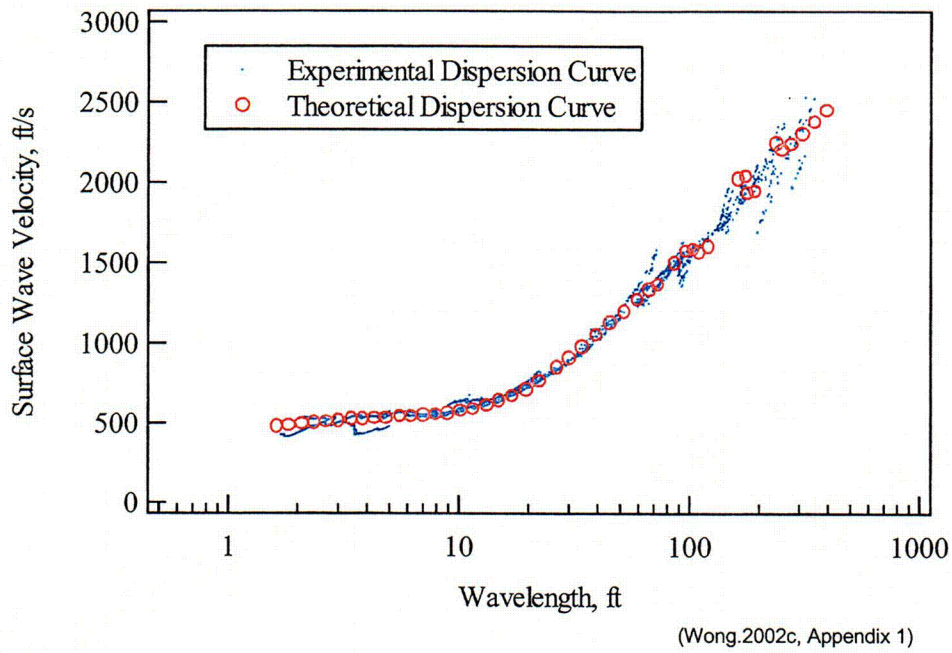
ATTACHMENT IX

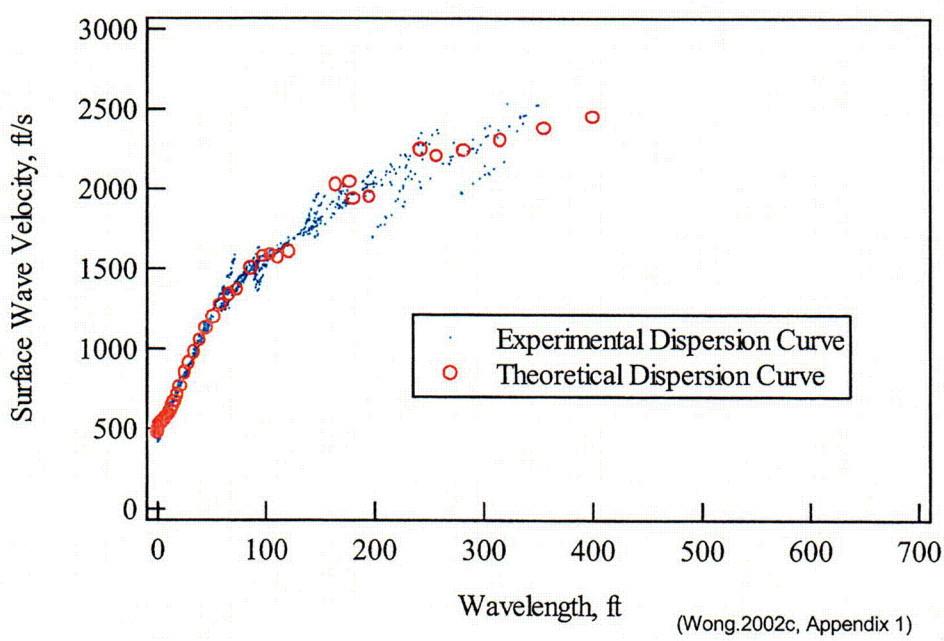
SASW VELOCITY PLOTS – WHB AREA

As described in Section 6.2.7, this attachment presents 34 figures showing detailed interpretive results for the SASW data performed in the WHB area. Each figure contains dispersion curves (both experimental and theoretical in linear and semi-log space) (Wong 2002c) and the resulting shear- and compression-wave velocity profiles. A total of 35 velocity profiles are presented. A detailed description of each analysis can be found in the associated appendix in scientific notebook SN-M&O-SCI-022-V1 (Wong 2002c).



(Wong.2002c, Appendix 1)

a. SASW-1 Dispersion Curves (Log Plot)

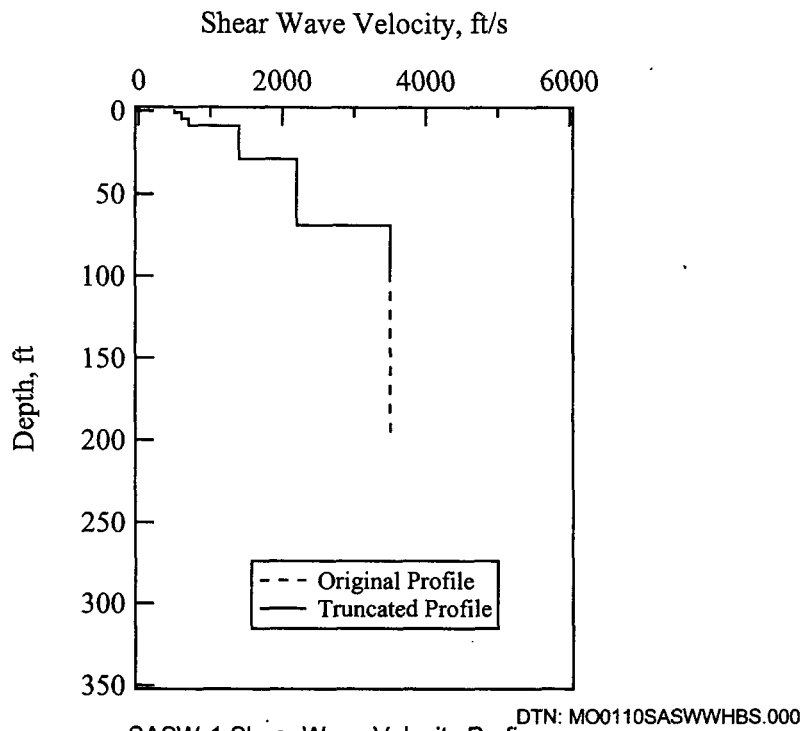


(Wong.2002c, Appendix 1)

b. SASW-1 Dispersion Curves (Linear Plot)

Figure IX-1. SASW-1 Results

C01



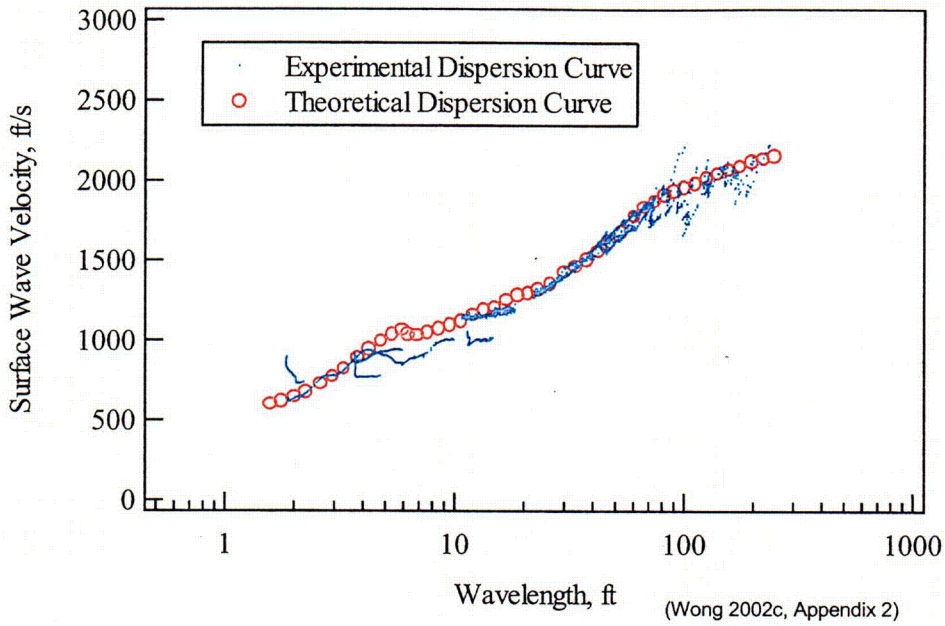
c. SASW-1 Shear Wave Velocity Profi..

Location: SASW-1

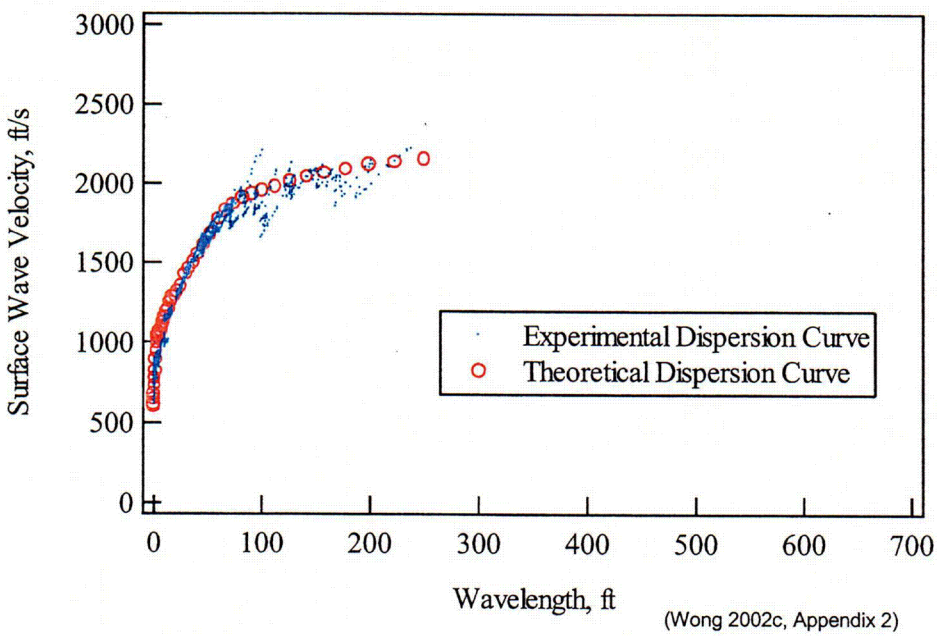
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio***	Mass Density*** pcf
1	1	866	500	0.25	120
2	4	1039	600	0.25	120
3	4	1212	700	0.25	120
4	20	2425	1400	0.25	120
5	40	3810	2200	0.25	120
6	29*	6062	3500	0.25	80
7	102**	6062	3500	0.25	80

DTN: MO0110SASWWHBS.000
* Vs profile truncated at 98 ft based on geological profile showing an offset fault beginning at a depth of approximately 98 ft.
** Additional layering used in matching the theoretical dispersion curve to the complete experimental dispersion curve
*** Poisson's ratio and mass density from Wong (2002c, Appendix 1)

Figure IX-1. SASW-1 Results (continued)



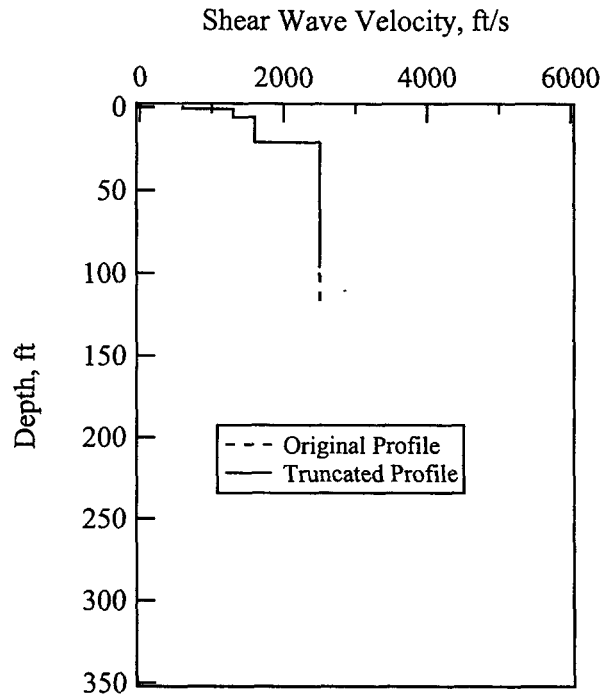
a. SASW-2 Dispersion Curves (Log Plot)



b. SASW-2 Dispersion Curves (Linear Plot)

Figure IX-2. SASW-2 Results

C02



DTN: MO0110SASWWHBS.000

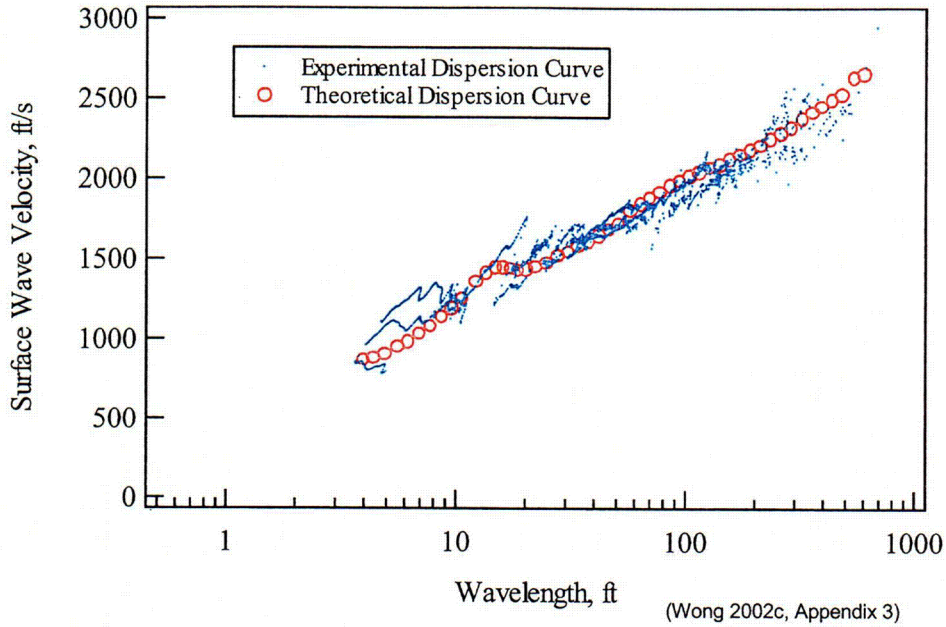
c. SASW-2 Shear Wave Velocity Profile

Location: SASW-2

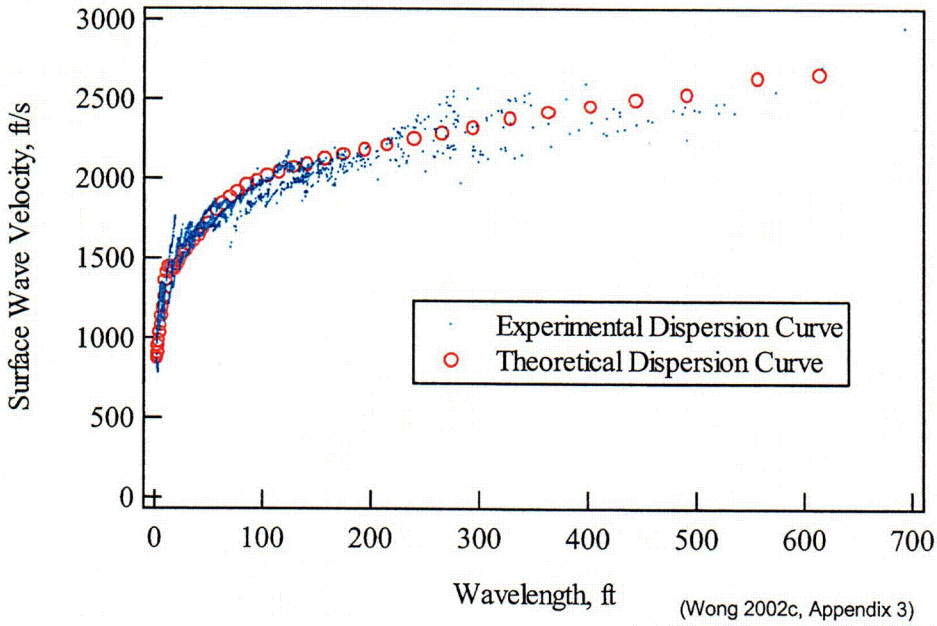
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio***	Mass Density*** pcf
1	1	1039	600	0.25	120
2	5	2252	1300	0.25	120
3	15	2771	1600	0.25	120
4	75*	4850	2500	0.25	120
5	24**	4850	2500	0.25	120

DTN: MO0110SASWWHBS.000
* Vs profile truncated at 96 ft based on geological profile showing an offset fault beginning at a depth of approximately 96 ft.
** Additional layering used in matching the theoretical dispersion curve to the complete experimental dispersion curve
*** Poisson's ratio and mass density from Wong (2002c, Appendix 2)

Figure IX-2. SASW-2 Results (continued)



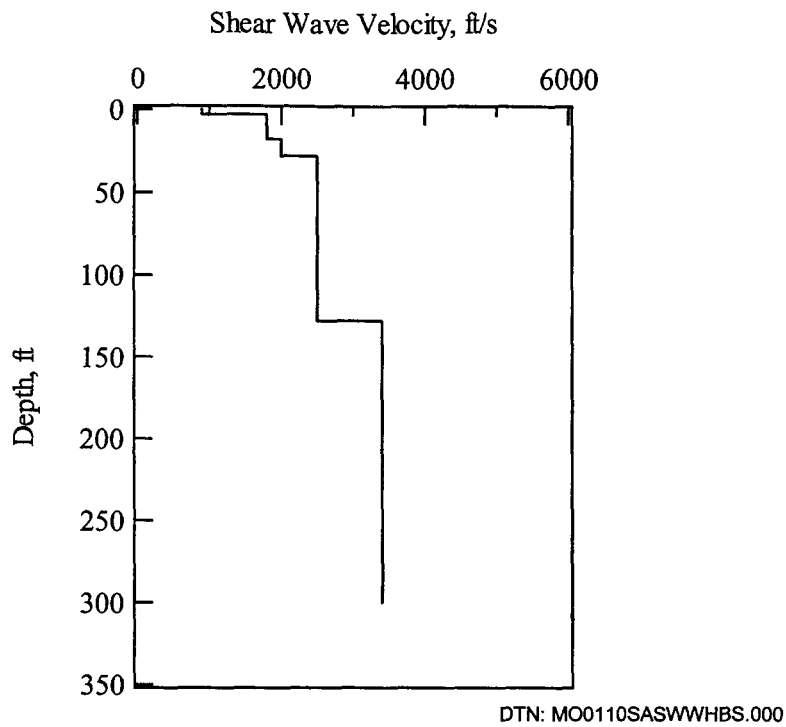
a. SASW-3 Dispersion Curves (Log Plot)



b. SASW-3 Dispersion Curves (Linear Plot)

Figure IX-3. SASW-3 Results

C03



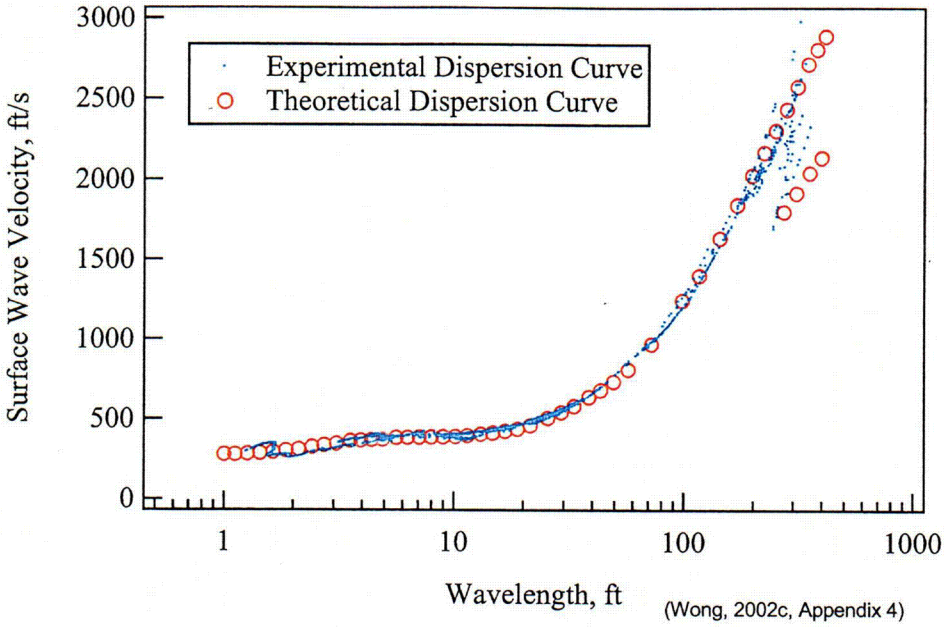
c. SASW-3 Shear Wave Velocity Profile

Location: SASW-3

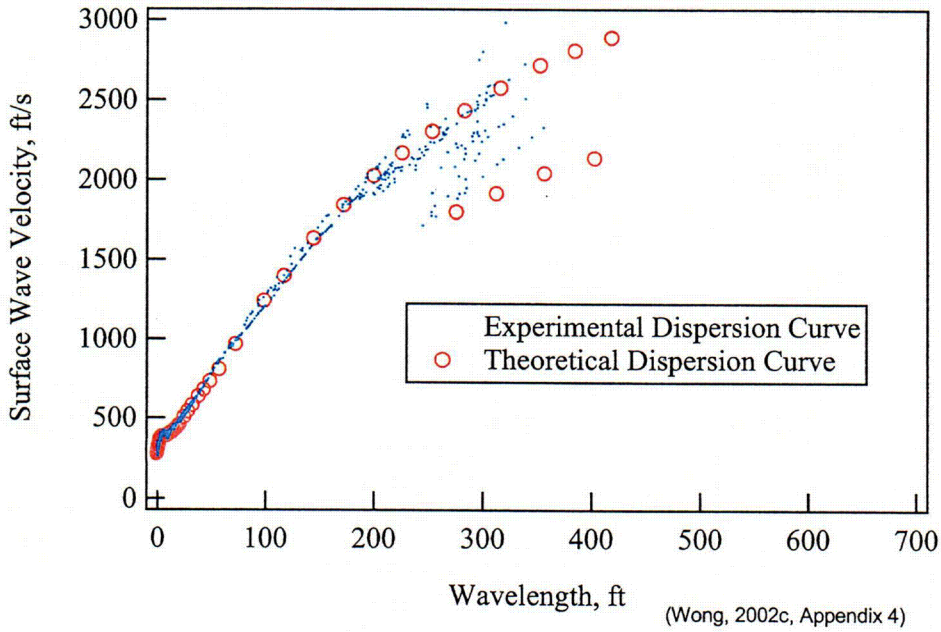
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	3	1559	900	0.25	120
2	15	3118	1800	0.25	120
3	10	3464	2000	0.25	120
4	100	4330	2500	0.25	120
5	173	5889	3400	0.25	80

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 3)

Figure IX-3. SASW-3 Results (continued)



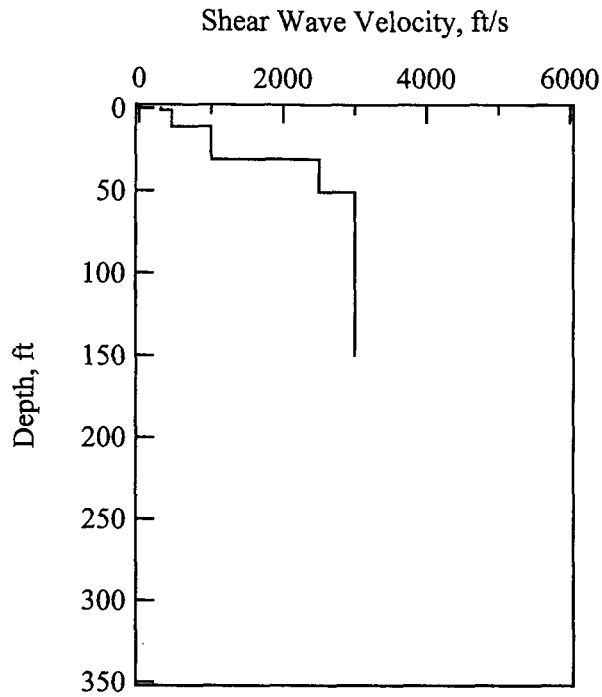
a. SASW-4 Dispersion Curves (Log Plot)



b. SASW-4 Dispersion Curves (Linear Plot)

Figure IX-4. SASW-4 Results

C04



DTN: MO0110SASWWHBS.000

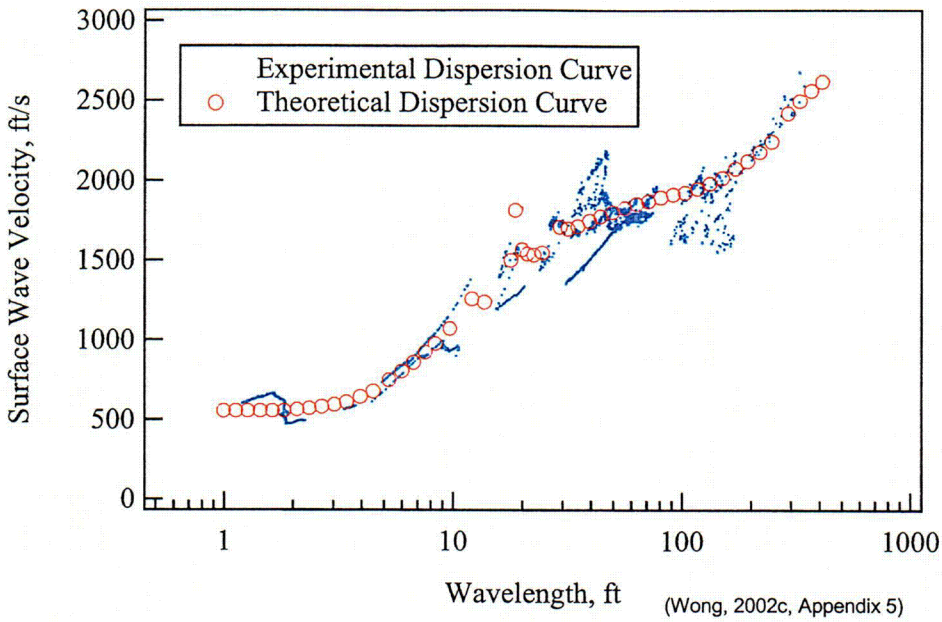
c. SASW-4 Shear Wave Velocity Profile

Location: SASW-4

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	520	300	0.25	120
2	10	779	450	0.25	120
3	20	1732	1000	0.25	120
4	20	4330	2500	0.25	120
5	100	5196	3000	0.25	80

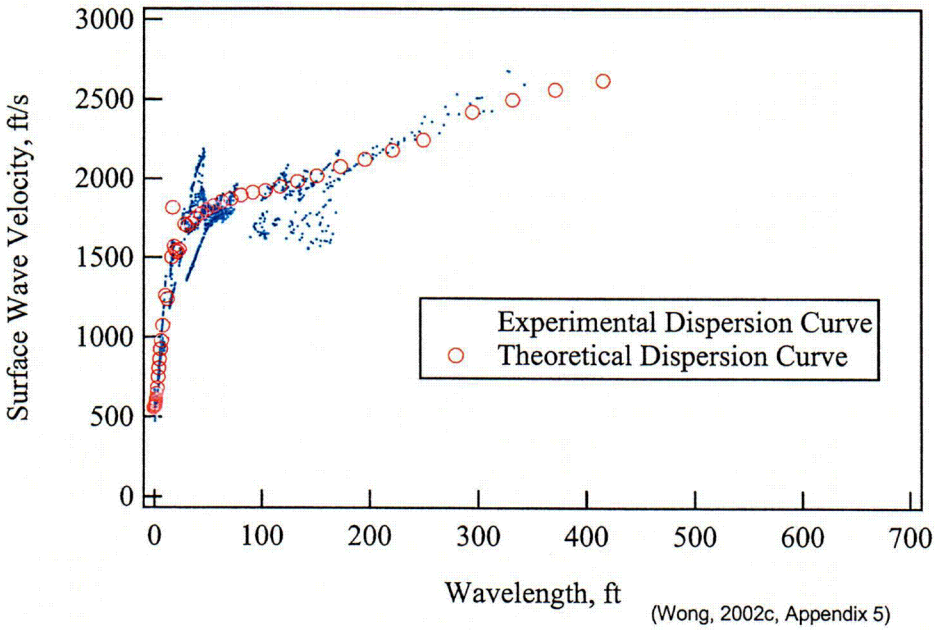
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 4)

Figure IX-4. SASW-4 Results (continued)



(Wong, 2002c, Appendix 5)

a. SASW-5 Dispersion Curves (Log Plot)

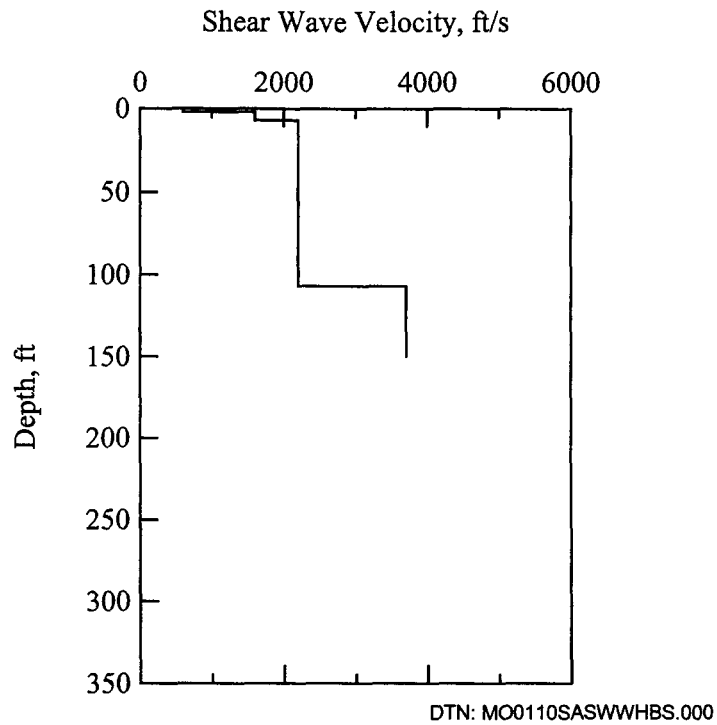


(Wong, 2002c, Appendix 5)

b. SASW-5 Dispersion Curves (Linear Plot)

Figure IX-5. SASW-5 Results

C05



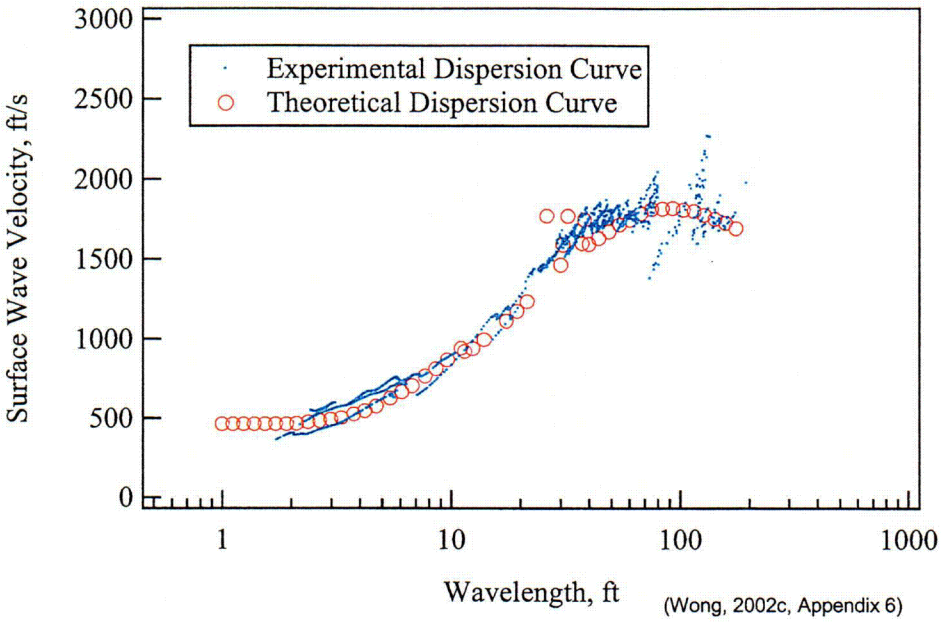
c. SASW-5 Shear Wave Velocity Profile

Location: SASW-5

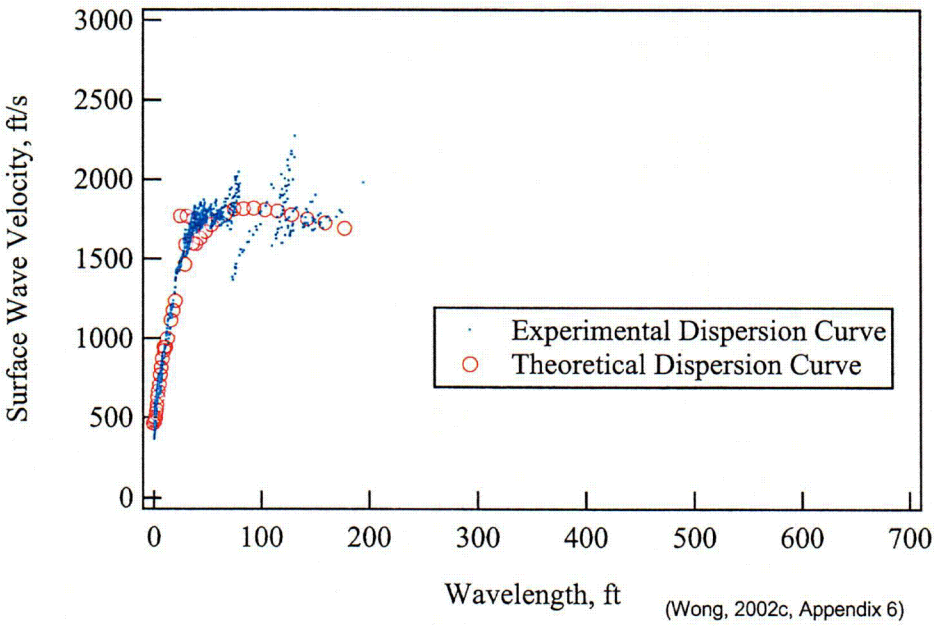
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2	1039	600	0.25	120
2	5	2771	1600	0.25	120
3	100	3810	2200	0.25	120
4	43	6408	3700	0.25	80

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 5)

Figure IX-5. SASW-5 Results (continued)



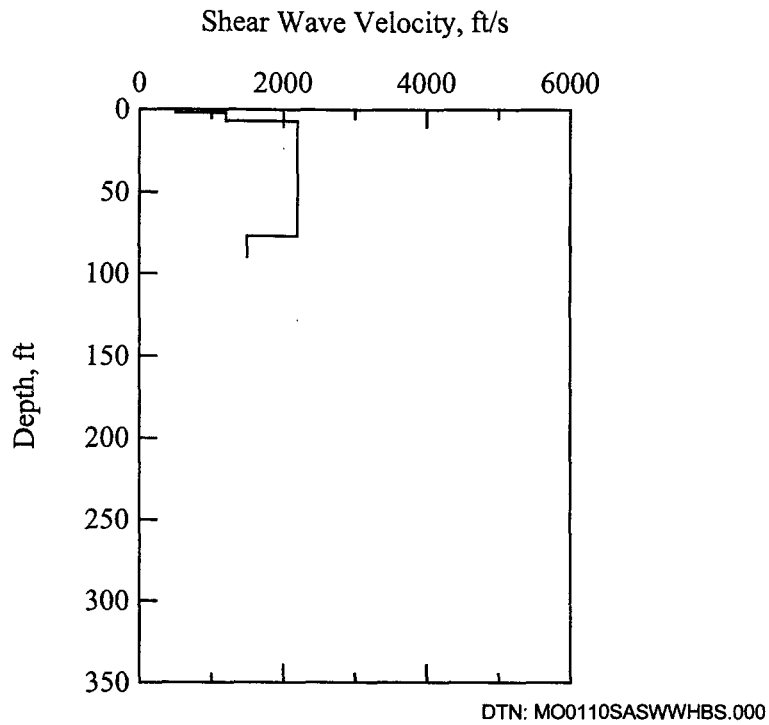
a. SASW-6 Dispersion Curves (Log Plot)



b. SASW-6 Dispersion Curves (Linear Plot)

Figure IX-6. SASW-6 Results

C06



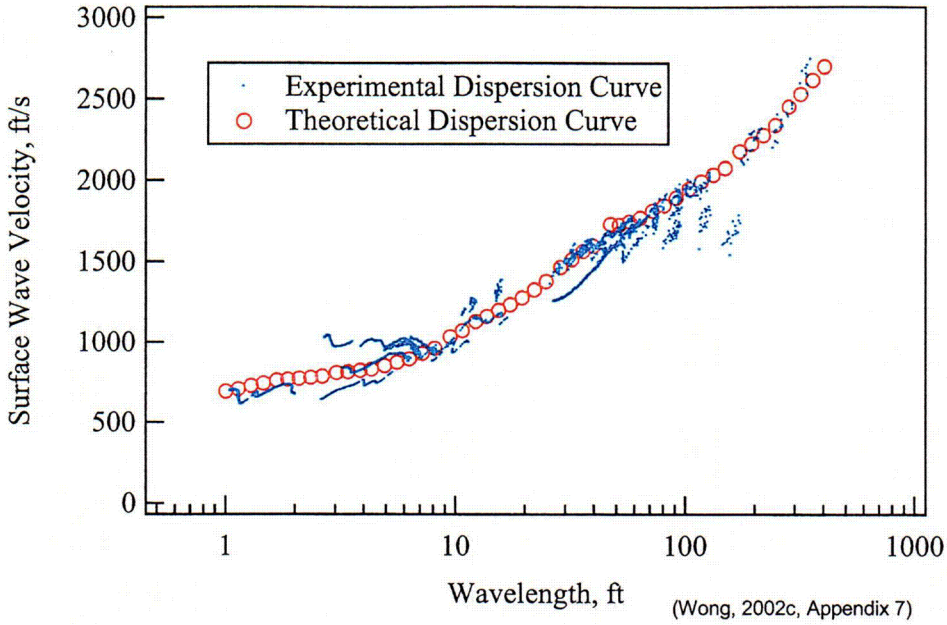
c. SASW-6 Shear Wave Velocity Profile

Location: SASW-6

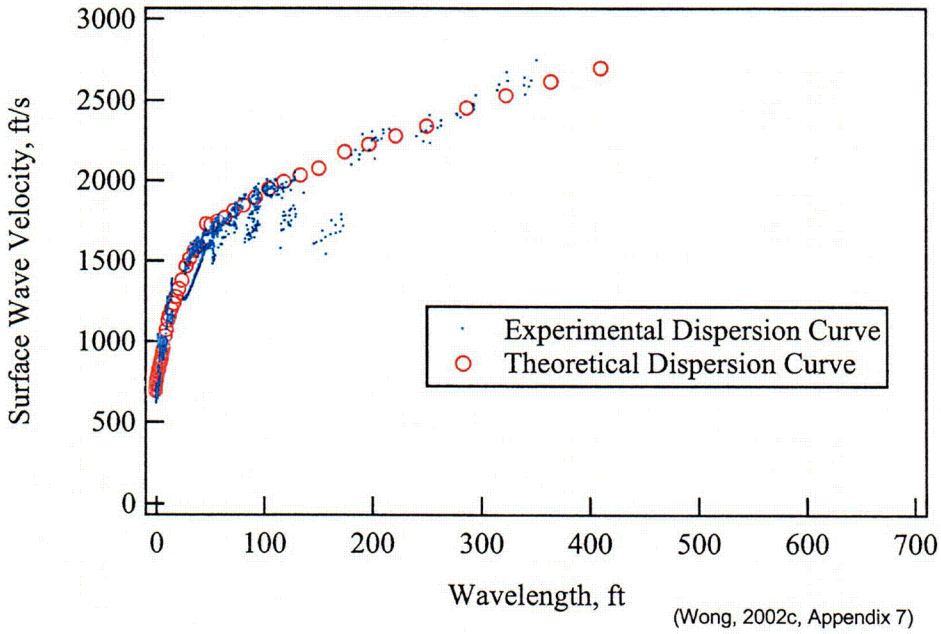
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2	866	500	0.25	120
2	5	2078	1200	0.25	120
3	50	3810	2200	0.25	120
4	20	3810	2200	0.25	120
5	13	2598	1500	0.25	120

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 6)

Figure IX-6. SASW-6 Results (continued)



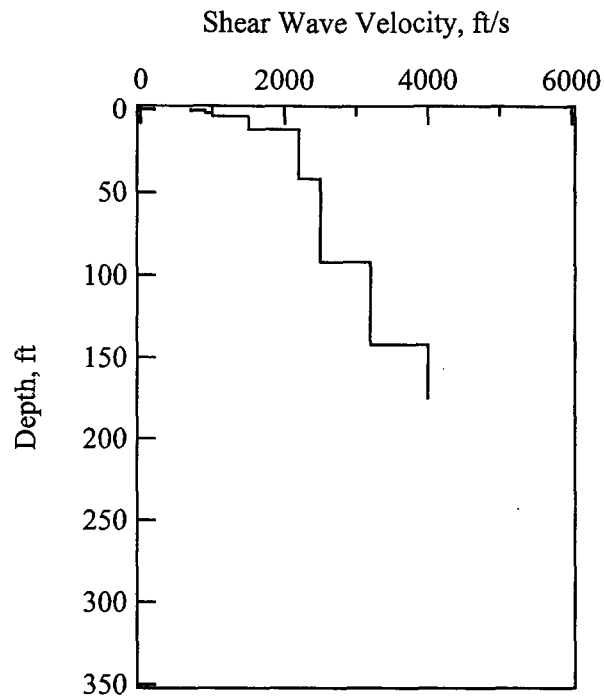
a. SASW-7 Dispersion Curves (Log Plot)



b. SASW-7 Dispersion Curves (Linear Plot)

Figure IX-7. SASW-7 Results (continued)

C07



DTN: MO0110SASWWHBS.000

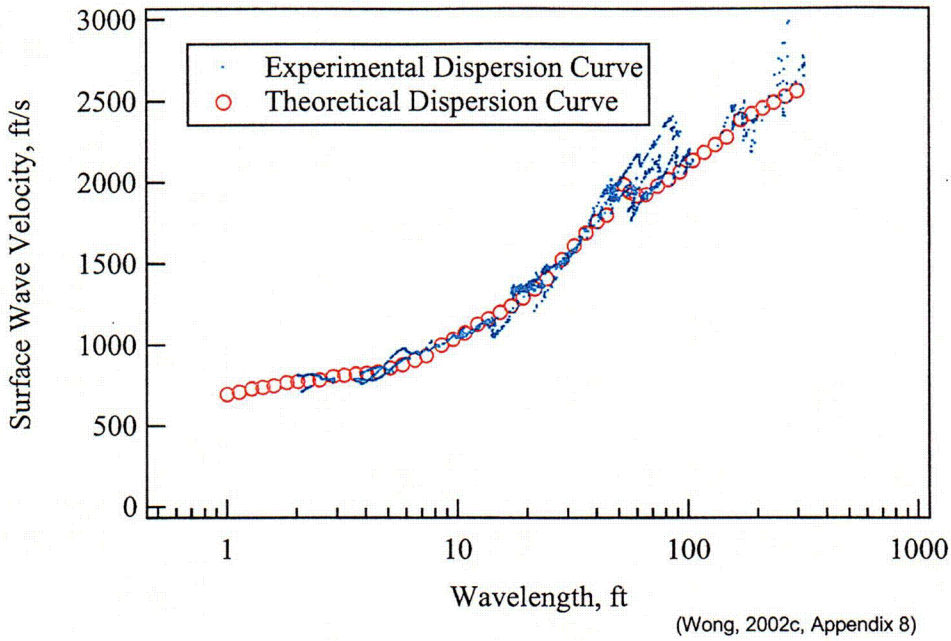
c. SASW-7 Shear Wave Velocity Profile

Location: SASW-7

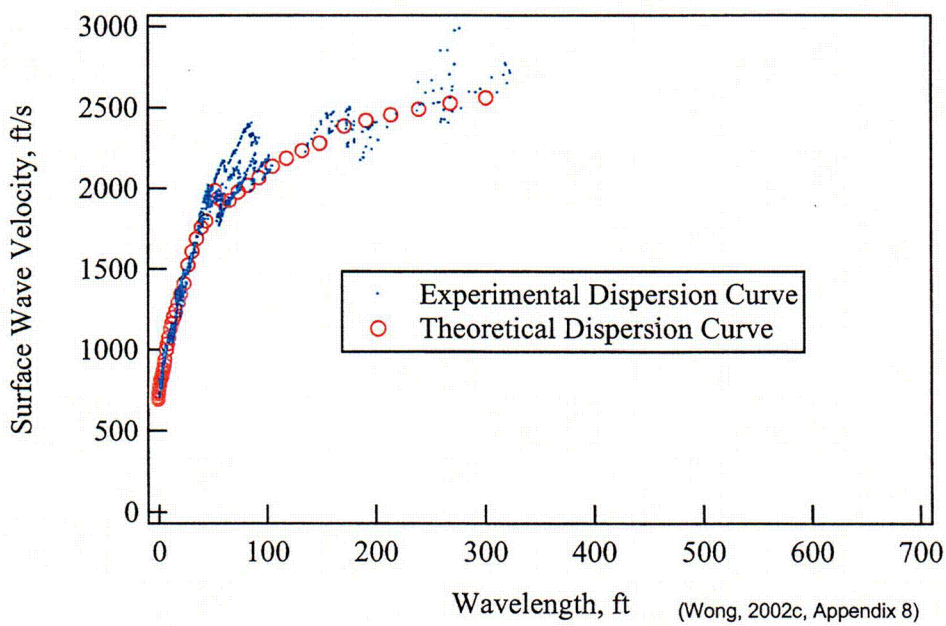
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.5	1212	700	0.25	120
2	1.5	1559	900	0.25	120
3	2.0	1732	1000	0.25	120
4	8.0	2598	1500	0.25	120
5	30	3810	2200	0.25	120
6	50	4330	2500	0.25	120
7	50	5542	3200	0.25	80
8	33	6982	4000	0.25	80

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 7)

Figure IX-7. SASW-7 Results (continued)



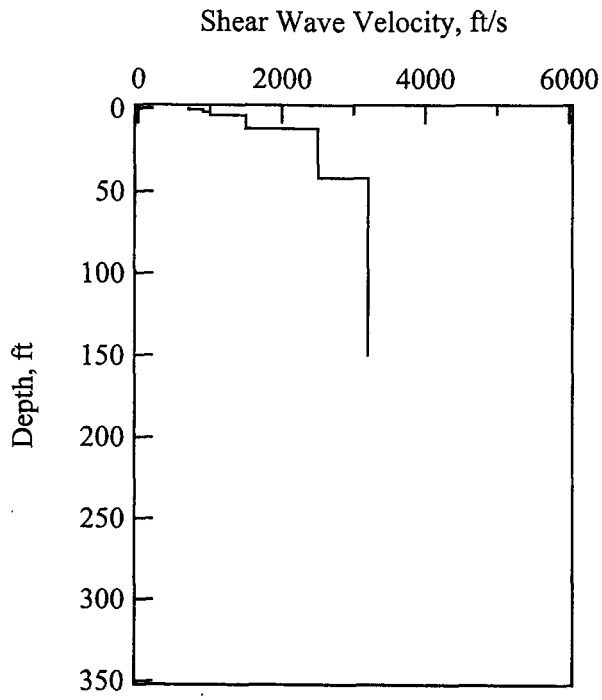
a. SASW-8 Dispersion Curves (Log Plot)



b. SASW-8 Dispersion Curves (Linear Plot)

Figure IX-8. SASW-8 Results

C08



DTN: MO0110SASWWHBS.000

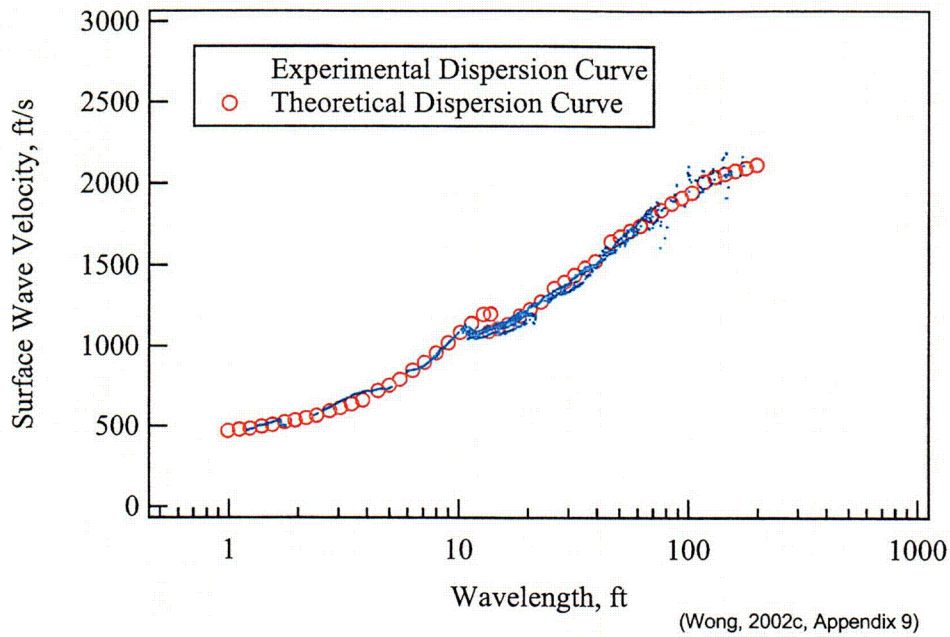
c. SASW-8 Shear Wave Velocity Profile

Location: SASW-8

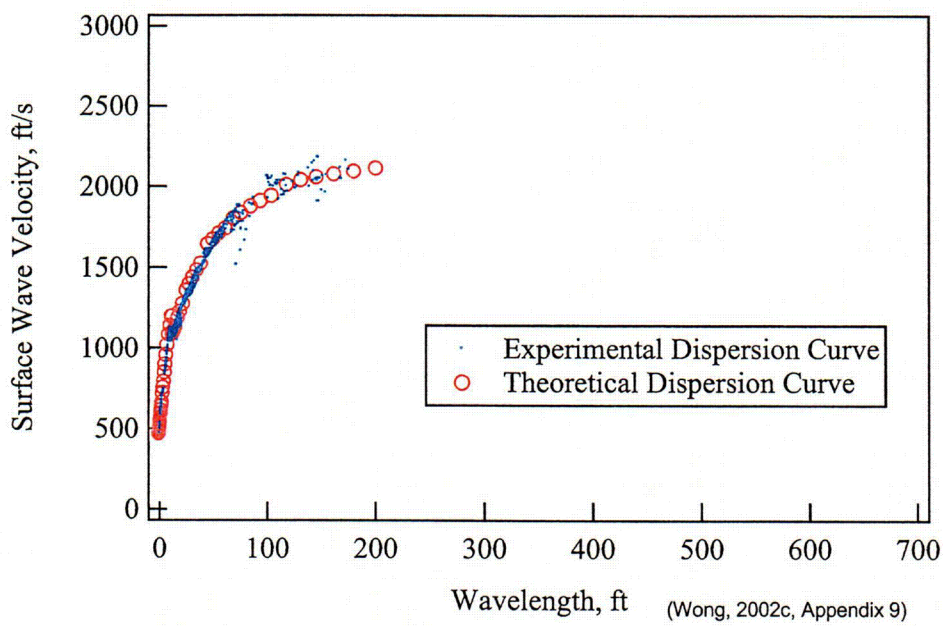
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.5	1212	700	0.25	120
2	1.5	1559	900	0.25	120
3	2.0	1732	1000	0.25	120
4	8	2598	1500	0.25	120
5	30	4330	2500	0.25	120
6	108	5543	3200	0.25	80

