CHAPTER 6 – PRESENTATION OF RESULTS

DESCRIPTION OF SITES

Five sites in Colorado and one site in Utah were tested. The locations of the sites are marked in Figure 24. Each site is described below. An extensive photo album of the sites and cores can be found in Appendix A.

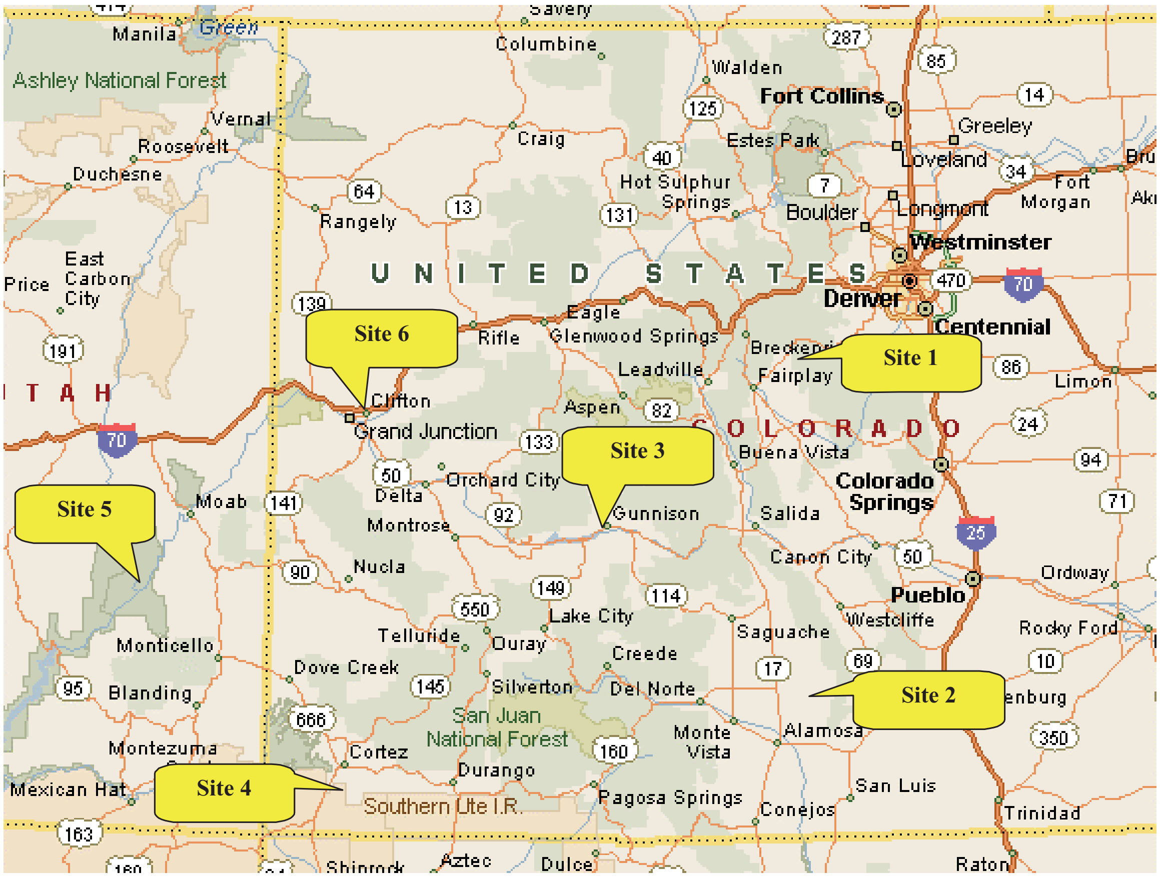


Figure 24. Map. Location of Sites.

Site 1: Tarryall Road

Site 1 was located at Mile Post 2, measuring from US Highway 285 near Jefferson, CO just a few miles west of Kenosha Pass (about 70 miles Southwest of Denver). The top layer at this site was a double surface treatment about 0.75 in. to 1 in. thick. The road was in a fair condition. No significant cracks on the pavement were found. This site was tested on October 27, 2003. Laboratory tests were not feasible on the cores retrieved from this site because they were too thin and not structurally sound.

