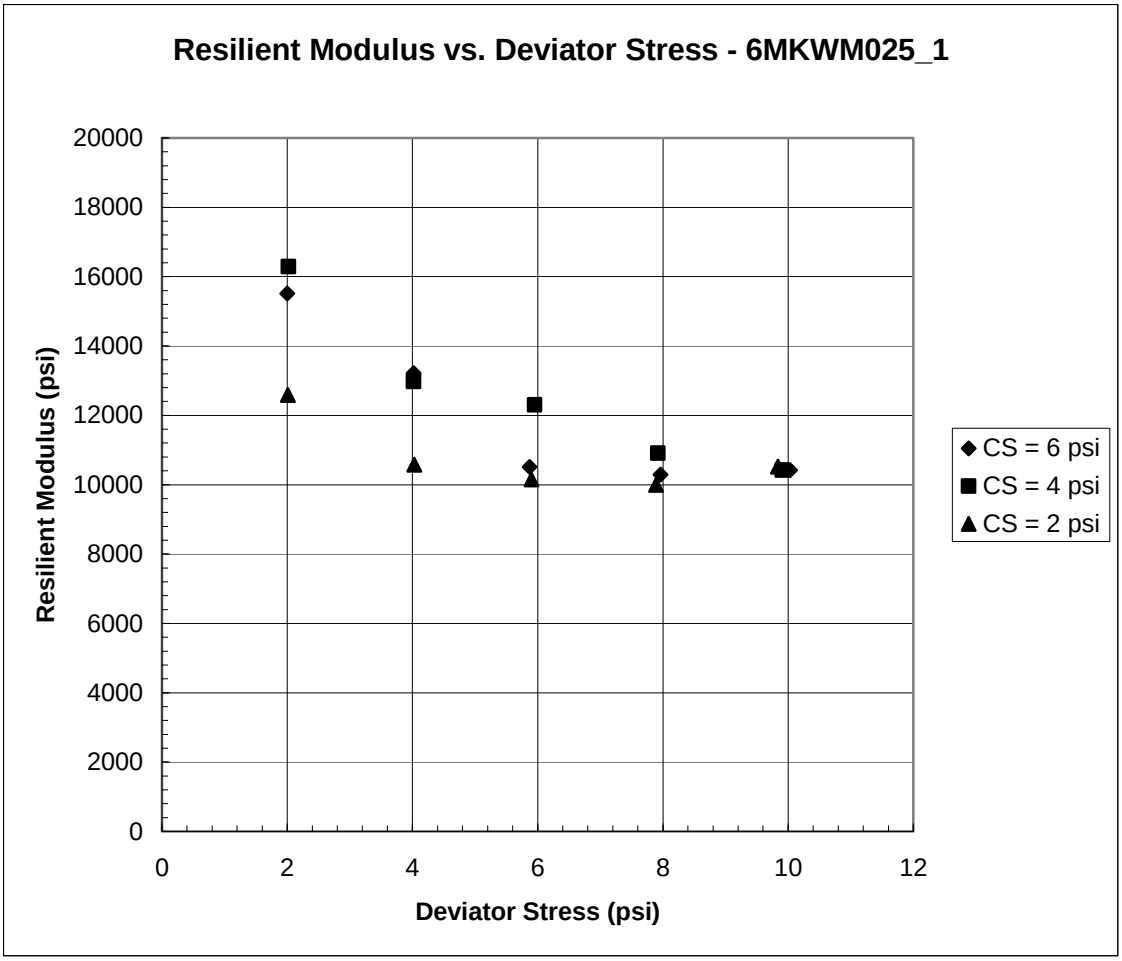
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.73	10055	10046	10008	9999	10366	10095
2	6	4.72	8392	8515	8528	8668	8516	8524
3	6	6.51	5838	5948	5865	5872	5878	5880
4	6	8.67	4401	4418	4439	4401	4399	4412
5	6	10.76	3699	3719	3724	3730	3728	3720
6	4	2.74	9397	9388	9397	9428	10027	9527
7	4	4.69	7341	7272	7357	7265	7373	7321
8	4	6.57	5144	5115	5104	5107	5103	5115
9	4	8.61	4095	4093	4089	4096	4121	4099
10	4	10.6	3635	3650	3647	3651	3645	3646
11	2	2.75	8660	8607	8651	8637	8647	8640
12	2	4.76	6586	6585	6575	6558	6564	6574
13	2	6.56	4595	4600	4600	4607	4632	4607
14	2	8.64	3765	3763	3767	3756	3746	3759
15	2	10.65	3383	3397	3407	3408	3398	3399



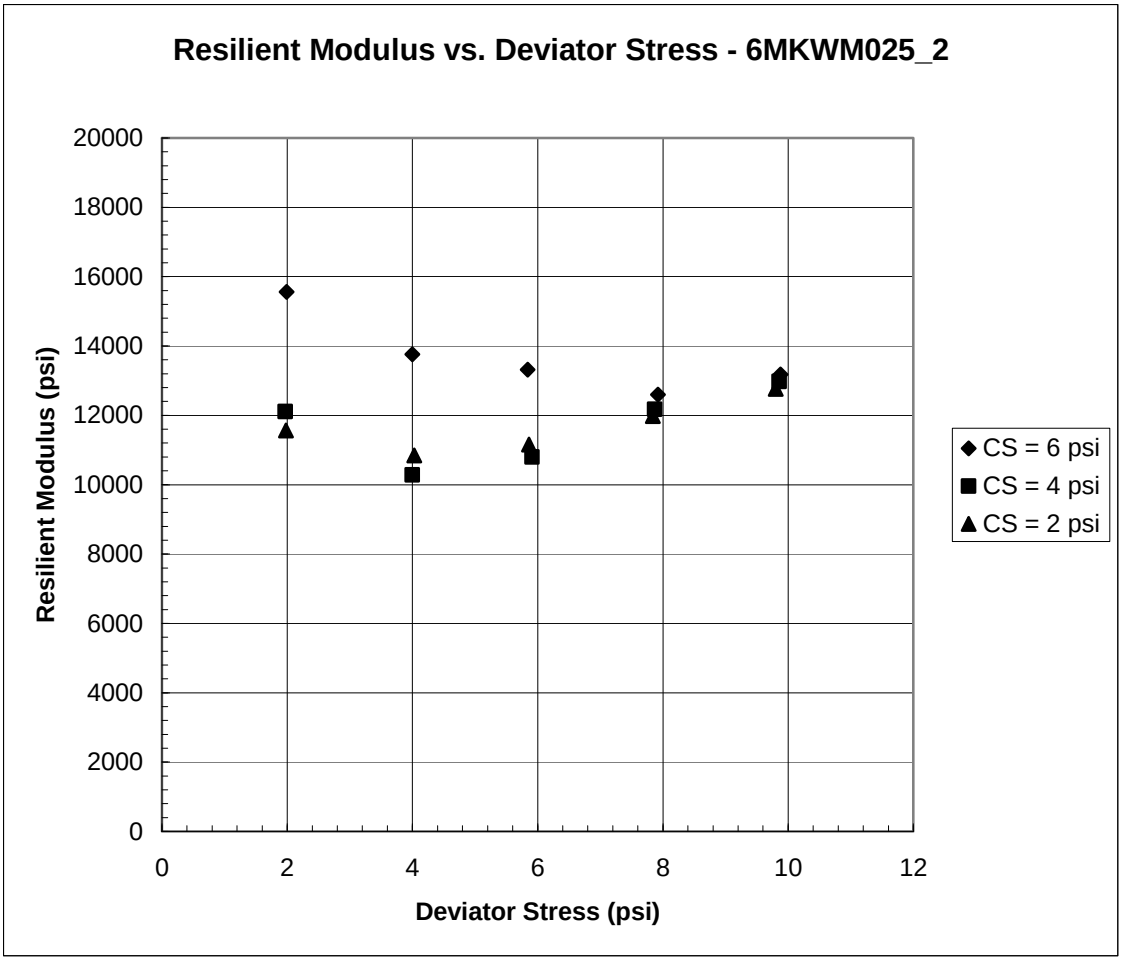
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.75	11680	11679	11645	11693	12177	11774
2	6	4.69	8060	8080	8077	8116	8118	8090
3	6	6.61	5214	5242	5183	5213	5207	5212
4	6	8.66	3937	3916	3933	3926	3926	3927
5	6	10.65	3421	3415	3406	3398	3430	3414
6	4	2.77	8716	8670	8743	8459	8425	8603
7	4	4.68	6681	6651	6557	6573	6655	6623
8	4	6.53	4757	4764	4799	4790	4749	4772
9	4	8.63	3717	3709	3686	3677	3694	3696
10	4	10.79	3302	3299	3300	3329	3309	3308
11	2	2.72	7969	8008	7751	7826	7746	7860
12	2	4.72	5747	5732	5706	5758	5736	5736
13	2	6.57	4222	4250	4241	4250	4243	4241
14	2	8.68	3436	3420	3425	3431	3437	3430
15	2	10.75	3121	3139	3130	3132	3130	3130



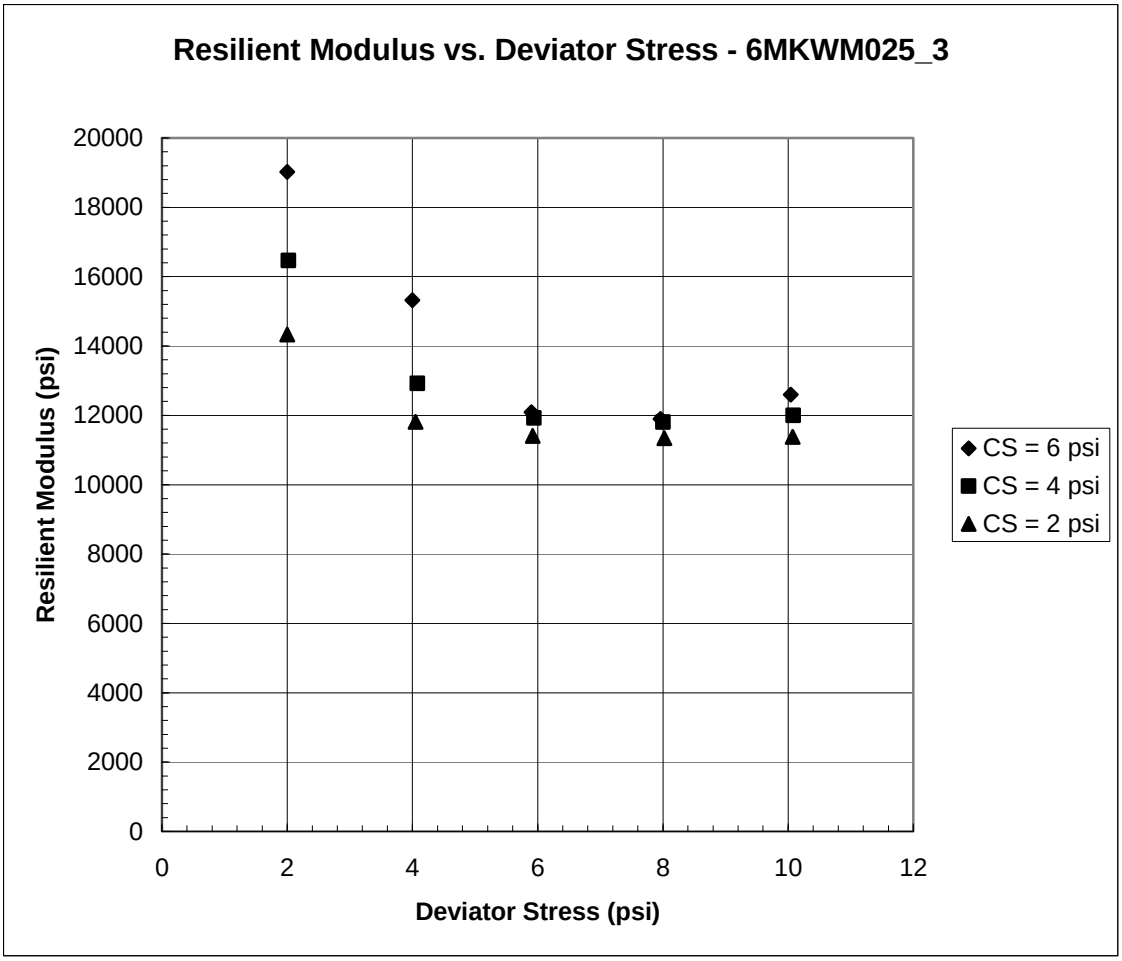
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.66	15086	15929	16097	14725	15741	15516
2	6	4.68	6949	6945	6861	7046	7001	6960
3	6	6.48	4120	4091	4011	4126	4112	4092
4	6	8.72	2799	2864	2829	2876	2864	2846
5	6	10.93	2603	2569	2642	2606	2627	2609
6	4	2.5	14107	15013	14176	14180	15074	14510
7	4	4.65	6694	6737	6774	6730	6686	6724
8	4	6.58	3810	3785	3785	3800	3822	3800
9	4	8.6	2998	2974	3018	3038	3008	3007
10	4	10.76	2655	2607	2663	2607	2660	2638
11	2	2.69	12633	21073	12753	20749	12253	15892
12	2	4.71	5951	5957	5981	6020	6010	5984
13	2	6.57	3547	3558	3529	3499	3514	3529
14	2	8.67	2749	2766	2773	2747	2772	2762
15	2	10.8	2571	2563	2575	2565	2564	2568



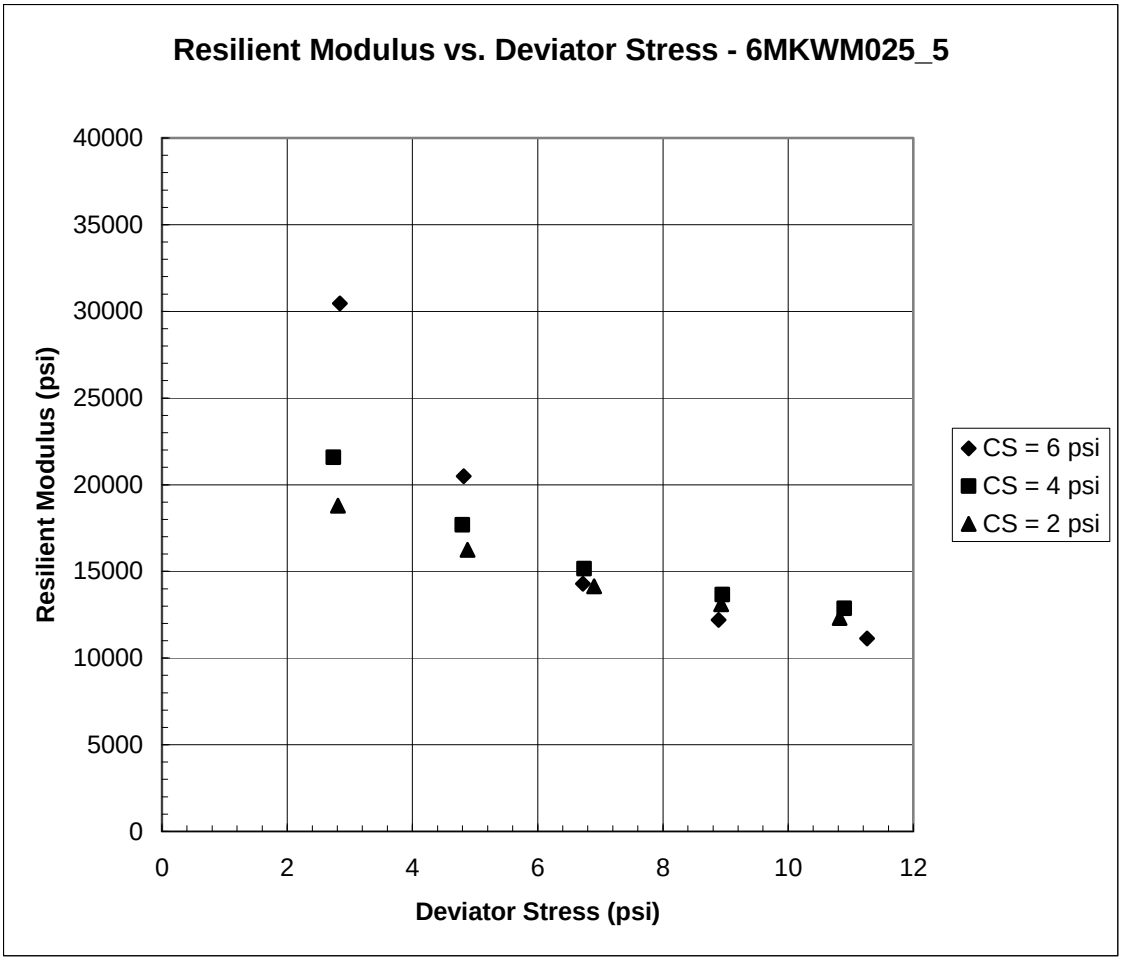
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2	15279	15354	15362	16245	15354	15519
2	6	4.02	12986	12958	13281	13276	13577	13216
3	6	5.87	10568	10568	10434	10421	10570	10512
4	6	7.96	10322	10335	10138	10324	10348	10293
5	6	10.03	10421	10405	10413	10422	10424	10417
6	4	2.02	16443	16471	16457	15550	16521	16289
7	4	4.02	12966	13276	13306	12681	12671	12980
8	4	5.95	12334	12355	12334	12358	12151	12306
9	4	7.92	11108	11107	10781	10653	10878	10905
10	4	9.91	10581	10256	10490	10271	10495	10419
11	2	2.01	13206	12594	12547	12022	12599	12593
12	2	4.03	10524	10756	10548	10525	10522	10575
13	2	5.9	10088	10090	10091	10373	10107	10150
14	2	7.89	10021	9941	9951	10041	10032	9997
15	2	9.84	10564	10592	10508	10502	10422	10518



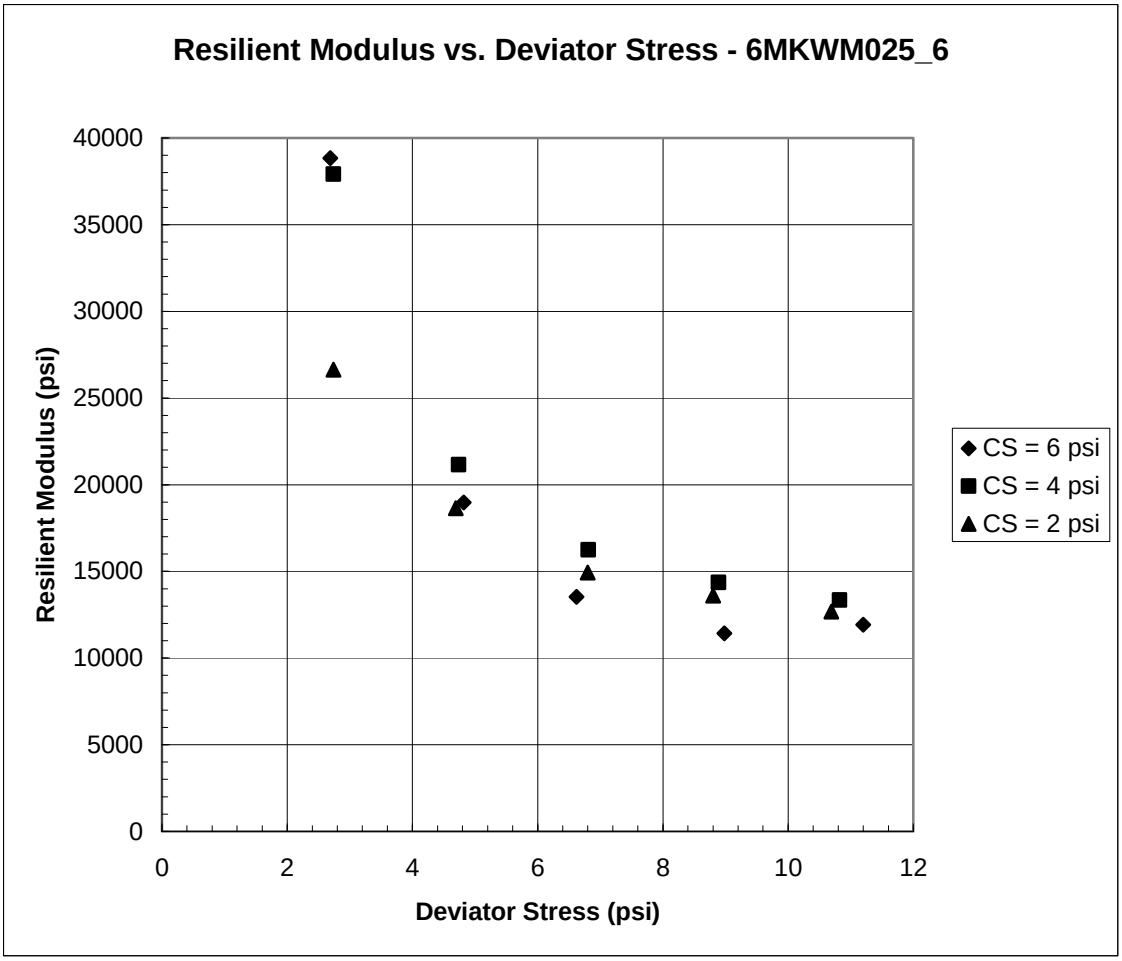
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	1.99	15276	15193	15125	16132	16086	15562
2	6	4	13727	14137	13403	13795	13765	13765
3	6	5.84	13427	13123	13206	13143	13674	13315
4	6	7.92	12381	12704	12519	12725	12664	12599
5	6	9.88	13328	13176	12960	13347	13107	13184
6	4	1.97	12295	12282	11749	11815	12395	12107
7	4	4	10230	10353	10220	10177	10427	10281
8	4	5.91	10989	10714	10686	10737	10842	10794
9	4	7.87	12010	12326	12022	12340	12188	12177
10	4	9.86	12824	13014	12943	13045	13060	12977
11	2	1.98	10903	11863	11857	11356	11854	11567
12	2	4.03	10909	10625	10720	11052	10904	10842
13	2	5.86	11213	11081	11195	11095	11195	11156
14	2	7.84	11852	12027	12142	11997	11861	11976
15	2	9.8	12715	12759	12716	12857	12772	12764



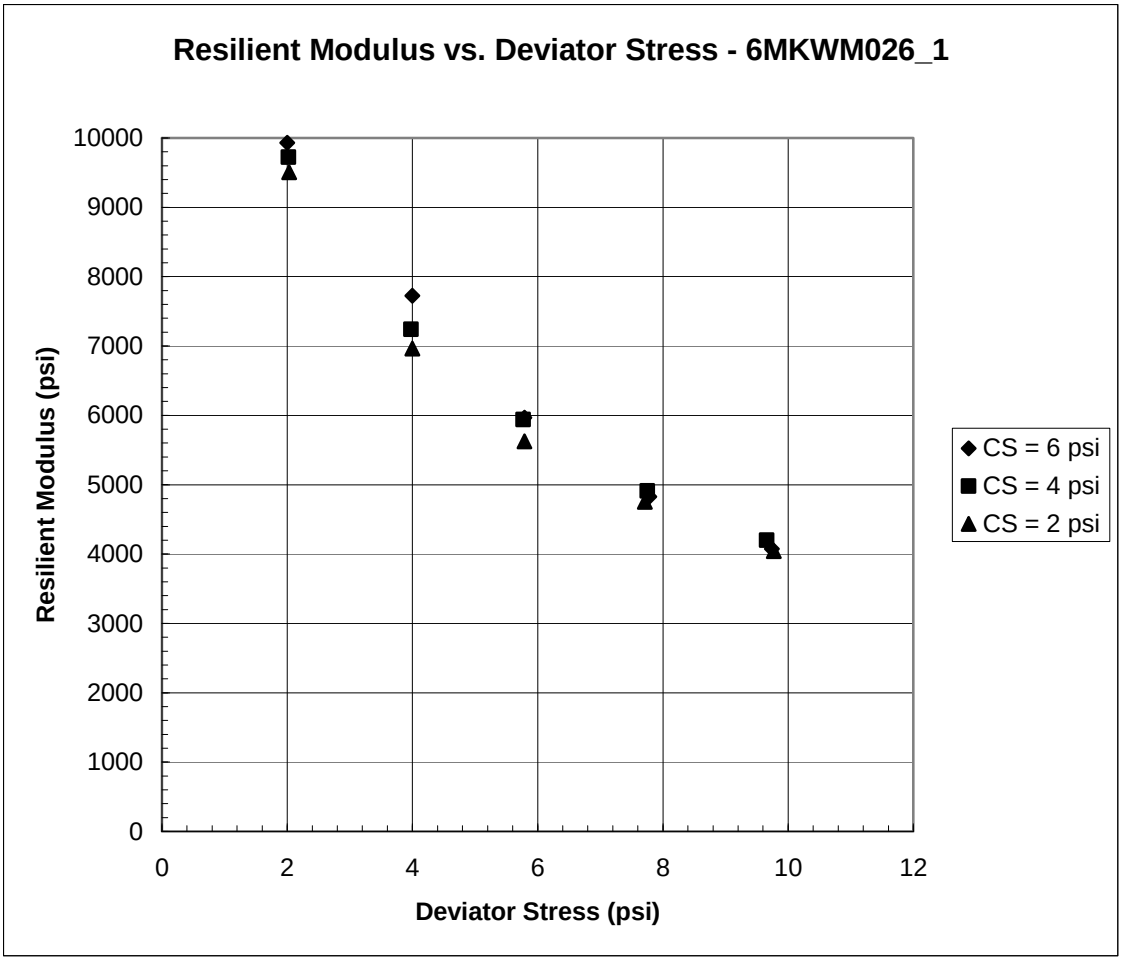
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2	18462	18541	18473	19772	19883	19026
2	6	4	15506	14918	15399	15402	15375	15320
3	6	5.9	11953	12044	12155	12244	12050	12089
4	6	7.96	11873	11828	11902	11849	12047	11900
5	6	10.04	12551	12571	12539	12797	12522	12596
6	4	2.02	16454	16455	16431	16526	16448	16463
7	4	4.08	12893	13098	12888	12810	12918	12921
8	4	5.94	11936	11763	12091	11936	11916	11928
9	4	8	11769	11697	11917	11822	11811	11803
10	4	10.08	11968	11941	12086	11930	12087	12002
11	2	2	14648	13869	13853	14586	14719	14335
12	2	4.05	11993	11507	11718	11940	11912	11814
13	2	5.92	11542	11296	11381	11454	11371	11409
14	2	8.02	11479	11348	11258	11221	11387	11339
15	2	10.07	11346	11463	11439	11390	11283	11384



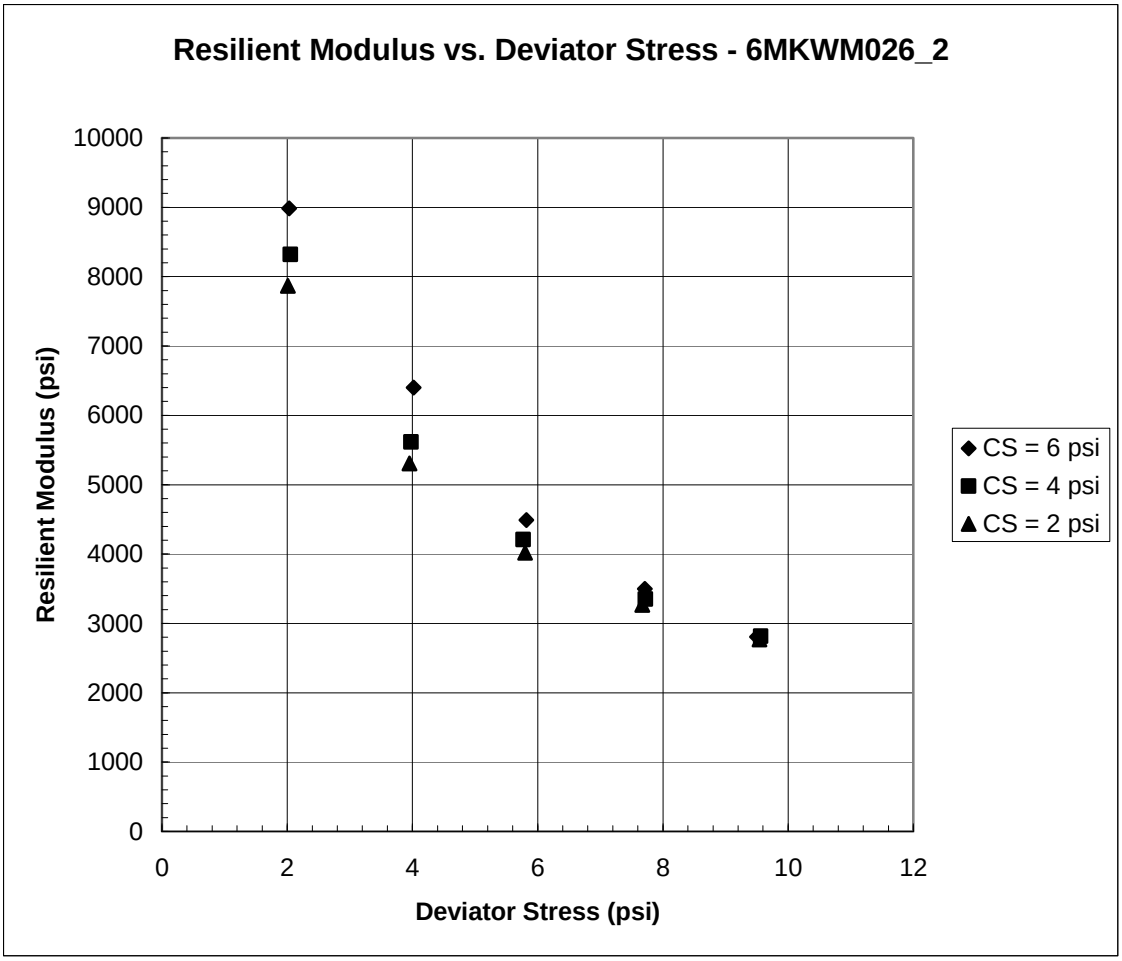
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.84	30597	30487	30444	30329	30453	30462
2	6	4.82	21038	20354	20362	20344	20382	20496
3	6	6.72	14173	14431	14404	14216	14192	14283
4	6	8.89	12061	12060	12183	12350	12334	12198
5	6	11.26	11082	11083	11083	11103	11264	11123
6	4	2.74	20704	22278	20536	22179	22206	21581
7	4	4.8	17840	17760	17722	17799	17287	17681
8	4	6.74	15246	15261	15275	15003	14966	15150
9	4	8.95	13698	13699	13686	13697	13529	13662
10	4	10.9	12803	12801	13043	12813	12906	12873
11	2	2.81	17653	18761	20000	18766	18785	18793
12	2	4.88	16224	16224	16264	16266	16199	16235
13	2	6.9	13949	14186	14213	14187	14192	14146
14	2	8.93	13057	13053	13213	13057	13187	13113
15	2	10.82	12256	12368	12267	12266	12374	12306