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 8)

Figure IX-8. SASW-8 Results (continued)



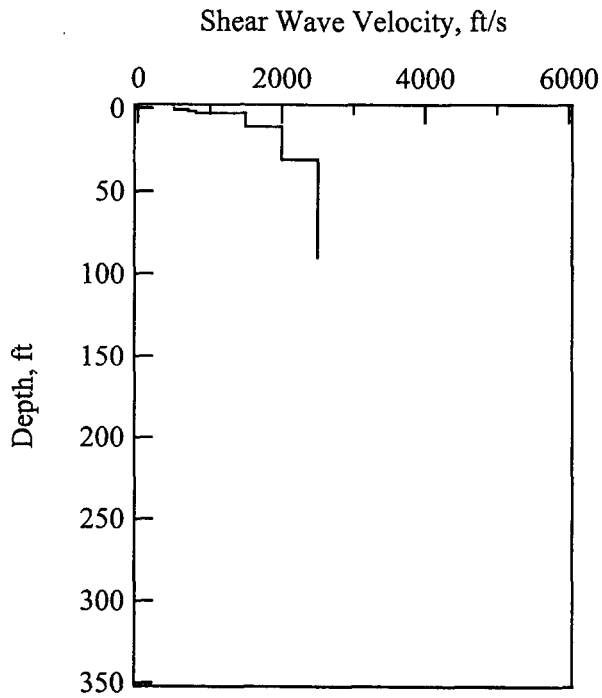
a. SASW-9 Dispersion Curves (Log Plot)



b. SASW-9 Dispersion Curves (Linear Plot)

Figure IX-9. SASW-9 Results

C09



DTN: MO0110SASWWHBS.000

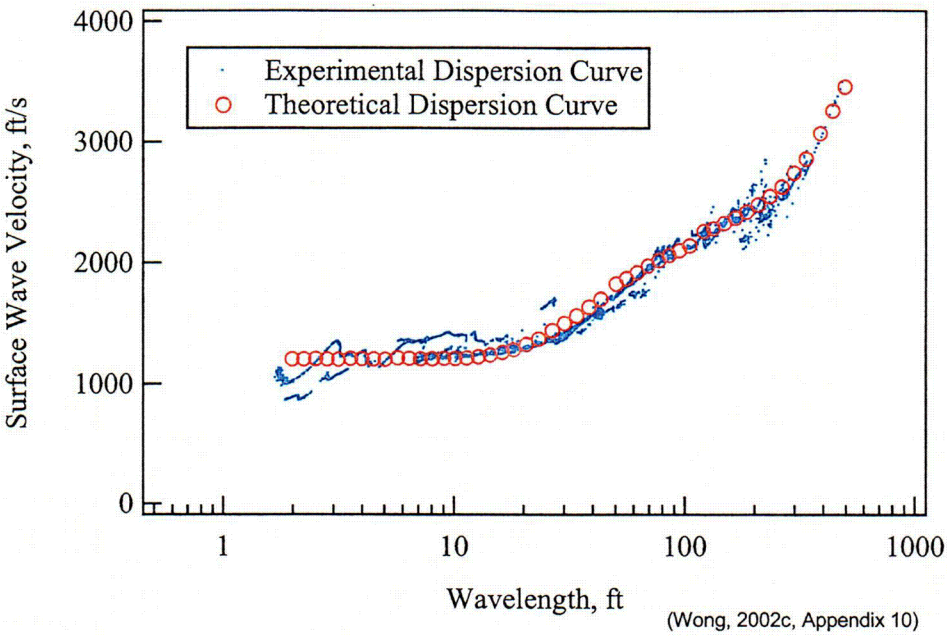
c. SASW-9 Shear Wave Velocity Profile

Location: SASW-9

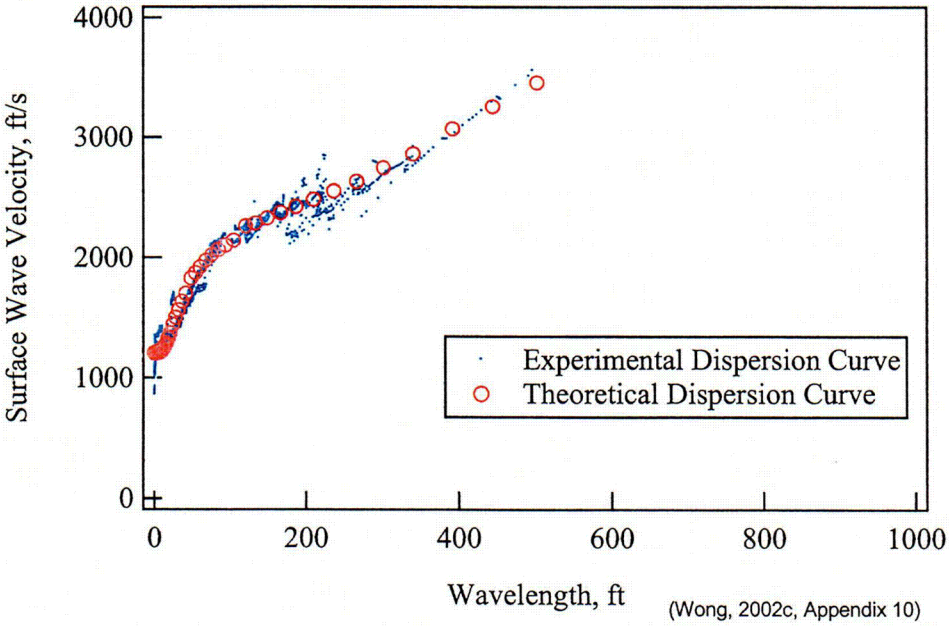
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.75	866	500	0.25	120
2	1	1212	700	0.25	120
3	1	1559	800	0.25	120
4	8	2598	1500	0.25	120
5	20	3464	2000	0.25	120
6	59	4330	2500	0.25	120

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 9)

Figure IX-9. SASW-9 Results (continued)



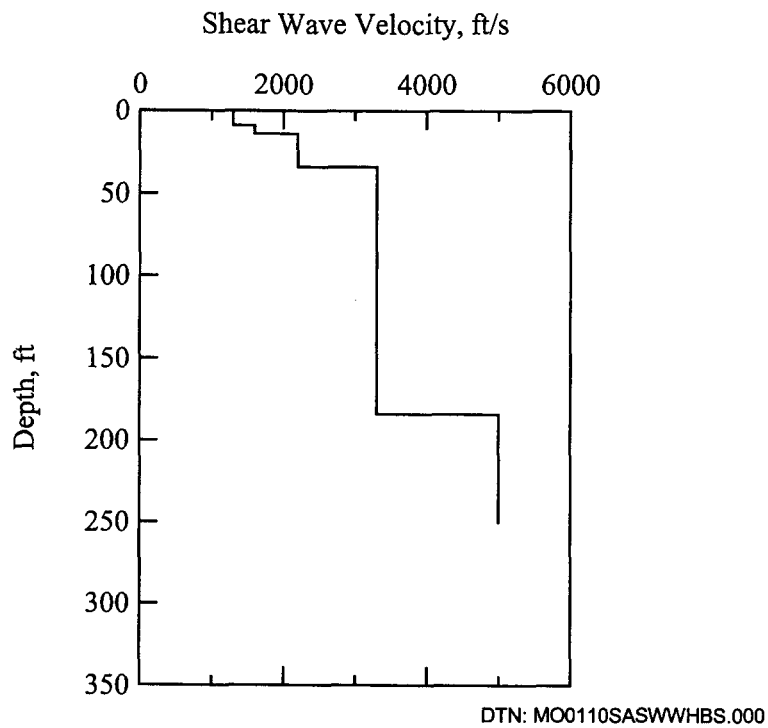
a. SASW-10+37 Dispersion Curves (Log Plot)



b. SASW-10+37 Dispersion Curves (Linear Plot)

Figure IX-10. SASW-10+37 Results

C10



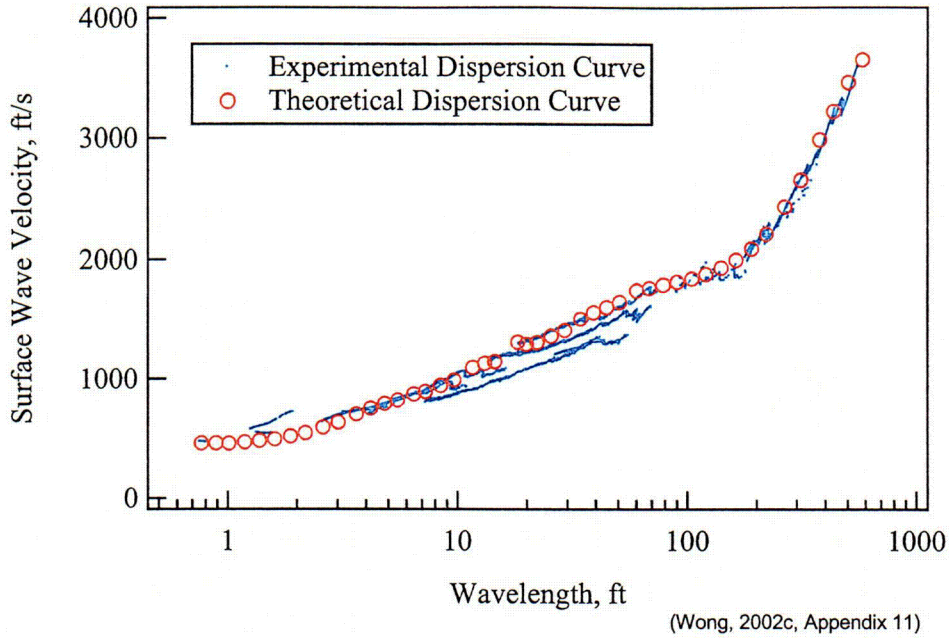
c. SASW-10+37 Shear Wave Velocity Profile

Location: SASW-10+37

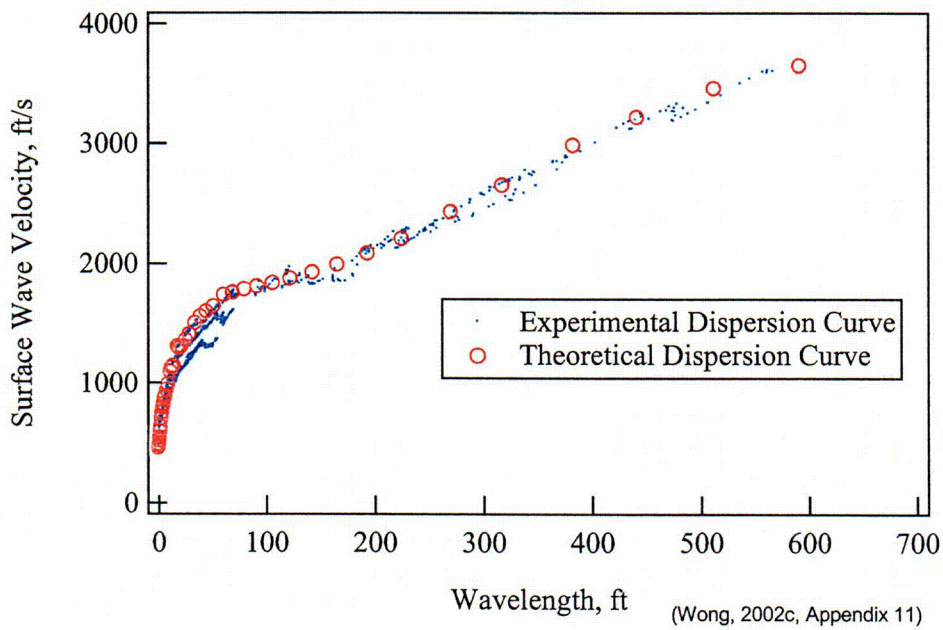
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	2251	1300	0.25	120
2	8	2251	1300	0.25	120
3	5	2771	1600	0.25	120
4	20	3810	2200	0.25	120
5	150	5716	3300	0.25	80
6	66	8660	5000	0.25	145

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 10)

Figure IX-10. SASW-10+37 Results (continued)



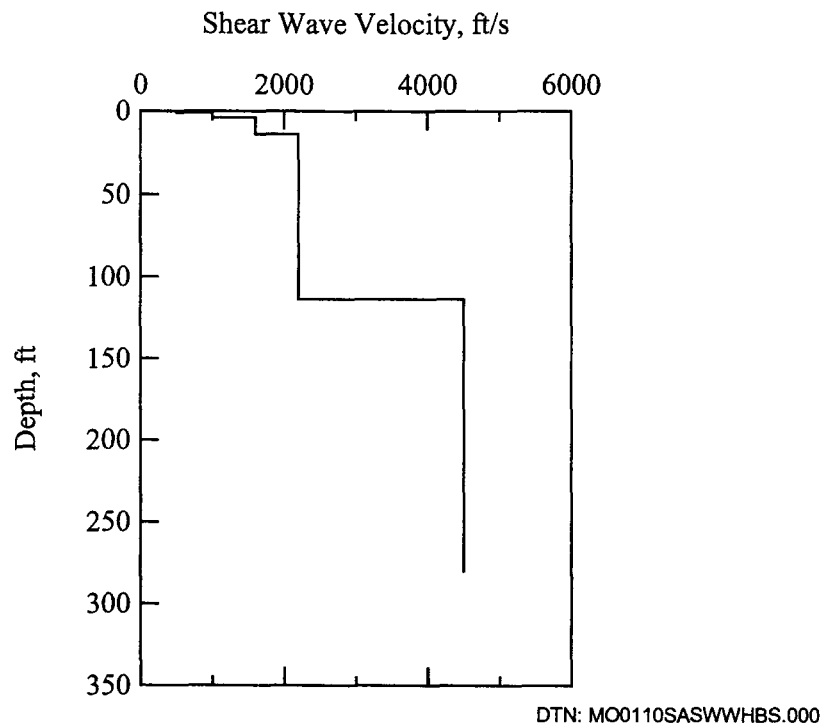
a. SASW-11 Dispersion Curves (Log Plot)



b. SASW-11 Dispersion Curves (Linear Plot)

Figure IX-11. SASW-11 Results

C11



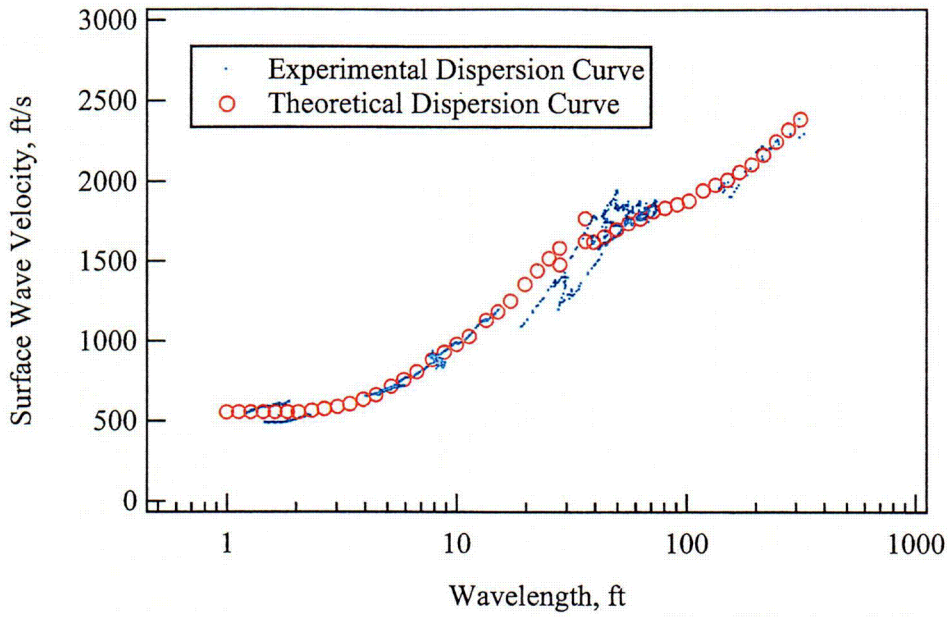
c. SASW-11 Shear Wave Velocity Profile

Location: SASW-11

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	866	500	0.25	120
2	3	1732	1000	0.25	120
3	10	2771	1600	0.25	120
4	100	3810	2200	0.25	120
5	166	7794	4500	0.25	145

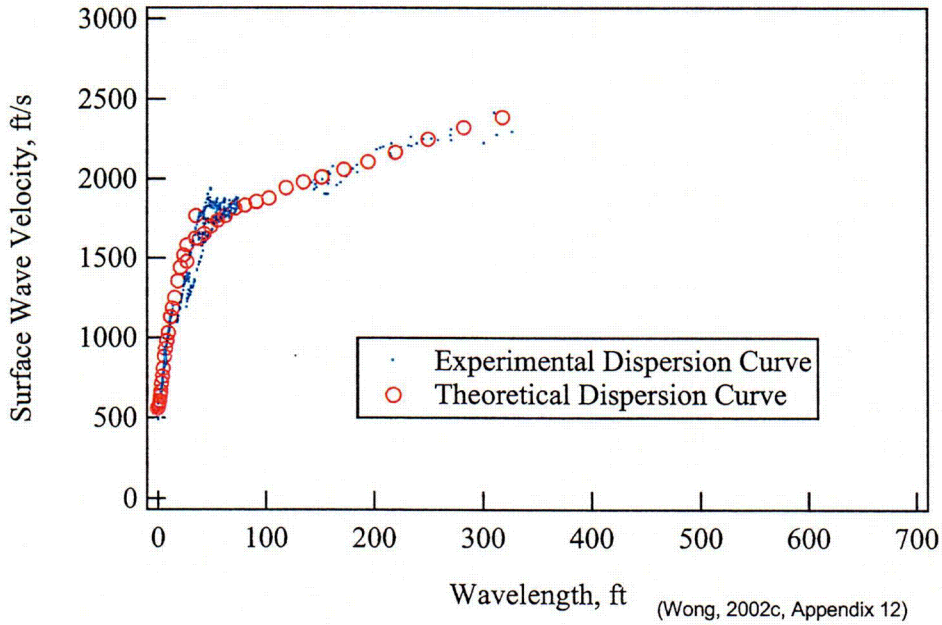
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 11)

Figure IX-11. SASW-11 Results (continued)



(Wong, 2002c, Appendix 12)

a. SASW-12 Dispersion Curves (Log . .--,

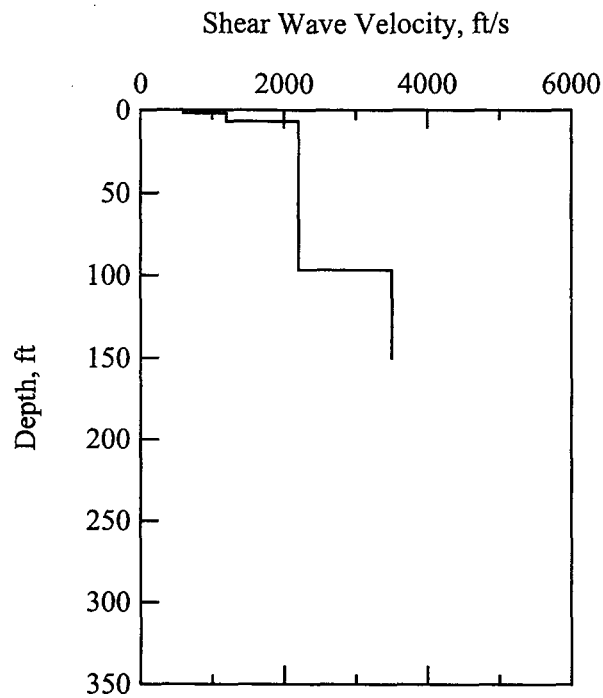


(Wong, 2002c, Appendix 12)

b. SASW-12 Dispersion Curves (Linear Plot)

Figure IX-12. SASW-12 Results

C12



DTN: MO0110SASWWHBS.000

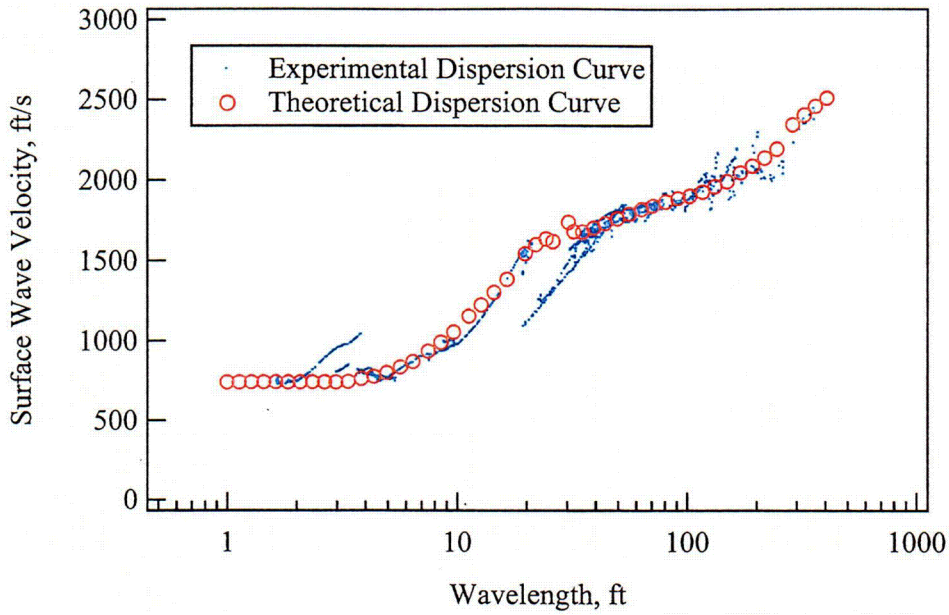
c. SASW-12 Shear Wave Velocity Profile

Location: SASW-12

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2	1039	600	0.25	120
2	5	2078	1200	0.25	120
3	90	3810	2200	0.25	120
4	53	6062	3500	0.25	80

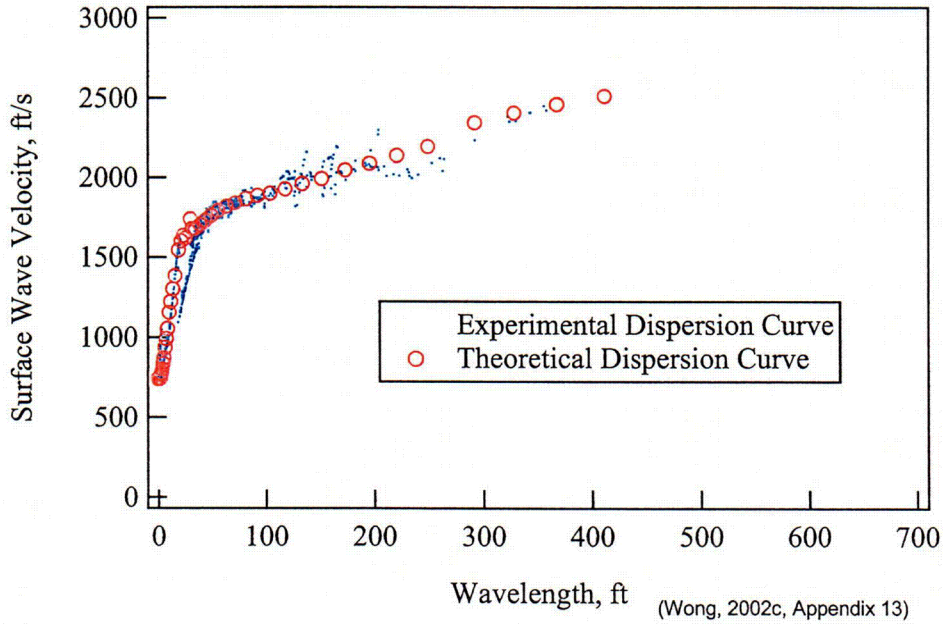
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 12)

Figure IX-12. SASW-12 Results (continued)



(Wong, 2002c, Appendix 13)

a. SASW-13 Dispersion Curves (Log Plot)

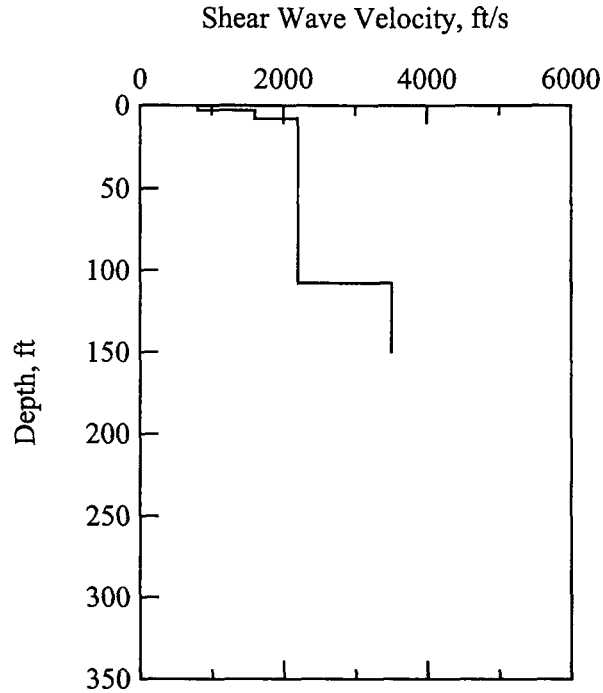


(Wong, 2002c, Appendix 13)

b. SASW-13 Dispersion Curves (Linear Plot)

Figure IX-13. SASW-13 Results

C13



DTN: MO0110SASWWHBS.000

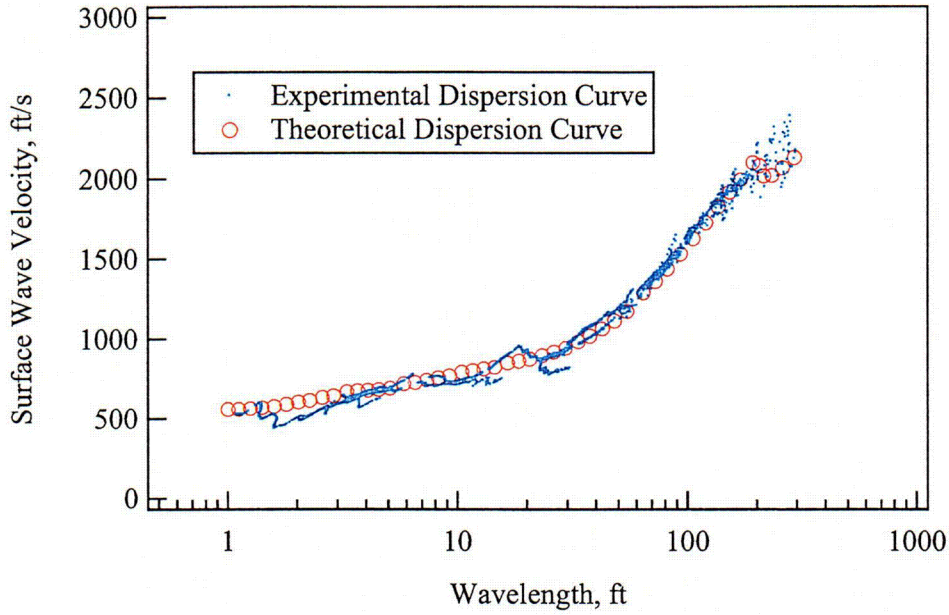
c. SASW-13 Shear Wave Velocity Profile

Location: SASW-13

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	3	1385	800	0.25	120
2	5	2771	1600	0.25	120
3	100	3810	2200	0.25	120
4	42	6062	3500	0.25	80

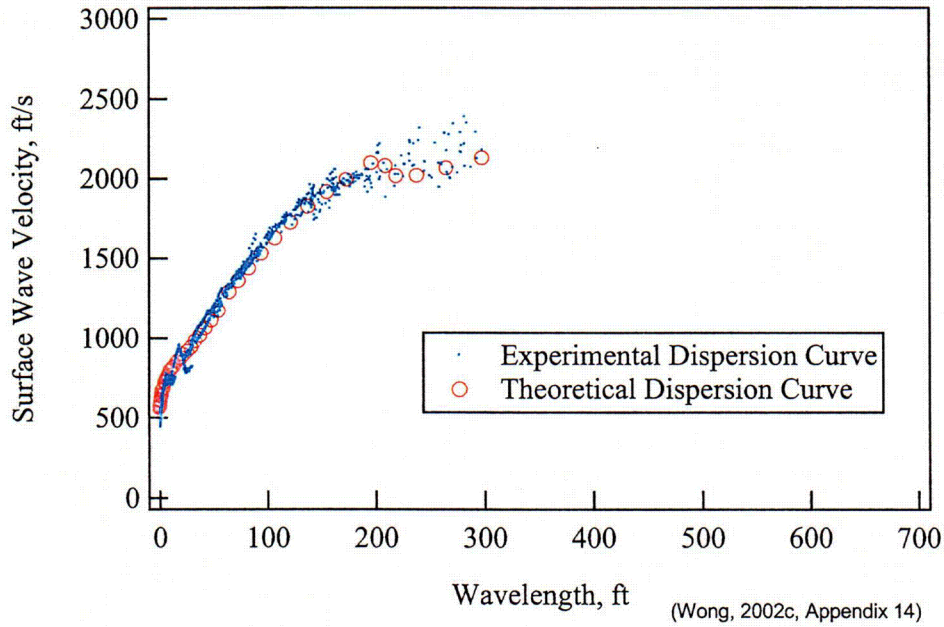
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 13)

Figure IX-13. SASW-13 Results (continued)



(Wong, 2002c, Appendix 14)

a. SASW-14 Dispersion Curves (Log Plot)

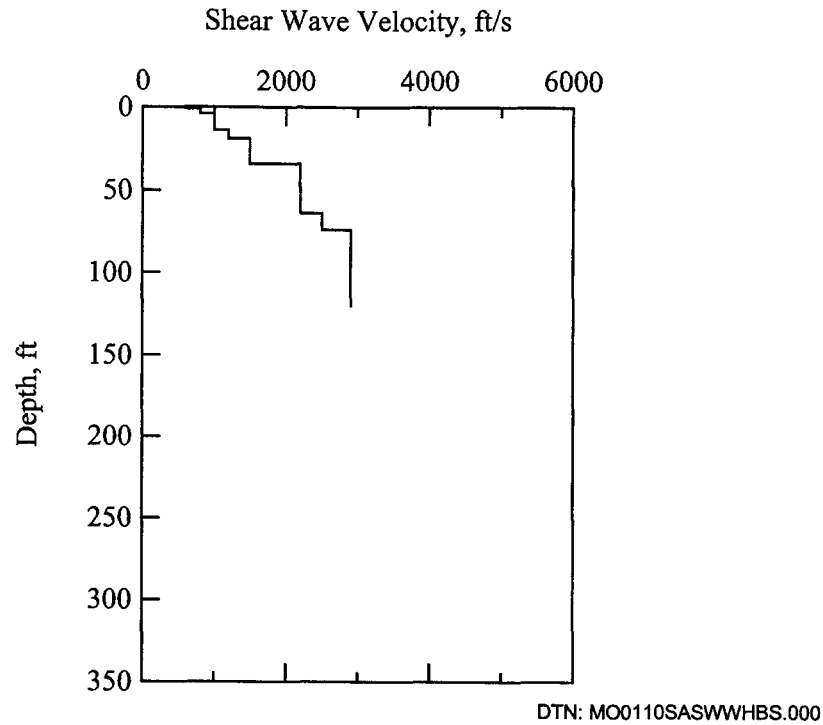


(Wong, 2002c, Appendix 14)

b. SASW-14 Dispersion Curves (Linear Plot)

Figure IX-14. SASW-14 Results

C14



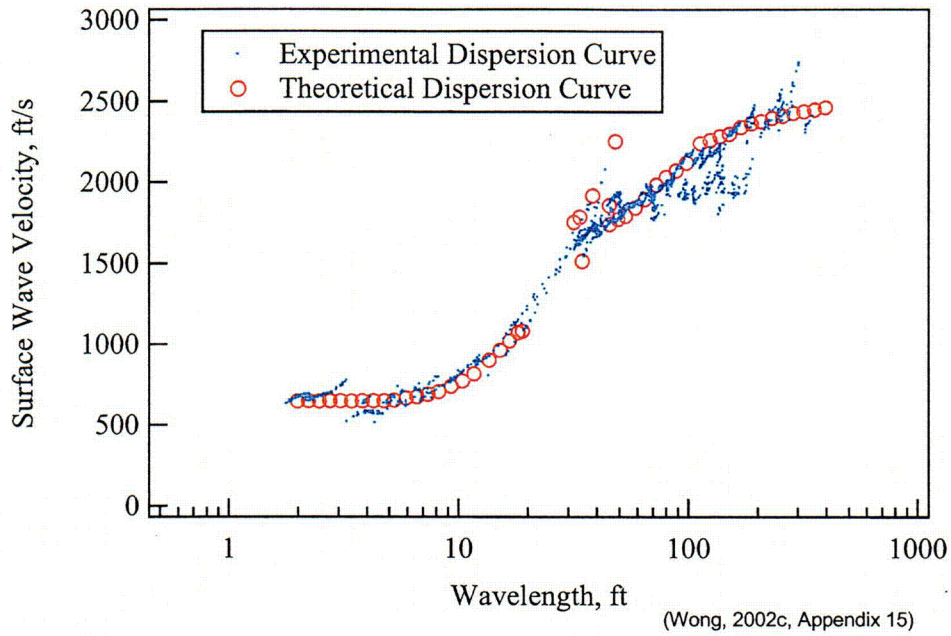
c. SASW-14 Shear Wave Velocity Profile

Location: SASW-14

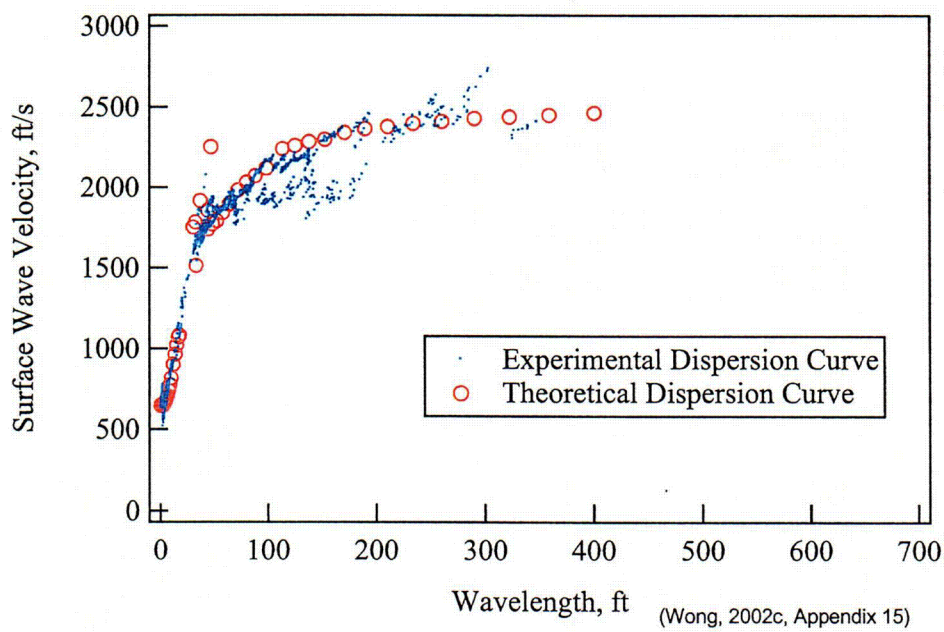
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	1039	600	0.25	120
2	3	1386	800	0.25	120
3	10	1732	1000	0.25	120
4	5	2078	1200	0.25	120
5	15	2598	1500	0.25	120
6	30	3810	2200	0.25	120
7	10	4330	2500	0.25	120
8	46	5023	2900	0.25	120

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 14)

Figure IX-14. SASW-14 Results (continued)



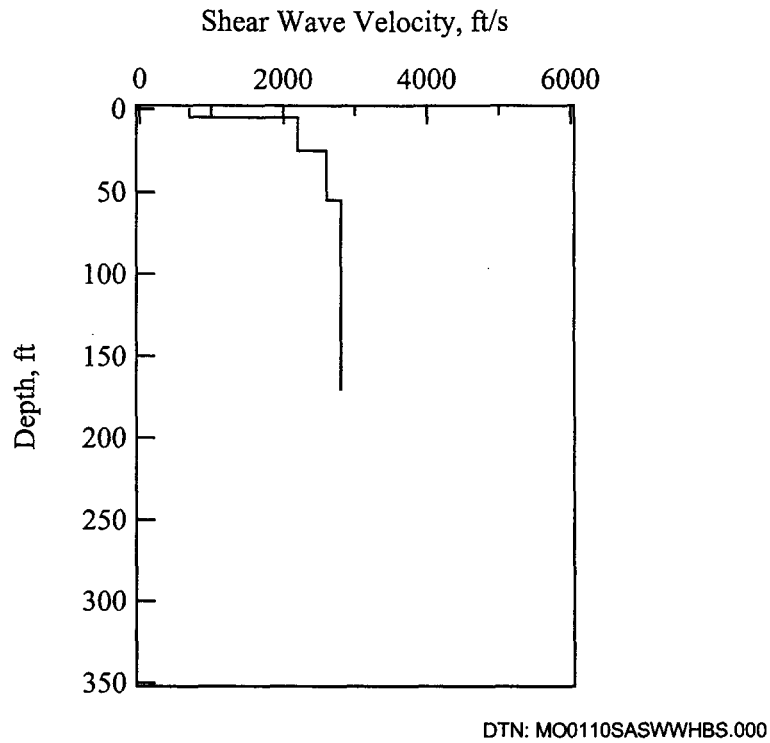
a. SASW-15 Dispersion Curves (Log Plot)



b. SASW-15 Dispersion Curves (Linear Plot)

Figure IX-15. SASW-15 Results

C15



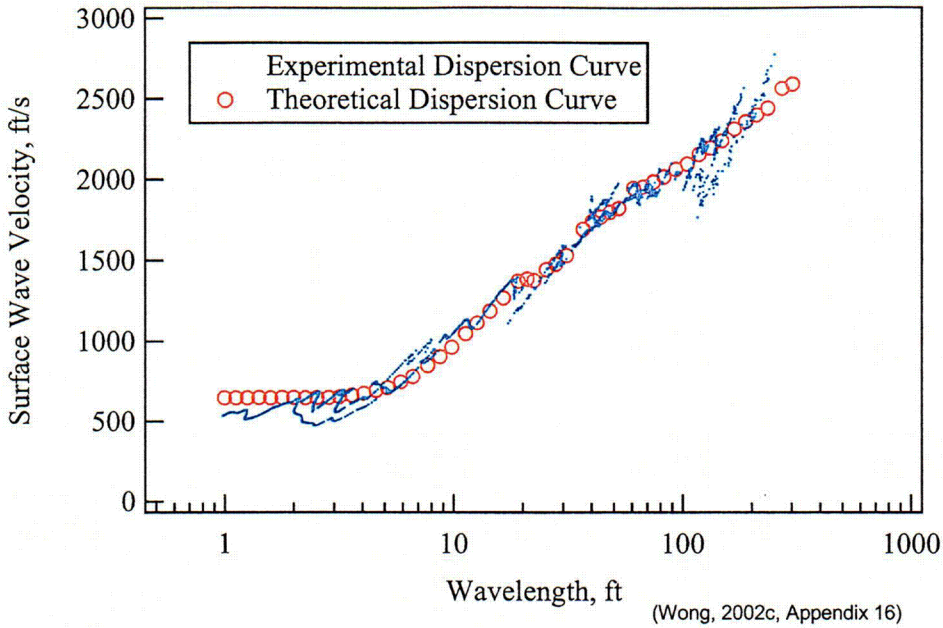
c. SASW-15 Shear Wave Velocity Profile

Location: SASW-15

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	5	1212	700	0.25	120
2	20	3810	2200	0.25	120
3	30	4503	2600	0.25	120
4	115	4850	2800	0.25	120

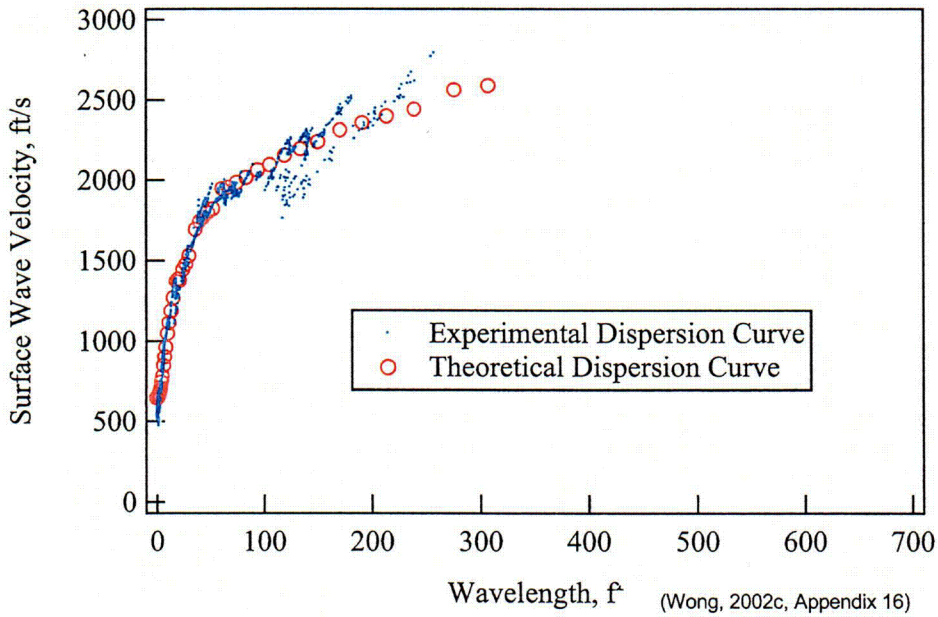
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 15)

Figure IX-15. SASW-15 Results (continued)



(Wong, 2002c, Appendix 16)

a. SASW-16 Dispersion Curves (Log Plot)

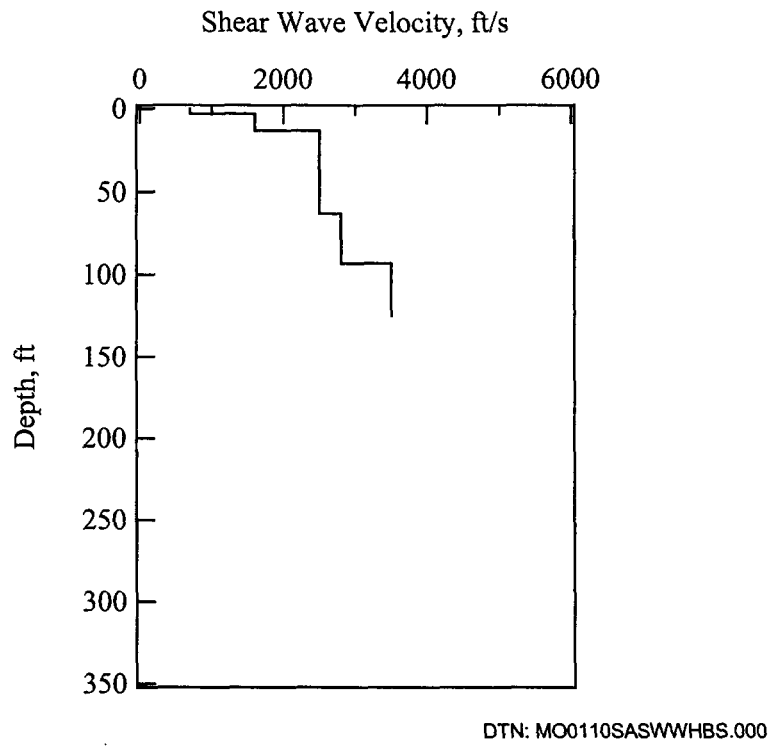


(Wong, 2002c, Appendix 16)

b. SASW-16 Dispersion Curves (Linear Plot)

Figure IX-16. SASW-16 Results

C16



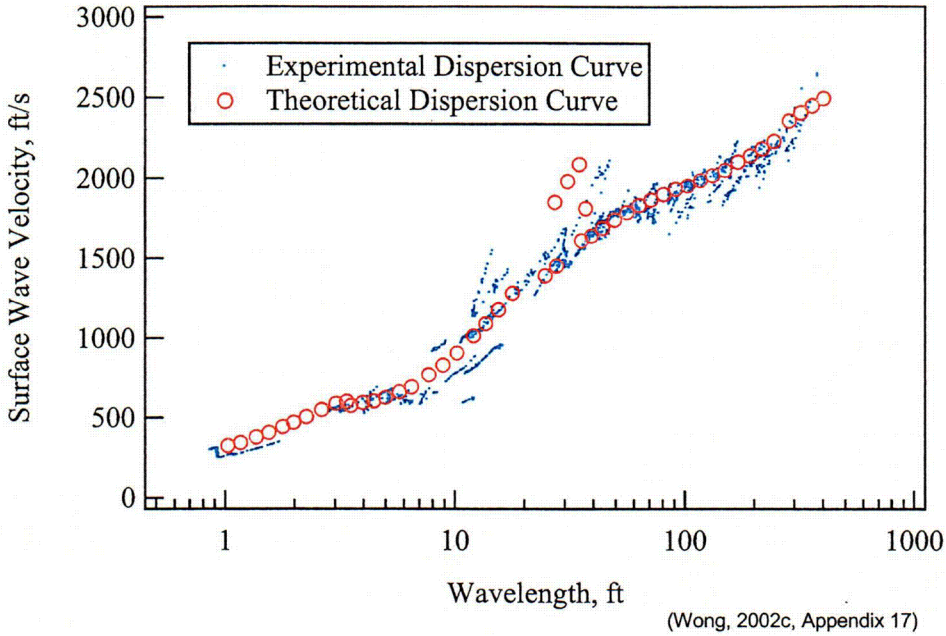
c. SASW-16 Shear Wave Velocity Profile

Location: SASW-16

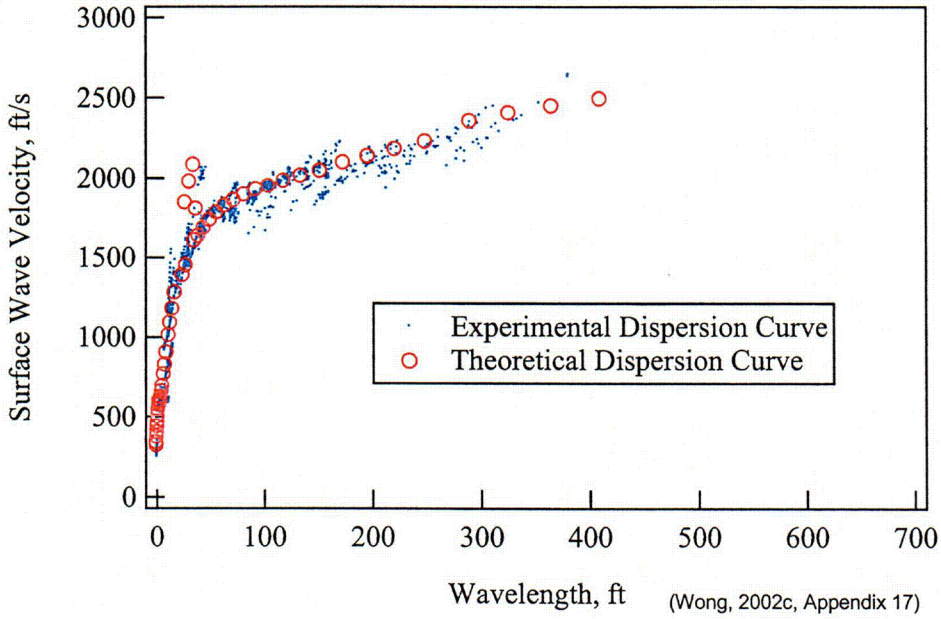
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	5	1212	700	0.25	120
2	10	2741	1600	0.25	120
3	50	4330	2500	0.25	120
4	30	4850	2800	0.25	120
5	32	6062	3500	0.25	80

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 16)

Figure IX-16. SASW-16 Results (continued)



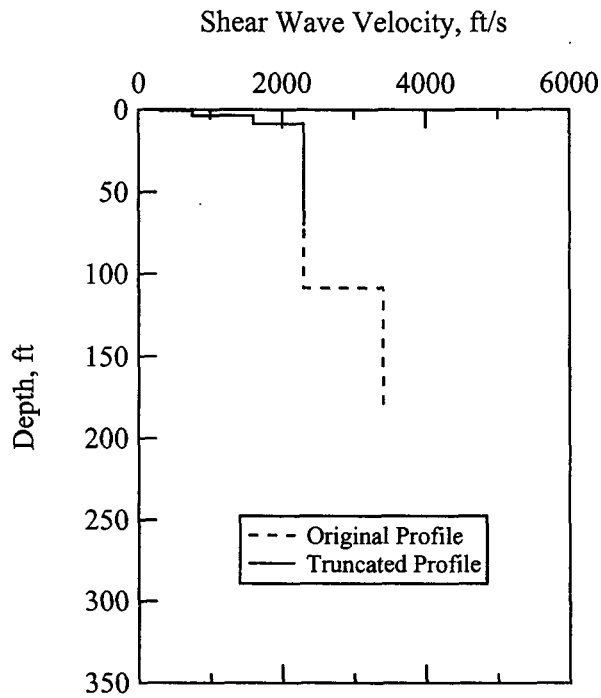
a. SASW-17 Dispersion Curves (Log Plot)



b. SASW-17 Dispersion Curves (Linear Plot)

Figure IX-17. SASW-17 Results

C17



DTN: MO0110SASWWHBS.000

c. SASW-17 Shear Wave Velocity Profile

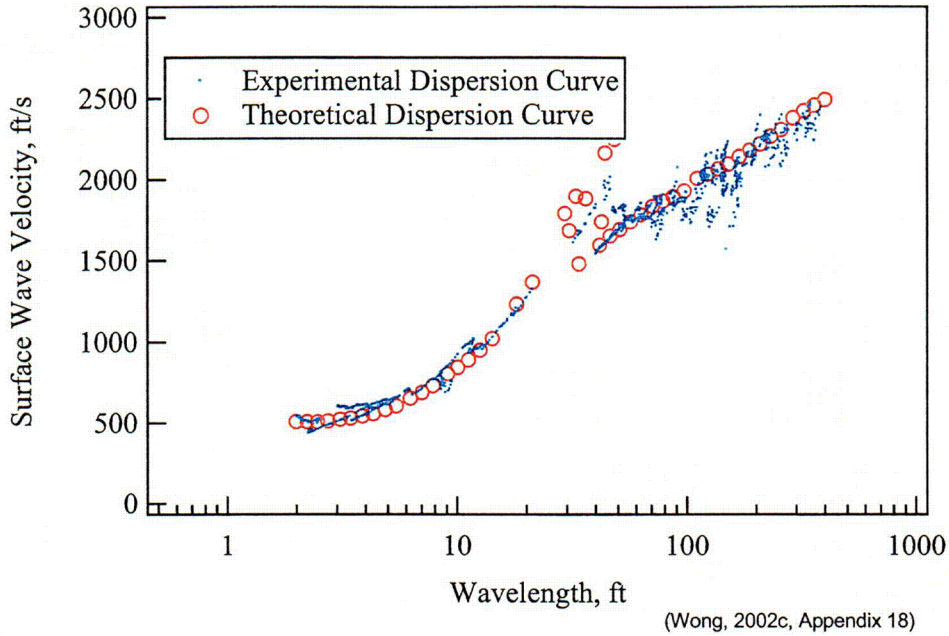
Location: SASW-17

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio***	Mass Density*** pcf
1	0.5	520	300	0.25	120
2	3	1299	750	0.25	120
3	5	2771	1600	0.25	120
4	62.5*	3983	2300	0.25	120
5	37.5**	3983	2300	0.25	120
6	72**	5889	3400	0.25	80

DTN: MO0110SASWWHBS.000

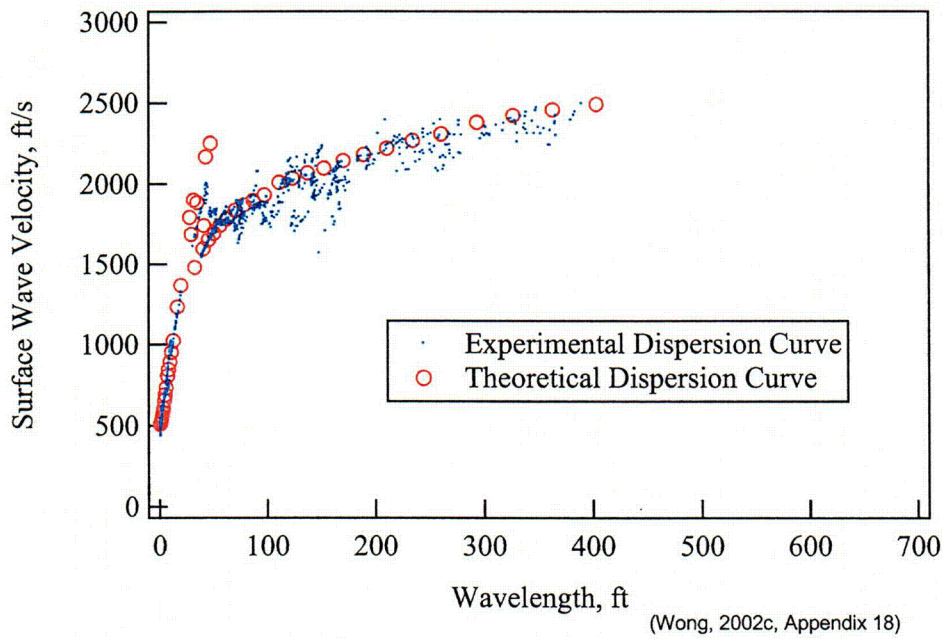
* Vs profile truncated at 70 ft based on geological profile showing an offset fault beginning at a depth of approximately 70 ft.
** Additional layering used in matching the theoretical dispersion curve to the complete experimental dispersion curve
*** Poisson's ratio and mass density from Wong (2002c, Appendix 17)

Figure IX-17. SASW-17 Results (continued)



(Wong, 2002c, Appendix 18)

a. SASW-18 Dispersion Curves (Log Plot)

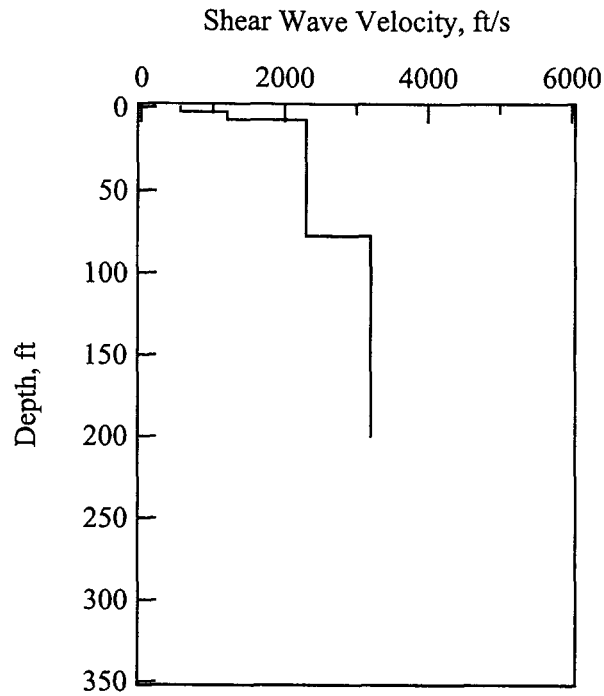


(Wong, 2002c, Appendix 18)

b. SASW-18 Dispersion Curves (Linear Plot)

Figure IX-18. SASW-18 Results

C18



DTN: MO0110SASWWHBS.000

c. SASW-18 Shear Wave Velocity Profile

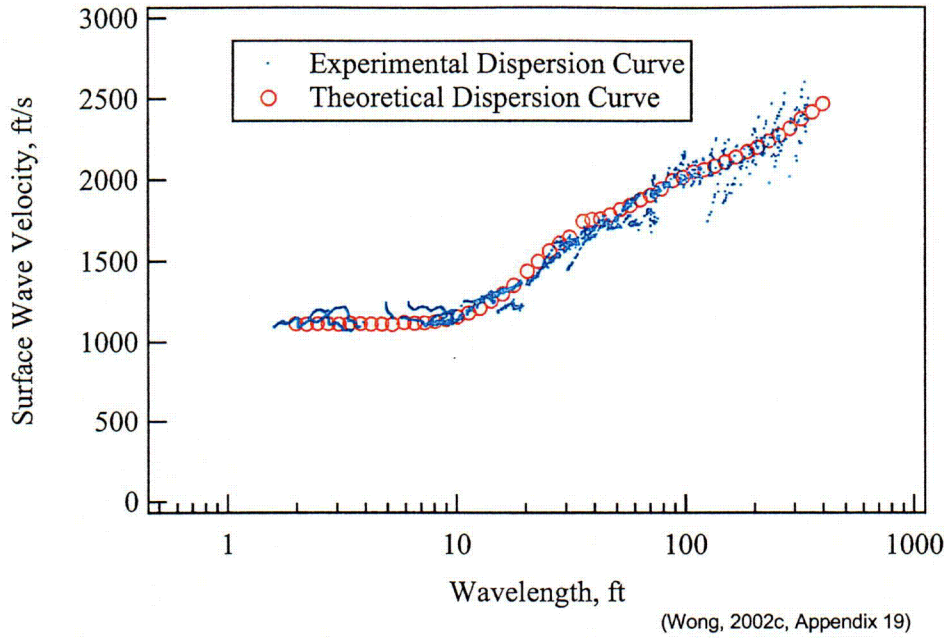
Location: SASW-18

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* cf
1	2.5	952	550	0.25	120
2	5	2078	1200	0.25	120
3	70	3983	2300	0.25	120
4	123	5542	3200	0.25	80

DTN: MO0110SASWWHBS.000

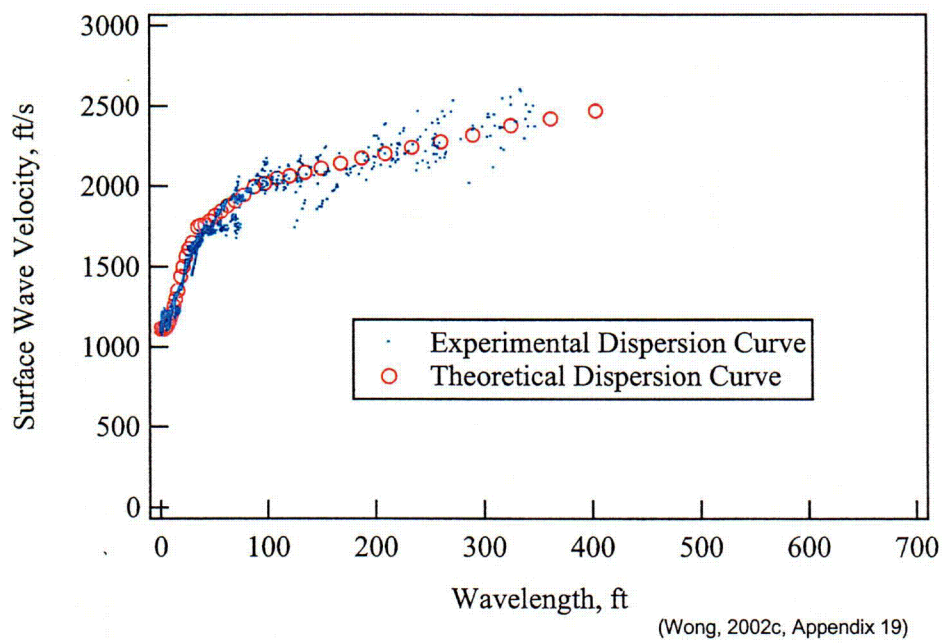
* Poisson's ratio and mass density from Wong (2002c, Appendix 18)

Figure IX-18. SASW-18 Results (continued)



(Wong, 2002c, Appendix 19)

a. SASW-19 Dispersion Curves (Log Plot)

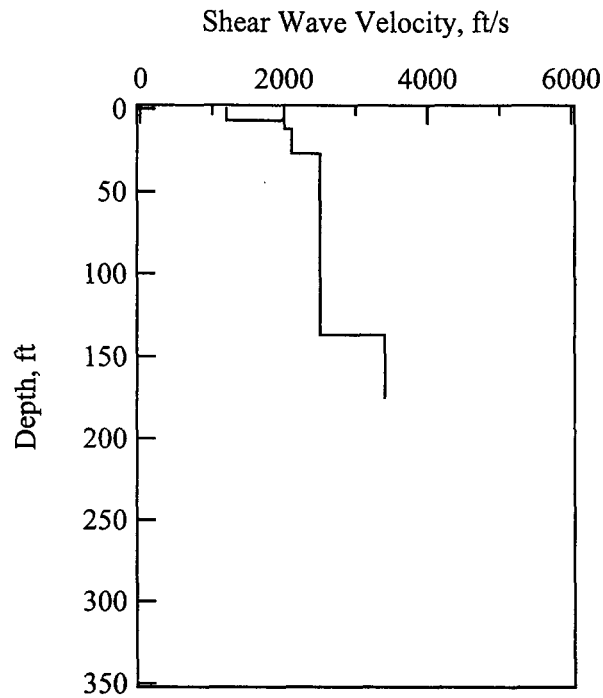


(Wong, 2002c, Appendix 19)

b. SASW-19 Dispersion Curves (Linear Plot)

Figure IX-19. SASW-19 Results

C19



DTN: MO0110SASWWHBS.000

c. SASW-19 Shear Wave Velocity Profile

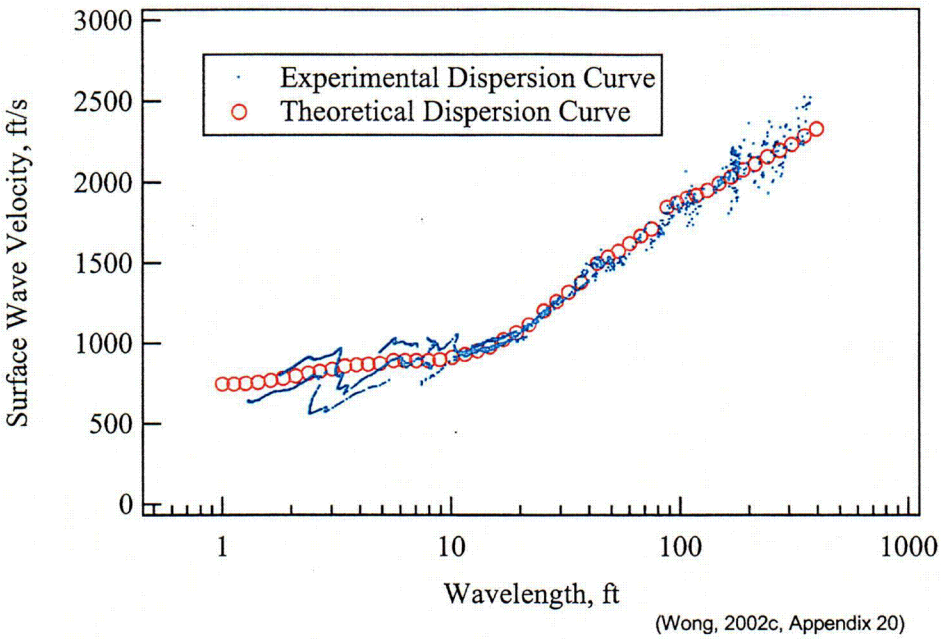
Location: SASW-19

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	7	2079	1200	0.25	120
2	5	3464	2000	0.25	120
3	15	3637	2100	0.25	120
4	110	4300	2500	0.25	120
5	38	5889	3400	0.25	80

DTN: MO0110SASWWHBS.000

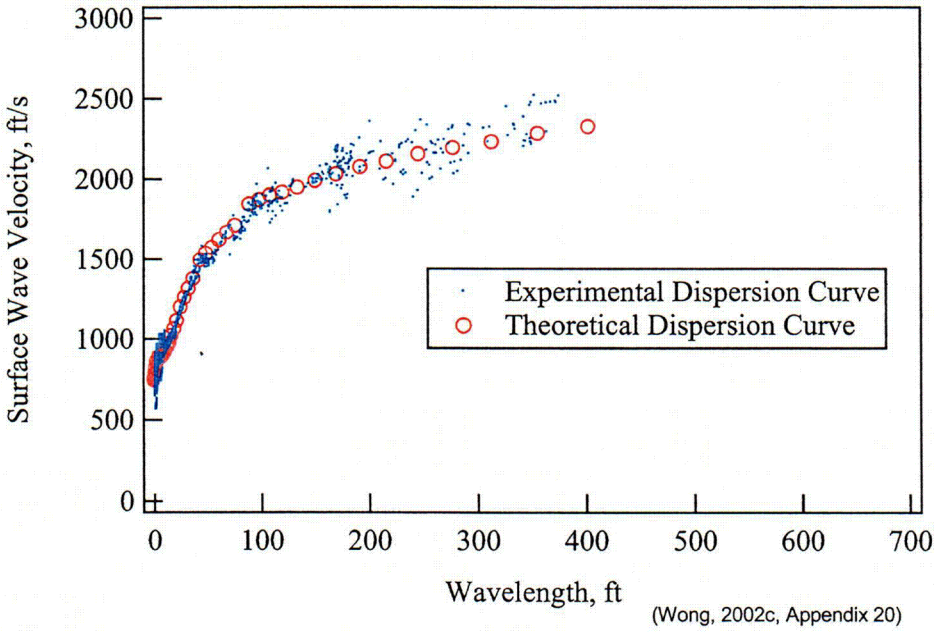
* Poisson's ratio and mass density from Wong (2002c, Appendix 19)

Figure IX-19. SASW-19 Results (continued)



(Wong, 2002c, Appendix 20)

a. SASW-20 Dispersion Curves (Log Plot)

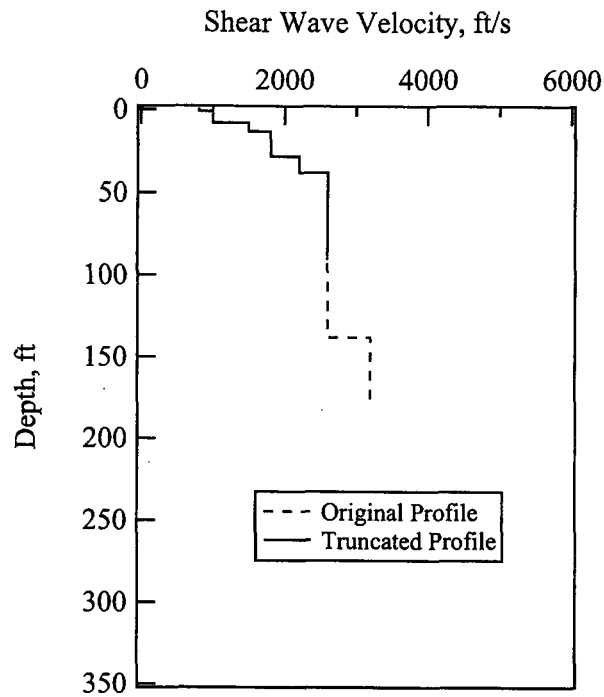


(Wong, 2002c, Appendix 20)

b. SASW-20 Dispersion Curves (Linear Plot)

Figure IX-20. SASW-20 Results

C20



DTN: MO0110SASWWHBS.000

c. SASW-20 Shear Wave Velocity Profile

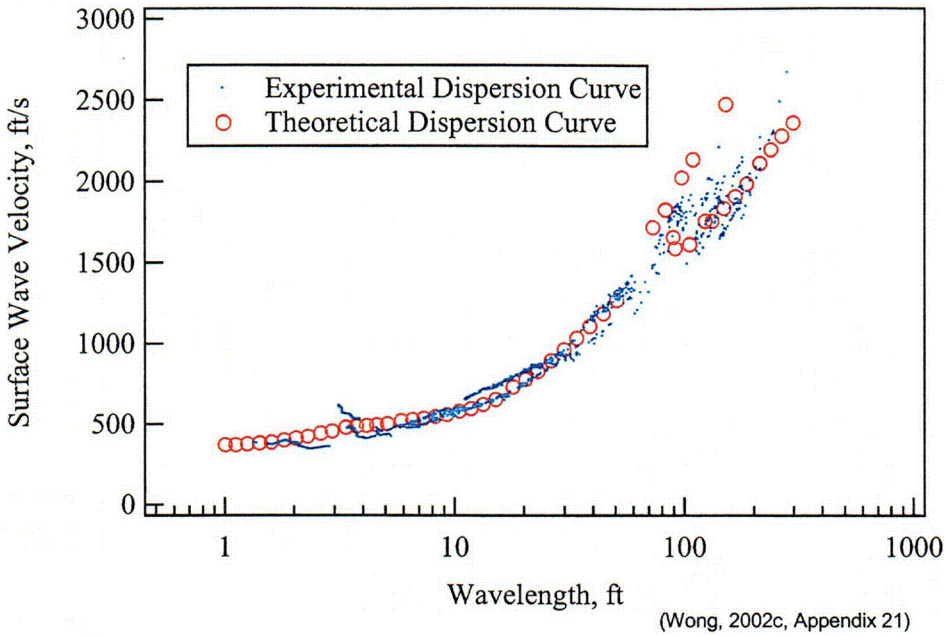
Location: SASW-20

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio***	Mass Density*** pcf
1	1	1386	800	0.25	120
2	7	1732	1000	0.25	120
3	5	2598	1500	0.25	120
4	15	3117	1800	0.25	120
5	10	3810	2200	0.25	120
6	52*	4503	2600	0.25	120
7	48**	4503	2600	0.25	120
8	37**	5542	3200	0.25	80

DTN: MO0110SASWWHBS.000

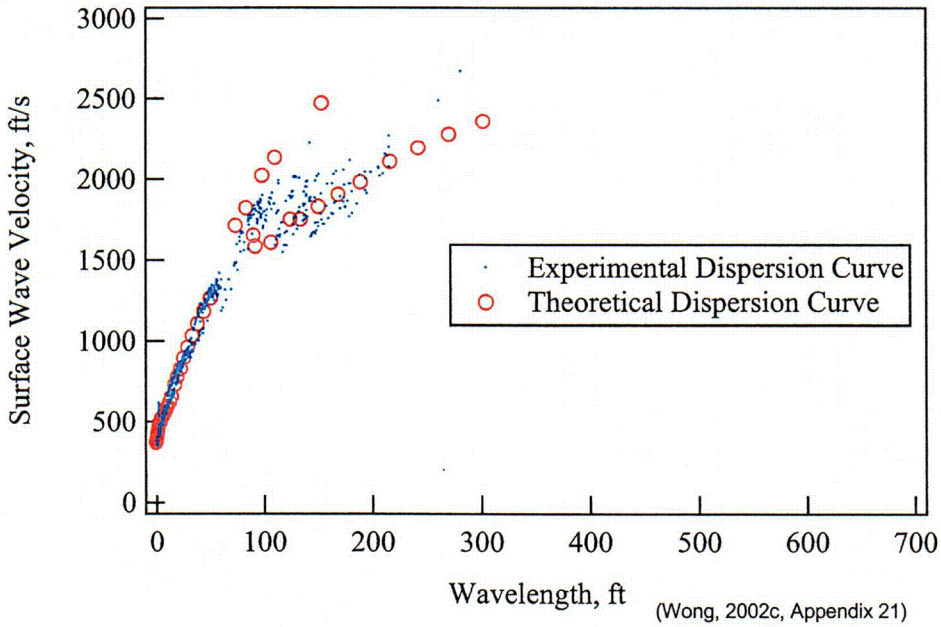
* Vs profile truncated at 90 ft based on geological profile showing an offset fault beginning at a depth of approximately 90 ft. (Attachment I)
** Additional layering used in matching the theoretical dispersion curve to the complete experimental dispersion curve
*** Poisson's ratio and mass density from Wong (2002c, Appendix 20)

Figure IX-20. SASW Results (continued)



(Wong, 2002c, Appendix 21)

a. SASW-21 Dispersion Curves (Log Plot)

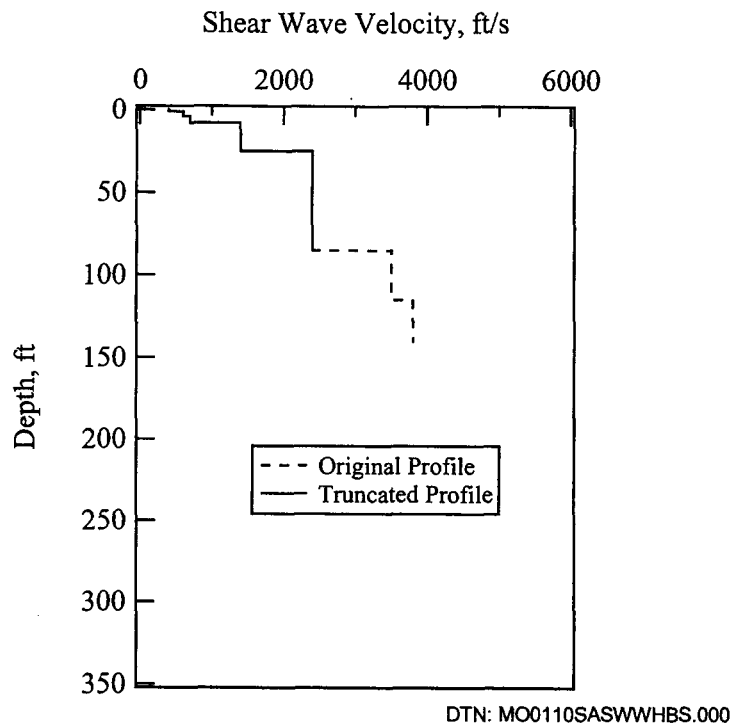


(Wong, 2002c, Appendix 21)

b. SASW-21 Dispersion Curves (Linear Plot)

Figure IX-21. SASW-21 Results

C21



c. SASW-21 Shear Wave Velocity Profile

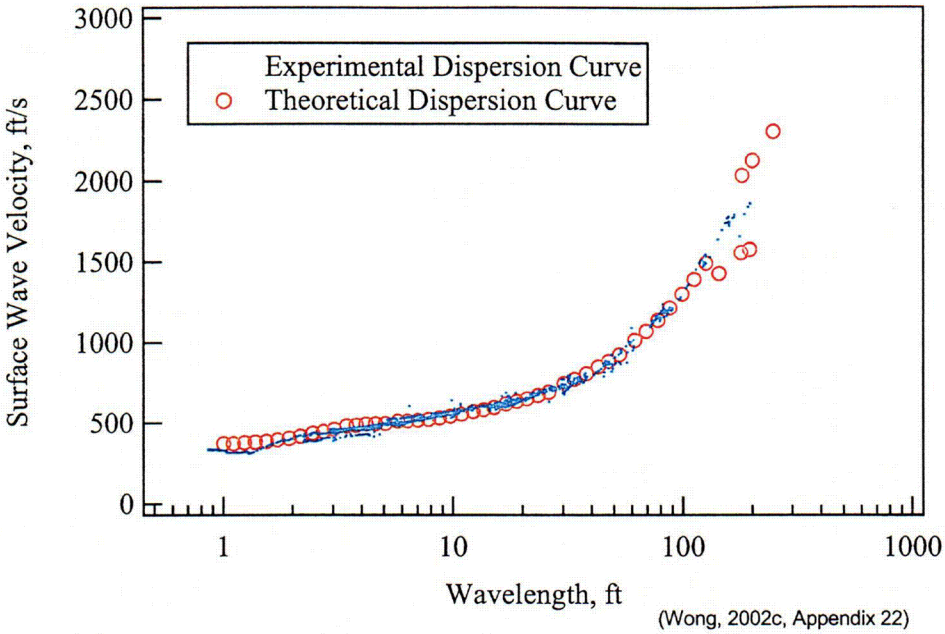
Location: SASW-21

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio***	Mass Density*** pcf
1	1	692	400	0.25	120
2	3	1039	600	0.25	120
3	4	1212	700	0.25	120
4	17	2424	1400	0.25	120
5	60*	4157	2400	0.25	120
6	30**	6062	3500	0.25	80
7	25**	6581	3800	0.25	80

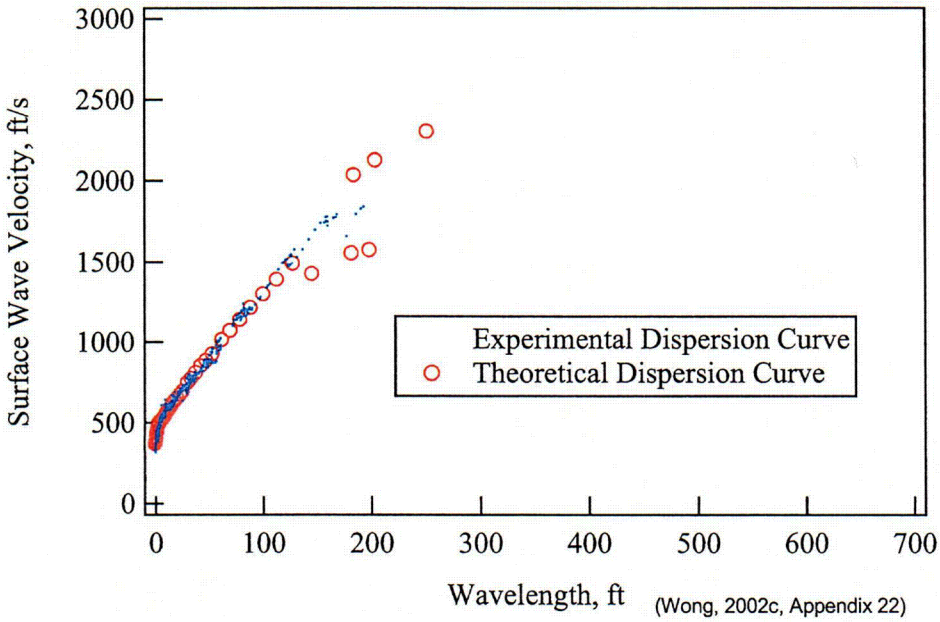
DTN: MO0110SASWWHBS.000

* Vs profile truncated at 85 ft based on geological profile showing an offset fault beginning at a depth of approximately 85 ft.
** Additional layering used in matching the theoretical dispersion curve to the complete experimental dispersion curve
*** Poisson's ratio and mass density from Wong (2002c, Appendix 21)

Figure IX-21. SASW-21 Results (continued)



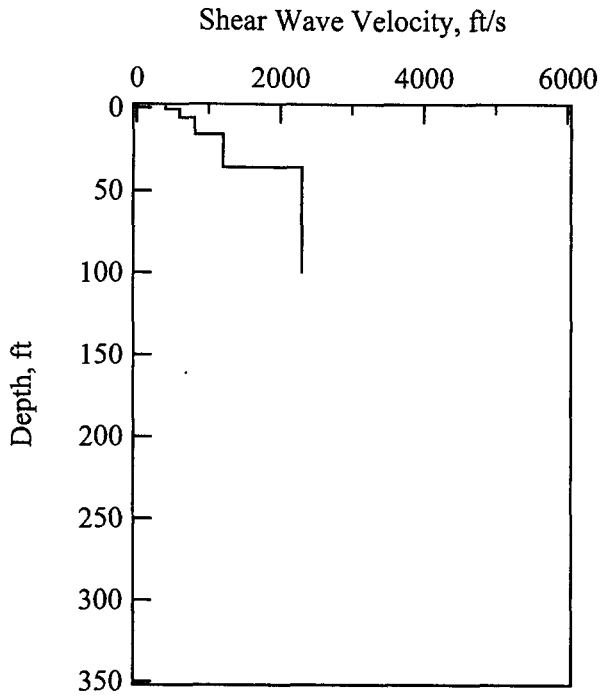
a. SASW-22 Dispersion Curves (Log Plot)



b. SASW-22 Dispersion Curves (Linear Plot)

Figure IX-22. SASW-22 Results

C22



DTN: MO0110SASWWHBS.000

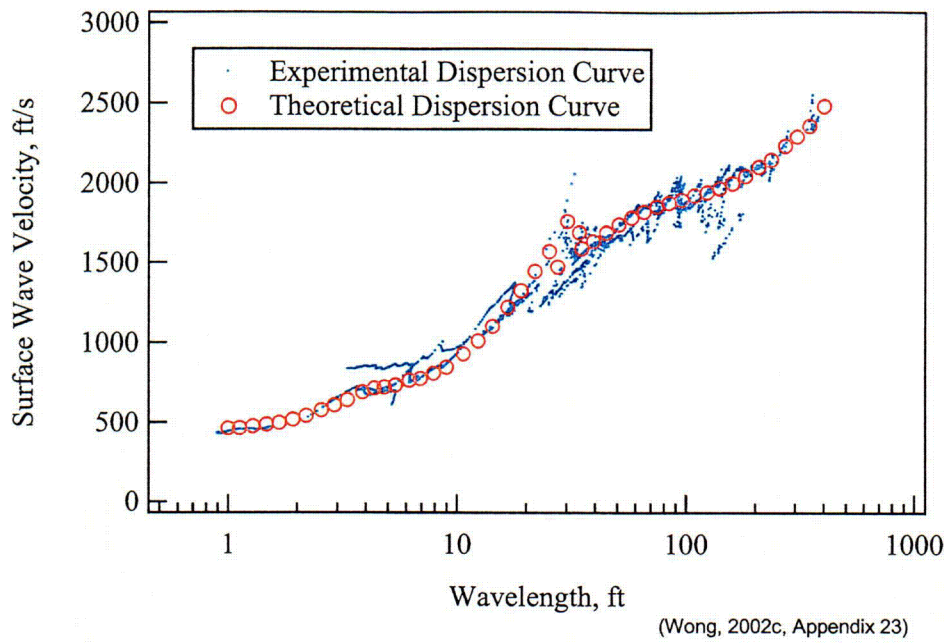
c. SASW-22 Shear Wave Velocity Profile

Location: SASW-22

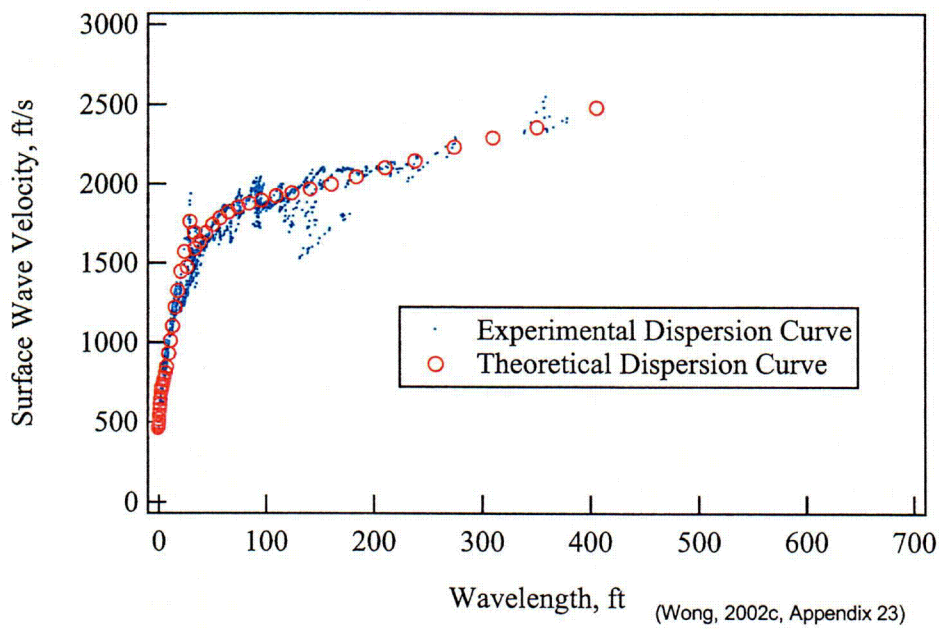
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	693	400	0.25	120
2	5	1039	600	0.25	120
3	10	1386	800	0.25	120
4	20	2078	1200	0.25	120
5	64	3984	2300	0.25	120

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 22)

Figure IX-22. SASW-22 Results (continued)



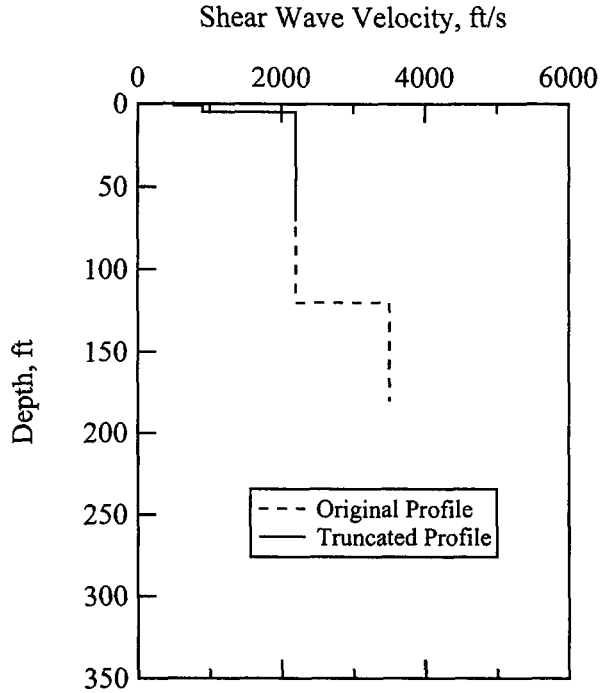
a. SASW-23 Dispersion Curves (Log Plot)



b. SASW-23 Dispersion Curves (Linear Plot)

Figure IX-23. SASW-23 Results

C23



DTN: MO0110SASWWHBS.000

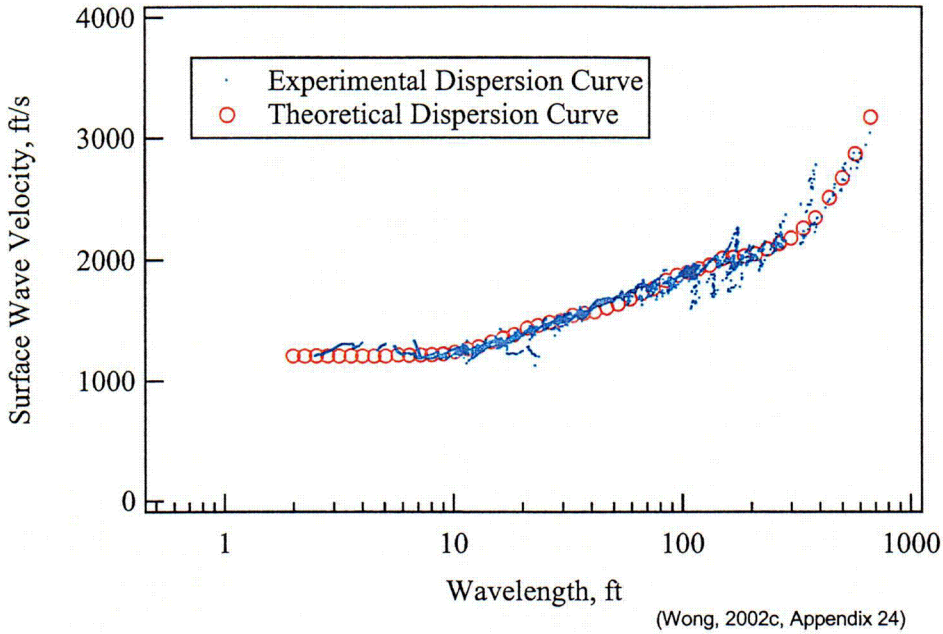
c. SASW-23 Shear Wave Velocity Profile

Location: SASW-23

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio***	Mass Density*** pcf
1	1	866	500	0.25	120
2	4	1559	900	0.25	120
3	65*	3810	2200	0.25	120
4	50**	3810	2200	0.25	120
5	60**	6062	3500	0.25	80

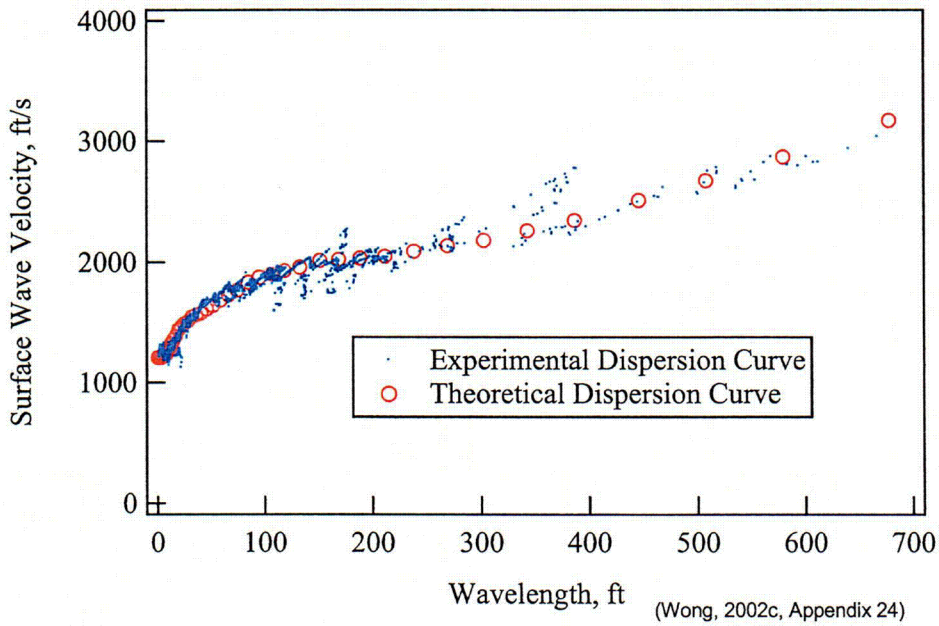
DTN: MO0110SASWWHBS.000
* Vs profile truncated at 70 ft based on geological profile showing an offset fault beginning at a depth of approximately 70 ft.
** Additional layering used in matching the theoretical dispersion curve to the complete experimental dispersion curve
*** Poisson's ratio and mass density from Wong (2002c, Appendix 23)

Figure IX-23. SASW-23 Results (continued)



(Wong, 2002c, Appendix 24)

a. SASW-24 Dispersion Curves (Log Plot)

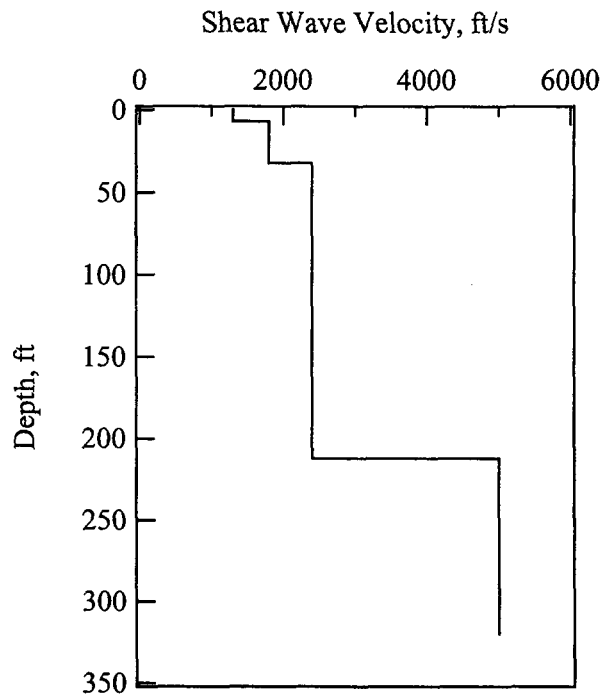


(Wong, 2002c, Appendix 24)

b. SASW-24 Dispersion Curves (Linear Plot)

Figure IX-24. SASW-24 Results

C24



DTN: MO0110SASWWHBS.000

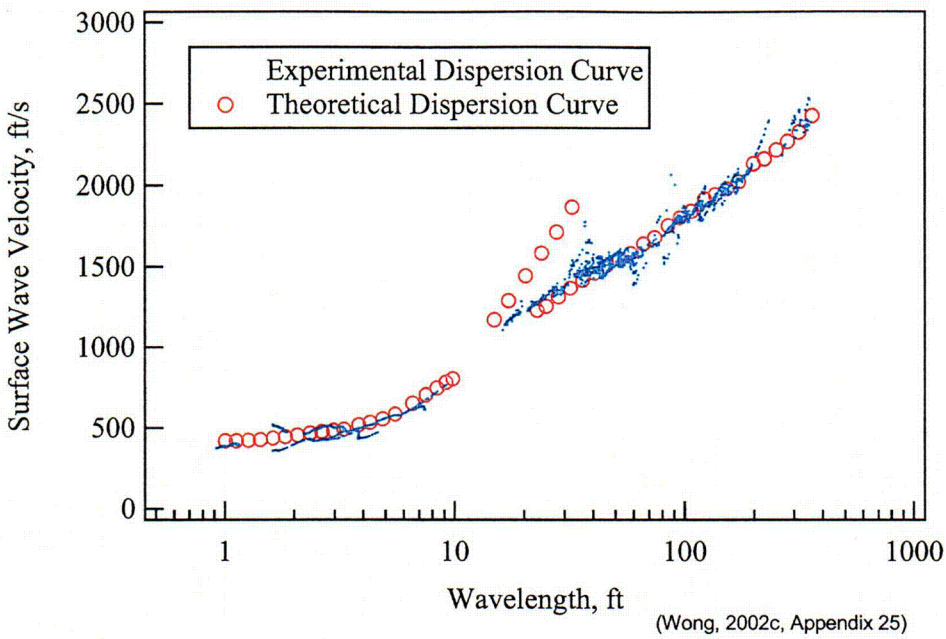
c. SASW-24 Shear Wave Velocity Profile

Location: SASW-24

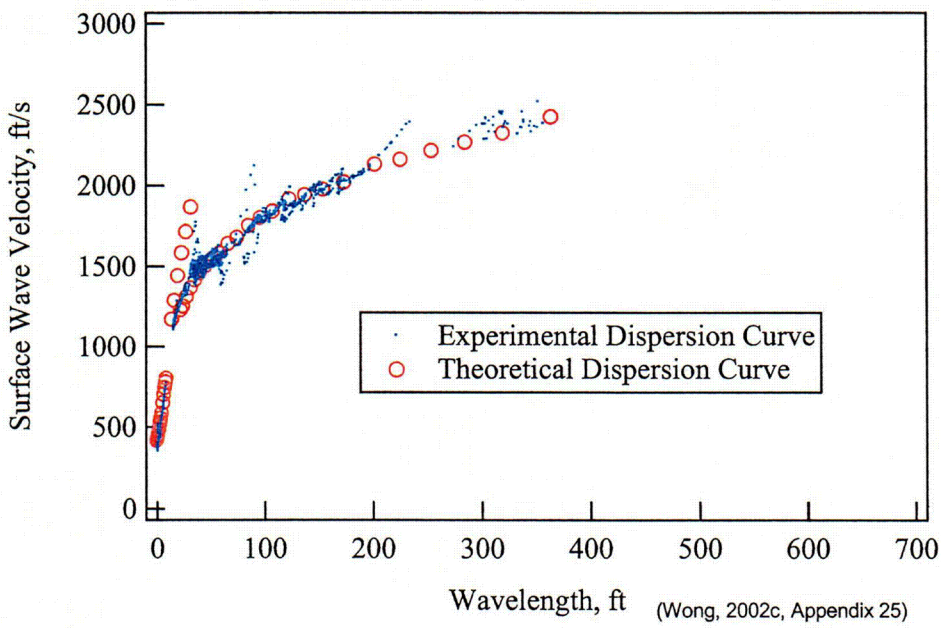
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	7	2252	1300	0.25	120
2	25	3118	1800	0.25	120
3	180	4157	2400	0.25	120
4	108	8660	5000	0.25	145

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 24)

Figure IX-24. SASW-24 Results (continued)



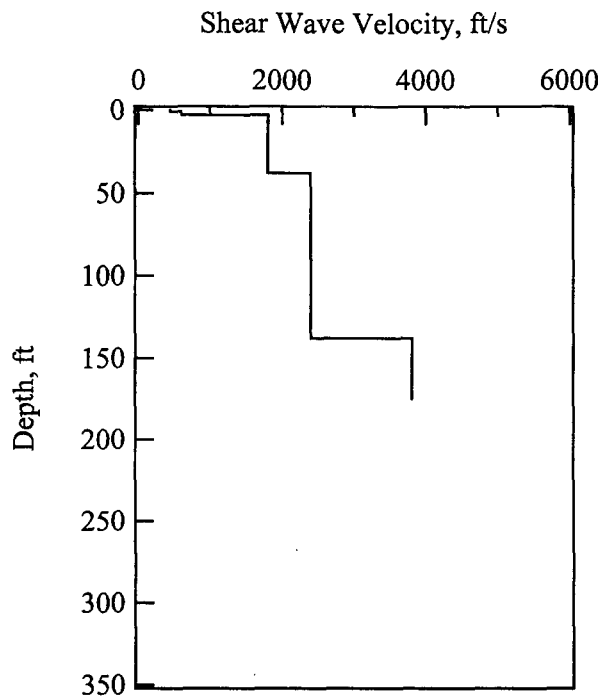
a. SASW-25 Dispersion Curves (Log Plot)



b. SASW-25 Dispersion Curves (Linear Plot)

Figure IX-25. SASW-25 Results

C25



DTN: MO0110SASWWHBS.000

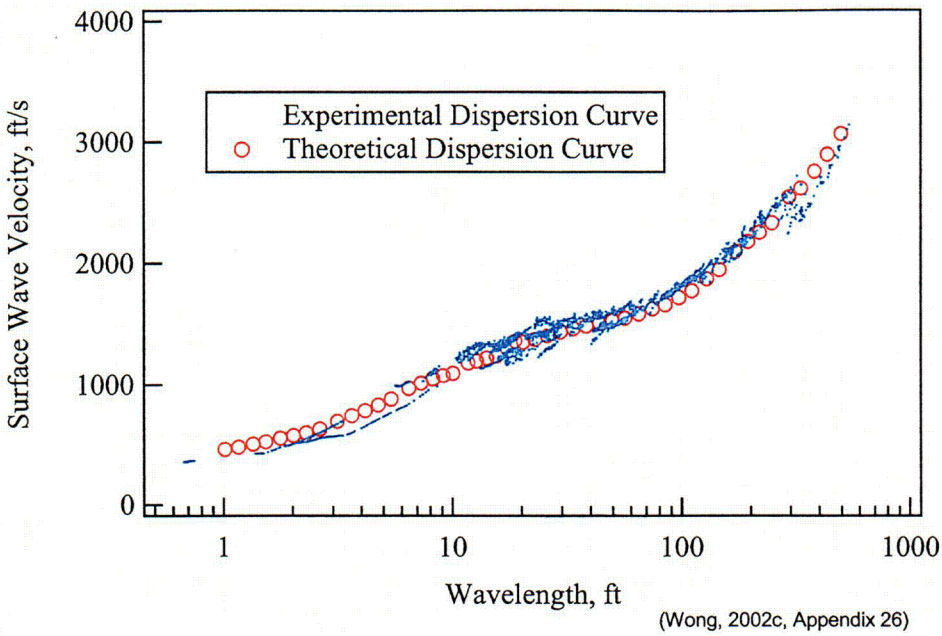
c. SASW-25 Shear Wave Velocity Profile

Location: SASW-25

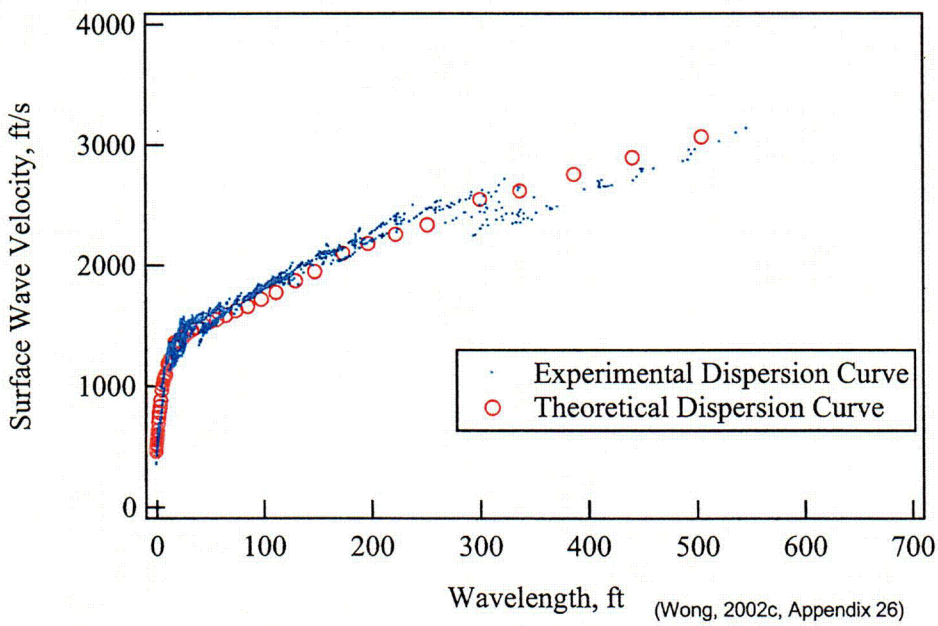
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	779	450	0.25	120
2	2	1039	600	0.25	120
3	35	3118	1800	0.25	120
4	100	4157	2400	0.25	120
5	37	6582	3800	0.25	80

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 25)

Figure IX-25. SASW-25 Results (continued)



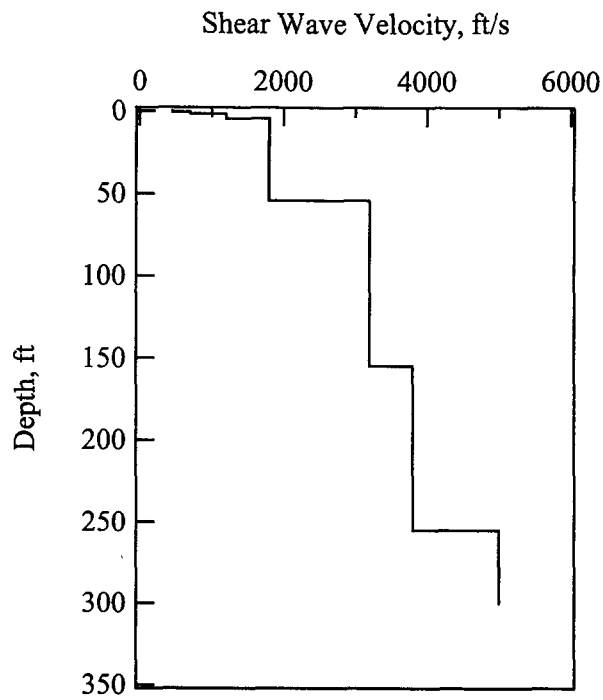
a. SASW-26 Dispersion Curves (Log Plot)



b. SASW-26 Dispersion Curves (Linear Plot)