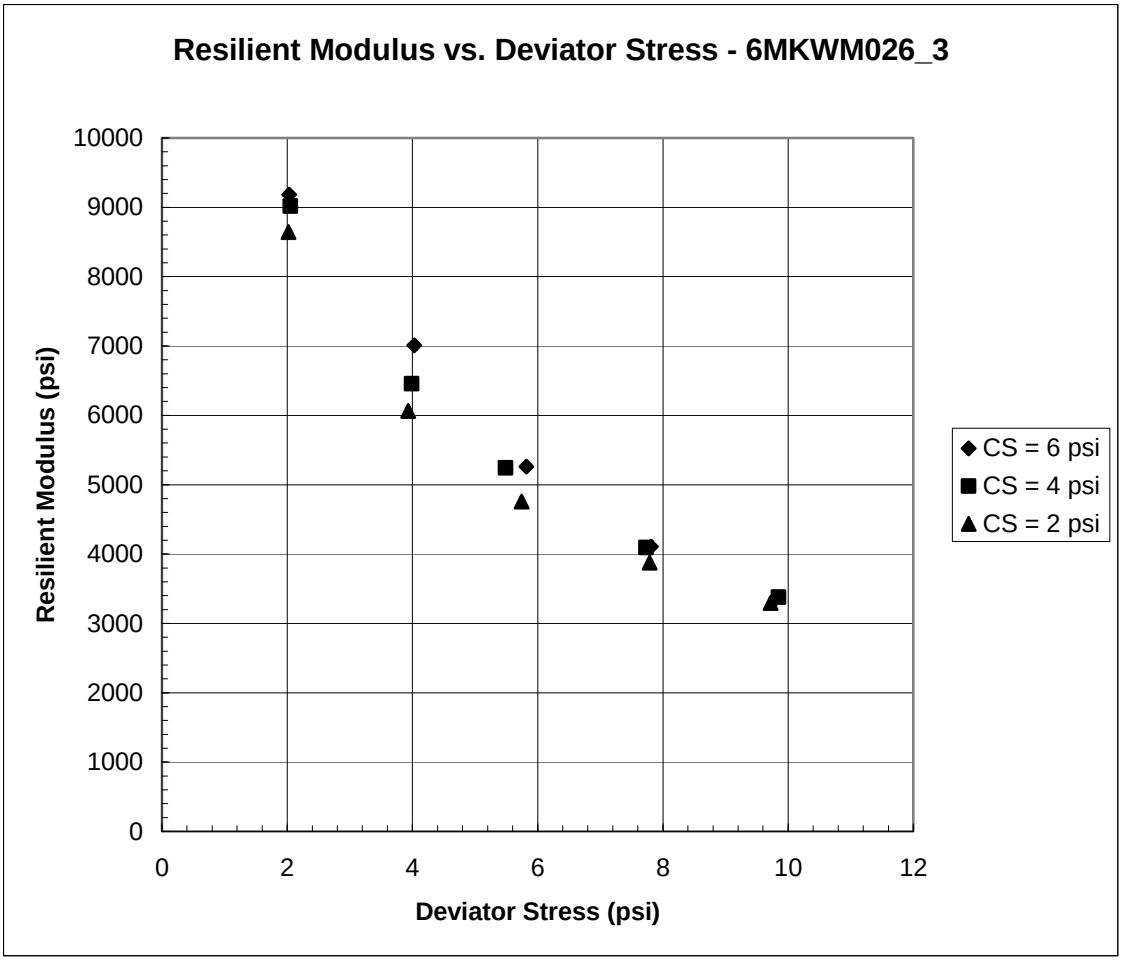
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.69	39932	39567	35242	40304	39161	38841
2	6	4.82	18934	19048	19069	18928	18933	18982
3	6	6.62	13669	13491	13673	13392	13408	13526
4	6	8.98	11331	11480	11360	11477	11439	11417
5	6	11.2	11874	11903	11915	11915	12038	11929
6	4	2.74	40835	40814	35509	36690	35731	37916
7	4	4.74	20617	21249	21247	21304	21312	21146
8	4	6.81	16248	16200	16215	16224	16288	16235
9	4	8.89	14341	14361	14385	14347	14327	14352
10	4	10.82	13276	13435	13187	13320	13466	13337
11	2	2.74	26349	26067	26060	28680	25997	26630
12	2	4.69	18276	18210	19522	18973	18265	18649
13	2	6.8	15080	14841	14807	14825	15082	14927
14	2	8.8	13677	13650	13364	13834	13500	13605
15	2	10.69	12649	12561	12785	12598	12786	12676



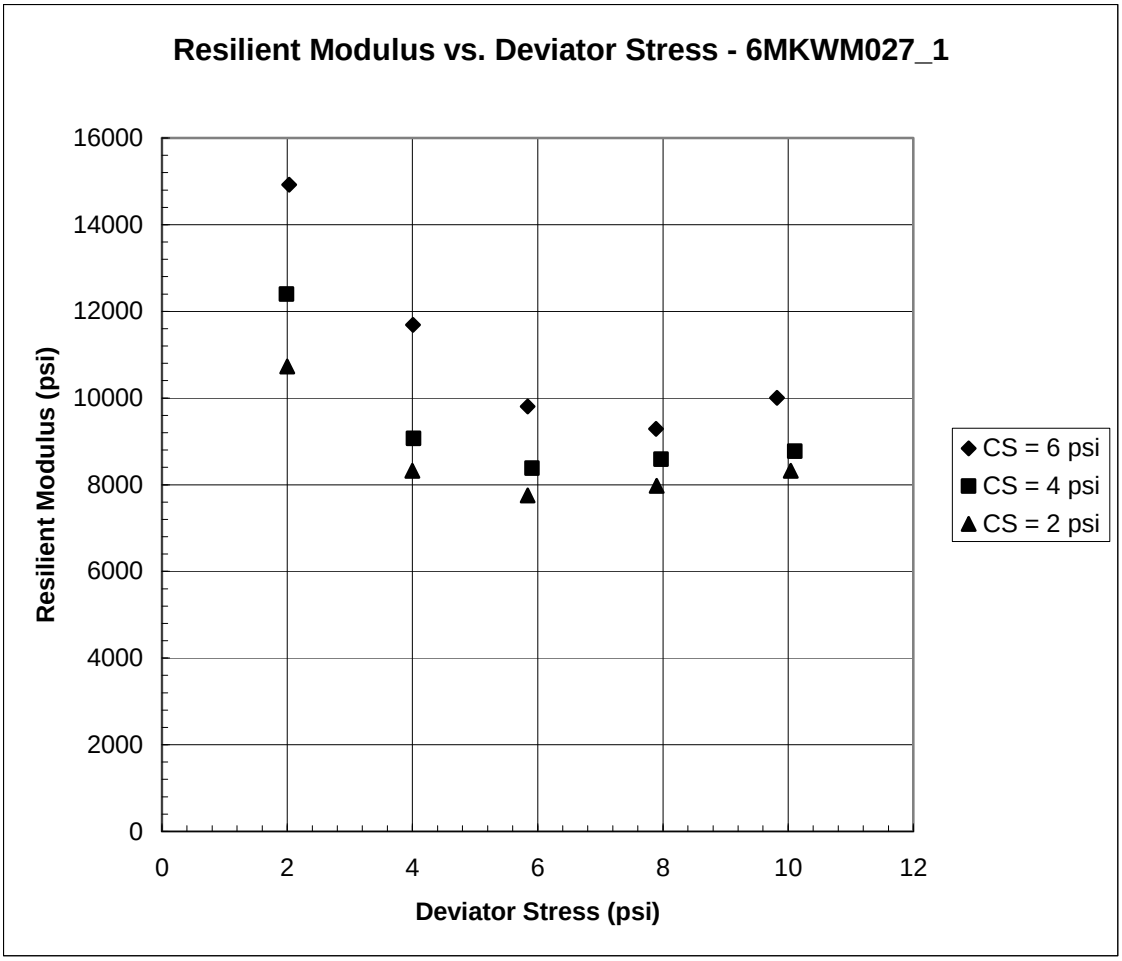
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2	10319	9957	10269	9581	9542	9933
2	6	4	7628	7806	7651	7895	7653	7727
3	6	5.79	5942	5976	5953	5966	5995	5966
4	6	7.78	4818	4827	4803	4805	4869	4825
5	6	9.74	4093	4061	4108	4073	4038	4075
6	4	2.02	9759	9719	10050	9364	9713	9721
7	4	3.98	7251	7239	7233	7255	7220	7239
8	4	5.77	5889	5979	5899	5988	5951	5941
9	4	7.75	4901	4888	4927	4893	4932	4908
10	4	9.66	4214	4202	4214	4180	4195	4201
11	2	2.03	9803	9390	9476	9396	9472	9507
12	2	4	6934	7057	6934	6870	7019	6963
13	2	5.79	5659	5575	5637	5617	5638	5625
14	2	7.71	4771	4733	4762	4790	4707	4753
15	2	9.77	4042	4013	4060	4085	4015	4043



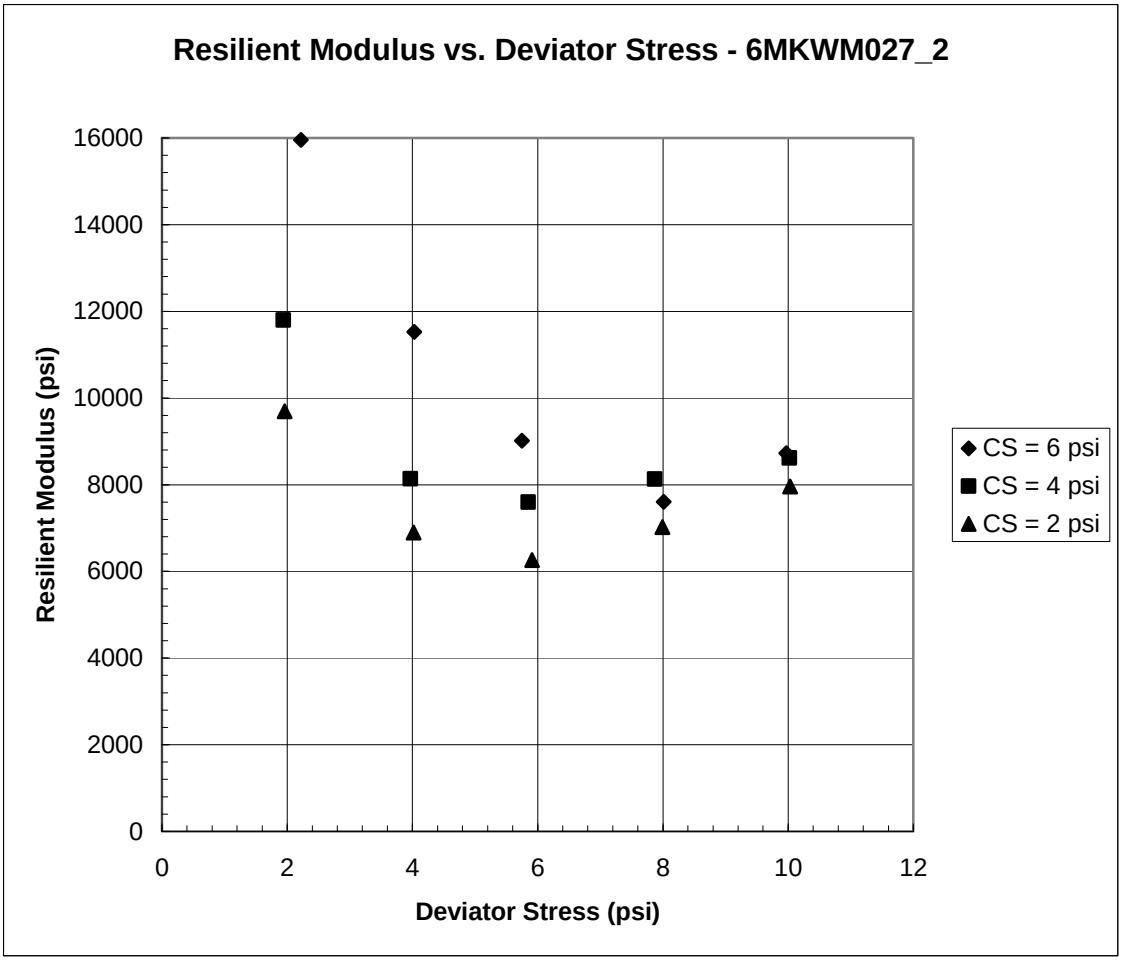
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.03	8911	9279	8993	9028	8714	8985
2	6	4.02	6389	6449	6405	6347	6407	6399
3	6	5.82	4562	4454	4510	4420	4516	4492
4	6	7.71	3509	3473	3505	3523	3476	3497
5	6	9.5	2782	2800	2805	2833	2800	2804
6	4	2.05	8327	8255	8348	8042	8619	8318
7	4	3.98	5608	5598	5657	5539	5690	5618
8	4	5.77	4182	4230	4191	4251	4191	4209
9	4	7.72	3355	3372	3334	3372	3325	3352
10	4	9.56	2801	2814	2823	2815	2829	2816
11	2	2.01	7903	7691	7908	7902	7944	7870
12	2	3.95	5322	5258	5407	5183	5355	5305
13	2	5.8	4006	4018	4027	4025	4020	4019
14	2	7.67	3289	3269	3249	3263	3254	3265
15	2	9.54	2744	2764	2774	2805	2751	2768



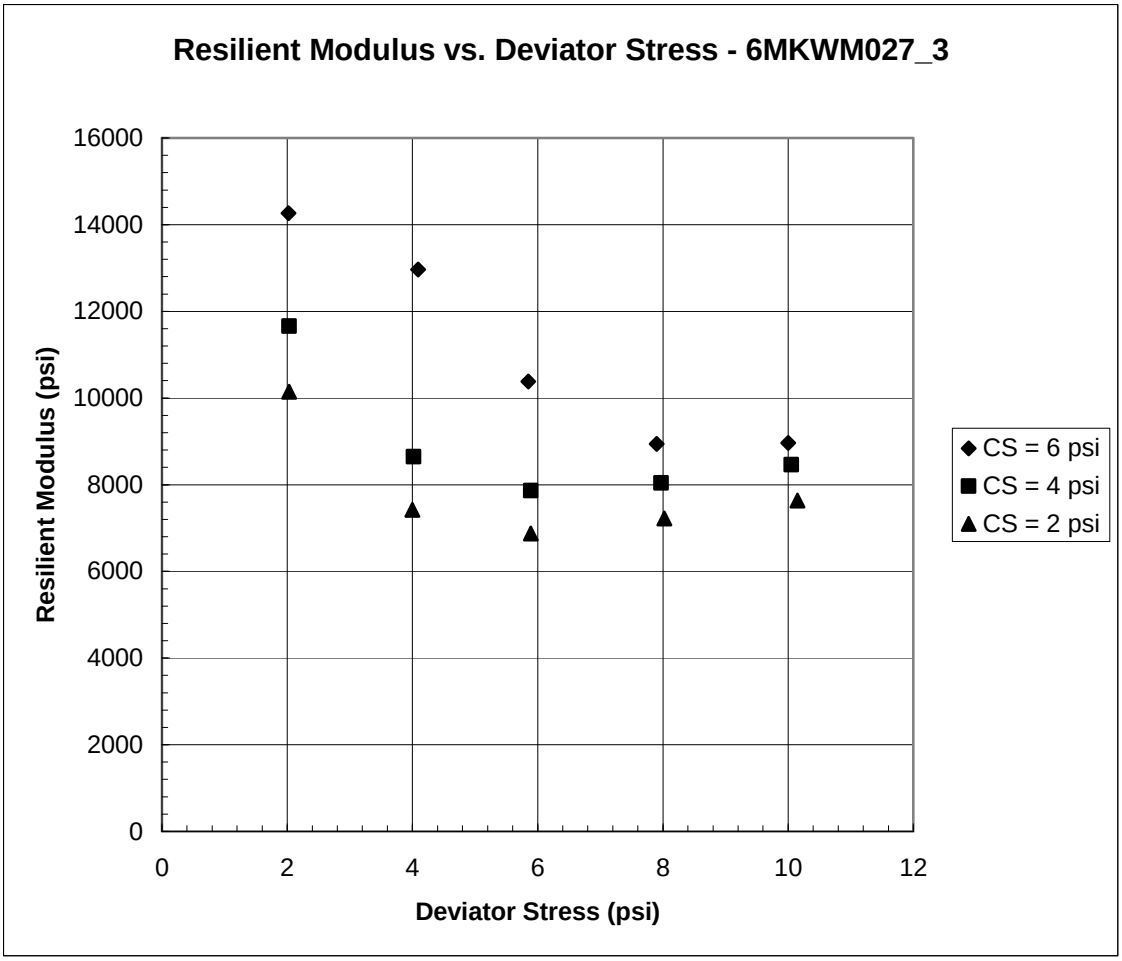
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.03	9411	9118	9120	9409	8858	9183
2	6	4.03	7043	7005	6958	7075	6975	7011
3	6	5.82	5246	5278	5253	5287	5237	5260
4	6	7.81	4084	4130	4081	4072	4157	4105
5	6	9.81	3340	3395	3341	3358	3378	3362
6	4	2.05	9269	8947	9223	8965	8685	9018
7	4	3.99	6359	6457	6431	6592	6444	6456
8	4	5.49	5269	5270	5210	5254	5218	5244
9	4	7.73	4110	4037	4117	4098	4098	4092
10	4	9.85	3359	3382	3391	3390	3363	3377
11	2	2.02	8539	8782	8572	8484	8835	8642
12	2	3.93	6187	6083	6041	6056	5942	6062
13	2	5.74	4755	4748	4763	4721	4798	4757
14	2	7.79	3906	3851	3894	3855	3886	3878
15	2	9.72	3272	3313	3272	3316	3290	3293



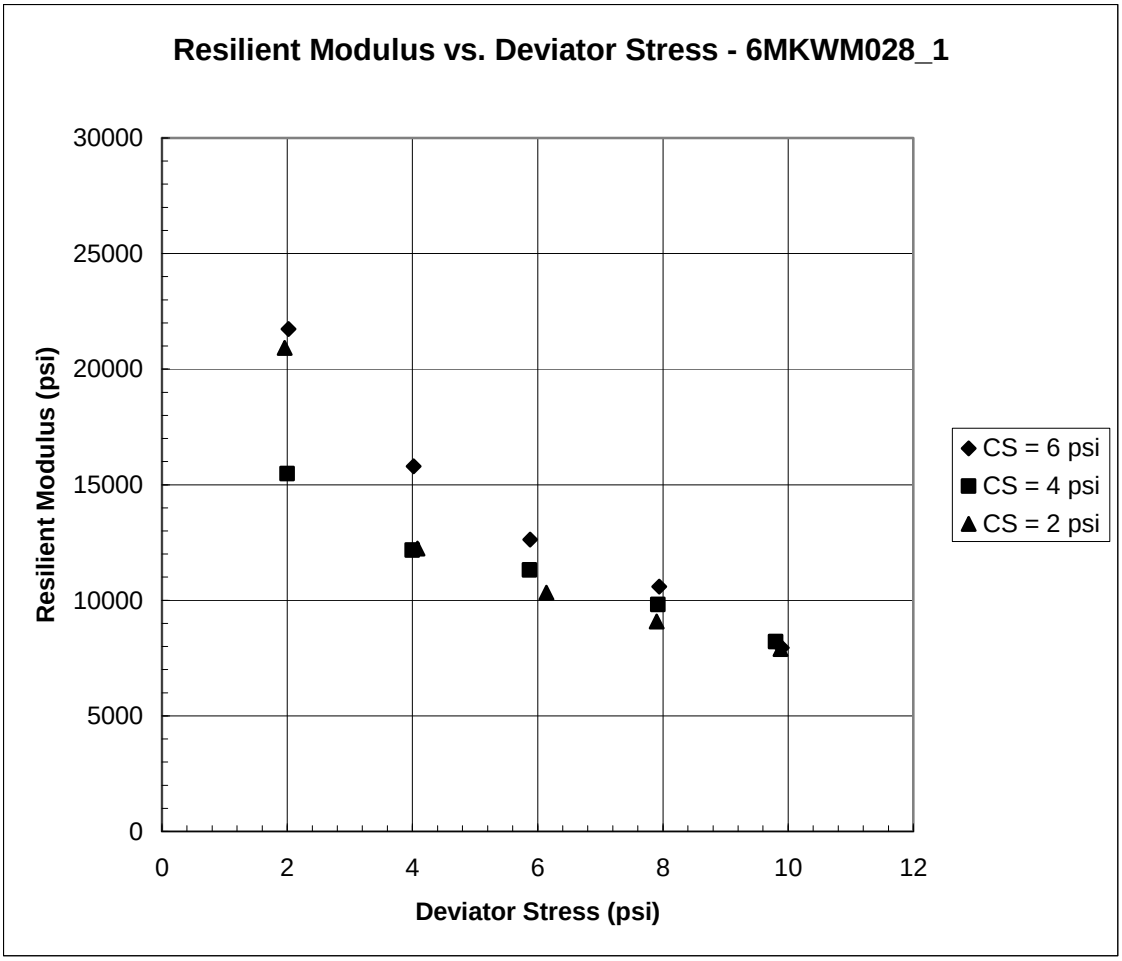
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.03	15387	15375	14617	14610	14623	14922
2	6	4.01	11498	11755	11721	11716	11745	11687
3	6	5.84	9855	9722	9853	9724	9871	9805
4	6	7.89	9254	9305	9208	9390	9272	9285
5	6	9.82	9988	10043	10000	9978	10030	10008
6	4	1.99	12360	12422	12358	11888	12970	12399
7	4	4.02	9169	9006	9145	8986	9017	9065
8	4	5.91	8513	8282	8323	8407	8379	8381
9	4	7.97	8586	8636	8466	8638	8606	8586
10	4	10.11	8820	8738	8785	8626	8900	8774
11	2	2	10665	10656	10617	11026	10671	10727
12	2	4	8329	8301	8340	8284	8354	8322
13	2	5.84	7789	7669	7839	7694	7766	7751
14	2	7.9	7933	7960	7977	7950	8036	7971
15	2	10.04	8378	8286	8342	8325	8268	8320



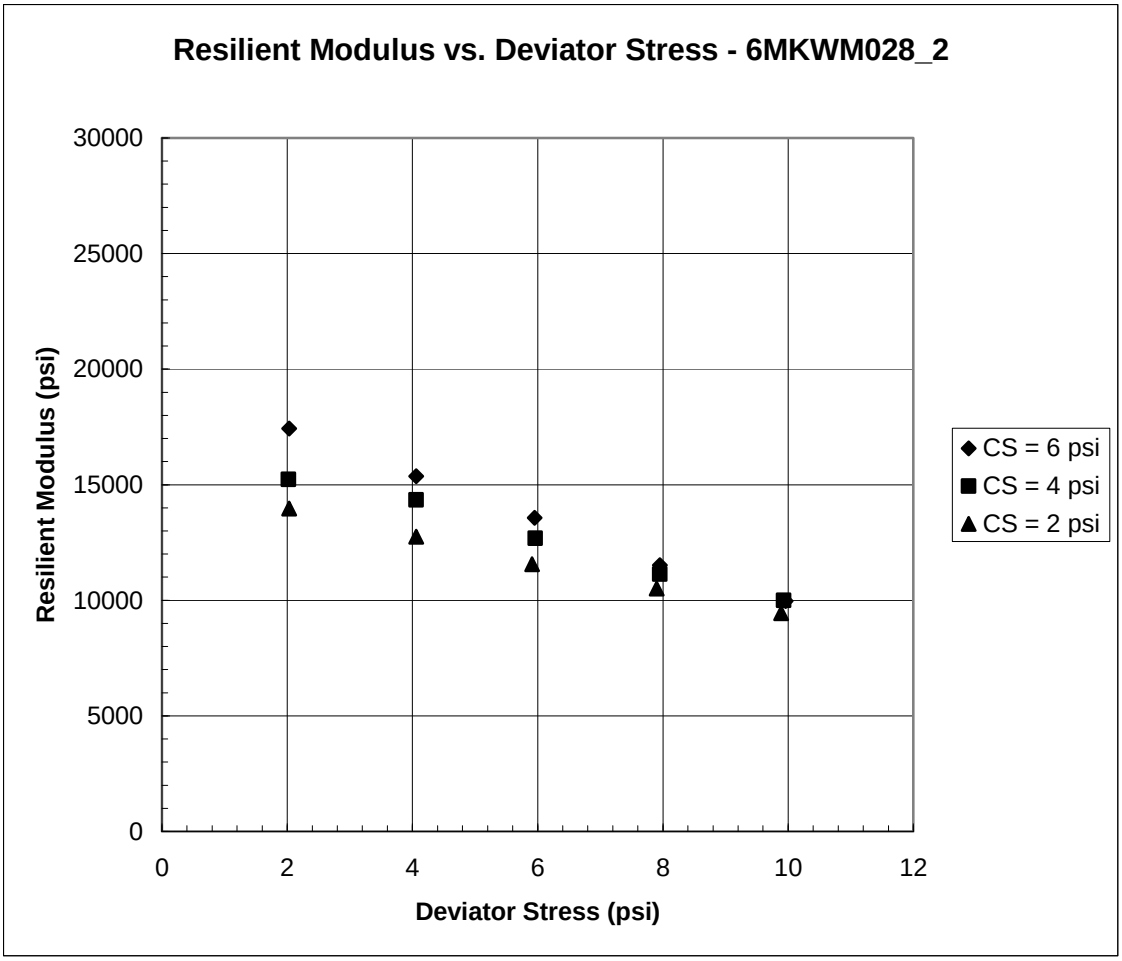
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.22	16372	15317	15712	17123	15269	15959
2	6	4.03	11670	11619	11402	11509	11414	11523
3	6	5.75	9174	8956	8953	8937	9069	9018
4	6	8.01	7556	7653	7568	7657	7586	7604
5	6	9.97	8628	8795	8645	8789	8763	8724
6	4	1.94	12118	11534	12120	11629	11608	11802
7	4	3.97	8156	8124	8142	8165	8109	8139
8	4	5.85	7538	7670	7542	7685	7560	7599
9	4	7.87	8138	8063	8159	8112	8169	8128
10	4	10.02	8634	8594	8631	8657	8582	8620
11	2	1.96	9649	9719	9641	9760	9684	9691
12	2	4.02	6975	6765	6990	6765	6994	6898
13	2	5.91	6261	6204	6265	6308	6276	6263
14	2	7.99	6990	7061	7001	7005	7058	7023
15	2	10.03	7905	8008	8066	7839	7999	7963



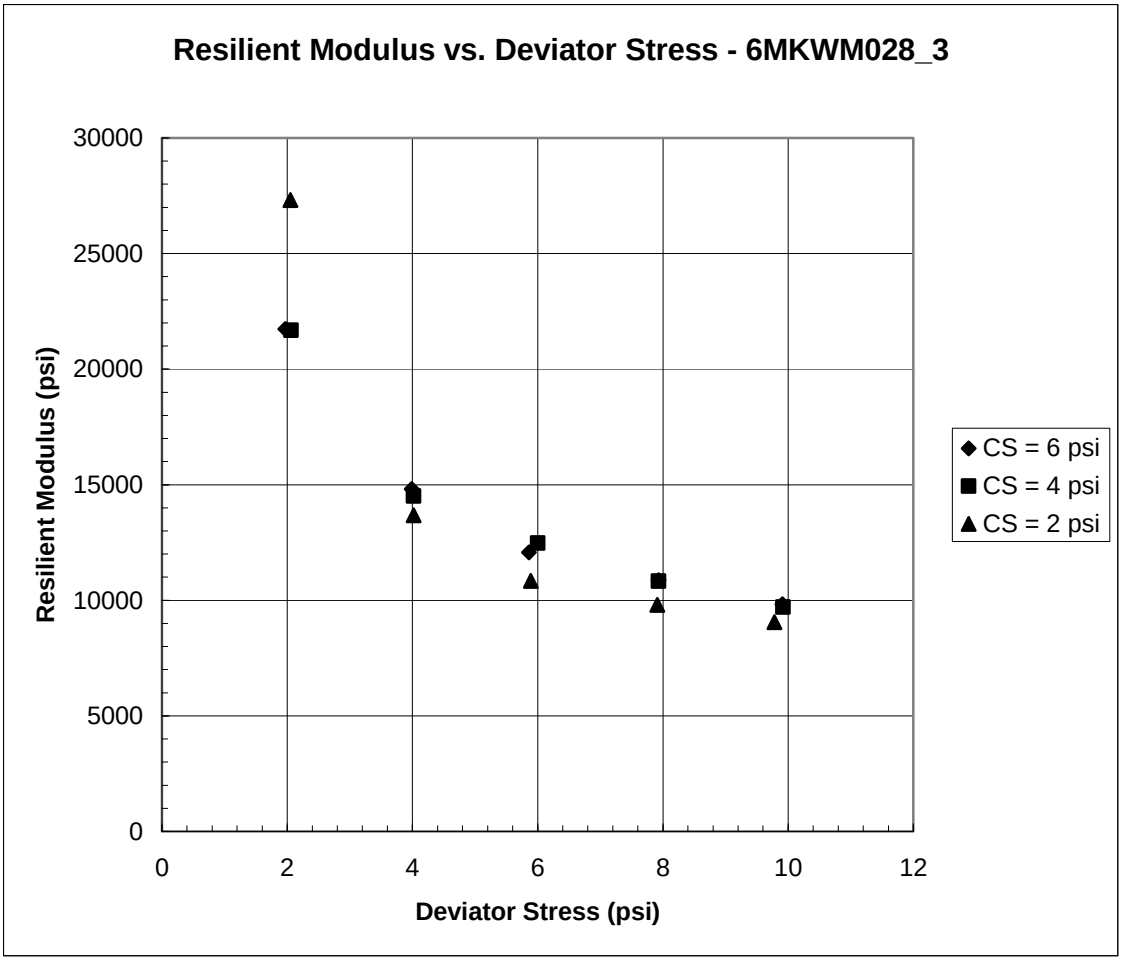
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.02	13836	13847	14656	14402	14599	14268
2	6	4.09	12837	12808	13064	13070	13064	12969
3	6	5.85	10249	10393	10485	10408	10354	10378
4	6	7.9	8934	8979	8929	9065	8799	8941
5	6	10	9002	8984	8919	8987	8932	8965
6	4	2.03	11673	11636	11733	11563	11687	11658
7	4	4.02	8612	8616	8776	8596	8646	8649
8	4	5.89	7856	7838	7966	7848	7804	7862
9	4	7.97	7990	8026	8008	8084	8085	8038
10	4	10.05	8459	8435	8505	8442	8476	8463
11	2	2.03	10032	10486	10083	10083	10042	10145
12	2	4	7430	7387	7433	7463	7373	7417
13	2	5.89	6872	6807	6818	6930	6951	6876
14	2	8.02	7179	7148	7317	7157	7309	7222
15	2	10.15	7582	7604	7671	7617	7691	7633