Figure IX-26. SASW-26 Results

C26



DTN: MO0110SASWWHBS.000

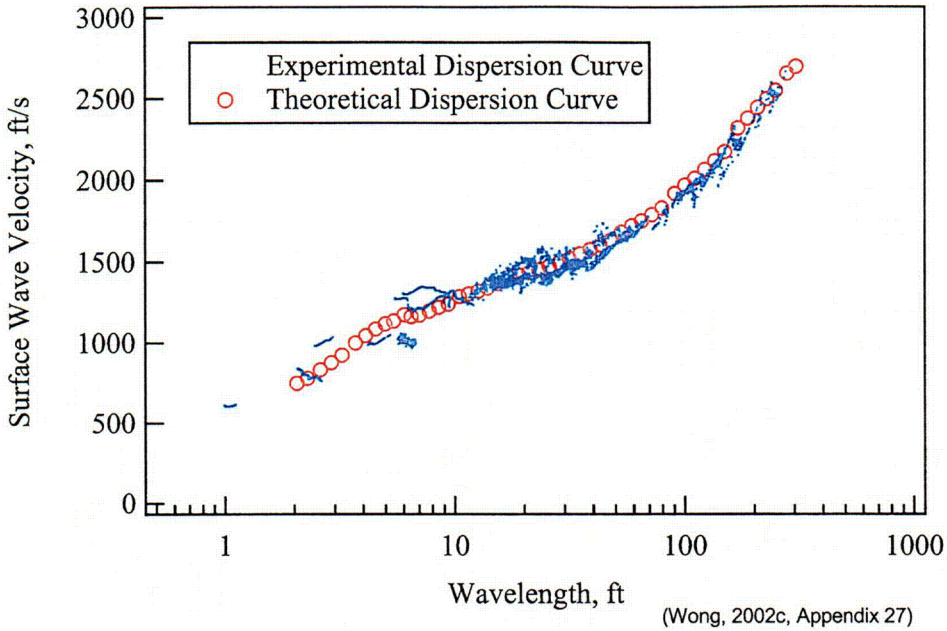
c. SASW-26 Shear Wave Velocity Profile

Location: SASW-26

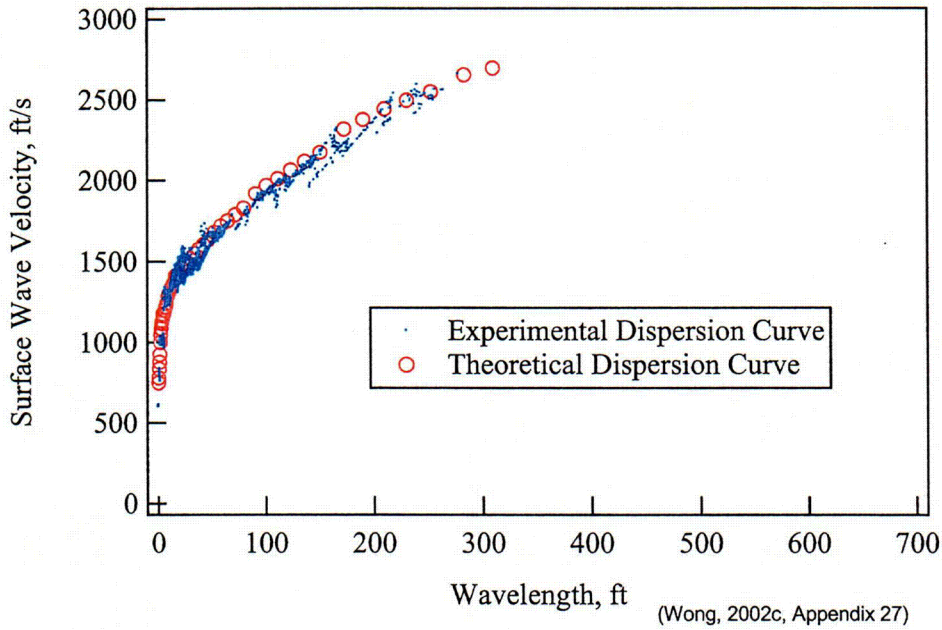
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.5	779	450	0.25	120
2	1	1212	700	0.25	120
3	3	2079	1200	0.25	120
4	50	3118	1800	0.25	120
5	100	5542	3200	0.25	80
6	100	6582	3800	0.25	80
7	46	8660	5000	0.25	145

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 26)

Figure IX-26. SASW-26 Results (continued)



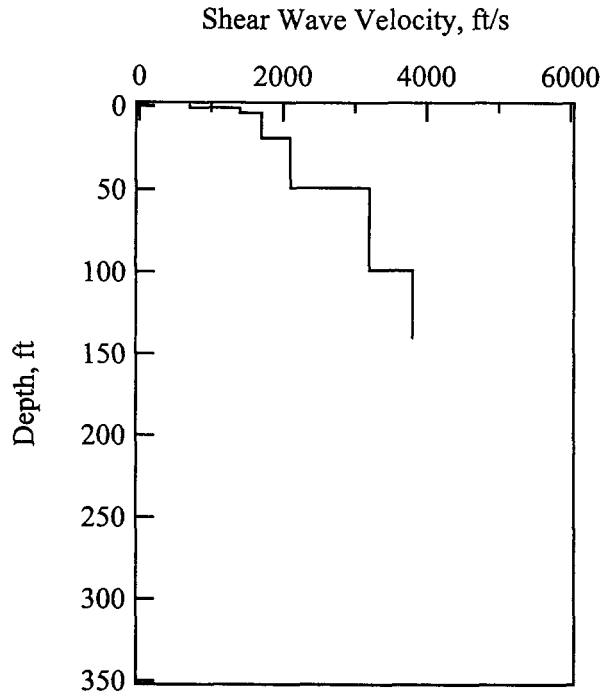
a. SASW-27 Dispersion Curves (Log Plot)



b. SASW-27 Dispersion Curves (Linear Plot)

Figure IX-27. SASW-27 Results

C27



DTN: MO0110SASWWHBS.000

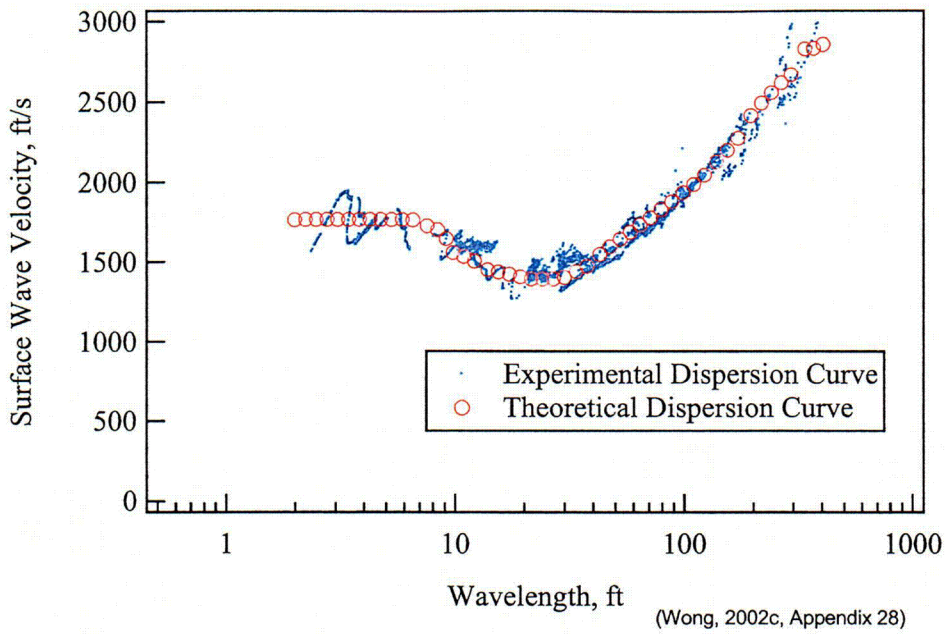
c. SASW-27 Shear Wave Velocity Profile

Location: SASW-27

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	1212	700	0.25	120
2	3	2425	1400	0.25	120
3	15	2945	1700	0.25	120
4	30	3637	2100	0.25	120
5	50	5543	3200	0.25	80
6	50	6582	3800	0.25	80

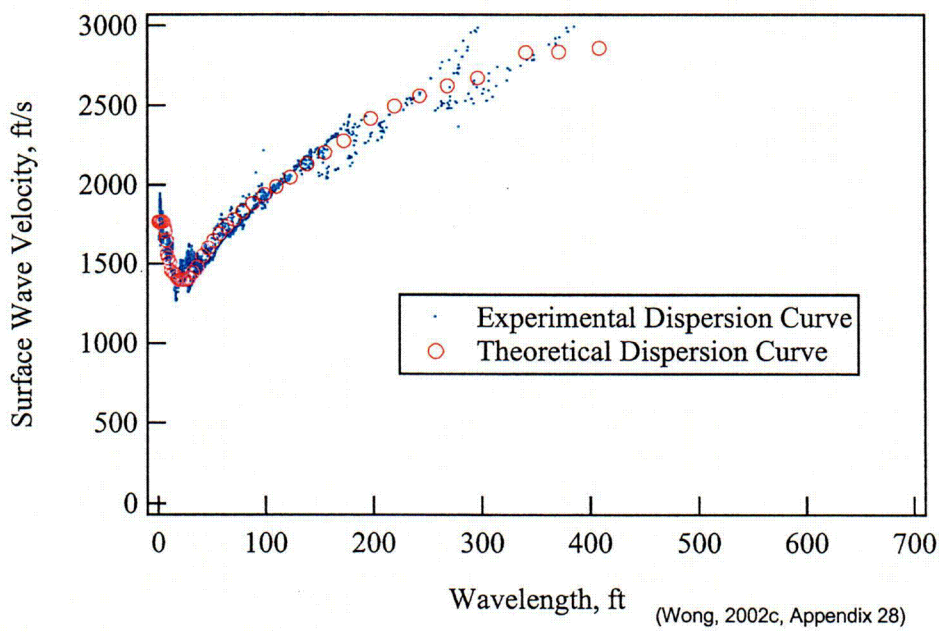
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 27)

Figure IX-27. SASW-27 Results (continued)



(Wong, 2002c, Appendix 28)

a. SASW-28 Dispersion Curves (Log Plot)

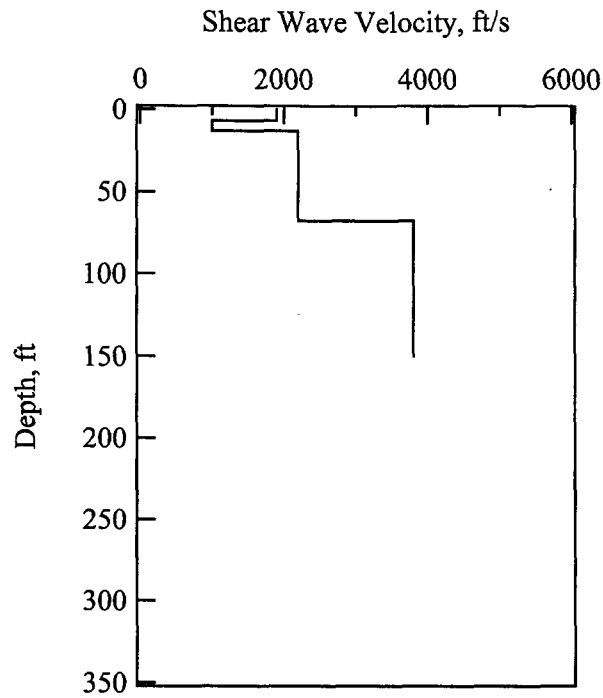


(Wong, 2002c, Appendix 28)

b. SASW-28 Dispersion Curves (Linear Plot)

Figure IX-28. SASW-28 Results

C28



DTN: MO0110SASWWHBS.000

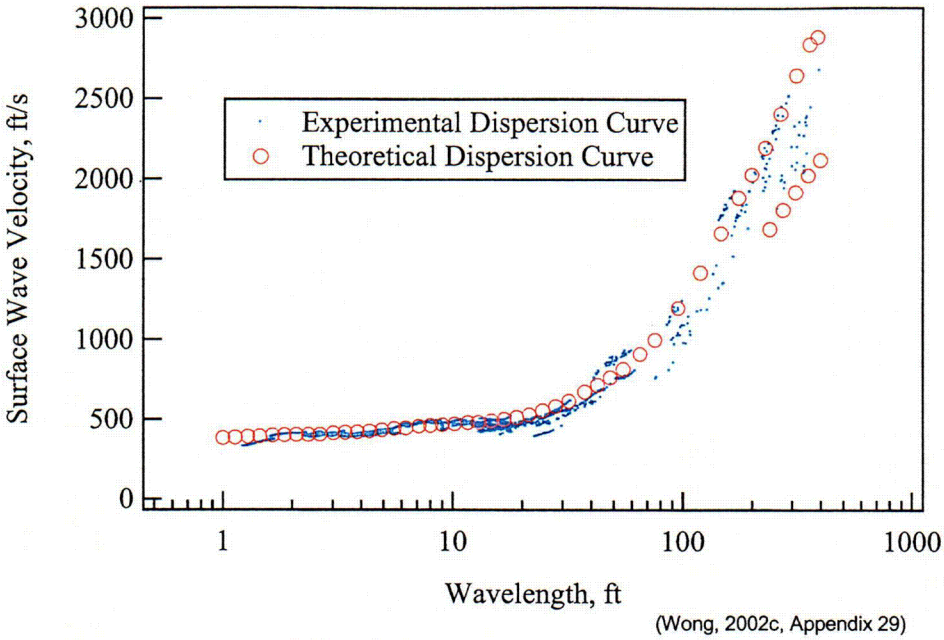
c. SASW-28 Shear Wave Velocity Profile

Location: SASW-28

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	7	3291	1900	0.25	120
2	6	1732	1000	0.25	120
3	55	3810	2200	0.25	120
4	82	6062	3800	0.25	80

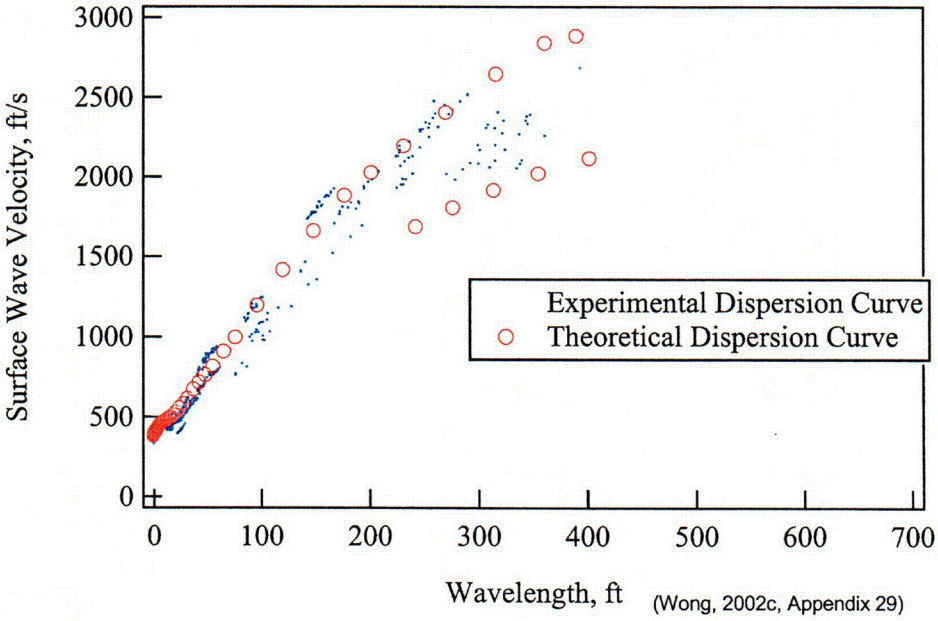
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 28)

Figure IX-28. SASW-28 Results (continued)



(Wong, 2002c, Appendix 29)

a. SASW-29 Dispersion Curves (Log Plot)

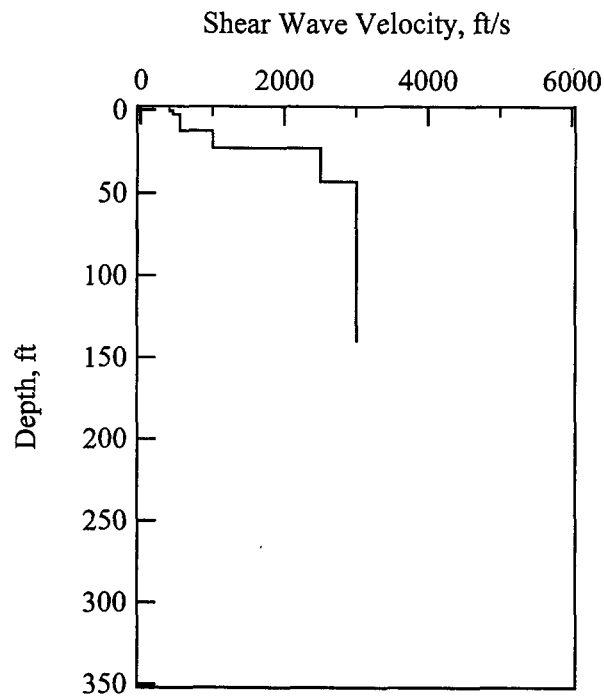


(Wong, 2002c, Appendix 29)

b. SASW-29 Dispersion Curves (Linear Plot)

Figure IX-29. SASW-29 Results

C29



DTN: MO0110SASWWHBS.000

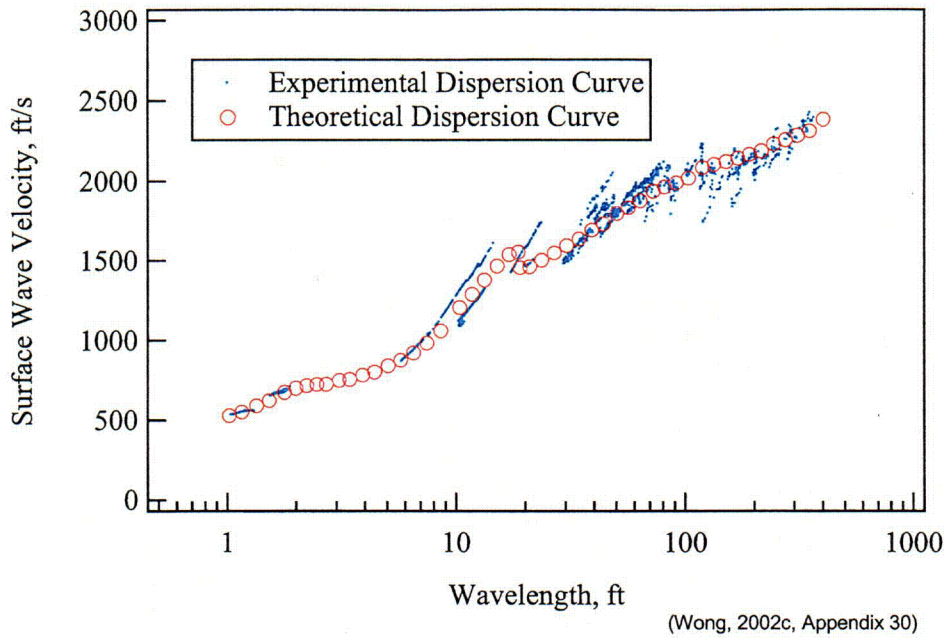
c. SASW-29 Shear Wave Velocity Profile

Location: SASW-29

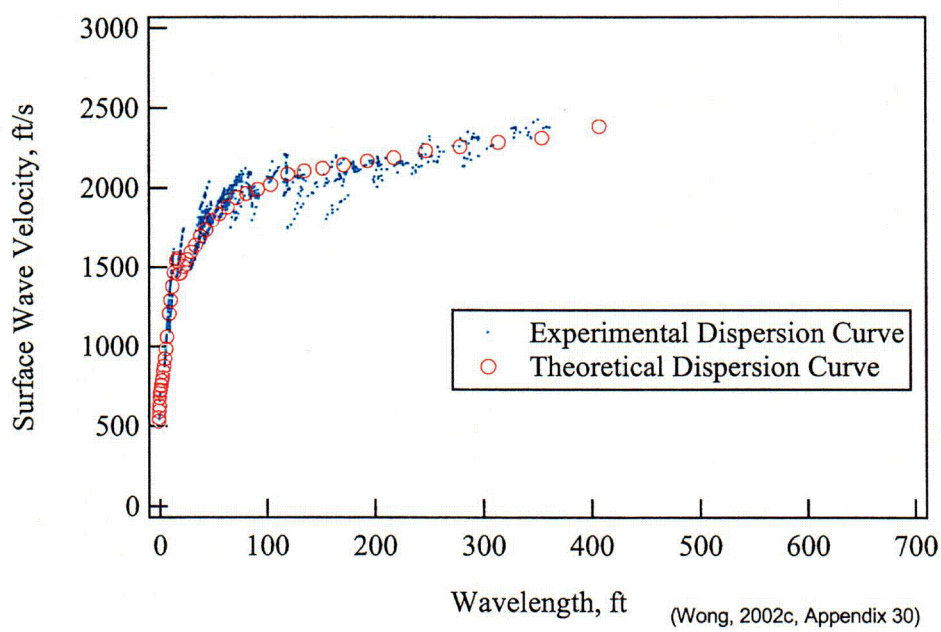
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.5	692	400	0.25	120
2	2	779	450	0.25	120
3	10	952	550	0.25	120
4	20	1732	1000	0.25	120
5	20	4330	2500	0.25	120
6	88	5196	3000	0.25	80

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 29)

Figure IX-29. SASW-29 Results (continued)



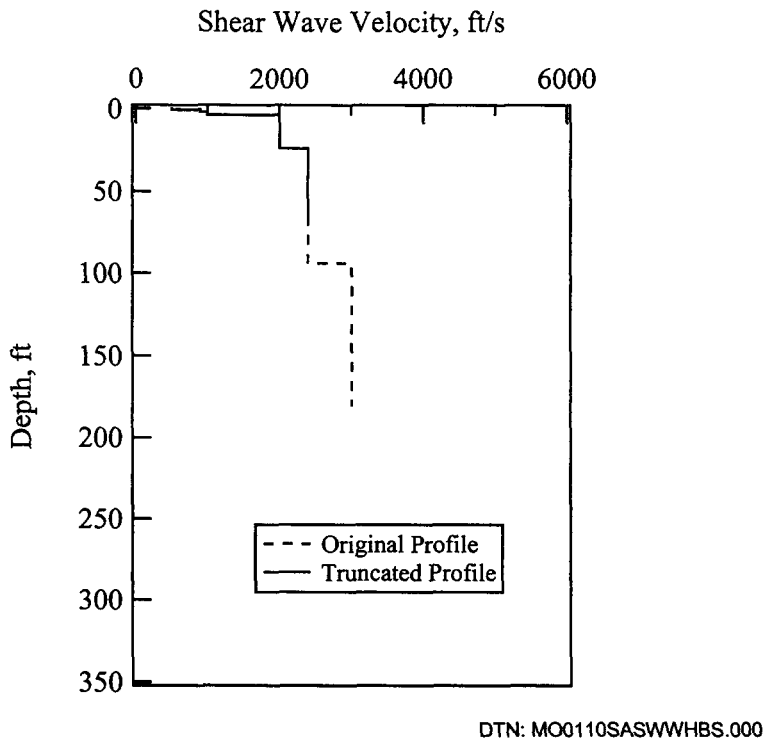
a. SASW-30 Dispersion Curves (Log Plot)



b. SASW-30 Dispersion Curves (Linear Plot)

Figure IX-30. SASW-30 Results

C30



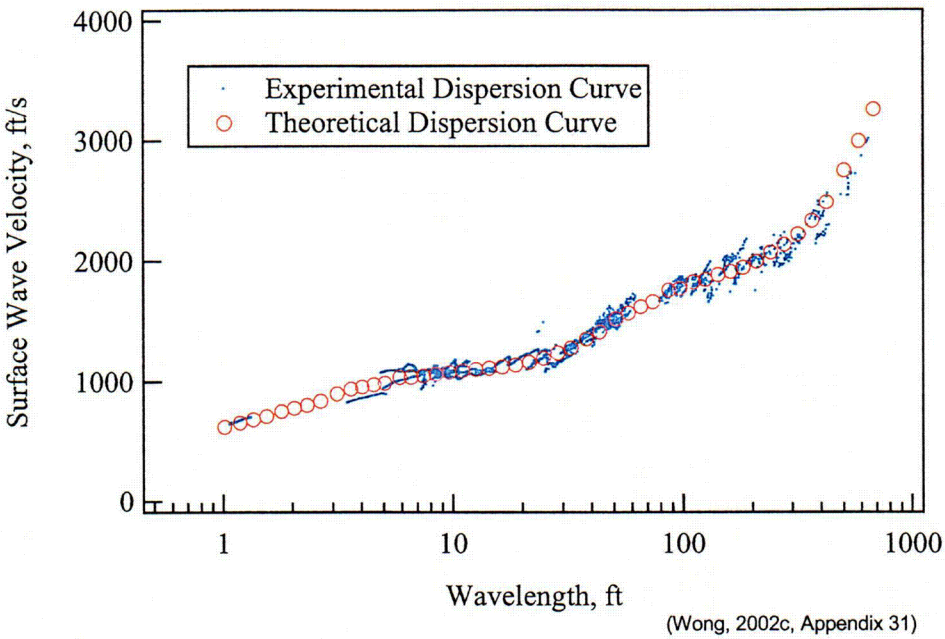
c. SASW-30 Shear Wave Velocity Profile

Location: SASW-30

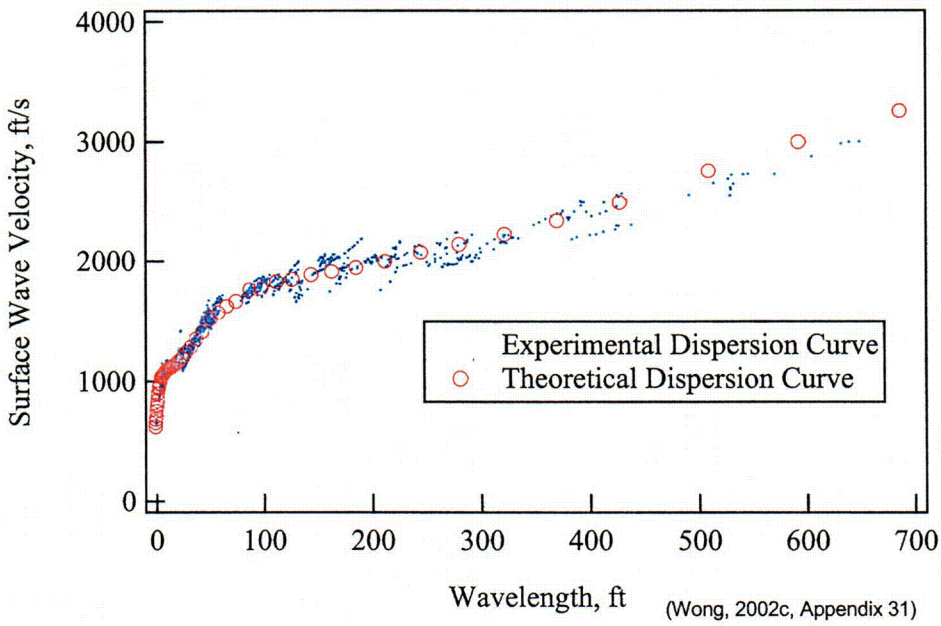
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio***	Mass Density*** pcf
1	0.5	866	500	0.25	120
2	1.5	1559	900	0.25	120
3	1.5	1732	1000	0.25	120
4	20	3464	2000	0.25	120
5	46.5*	4157	2400	0.25	120
6	23.5**	4157	2400	0.25	120
7	82**	5196	3000	0.25	80

DTN: MO0110SASWWHBS.000
* Vs profile truncated at 70 ft based on geological profile showing an offset fault beginning at a depth of approximately 70 ft.
** Additional layering used in matching the theoretical dispersion curve to the complete experimental dispersion curve
*** Poisson's ratio and mass density from Wong (2002c, Appendix 30)

Figure IX-30. SASW-30 Results (continued)



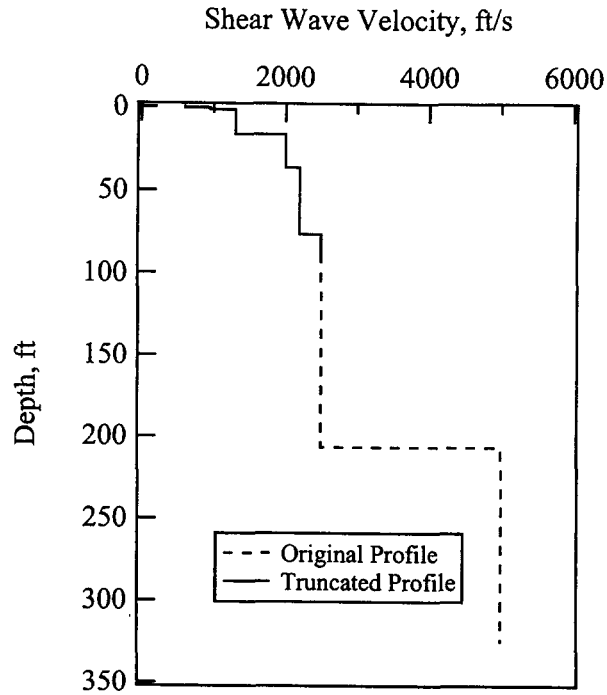
a. SASW-31 Dispersion Curves (Log Plot)



b. SASW-31 Dispersion Curves (Linear Plot)

Figure IX-31. SASW-31 Results

C31



DTN: MO0110SASWWHBS.000

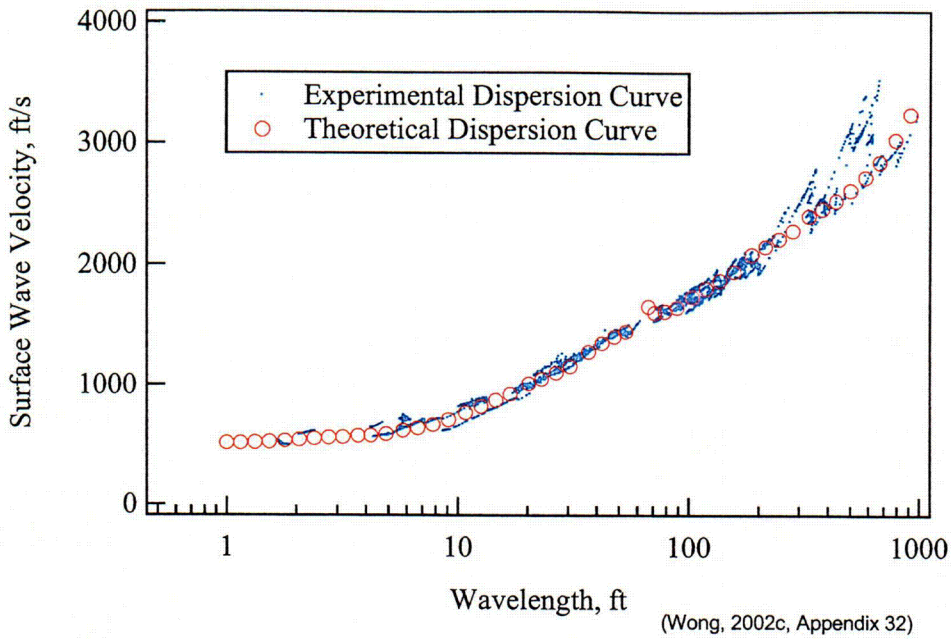
c. SASW-31 Shear Wave Velocity Profile

Location: SASW-31

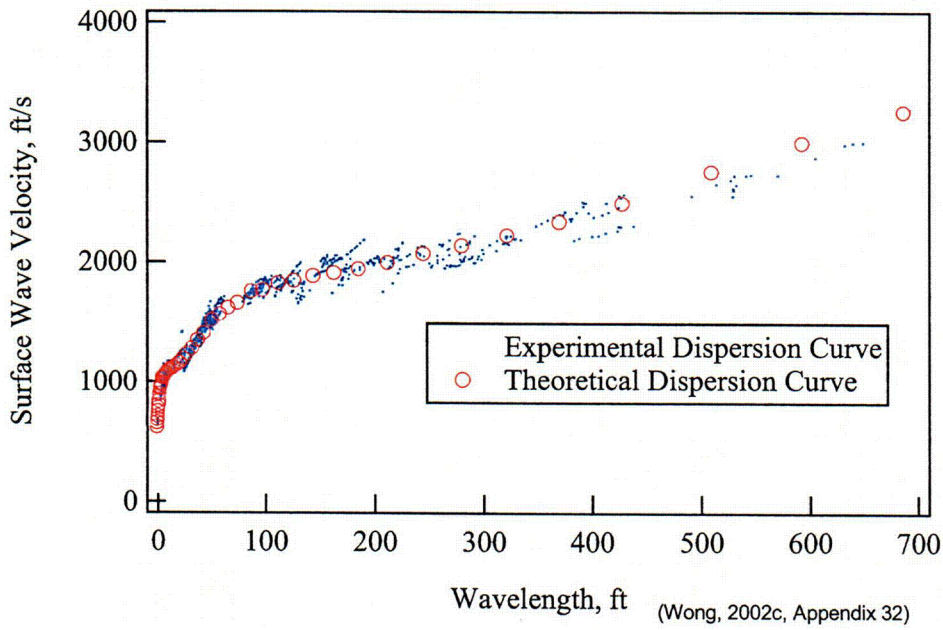
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio***	Mass Density*** pcf
1	0.5	1039	600	0.25	120
2	1	1645	950	0.25	120
3	15	2251	1300	0.25	120
4	20	3464	2000	0.25	120
5	40	3811	2200	0.25	120
6	13.5*	4330	2500	0.25	120
7	116.5**	4330	2500	0.25	120
8	118	8660	5000	0.25	145

DTN: MO0110SASWWHBS.000
* Vs profile truncated at 90 ft based on geological profile showing an offset fault beginning at a depth of approximately 90 ft.
** Additional layering used in matching the theoretical dispersion curve to the complete experimental dispersion curve
*** Poisson's ratio and mass density from Wong (2002c, Appendix 31)

Figure IX-31. SASW-31 Results (continued)



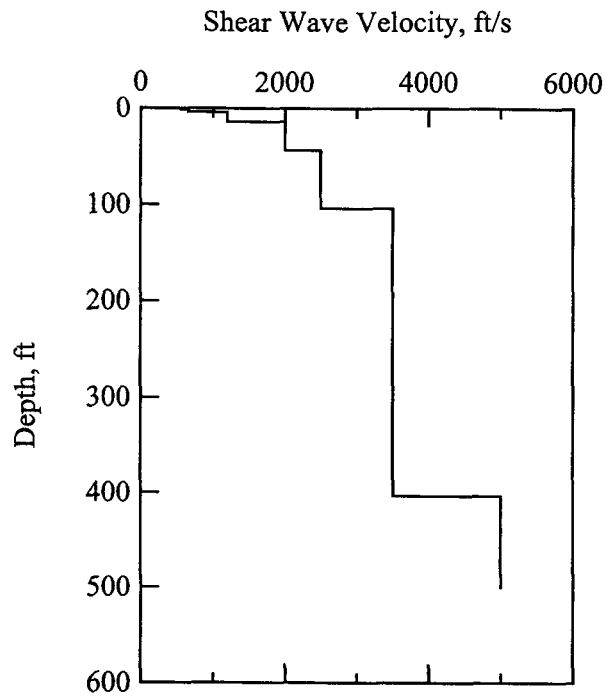
a. SASW-32+35 Dispersion Curves (Log Plot)



b. SASW-32+35 Dispersion Curves (Linear Plot)

Figure IX-32. SASW-32+35 Results

C32



DTN: MO0110SASWWHBS.000

c. SASW-32+35 Shear Wave Velocity Profile

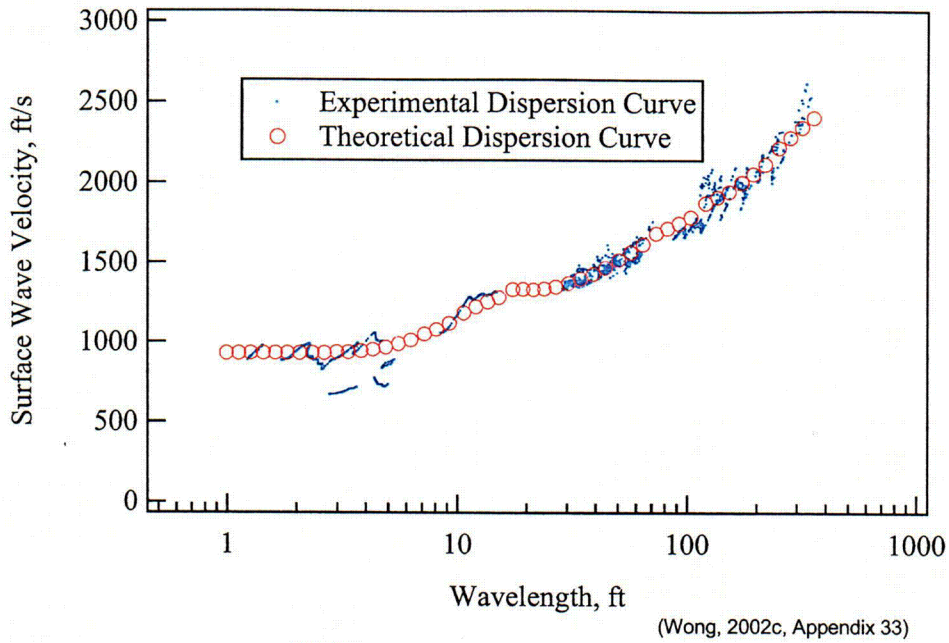
Location: SASW-32+35

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	953	550	0.25	120
2	3	1126	650	0.25	120
3	10	2079	1200	0.25	120
4	30	3464	2000	0.25	120
5	60	4330	2500	0.25	120
6	300	5543	3500	0.25	80
7	96	8660	5000	0.25	145

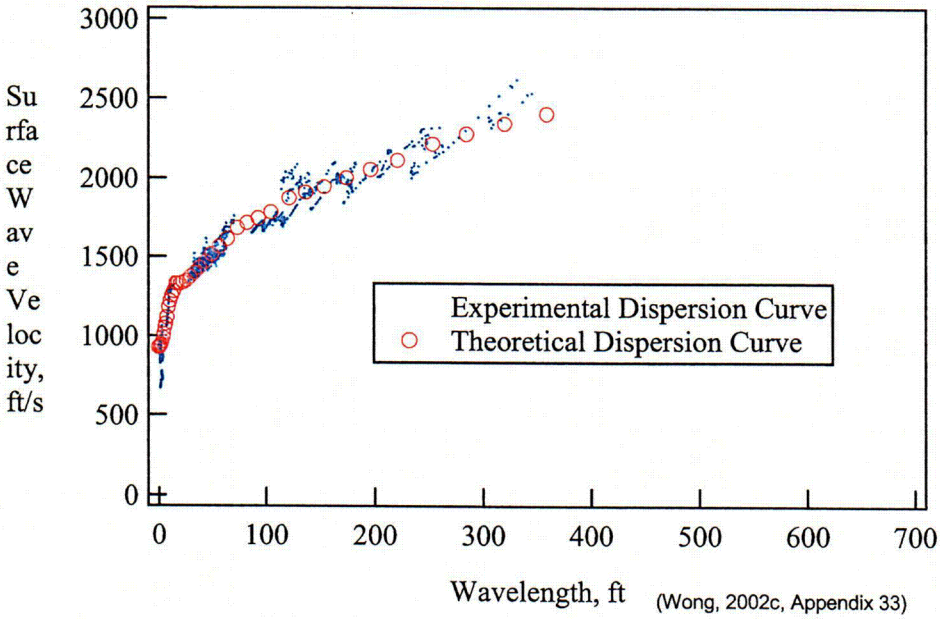
DTN: MO0110SASWWHBS.000

* Poisson's ratio and mass density from Wong (2002c, Appendix 32)

Figure IX-32. SASW-32+35 Results (continued)



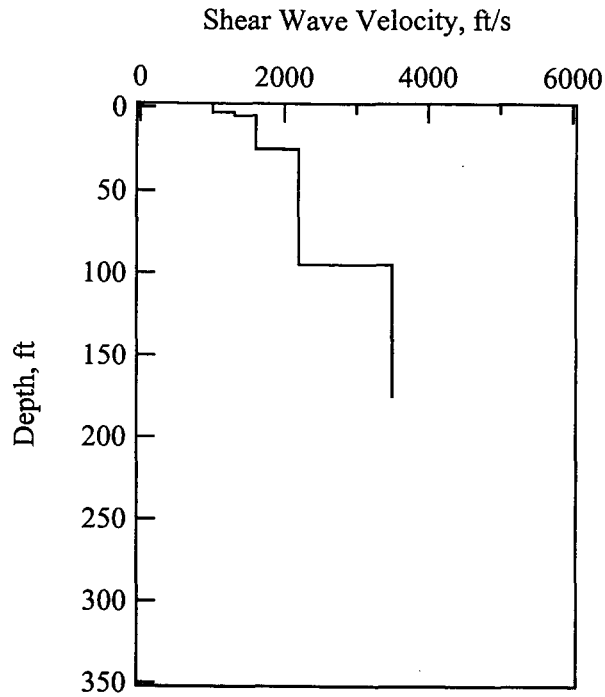
a. SASW-33 Dispersion Curves (Log Plot)



b. SASW-33 Dispersion Curves (Linear Plot)

Figure IX-33. SASW-33 Results

C33



DTN: MO0110SASWWHBS.000

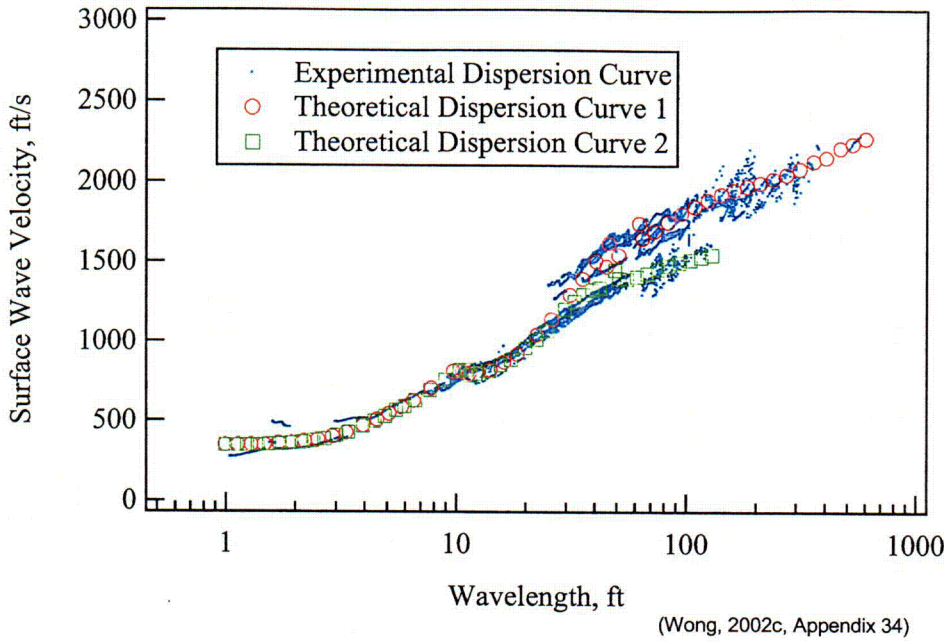
c. SASW-33 Shear Wave Velocity Profile

Location: SASW-33

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	3	1732	1000	0.25	120
2	2	2252	1300	0.25	120
3	20	2771	1600	0.25	120
4	70	3810	2200	0.25	120
5	80	6062	3500	0.25	80

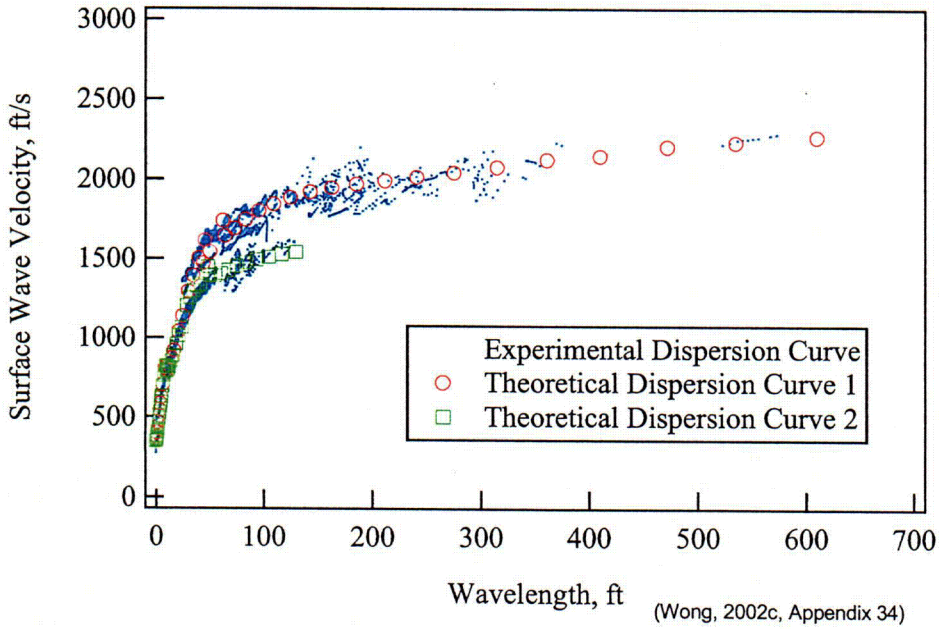
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 33)

Figure IX-33. SASW-33 Results (continued)



(Wong, 2002c, Appendix 34)

a. SASW-34+36 Dispersion Curves (Log Plot)

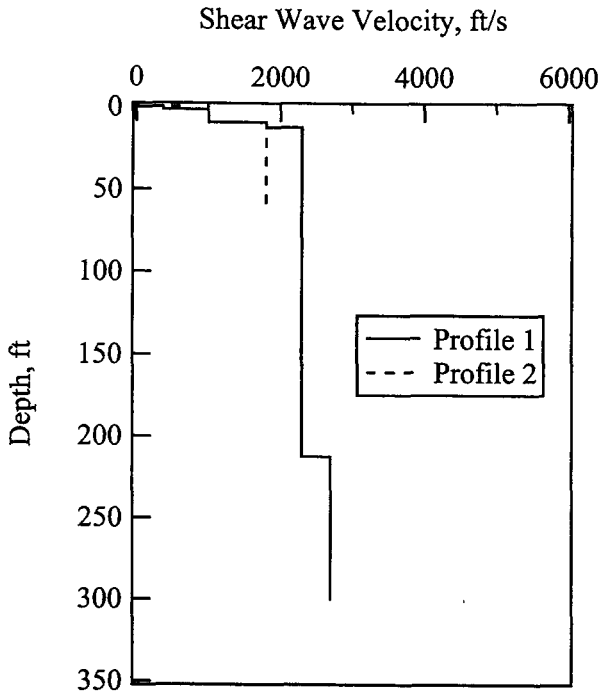


(Wong, 2002c, Appendix 34)

b. SASW-34+36 Dispersion Curves (Linear Plot)

Figure IX-34. SASW-34+36 Results

C34



DTN: MO0110SASWWHBS.000

c. SASW-34+36 Shear Wave Velocity Profile

Location: SASW-34+36 Profile 1

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1.5	650	375	0.25	120
2	8	1732	1000	0.25	120
3	3	3117	1800	0.25	120
4	200	3983	2300	0.25	120
5	88	4676	2700	0.25	120

Location: SASW-34+36 Profile 2

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	650	375	0.25	120
2	8	1732	1000	0.25	120
3	51	3117	1800	0.25	120

DTN: MO0110SASWWHBS.000

* Poisson's ratio and mass density from Wong (2002c, Appendix 34)

Figure IX-34. SASW-34+36 Results (continued)

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ATTACHMENT X

BOREHOLE GEOPHYSICAL SURVEYS

ATTACHMENT X

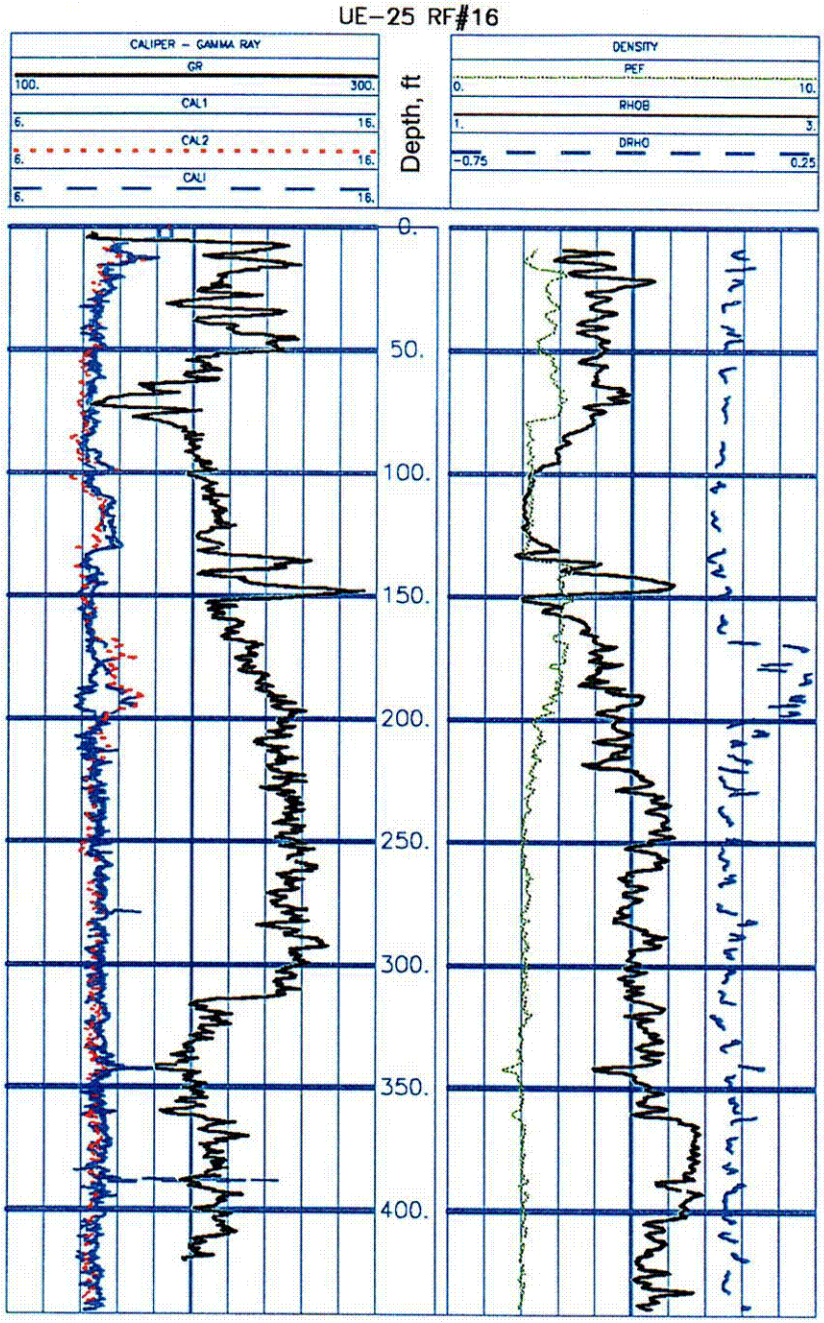
BOREHOLE GEOPHYSICAL SURVEYS

As mentioned in Section 6.2.8, this attachment presents plots of the data from borehole geophysical measurements. The results are presented in the following order: borehole RF#16, RF#18, RF#20, RF#21, RF#22, RF#24 and RF#28.

The parameters shown on the plots are defined as follows:

Name	Description	Definition	Units
CAL1	Caliper 1 from 4-arm caliper tool	Borehole radius along a vertical plane 90° away from CAL2	inches
CAL2	Caliper 1 from 4-arm caliper tool	Borehole radius along a vertical plane 90° away from CAL1	inches
CAL	Caliper from density tool	Borehole radius along a vertical plane coincident with the density source-detectors	inches
Depth	Measured depth	Depth into the borehole	feet
DRHO	Bulk density correction	The amount of density correction computed from the long-spaced and short-spaced detectors. This value is included in the RHOB data	gm/cm^3
RHOB	Bulk density	The mass per unit volume of a formation	gm/cm^3
GR	Gamma ray intensity	Passive measurement of gamma rays emitted by K40 and the radioactive elements of uranium and potassium. The response, measured at the tool is given by: $GR = \frac{\Sigma \rho_i V_i A_i}{\rho_b}$ where: ρ_i = the densities of the radioactive minerals V_i = the bulk volume factors of the minerals A_i = proportionality factors corresponding to the radioactivity of the mineral. ρ_b = bulk density	G_{API} (see note)
PEF	Photoelectric capture cross section	Photoelectric cross section (PEF); related to Z by the following relationship: $PEF = \frac{Z^{3.6}}{10}$ where: Z is the atomic number	--

Note: The G_{API} units are based on an American Petroleum Institute calibration standard. Gamma ray (GR) count rates frequently vary significantly between detectors, even those of the same design. For this reason, GR detectors are calibrated in normalized count rate units. GR logs run in low radioactivity environments are often calibrated in API units. GR API calibration units are based on GR logging tool response to the API Calibration Pits maintained by the University of Houston (Schlumberger Educational Services 1987, page 24). Prior to the API calibration procedure, GR logs were scaled in microgram of radium-equivalent per ton of formation (μg Ra-eq/ton).

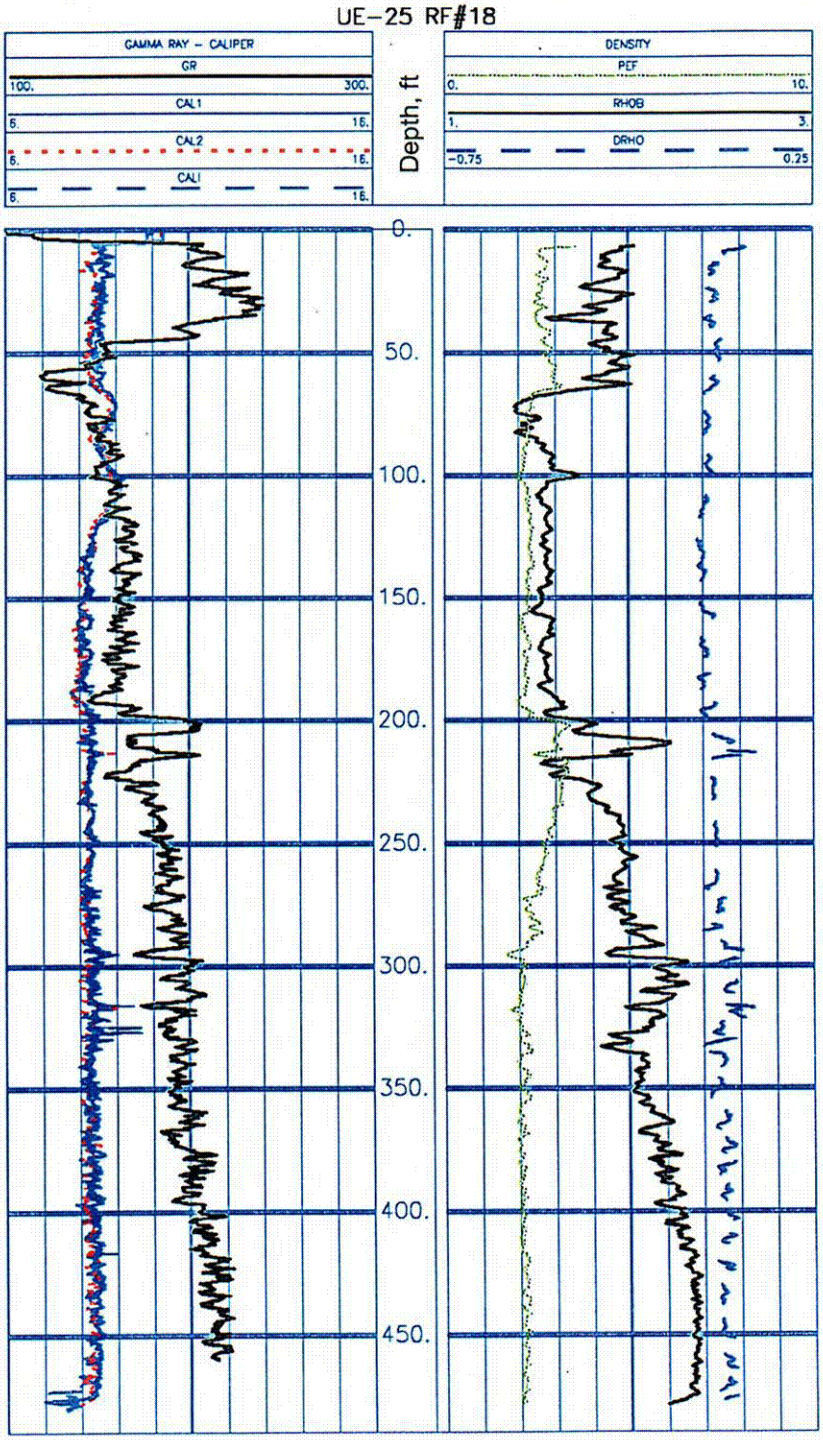


DTN: MO0112GPLOGWHB.001

Note: DRHO, RHOB are in g/cm^3
CAL1, CAL2 and CAL are in inches
GR is in G_{API}.

Figure X-1. Geophysical Log of Borehole RF#16

C35

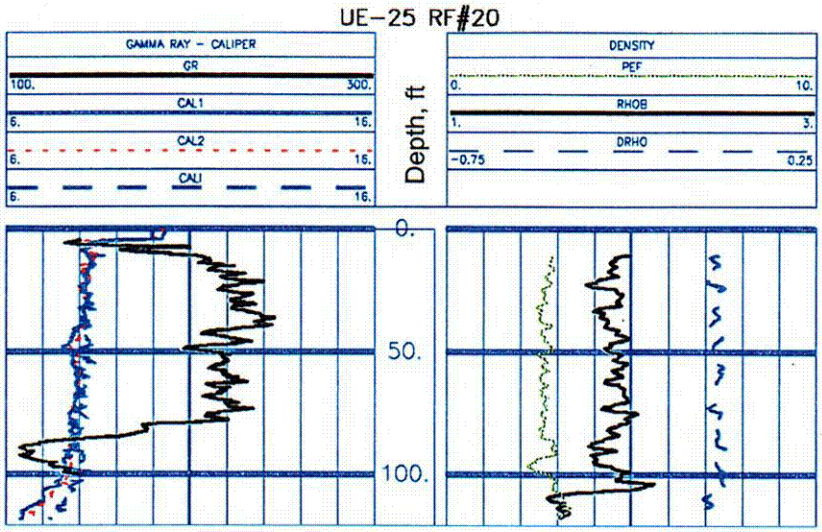


DTN: MO0112GPLOGWHB.001

Note: DRHO, RHOB are in g/cm^3
CAL1, CAL2 and CAL are in inches
GR is in G_{API}.

Figure X-2. Geophysical Log of Borehole RF#18

C36

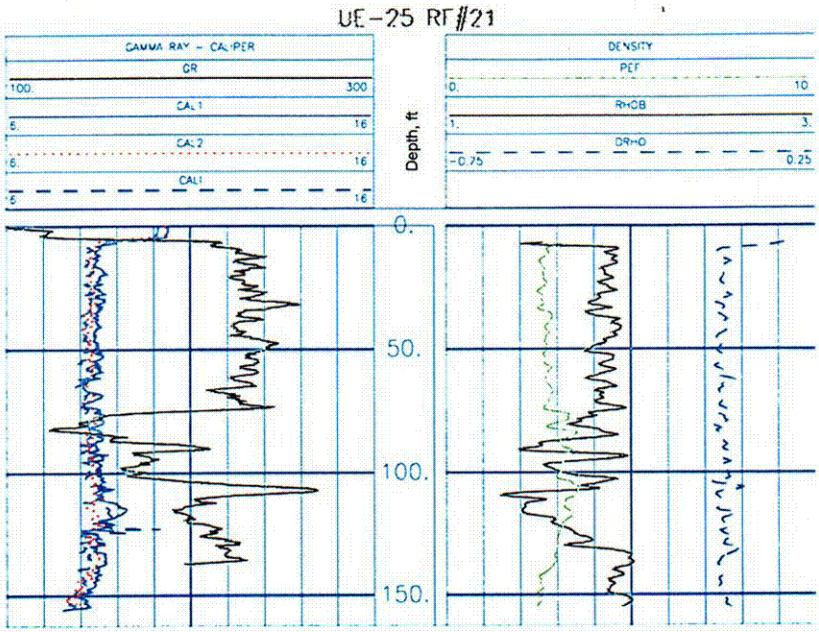


DTN: MO0112GPLOGWHB.001

Note: DRHO, RHOB are in g/cm^3
CAL1, CAL2 and CAL are in inches
GR is in G_{API}.

Figure X-3. Geophysical Log of Borehole RF#20

C37

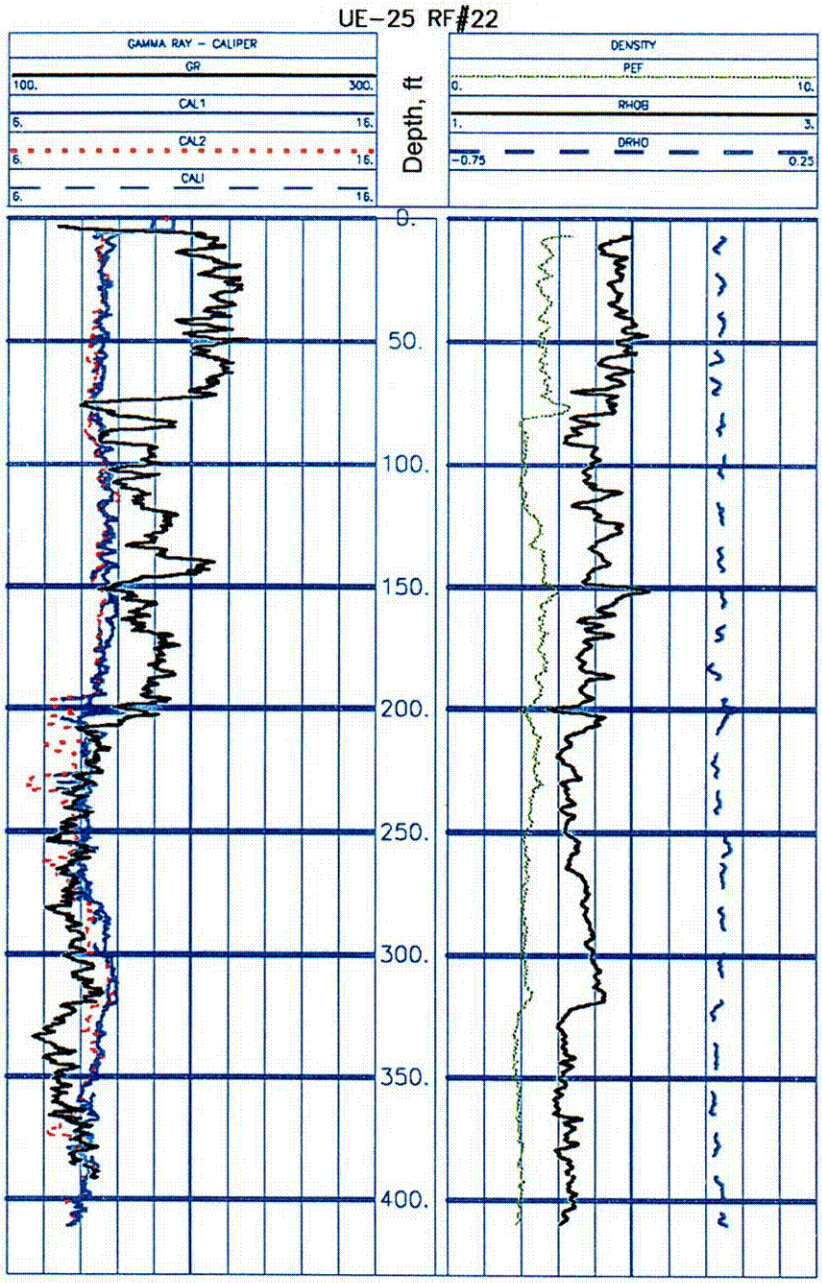


DTN: MO0112GPLOGWHB.001

Note: DRHO, RHOB are in g/cm^3
CAL1, CAL2 and CAL are in inches
GR is in G_{API}.

Figure X-4. Geophysical Log of Borehole RF#21

C38

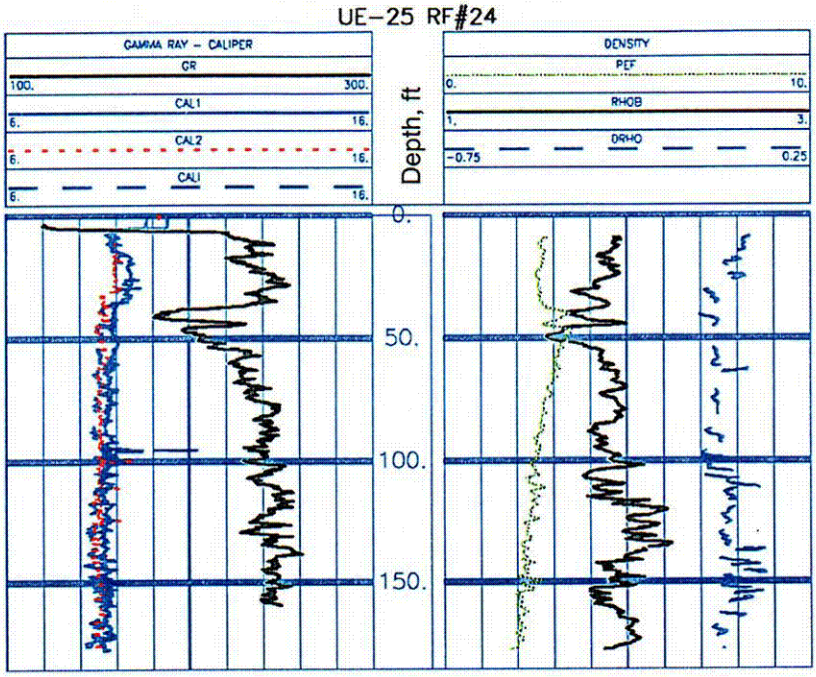


DTN: MO0112GPLOGWHB.001

Note: DRHO, RHOB are in g/cm^3
CAL1, CAL2 and CAL are in inches
GR is in G_{API}.

Figure X-5. Geophysical Log of Borehole RF#22

C39

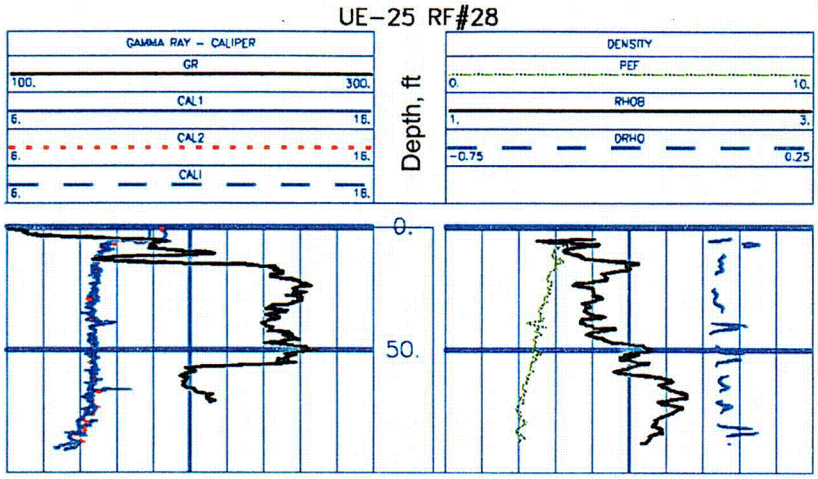


DTN: MO0112GPLOGWHB.001

Note: DRHO, RHOB are in g/cm^3
CAL1, CAL2 and CAL are in inches
GR is in G_{API}.

Figure X-6. Geophysical Log of Borehole RF#24

C4



DTN: MO0112GPLOGWHB.001

Note: DRHO, RHOB are in g/cm^3
CAL1, CAL2 and CAL are in inches
GR is in G_{API}.

Figure X-7. Geophysical Log of Borehole RF#2

C41

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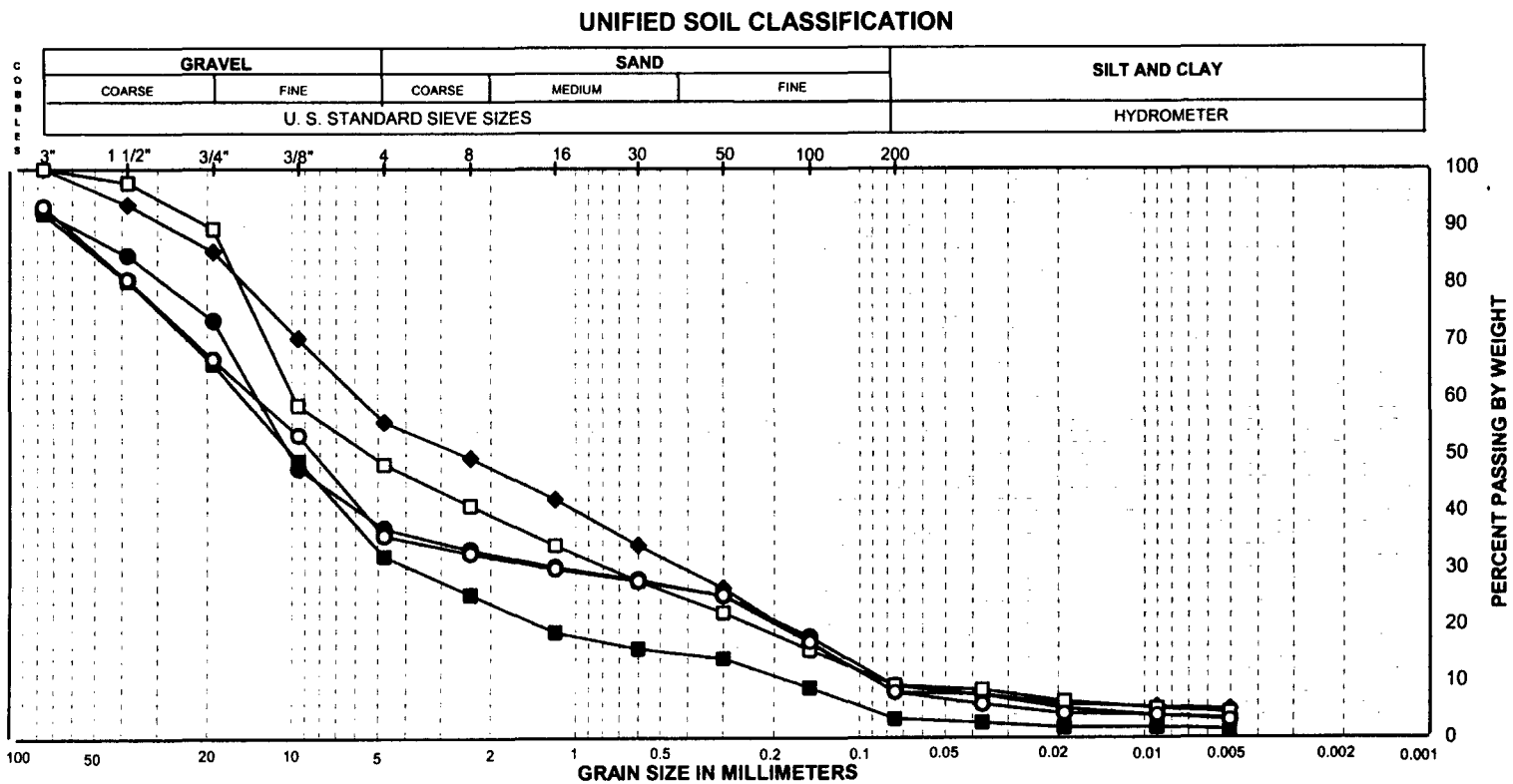
ATTACHMENT XI

GEOTECHNICAL LABORATORY STATIC TESTING – WHB AREA

ATTACHMENT XI

GEOTECHNICAL LABORATORY STATIC TESTING – WHB AREA

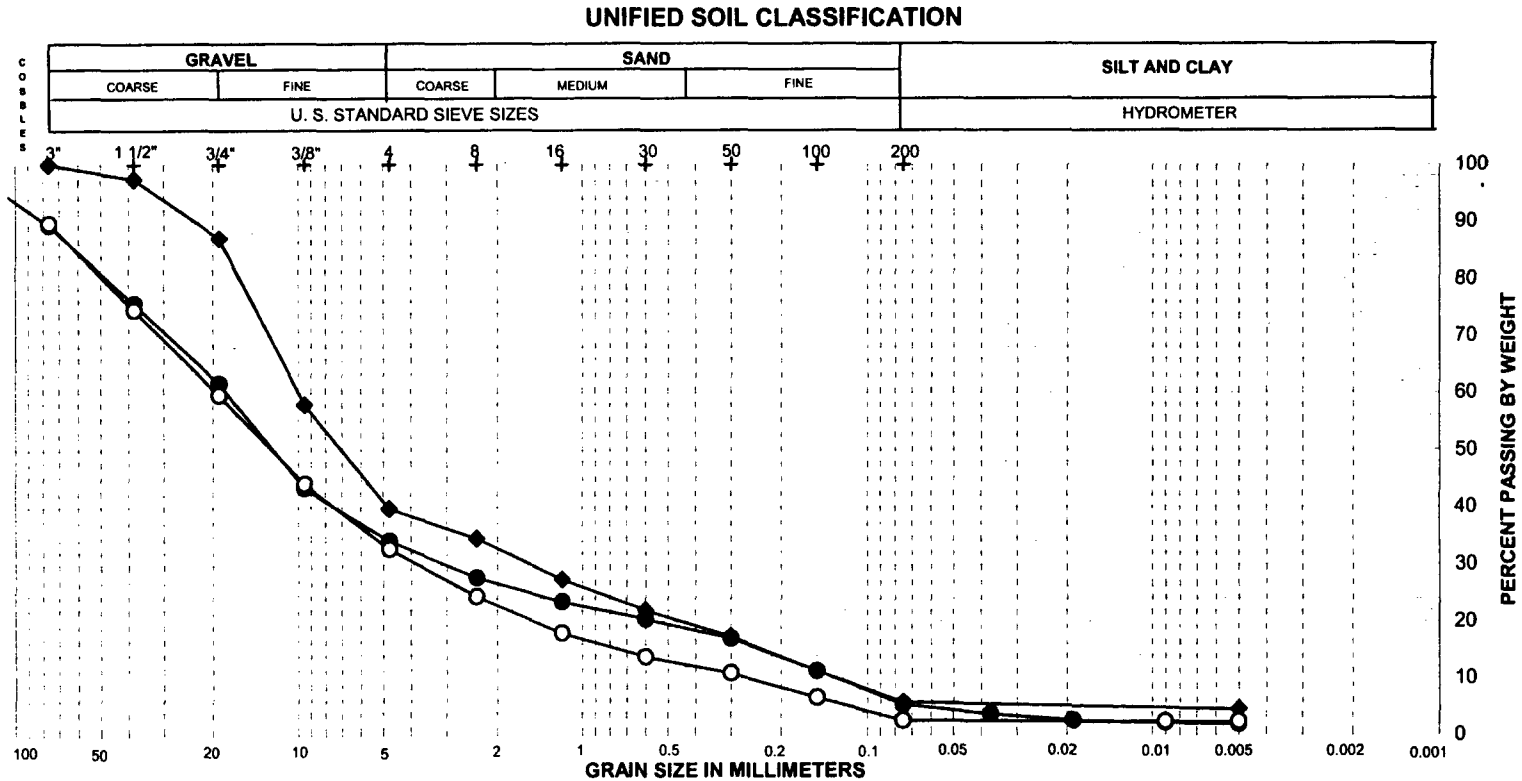
The geotechnical laboratory in Denver, Colorado, performed tests on the alluvium removed from in-place density test excavations performed in test pits TP-WHB-1 through -4. Most of the results are presented in Section 6.2.9 of the main text. This attachment presents plots of the particle-size distribution tests.



Exploration No.	Depth (ft)	SYMBOL	$W_{\#4}$ (%)	LL	PI	%<5 μm	Description and Classification	D_{60}	D_{30}	D_{10}	Cu	Cc
TP-WHB-1	4.0	○	7.9	NP	NP	3.0	Well-graded Gravel with silt and sand (GW-GM)	13	1.21	0.09	144.7	1.2
TP-WHB-1	12.0	●	7.5	NP	NP	3.3	Well-graded Gravel with silt and sand (GW-GM)	13.3	1.12	0.08	166.3	1.2
TP-WHB-1	12.0	□	4.4	NP	NP	4.4	Poorly graded Gravel with silt and sand (GP-GM)	9.88	0.77	0.09	109.8	0.7
TP-WHB-1	12.3	◆	5.6	NP	NP	4.9	Poorly graded Sand with silt and gravel (SP-SM)	6.04	0.41	0.09	67.1	0.3
TP-WHB-1	20.0	■	4.8	NP	NP	1.4	Poorly graded Gravel with sand (GP)	14.8	4.09	0.17	87.1	6.6

DTN: GS020483114233.004

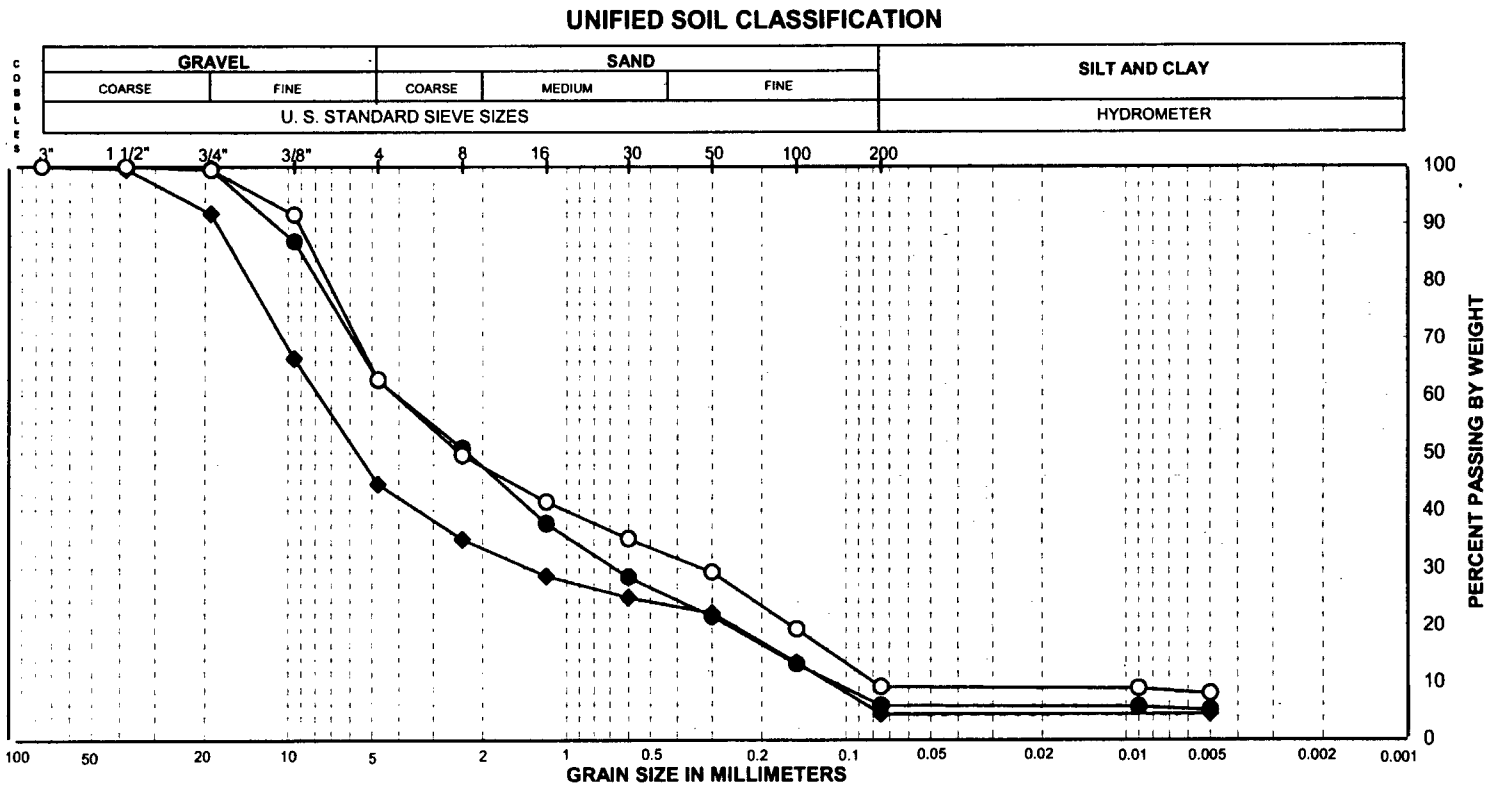
Figure XI-1. Particle-Size Distribution for Samples from Test Pit TP-WHB-1



Exploration No.	Depth (ft)	SYMBOL	$W_{\#4}$ (%)	LL	PI	%<5 μm	Description and Classification	D_{60}	D_{30}	D_{10}	Cu	Cc
TP-WHB-2	8.0	○	10.6	NP	NP	2.3	Poorly graded Gravel with sand (GP)					
TP-WHB-2	12.0	●	5.8	NP	NP	1.9	Poorly graded Gravel with silt and sand (GP-GM)	17.8	3.09	0.13	137	4.1
TP-WHB-2	16.0	◆	8.7	NP	NP	4.5	Well-graded Gravel with silt and sand (GW-GM)	10	1.49	0.13	76.9	1.7

DTN: GS020483114233.004

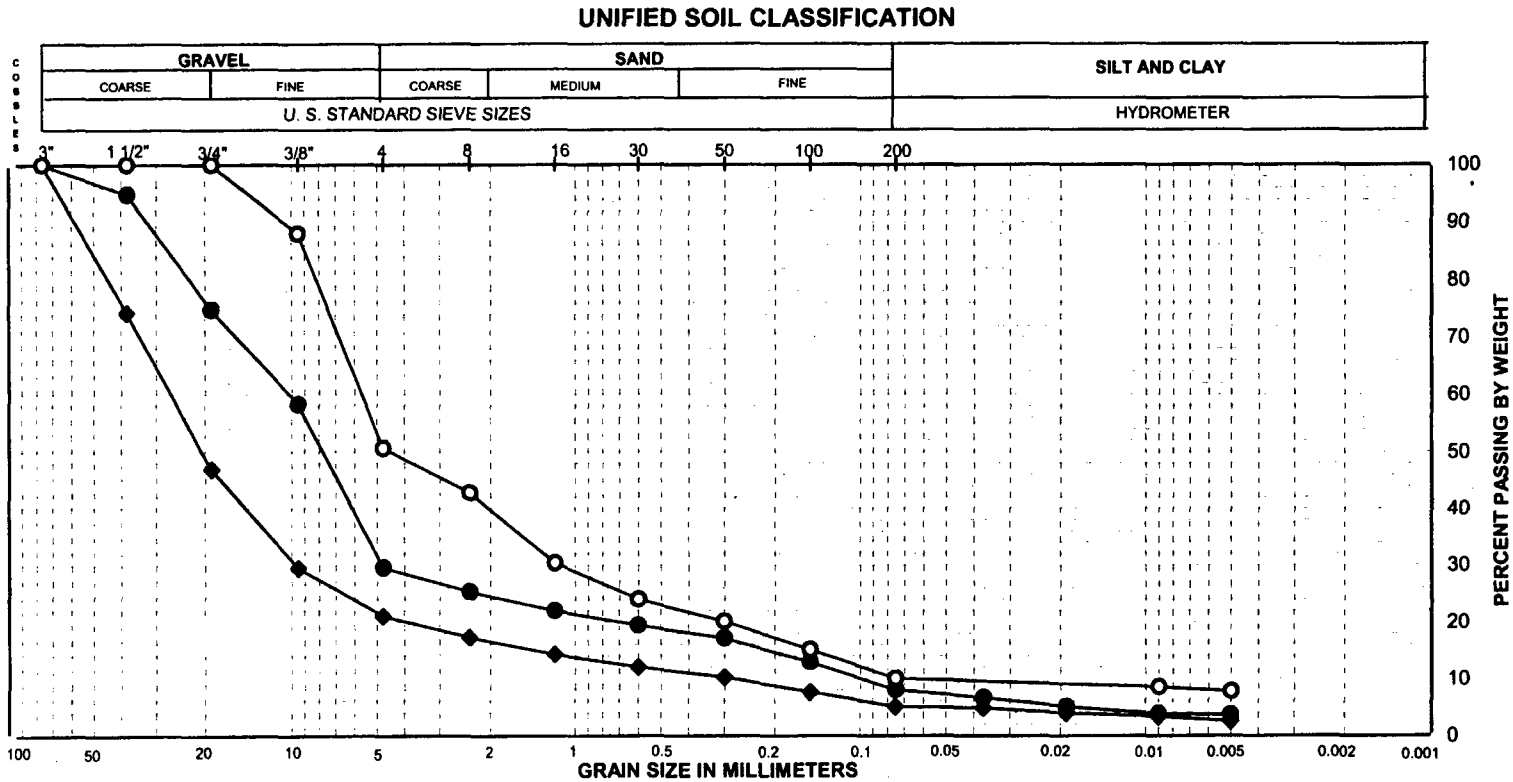
Figure XI-2. Particle-Size Distribution for Samples from Test Pit TP-WHB-2



Exploration No.	Depth (ft)	SYMBOL	$W_{-\#4}$ (%)	LL	PI	%<5 μm	Description and Classification	D_{60}	D_{30}	D_{10}	Cu	Cc
TP-WHB-2	16.0	○	7.4	NP	NP	8.0	Well-graded Sand with silt and gravel (SW-SM)	4.35	0.32	0.02	218	1.2
TP-WHB-2	16.0	●	5.3	NP	NP	5.1	Poorly graded Sand with silt and gravel (SP-SM)	4.25	0.69	0.12	35.4	0.9
TP-WHB-2	19.0	◆	9.6	NP	NP	4.5	Well-graded Gravel with sand (GW)	8.02	1.4	0.12	66.8	2.0

DTN: GS020483114233.004

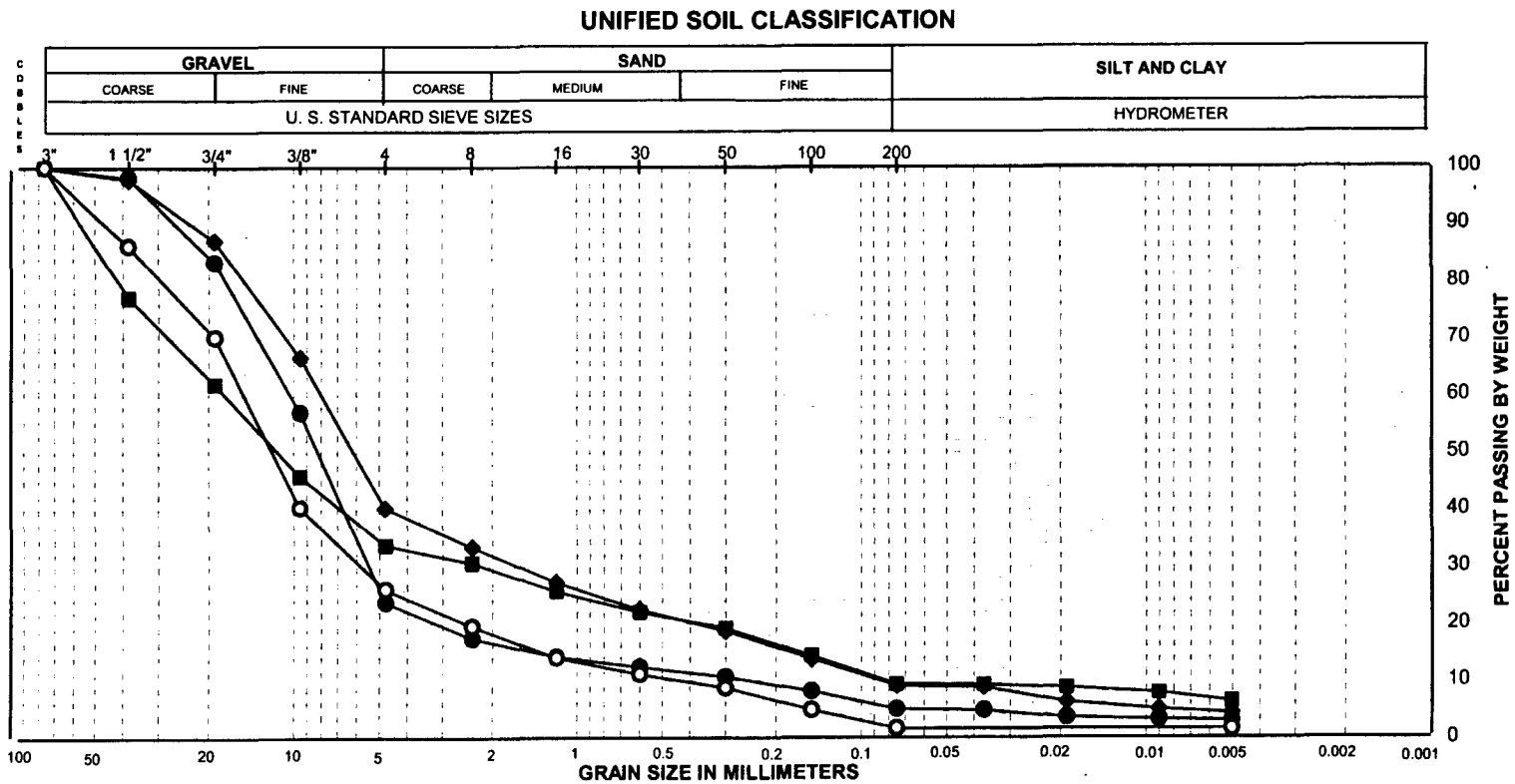
Figure XI-3. Particle-Size Distribution for Samples from Test Pit TP-WHB-2



Exploration No.	Depth (ft)	SYMBOL	$W_{\#4}$ (%)	LL	PI	%<5 μm	Description and Classification	D_{60}	D_{30}	D_{10}	Cu	Cc
TP-WHB-3	8.0	○	3.5	NP	NP	7.7	Poorly graded Gravel with silt and sand (GP-GM)	5.81	1.15	0.02	290.5	11.4
TP-WHB-3	8.0	●	4.4	NP	NP	3.6	Poorly graded Gravel with silt and sand (GP-GM)	10	4.82	0.10	100.1	23.2
TP-WHB-3	8.0	◆	5.1	NP	NP	2.5	Poorly graded Gravel with silt and sand (GP-GM)	26.9	9.8	0.28	96.1	12.8

DTN: GS020483114233.004

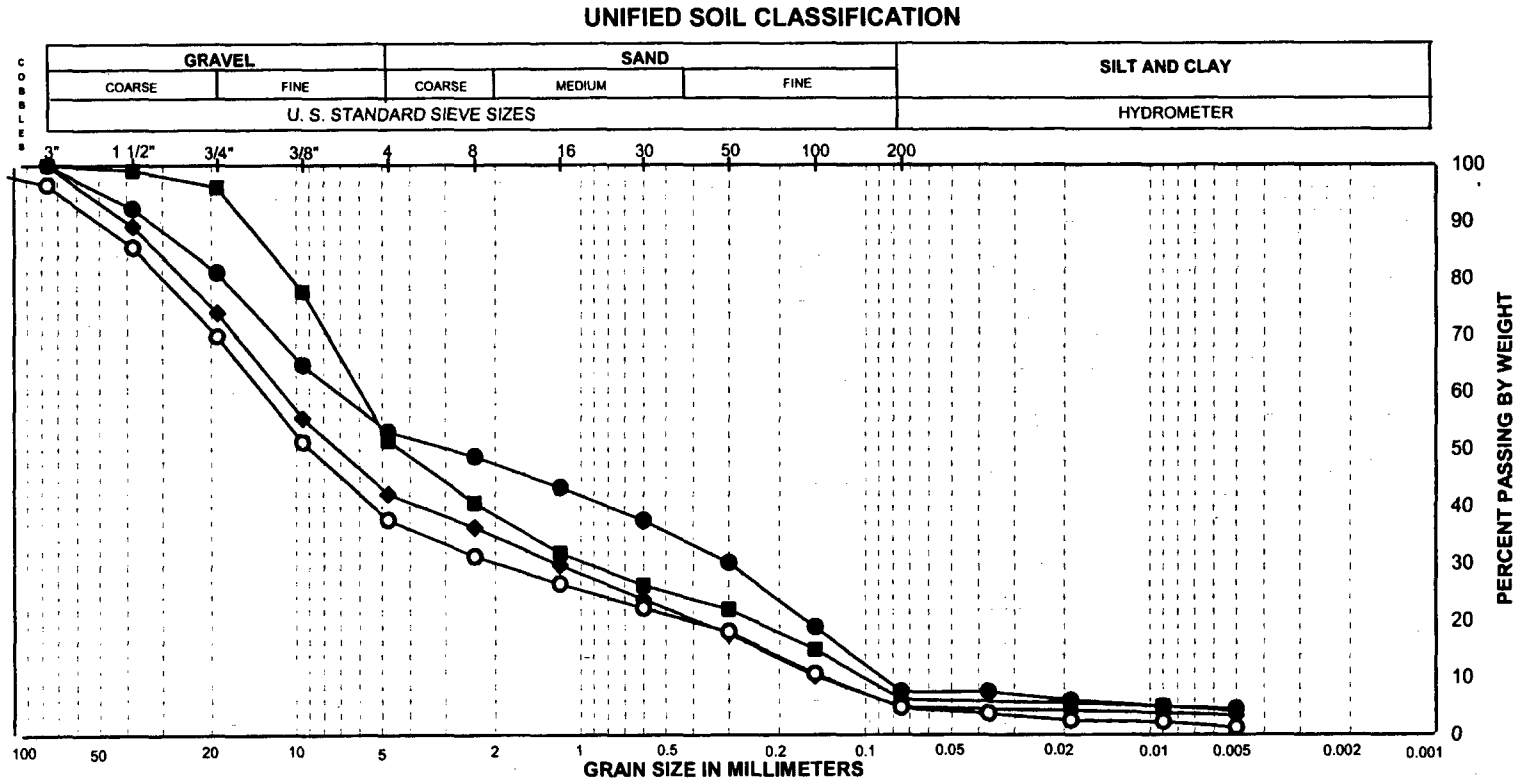
Figure XI-4. Particle-Size Distribution for Samples from Test Pit TP-WHB-3



Exploration No.	Depth (ft)	SYMBOL	$W_{-\#4}$ (%)	LL	PI	%<5 μm	Description and Classification	D_{60}	D_{30}	D_{10}	Cu	Cc
TP-WHB-3	12.0	○	8.9	NP	NP	1.5	Poorly graded Gravel with sand (GP)	14.9	6.32	0.42	35.5	6.4
TP-WHB-3	12.0	●	6.9	NP	NP	2.9	Poorly graded Gravel with sand (GP)	10.1	5.63	0.24	42.1	13.1
TP-WHB-3	12.0	◆	4.1	NP	NP	4.3	Poorly graded Gravel with silt and sand (GP-GM)	8.09	1.55	0.09	89.9	3.3
TP-WHB-3	19.0	■	16.0	NP	NP	6.3	Well-graded Gravel with silt and sand (GW-GM)	17.3	2.07	0.09	192.4	2.7

DTN: GS020483114233.004

Figure XI-5. Particle-Size Distribution for Samples from Test Pit TP-WHB-3



Exploration No.	Depth (ft)	SYMBOL	$W_{\#4}$ (%)	LL	PI	%<5 μm	Description and Classification	D_{60}	D_{30}	D_{10}	Cu	Cc
TP-WHB-4	4.0	○	6.7	NP	NP	1.2	Well-graded Gravel with sand (GW)	13.9	2.09	0.14	99.1	2.2
TP-WHB-4	8.0	●	6.9	NP	NP	4.5	Poorly graded Gravel with silt and sand (GP-GM)	7.56	0.3	0.09	84.0	0.1
TP-WHB-4	12.0	◆	8.0	NP	NP	3.4	Poorly graded Gravel with sand (GP)	11.3	1.2	0.15	75.5	0.8
TP-WHB-4	16.0	■	8.0	NP	NP	4.2	Well-graded Gravel with silt and sand (GW-GM)	6.11	0.98	0.11	55.5	1.4

DTN: GS020483114233.004

Figure XI-6. Particle-Size Distribution for Samples from Test Pit TP-WHB-4

ATTACHMENT XII

GEOTECHNICAL LABORATORY DYNAMIC TESTING – WHB AREA

As discussed in Section 6.2.10, this attachment presents the results of resonant column and torsional shear (RCTS) tests on core samples of alluvium and bedrock taken from boreholes advanced in the WHB Area. Results are presented in plots and tables as follows:

- Figures XII-1 through XII-19, plots of RCTS test results for Specimens UTA-20-A through UTA-20-D, UTA-23-A through UTA-23-J, UTA-23-Q through UTA-23-T, and UTA-23-X, respectively.

- Figures XII-20 through XII-22, plots of variation in normalized small-strain shear modulus with excitation frequency of intact tuff specimens.

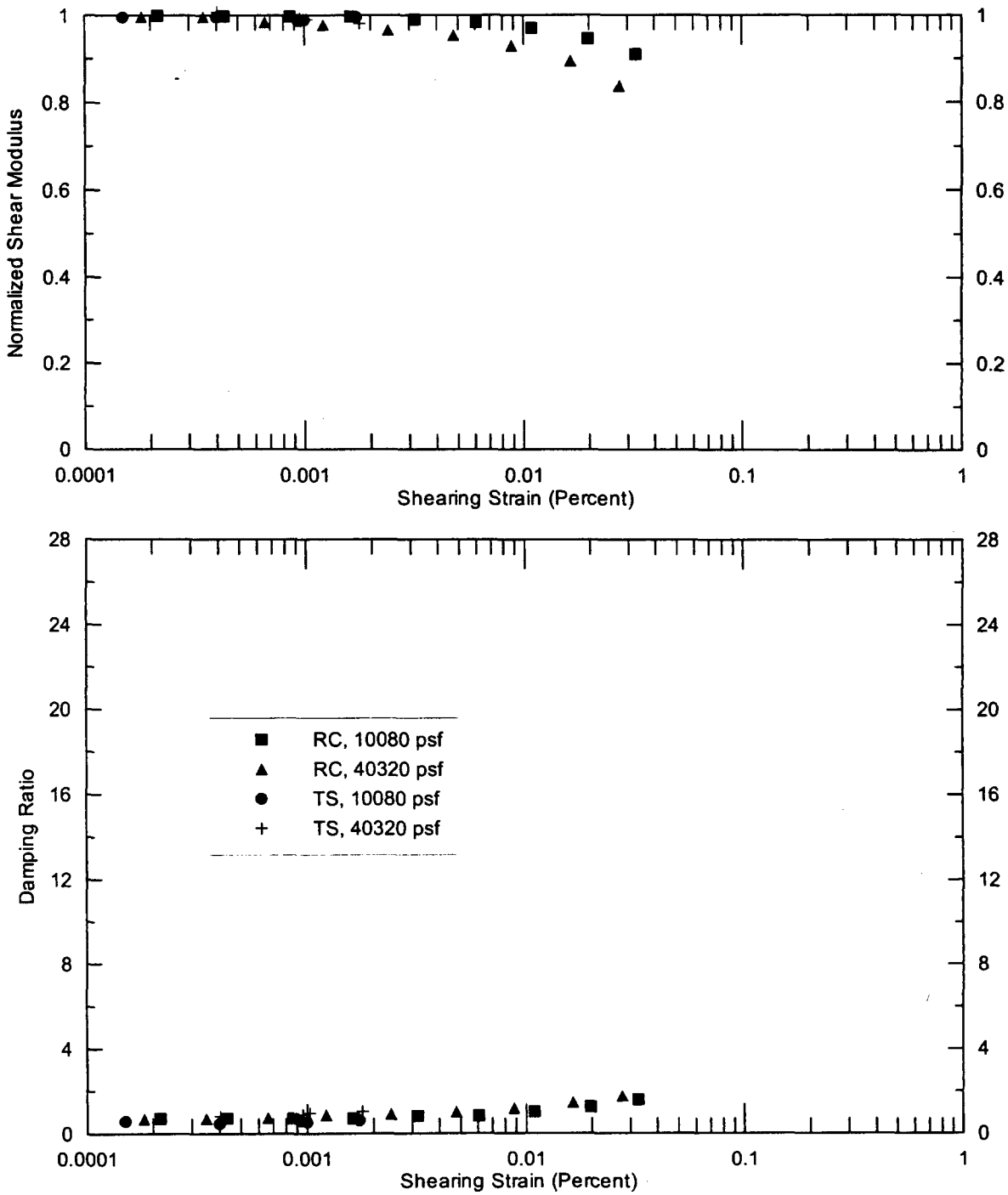
- Figures XII-23 through XII-25, plots of variation in normalized small-strain material damping ratio with excitation frequency of intact tuff specimens.

- Figure XII-26, plot of variation in small-strain shear modulus with excitation frequency of reconstituted Quaternary alluvium specimen recovered from borehole UE-25 RF#17.

- Figure XII-27, plot of variation in small-strain material damping ratio with excitation frequency of reconstituted Quaternary alluvium specimen recovered from borehole UE-25 RF#17.