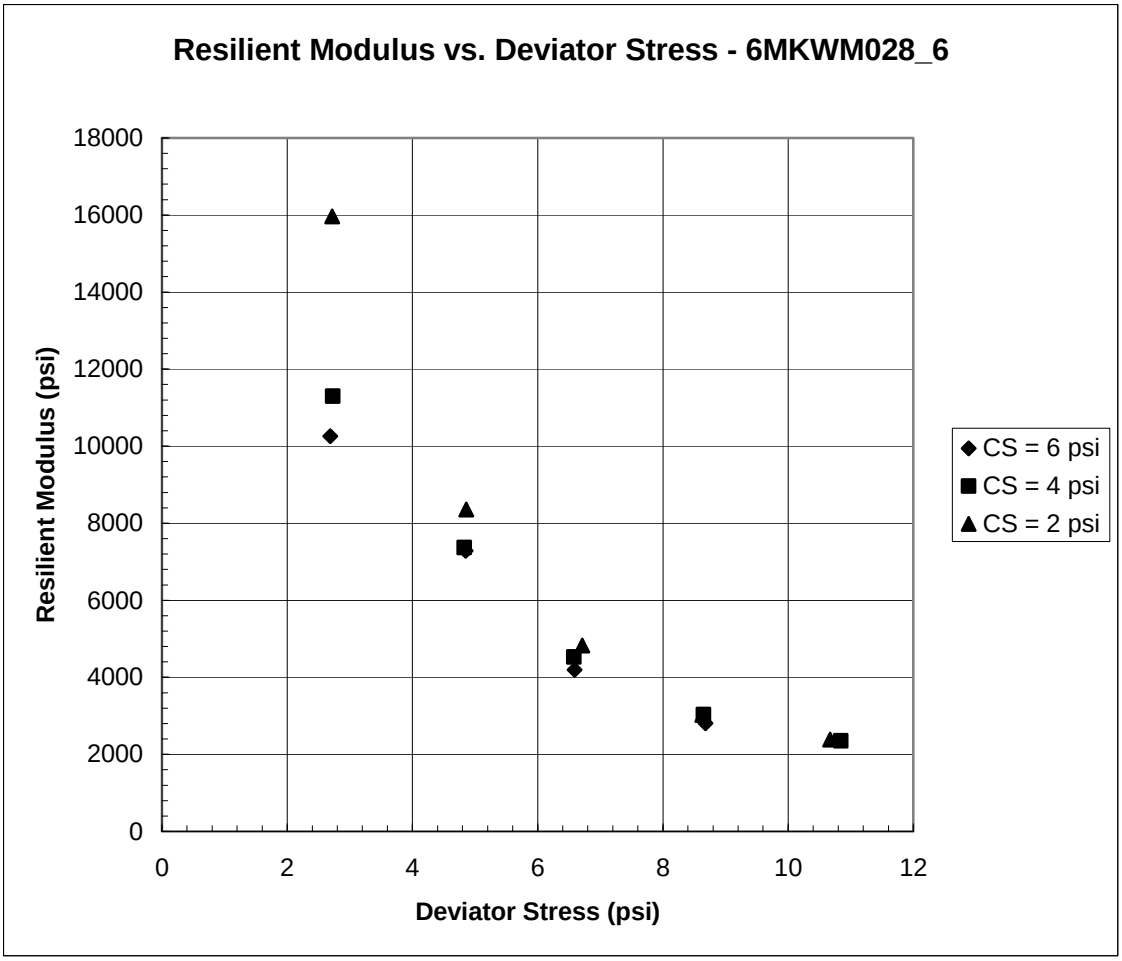
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.02	20637	20798	20704	22288	24269	21739
2	6	4.02	15224	16047	15648	16031	16025	15795
3	6	5.88	12612	12376	13008	12560	12599	12631
4	6	7.94	10858	10406	10534	10614	10563	10595
5	6	9.9	7945	7898	7943	7972	7959	7943
6	4	2	16978	15881	14994	14383	15142	15476
7	4	4	12151	12549	11924	12237	12016	12175
8	4	5.87	11518	11539	11205	11231	11092	11317
9	4	7.92	9750	9622	9667	10085	9920	9809
10	4	9.8	8221	8212	8210	8220	8213	8215
11	2	1.96	20256	21858	18748	23443	20263	20914
12	2	4.08	12257	11975	12490	12234	12267	12245
13	2	6.14	10282	10235	10566	10392	10172	10329
14	2	7.9	9112	9116	9084	8987	9081	9076
15	2	9.88	7889	7849	7939	7880	7898	7891



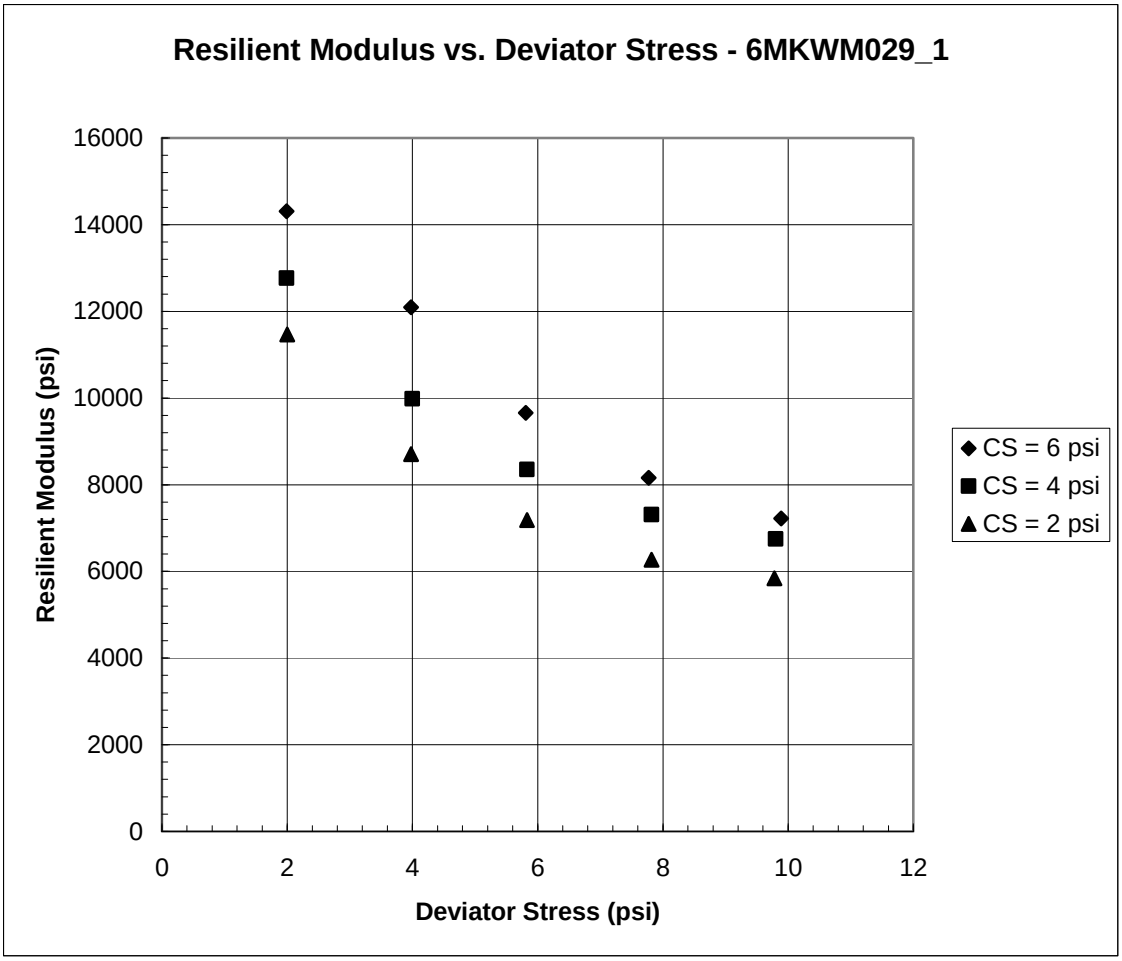
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.03	16821	17871	17806	16742	17923	17432
2	6	4.06	15362	15766	15373	14957	15384	15368
3	6	5.95	13925	13466	13712	13489	13254	13569
4	6	7.95	11497	11485	11627	11602	11403	11523
5	6	9.96	9992	9967	9983	9910	9966	9964
6	4	2.02	15736	15697	14915	14830	14942	15224
7	4	4.06	14571	14162	14199	14558	14237	14345
8	4	5.96	12841	12633	12823	12477	12664	12687
9	4	7.95	11036	11271	11034	11027	11271	11128
10	4	9.93	10096	10090	9872	10081	9865	10001
11	2	2.03	14224	13548	14184	13589	14268	13963
12	2	4.06	12915	12919	12627	12668	12603	12746
13	2	5.91	11340	11660	11470	11664	11638	11554
14	2	7.9	10521	10554	10531	10455	10444	10501
15	2	9.89	9436	9441	9438	9441	9435	9438



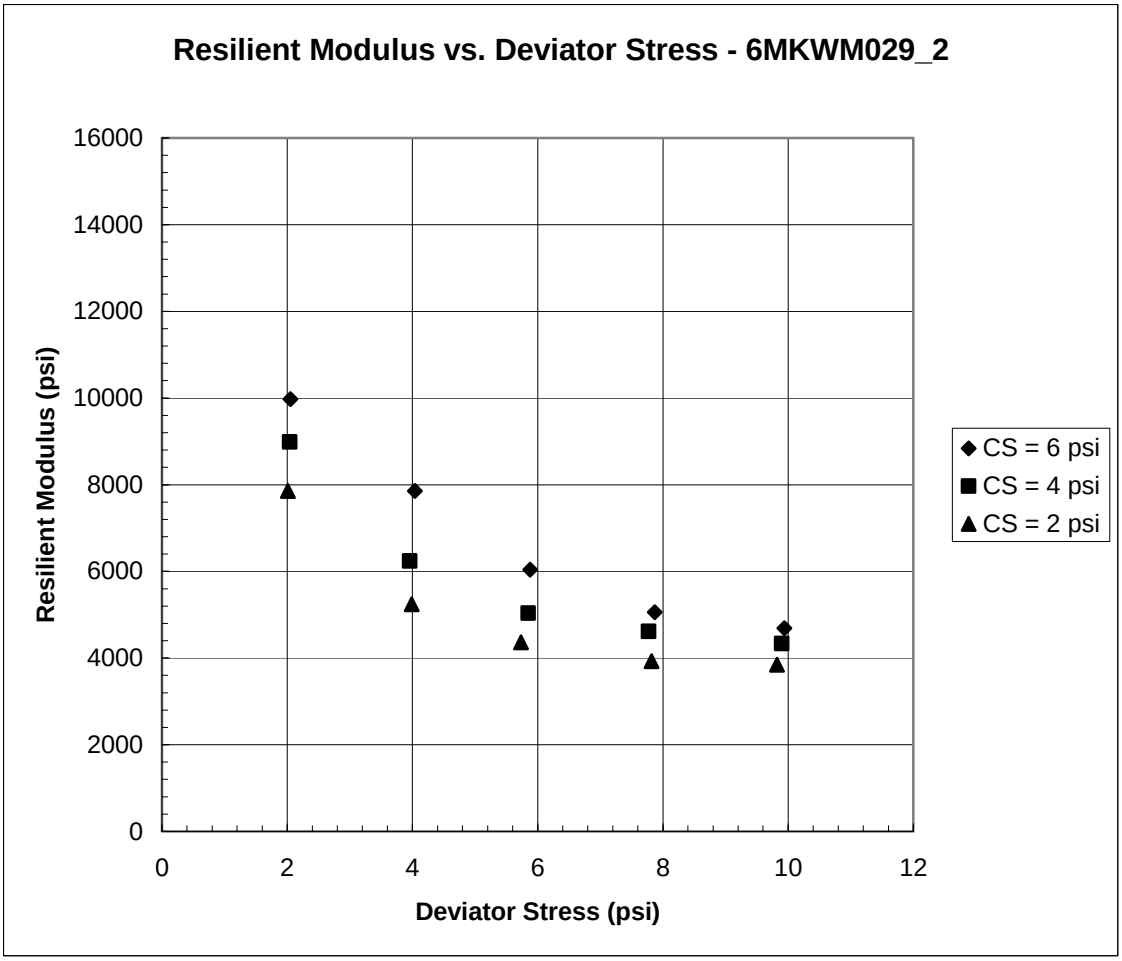
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	1.97	21592	21799	21991	21603	21664	21730
2	6	3.99	14672	15032	15019	14688	14667	14815
3	6	5.86	11990	12278	11994	12057	12028	12069
4	6	7.93	10977	10820	10886	10827	10860	10874
5	6	9.91	9853	9752	9863	9780	9934	9836
6	4	2.06	21352	22122	21159	21095	22639	21674
7	4	4.02	14421	14435	14360	14495	14822	14507
8	4	6	12353	12471	12717	12316	12528	12477
9	4	7.93	11009	10695	10864	10693	10843	10821
10	4	9.92	9654	9794	9614	9713	9733	9702
11	2	2.05	26815	27313	26356	27300	28785	27314
12	2	4.02	13359	13803	13664	13823	13734	13677
13	2	5.89	10833	10861	10831	10843	10863	10846
14	2	7.91	9763	9749	9801	9768	9896	9796
15	2	9.78	9030	9070	9034	9070	9038	9048



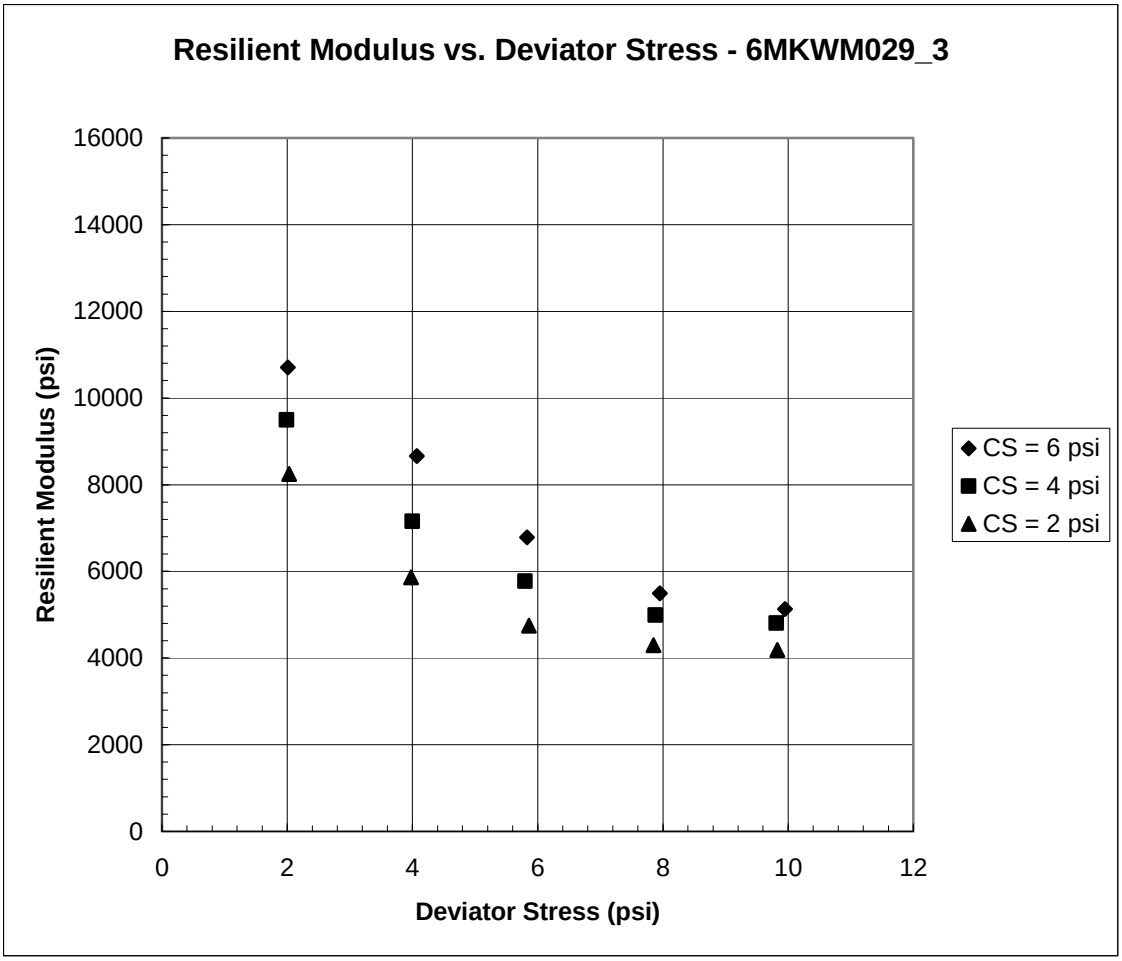
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.69	10173	10314	10399	10195	10199	10256
2	6	4.85	7248	7193	7293	7338	7345	7283
3	6	6.59	4231	4203	4197	4195	4145	4194
4	6	8.68	2796	2838	2813	2828	2770	2809
5	6							
6	4	2.73	11474	11097	11459	11200	11270	11300
7	4	4.83	7399	7257	7285	7433	7472	7369
8	4	6.58	4569	4539	4479	4513	4520	4524
9	4	8.65	3059	3072	3022	3028	2956	3028
10	4	10.84	2297	2361	2395	2374	2342	2354
11	2	2.72	13920	16132	16453	13004	20335	15969
12	2	4.86	8159	8478	8252	8330	8545	8353
13	2	6.71	4827	4819	4844	4813	4822	4825
14	2	8.63	3037	3027	3003	3006	3024	3020
15	2	10.67	2414	2431	2277	2394	2392	2381



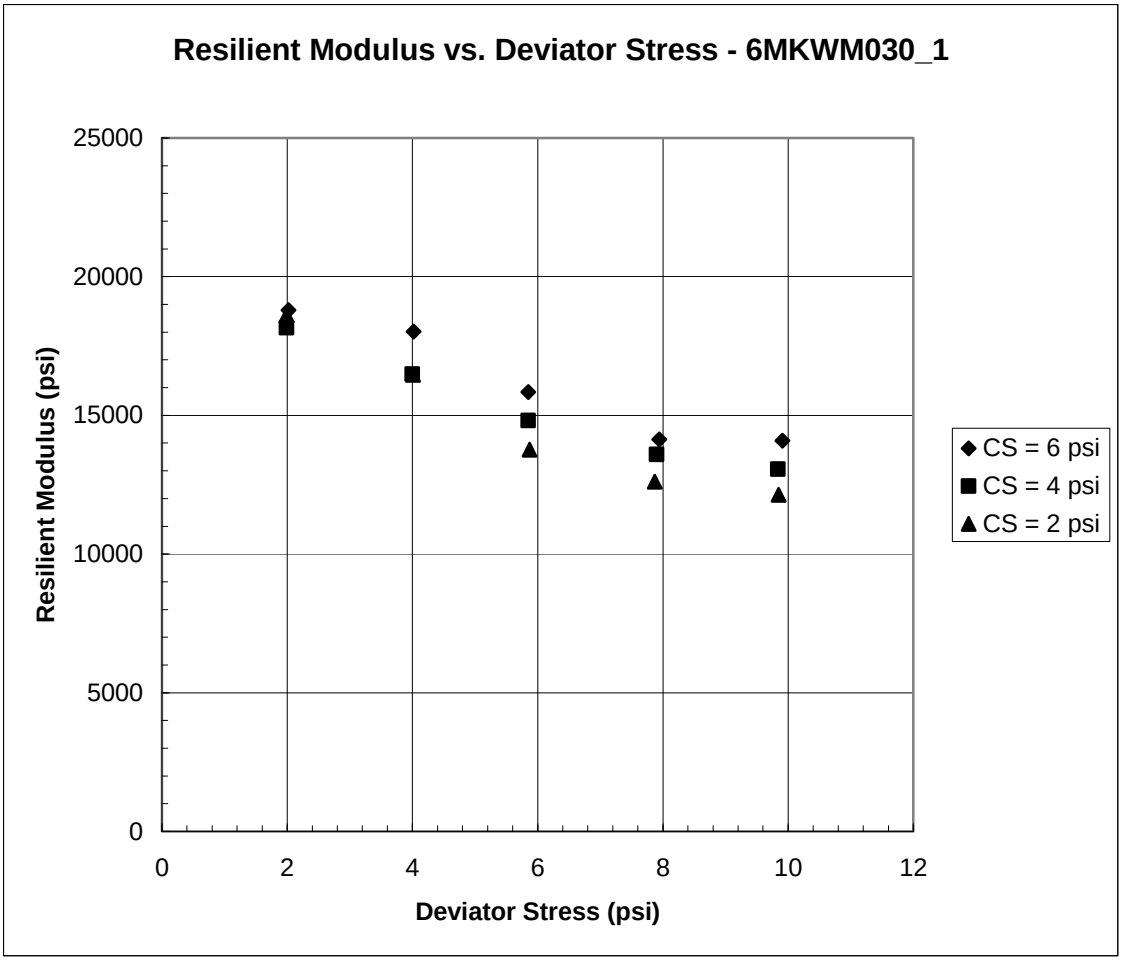
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	1.99	14199	14193	14067	14953	14140	14310
2	6	3.98	11997	12085	11758	12313	12312	12093
3	6	5.81	9523	9686	9734	9606	9732	9656
4	6	7.77	8093	8172	8225	8133	8172	8159
5	6	9.89	7203	7227	7244	7203	7220	7219
6	4	1.99	12249	12921	12866	12866	12911	12763
7	4	4	9964	10167	9987	9944	9840	9981
8	4	5.83	8313	8274	8481	8274	8399	8348
9	4	7.82	7305	7283	7352	7292	7313	7309
10	4	9.8	6723	6753	6722	6762	6768	6746
11	2	2	11371	11878	10922	11310	11832	11463
12	2	3.98	8702	8837	8722	8533	8719	8703
13	2	5.83	7242	7186	7230	7063	7195	7183
14	2	7.82	6266	6224	6281	6296	6276	6269
15	2	9.78	5863	5831	5863	5874	5773	5841



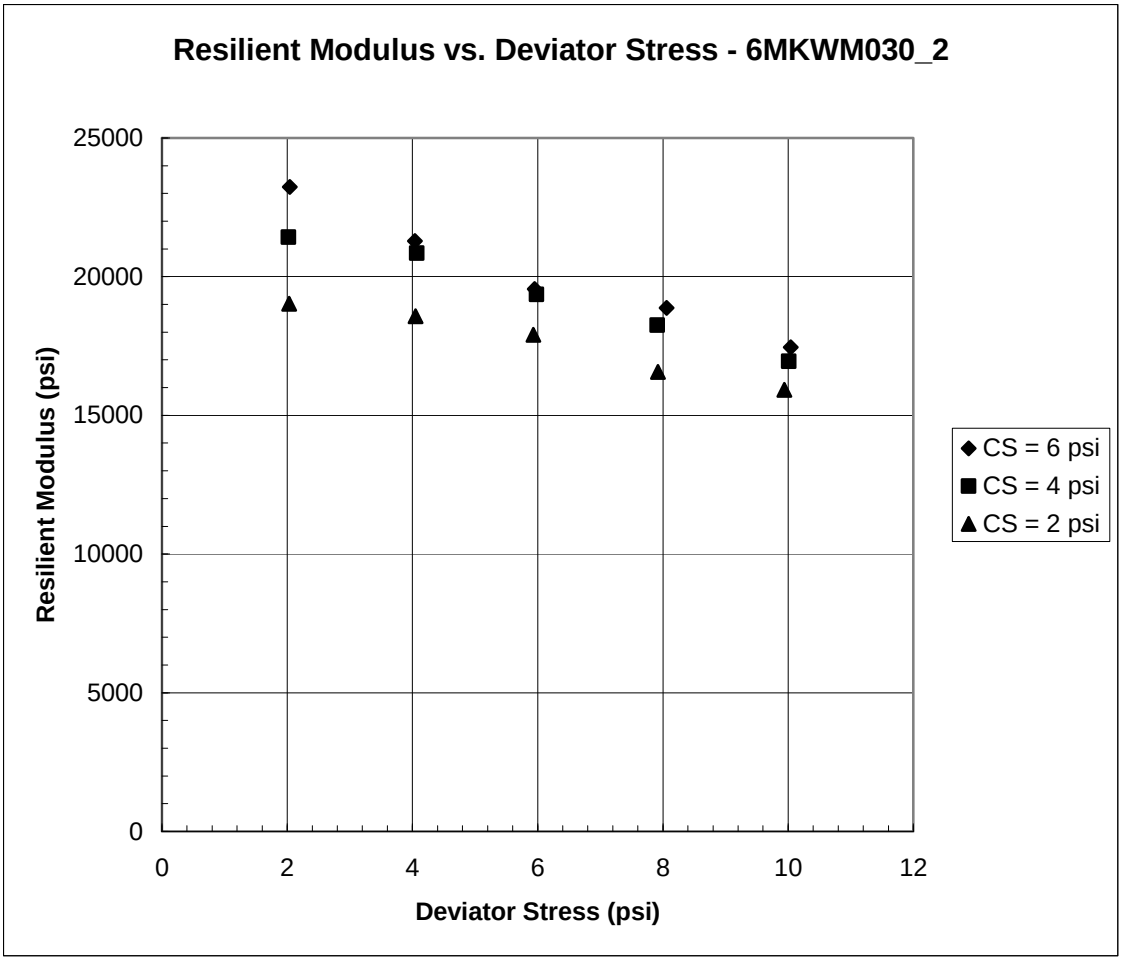
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.05	10062	10026	10021	10067	9684	9972
2	6	4.04	7852	7962	7856	7752	7874	7859
3	6	5.88	5968	5970	6144	6012	6100	6039
4	6	7.87	5088	5031	5065	5077	5019	5056
5	6	9.94	4689	4686	4690	4686	4709	4692
6	4	2.04	9070	8757	9036	9032	9037	8987
7	4	3.96	6167	6319	6179	6333	6192	6238
8	4	5.85	5043	4970	5077	4978	5104	5035
9	4	7.77	4619	4583	4619	4643	4615	4616
10	4	9.9	4307	4378	4311	4351	4312	4332
11	2	2.01	8153	7723	7680	8201	7532	7858
12	2	3.99	5256	5245	5209	5257	5258	5245
13	2	5.73	4327	4277	4429	4376	4398	4361
14	2	7.82	3923	3946	3923	3956	3887	3927
15	2	9.82	3842	3850	3849	3842	3836	3844



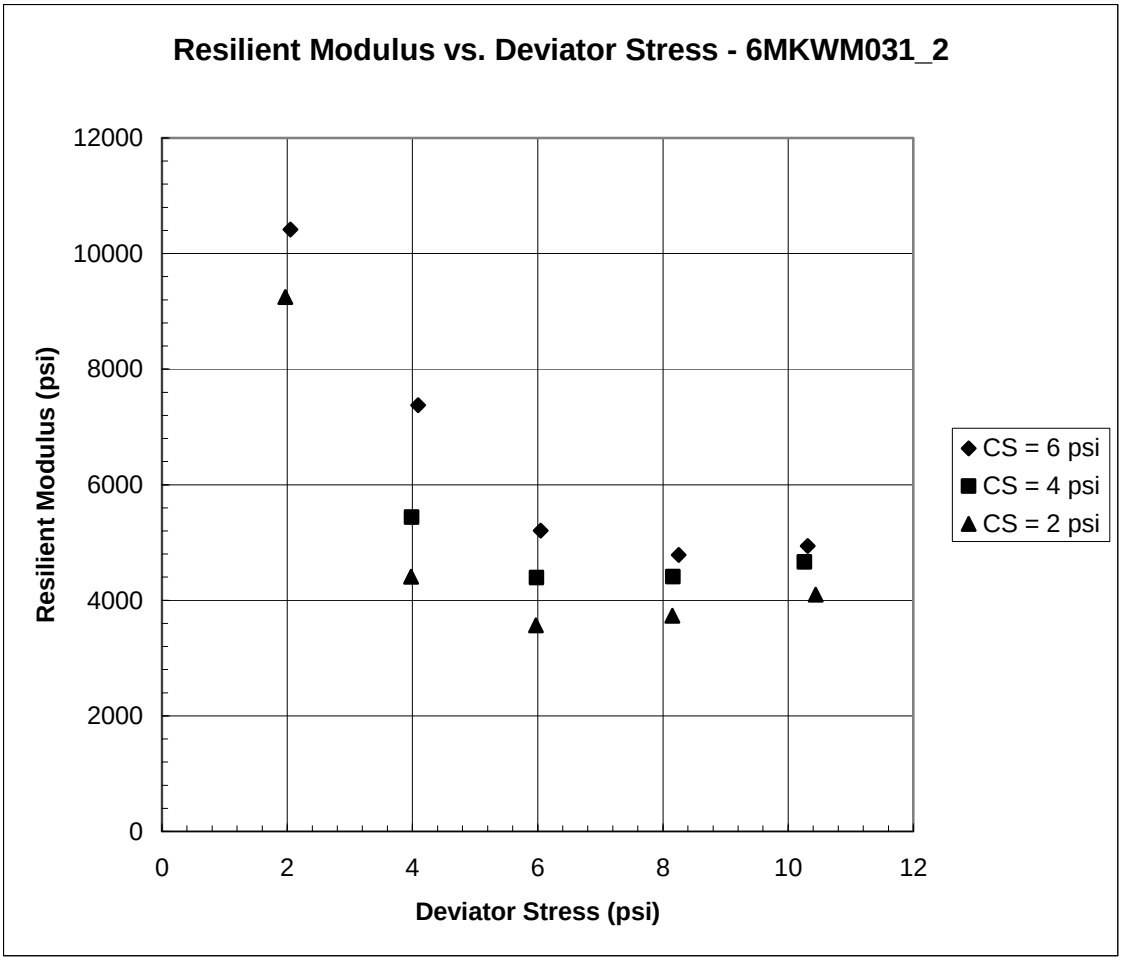
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.01	10988	10483	10991	10536	10539	10708
2	6	4.07	8891	8643	8609	8682	8483	8662
3	6	5.83	6685	6841	6829	6820	6732	6782
4	6	7.95	5463	5458	5522	5491	5523	5492
5	6	9.95	5134	5121	5128	5152	5133	5134
6	4	1.99	9732	9502	9362	9452	9419	9493
7	4	4	6977	7278	7080	7263	7187	7157
8	4	5.8	5799	5754	5797	5764	5766	5776
9	4	7.88	4996	4996	5007	4957	5002	4992
10	4	9.81	4800	4841	4789	4827	4790	4809
11	2	2.03	8294	8226	8466	8264	7997	8249
12	2	3.98	5802	5905	5847	5905	5861	5864
13	2	5.86	4735	4800	4716	4778	4724	4750
14	2	7.85	4316	4289	4302	4285	4308	4300
15	2	9.83	4178	4225	4191	4162	4182	4187



Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.02	18980	19049	17836	19132	18962	18792
2	6	4.02	18423	17367	18464	17365	18509	18026
3	6	5.85	15755	15777	15760	16065	15817	15835
4	6	7.94	13972	14283	14134	14115	14149	14130
5	6	9.91	14027	14158	14027	14037	14160	14082
6	4	1.99	18915	18799	17692	17688	17721	18163
7	4	4	16752	16756	16284	16757	15854	16481
8	4	5.85	14459	14969	14970	14732	14961	14818
9	4	7.9	13742	13435	13417	13746	13592	13586
10	4	9.84	13167	13170	12839	13170	12969	13063
11	2	1.99	18777	17664	20113	18710	17755	18604
12	2	4.01	16812	16346	16386	16347	16399	16458
13	2	5.87	13446	13644	13671	14129	13925	13763
14	2	7.87	12659	12531	12674	12543	12656	12613
15	2	9.85	12135	12134	12123	12132	12141	12133

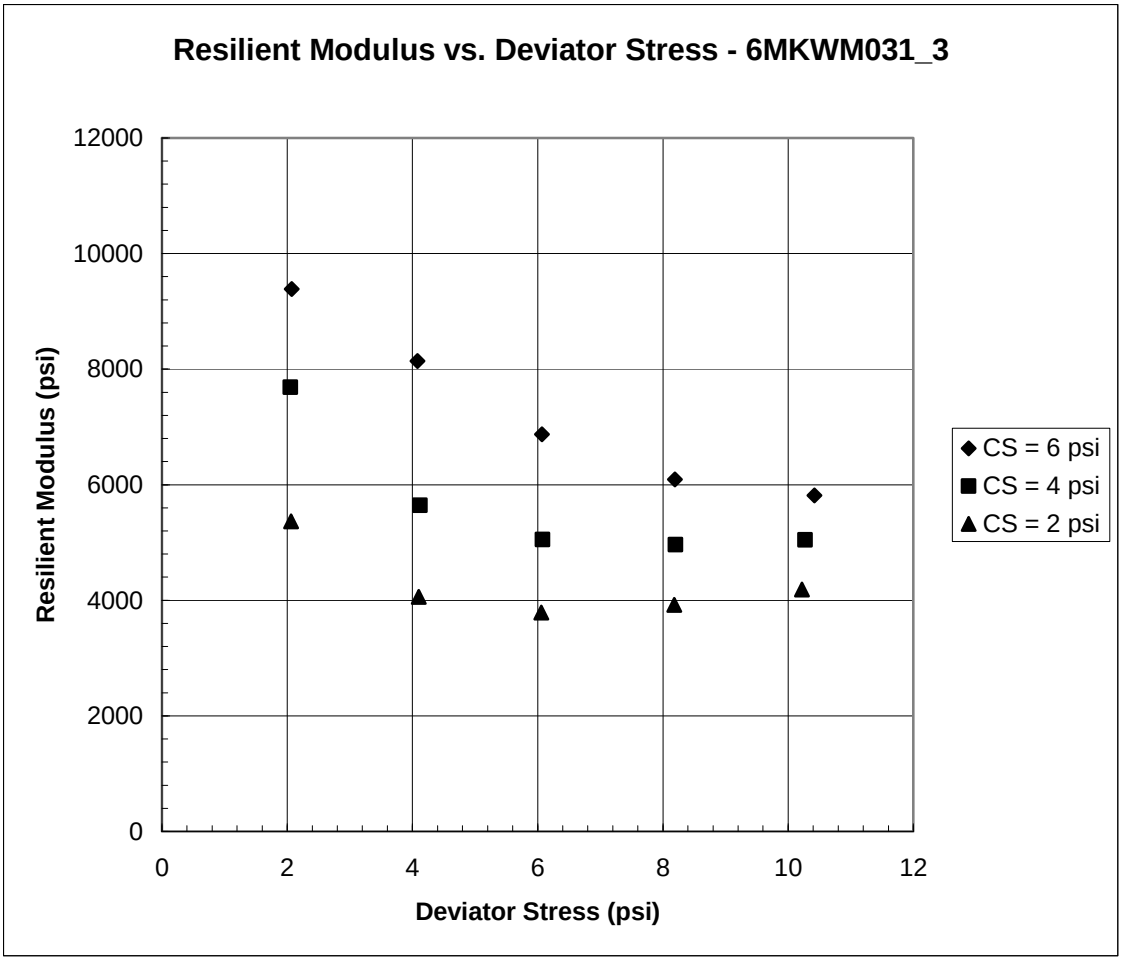


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.04	23242	23272	23250	23167	23258	23238
2	6	4.04	20672	21458	21359	21501	21441	21286
3	6	5.95	20080	19202	19214	19668	19635	19560
4	6	8.06	18767	18714	19392	18763	18757	18879
5	6	10.04	17401	17350	17401	17789	17358	17460
6	4	2.02	21486	21398	21412	21380	21412	21418
7	4	4.07	20804	20854	20818	20898	20861	20847
8	4	5.98	19380	19353	19355	19352	19326	19353
9	4	7.91	18355	18337	18379	18075	18096	18248
10	4	10.01	16901	16904	16919	17097	16936	16952
11	2	2.03	18841	18760	18684	18758	20091	19027
12	2	4.05	18806	18225	18803	18230	18800	18573
13	2	5.93	17608	18329	17607	17991	17994	17906
14	2	7.92	16549	16316	16805	16333	16802	16561
15	2	9.94	16069	16056	15888	15543	16065	15924

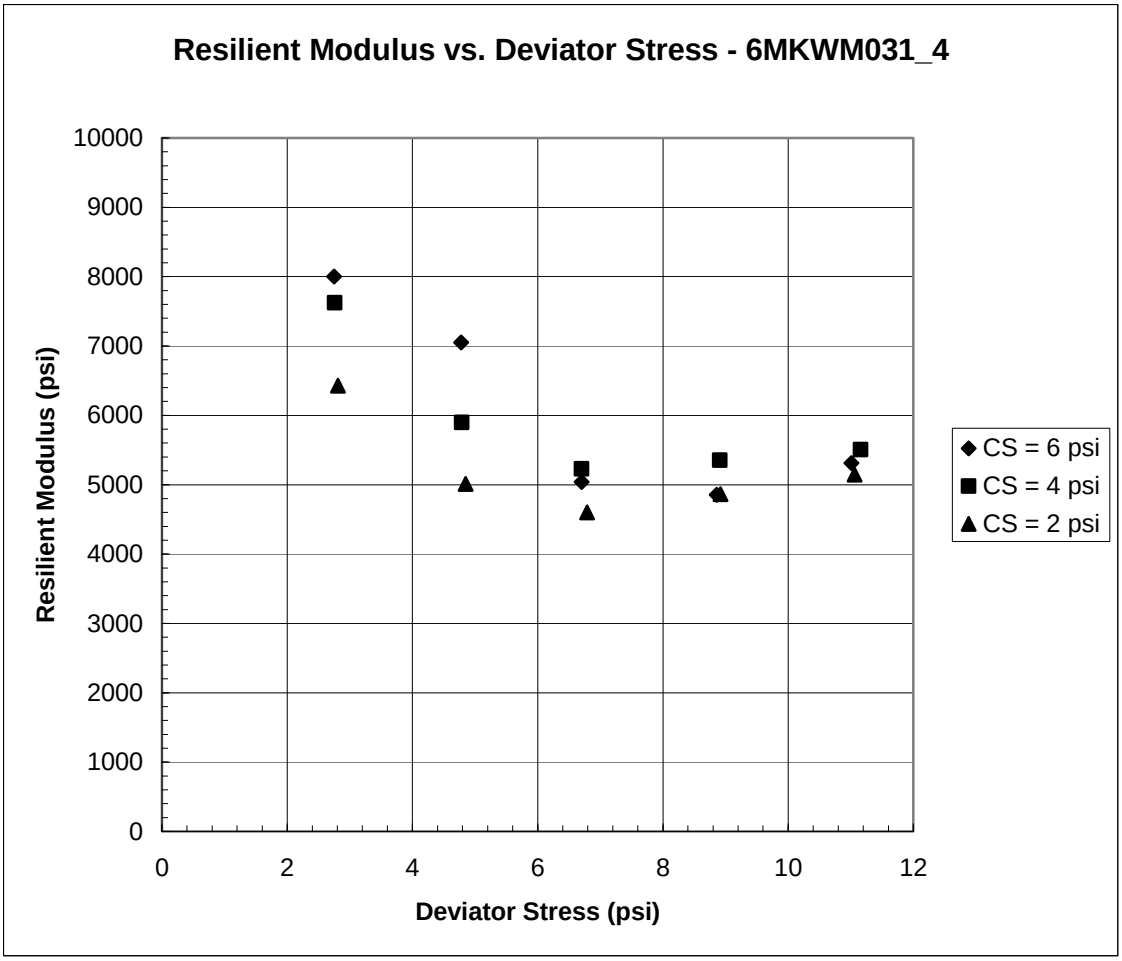


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.05	10357	11015	10259	10219	10227	10415
2	6	4.09	7396	7361	7287	7396	7428	7374
3	6	6.05	5184	5163	5230	5246	5212	5207
4	6	8.25	4822	4821	4775	4724	4789	4786
5	6	10.31	4925	4938	4924	4939	4956	4937
6	4	2.06	18674	17835	17010	16959	17954	17686.4
7	4	3.99	5412	5320	5484	5463	5514	5438
8	4	5.98	4387	4399	4428	4372	4384	4394
9	4	8.16	4380	4344	4409	4400	4496	4406
10	4	10.26	4657	4648	4677	4675	4645	4660
11	2	1.97	8939	9181	9427	9484	9211	9249
12	2	3.98	4324	4567	4356	4518	4287	4410
13	2	5.97	3539	3628	3548	3538	3575	3566
14	2	8.15	3678	3655	3735	3789	3814	3734
15	2	10.44	4113	4096	4102	4099	4085	4099

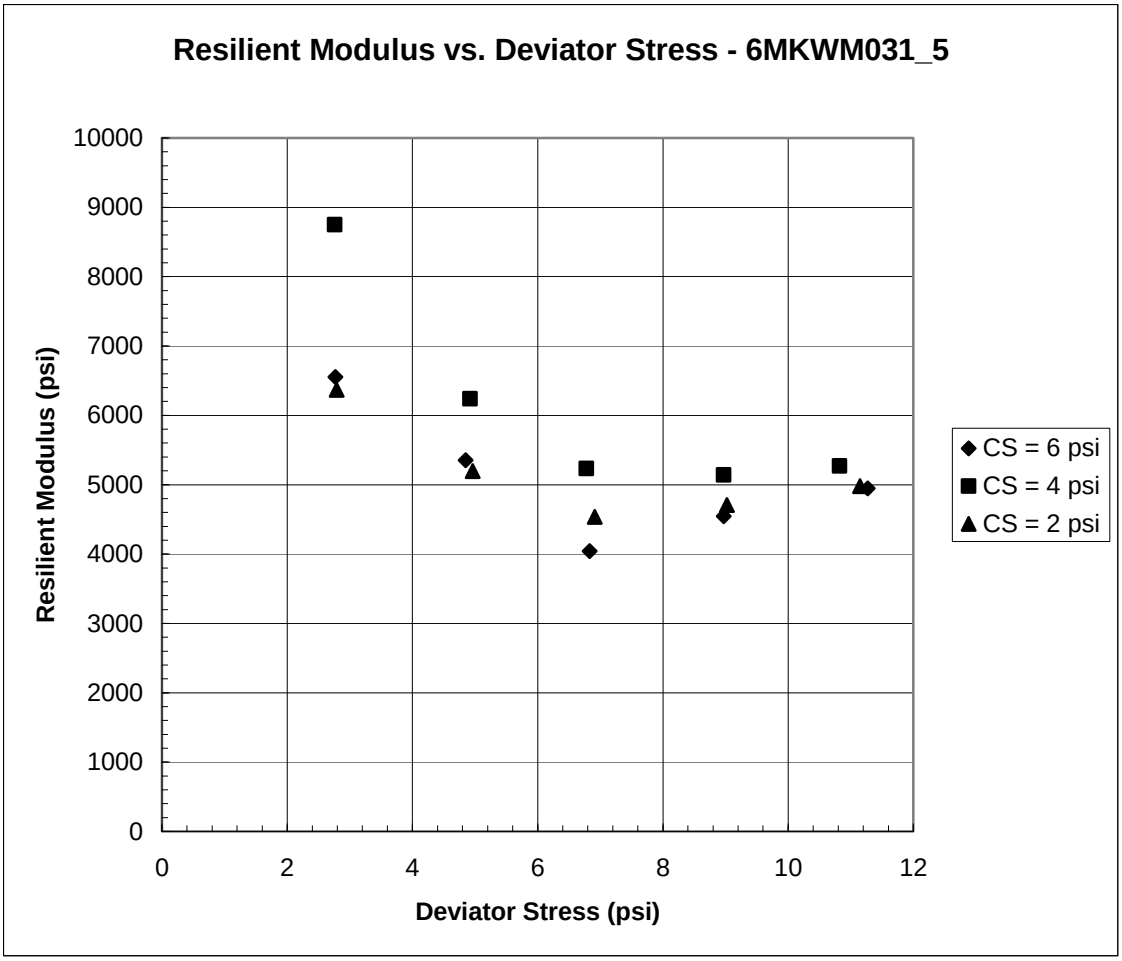
Not used in re-analysis
Calculated



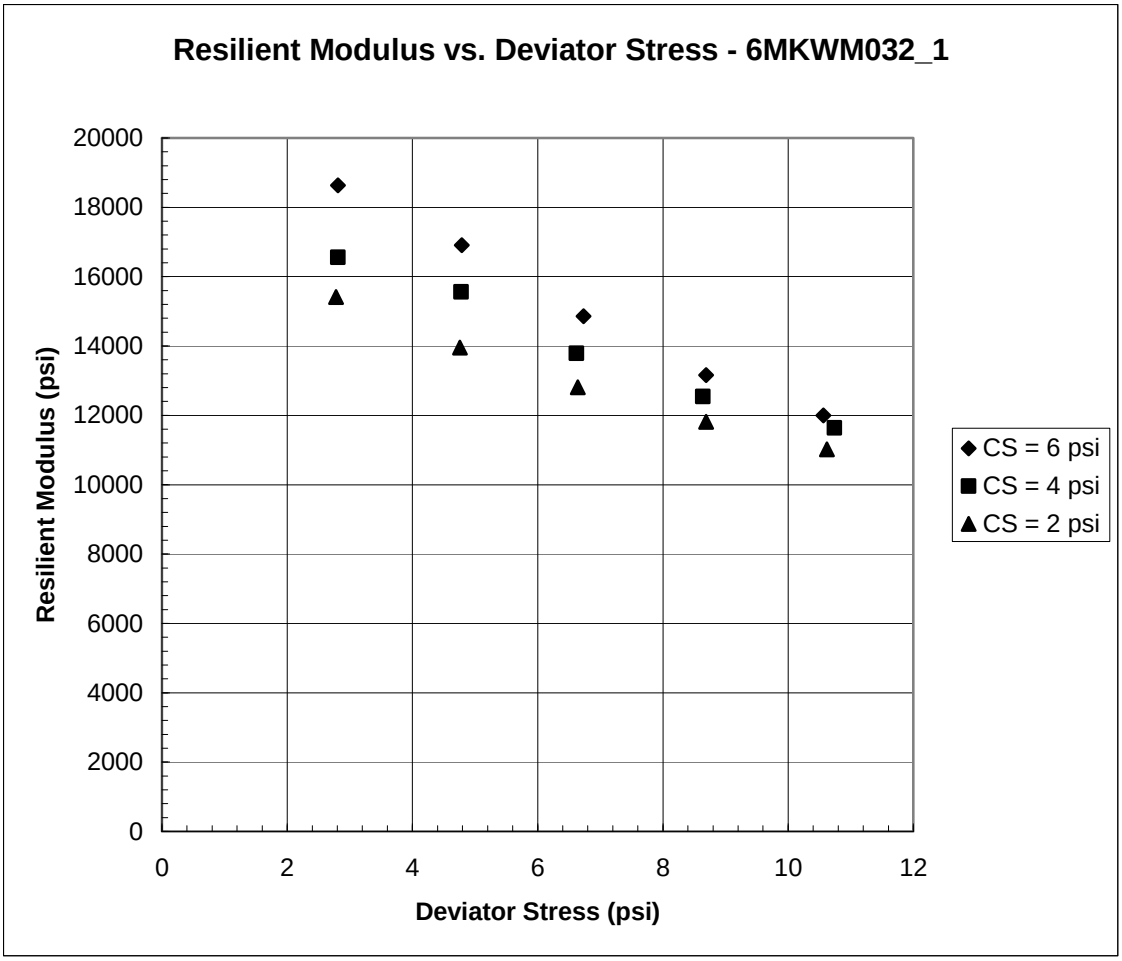
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.07	9362	9327	9322	9356	9572	9388
2	6	4.08	8304	8060	8012	8101	8219	8139
3	6	6.07	6860	6818	6955	6909	6825	6873
4	6	8.19	6101	6050	6112	6081	6099	6089
5	6	10.42	5794	5805	5815	5799	5856	5814
6	4	2.05	7527	7726	7727	7729	7732	7688
7	4	4.12	5603	5620	5676	5682	5633	5643
8	4	6.08	5071	5078	5049	5038	5025	5052
9	4	8.2	4963	4941	4941	4952	5020	4963
10	4	10.27	5031	5058	5040	5048	5056	5046
11	2	2.06	5370	5270	5415	5396	5391	5368
12	2	4.1	4038	4039	4048	4104	4058	4057
13	2	6.06	3804	3799	3787	3788	3760	3788
14	2	8.18	3933	3911	3911	3919	3916	3918
15	2	10.22	4200	4209	4177	4181	4161	4186



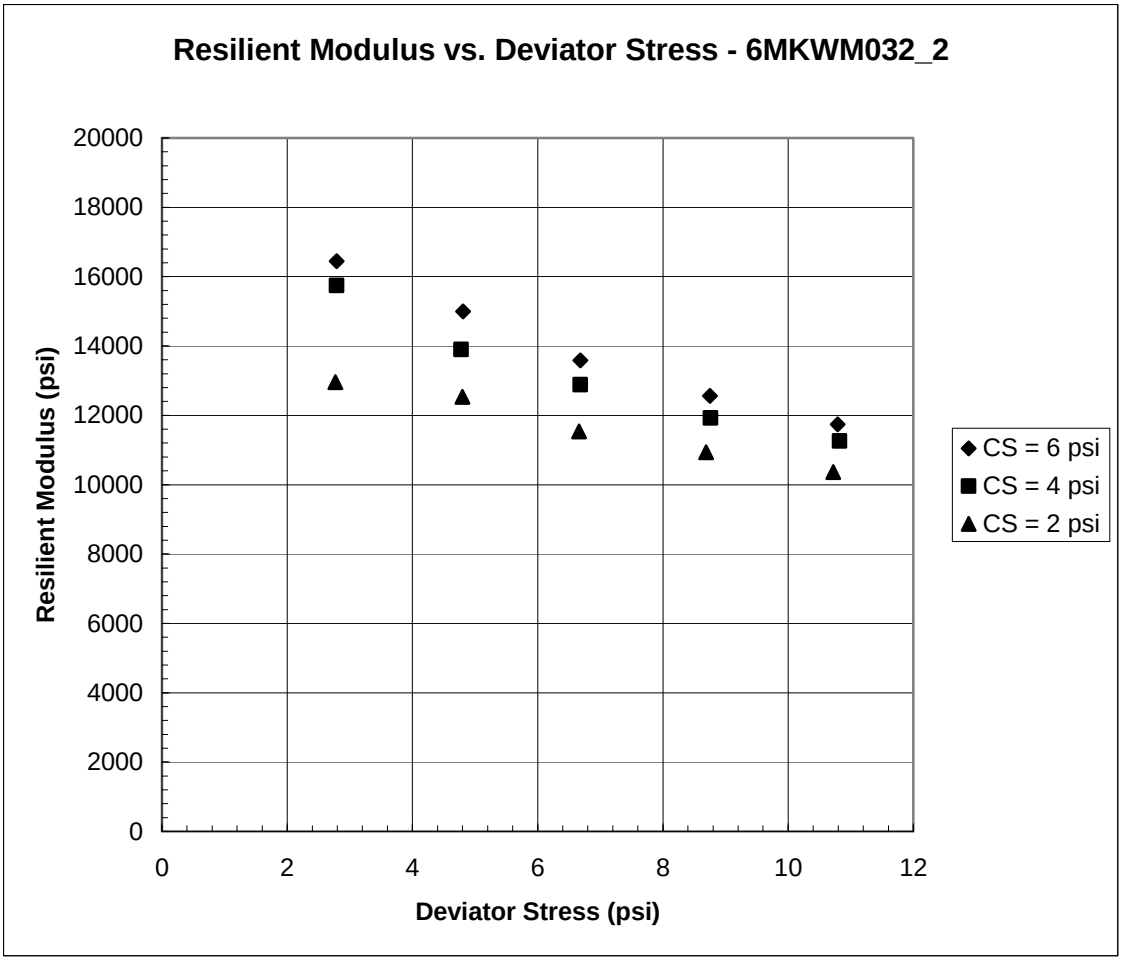
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.75	8019	8005	8006	7972	8006	8002
2	6	4.78	7006	7024	7023	7105	7102	7052
3	6	6.7	5061	4996	5030	5030	5073	5038
4	6	8.86	4838	4848	4862	4863	4857	4854
5	6	11.01	5352	5271	5292	5315	5319	5310
6	4	2.76	7653	7649	7617	7614	7585	7624
7	4	4.79	5911	5836	5906	5915	5921	5898
8	4	6.7	5199	5285	5215	5245	5191	5227
9	4	8.91	5372	5324	5296	5378	5389	5352
10	4	11.16	5499	5498	5514	5509	5508	5506
11	2	2.81	6514	6354	6386	6373	6511	6428
12	2	4.85	5015	5031	5028	5028	4963	5013
13	2	6.79	4642	4605	4574	4582	4595	4600
14	2	8.92	4857	4829	4862	4869	4892	4862
15	2	11.06	5156	5099	5143	5147	5192	5147



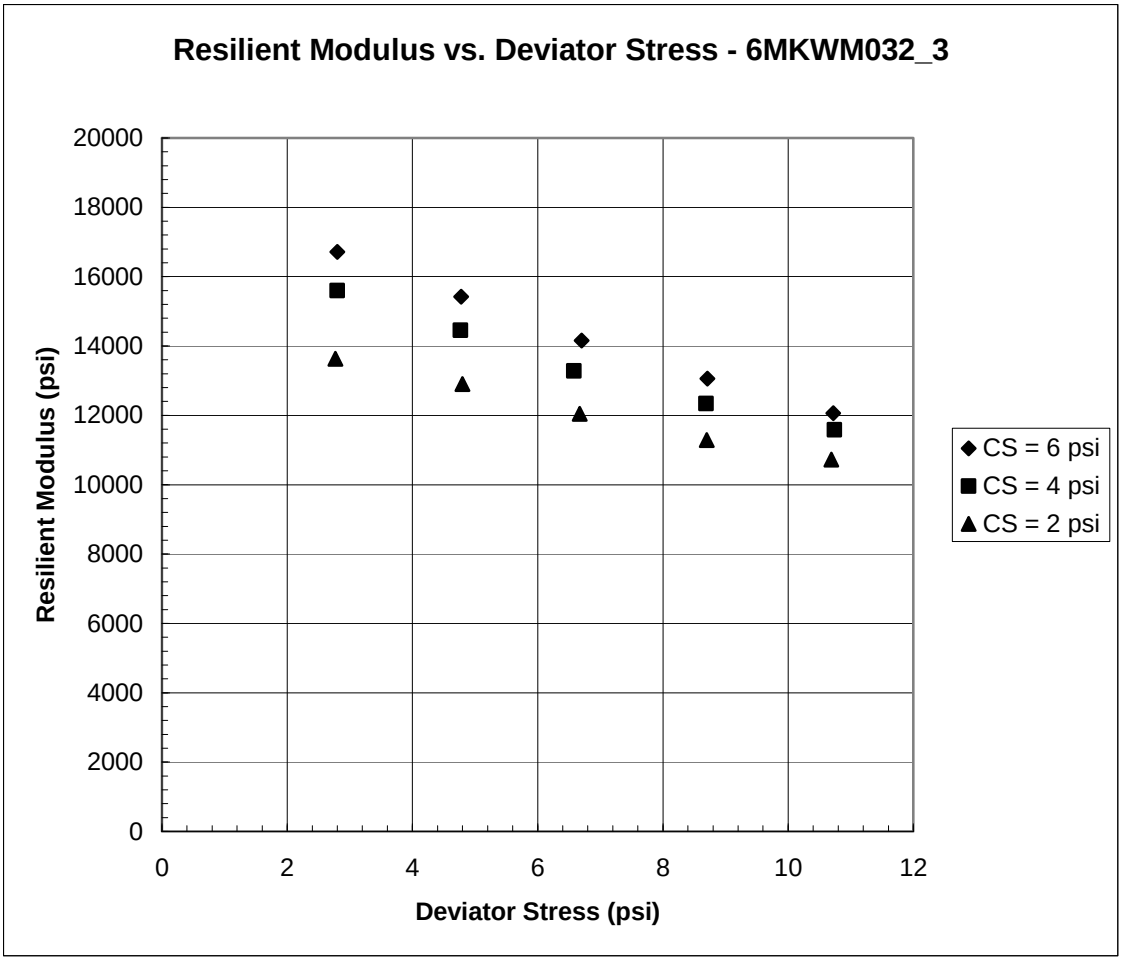
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.77	6579	6544	6488	6477	6688	6555
2	6	4.85	5308	5326	5352	5399	5381	5353
3	6	6.83	4069	4045	4017	4035	4045	4042
4	6	8.97	4552	4539	4534	4518	4593	4547
5	6	11.27	4907	4924	4970	4981	4964	4949
6	4	2.76	8796	8750	8704	8745	8752	8749
7	4	4.92	6200	6186	6242	6321	6235	6237
8	4	6.78	5226	5255	5260	5231	5199	5234
9	4	8.97	5136	5124	5135	5135	5162	5139
10	4	10.82	5232	5224	5321	5290	5291	5272
11	2	2.79	6398	6361	6292	6312	6481	6369
12	2	4.96	5221	5217	5175	5145	5215	5194
13	2	6.91	4568	4504	4517	4537	4561	4537
14	2	9.02	4653	4711	4728	4721	4713	4705
15	2	11.15	4958	4959	4970	5002	5003	4978



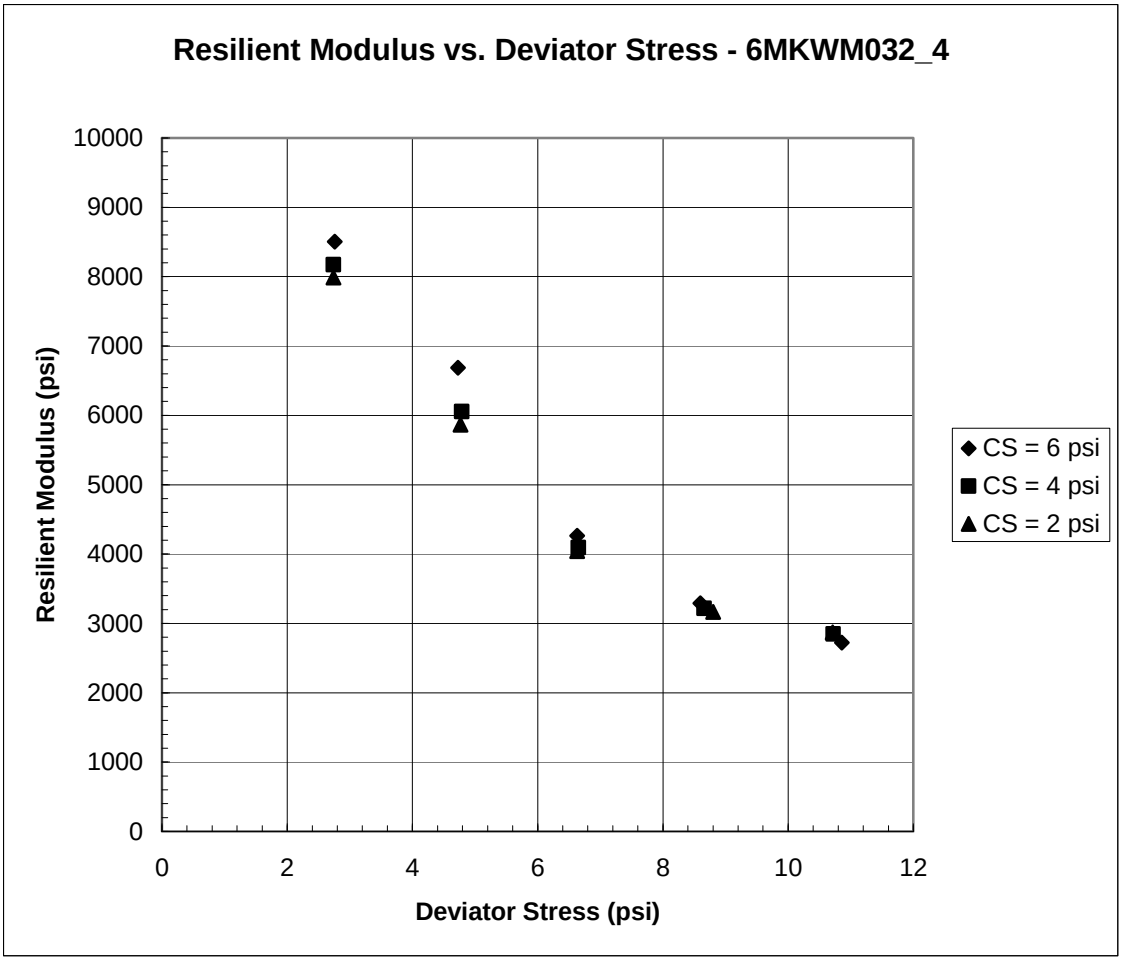
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.81	18567	18651	18722	18546	18696	18636
2	6	4.79	16608	16617	17150	17129	17047	16910
3	6	6.73	14832	14770	14814	14802	15082	14860
4	6	8.69	13103	13256	13295	13088	13044	13157
5	6	10.56	11988	11968	11965	11974	12088	11997
6	4	2.81	16457	16514	16606	16684	16528	16558
7	4	4.78	15654	15693	15628	15587	15241	15561
8	4	6.62	13766	13777	13558	13799	14050	13790
9	4	8.64	12550	12566	12554	12509	12532	12542
10	4	10.74	11551	11624	11640	11735	11631	11636
11	2	2.78	15420	15489	15432	15424	15323	15417
12	2	4.76	13678	14006	14005	14033	14040	13952
13	2	6.64	12805	12820	12823	12801	12783	12807
14	2	8.69	11854	11688	11839	11850	11851	11816
15	2	10.62	11024	11032	11022	11000	11010	11017



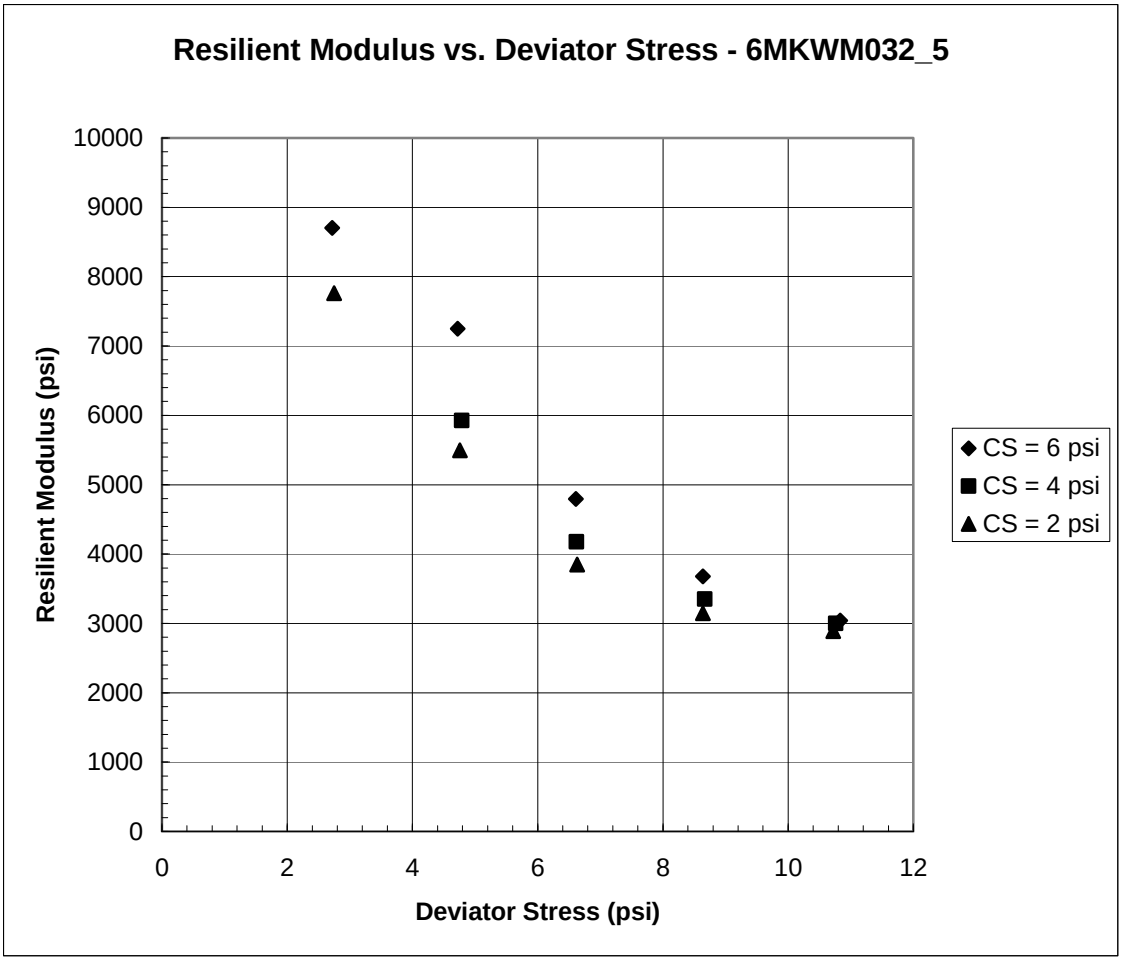
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.79	16486	16404	16472	16486	16400	16450
2	6	4.81	14996	15022	14985	14999	15006	15002
3	6	6.68	13773	13517	13555	13535	13552	13586
4	6	8.75	12636	12652	12495	12505	12505	12559
5	6	10.79	11723	11744	11732	11746	11756	11740
6	4	2.79	15527	14717	15576	16464	16448	15746
7	4	4.78	14188	13843	13846	13815	13819	13903
8	4	6.68	13144	13113	12711	12732	12731	12886
9	4	8.76	11908	12017	11896	11893	11893	11921
10	4	10.82	11240	11218	11230	11317	11317	11264
11	2	2.77	13343	13228	12715	12723	12769	12956
12	2	4.8	12698	12693	12433	12430	12430	12537
13	2	6.66	11473	11506	11666	11514	11504	11533
14	2	8.69	10983	10992	10977	10867	10876	10939
15	2	10.72	10314	10380	10377	10380	10387	10368



Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.8	16496	17378	16515	16625	16555	16714
2	6	4.78	15276	15278	15285	15629	15657	15425
3	6	6.7	14027	14023	14478	14235	14025	14157
4	6	8.71	13158	13006	12993	12988	13157	13061
5	6	10.72	12122	12018	12032	12031	12123	12065
6	4	2.8	15575	15577	15665	15583	15581	15596
7	4	4.77	14454	14431	14437	14470	14468	14452
8	4	6.58	13275	13254	13275	13294	13295	13279
9	4	8.69	12530	12259	12260	12391	12260	12340
10	4	10.74	11579	11576	11581	11578	11581	11579
11	2	2.77	13227	13234	13852	13923	13927	13632
12	2	4.8	12985	12949	12948	12696	12949	12905
13	2	6.67	11968	11981	12132	11988	12172	12048
14	2	8.7	11319	11309	11299	11303	11204	11287
15	2	10.69	10731	10724	10732	10732	10721	10728

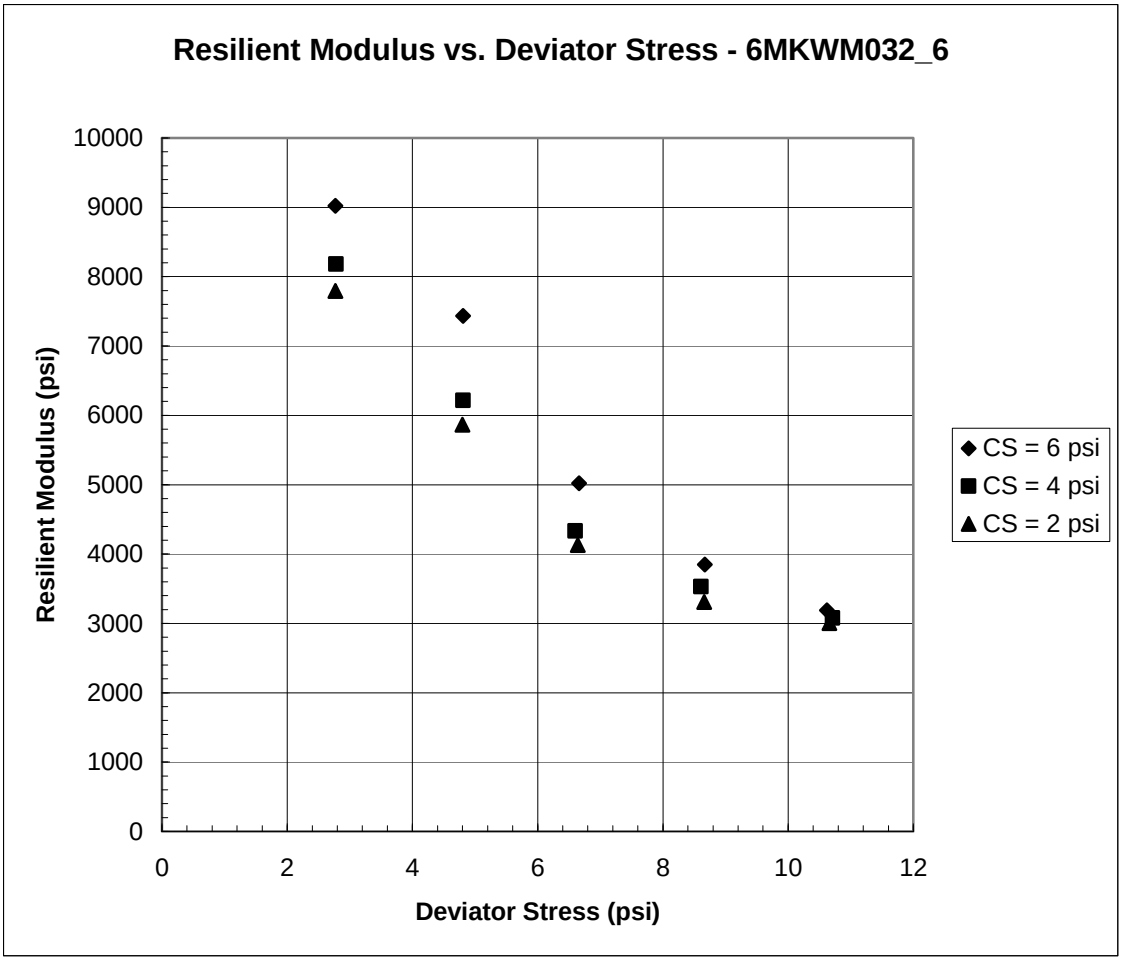


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.76	8527	8487	8493	8527	8491	8505
2	6	4.73	6661	6706	6691	6760	6624	6688
3	6	6.63	4283	4231	4251	4278	4279	4264
4	6	8.6	3278	3295	3289	3291	3291	3289
5	6	10.86	2724	2720	2698	2731	2749	2724
6	4	2.74	8144	8216	8183	8179	8141	8173
7	4	4.79	6089	6028	6040	6056	6068	6056
8	4	6.65	4093	4114	4094	4101	4062	4093
9	4	8.66	3232	3218	3212	3207	3222	3218
10	4	10.72	2834	2838	2847	2852	2854	2845
11	2	2.74	8178	7915	7921	7965	7956	7987
12	2	4.77	5870	5823	5880	5890	5867	5866
13	2	6.63	4049	4055	4029	4018	4062	4043
14	2	8.8	3184	3148	3191	3203	3095	3164
15	2	10.71	2857	2872	2870	2893	2859	2870

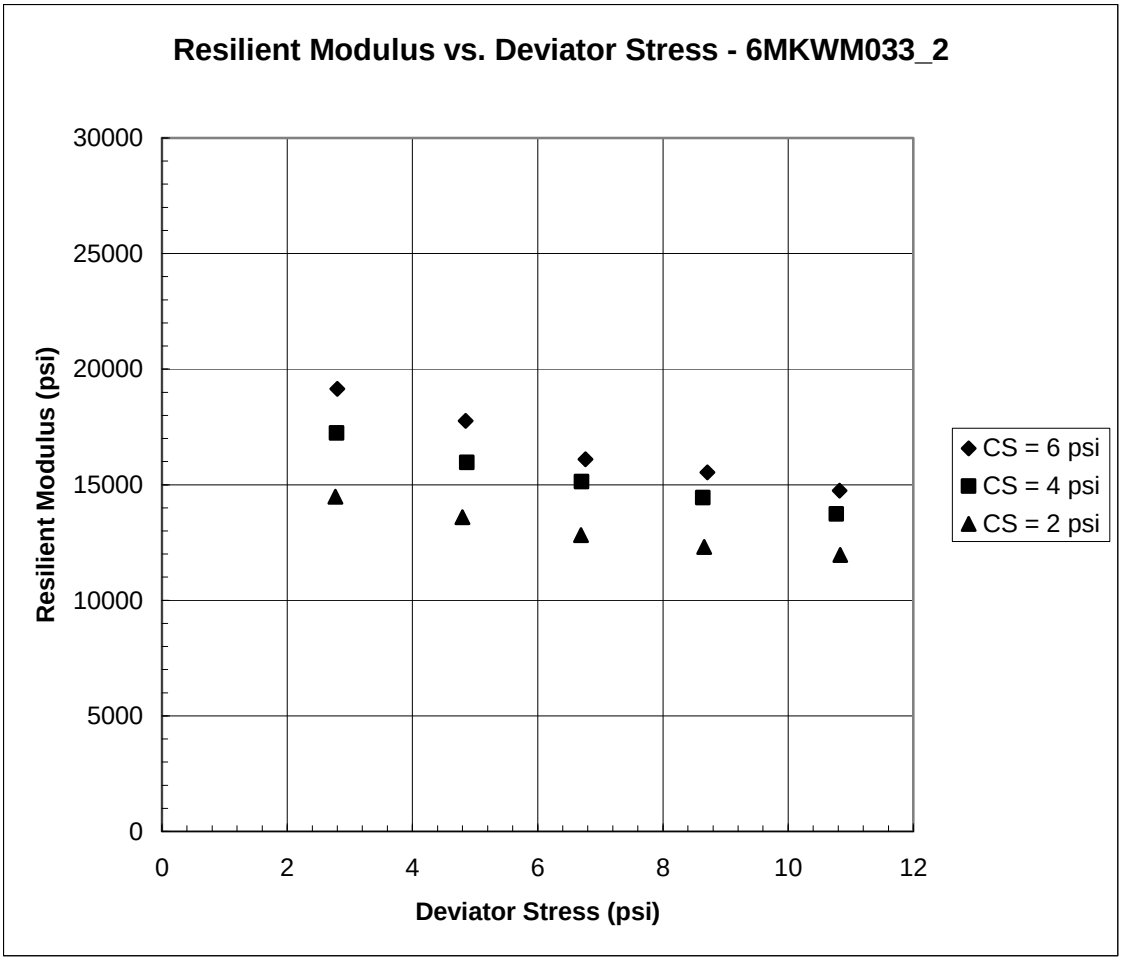


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.72	8901	8860	8601	8598	8556	8703
2	6	4.72	7244	7229	7240	7251	7291	7251
3	6	6.61	4798	4797	4852	4780	4753	4796
4	6	8.64	3675	3665	3669	3697	3692	3680
5	6	10.83	3054	3048	3029	3039	3043	3043
6	4	2.79	16832	16846	16842	16851	16766	16827.4
7	4	4.79	5906	5862	5920	5934	6007	5926
8	4	6.62	4166	4170	4198	4196	4155	4177
9	4	8.67	3375	3354	3367	3330	3323	3350
10	4	10.76	2985	2987	3002	3008	3014	2999
11	2	2.75	7768	7594	7830	7819	7796	7762
12	2	4.76	5506	5502	5498	5485	5500	5498
13	2	6.63	3849	3837	3832	3849	3878	3849
14	2	8.64	3118	3126	3143	3173	3172	3146
15	2	10.72	2883	2885	2896	2898	2889	2890

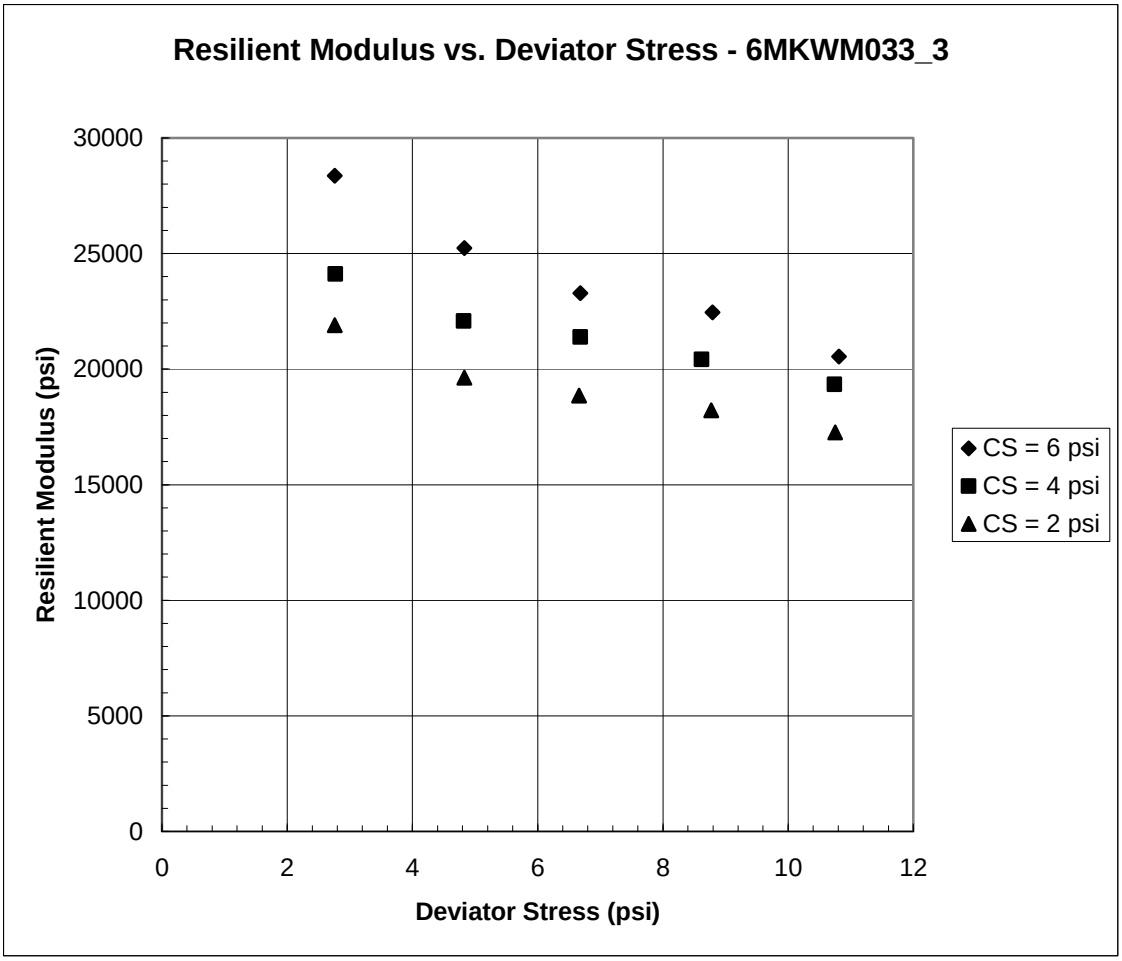
Not used in re-analysis
Calculated



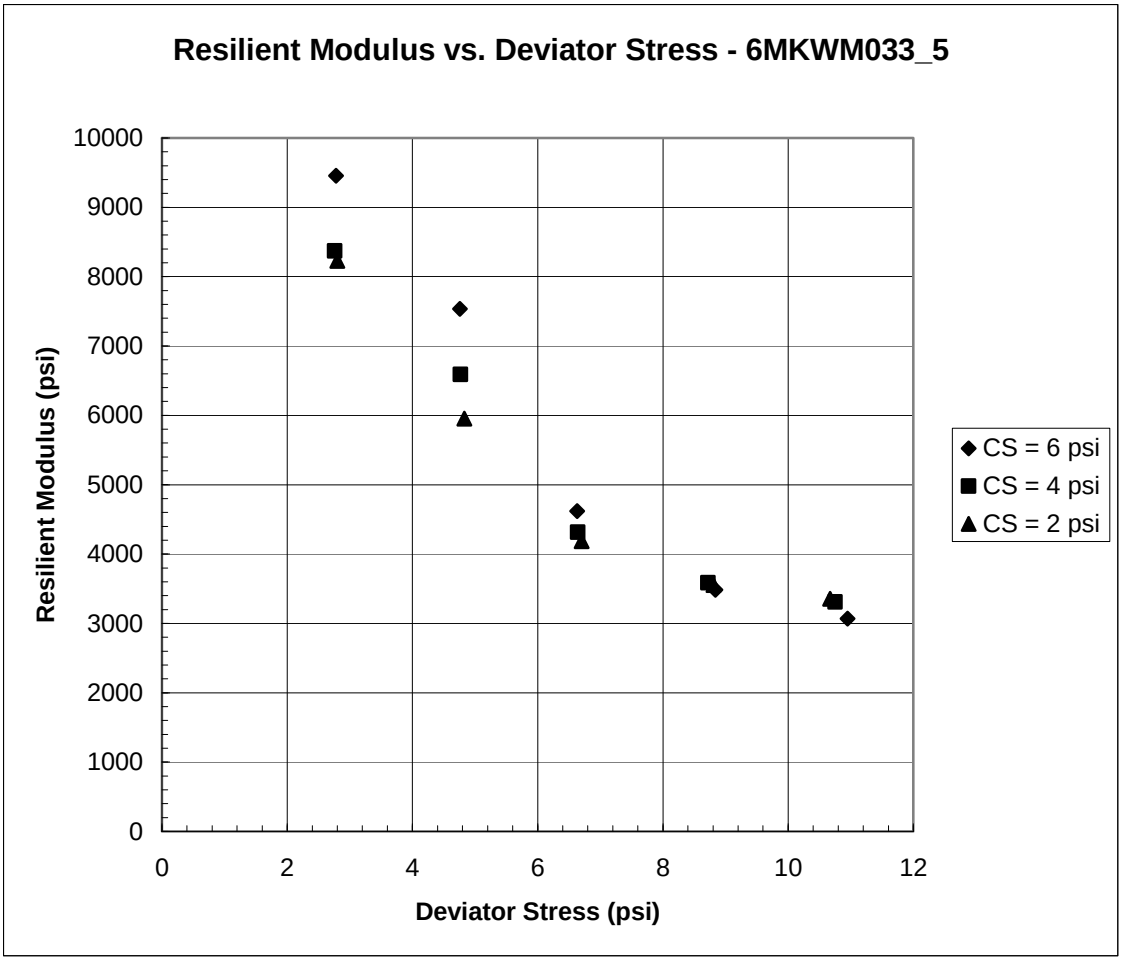
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.77	9112	9156	8804	8880	9156	9022
2	6	4.81	7418	7440	7469	7437	7413	7435
3	6	6.66	5040	5026	5006	5033	5011	5023
4	6	8.67	3815	3848	3846	3860	3874	3849
5	6	10.62	3199	3193	3187	3192	3173	3189
6	4	2.78	8151	8426	8162	7938	8233	8182
7	4	4.81	6133	6148	6288	6211	6289	6214
8	4	6.6	4369	4347	4326	4298	4312	4331
9	4	8.61	3515	3560	3490	3547	3538	3530
10	4	10.71	3058	3077	3092	3082	3070	3076
11	2	2.77	7877	7516	7706	7949	7910	7792
12	2	4.8	5849	5919	5893	5893	5766	5864
13	2	6.64	4103	4131	4093	4156	4157	4128
14	2	8.66	3386	3302	3272	3336	3251	3309
15	2	10.66	3005	2989	2995	3014	3009	3002



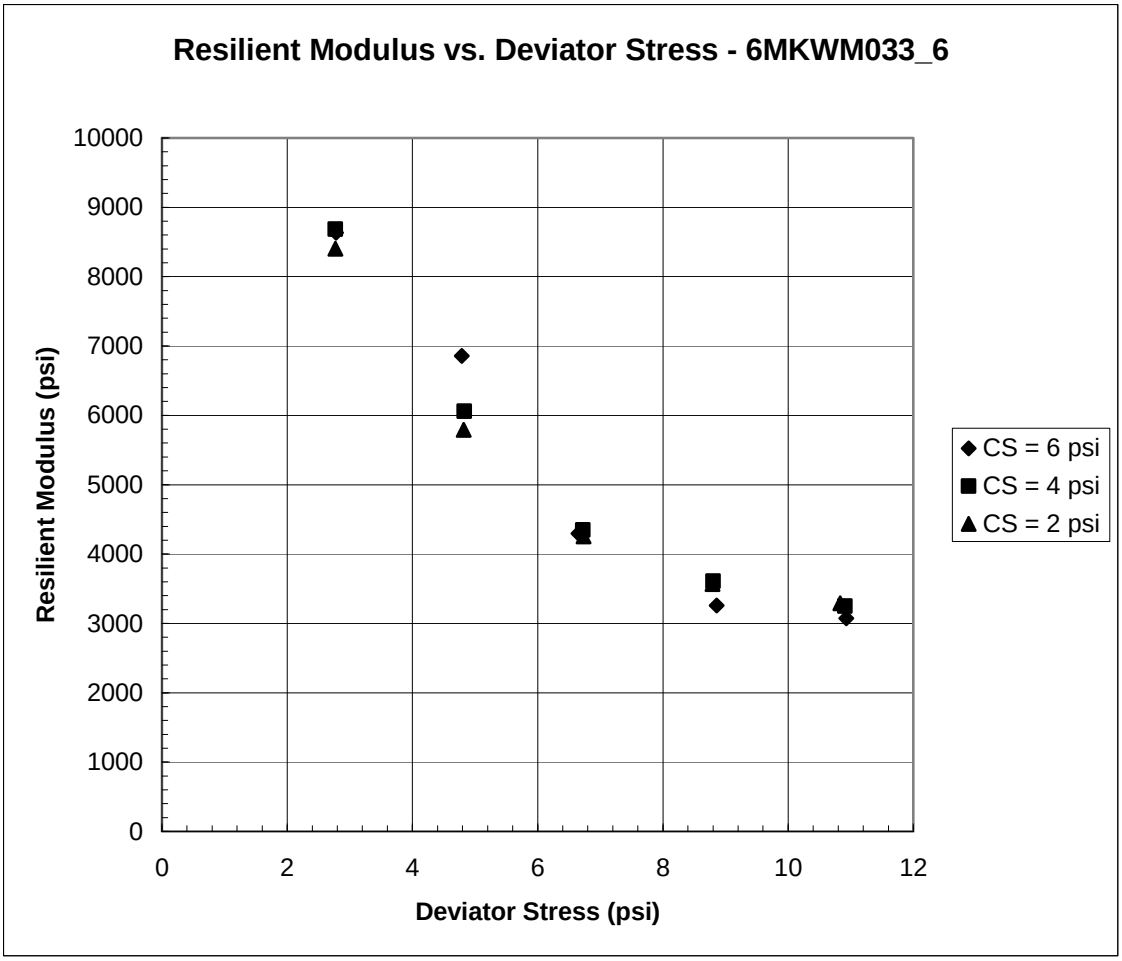
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.8	18398	18380	19714	19522	19714	19146
2	6	4.85	17780	17737	17778	17772	17728	17759
3	6	6.76	16211	16237	16236	15926	15890	16100
4	6	8.71	15369	15545	15561	15578	15615	15534
5	6	10.82	14844	14840	14679	14677	14694	14747
6	4	2.79	17229	17204	17299	17281	17173	17237
7	4	4.87	15956	15949	16014	15964	15935	15964
8	4	6.7	15234	15163	15161	15177	14916	15130
9	4	8.64	14450	14433	14429	14426	14444	14436
10	4	10.77	13783	13650	13770	13755	13732	13738
11	2	2.77	14507	14434	14525	14443	14466	14475
12	2	4.8	13459	13422	13800	13489	13827	13599
13	2	6.69	12861	12847	12666	12837	12873	12817
14	2	8.66	12280	12278	12259	12281	12429	12305
15	2	10.83	11994	12014	11913	11894	12000	11963



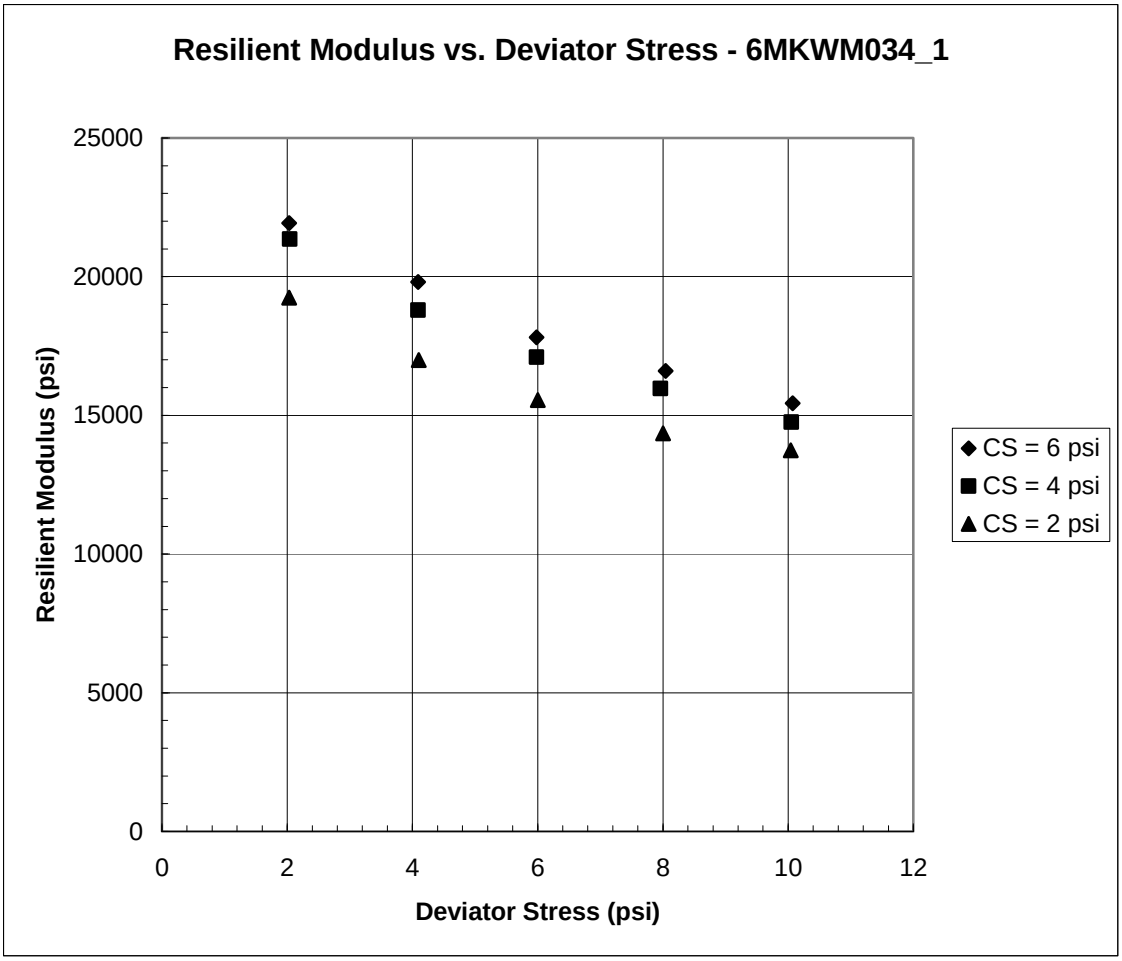
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.76	26257	28752	29035	28853	28911	28361
2	6	4.83	25523	24376	24381	26504	25374	25232
3	6	6.68	23643	23496	22860	23520	22927	23289
4	6	8.79	22546	22512	22573	22583	22079	22458
5	6	10.81	20617	20499	20529	20539	20523	20542
6	4	2.77	24077	24071	24170	24057	24214	24118
7	4	4.82	21594	22403	22387	22470	21588	22088
8	4	6.68	21731	21214	21111	21175	21700	21386
9	4	8.62	20405	20410	20425	20422	20465	20426
10	4	10.74	19581	19280	19278	19284	19313	19347
11	2	2.76	20657	22303	22141	22069	22341	21902
12	2	4.83	19527	19501	19508	19503	20136	19635
13	2	6.66	18738	18332	18743	19225	19220	18852
14	2	8.77	18235	18253	18216	18171	18194	18214
15	2	10.75	17213	17223	17230	17447	17177	17258



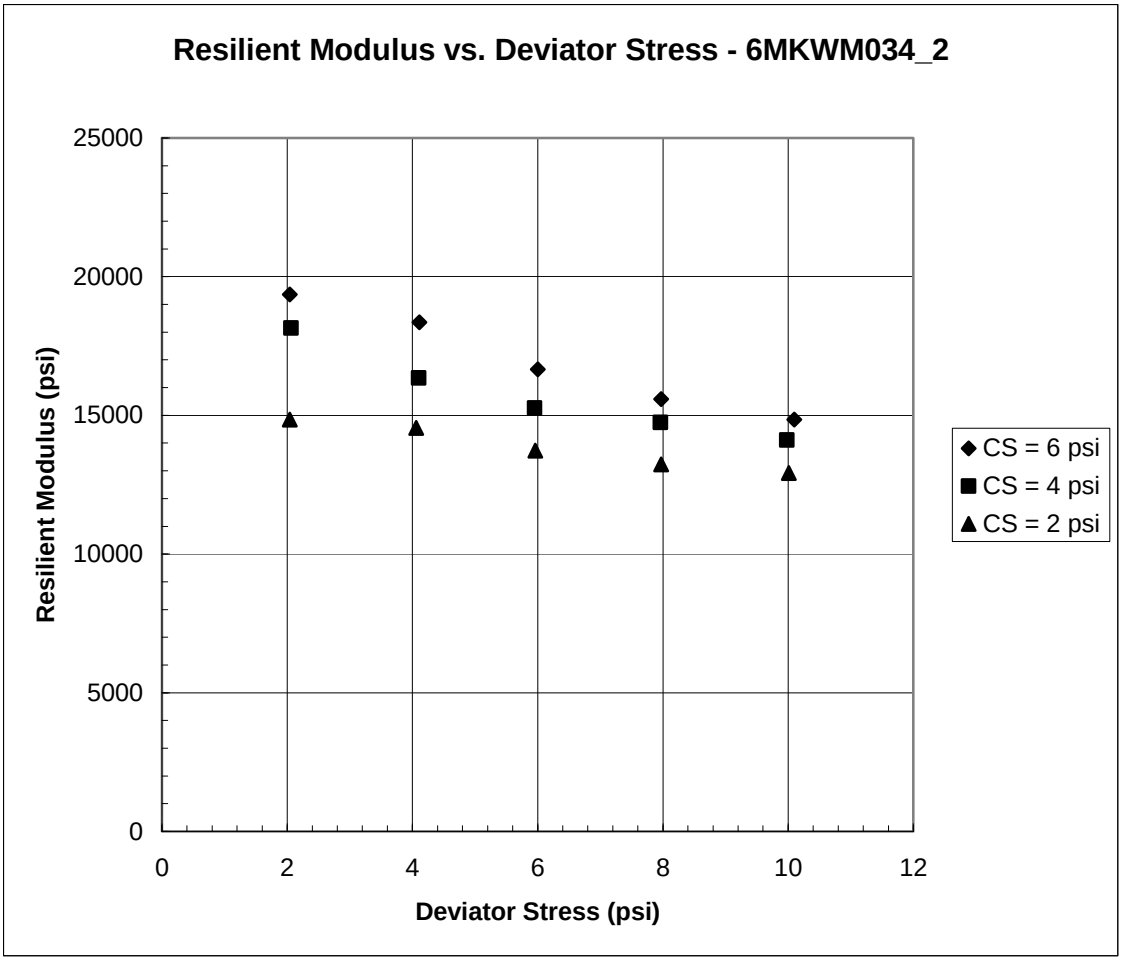
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.78	9429	9432	9472	9479	9472	9457
2	6	4.76	7434	7641	7607	7494	7509	7537
3	6	6.63	4592	4630	4637	4596	4637	4618
4	6	8.84	3469	3489	3482	3489	3486	3483
5	6	10.95	3055	3063	3060	3088	3080	3069
6	4	2.76	8277	8303	8270	8510	8501	8372
7	4	4.77	6634	6518	6545	6628	6631	6591
8	4	6.64	4299	4327	4323	4319	4319	4317
9	4	8.72	3594	3591	3579	3585	3570	3584
10	4	10.75	3312	3295	3310	3315	3314	3309
11	2	2.8	8196	8266	8223	8225	8226	8227
12	2	4.83	5916	5927	5999	5941	5981	5953
13	2	6.7	4159	4200	4210	4184	4179	4186
14	2	8.81	3539	3556	3553	3565	3560	3554
15	2	10.67	3365	3353	3347	3355	3367	3357