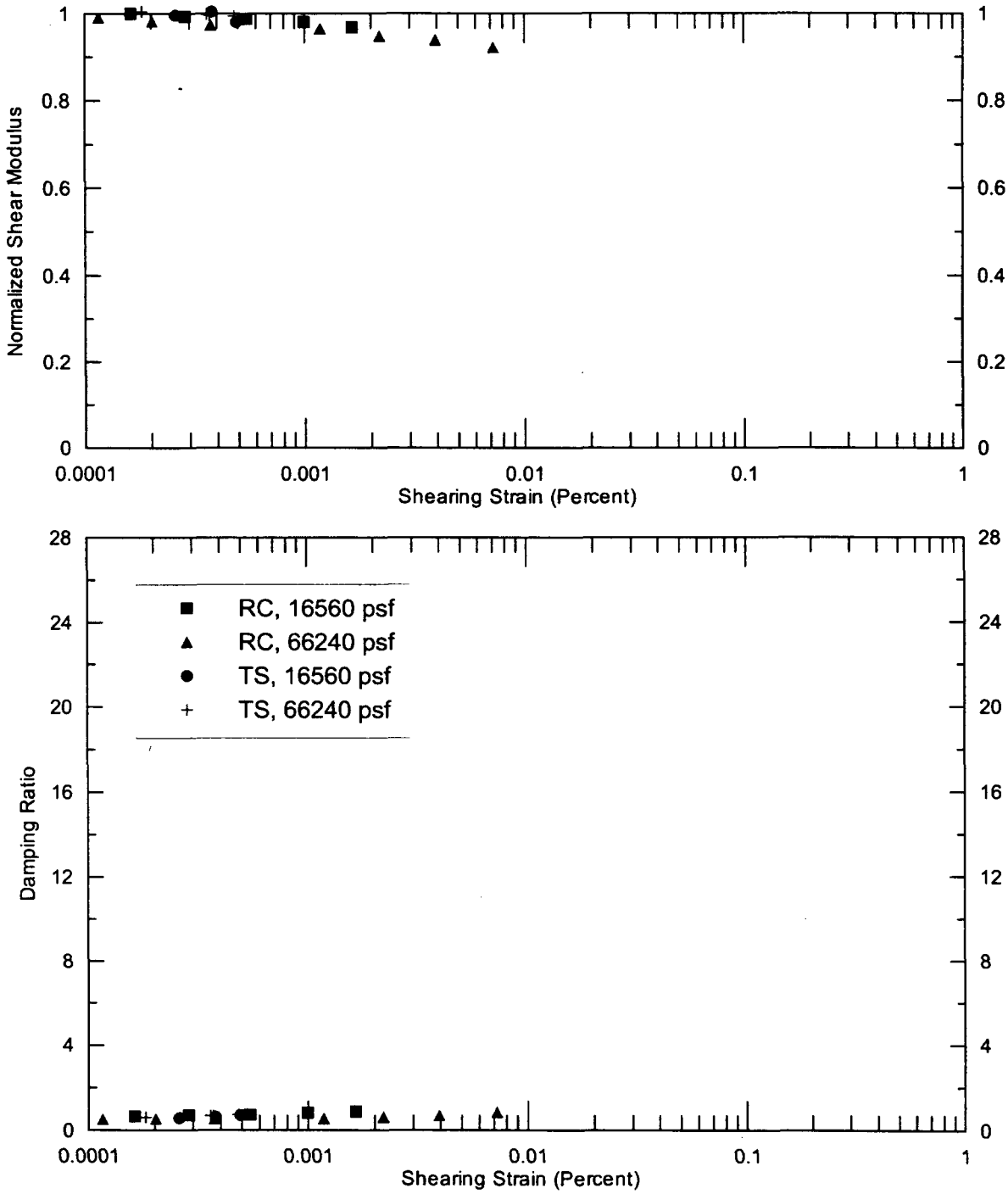
- Figure XII-28, plot of comparison of small-strain shear wave velocity measured with fixed-free and free-free resonant columns.

- Tables XII-1 through XII-19 present results of RCTS tests for Specimens UTA-20-A through UTA-20-D, UTA-23-A through UTA-23-J, UTA-23-Q through UTA-23-T and UTA-23-X. Each table spans two pages. These data are contained in DTN: MO0203DHRSSWHB.001. The first table for each specimen contains effective isotropic confining pressure in psi, psf and kPa units. The data in the above DTN is in psf units only. The data in psi and kPa and low- amplitude shear modulus in MPa are from Scientific Notebook SN-M&O-SCI-033-VI (Wong 2002e, Appendices 6 through 9, 15 through 24, 31 through 34, and 38).



DTN: MO0203DHRSSWHB.001

Figure XII-1. Resonant Column and Torsional Shear Results for Specimen UTA-20-A



DTN: MO0203DHRSSWHB.001

Figure XII-2. Resonant Column and Torsional Shear Results for Specimen UTA-20-B

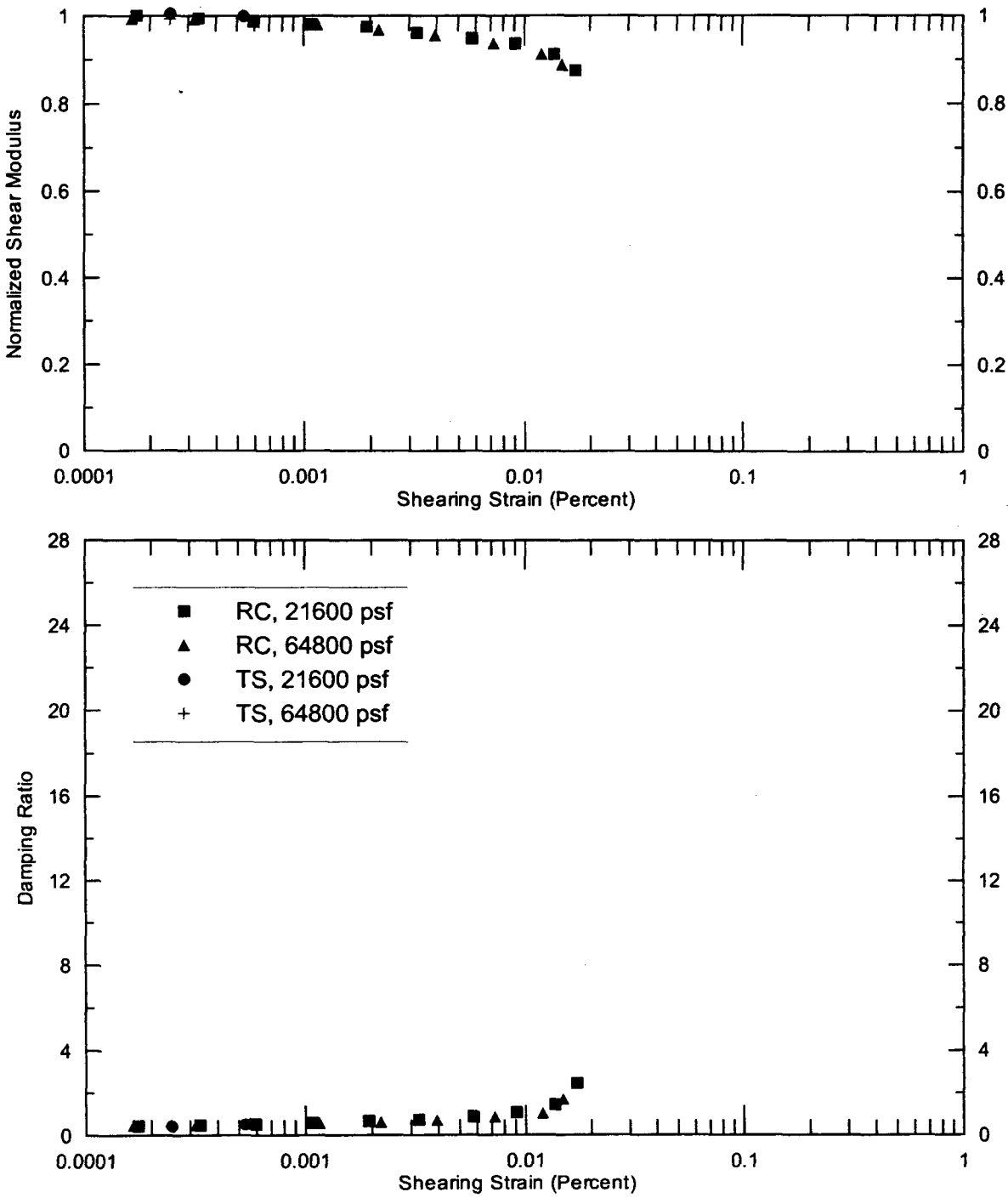
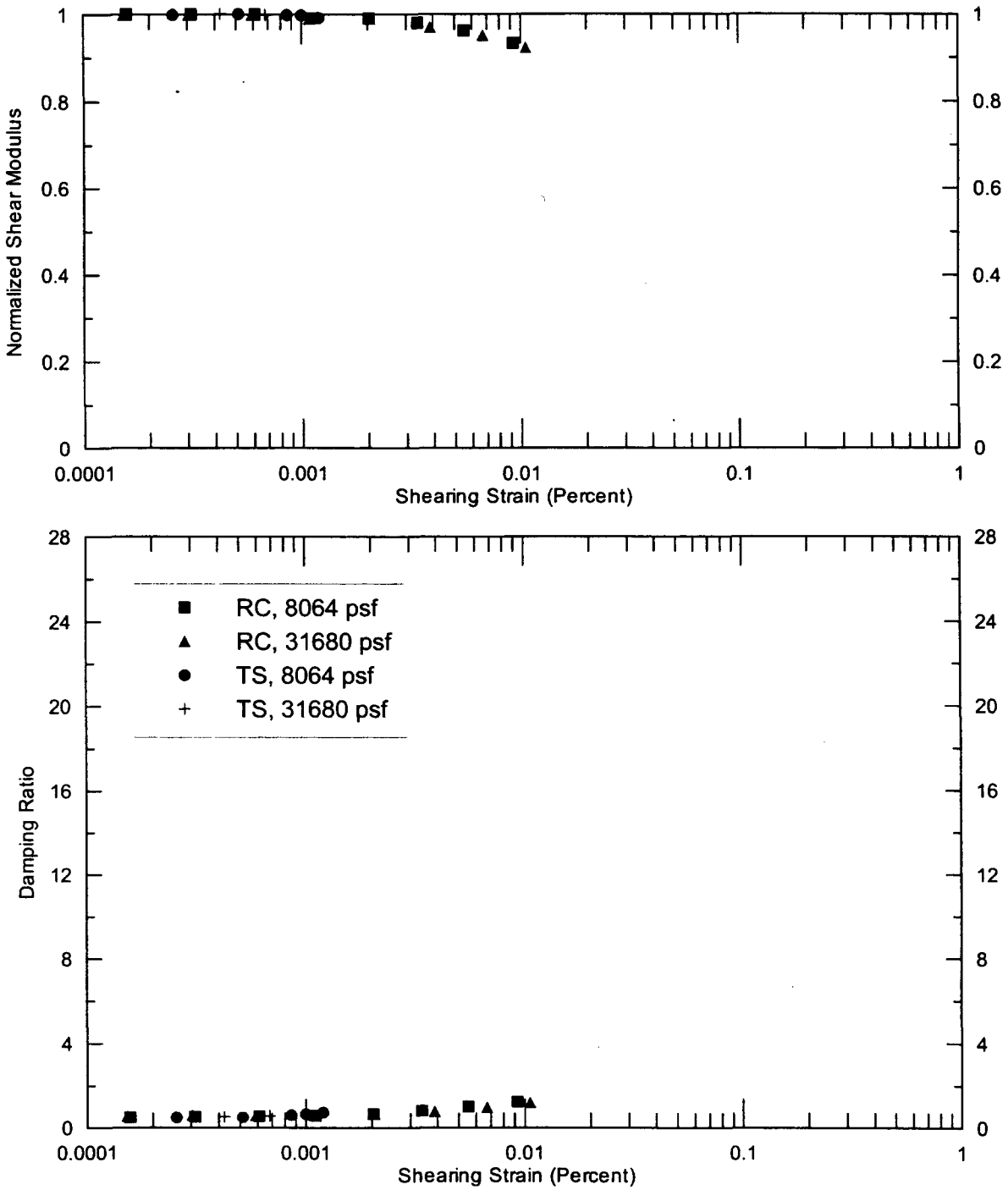


Figure XII-3. Resonant Column and Torsional Shear Results for Specimen UTA-20-C



DTN: MO0203DHRSSWHB.001

Figure XII-4. Resonant Column and Torsional Shear Results for Specimen UTA-20-D

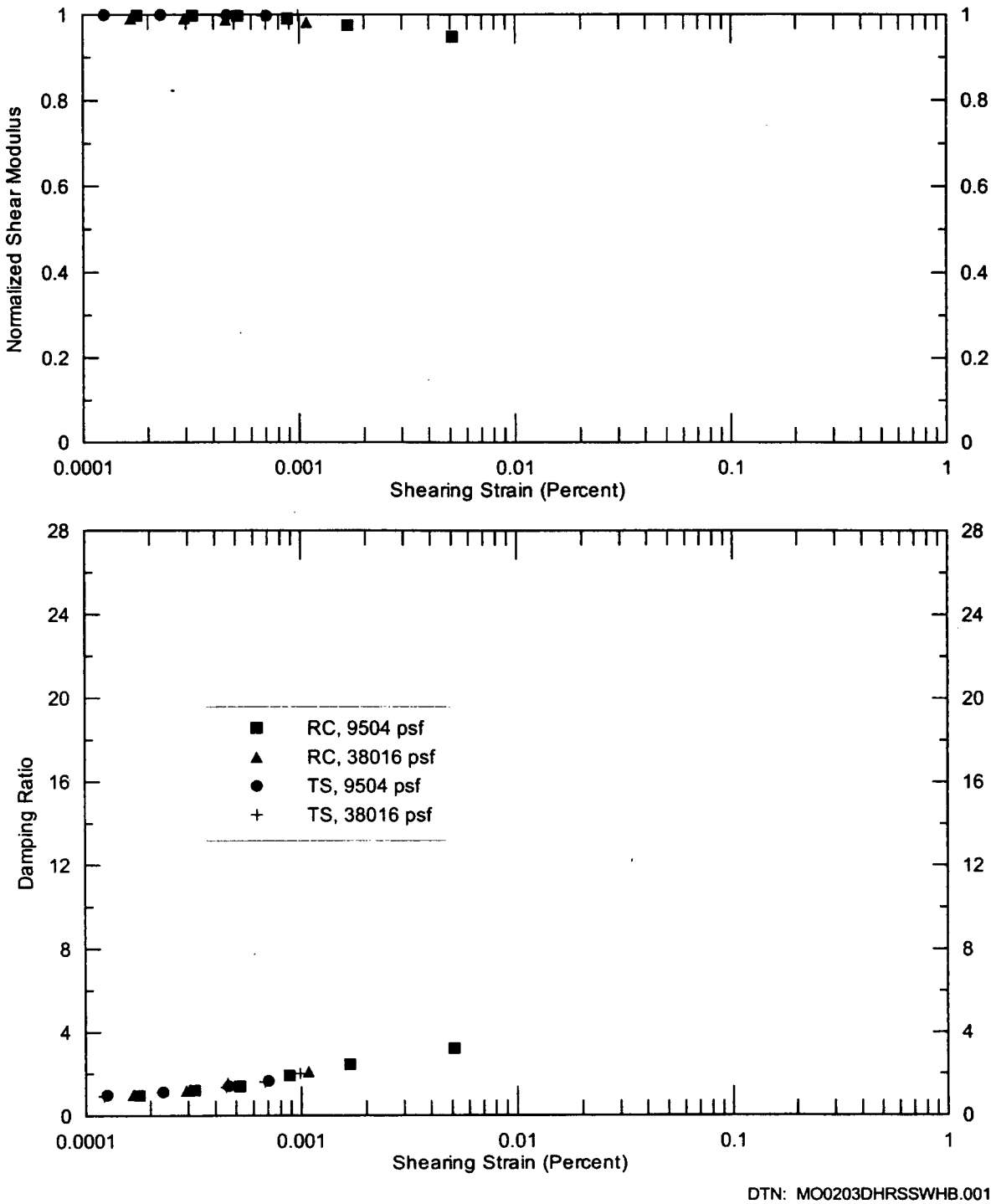
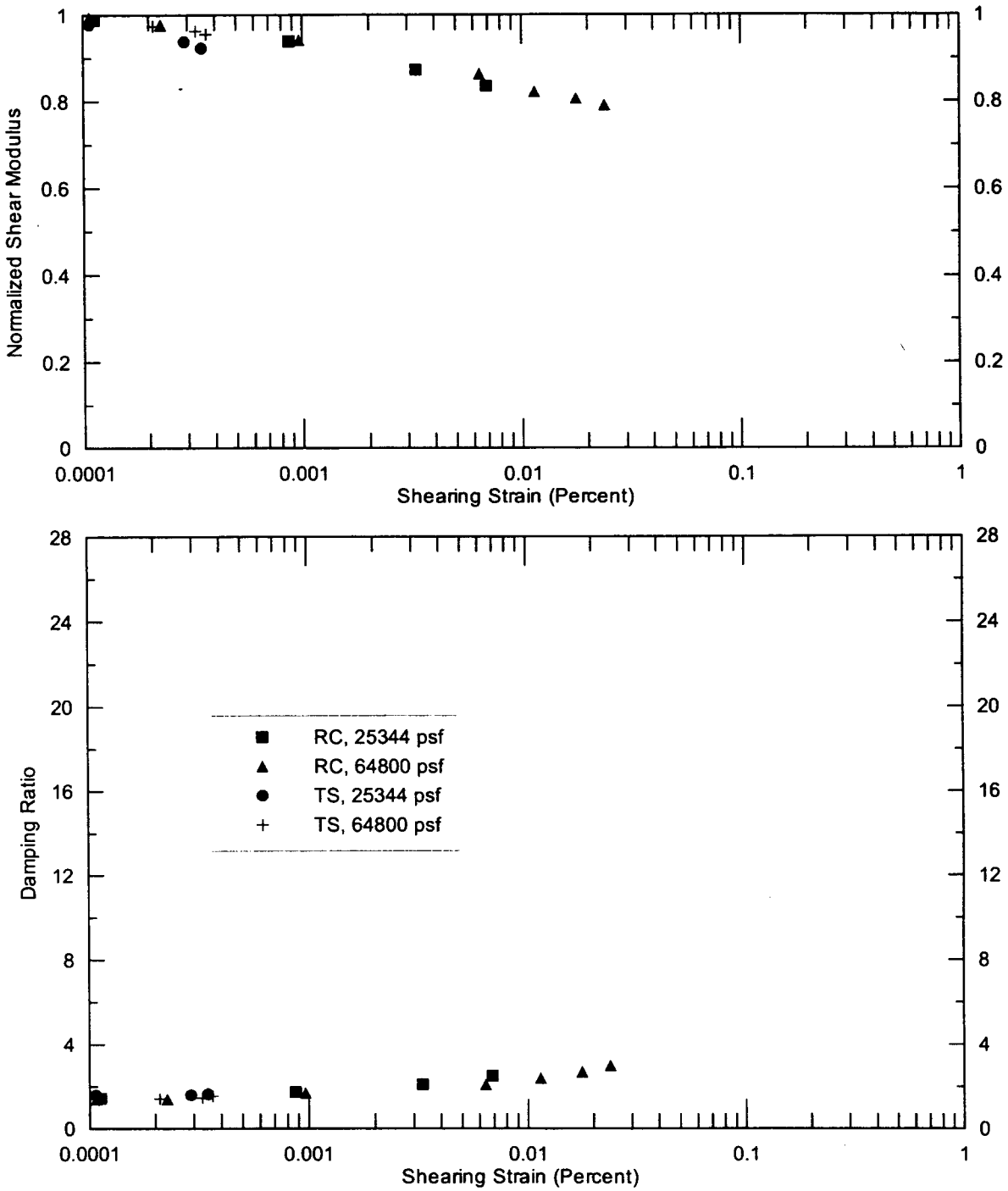
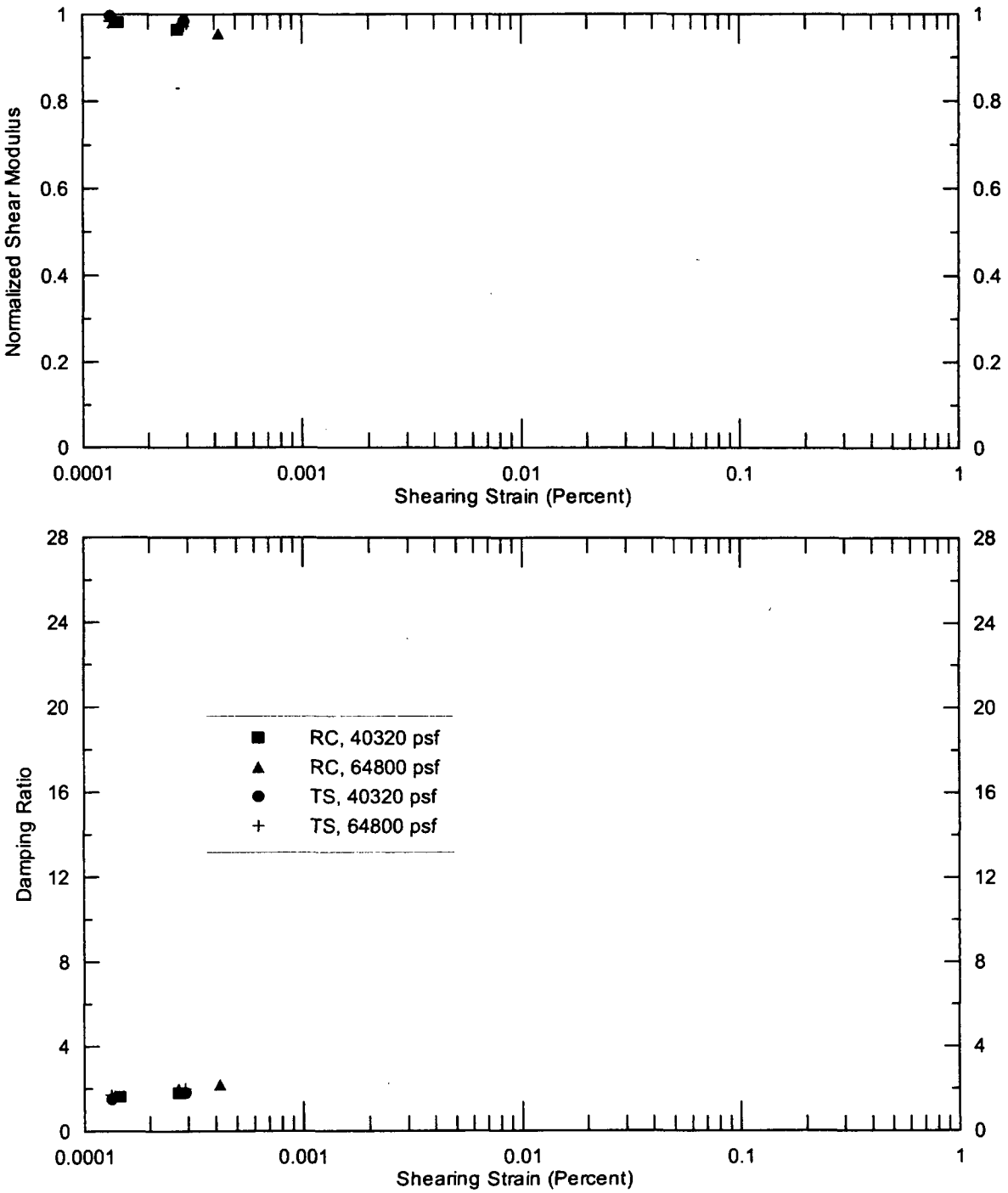


Figure XII-5. Resonant Column and Torsional Shear Results for Specimen UTA-23-A



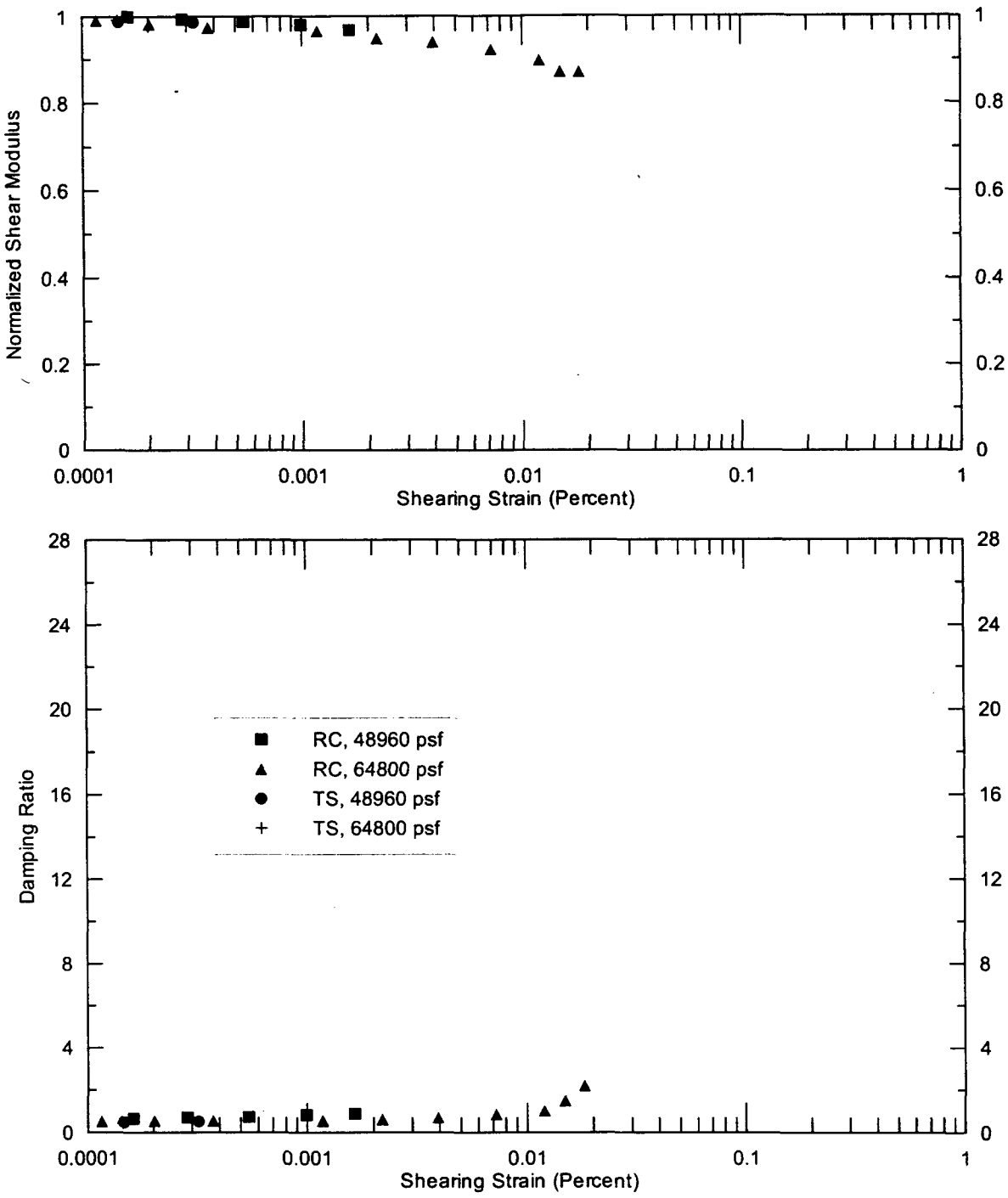
DTN: MO0203DHRSSWHB.001

Figure XII-6. Resonant Column and Torsional Shear Results for Specimen UTA-23-B



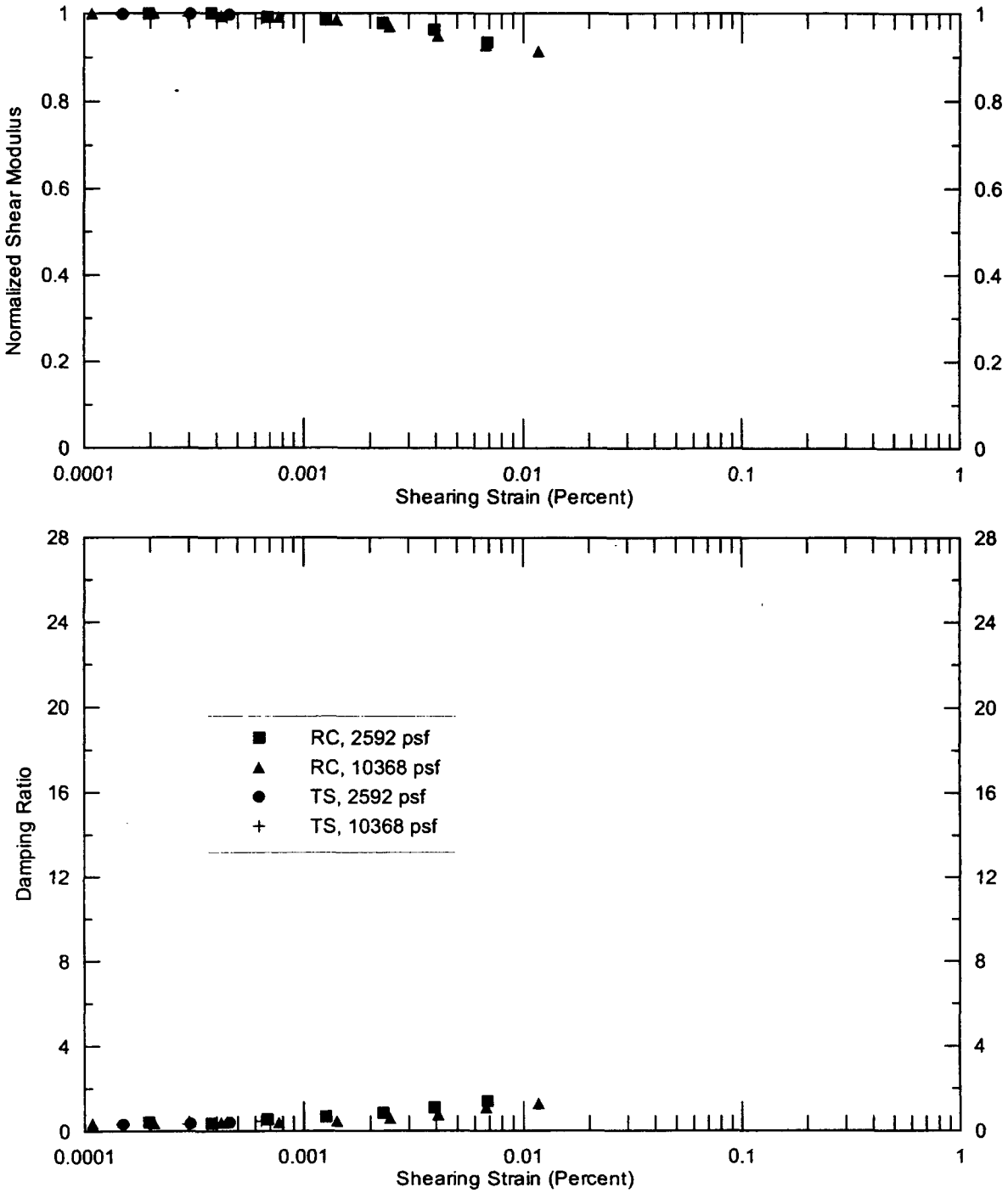
DTN: MO0203DHRSSWHB.001

Figure XII-7. Resonant Column and Torsional Shear Results for Specimen UTA-23-C



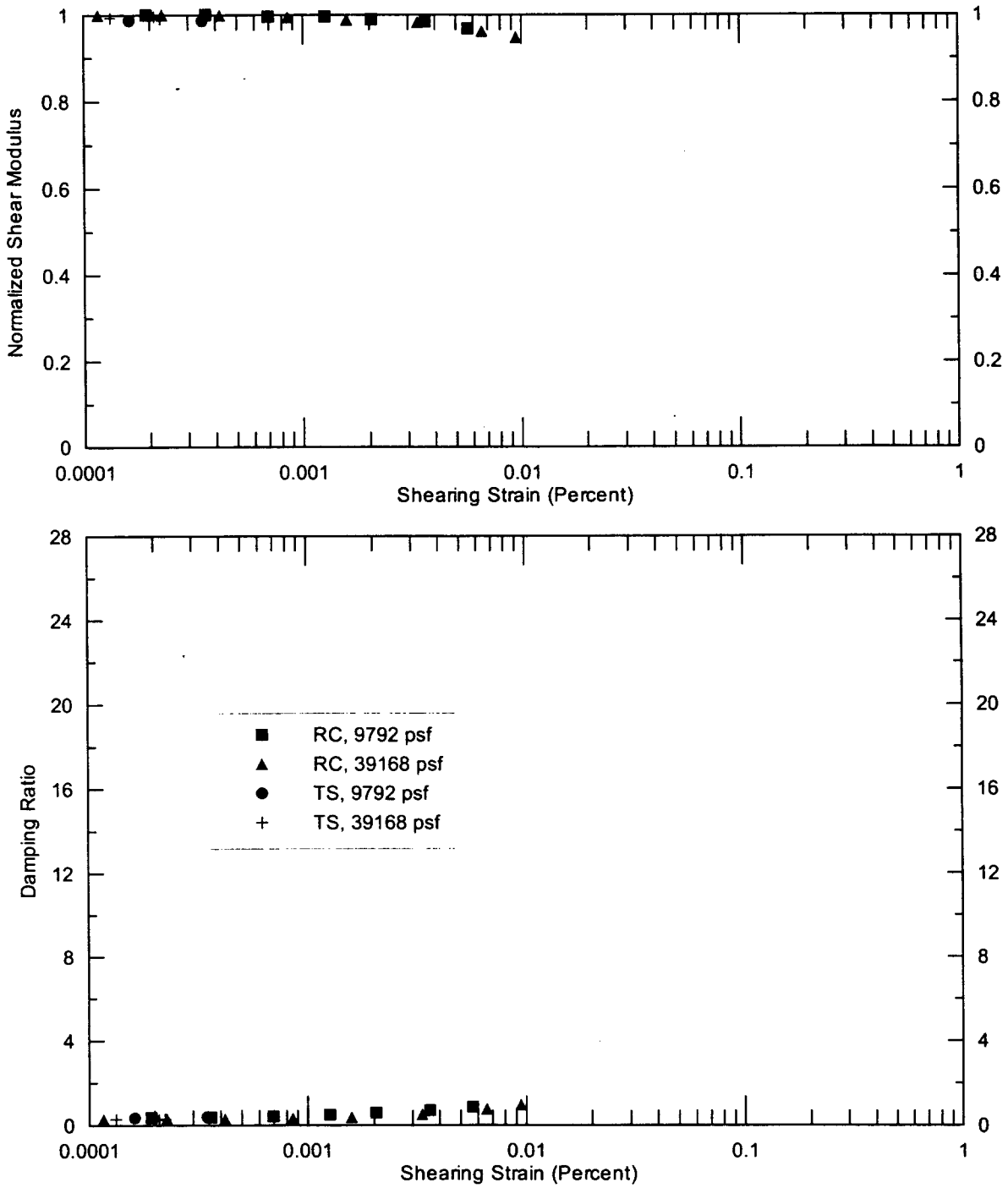
DTN: MO0203DHRSSWHB.001

Figure XII-8. Resonant Column and Torsional Shear Results for Specimen UTA-23-D



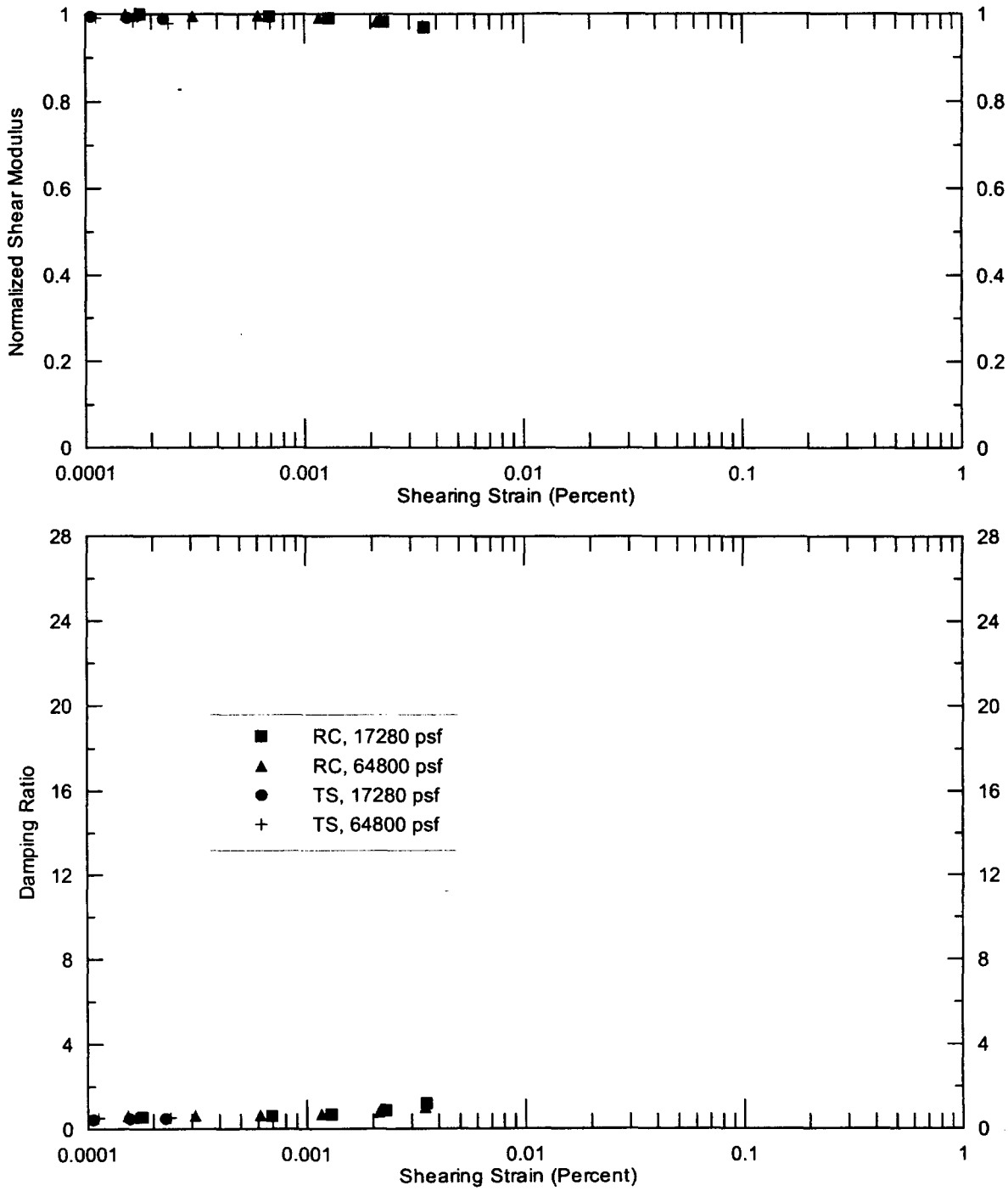
DTN: MO0203DHRSSWHB.001

Figure XII-9. Resonant Column and Torsional Shear Results for Specimen UTA-23-E



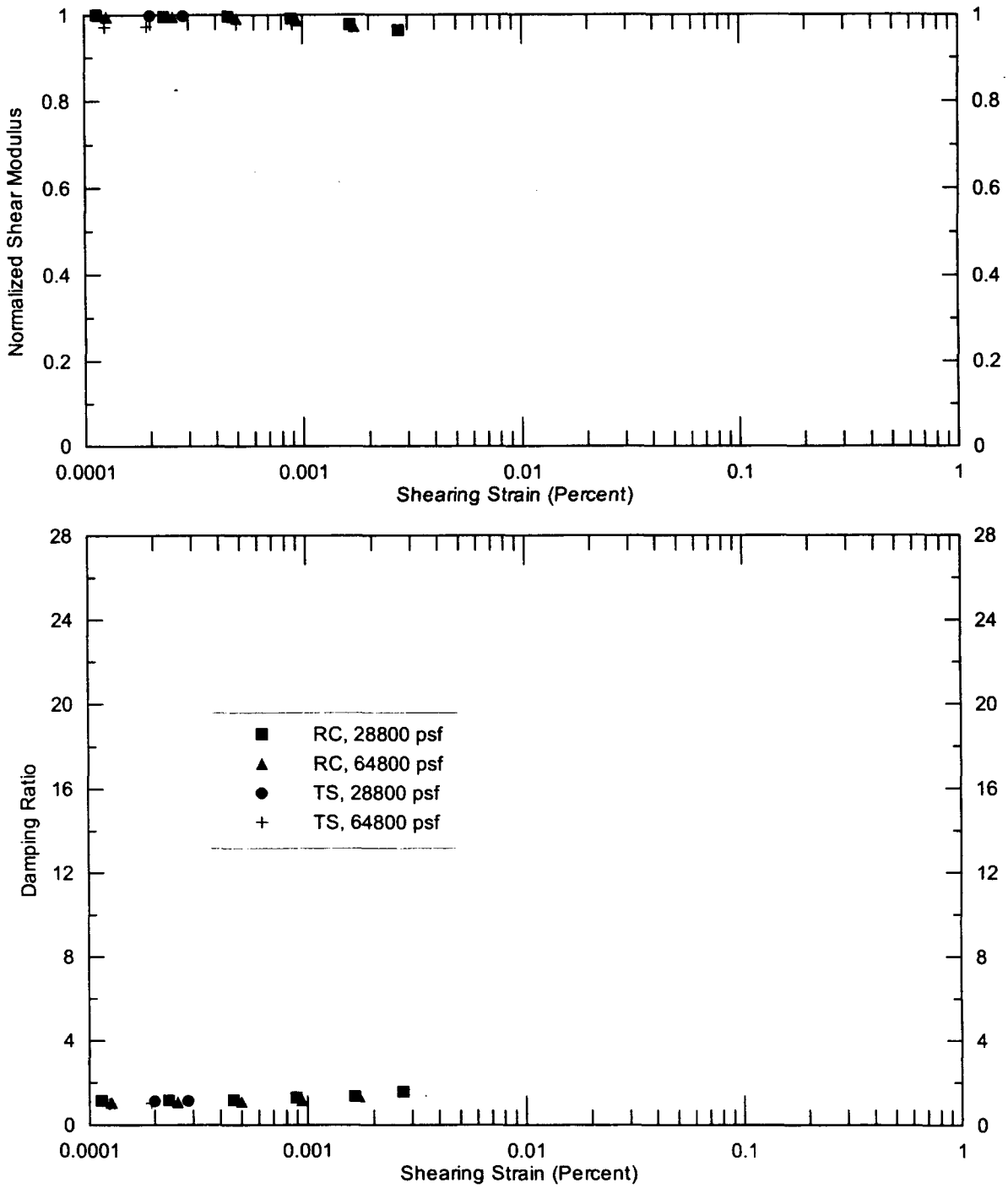
DTN: MO0203DHRSSWHB.001

Figure XII-10. Resonant Column and Torsional Shear Results for Specimen UTA-23-F



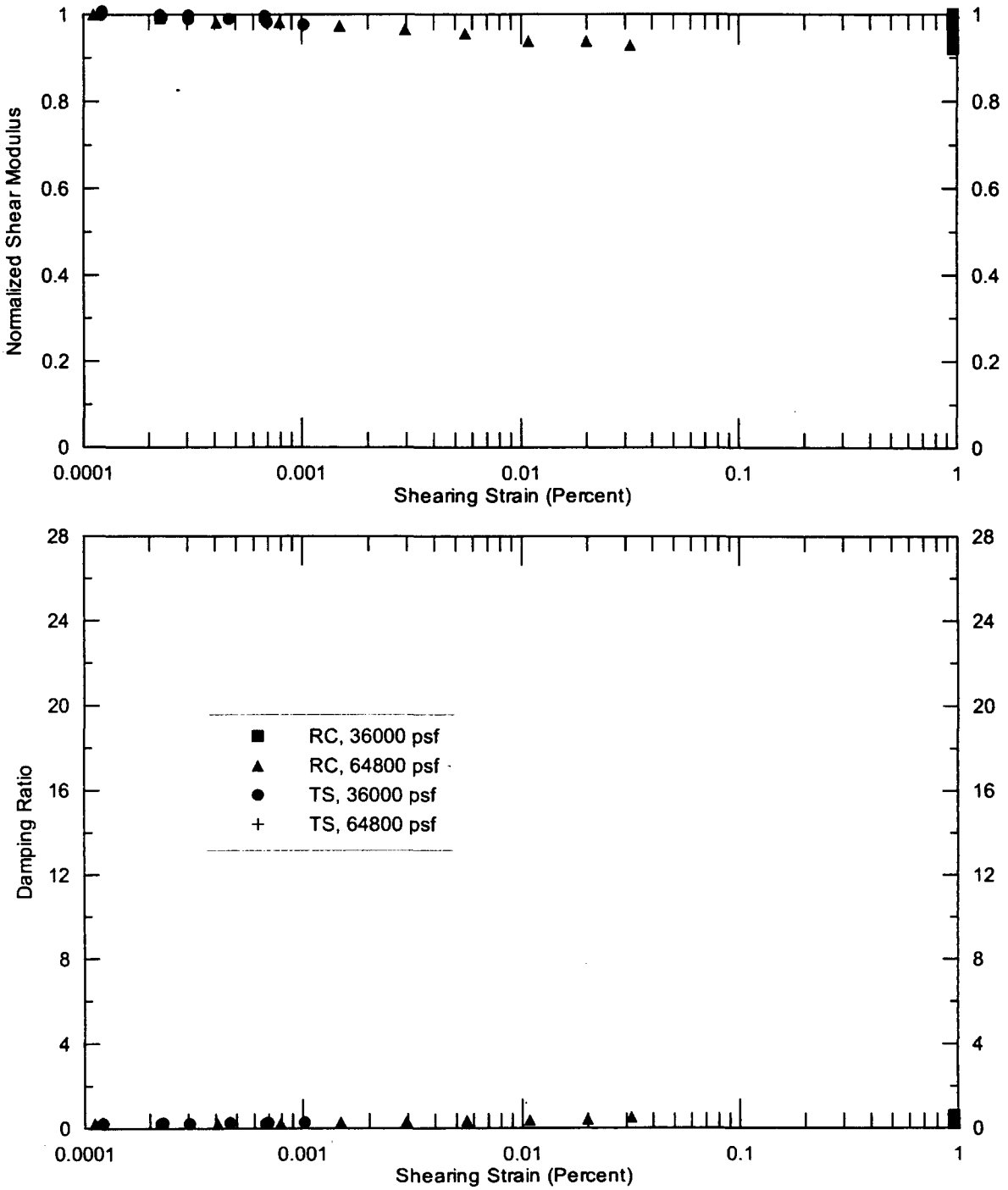
DTN: MO0203DHRSSWHB.001

Figure XII-11. Resonant Column and Torsional Shear Results for Specimen UTA-23-G



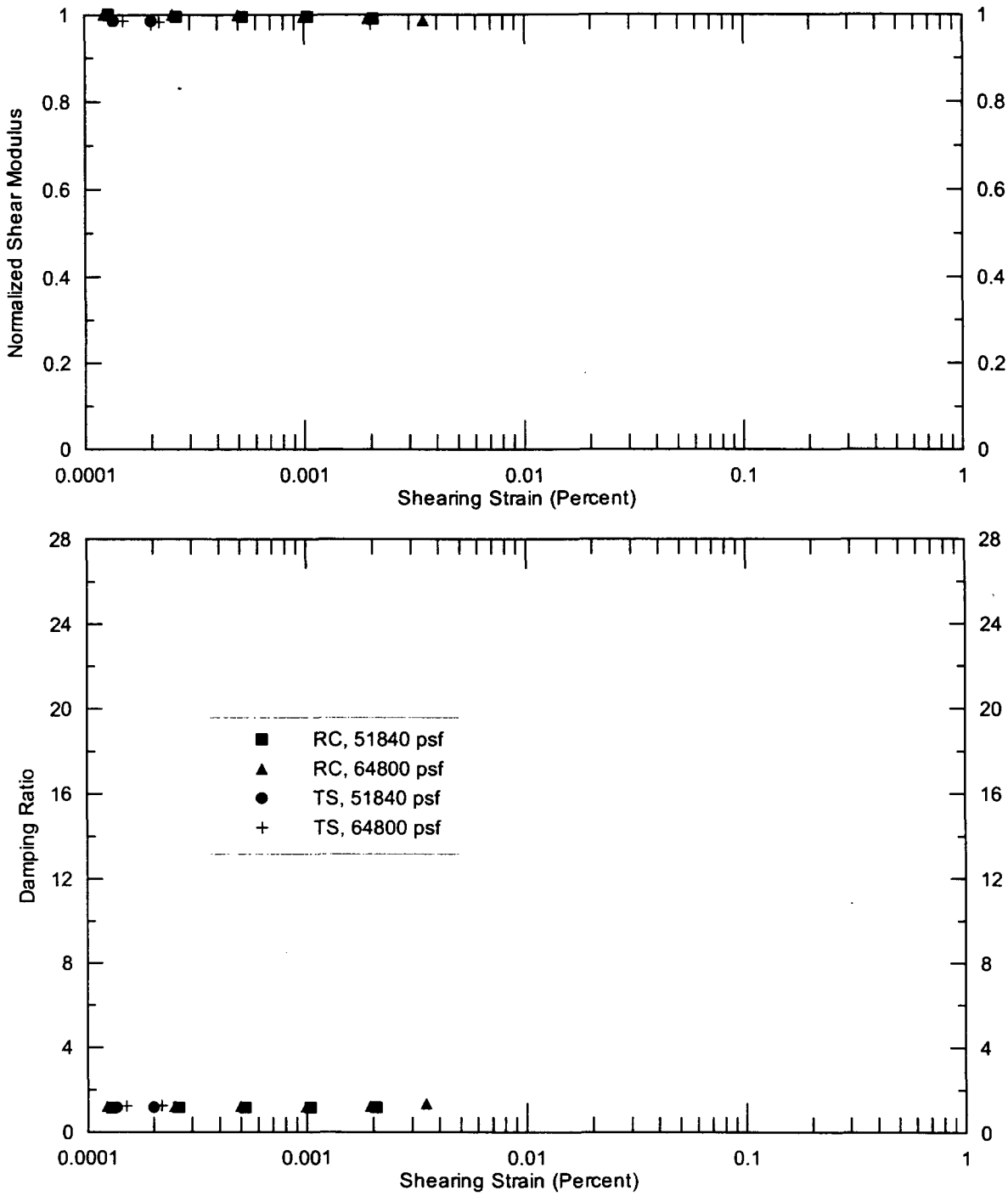
DTN: MO0203DHRSSWHB.001

Figure XII-12. Resonant Column and Torsional Shear Results for Specimen UTA-23-H



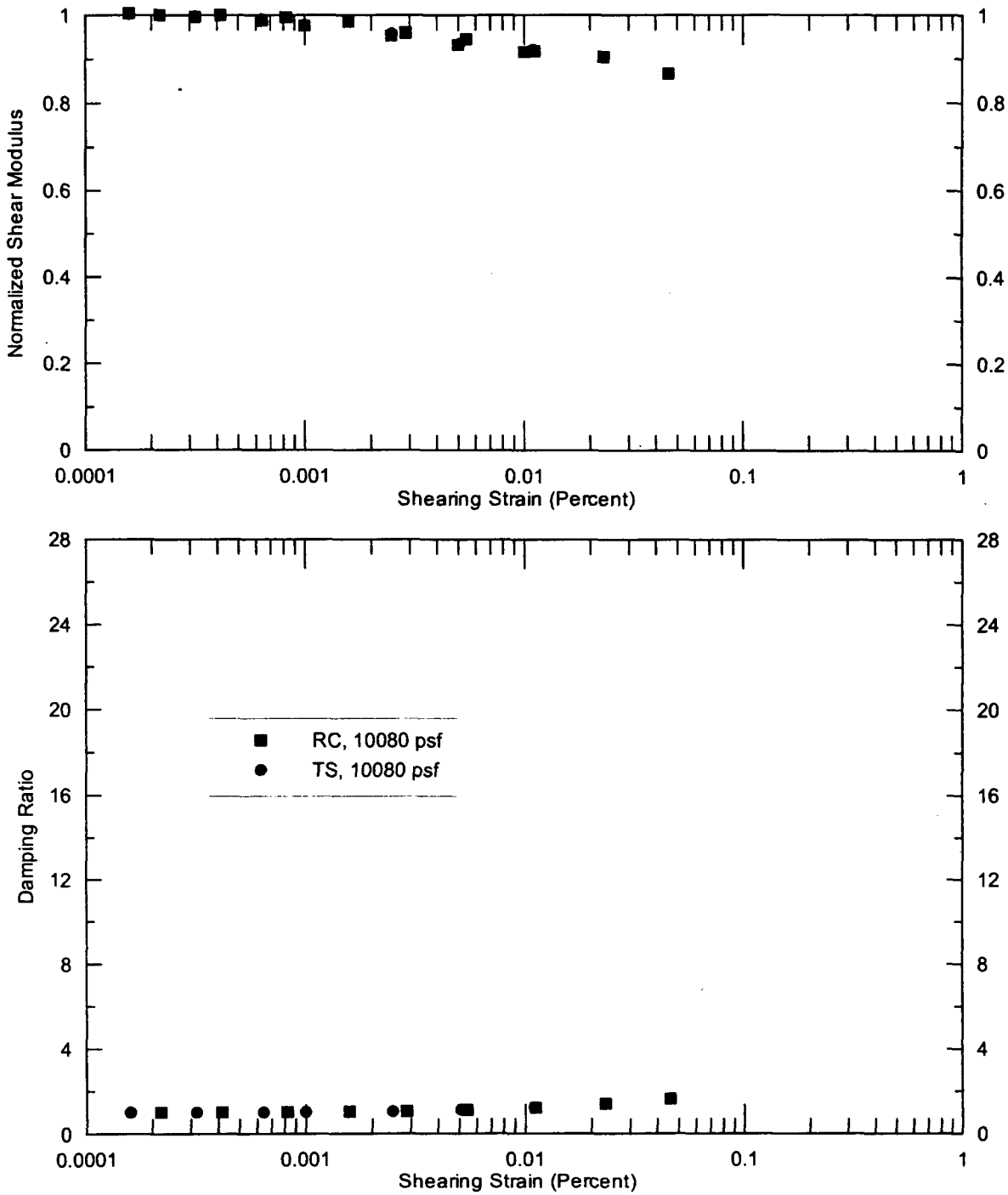
DTN: MO0203DHRSSWHB.001

Figure XII-13. Resonant Column and Torsional Shear Results for Specimen UTA-23-I



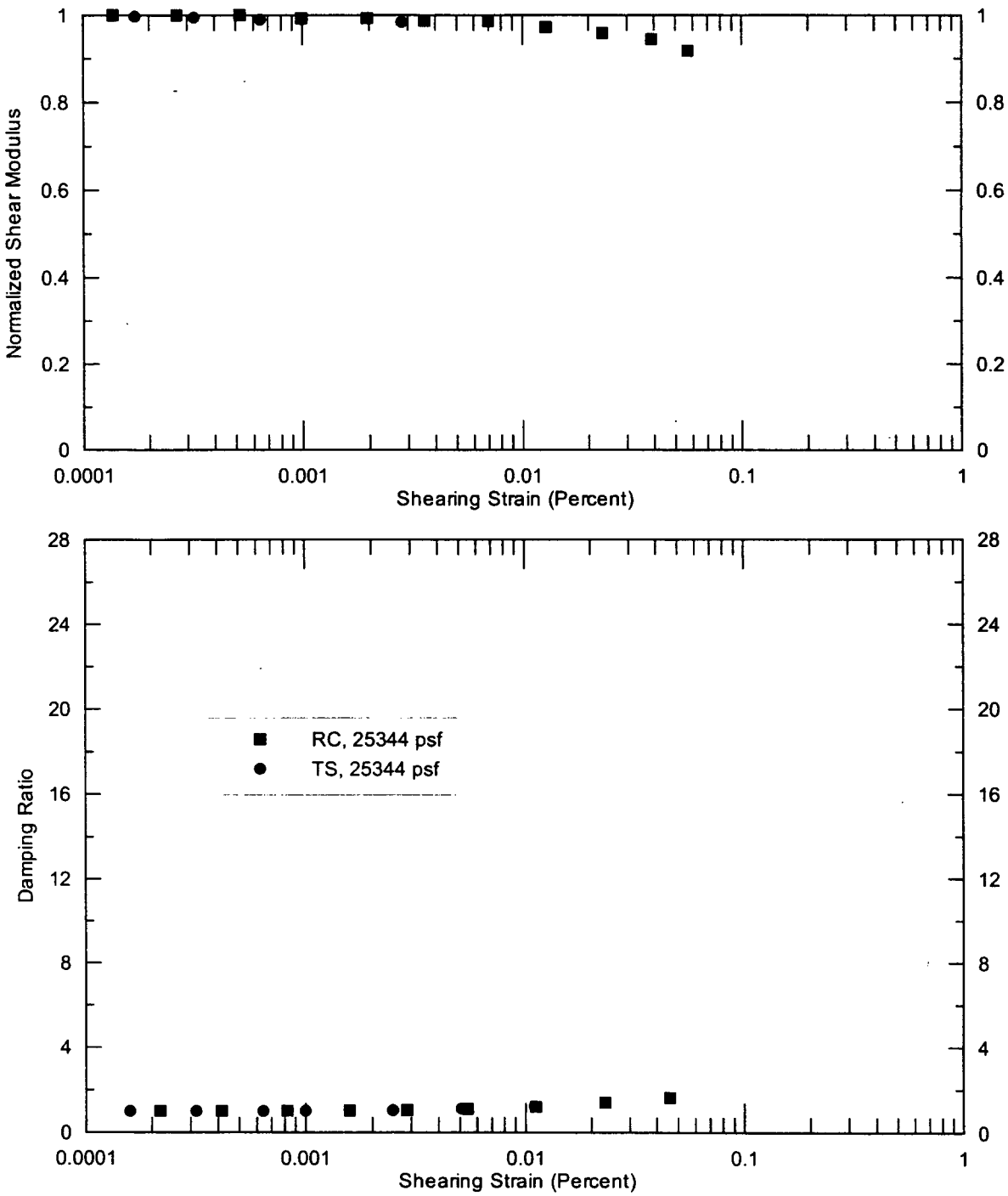
DTN: MO0203DHRSSWHB.001

Figure XII-14. Resonant Column and Torsional Shear Results for Specimen UTA-23-J



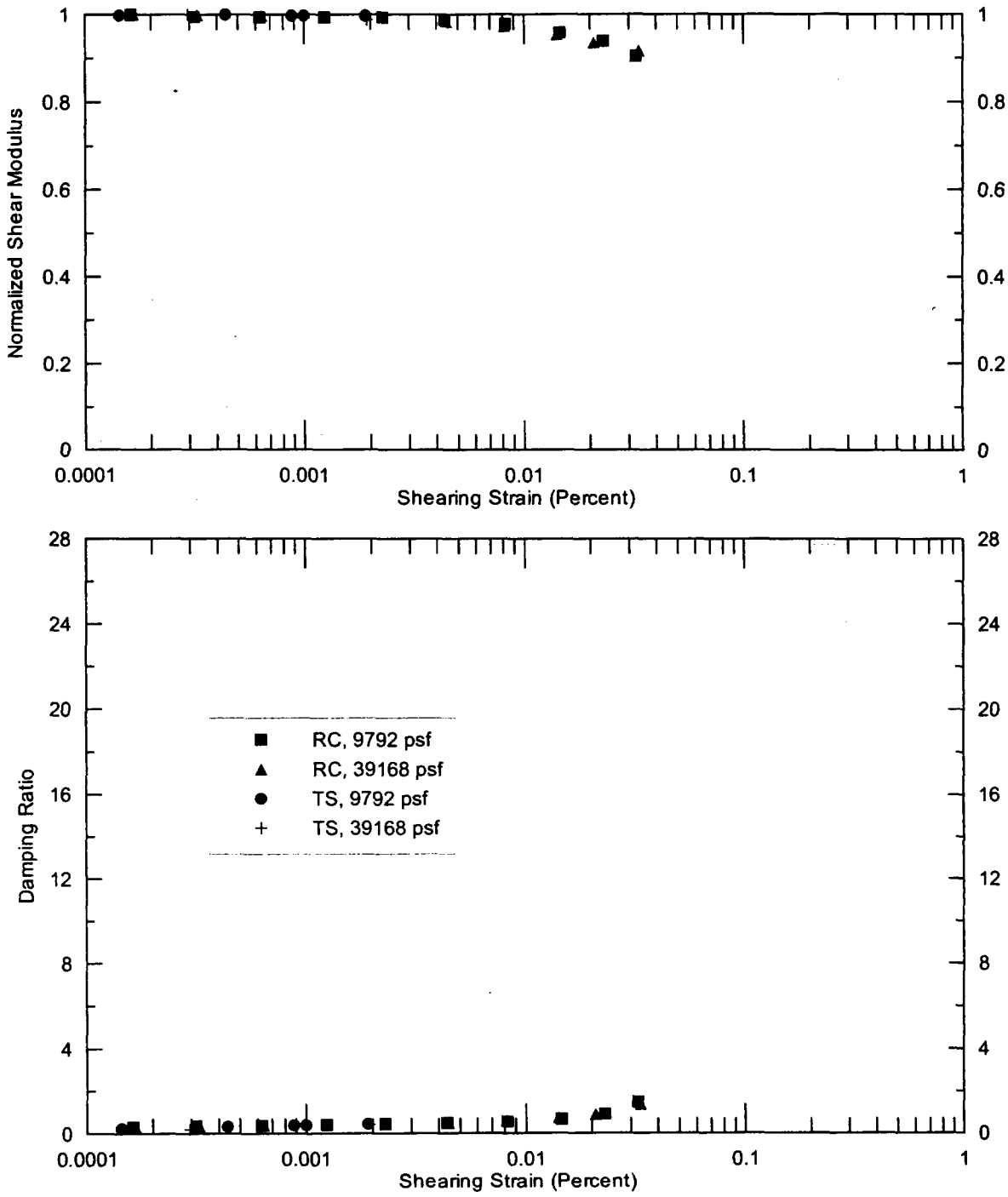
DTN: MO0203DHRSSWHB.001

Figure XII-15. Resonant Column and Torsional Shear Results for Specimen UTA-23-Q



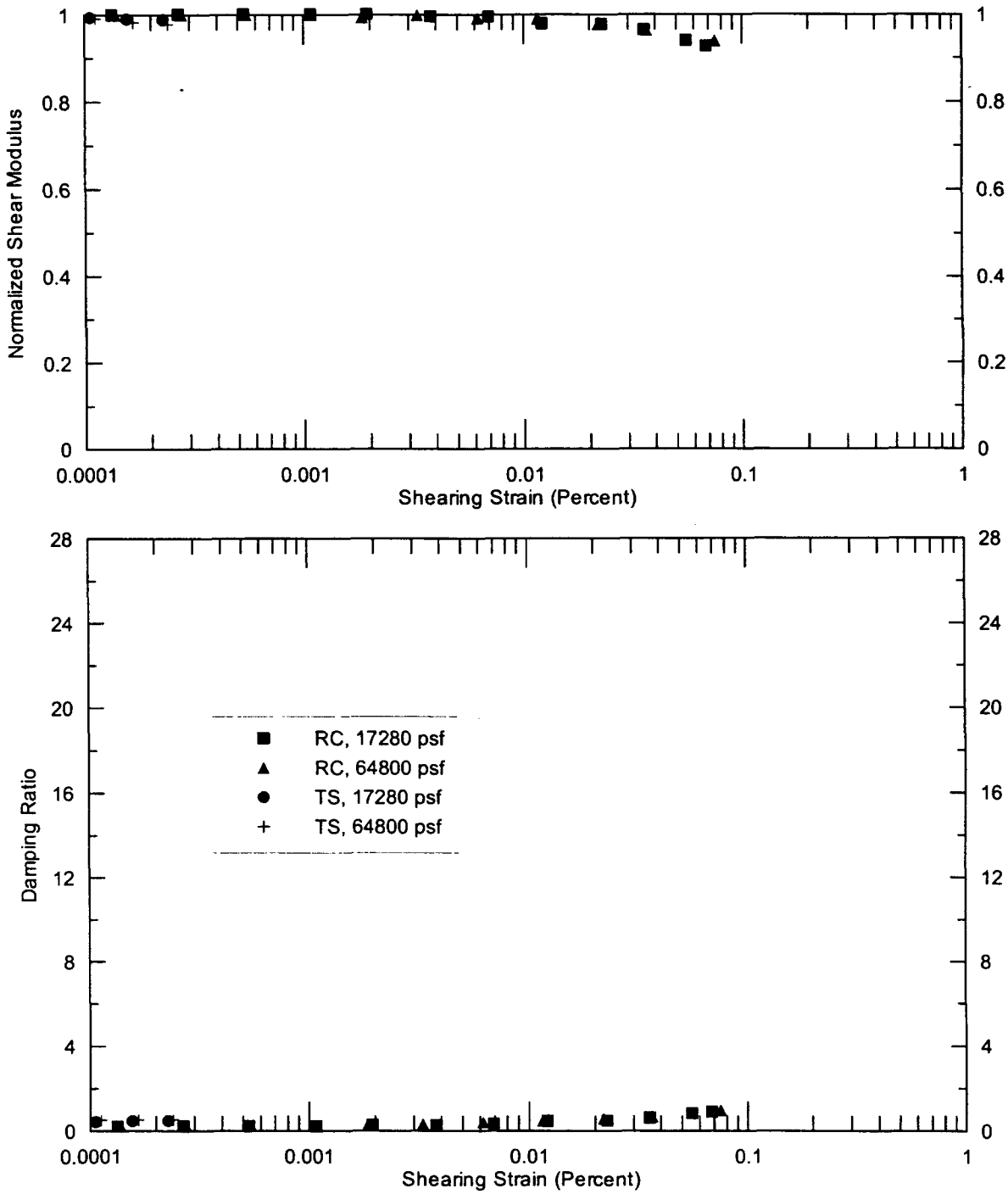
DTN: MO0203DHRSSWHB.001

Figure XII-16. Resonant Column and Torsional Shear Results for Specimen UTA-23-R



DTN: MO0203DHRSSWHB.001

Figure XII-17. Resonant Column and Torsional Shear Results for Specimen UTA-23-S



DTN: MO0203DHRSSWHB.001

Figure XII-18. Resonant Column and Torsional Shear Results for Specimen UTA-23-T

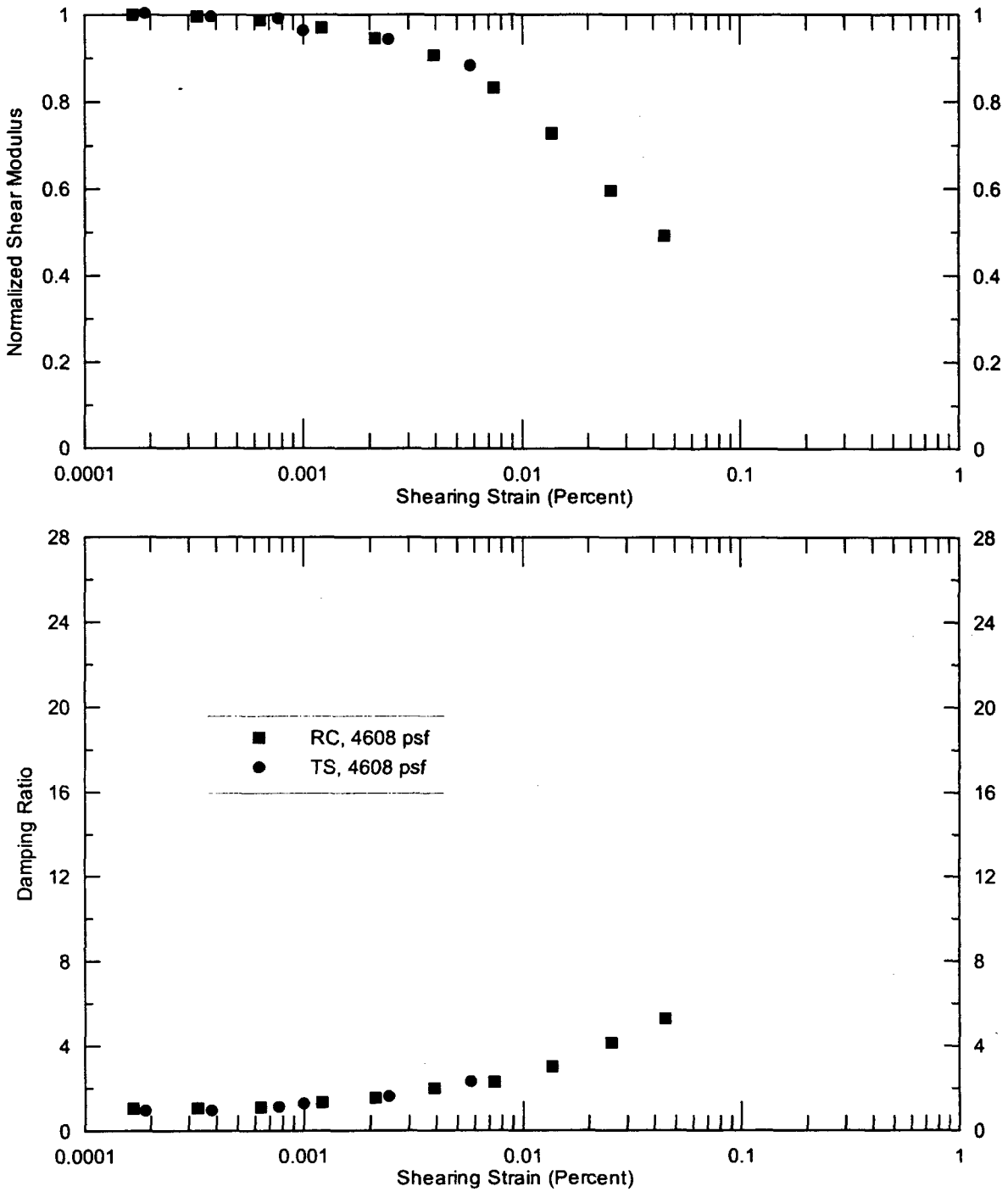
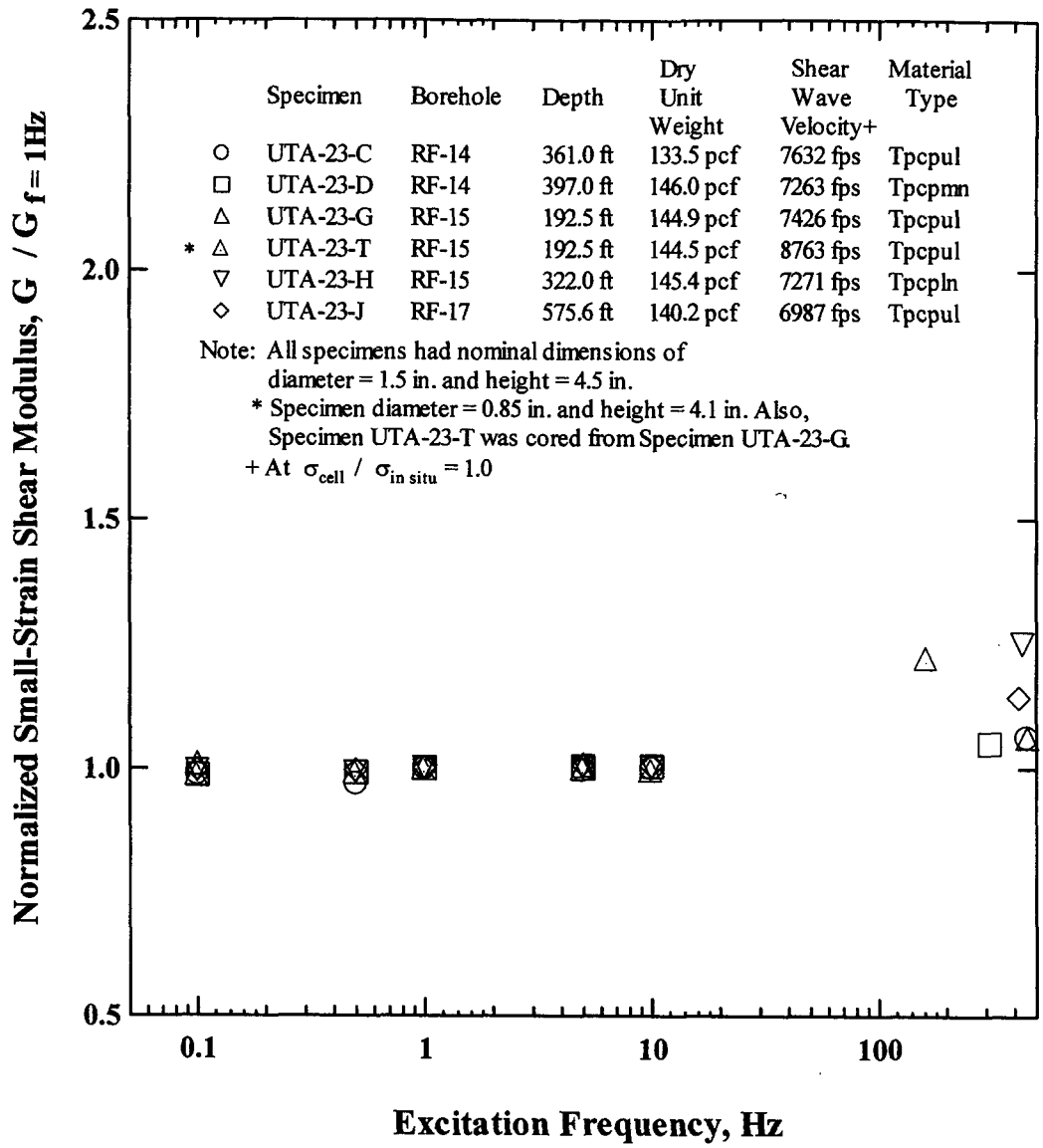
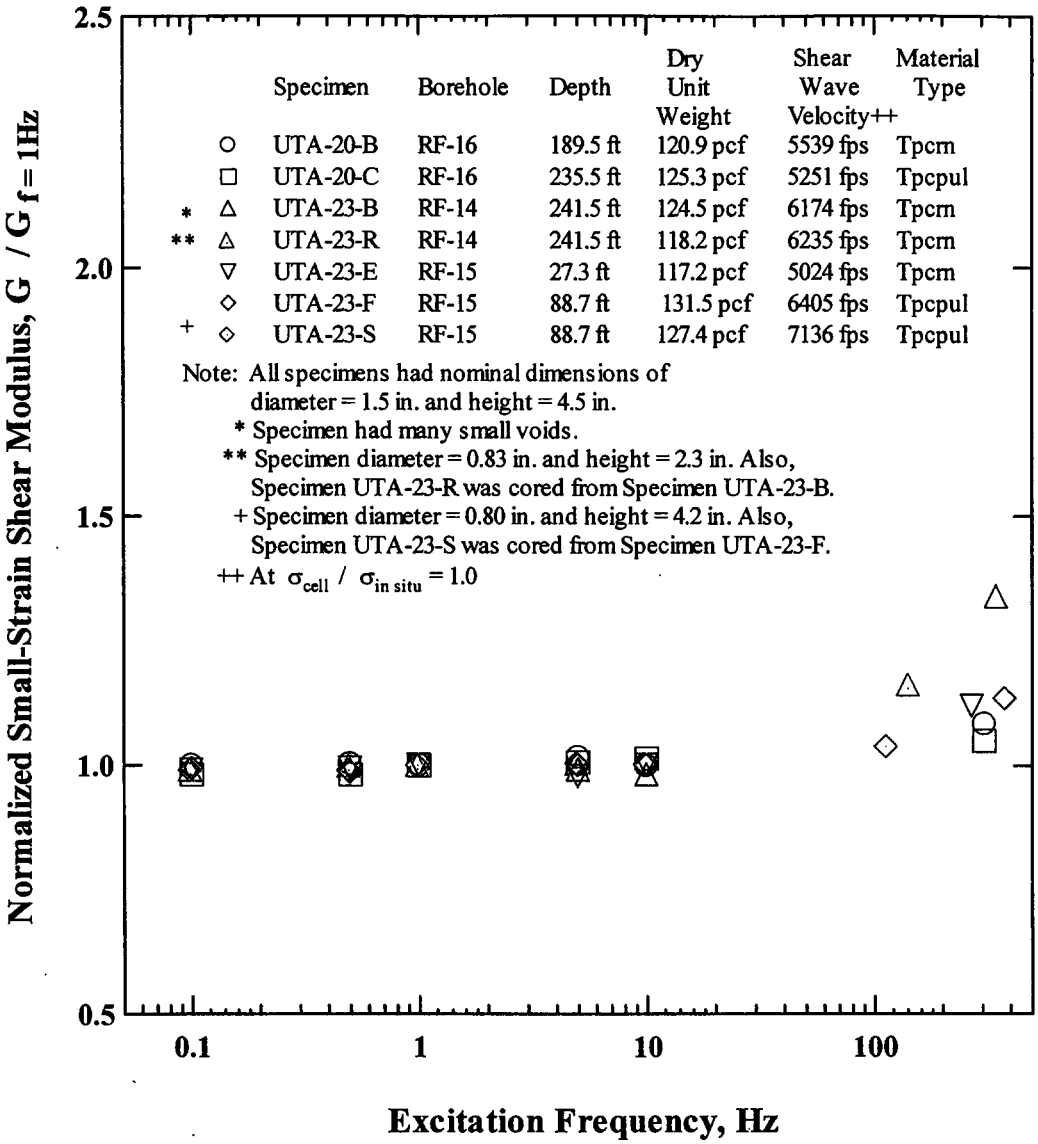


Figure XII-19. Resonant Column and Torsional Shear Results for Specimen UTA-23-X



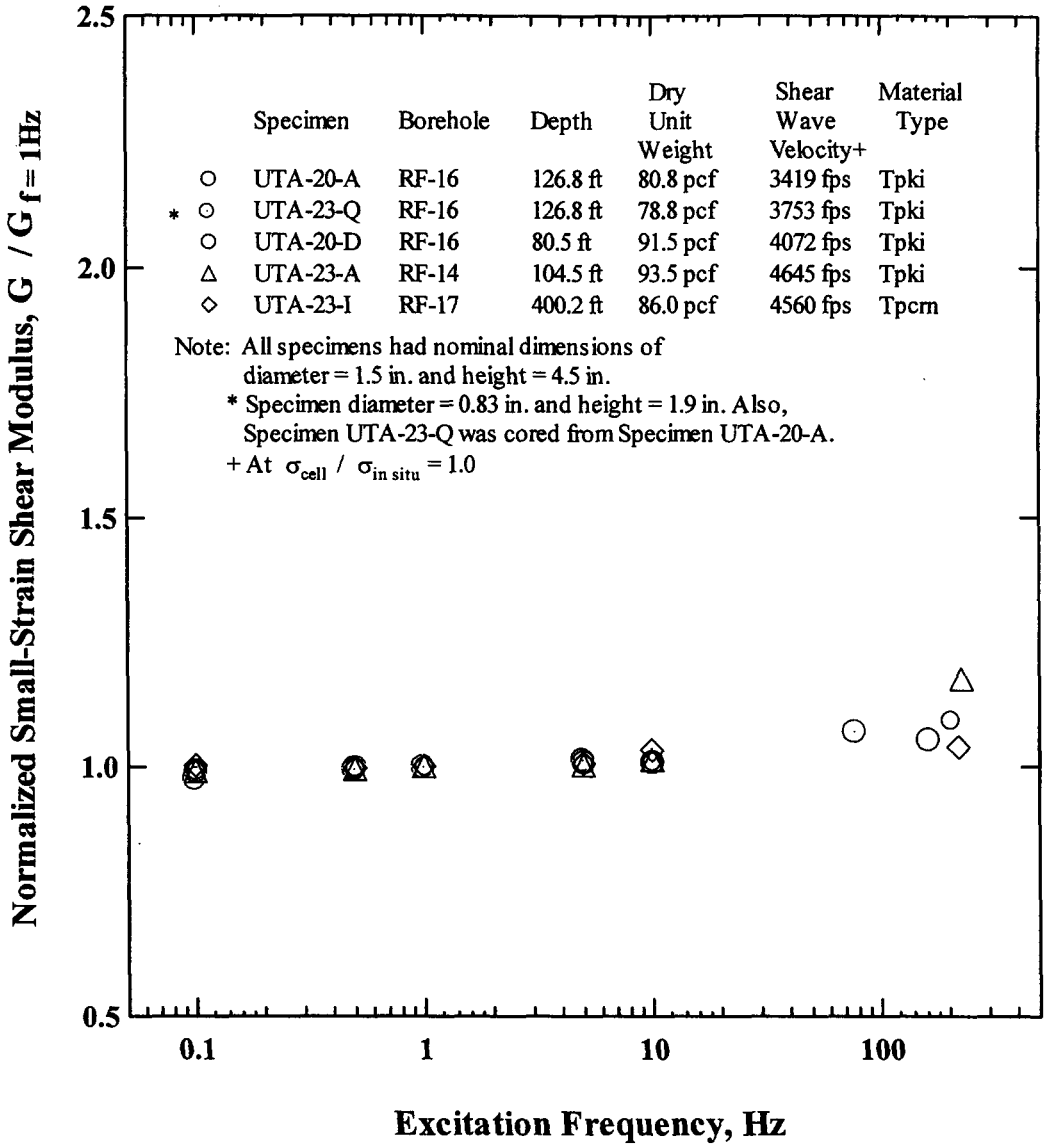
(Wong, 2002e, Appendix 42, page 65)

Figure XII-20. Variation in Normalized Small-Strain Shear Modulus with Excitation Frequency of Intact Tuff Specimens with a Dry Unit Weight Between 133 pcf (2.13g/ cm 3) and 147 pdf (2.36 g/ cm3).



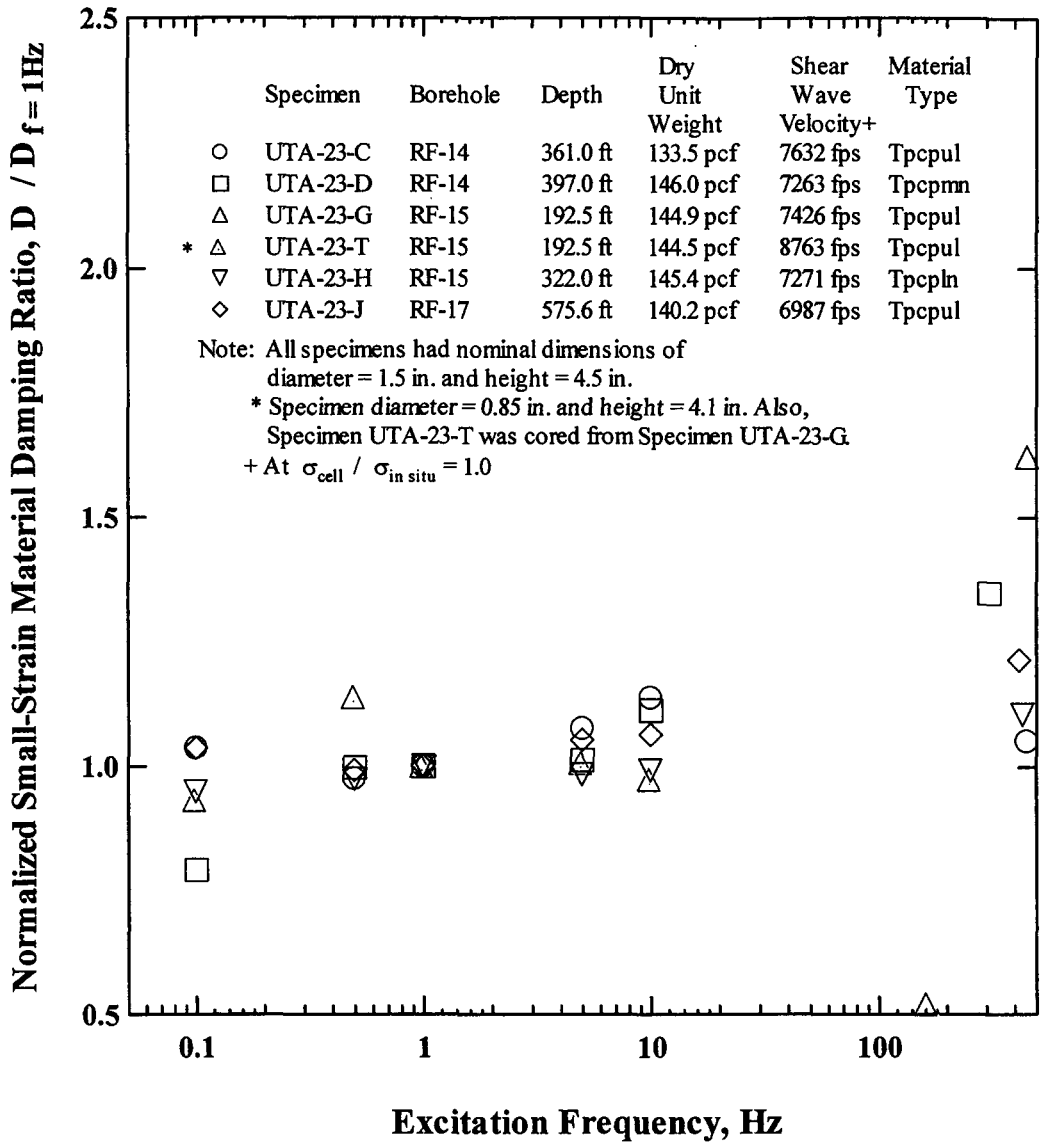
(Wong, 2002e, Appendix 42, page 66)

Figure XII-21. Variation in Normalized Small-Strain Shear Modulus with Excitation Frequency of Intact Tuff Specimens with a Dry Unit Weight Between 117 pcf (1.88 g/cm3) and 132 pcf (2.12 g/cm3).



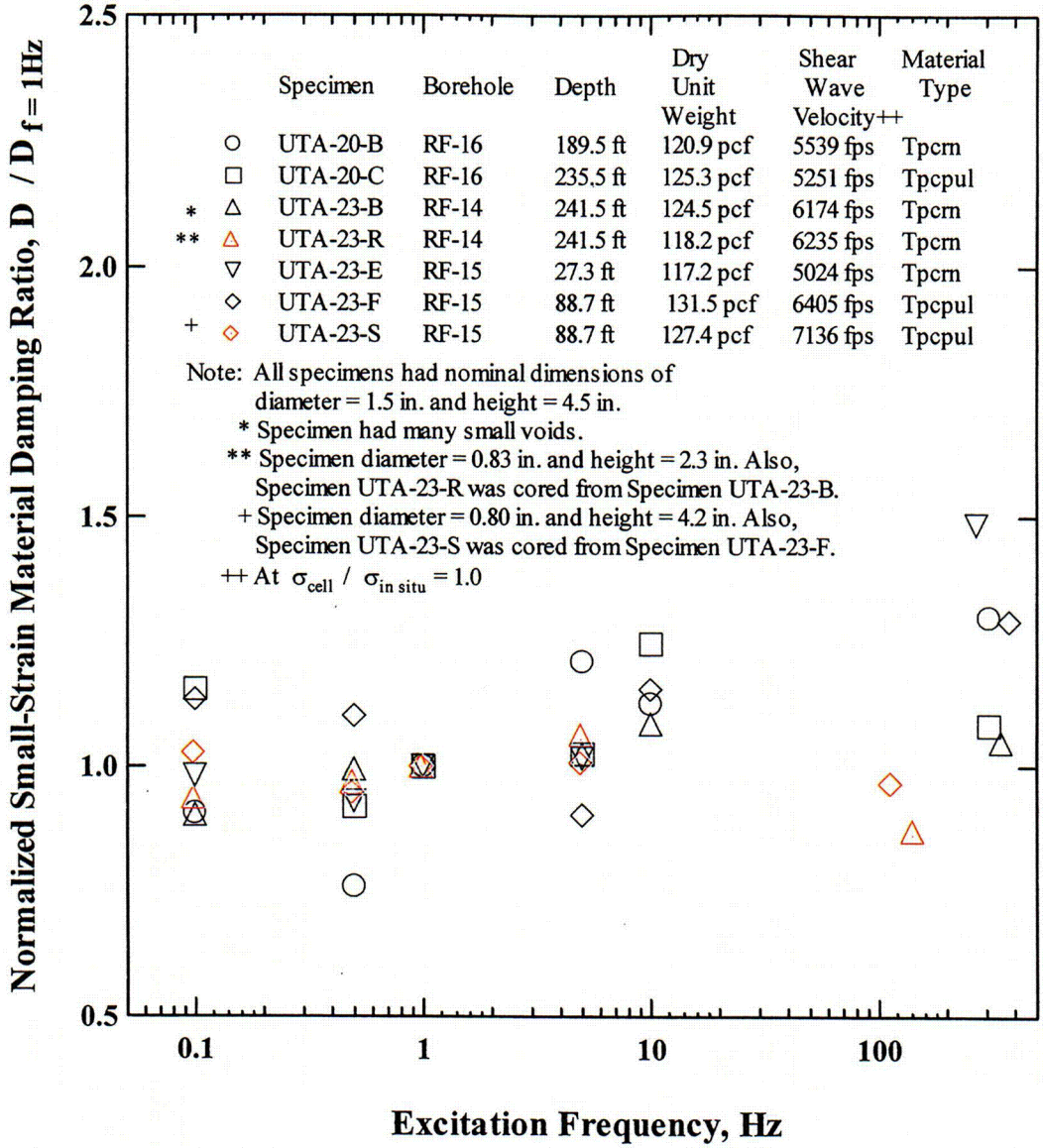
(Wong, 2002e, Appendix 42, page 67)

Figure XII-22. Variation in Normalized Small-Strain Shear Modulus with Excitation Frequency of Intact Tuff Specimens with a Dry Unit Weight Between 78 pcf (1.25 g/cm3) and 94 pcf (1.51 g/cm3).



(Wong, 2002e, Appendix 42, page 68)

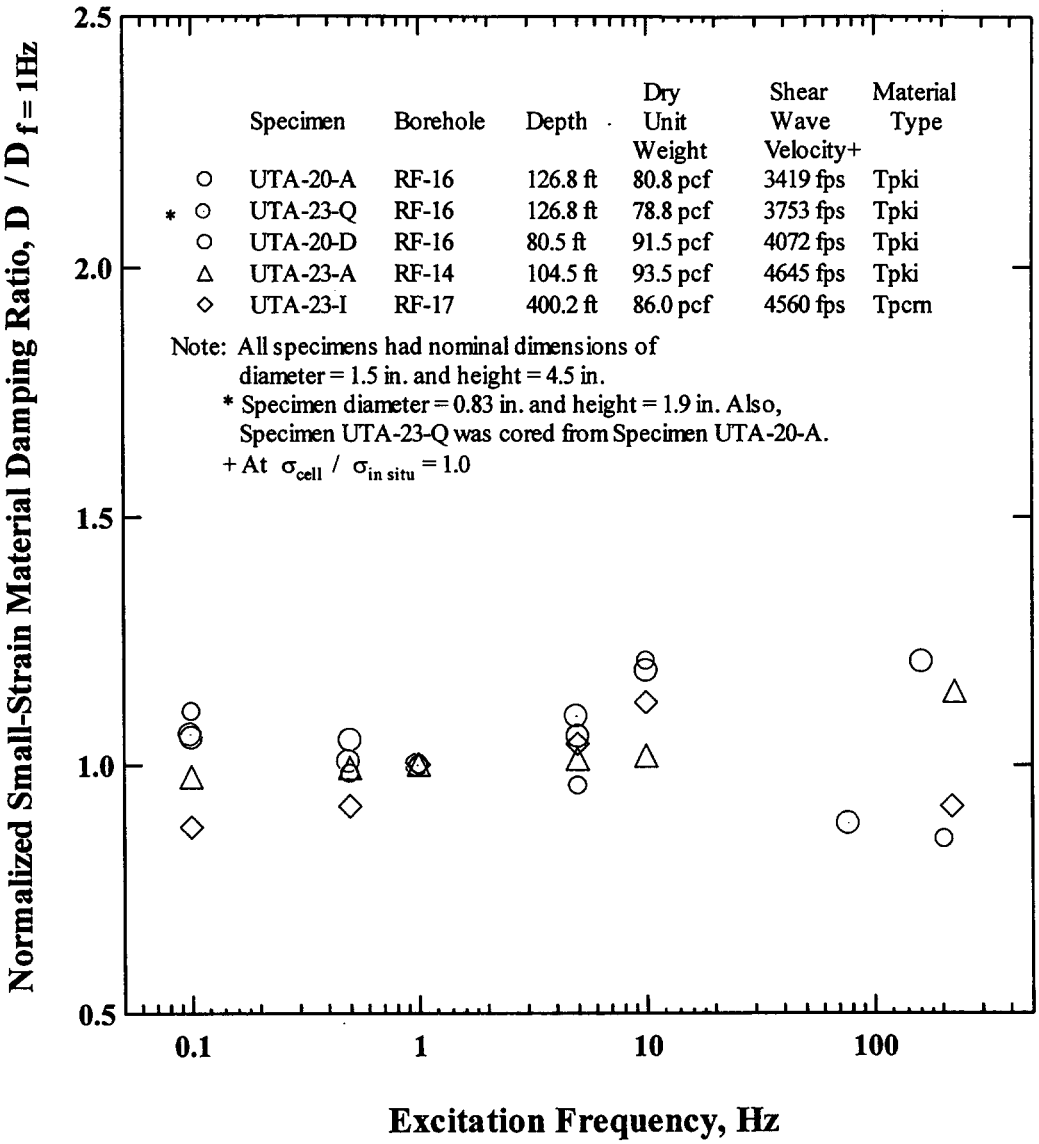
Figure XII-23. Variation in Normalized Small-Strain Material Damping Ratio with Excitation Frequency of Intact Tuff Specimens with a Dry Unit Weight Between 133 pcf (2.13 g/cm3) and 147 pcf (2.36 g/cm3).



(Wong, 2002e, Appendix 42, page 69)

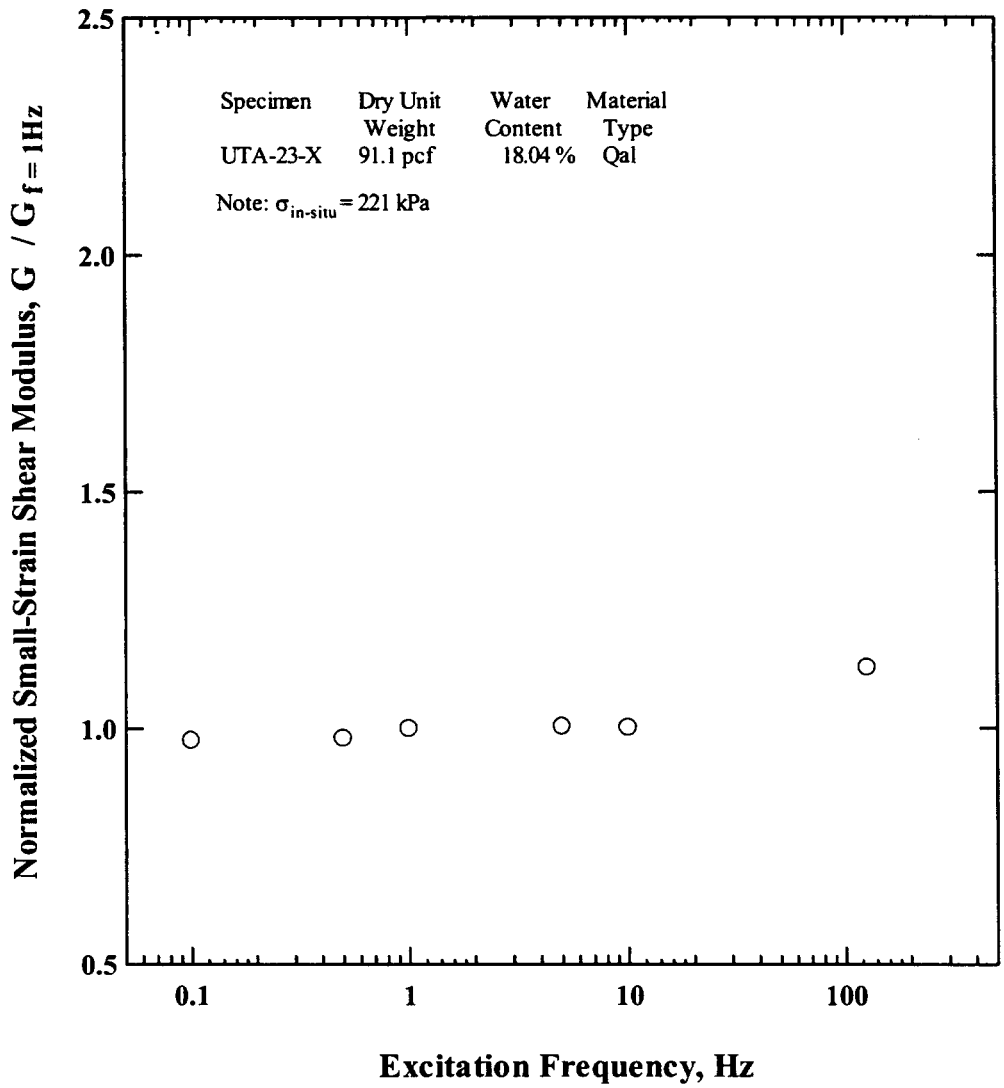
Figure XII-24. Variation in Normalized Small-Strain Material Damping Ratio with Excitation Frequency of Intact Tuff Specimens with a Dry Unit Weight Between 117 pcf 1.88 g/cm3) and 132 pcf (2.12 g/cm3).

C42



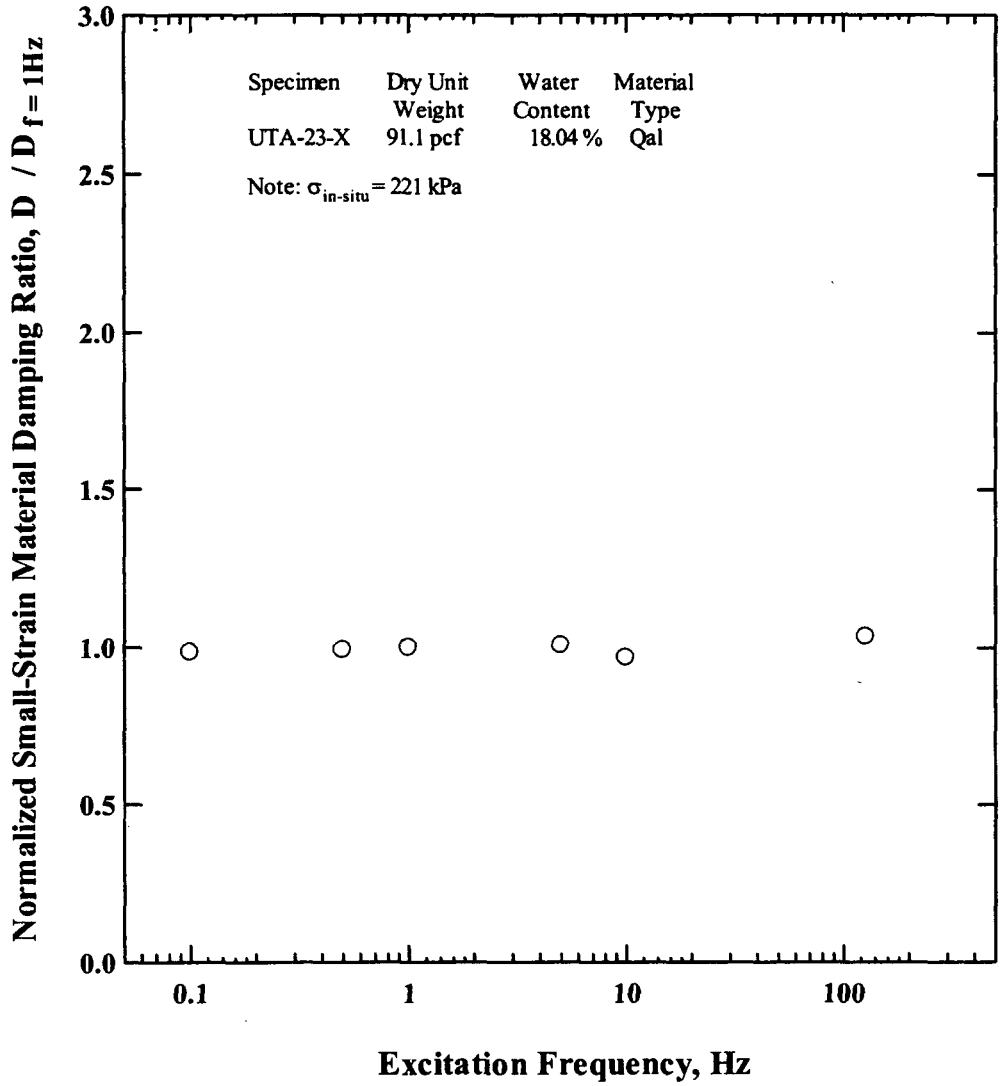
(Wong, 2002e, Appendix 42, page 70)

Figure XII-25. Variation in Normalized Small-Strain Material Damping Ratio with Excitation Frequency of Intact Tuff Specimens with a Dry Unit Weight Between 78 pcf (1.25 g/cm3) and 94 pcf (1.51 g/cm3).