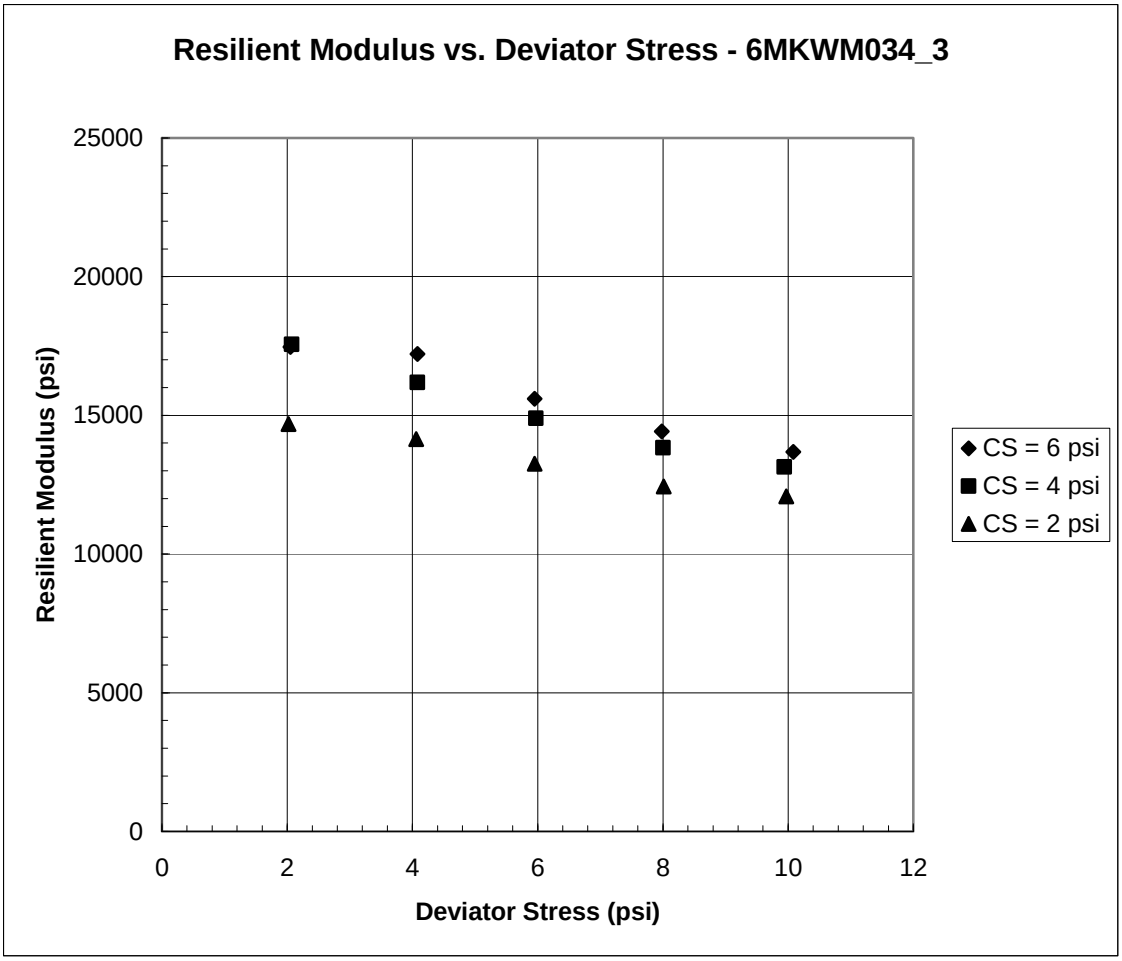
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.78	8631	8608	8640	8707	8582	8634
2	6	4.79	6868	6866	6790	6880	6881	6857
3	6	6.65	4276	4330	4310	4297	4269	4296
4	6	8.86	3261	3254	3250	3243	3270	3256
5	6	10.93	3051	3069	3069	3087	3086	3072
6	4	2.77	8778	8859	8572	8610	8601	8684
7	4	4.83	6112	6050	6005	6038	6098	6060
8	4	6.72	4325	4345	4352	4359	4358	4348
9	4	8.8	3608	3595	3622	3610	3608	3609
10	4	10.91	3256	3245	3243	3234	3261	3248
11	2	2.77	8285	8573	8563	8254	8335	8402
12	2	4.82	5782	5781	5805	5806	5793	5793
13	2	6.73	4239	4281	4273	4234	4239	4253
14	2	8.79	3560	3565	3563	3576	3574	3568
15	2	10.83	3289	3287	3297	3299	3281	3291



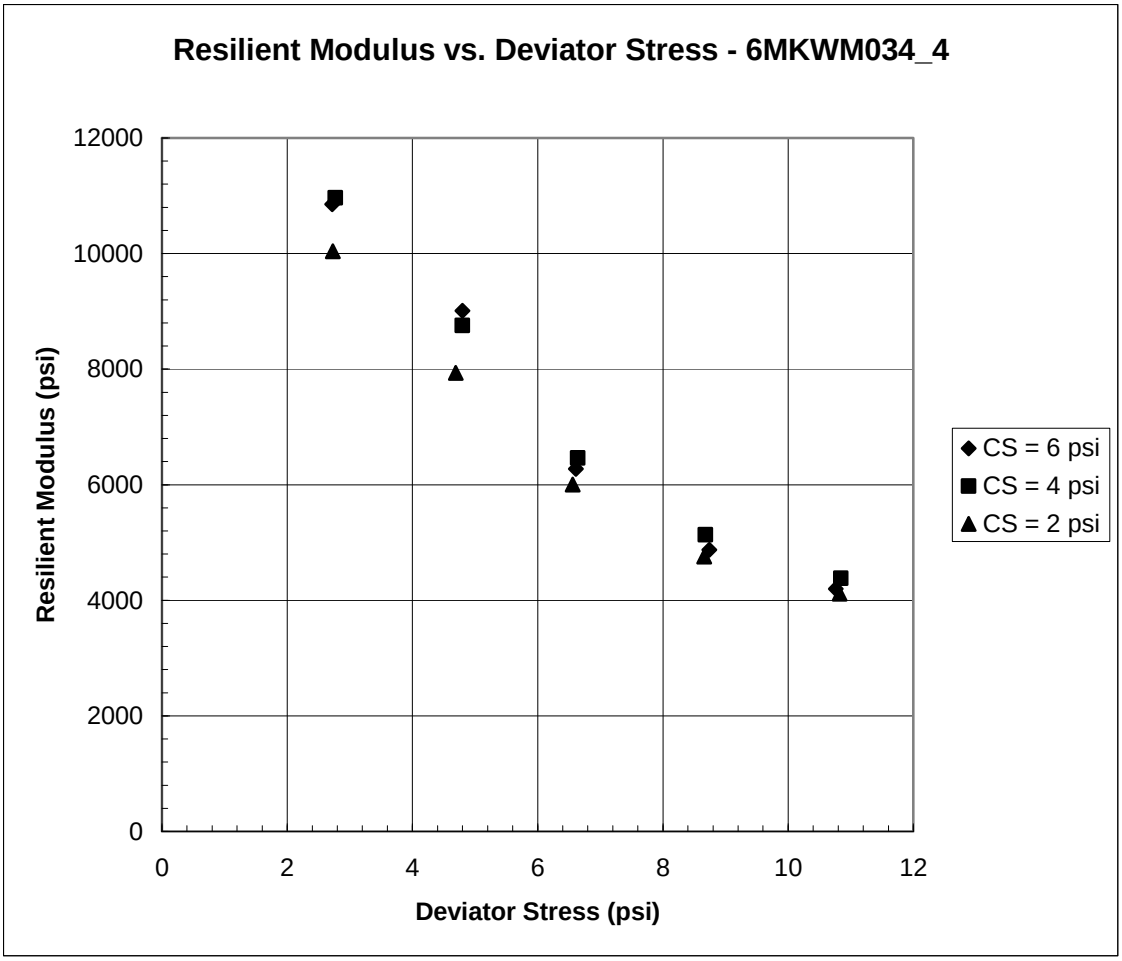
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.03	22235	20565	20544	22285	23997	21926
2	6	4.09	20020	19422	20102	19403	20099	19809
3	6	5.98	18181	17756	17707	17673	17758	17815
4	6	8.04	16579	16595	16639	16646	16559	16604
5	6	10.07	15486	15397	15415	15443	15460	15440
6	4	2.04	20706	22228	20804	22295	20725	21351
7	4	4.09	18812	18725	18770	18822	18828	18792
8	4	5.98	17097	17398	17012	16989	17002	17100
9	4	7.96	15924	15937	15972	15977	16019	15966
10	4	10.05	14792	14790	14752	14741	14721	14759
11	2	2.03	19177	19246	19244	19330	19244	19248
12	2	4.1	16768	17268	17179	16624	17103	16988
13	2	6	15499	15525	15562	15580	15591	15551
14	2	8	14457	14473	14417	14196	14216	14352
15	2	10.04	13724	13610	13768	13786	13816	13741



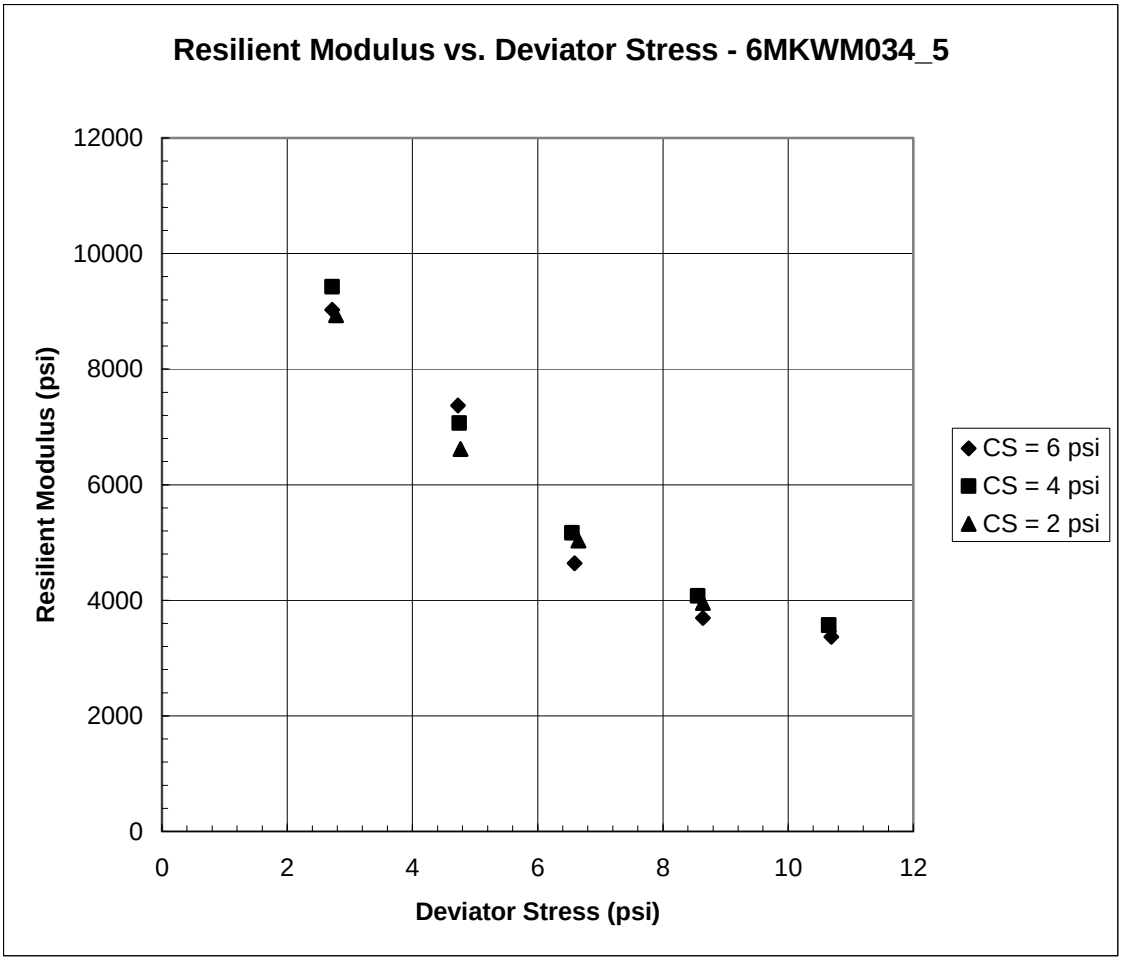
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.04	19283	19371	19381	19455	19282	19354
2	6	4.11	18412	18349	18329	18371	18319	18356
3	6	6	16796	16428	16472	16450	17159	16661
4	6	7.97	15583	15601	15580	15582	15558	15581
5	6	10.1	14727	15011	14873	14739	14889	14848
6	4	2.06	18409	18397	18325	18330	17252	18143
7	4	4.1	16688	16233	16268	16255	16265	16342
8	4	5.95	15441	15162	15163	15413	15159	15267
9	4	7.96	14735	14749	14754	14744	14759	14748
10	4	9.98	14128	14096	14108	14084	14110	14105
11	2	2.04	14525	15298	14528	15369	14547	14853
12	2	4.06	14482	14102	14832	14514	14820	14550
13	2	5.96	13732	13734	13735	13709	13723	13726
14	2	7.97	13384	13233	13218	13218	13101	13231
15	2	10.01	12891	12873	13110	12863	12858	12919



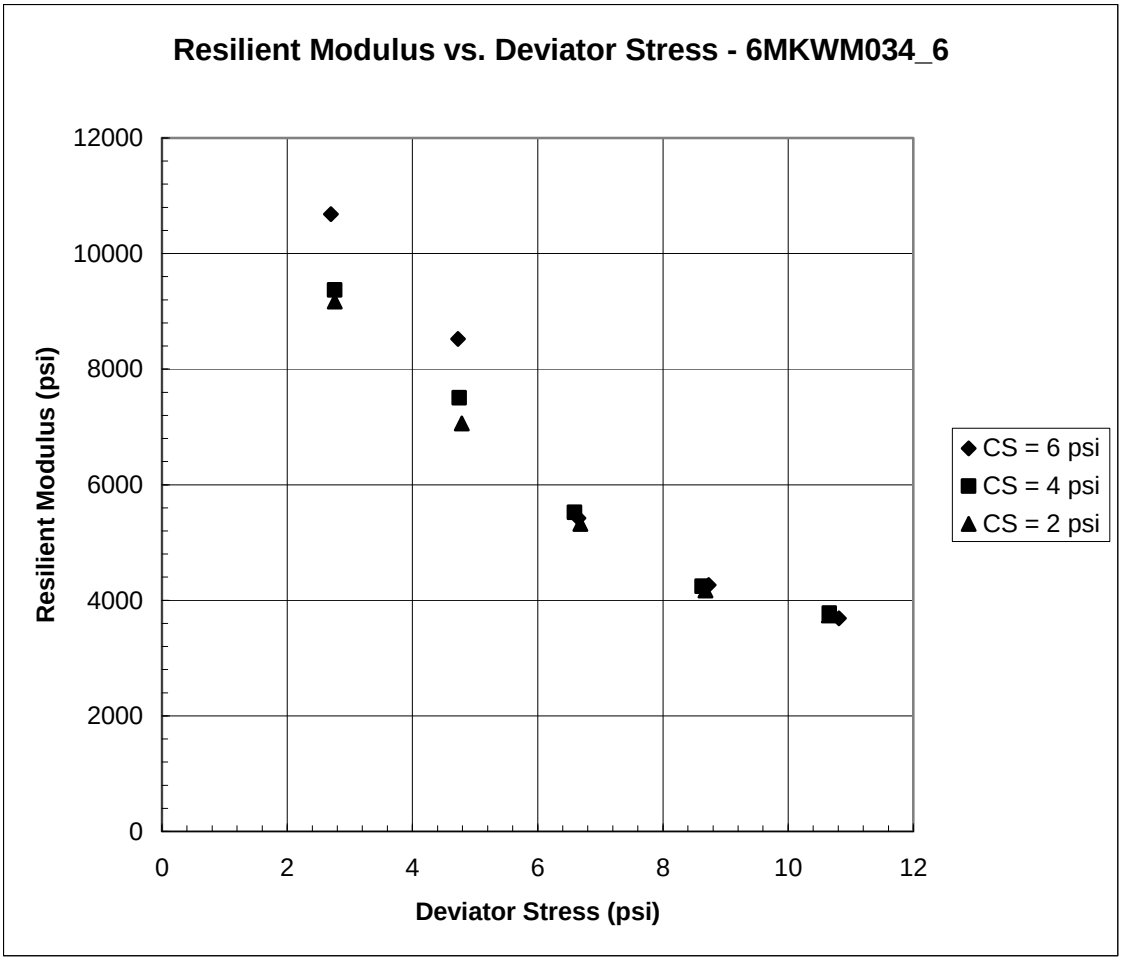
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.05	17173	17310	17259	17199	18378	17464
2	6	4.08	17633	17055	17111	17138	17143	17216
3	6	5.95	15417	15722	15725	15720	15417	15600
4	6	7.98	14232	14238	14420	14602	14620	14422
5	6	10.08	13580	13713	13716	13718	13690	13684
6	4	2.07	17252	18458	17308	17399	17393	17562
7	4	4.08	16160	16188	16191	16198	16196	16187
8	4	5.97	14944	14921	14949	14688	14949	14890
9	4	8	13772	13773	13757	13937	13954	13838
10	4	9.94	13150	13135	13136	13127	13136	13137
11	2	2.02	15147	15172	14335	14414	14345	14683
12	2	4.06	14114	14115	14184	14168	14131	14142
13	2	5.95	13272	13278	13455	13261	13038	13261
14	2	8.01	12439	12430	12440	12457	12441	12442
15	2	9.97	12153	11959	11960	12161	12165	12080



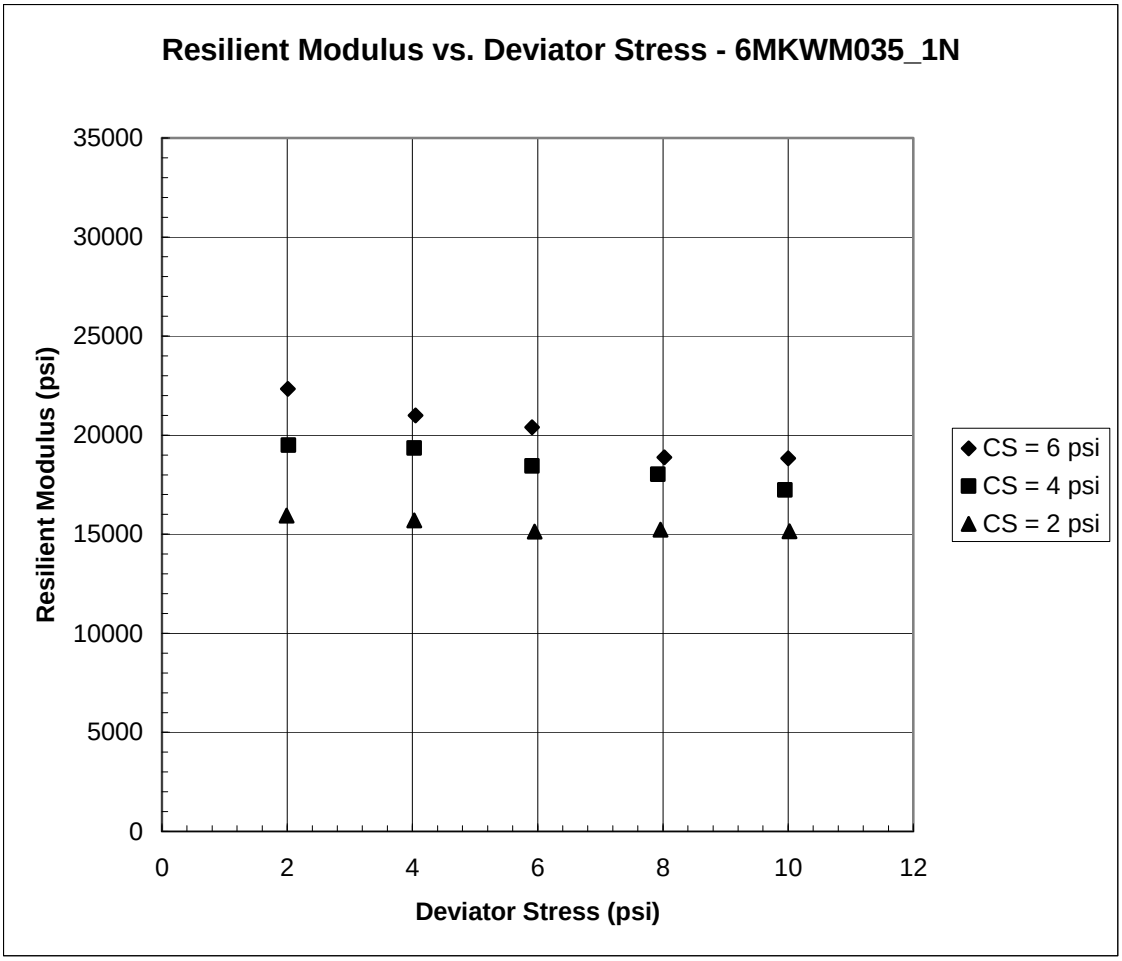
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.72	10846	10891	10833	10841	10862	10855
2	6	4.8	9005	9003	9045	9022	8974	9010
3	6	6.61	6270	6260	6268	6281	6291	6274
4	6	8.74	4855	4866	4881	4881	4875	4872
5	6	10.76	4208	4205	4187	4192	4195	4197
6	4	2.77	10813	11237	10794	10796	11182	10964
7	4	4.8	8758	8759	8761	8772	8733	8757
8	4	6.64	6459	6502	6446	6449	6458	6463
9	4	8.68	5133	5123	5114	5167	5144	5136
10	4	10.84	4387	4382	4389	4373	4357	4378
11	2	2.73	10228	10544	9794	9801	9844	10042
12	2	4.69	8051	7881	7907	7924	7918	7936
13	2	6.56	5995	6010	6002	6025	5994	6005
14	2	8.66	4771	4749	4749	4736	4785	4758
15	2	10.82	4147	4121	4105	4086	4114	4115



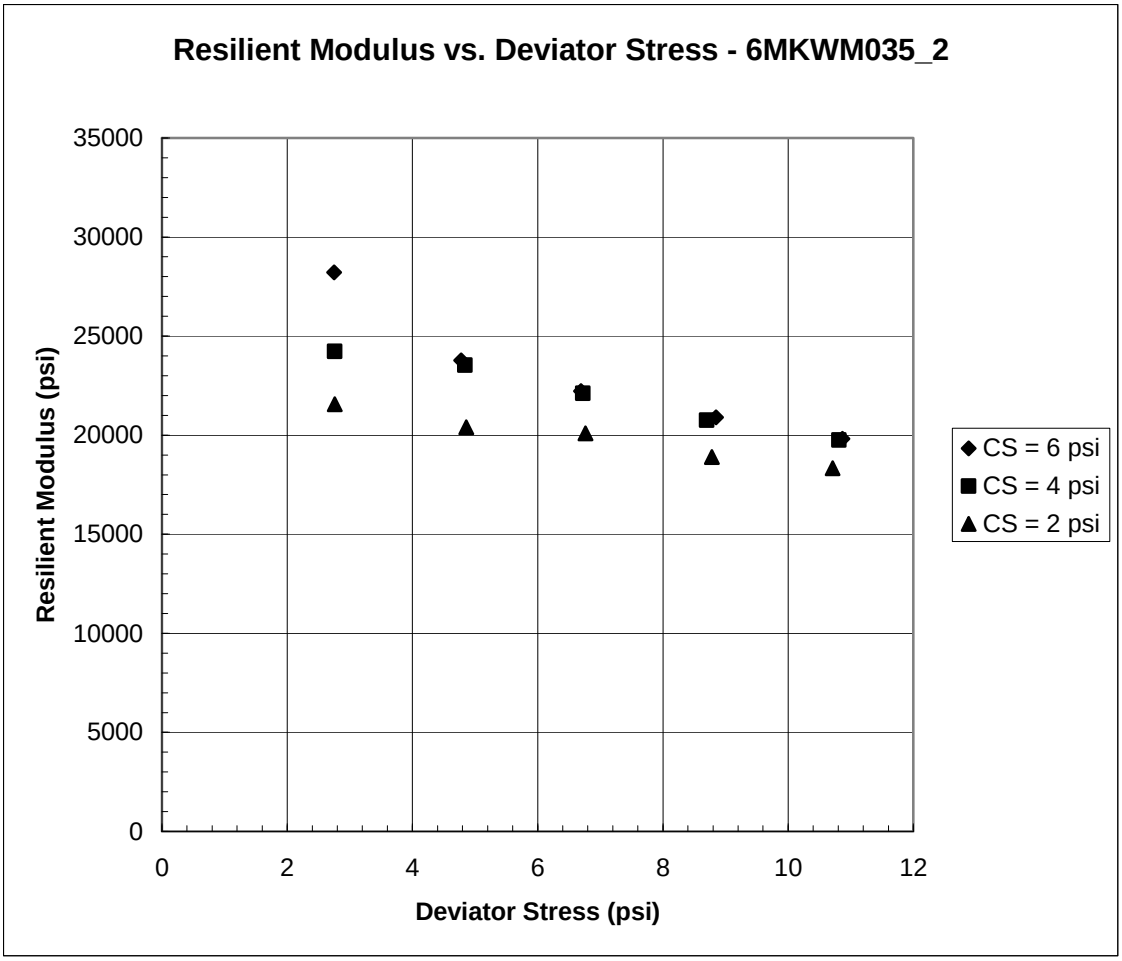
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.72	8875	9200	8961	9192	8919	9029
2	6	4.73	7423	7402	7314	7298	7403	7368
3	6	6.59	4626	4667	4652	4643	4612	4640
4	6	8.64	3706	3699	3700	3648	3713	3693
5	6	10.69	3374	3348	3371	3371	3365	3366
6	4	2.72	9480	9493	9178	9482	9484	9423
7	4	4.75	7030	7112	7095	6997	7093	7065
8	4	6.55	5185	5157	5156	5169	5172	5168
9	4	8.56	4062	4092	4076	4087	4048	4073
10	4	10.65	3579	3565	3562	3575	3567	3570
11	2	2.78	8960	8928	8923	8924	8920	8931
12	2	4.77	6578	6571	6593	6667	6666	6615
13	2	6.65	5048	5001	5043	5033	5043	5034
14	2	8.64	3980	3949	3939	3946	3949	3953
15	2	10.65	3571	3585	3573	3564	3567	3572



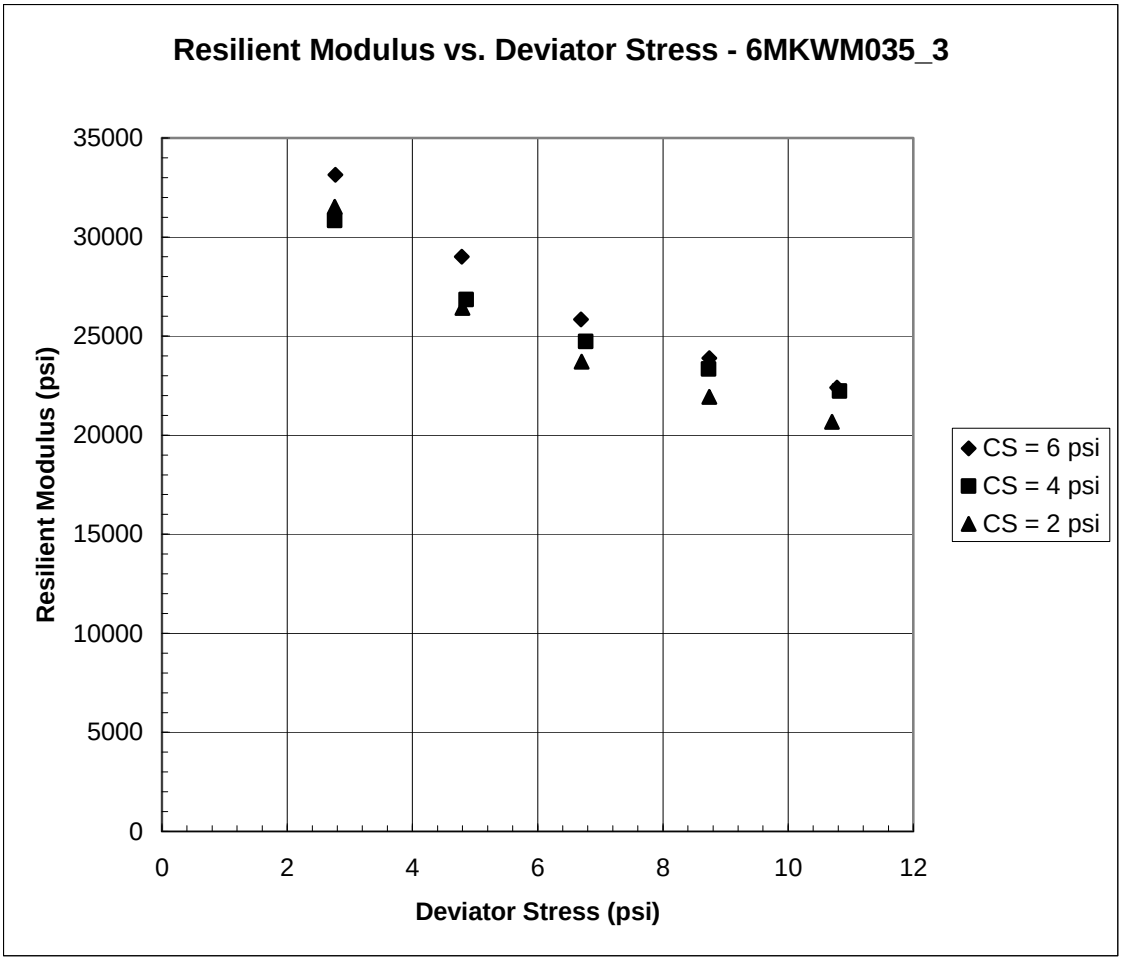
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.7	10492	10719	10723	10710	10776	10684
2	6	4.73	8559	8460	8461	8578	8560	8524
3	6	6.65	5397	5399	5446	5424	5456	5424
4	6	8.73	4251	4258	4283	4274	4259	4265
5	6	10.81	3693	3690	3676	3688	3687	3687
6	4	2.76	9381	9377	9328	9380	9372	9368
7	4	4.75	7419	7530	7545	7607	7412	7503
8	4	6.59	5516	5523	5515	5525	5524	5520
9	4	8.63	4220	4260	4243	4242	4236	4240
10	4	10.66	3781	3794	3766	3776	3765	3777
11	2	2.76	9337	9340	9019	9057	9103	9171
12	2	4.79	7074	7093	7093	7062	6979	7060
13	2	6.68	5298	5331	5282	5356	5347	5323
14	2	8.68	4097	4206	4211	4224	4123	4172
15	2	10.65	3747	3730	3723	3746	3741	3737