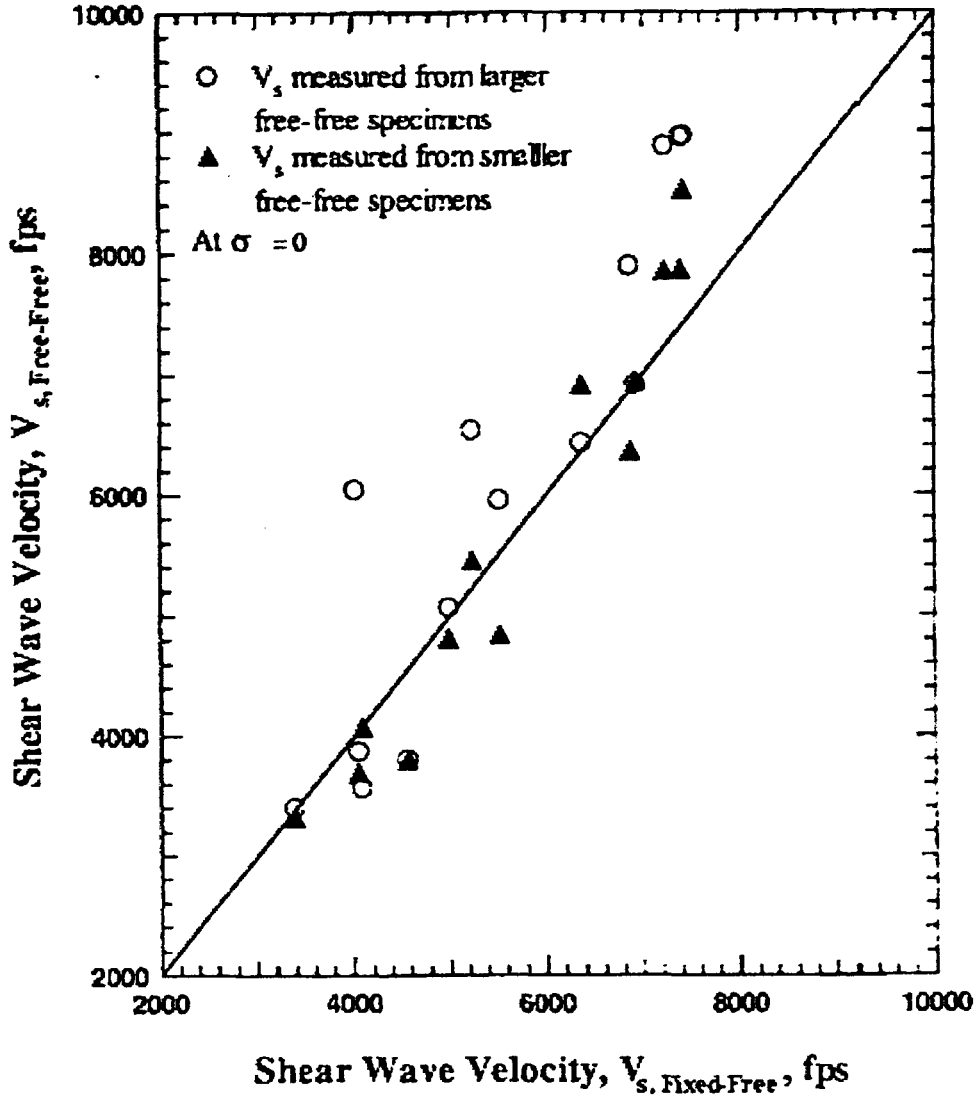
(Wong 2002e, Appendix 42, page 71)

Figure XII-26. Variation in Small-Strain Shear Modulus with Excitation Frequency of Reconstituted Quaternary Alluvium Specimen Recovered from Borehole UE-25 RF#17



(Wong 2002e, Appendix 42, page 72)

Figure XII-27. Variation in Small-Strain Material Damping Ratio with Excitation Frequency of Reconstituted Quaternary Alluvium Specimen Recovered from Borehole UE-25 RF#17



(Wong 2002e, Appendix 42, page 77)

Figure XII-28. Comparison of Small-Strain Shear-Wave Velocity Measured with Fixed-Free and Free-Free Resonant Columns

Table XII-1a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-20-A.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	31500	1510	3387	1.10
18	2520	120.8	31484	1509	3387	0.85
35	5040	241.6	31648	1517	3396	0.70
70	10080	483.2	32094	1539	3419	0.72
140	20160	966.5	32183	1543	3419	0.73
280	40320	1932.9	32691	1567	3431	0.61

Table XII-1b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-A; Effective Confining Pressure, σ_o' = 70 psi (10.1 ksf = 483 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average* Shearing Strain, %	Material Damping Ratio×, D, %
2.16E-04	32076	1.00	2.07E-04	0.70
4.33E-04	32034	1.00	4.14E-04	0.71
8.62E-04	31993	1.00	8.26E-04	0.70
1.63E-03	31988	1.00	1.56E-03	0.69
3.19E-03	31789	0.99	3.02E-03	0.80
6.06E-03	31563	0.98	5.76E-03	0.81
1.09E-02	31133	0.97	1.03E-02	1.00
1.98E-02	30356	0.95	1.83E-02	1.24
3.28E-02	29214	0.91	2.98E-02	1.57

* Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

× Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-1c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-A; Effective Confining Pressure, σ_o' = 70 psi (10.1 ksf = 483 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
8.00E-05	30570	1.00	0.60	8.10E-05	30400	1.00	0.39
1.50E-04	30290	1.00	0.57	1.51E-04	30210	0.99	0.56
4.01E-04	30300	1.00	0.46	4.01E-04	30200	0.99	0.51
9.39E-04	30200	0.99	0.58	9.39E-04	30100	0.99	0.58
1.00E-03	30100	0.99	0.52	9.98E-04	30050	0.99	0.58
1.73E-03	30050	1.00	0.60	1.71E-03	30050	0.99	0.64

DTN: MO0203DHRSSWHB.001

Table XII-1d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-A; Effective Confining Pressure, so' = 280 psi (40.3 ksf = 1933 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio×, D, %
9.34E-05	32721	1.00	8.95E-05	0.69
4.80E-05	32724	1.00	4.60E-05	0.68
1.83E-04	32612	1.00	1.75E-04	0.68
3.50E-04	32599	1.00	3.35E-04	0.70
6.64E-04	32200	0.98	6.32E-04	0.74
1.22E-03	31998	0.98	1.16E-03	0.86
2.42E-03	31602	0.97	2.28E-03	0.91
4.79E-03	31206	0.95	4.49E-03	1.01
8.84E-03	30424	0.93	8.22E-03	1.17
1.64E-02	29279	0.89	1.50E-02	1.45
2.77E-02	27385	0.84	2.49E-02	1.75

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

× Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-1e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-A; Effective Confining Pressure, σ_o' = 280 psi (40.3 ksf = 1933 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
4.04E-04	28500	1.01	0.80	4.04E-04	28000	1.00	0.78
9.56E-04	28070	0.99	0.88	9.58E-04	28080	1.00	0.98
1.03E-03	28000	0.99	0.95	1.03E-03	28000	1.00	0.94
1.79E-03	27730	0.98	1.02	1.79E-03	27760	0.99	1.08

DTN: MO0203DHRSSWHB.001

Table XII-2a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-20-B

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	115000	5513	5522	0.70
29	4176	200.2	115670	5545	5539	0.63
58	8352	400.4	115700	5547	5539	0.62
115	16560	793.9	115670	5545	5539	0.64
230	33120	1587.8	115620	5543	5538	0.63
460	66240	3175.5	115730	5548	5540	0.62

Table XII-2b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-B; Effective Confining Pressure, σ_o' = 115 psi (16.6 ksf = 794 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
1.23E-05	115710	1.00	1.19E-05	0.61
2.37E-05	115700	1.00	2.28E-05	0.63
4.61E-05	115690	1.00	4.43E-05	0.63
8.77E-05	115690	1.00	8.43E-05	0.64
1.62E-04	115700	1.00	1.56E-04	0.65
2.87E-04	114950	0.99	2.74E-04	0.71
5.44E-04	114220	0.99	5.20E-04	0.73
9.96E-04	113470	0.98	9.46E-04	0.82
1.65E-03	112010	0.97	1.56E-03	0.87

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-2c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-B; Effective Confining Pressure, σ_o' = 115 psi (16.6 ksf = 794 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
3.80E-04	107500	1.00	0.62	3.71E-04	107000	1.00	0.66
2.60E-04	106600	1.00	0.57	2.60E-04	106100	1.00	0.61
4.93E-04	104900	0.98	0.70	4.95E-04	105000	0.99	0.67

DTN: MO0203DHRSSWHB.001

Table XII-2d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-B; Effective Confining Pressure, σ_o' = 460 psi (66.2 ksf = 3176 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
7.60E-06	116000	1.00	7.36E-06	0.52
1.48E-05	116000	1.00	1.43E-05	0.52
2.92E-05	116000	1.00	2.83E-05	0.53
5.90E-05	115000	0.99	5.71E-05	0.52
1.16E-04	115000	0.99	1.12E-04	0.53
2.03E-04	114000	0.98	1.96E-04	0.54
3.76E-04	113000	0.97	3.63E-04	0.55
1.18E-03	112000	0.97	1.14E-03	0.55
2.20E-03	110000	0.95	2.12E-03	0.62
3.95E-03	109000	0.94	3.78E-03	0.70
7.24E-03	107000	0.92	6.87E-03	0.86
1.20E-02	104000	0.90	1.13E-02	1.01
1.49E-02	101000	0.87	1.36E-02	1.49

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-2e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-B; Effective Confining Pressure, σ_o' = 460 psi (66.2 ksf = 3176 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
3.71E-04	105900	1.00	0.66	3.58E-04	106400	1.00	0.62
1.82E-04	106800	1.00	0.60	1.82E-04	106700	1.00	0.62
3.60E-04	106180	1.00	0.68	3.60E-04	106180	1.00	0.69
4.80E-04	105700	0.99	0.72	4.78E-04	106500	1.00	0.67

DTN: MO0203DHRSSWHB.001

Table XII-3a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-20-C

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	109000	5225	5233	0.60
38	5472	262.3	109130	5232	5236	0.57
75	10800	517.7	109160	5233	5236	0.55
150	21600	1035.5	109810	5264	5251	0.48
300	43200	2071.0	109890	5268	5252	0.46
450	64800	3106.5	110620	5303	5268	0.46

Table XII-3b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-C; Effective Confining Pressure, σ_o' = 150 psi (21.6 ksf = 1035 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average* Shearing Strain, %	Material Damping Ratio×, D, %
2.33E-05	109200	1.00	2.27E-05	0.40
4.62E-05	109110	1.00	4.50E-05	0.43
9.10E-05	109200	1.00	8.87E-05	0.41
1.74E-04	109200	1.00	1.70E-04	0.43
3.34E-04	108510	0.99	3.25E-04	0.47
5.95E-04	107800	0.99	5.76E-04	0.51
1.08E-03	106990	0.98	1.05E-03	0.57
1.94E-03	106410	0.97	1.87E-03	0.66
3.27E-03	104900	0.96	3.13E-03	0.72
5.79E-03	103530	0.95	5.49E-03	0.86
9.09E-03	102180	0.94	8.53E-03	1.05
1.37E-02	99564	0.91	1.26E-02	1.43
1.72E-02	95542	0.88	1.49E-02	2.43

* Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

× Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-3c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-C; Effective Confining Pressure, σ_o' = 150 psi (21.6 ksf = 1035 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.49E-04	100800	1.00	0.42	2.48E-04	100800	1.00	0.45
5.35E-04	100200	1.00	0.50	5.35E-04	100200	1.00	0.52

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Table XII-3d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-C; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
2.23E-05	111000	1.00	2.17E-05	0.44
4.38E-05	111000	1.00	4.26E-05	0.42
8.65E-05	111000	1.00	8.41E-05	0.45
1.66E-04	110000	0.99	1.61E-04	0.47
3.20E-04	110000	0.99	3.11E-04	0.49
5.98E-04	109000	0.99	5.79E-04	0.53
1.16E-03	109000	0.98	1.12E-03	0.56
2.20E-03	107000	0.97	2.12E-03	0.62
3.95E-03	106000	0.96	3.79E-03	0.70
7.24E-03	104000	0.94	6.86E-03	0.86
1.20E-02	101000	0.91	1.13E-02	1.01
1.49E-02	98300	0.89	1.34E-02	1.69

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-3e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-C; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.48E-04	100800	0.99	0.43	2.48E-04	100800	1.00	0.43
5.31E-04	101600	1.00	0.49	5.35E-04	102000	1.01	0.49

DTN: MO0203DHRSSWHB.001

Table XII-4a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-20-D

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	50500	2421	4050	0.77
14	2016	96.6	50525	2422	4052	0.57
28	4032	193.3	51031	2446	4072	0.52
56	8064	386.6	51035	2447	4072	0.52
110	15840	759.4	50983	2444	4071	0.53
220	31680	1518.7	50514	2422	4051	0.52

Table XII-4b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-D; Effective Confining Pressure, σ_o' = 56 psi (8.1 ksf = 387 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
7.88E-05	50988	1.00	7.65E-05	0.47
1.58E-04	50995	1.00	1.53E-04	0.49
3.13E-04	50988	1.00	3.03E-04	0.52
6.12E-04	50985	1.00	5.91E-04	0.54
1.11E-03	50544	0.99	1.07E-03	0.56
2.04E-03	50488	0.99	1.96E-03	0.65
3.39E-03	49996	0.98	3.23E-03	0.81
5.54E-03	49070	0.96	5.21E-03	1.00
9.25E-03	47607	0.93	8.58E-03	1.24

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-4c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-D; Effective Confining Pressure, σ_o' = 56 psi (8.1 ksf = 387 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.58E-04	46230	1.00	0.48	2.58E-04	46200	1.00	0.52
5.15E-04	46330	1.00	0.49	5.15E-04	46400	1.00	0.58
8.59E-04	46220	1.00	0.60	8.59E-04	46300	1.00	0.58
1.00E-03	46200	1.00	0.65	1.00E-03	46300	1.00	0.68
1.20E-03	45900	0.99	0.72	1.20E-03	46000	0.99	0.71

DTN: MO0203DHRSSWHB.001

Table XII-4d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-D; Effective Confining Pressure, σ_o' = 220 psi (31.7 ksf = 1519 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
7.64E-05	50506	1.00	7.76E-05	0.59
1.53E-04	50512	1.00	1.48E-04	0.54
3.05E-04	50514	1.00	3.10E-04	0.59
5.92E-04	50514	1.00	5.71E-04	0.58
1.08E-03	50023	0.99	1.04E-03	0.62
2.06E-03	50025	0.99	1.98E-03	0.66
3.89E-03	49046	0.97	3.71E-03	0.78
6.74E-03	48068	0.95	6.35E-03	0.98
1.06E-02	46631	0.92	9.85E-03	1.20

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-4e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-D; Effective Confining Pressure, σ_o' = 220 psi (31.7 ksf = 1519 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
4.25E-04	46930	1.00	0.51	4.25E-04	46700	1.00	0.51
6.82E-04	46800	1.00	0.56	6.82E-04	46800	1.00	0.61
1.00E-03	46650	1.00	0.62	1.00E-03	46700	1.00	0.62

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Table XII-5a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-A

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	61700	2958	4086	0.99
16	2304	110.5	63477	3043	4566	0.99
33	4752	227.8	63477	3043	4566	0.99
66	9504	455.6	65697	3149	4645	1.00
132	19008	911.2	65623	3146	4643	0.97
264	38016	1822.5	65673	3148	4645	0.94

Table XII-5b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-A; Effective Confining Pressure, σ_o' = 66 psi (9.5 ksf = 455.6 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
2.31E-05	65143	1.00	2.19E-05	0.84
4.58E-05	65140	1.00	4.34E-05	0.89
9.08E-05	65062	1.00	8.58E-05	0.93
1.78E-04	65000	1.00	1.68E-04	0.95
3.22E-04	65050	1.00	3.15E-04	1.20
5.20E-04	64900	1.00	4.78E-04	1.39
8.83E-04	64500	0.99	7.87E-04	1.90
1.68E-03	63500	0.97	1.46E-03	2.43
5.14E-03	61740	0.95	4.77E-03	3.20

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-5c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-A; Effective Confining Pressure, σ_o' = 66 psi (9.5 ksf = 455.6 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
6.40E-05	54800	1.00	0.90	6.40E-05	54700	1.00	0.91
1.26E-04	54730	1.00	0.98	1.26E-04	54640	1.00	1.00
2.30E-04	54740	1.00	1.12	2.30E-04	54600	1.00	1.14
4.62E-04	54700	1.00	1.40	4.62E-04	54500	1.00	1.42
7.07E-04	54630	1.00	1.65	7.07E-04	54430	1.00	1.67

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Table XII-5d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-A; Effective Confining Pressure, σ_o' = 264 psi (38.0 ksf = 1822 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
2.40E-05	65679	1.00	2.27E-05	0.86
4.67E-05	65629	1.00	4.42E-05	0.86
9.20E-05	65620	1.00	8.67E-05	0.95
1.67E-04	65200	0.99	1.57E-04	1.01
2.96E-04	65100	0.99	2.75E-04	1.19
4.58E-04	65000	0.99	4.16E-04	1.56
1.08E-03	64500	0.98	9.76E-04	2.10

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-5e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-A; Effective Confining Pressure, σ_o' = 264 psi (38.0 ksf = 1822 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
6.20E-05	55800	1.00	0.87	6.20E-05	55700	1.00	0.88
1.22E-04	55680	1.00	0.92	1.22E-04	55700	1.00	0.93
2.28E-04	55650	1.00	1.10	2.28E-04	55700	1.00	1.11
4.50E-04	55620	1.00	1.35	4.50E-04	55600	1.00	1.38
6.80E-04	55610	1.00	1.60	6.80E-04	55500	1.00	1.62
9.90E-04	55600	1.00	2.00	9.90E-04	55400	1.00	2.05

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Table XII-6a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-B

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	63500	3044	4022	2.33
44	6336	303.7	143300	6870	6035	1.34
88	12672	607.5	149300	7157	6159	1.33
176	25344	1215.0	150100	7196	6174	1.30
352	50688	2430.0	151870	7281	6209	1.30
450	64800	3106.5	151930	7283	6209	1.29

Table XII-6b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-B; Effective Confining Pressure, σ_o' = 176 psi (25.3 ksf = 1215 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio^x, D, %
2.26E-06	151120	1.00	1.97E-06	1.20
3.89E-06	150260	0.99	3.44E-06	1.25
7.56E-06	151100	1.00	6.24E-06	1.30
1.49E-05	150090	0.99	1.26E-05	1.40
2.97E-05	150090	0.99	2.49E-05	1.42
5.55E-05	150090	0.99	4.62E-05	1.43
1.13E-04	149000	0.99	9.39E-05	1.44
8.72E-04	142000	0.94	7.90E-04	1.74
3.31E-03	131950	0.87	3.08E-03	2.10
6.91E-03	126230	0.84	6.61E-03	2.50
1.12E-02	123000	0.81	1.07E-02	2.80

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-6c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-B; Effective Confining Pressure, σ_o' = 176 psi (25.3 ksf = 1215 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.63E-05	129800	1.01	1.54	2.63E-05	127600	1.00	1.55
5.22E-05	129000	0.99	1.57	5.20E-05	127000	1.00	1.58
1.07E-04	127000	0.98	1.59	1.07E-04	124400	0.97	1.60
2.92E-04	122000	0.94	1.60	2.92E-04	121600	0.95	1.61
3.49E-04	120000	0.92	1.65	3.49E-04	119600	0.94	1.66

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Table XII-6d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-B; Effective Confining Pressure, σ_o' = 450 psi (64.8ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
3.87E-06	152790	1.00	3.28E-06	1.20
7.33E-06	152810	1.00	6.35E-06	1.22
1.44E-05	152810	1.00	1.17E-05	1.30
2.92E-05	152970	1.00	2.48E-05	1.31
5.43E-05	152800	1.00	4.55E-05	1.31
1.07E-04	151950	0.99	1.50E-04	1.38
2.28E-04	149370	0.98	1.87E-04	1.40
9.68E-04	144000	0.94	9.01E-04	1.70
6.43E-03	132000	0.86	6.09E-03	2.10
1.15E-02	127000	0.82	1.09E-02	2.40
1.78E-02	123230	0.81	1.68E-02	2.70
2.40E-02	120990	0.79	2.24E-02	3.00

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-6e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-B; Effective Confining Pressure, σ_o' = 450 psi (64.8ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
5.20E-05	152660	1.00	1.40	5.60E-05	152110		1.41
9.50E-05	149000	0.98	1.40	9.64E-05	149000	0.99	1.42
2.10E-04	148700	0.97	1.42	2.07E-04	147000	0.98	1.43
3.29E-04	147000	0.96	1.45	3.10E-04	146000	0.97	1.47
3.66E-04	146000	0.96	1.54	3.50E-04	145000	0.97	1.55

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Table XII-7a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-C

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	200000	9588	6925	1.80
70	10080	483.2	205870	9869	6984	1.80
140	20160	966.5	242020	11602	7570	1.70
280	40320	1932.9	276820	13271	7632	1.66
450	64800	3106.5	280450	13445	7682	1.98

Table XII-7b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-C; Effective Confining Pressure, σ_o' = 280psi (40.3ksf = 1933kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average* Shearing Strain, %	Material Damping Ratio×, D, %
1.33E-06	279300	1.00	1.26E-06	0.89
2.49E-06	277780	0.99	2.24E-06	1.73
4.84E-06	279290	1.00	4.35E-06	1.76
1.00E-05	278050	1.00	7.52E-06	1.27
1.92E-05	278070	1.00	1.77E-05	1.28
3.62E-05	277770	0.99	3.19E-05	1.31
7.31E-05	276570	0.99	6.45E-05	1.42
1.46E-04	274150	0.98	1.31E-04	1.62
2.72E-04	269330	0.96	2.26E-04	1.80

* Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

× Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-7c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-C; Effective Confining Pressure, σ_o' = 280psi (40.3ksf = 1933kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
3.54E-05	254000	1.00	1.35	3.54E-05	251000	1.00	1.36
6.62E-05	254000	1.00	1.38	6.70E-05	251000	1.00	1.37
1.34E-04	253700	1.00	1.50	1.35E-04	250000	1.00	1.51
2.92E-04	245000	0.98	1.80	2.92E-04	244800	0.98	1.82

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Table XII-7d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-C; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
2.31E-06	280470	1.00	2.03E-06	2.15
4.37E-06	280470	1.00	3.59E-06	3.34
8.74E-06	279230	1.00	7.50E-06	2.57
1.76E-05	278940	0.99	1.60E-05	1.25
3.30E-05	279260	1.00	2.85E-05	1.29
6.69E-05	277730	0.99	5.69E-05	1.40
1.38E-04	275300	0.98	1.23E-04	1.65
2.72E-04	271700	0.97	2.26E-04	2.00
4.19E-04	268000	0.96	3.11E-04	2.20

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-7e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-C; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.79E-05	251000	1.00	1.39	1.80E-05	250000	1.00	1.39
3.62E-05	250000	1.00	1.42	3.64E-05	250000	1.00	1.43
6.60E-05	250000	1.00	1.49	6.70E-05	249000	1.00	1.50
1.33E-04	247000	0.98	1.70	1.34E-04	246700	0.99	1.71
2.91E-04	244000	0.97	2.00	2.90E-04	243500	0.97	2.03

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Table XII-8a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-D

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	230000	11026	7426	1.35
70	10080	483.2	239370	11475	7214	0.86
170	24480	1173.6	241050	11556	7234	0.93
340	48960	2347.1	243190	11658	7263	1.09
450	64800	3106.5	245370	11763	7299	1.00

Table XII-8b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-D; Effective Confining Pressure, σ_o' = 340 psi (49.0 ksf = 2347 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
1.23E-05	243400	1.00	1.19E-05	0.61
2.37E-05	243156	1.00	2.28E-05	0.63
4.61E-05	243156	1.00	4.43E-05	0.63
8.77E-05	241690	1.00	8.43E-05	0.64
1.62E-04	241690	1.00	1.56E-04	0.65
2.87E-04	241696	0.99	2.74E-04	0.71
5.44E-04	240260	0.99	5.20E-04	0.73
9.96E-04	238532	0.98	9.46E-04	0.82
1.65E-03	235611	0.97	1.56E-03	0.87

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-8c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-D; Effective Confining Pressure, σ_o' = 340 psi (49.0 ksf = 2347 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.20E-05	230000	1.00	0.42	1.20E-05	229000	1.00	0.42
1.99E-05	229800	1.00	0.43	1.99E-05	228500	1.00	0.44
3.87E-05	228000	0.99	0.44	3.95E-05	228400	1.00	0.47
7.37E-05	228200	0.99	0.47	7.95E-05	228200	0.99	0.50
1.47E-04	228100	0.99	0.49	1.47E-04	228100	0.99	0.52
3.22E-04	228000	0.99	0.52	3.22E-04	228000	0.99	0.55

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Table XII-8d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-D; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
7.60E-06	246300	1.00	7.36E-06	0.52
1.48E-05	246000	1.00	1.43E-05	0.52
2.92E-05	246000	1.00	2.83E-05	0.53
5.90E-05	245000	0.99	5.71E-05	0.52
1.16E-04	245000	0.99	1.12E-04	0.53
2.03E-04	244000	0.98	1.96E-04	0.54
3.76E-04	243000	0.97	3.63E-04	0.55
1.18E-03	242000	0.97	1.14E-03	0.55
2.20E-03	241000	0.95	2.12E-03	0.62
3.95E-03	239000	0.94	3.78E-03	0.70
7.24E-03	237000	0.92	6.87E-03	0.86
1.20E-02	234000	0.90	1.13E-02	1.01
1.49E-02	231000	0.87	1.36E-02	1.49
1.82E-02	230000	0.87	1.60E-02	2.19

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-8e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-D; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.97E-05	231000	1.00	0.40	1.97E-05	231000	1.00	0.40
3.85E-05	230800	1.00	0.40	3.85E-05	230800	1.00	0.41
7.25E-05	230000	0.99	0.42	7.25E-05	230300	0.99	0.42
1.45E-04	230000	0.99	0.43	1.45E-04	230000	0.99	0.43

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Table XII-9a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-E

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	91500	4386	4987	0.63
5	648	31.1	92280	4424	5024	0.48
9	1296	62.1	92155	4418	5021	0.42
18	2592	124.3	92275	4424	5024	0.44
36	5184	248.5	92274	4424	5023	0.42
72	10368	497.0	92280	4424	5023	0.41

Table XII-9b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-E; Effective Confining Pressure, σ_o' = 18 psi (2.6 ksf = 124 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio×, D, %
2.52E-05	92273	1.00	2.47E-05	0.35
5.00E-05	92272	1.00	4.88E-05	0.42
9.83E-05	92845	1.01	9.59E-05	0.39
1.97E-04	92168	1.00	1.92E-04	0.41
3.80E-04	92252	1.00	3.72E-04	0.36
6.83E-04	91494	0.99	6.60E-04	0.55
1.26E-03	90827	0.98	1.21E-03	0.67
2.30E-03	90257	0.98	2.18E-03	0.84
3.93E-03	88840	0.96	3.68E-03	1.10
6.89E-03	86212	0.93	6.33E-03	1.39

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

× Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-9c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-E; Effective Confining Pressure, σ_o' = 18 psi (2.6 ksf = 124 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
4.60E-05	81000	1.00	0.30	4.60E-05	80960	1.00	0.31
8.60E-05	80900	1.00	0.31	8.60E-05	80900	1.00	0.32
1.50E-04	80800	1.00	0.32	1.60E-04	80880	1.00	0.33
3.05E-04	80840	1.00	0.36	3.05E-04	80800	1.00	0.37
4.59E-04	80700	1.00	0.40	4.59E-04	80700	1.00	0.40

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Table XII-9d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-E; Effective Confining Pressure, σ_o' = 72 psi (10.4 ksf = 497 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
2.82E-05	92231	1.00	2.76E-05	0.32
5.48E-05	92214	1.00	5.35E-05	0.37
1.09E-04	92215	1.00	1.06E-04	0.36
2.08E-04	92295	1.00	1.96E-04	0.37
4.20E-04	91614	0.99	4.10E-04	0.39
7.72E-04	91526	0.99	7.53E-04	0.40
1.42E-03	90862	0.99	1.38E-03	0.46
2.46E-03	89531	0.97	2.37E-03	0.59
4.10E-03	87555	0.95	3.92E-03	0.75
6.79E-03	85601	0.93	6.34E-03	1.10
1.17E-02	84306	0.91	1.09E-02	1.28

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-9e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-E; Effective Confining Pressure, σ_o' = 72 psi (10.4 ksf = 497 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
7.80E-05	82240	1.00	0.29	7.80E-05	82000	1.00	0.30
1.48E-04	81700	1.00	0.31	1.48E-04	81700	1.00	0.32
2.96E-04	81400	0.99	0.33	2.98E-04	81300	0.99	0.34
4.46E-04	81100	0.99	0.41	4.50E-04	81000	0.99	0.40
6.40E-04	81000	0.99	0.46	6.40E-04	80900	0.99	0.47

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Table XII-10a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-F

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	167000	8006	6368	0.40
17	2448	117.4	167700	8039	6383	0.39
34	4896	234.7	167900	8049	6387	0.38
68	9792	469.4	168870	8096	6405	0.34
136	19584	938.9	169660	8133	6418	0.33
272	39168	1877.7	169980	8149	6422	0.33

Table XII-10b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-F; Effective Confining Pressure, σ_o' = 68 psi (9.8 ksf = 469 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
1.25E-05	168710	1.00	1.23E-05	0.36
2.47E-05	168690	1.00	2.42E-05	0.37
4.93E-05	168700	1.00	4.84E-05	0.35
9.79E-05	168690	1.00	9.57E-05	0.37
1.93E-04	168700	1.00	1.89E-04	0.36
3.62E-04	168700	1.00	3.54E-04	0.37
6.97E-04	167960	1.00	6.80E-04	0.40
1.26E-03	167980	1.00	1.22E-03	0.49
2.05E-03	166920	0.99	1.98E-03	0.58
3.62E-03	166000	0.98	3.44E-03	0.70
5.71E-03	163400	0.97	5.41E-03	0.85

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-10c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-F; Effective Confining Pressure, σ_o' = 68 psi (9.8 ksf = 469 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.10E-05	148000	1.00	0.26	2.10E-05	147500	1.00	0.27
4.30E-05	147000	0.99	0.28	4.30E-05	146800	1.00	0.29
8.20E-05	146600	0.99	0.31	8.20E-05	146300	0.99	0.32
1.62E-04	146200	0.99	0.35	1.62E-04	145500	0.99	0.36
3.49E-04	146000	0.99	0.40	3.49E-04	145000	0.98	0.41

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Table XII-10d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-F; Effective Confining Pressure, σ_o' = 272 psi (39.2 ksf = 1878 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
2.97E-05	170780	1.00	2.92E-05	0.30
1.48E-05	170830	1.00	1.45E-05	0.29
5.87E-05	170820	1.00	5.76E-05	0.29
1.16E-04	170830	1.00	1.14E-04	0.29
2.28E-04	170790	1.00	2.24E-04	0.30
4.20E-04	170650	1.00	4.12E-04	0.30
8.56E-04	169920	0.99	8.39E-04	0.32
1.59E-03	168870	0.99	1.55E-03	0.37
3.34E-03	167980	0.98	3.25E-03	0.51
5.88E-05	170670	1.00	5.77E-05	0.29
6.61E-03	164410	0.96	6.30E-03	0.76
9.46E-03	161960	0.95	8.92E-03	0.97

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-10e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-F; Effective Confining Pressure, σ_o' =272 psi (39.2 ksf = 1878 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.30E-05	170000	1.00	0.22	2.30E-05	170000	1.00	0.23
4.72E-05	169500	1.00	0.23	4.72E-05	169500	1.00	0.24
2.10E-04	169000	1.00	0.25	2.07E-04	169000	1.00	0.26
1.33E-04	168800	0.99	0.28	1.34E-04	168500	0.99	0.28
2.24E-04	168500	0.99	0.29	2.24E-04	168300	0.99	0.30
3.55E-04	168300	0.99	0.31	3.50E-04	168100	0.99	0.32

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Table XII-11a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-G

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	247570	11868	7398	0.50
30	4320	207.1	248640	11920	7414	0.51
60	8640	414.2	248710	11923	7415	0.48
120	17280	828.4	249540	11963	7426	0.48
240	34560	1656.8	249960	11983	7431	0.47
450	64800	3106.5	251140	12040	7444	0.46

Table XII-11b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-G; Effective Confining Pressure, σ_o' = 120 psi (17.3 ksf = 828 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio×, D, %
5.98E-06	249870	1.00	5.78E-06	0.56
1.19E-05	249620	1.00	1.15E-05	0.53
1.19E-05	249630	1.00	1.15E-05	0.53
2.37E-05	249610	1.00	2.30E-05	0.53
4.73E-05	249630	1.00	4.63E-05	0.53
9.43E-05	249600	1.00	9.12E-05	0.54
1.78E-04	249670	1.00	1.72E-04	0.55
6.95E-04	248530	0.99	6.70E-04	0.60
1.29E-03	247470	0.99	1.24E-03	0.69
2.30E-03	245310	0.98	2.18E-03	0.88
3.52E-03	242090	0.97	3.27E-03	1.20

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

× Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-11c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-G; Effective Confining Pressure, σ_o' =120 psi (17.3 ksf = 828 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
5.24E-05	235000	1.01	0.42	5.24E-05	232900	1.00	0.43
1.06E-04	232200	0.99	0.43	1.06E-04	231500	1.00	0.44
1.56E-04	231500	0.99	0.47	1.56E-04	231000	0.99	0.48
2.28E-04	231000	0.99	0.48	2.28E-04	230600	0.99	0.49

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Table XII-11d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-G; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
5.29E-06	251140	1.00	5.09E-06	0.61
1.05E-05	251170	1.00	1.01E-05	0.58
2.09E-05	251110	1.00	2.01E-05	0.59
4.13E-05	251400	1.00	3.98E-05	0.60
8.30E-05	251110	1.00	7.99E-05	0.61
1.54E-04	251120	1.00	1.48E-04	0.62
3.11E-04	250010	1.00	3.00E-04	0.63
6.16E-04	250280	1.00	5.92E-04	0.64
1.17E-03	248950	0.99	1.12E-03	0.69
2.14E-03	246820	0.98	2.04E-03	0.79
3.48E-03	244630	0.97	3.27E-03	1.00

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-11e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-G; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.93E-05	240000	1.00	0.47	2.93E-05	239600	1.00	0.48
5.50E-05	238400	1.00	0.48	5.50E-05	238000	1.00	0.49
1.12E-04	237000	0.99	0.50	1.12E-04	236700	0.99	0.51
1.66E-04	235000	0.98	0.51	1.66E-04	234000	0.98	0.52
2.40E-04	234000	0.98	0.52	2.40E-04	233000	0.98	0.53

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Table XII-12a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-H

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	238000	11410	7230	1.01
50	7200	345.2	238470	11432	7238	1.00
100	14400	690.3	239570	11485	7254	0.99
200	28800	1380.7	240740	11541	7271	0.98
400	57600	2761.3	246420	11813	7355	1.03
450	64800	3106.5	246490	11817	7356	1.10

Table XII-12b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-H; Effective Confining Pressure, σ_o' = 200 psi (28.8 ksf = 1381 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
3.99E-06	240840	1.00	3.79E-06	0.82
7.80E-06	240840	1.00	7.31E-06	1.07
1.54E-05	240850	1.00	1.44E-05	1.15
3.08E-05	240840	1.00	2.87E-05	1.13
6.15E-05	240820	1.00	5.74E-05	1.12
1.14E-04	240870	1.00	1.06E-04	1.15
2.32E-04	239720	1.00	2.16E-04	1.15
4.60E-04	239710	1.00	4.28E-04	1.17
8.89E-04	238640	0.99	8.22E-04	1.28
1.65E-03	235340	0.98	1.52E-03	1.36
2.74E-03	232080	0.96	2.49E-03	1.56

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-12c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-H; Effective Confining Pressure, σ_o' = 200 psi (28.8 ksf = 1381 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
3.54E-05	189900	1.00	1.10	3.54E-05	189900	1.00	1.11
6.67E-05	189900	1.00	1.11	6.67E-05	188600	1.00	1.12
2.00E-04	189500	1.00	1.12	2.00E-04	188500	0.99	1.13
2.85E-04	189400	1.00	1.13	2.90E-04	188000	0.99	1.14

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Table XII-12d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-H; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
4.48E-06	246500	1.00	4.23E-06	0.95
8.72E-06	246520	1.00	8.17E-06	1.04
1.72E-05	246520	1.00	1.62E-05	1.05
3.43E-05	245420	1.00	3.23E-05	1.03
6.83E-05	245390	1.00	6.41E-05	1.03
1.26E-04	245400	1.00	1.19E-04	1.04
1.27E-04	245430	1.00	1.19E-04	1.05
2.56E-04	245390	1.00	2.39E-04	1.07
5.01E-04	244270	0.99	4.69E-04	1.09
9.46E-04	243170	0.99	8.82E-04	1.15
1.72E-03	239840	0.97	1.59E-03	1.35

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-12e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-H; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.69E-05	204000	1.01	0.91	1.69E-05	199800	1.00	0.91
3.50E-05	198500	0.99	0.92	3.50E-05	198000	1.00	0.93
6.50E-05	197100	0.98	0.94	6.50E-05	197000	0.99	0.95
1.24E-04	195500	0.97	0.98	1.24E-04	196000	0.99	1.00
1.93E-04	195600	0.97	1.02	1.93E-04	195300	0.98	1.04

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Table XII-13a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-I

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	55665	2669	4559	0.25
62	8928	428.0	55728	2672	4561	0.24
125	18000	862.9	55715	2671	4559	0.26
250	36000	1725.8	55766	2673	4560	0.21
450	64800	3106.5	55770	2674	4562	0.22

Table XII-13b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-I; Effective Confining Pressure, σ_o' = 250 psi (36.0 ksf = 1726 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio^x, D, %
6.01E-05	56273	1.00	5.95E-05	0.20
1.14E-04	55722	0.99	1.13E-04	0.22
2.39E-04	55725	0.99	2.36E-04	0.23
4.36E-04	55776	0.99	4.30E-04	0.22
9.02E-04	55206	0.98	8.82E-04	0.23
1.65E-03	55215	0.98	1.62E-03	0.22
3.08E-03	54727	0.97	3.03E-03	0.27
5.76E-03	54276	0.96	5.65E-03	0.31
1.10E-02	53740	0.95	1.08E-02	0.36
1.91E-02	52806	0.94	1.85E-02	0.47
2.87E-02	51833	0.92	2.77E-02	0.59

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-13c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-I; Effective Confining Pressure, σ_o' = 250 psi (36.0 ksf = 1726 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
5.99E-05	54010	1.00	0.18	6.00E-05	53450	1.00	0.19
1.21E-04	53900	1.00	0.19	1.21E-04	53500	1.00	0.19
2.26E-04	53500	0.99	0.20	2.26E-04	53400	1.00	0.21
3.05E-04	53440	0.99	0.21	3.05E-04	53360	1.00	0.22
6.79E-04	53400	0.99	0.22	6.80E-04	53300	1.00	0.23

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Table XII-13d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-I; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
6.26E-05	55769	1.00	6.17E-05	0.23
1.11E-04	55770	1.00	1.10E-04	0.22
2.27E-04	55318	0.99	2.23E-04	0.23
4.09E-04	54765	0.98	3.85E-04	0.23
7.95E-04	54764	0.98	7.80E-04	0.24
1.49E-03	54315	0.97	1.47E-03	0.29
2.97E-03	53833	0.97	2.91E-03	0.32
5.59E-03	53338	0.96	5.46E-03	0.36
1.08E-02	52369	0.94	1.06E-02	0.38
2.00E-02	52361	0.94	1.95E-02	0.43
3.17E-02	51829	0.93	3.07E-02	0.53

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-13e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-I; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.22E-04	53900	1.01	0.22	1.22E-04	53900	1.01	0.23
2.31E-04	53200	0.99	0.24	2.31E-04	53200	0.99	0.25
4.66E-04	53000	0.99	0.26	4.66E-04	53000	0.99	0.27
6.96E-04	52600	0.98	0.27	6.96E-04	52500	0.98	0.28
1.02E-03	52300	0.98	0.28	1.02E-03	52200	0.97	0.29

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Table XII-14a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-J

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	202000	9684	6869	1.30
90	12960	621.3	202580	9712	6887	1.16
180	25920	1242.6	205740	9863	6939	1.15
360	51840	2485.2	208720	10006	6987	1.14
450	64800	3106.5	208840	10012	6988	1.14

Table XII-14b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-J; Effective Confining Pressure, σ_o' = 360 psi (51.8 ksf = 2485 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio^x, D, %
4.37E-06	208690	1.00	4.04E-06	1.28
8.60E-06	208700	1.00	8.12E-06	1.14
1.72E-05	207710	1.00	1.60E-05	1.14
3.41E-05	208680	1.00	3.18E-05	1.15
6.88E-05	208660	1.00	6.73E-05	1.14
1.28E-04	208670	1.00	1.20E-04	1.14
2.61E-04	207720	1.00	2.43E-04	1.16
5.23E-04	207680	1.00	4.87E-04	1.15
1.04E-03	207680	1.00	9.68E-04	1.15
2.06E-03	206680	0.99	1.92E-03	1.16

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-14c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-J; Effective Confining Pressure, σ_o' = 360 psi (51.8 ksf = 2485 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.79E-05	185000	1.00	1.15	1.80E-05	185000	1.00	1.16
3.60E-05	182200	0.99	1.16	3.60E-05	182000	0.99	1.16
6.80E-05	181400	0.99	1.15	6.85E-05	181300	0.99	1.17
1.35E-04	181000	0.99	1.16	1.35E-04	181000	0.99	1.17
2.00E-04	181000	0.99	1.17	2.00E-04	180800	0.99	1.18

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Table XII-14d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-J; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
4.32E-06	208750	1.00	4.07E-06	0.98
8.38E-06	208720	1.00	7.72E-06	1.33
1.65E-05	209730	1.00	1.53E-05	1.19
3.27E-05	209760	1.00	3.04E-05	1.19
6.59E-05	208750	1.00	6.12E-05	1.21
1.23E-04	208930	1.00	1.14E-04	1.22
2.51E-04	208710	1.00	2.33E-04	1.21
5.00E-04	208700	1.00	4.64E-04	1.22
9.95E-04	207700	1.00	9.25E-04	1.20
1.95E-03	206950	0.99	1.80E-03	1.23
3.48E-03	205930	0.99	3.21E-03	1.35

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-14e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-J; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.10E-05	190300	1.00	1.20	2.10E-05	190000	1.00	1.21
4.08E-05	189400	1.00	1.21	4.08E-05	189200	1.00	1.23
7.40E-05	188000	0.99	1.22	7.40E-05	187600	0.99	1.24
1.50E-04	187600	0.99	1.23	1.50E-04	186000	0.98	1.24
2.18E-04	187000	0.98	1.24	2.18E-04	185000	0.98	1.25

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Table XII-15a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-Q

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	32915	1578	3576	1.41
18	2520	120.8	34160	1638	3643	1.32
35	5040	241.6	35159	1686	3696	1.24
70	10080	483.2	36283	1739	3753	1.22

Table XII-15b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-Q; Effective Confining Pressure, σ_o' = 70 psi (10.1 ksf = 483 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio×, D, %
4.17E-04	36188	1.00	3.95E-04	1.00
2.19E-04	36205	1.00	2.04E-04	1.00
8.24E-04	36010	1.00	7.69E-04	1.01
1.58E-03	35641	0.98	1.47E-03	1.03
2.88E-03	34719	0.96	2.66E-03	1.04
5.43E-03	34183	0.94	4.97E-03	1.10
1.12E-02	33201	0.92	1.02E-02	1.20
2.31E-02	32754	0.91	2.11E-02	1.40
4.59E-02	31375	0.87	4.16E-02	1.63

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

× Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-15c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-Q; Effective Confining Pressure, σ_o' = 70 psi (10.1 ksf = 483 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.59E-04	34470	1.00	1.00	1.59E-04	34210	1.00	1.00
3.19E-04	34170	1.00	1.00	3.19E-04	34030	1.00	1.00
6.42E-04	33910	0.99	1.00	6.43E-04	33800	0.99	1.00
1.00E-03	33490	0.98	1.01	1.00E-03	33341	0.98	1.02
2.48E-03	32700	0.95	1.03	2.49E-03	32680	0.96	1.04
5.00E-03	32000	0.93	1.10	5.09E-03	31900	0.93	1.12
1.00E-02	31430	0.92	1.21	1.10E-02	31420	0.92	1.23

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Table XII-16a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-R

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	144760	6940	6231	0.25
44	6336	303.7	145030	6953	6235	0.26
88	12672	607.5	145160	6959	6231	0.28
176	25344	1215.0	145370	6969	6235	0.27

Table XII-16b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-R; Effective Confining Pressure, σ_o' = 176 psi (25.3 ksf = 1215 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio×, D, %
2.69E-04	145390	1.00	2.65E-04	0.25
1.37E-04	145390	1.00	1.35E-04	0.25
5.24E-04	145390	1.00	5.15E-04	0.26
9.94E-04	144380	0.99	9.77E-04	0.28
1.97E-03	144380	0.99	1.93E-03	0.31
3.58E-03	143360	0.99	3.50E-03	0.33
6.98E-03	143380	0.99	6.82E-03	0.37
1.28E-02	141360	0.97	1.25E-02	0.44
2.33E-02	139410	0.96	2.25E-02	0.56
3.89E-02	137410	0.95	3.72E-02	0.72
5.71E-02	133530	0.92	5.40E-02	0.92

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

× Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-16c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-R; Effective Confining Pressure, σ_o' = 176 psi (25.3 ksf = 1215 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
4.07E-05	125000	1.00	0.25	4.07E-05	125000	1.00	0.25
8.60E-05	125000	1.00	0.26	8.60E-05	124800	1.00	0.27
1.73E-04	124800	1.00	0.28	1.73E-04	124600	1.00	0.29
3.22E-04	124600	1.00	0.29	3.23E-04	124300	0.99	0.30
6.47E-04	124000	0.99	0.30	6.47E-04	123700	0.99	0.31
1.00E-03	123900	0.99	0.31	1.00E-03	123800	0.99	0.32
2.82E-03	123100	0.98	0.33	2.83E-03	123000	0.98	0.34

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Table XII-17a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-S

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	210000	10067	6368	0.40
17	2448	117.4	210480	10090	7130	0.34
34	4896	234.7	210500	10091	7408	0.35
68	9792	469.4	210880	10110	7136	0.34
136	19584	938.9	208590	10000	7096	0.34
272	39168	1877.7	208840	10012	6422	0.33

Table XII-17b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-S; Effective Confining Pressure, σ_o' = 68 psi (9.8 ksf = 469 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio^x, D, %
8.19E-05	211290	1.00	8.08E-05	0.30
1.62E-04	211070	1.00	1.59E-04	0.30
3.17E-04	209980	0.99	3.10E-04	0.35
6.28E-04	209800	0.99	6.14E-04	0.36
1.24E-03	209790	0.99	1.21E-03	0.40
2.29E-03	209600	0.99	2.23E-03	0.44
4.37E-03	208470	0.99	4.24E-03	0.49
8.25E-03	206290	0.98	7.98E-03	0.55
1.46E-02	202330	0.96	1.40E-02	0.64
2.30E-02	198360	0.94	2.17E-02	0.89
3.24E-02	190970	0.90	2.96E-02	1.47

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-17c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-S; Effective Confining Pressure, σ_o' = 68 psi (9.8 ksf = 469 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.52E-05	201100	1.00	0.22	1.52E-05	201000	1.00	0.23
1.44E-04	200000	1.00	0.23	1.44E-04	199999	1.00	0.24
4.40E-04	200000	1.00	0.32	4.40E-04	200000	1.00	0.33
8.80E-04	200000	1.00	0.38	8.80E-04	200000	1.00	0.39
1.00E-03	200000	1.00	0.39	1.00E-03	200000	1.00	0.40
1.91E-03	200000	1.00	0.44	1.91E-03	200000	1.00	0.46

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Table XII-17d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-S; Effective Confining Pressure, σ_o' = 272 psi (39.2 ksf = 1878 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
8.28E-05	208860	1.00	8.17E-05	0.30
1.67E-04	208870	1.00	1.63E-04	0.33
3.28E-04	208670	1.00	3.22E-04	0.32
6.42E-04	208300	1.00	6.27E-04	0.37
1.25E-03	207900	1.00	1.22E-03	0.39
2.29E-03	207570	0.99	2.23E-03	0.42
4.44E-03	205360	0.98	4.32E-03	0.47
8.18E-03	203200	0.97	7.89E-03	0.58
1.42E-02	199240	0.95	1.35E-02	0.73
2.09E-02	195320	0.94	1.98E-02	0.88
3.34E-02	191420	0.92	3.00E-02	1.36

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-17e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-S; Effective Confining Pressure, σ_o' = 272 psi (39.2 ksf = 1878 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
7.45E-05	202200	1.00	0.17	2.02E+05	202000	1.00	0.18
2.96E-04	202000	1.00	0.19	2.96E-04	201200	1.97	0.19
1.00E-03	200300	0.99	0.37	1.00E-03	200000	0.99	0.38
1.94E-03	199600	0.99	0.44	1.00E-03	199500	0.99	0.50

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Table XII-18a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-T

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	247570	11868	7398	0.50
30	4320	207.1	344310	16506	8752	0.24
60	8640	414.2	344800	16530	8757	0.24
120	17280	828.4	345320	16555	8763	0.23
240	34560	1656.8	342860	16437	8729	0.22
450	64800	3106.5	342970	16442	8728	0.22

Table XII-18b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-T; Effective Confining Pressure, σ_o' = 120 psi (17.3 ksf = 828 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
1.33E-04	345290	1.00	1.30E-04	0.21
6.59E-05	344940	1.00	6.47E-05	0.21
2.67E-04	345780	1.00	2.61E-04	0.22
5.31E-04	345760	1.00	5.24E-04	0.21
5.32E-04	345760	1.00	5.25E-04	0.22
1.08E-03	345800	1.00	1.06E-03	0.22
1.94E-03	345790	1.00	1.91E-03	0.26
3.79E-03	343910	1.00	3.73E-03	0.28
6.94E-03	343570	1.00	6.80E-03	0.33
1.21E-02	338170	0.98	1.18E-02	0.47
2.28E-02	337750	0.98	2.21E-02	0.49
3.56E-02	333190	0.96	3.43E-02	0.62
5.54E-02	324520	0.94	5.27E-02	0.82
6.84E-02	320060	0.93	6.47E-02	0.89

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-18c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-T; Effective Confining Pressure, σ_o' = 120 psi (17.3 ksf = 828 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
5.24E-05	285000	1.00	0.42	5.24E-05	282900	1.00	0.43
1.06E-04	282000	0.99	0.43	1.06E-04	281500	1.00	0.44
1.56E-04	281000	0.99	0.47	1.56E-04	281000	0.99	0.48
2.28E-04	281000	0.99	0.48	2.28E-04	280600	0.99	0.49

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Table XII-18d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-T; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
6.95E-05	343170	1.00	6.86E-05	0.22
1.38E-04	343170	1.00	1.36E-04	0.22
1.38E-04	343180	1.00	1.36E-04	0.22
2.75E-04	343150	1.00	2.71E-04	0.23
5.43E-04	343210	1.00	5.36E-04	0.21
1.09E-03	343180	1.00	1.07E-03	0.22
1.85E-03	341030	0.99	1.82E-03	0.25
3.30E-03	342790	1.00	3.23E-03	0.32
6.20E-03	340140	0.99	6.05E-03	0.40
1.16E-02	339770	0.99	1.13E-02	0.47
2.19E-02	335160	0.98	2.12E-02	0.57
3.65E-02	330670	0.96	3.50E-02	0.67
7.52E-02	322430	0.94	7.08E-02	0.97

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-18e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-T; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.93E-05	290000	1.00	0.47	2.93E-05	289600	1.00	0.48
5.50E-05	288400	1.00	0.48	5.50E-05	288000	1.00	0.49
1.12E-04	287400	0.99	0.50	1.12E-04	286700	0.99	0.51
1.66E-04	285000	0.98	0.51	1.66E-04	284000	0.98	0.52
2.40E-04	284000	0.98	0.52	2.40E-04	283300	0.98	0.53

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Table XII-19a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-X

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,	Void Ratio, e
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %	
8	1152	55.2	1098	53	573	2.17	0.81
16	2304	110.5	1875	90	749	1.59	0.81
32	4608	220.9	2854	137	923	1.29	0.81

Table XII-19b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-X; Effective Confining Pressure, σ_o' = 32 psi (4.6 ksf = 220 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio×, D, %
8.56E-05	2852	1.00	8.04E-05	1.02
1.66E-04	2851	1.00	1.55E-04	1.04
3.28E-04	2839	1.00	3.06E-04	1.06
6.37E-04	2813	0.99	5.90E-04	1.10
1.21E-03	2765	0.97	1.12E-03	1.34
2.12E-03	2696	0.95	1.93E-03	1.54
3.93E-03	2585	0.91	3.49E-03	1.99
7.40E-03	2374	0.83	6.46E-03	2.28
1.37E-02	2077	0.73	1.14E-02	3.02
2.55E-02	1699	0.60	2.01E-02	4.14
4.49E-02	1402	0.49	3.34E-02	5.27

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

× Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-19c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-X; Effective Confining Pressure, σ_o' = 32 psi (4.6 ksf = 220 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.89E-04	2500	1.00	0.95	1.89E-04	2499	1.00	0.96
3.80E-04	2480	1.00	0.96	3.80E-04	2478	1.00	0.98
7.71E-04	2470	0.99	1.12	7.71E-04	2465	0.99	1.14
1.00E-03	2400	0.96	1.28	1.00E-03	2395	0.96	1.30
2.44E-03	2350	0.94	1.62	2.44E-03	2320	0.93	1.63
5.77E-03	2200	0.88	2.32	5.79E-03	2180	0.88	2.34

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