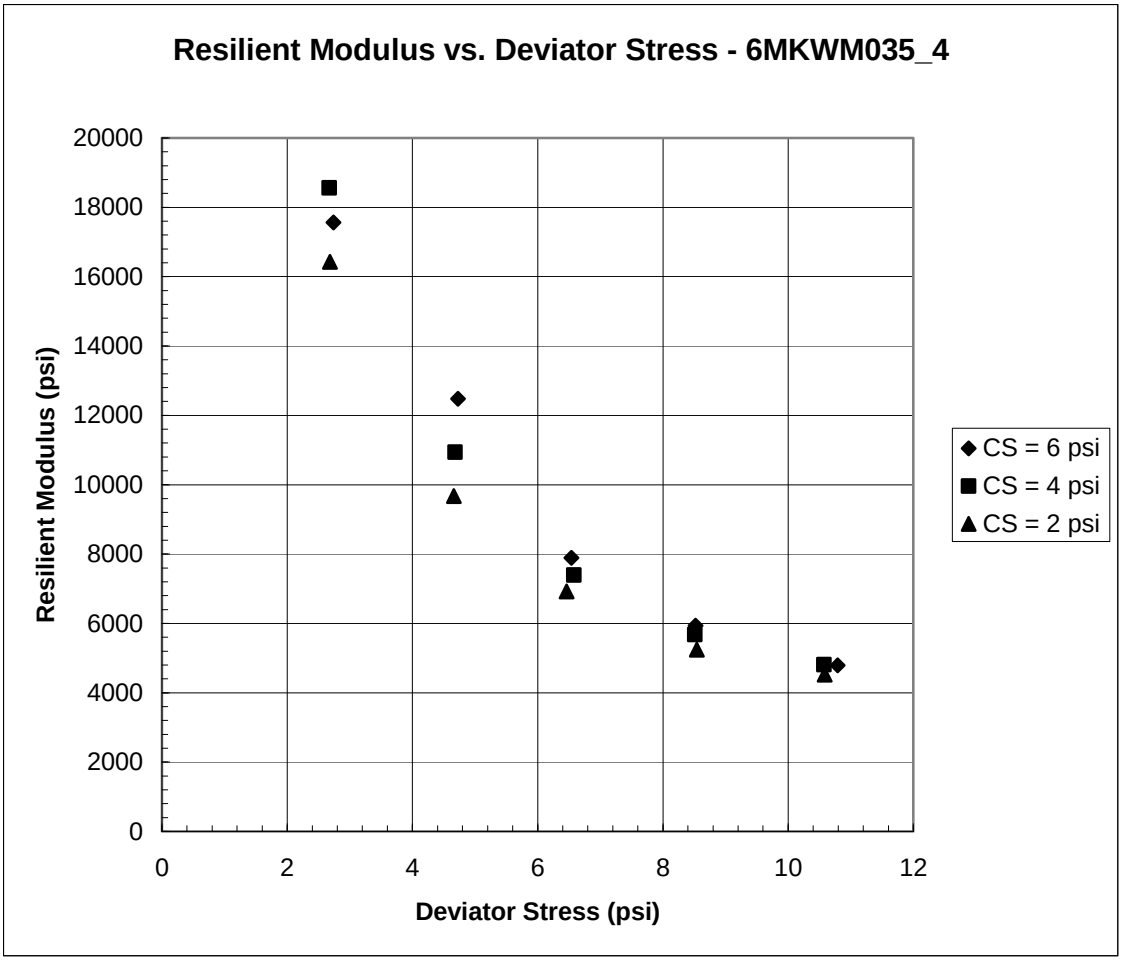
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.01	22321	22335	22403	22334	22310	22340
2	6	4.05	20803	20900	20793	20846	21607	20990
3	6	5.91	20209	20187	20181	20703	20729	20402
4	6	8.02	18873	18876	18893	18874	18894	18882
5	6	10	18880	18885	18633	18885	18872	18831
6	4	2.02	19532	19449	19431	19547	19481	19488
7	4	4.03	19363	19311	19310	19366	19366	19343
8	4	5.91	18454	18453	18418	18454	18458	18448
9	4	7.92	18045	18003	18024	18023	18046	18028
10	4	9.95	17181	17178	17193	17394	17183	17226
11	2	1.99	15976	15919	15969	15915	15962	15948
12	2	4.03	15690	15701	15691	15692	15694	15694
13	2	5.95	14994	15014	15013	15310	15297	15126
14	2	7.96	15228	15215	15246	15237	15244	15234
15	2	10.02	15153	15151	15151	15139	15130	15145



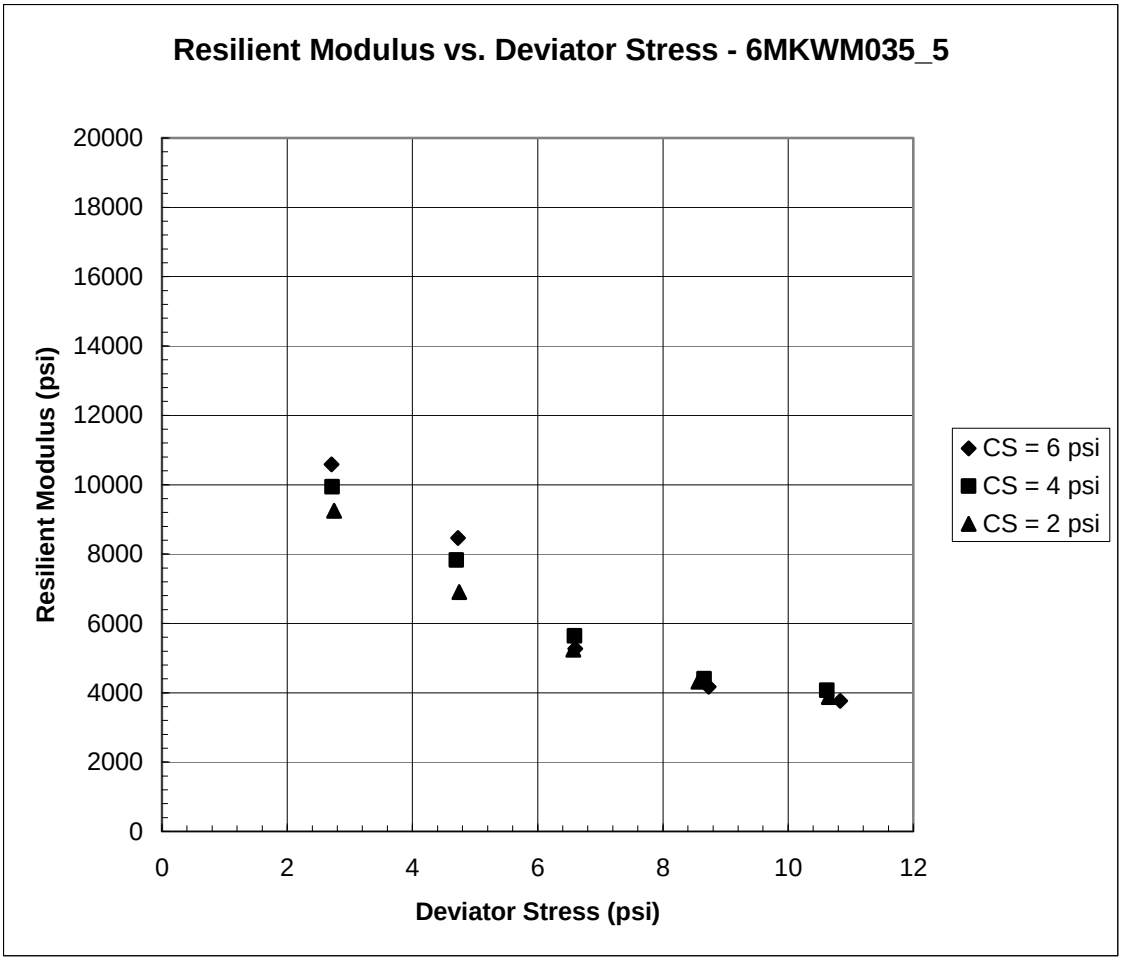
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.75	28637	28767	26130	28753	28766	28210
2	6	4.78	24124	23162	24174	24228	23215	23780
3	6	6.69	22416	21915	22479	22453	21882	22229
4	6	8.85	20825	20805	20803	20830	21221	20897
5	6	10.87	19955	19938	19648	19922	19633	19819
6	4	2.76	24294	24047	22334	24162	26259	24219
7	4	4.84	23445	23540	23558	23524	23561	23526
8	4	6.72	21982	22034	22030	21959	22591	22119
9	4	8.7	20745	20736	20749	20791	20785	20761
10	4	10.81	19813	19832	19798	19523	19779	19749
11	2	2.76	22121	20614	22216	20597	22299	21569
12	2	4.86	20385	20392	20466	20389	20393	20405
13	2	6.76	20122	20088	20057	20090	20119	20095
14	2	8.78	18918	18882	18934	18895	18888	18904
15	2	10.71	18376	18324	18328	18312	18327	18334



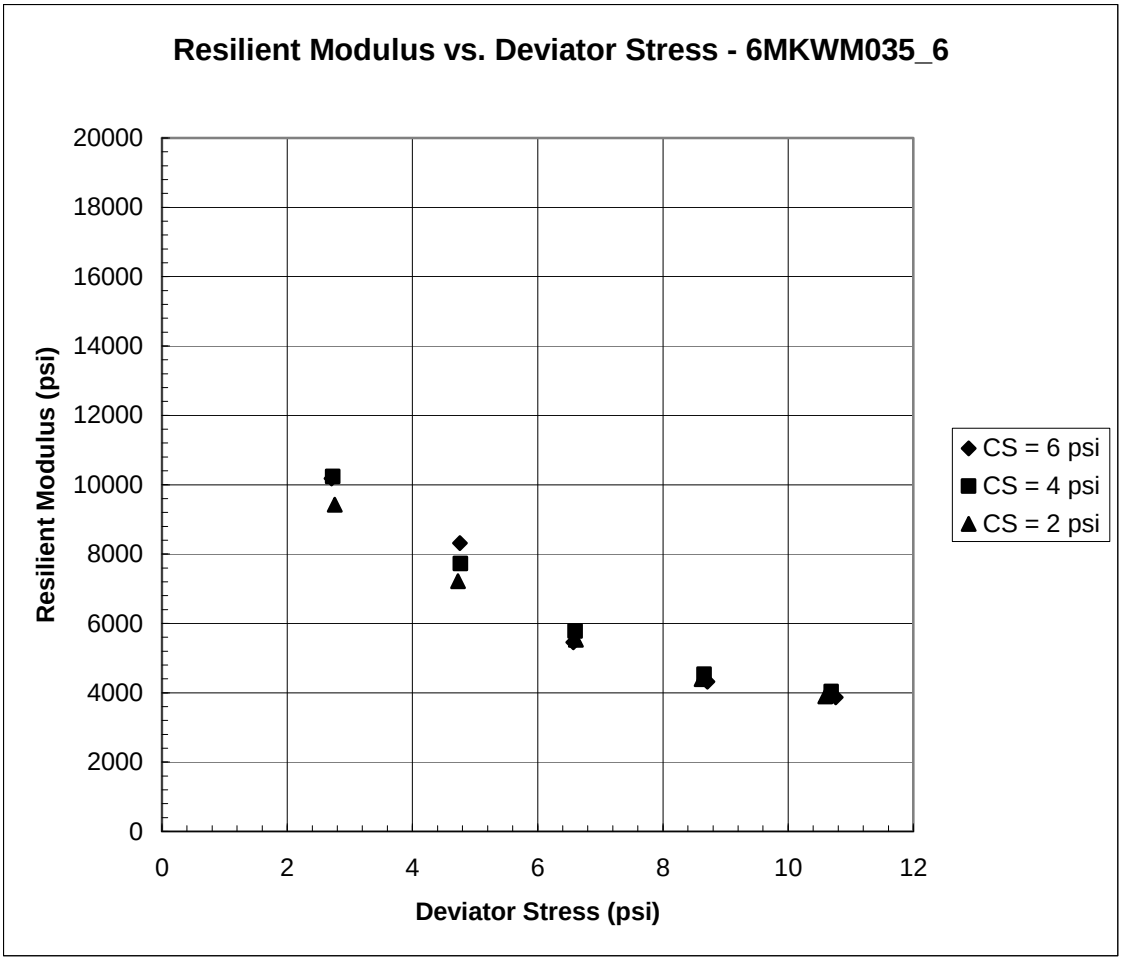
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.77	32223	32319	32324	32339	36526	33146
2	6	4.79	29015	29070	29020	29004	28953	29013
3	6	6.69	25030	25031	25781	26653	26713	25842
4	6	8.74	23899	23923	23893	23837	23859	23882
5	6	10.78	22460	22434	22441	22132	22520	22397
6	4	2.76	28923	32219	28961	32039	32026	30833
7	4	4.86	26900	26852	26881	26773	26844	26850
8	4	6.77	24683	24691	24800	24773	24684	24726
9	4	8.73	23401	23359	23323	23298	23295	23335
10	4	10.82	22208	22195	22249	22254	22234	22228
11	2	2.76	32187	28842	32046	32190	32363	31525
12	2	4.8	26434	26433	26379	26428	26445	26424
13	2	6.7	23678	23748	23754	23677	23680	23708
14	2	8.74	22031	21585	21981	22024	22077	21940
15	2	10.7	20703	20685	20663	20649	20649	20670



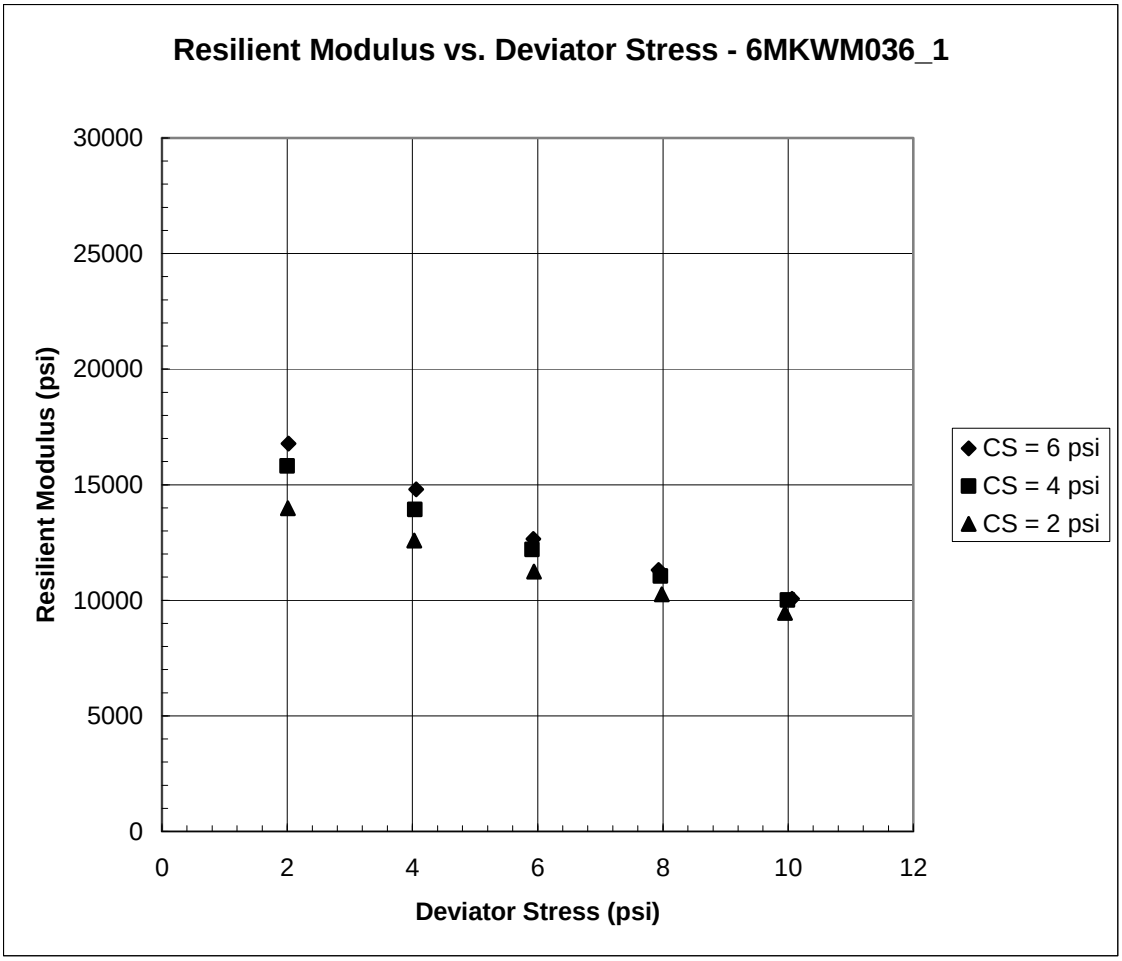
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.74	17191	17453	18146	17054	17978	17564
2	6	4.73	12524	12316	12342	12574	12629	12477
3	6	6.54	7877	7855	7836	7942	7937	7890
4	6	8.52	5918	5921	5957	5950	5917	5932
5	6	10.79	4805	4726	4819	4764	4820	4787
6	4	2.67	18515	18611	18503	18498	18690	18563
7	4	4.68	11020	10989	11421	10747	10496	10934
8	4	6.58	7357	7353	7431	7513	7301	7391
9	4	8.51	5648	5625	5692	5700	5694	5672
10	4	10.57	4831	4830	4750	4822	4829	4813
11	2	2.68	16512	16306	16216	16584	16542	16432
12	2	4.66	9766	9621	9758	9596	9608	9670
13	2	6.46	6932	6867	6856	7008	6957	6924
14	2	8.54	5255	5258	5284	5195	5225	5243
15	2	10.58	4501	4540	4528	4507	4528	4521



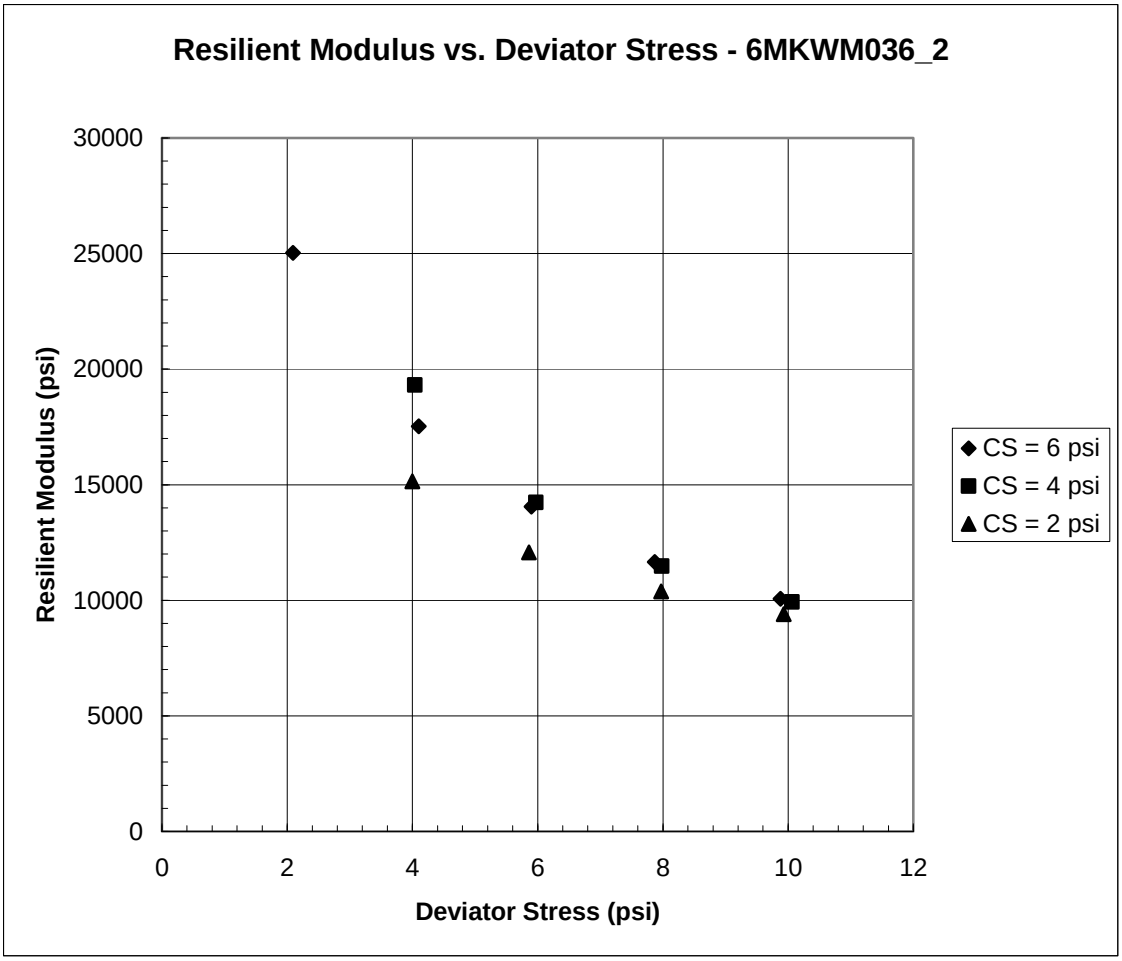
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.71	10517	10548	10510	10907	10458	10588
2	6	4.73	8353	8232	8496	8631	8608	8464
3	6	6.6	5298	5264	5224	5270	5305	5272
4	6	8.73	4178	4159	4178	4192	4170	4175
5	6	10.83	3776	3772	3766	3747	3772	3767
6	4	2.72	10212	9864	9824	9909	9872	9936
7	4	4.7	7837	7835	7836	7817	7821	7829
8	4	6.59	5632	5632	5634	5639	5641	5636
9	4	8.66	4415	4390	4432	4372	4403	4402
10	4	10.62	4058	4059	4070	4084	4090	4072
11	2	2.75	9395	9402	9352	9021	9075	9249
12	2	4.75	6873	6901	6902	6889	6973	6908
13	2	6.57	5271	5264	5222	5220	5226	5241
14	2	8.57	4309	4311	4315	4342	4321	4320
15	2	10.65	3846	3885	3876	3877	3888	3874



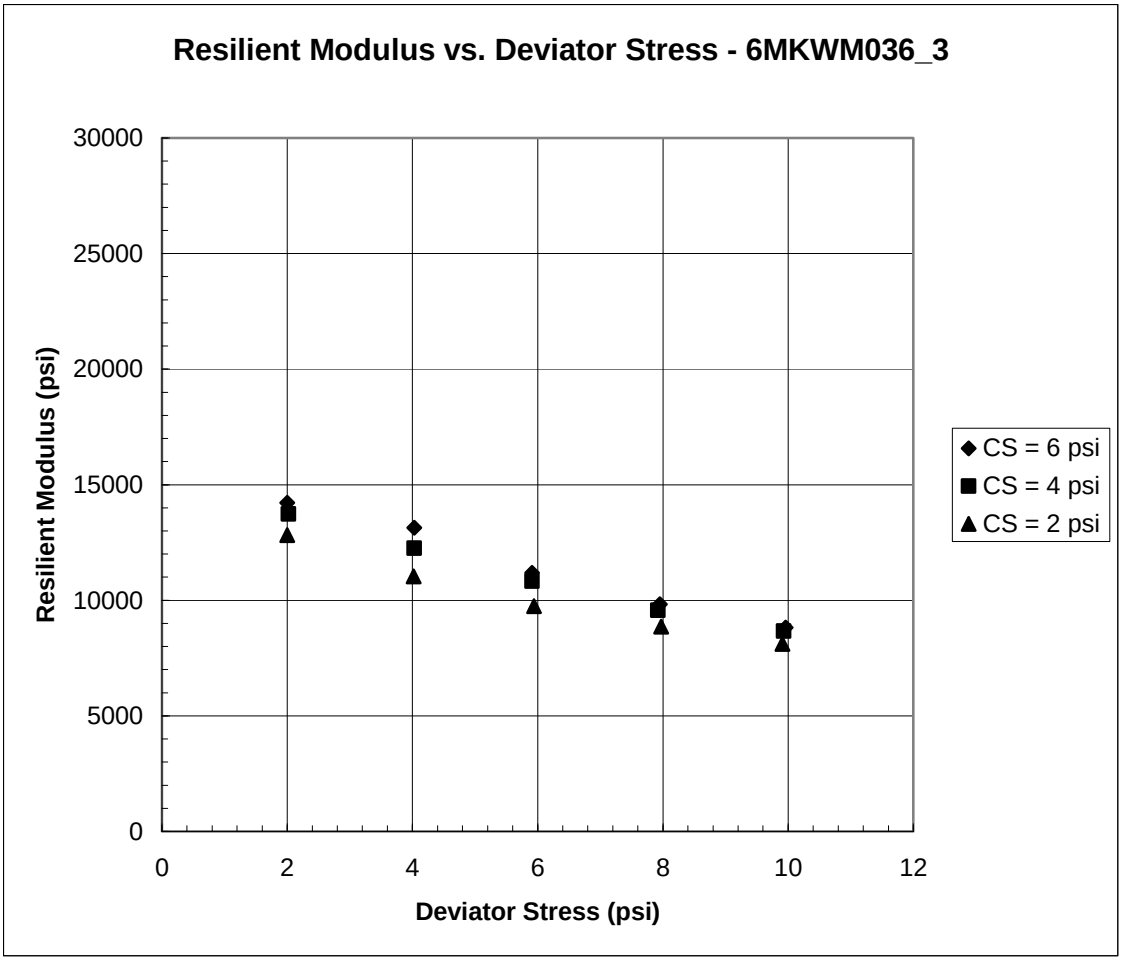
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.71	10231	10182	10138	10172	10182	10181
2	6	4.76	8287	8287	8305	8307	8407	8318
3	6	6.57	5472	5437	5412	5473	5481	5455
4	6	8.71	4289	4308	4315	4344	4330	4317
5	6	10.76	3859	3857	3867	3860	3870	3863
6	4	2.73	10272	10219	10265	10168	10268	10239
7	4	4.77	7653	7653	7772	7686	7860	7725
8	4	6.6	5773	5817	5798	5728	5764	5776
9	4	8.66	4524	4529	4529	4530	4544	4531
10	4	10.69	4011	4035	4040	4043	4022	4030
11	2	2.76	9411	9400	9489	9399	9407	9421
12	2	4.73	7221	7218	7221	7218	7206	7217
13	2	6.61	5467	5510	5558	5542	5545	5524
14	2	8.62	4387	4398	4393	4392	4387	4392
15	2	10.59	3921	3886	3887	3901	3900	3899



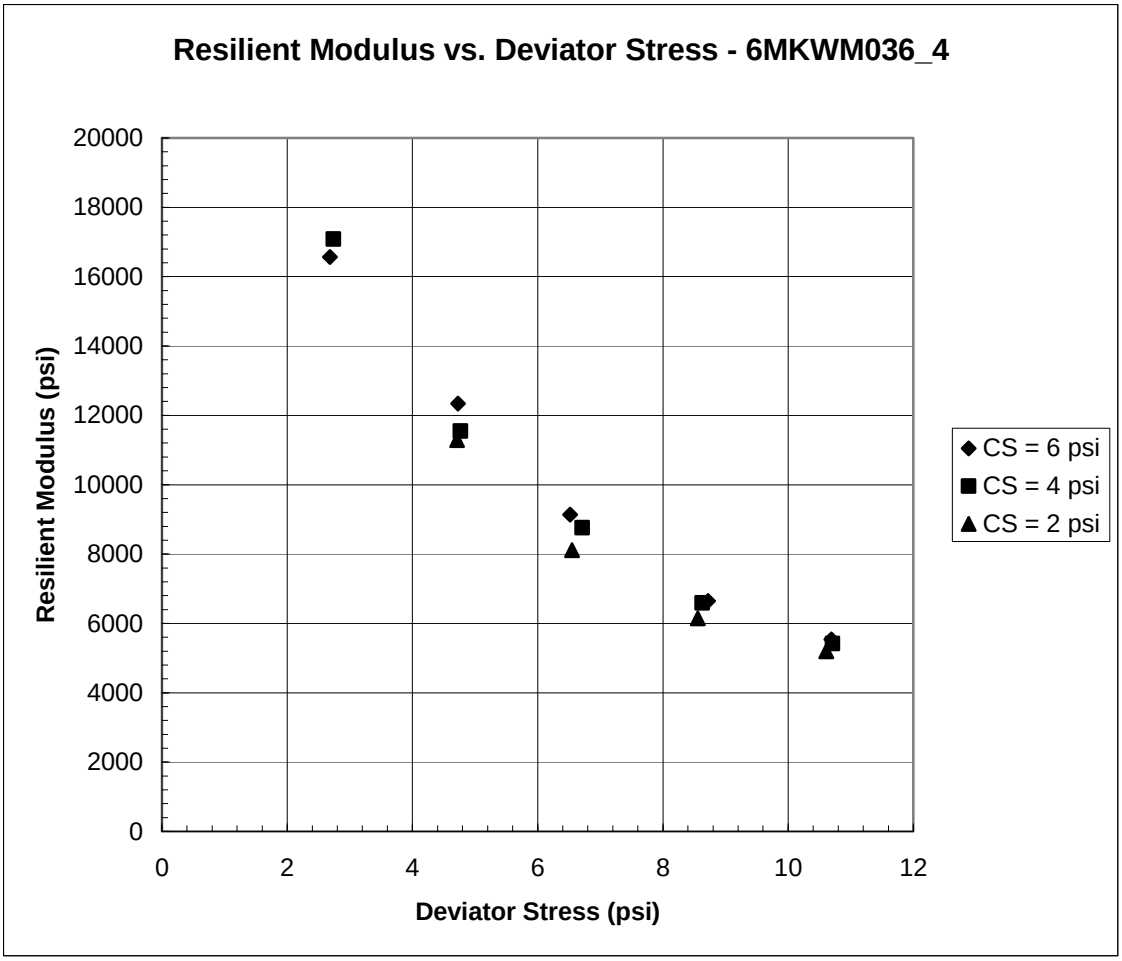
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.02	16928	15996	17011	16949	17008	16779
2	6	4.06	14830	14830	14795	14798	14749	14800
3	6	5.93	12526	12539	12737	12751	12732	12657
4	6	7.93	11249	11260	11333	11336	11359	11308
5	6	10.06	10029	10030	10037	10112	10112	10064
6	4	2	15216	15874	15981	15968	16002	15808
7	4	4.04	13677	14014	13991	13958	14021	13932
8	4	5.91	12152	11968	12152	12170	12545	12198
9	4	7.96	10963	11176	11069	11070	10963	11048
10	4	9.99	9894	9967	10044	10115	10051	10014
11	2	2.01	14377	14303	14382	13709	13130	13980
12	2	4.03	12772	12772	12437	12443	12469	12579
13	2	5.94	11226	11246	11233	11227	11246	11236
14	2	7.98	10297	10300	10288	10184	10195	10253
15	2	9.95	9462	9452	9460	9461	9463	9460



Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.09	25174	24942	25097	25273	24671	25031
2	6	4.1	17788	16834	17724	18135	17156	17527
3	6	5.9	14156	14215	13775	14052	14036	14047
4	6	7.87	11688	11724	11656	11607	11585	11652
5	6	9.88	10093	9993	9996	10084	10183	10070
6	4	2.02						
7	4	4.04	19415	19187	19254	19397	19292	19309
8	4	5.97	14274	14195	14132	14159	14392	14231
9	4	7.98	11374	11365	11494	11565	11606	11480
10	4	10.06	9873	9906	9917	10000	9915	9922
11	2	1.98						
12	2	4	15408	15327	15008	14926	15084	15151
13	2	5.86	12056	12113	12064	12099	12053	12077
14	2	7.97	10374	10282	10304	10434	10528	10385
15	2	9.93	9398	9382	9401	9412	9440	9407

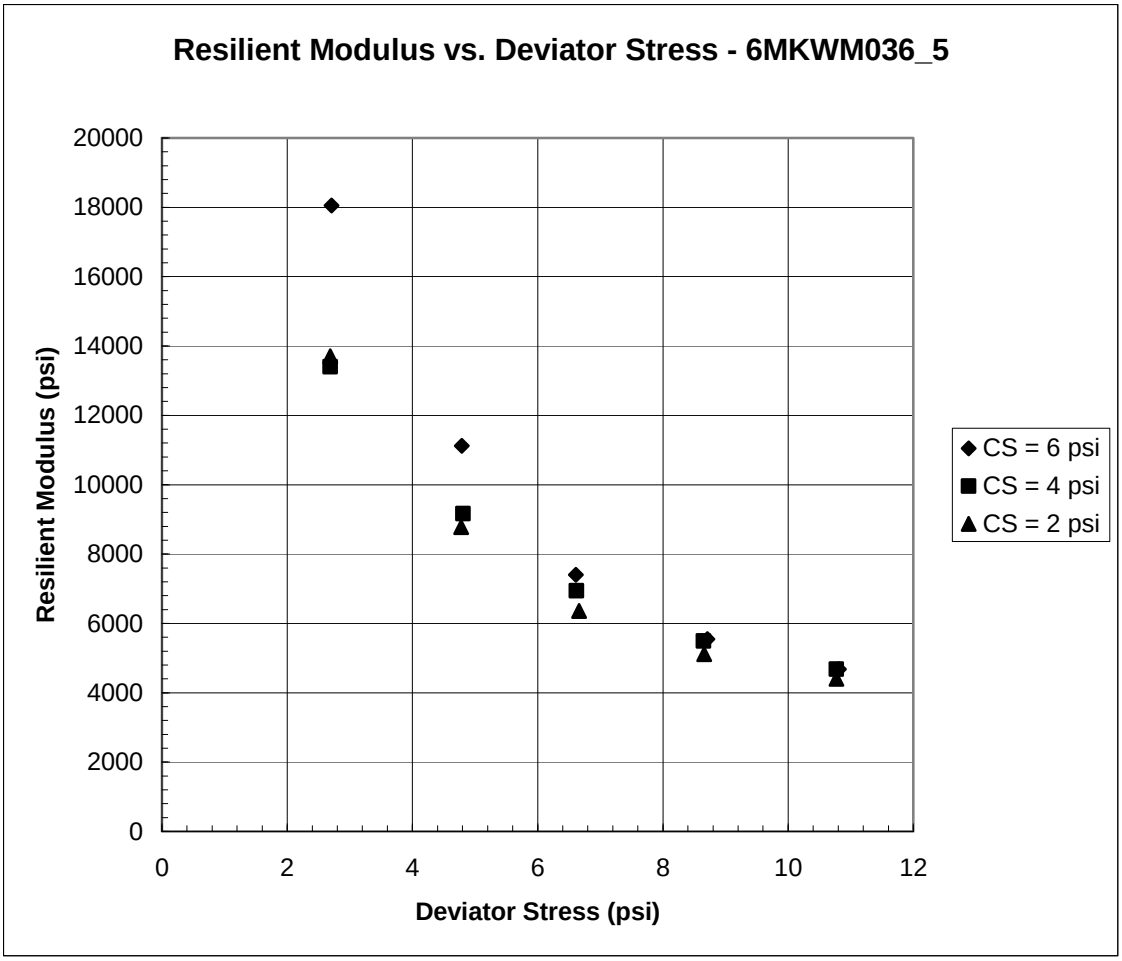


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2	14346	14299	14405	14414	13659	14224
2	6	4.03	12793	13079	13387	13381	13052	13138
3	6	5.91	11073	11188	11220	11247	11204	11186
4	6	7.95	9854	9844	9866	9841	9755	9832
5	6	9.96	8807	8749	8806	8817	8918	8819
6	4	2.02	13852	13848	13868	13847	13225	13728
7	4	4.03	12270	12240	12216	12272	12244	12248
8	4	5.91	10792	10809	10805	10938	10785	10826
9	4	7.92	9563	9551	9541	9632	9552	9568
10	4	9.93	8658	8660	8665	8666	8658	8661
11	2	2	12416	13026	12528	13057	13042	12814
12	2	4.02	11032	11083	11048	11009	11020	11038
13	2	5.94	9741	9735	9742	9736	9753	9741
14	2	7.97	8800	8956	8867	8867	8847	8867
15	2	9.91	8093	8113	8114	8105	8106	8106

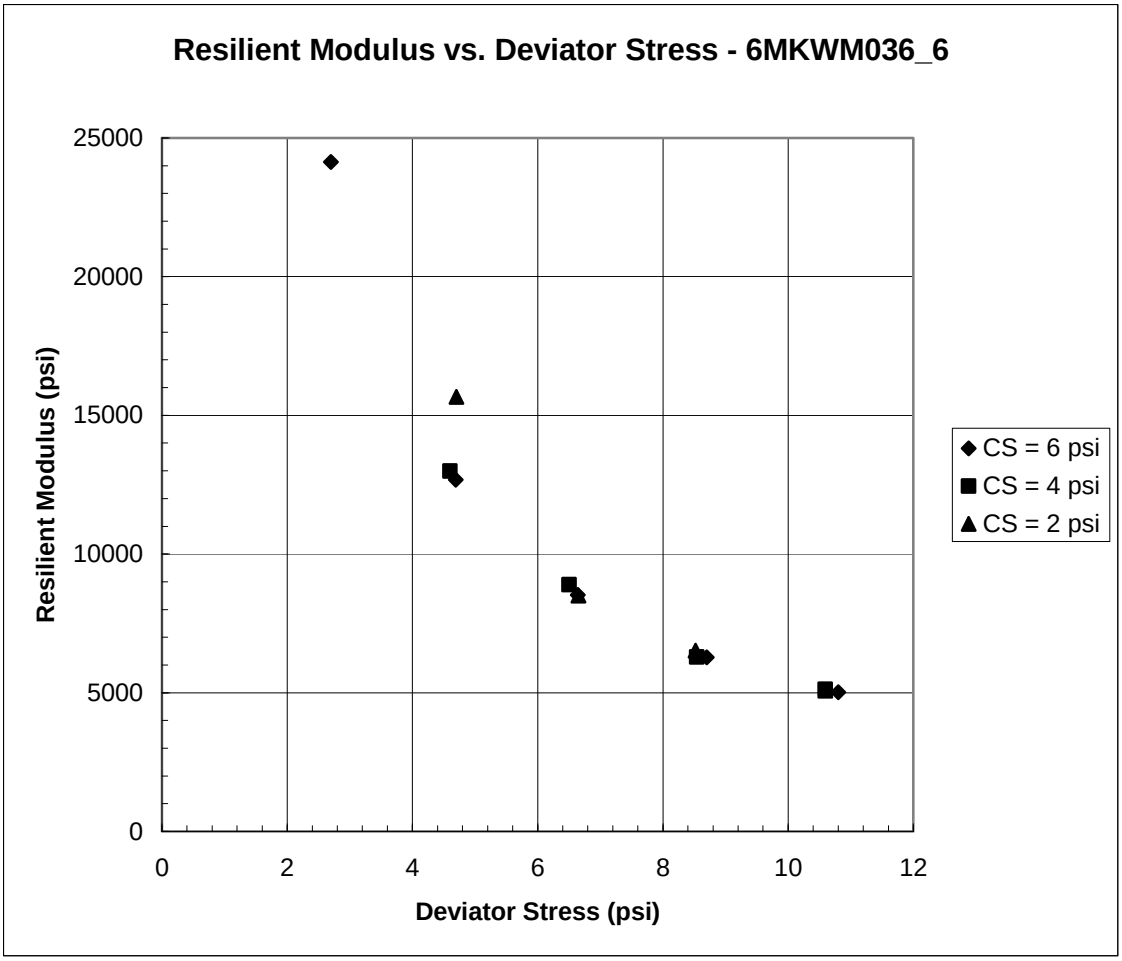


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.68	16512	16547	16345	16687	16737	16565
2	6	4.73	12426	12311	12288	12355	12334	12343
3	6	6.52	9098	9111	9112	9209	9144	9135
4	6	8.72	6653	6618	6615	6650	6710	6649
5	6	10.69	5531	5430	5574	5587	5574	5539
6	4	2.74	16292	15759	16270	15927	21191	17088
7	4	4.77	11307	11568	11684	11505	11675	11548
8	4	6.71	8900	8689	8809	8714	8703	8763
9	4	8.63	6590	6483	6615	6630	6623	6588
10	4	10.71	5356	5434	5434	5446	5432	5420
11	2	2.64	27972	26917	28105	27562	33226	28756.4
12	2	4.71	10657	11231	11032	11336	12169	11285
13	2	6.55	8065	8089	8128	8127	8137	8109
14	2	8.56	6127	6145	6168	6147	6147	6147
15	2	10.61	5184	5196	5205	5223	5170	5195

Not used in original analysis
Calculated

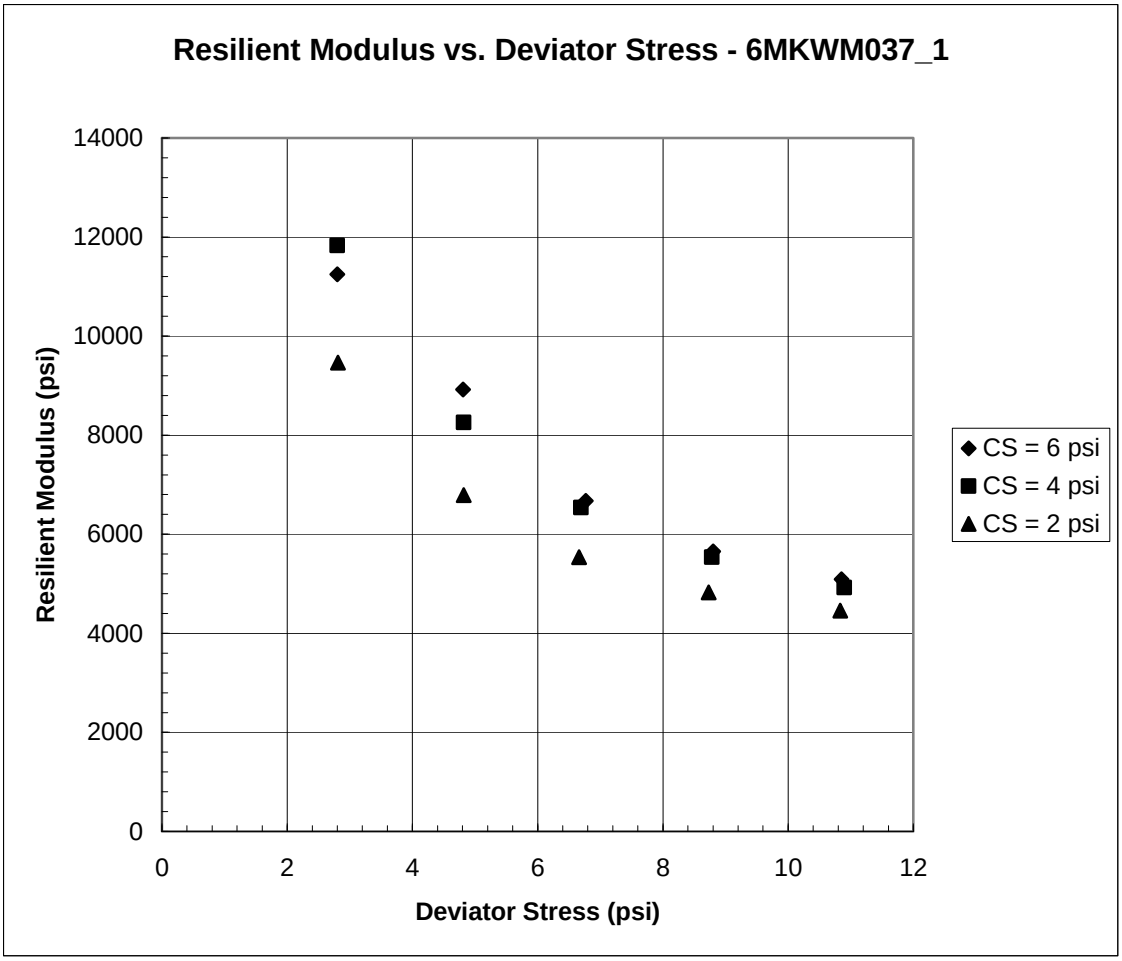


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.71	18099	18029	17913	17655	18554	18050
2	6	4.79	11056	11097	11127	11264	11083	11125
3	6	6.61	7444	7416	7343	7412	7393	7402
4	6	8.71	5538	5485	5532	5579	5600	5547
5	6	10.81	4664	4695	4680	4659	4697	4679
6	4	2.69	13432	13288	13364	14008	12935	13405
7	4	4.81	9256	9325	9106	9053	9074	9163
8	4	6.62	6990	6859	6920	6947	7006	6944
9	4	8.65	5475	5440	5494	5538	5497	5489
10	4	10.77	4716	4680	4658	4673	4675	4680
11	2	2.69	13287	13034	14086	14134	13979	13704
12	2	4.78	8913	8899	8746	8593	8745	8779
13	2	6.66	6340	6301	6356	6376	6413	6357
14	2	8.66	5111	5093	5133	5110	5099	5109
15	2	10.77	4383	4391	4436	4419	4387	4403

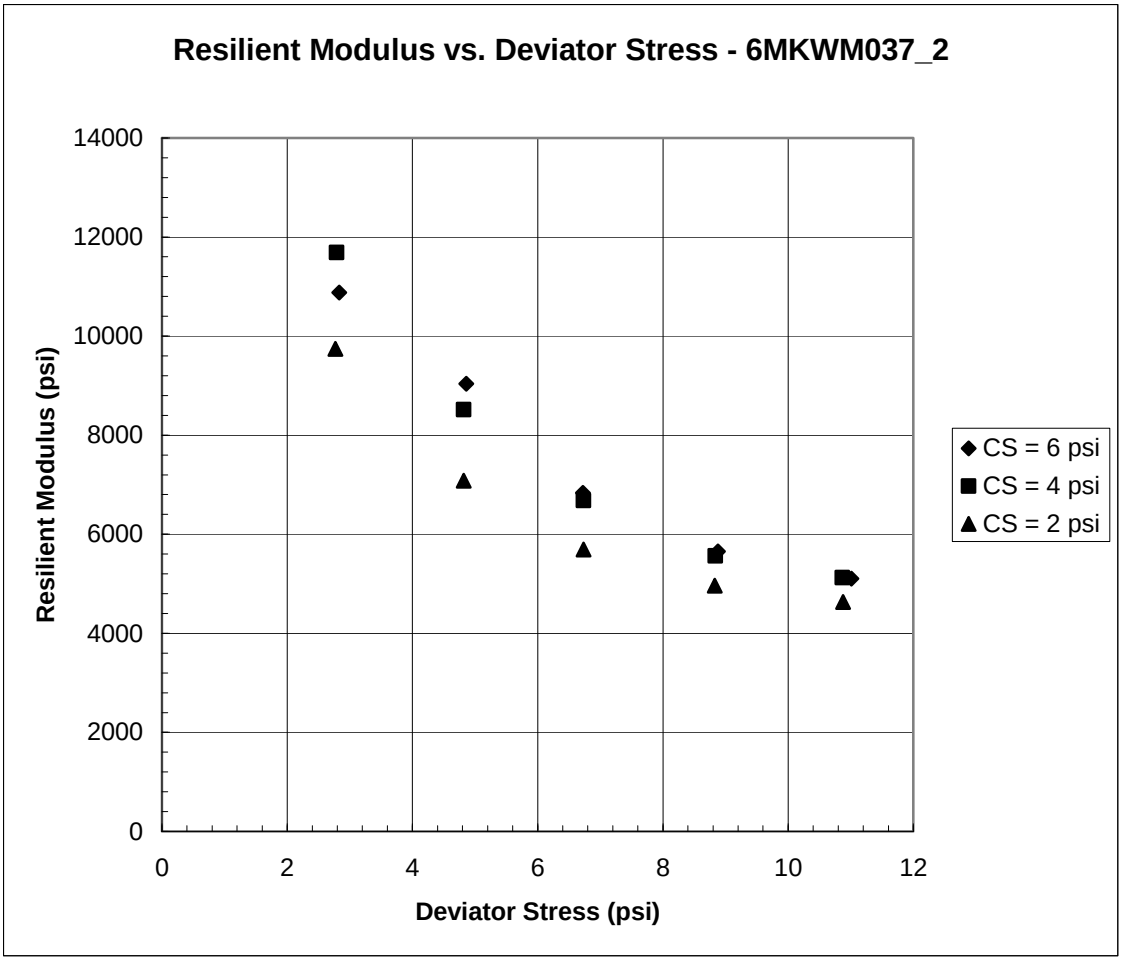


Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.7	24474	23159	22633	33032	17372	24134
2	6	4.69	12639	12636	12721	12917	12491	12681
3	6	6.64	8589	8550	8480	8615	8377	8522
4	6	8.7	6315	6265	6290	6274	6210	6271
5	6	10.8	4945	4928	5046	5067	5092	5016
6	4	2.63	55152	54728	67223	67777	67941	62564.2
7	4	4.6	12099	12558	12473	12459	15366	12991
8	4	6.5	9021	8851	8815	8844	8946	8895
9	4	8.54	6219	6260	6345	6310	6287	6284
10	4	10.59	5135	5130	5102	5102	5114	5117
11	2	2.74	144610	143155	145210	145492	289456	173584.6
12	2	4.7	13809	17566	12968	17289	16705	15667
13	2	6.65	8464	8139	9131	8652	8114	8500
14	2	8.52	6376	6314	6643	6614	6645	6518
15	2	10.59	5117	5110	4952	5110	5111	5080

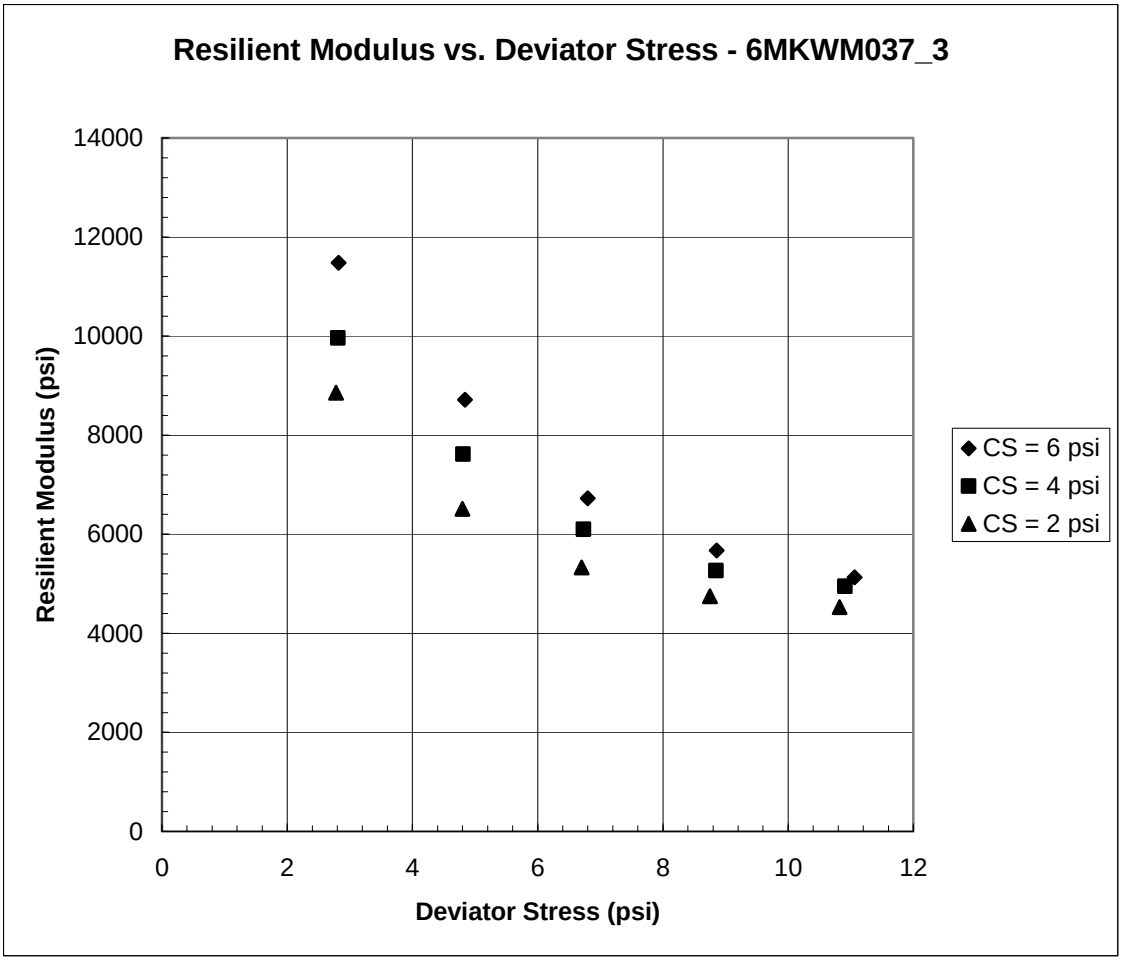
Not used in original analysis
Calculated



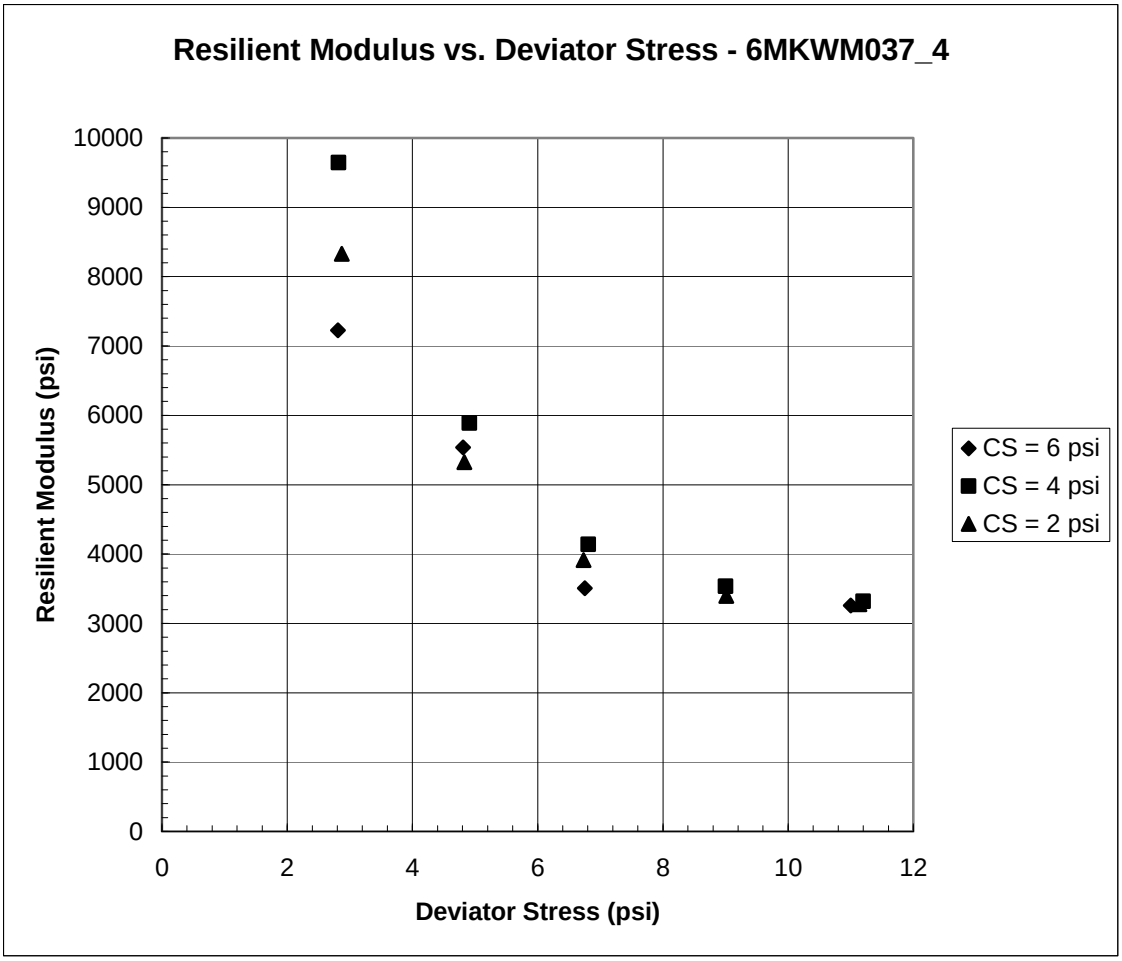
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.8	11426	11378	10959	11057	11428	11249
2	6	4.81	8816	8796	8978	9022	8990	8920
3	6	6.77	6702	6714	6694	6638	6630	6676
4	6	8.8	5644	5610	5680	5685	5637	5651
5	6	10.85	5093	5061	5093	5096	5099	5089
6	4	2.8	11857	11821	11859	11801	11809	11829
7	4	4.82	8362	8223	8226	8206	8262	8256
8	4	6.69	6535	6479	6534	6545	6595	6538
9	4	8.78	5563	5555	5553	5519	5493	5537
10	4	10.9	4909	4909	4935	4918	4931	4920
11	2	2.81	9315	9554	9617	9576	9266	9466
12	2	4.82	6830	6819	6785	6711	6806	6790
13	2	6.66	5530	5495	5532	5541	5585	5537
14	2	8.73	4799	4849	4842	4832	4791	4823
15	2	10.83	4441	4450	4462	4468	4456	4456



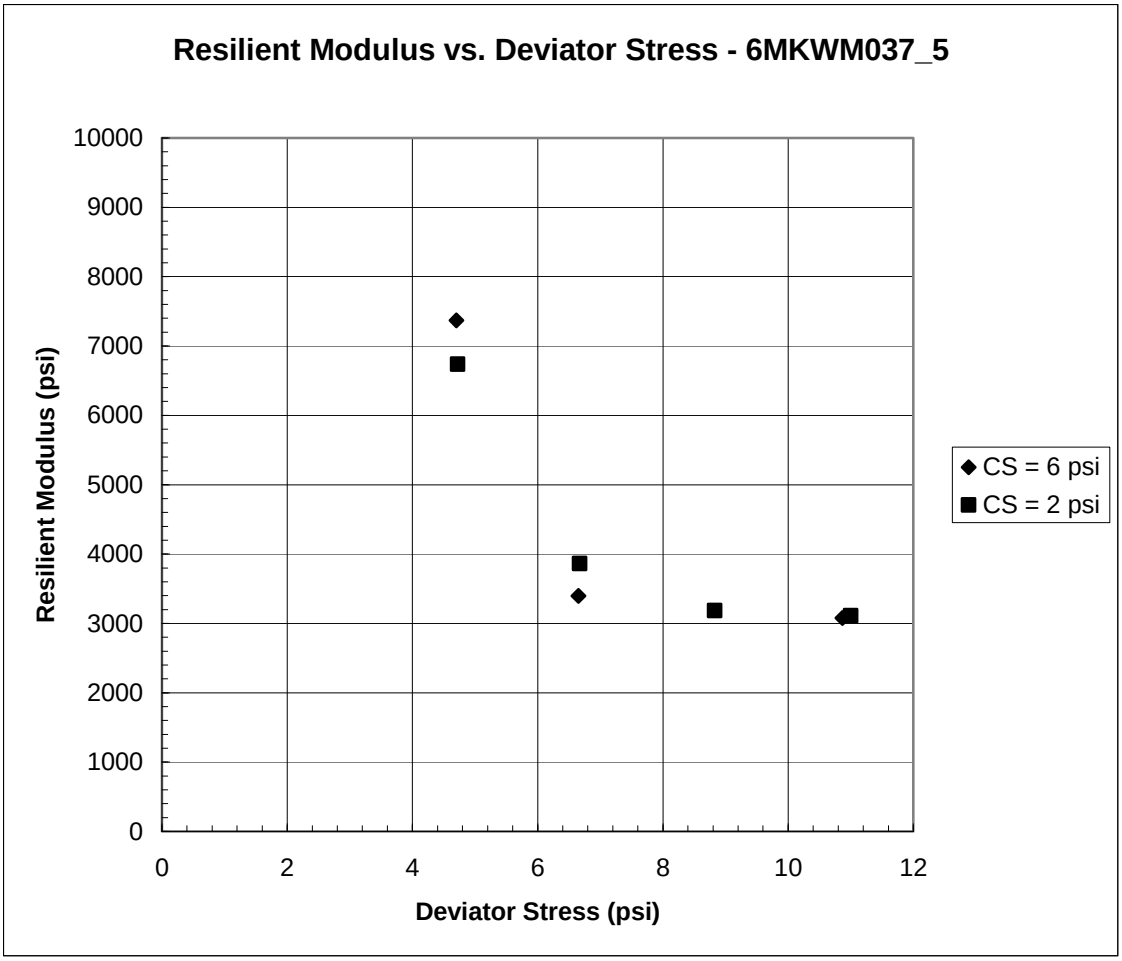
Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.83	11132	10699	11136	10727	10719	10882
2	6	4.86	8817	9086	9115	9115	9064	9039
3	6	6.72	6861	6872	6797	6792	6844	6833
4	6	8.88	5606	5630	5667	5696	5655	5651
5	6	11.01	5119	5094	5100	5102	5104	5104
6	4	2.79	11804	12233	11309	11763	11312	11684
7	4	4.82	8443	8588	8482	8482	8587	8516
8	4	6.73	6677	6730	6720	6606	6670	6680
9	4	8.84	5575	5556	5562	5560	5569	5564
10	4	10.87	5098	5144	5153	5111	5098	5121
11	2	2.77	9667	9652	9718	10035	9650	9745
12	2	4.82	7135	7135	7019	7052	7067	7082
13	2	6.73	5665	5673	5690	5696	5726	5690
14	2	8.83	4981	4980	4953	4954	4928	4959
15	2	10.88	4622	4627	4627	4657	4622	4631



Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.82	11434	11431	12017	11435	11087	11481
2	6	4.84	8760	8632	8759	8633	8779	8713
3	6	6.8	6725	6666	6727	6737	6780	6727
4	6	8.86	5705	5651	5713	5647	5646	5672
5	6	11.06	5115	5148	5124	5121	5145	5131
6	4	2.81	9882	9884	9928	10233	9878	9961
7	4	4.81	7671	7569	7554	7589	7690	7615
8	4	6.73	6077	6086	6148	6094	6079	6097
9	4	8.85	5285	5281	5231	5239	5288	5265
10	4	10.91	4932	4941	4944	4946	4972	4947
11	2	2.78	8893	8821	8849	8862	8863	8857
12	2	4.8	6440	6532	6536	6522	6523	6510
13	2	6.7	5339	5333	5324	5340	5299	5327
14	2	8.75	4728	4727	4758	4755	4761	4746
15	2	10.82	4535	4497	4550	4536	4536	4531



Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.81	7323	7155	7057	7314	7291	7228
2	6	4.81	5517	5528	5543	5542	5557	5537
3	6	6.75	3508	3527	3498	3511	3492	3507
4	6							
5	6	11	3255	3282	3277	3242	3240	3259
6	4	2.82	9663	9712	9606	9562	9681	9645
7	4	4.91	5936	5866	5863	5882	5896	5889
8	4	6.81	4132	4123	4149	4157	4140	4140
9	4	9	3516	3553	3537	3540	3539	3537
10	4	11.2	3314	3294	3319	3323	3328	3316
11	2	2.87	8295	8071	8347	8353	8584	8330
12	2	4.83	5291	5370	5323	5323	5326	5327
13	2	6.73	3922	3924	3942	3896	3887	3914
14	2	9.01	3390	3376	3386	3417	3415	3397
15	2	11.14	3258	3266	3272	3286	3296	3276



Sequence	CS (psi)	DS (psi)	Mr 1 (psi)	Mr 2 (psi)	Mr 3 (psi)	Mr 4 (psi)	Mr 5 (psi)	Mr AVG (psi)
1	6	2.68	18728	18838	19600	18699	19024	18977.8
2	6	4.7	6885	7003	7278	7830	7848	7369
3	6	6.65	3416	3435	3323	3413	3398	3397
4	6							
5	6	10.87	3074	3075	3077	3066	3092	3077
6	4		20565	22000	21433	22339		
7	4	4.69	15361	19539	25078	21199	17119	19659.2
8	4	6.31	5398	5090	5205	5105	4992	5158
9	4	8.57	3492	3491	3495	3516	3585	3516
10	4	10.93	3114	3108	3116	3126	3135	3120
11	2	2.65	24060	33091	17808	33002	33706	28333.4
12	2	4.72	6853	6650	6693	6626	6862	6737
13	2	6.67	3894	3881	3800	3865	3875	3863
14	2	8.83	3216	3198	3112	3193	3195	3183
15	2	11	3118	3096	3101	3109	3117	3108

Calculated

Missouri Department of Transportation
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