Site 2: Great Sand Dunes National Monument

Site 2 was located on the southbound lane of Route 150. Field tests started in front of the Amphitheater parking lot and extended to about 0.25 miles south of it. The thickness of the ACP layer was reported as 2 to 3 in. The road way was visually in a fair condition given that it had been placed several years ago. Transverse cracks were observed every 50 ft with some infrequent longitudinal cracks. No shoulder had been constructed on the side of the road.

Site 3: Taylor River Road

Site 3, located on Route 135, was a newly-constructed pavement section about 4 in. thick. The construction project covered from Mile Post 14 to Mile Post 19, starting from the town of Almont. Field tests were started at Mile Post 15.5 and covered about one-quarter of a mile, finishing at Mile Post 15.25. The first test point was located on a small parking area.

Site 4: Mesa Verde National Park

Site 4 was located about five miles south of the main entrance to the park. A newly overlaid section of the road was tested. Based on the visual observation immediately before and after the test section, the underlying ACP was heavily cracked. However, the section tested exhibited isolated cracks. The cores retrieved from the site demonstrated varying degrees of stripping in the underlying layer, especially towards the end of the test section.

Site 5: Canyonlands National Park – The Needles

The project, which covered the last 6 miles of the main road of the Park, was nominally 2 in. of new pavement over a recycled pavement. The road is visually in fair condition with isolated longitudinal and transverse cracks. The section tested did not contain any cracks and seemed in good condition.

Site 6: Colorado National Monument

The project covered the first 15 miles of the Monument Rimrock Drive, starting from the Fruita Entrance of IH-70. The section selected for field tests was a straight section of road in front of the Visitors Center. The test section was in poor condition with very frequent longitudinal and transverse cracks. The ACP was nominally 5 in. thick, with the top 2 in. being of significantly higher quality.

VOLUMETRIC PROPERTIES

The variation in gradation, AC content and air voids for all sites tested are summarized in Table 2. The detailed results can be found in Appendix B. The AC contents are in the range of 6% to 9%, which is typically greater than anticipated for normal mix designs. At Site 2, the coefficient of variation for the AC content is about 37%. This occurs because the AC content of one of the cores is about 3.6%. This point corresponds to the core with the lowest seismic modulus among the cores that were tested for AC content.

On the average, the voids in total mix (VTMs) at different sites vary from a low of about 2% at Site 6 to a high of about 8.5% at Site 5. The two highest air voids correspond to the two sites with the newer AC layer, with the lowest corresponding to Site 6 corresponding to one of the oldest.

Table 2. Volumetric Information from Cores Retrieved from Different Sites.

Site	AC Content	Voids in Total Mix	Modulus with Ultrasonic Device, ksi	Gradation (Percent Passing)						
				1/2 in.	3/8 in.	No. 4	No. 10	No. 40	No. 80	No. 200
1	No test was conducted because the site was covered with surface treatment only									
2	7.2% (37.2%)	3.3% (47.1%)	1619 (15.8%)	94.4 (4.6%)	83.4 (6.6%)	52.8 (9.9%)	33.0 (13.8%)	18.3 (20.7%)	11.8 (32.8%)	4.2 (56.7%)
3	6.0% (5%)*	5.45 (17.6%)	2208 (4.5)	99.2 (1%)	81.0 (5%)	51.4 (7%)	30.4 (4%)	13.9 (4%)	8.4 (7%)	3.8 (15%)
4	7.2% (13.1%)	6.8% (14.6%)	1388 (24.2%)	95.3 (5.7%)	81.0 (3.6%)	53.6 (4.9%)	34.5 (5.2%)	21.6 (11.7%)	12.2 (10.1%)	4.7 (12.5%)
5	7.3% (5.9%)	8.4% (6.7%)	1961 (6.1%)	98.2 (3.6%)	81.8 (1.8%)	48.4 (7.5%)	29.6 (10.4%)	18.1 (13.2%)	11.4 (24.9%)	5.5 (51.0%)
6	8.7% (10.8%)	2.1% (33.7%)	1841 (12.2%)	93.9 (4.7%)	79.2 (1.6%)	53.2 (5.2%)	37.2 (10.7%)	22.9 (16.5%)	11.5 (12.7%)	3.4 (55.1%)

* Numbers in parentheses are the coefficients of variation

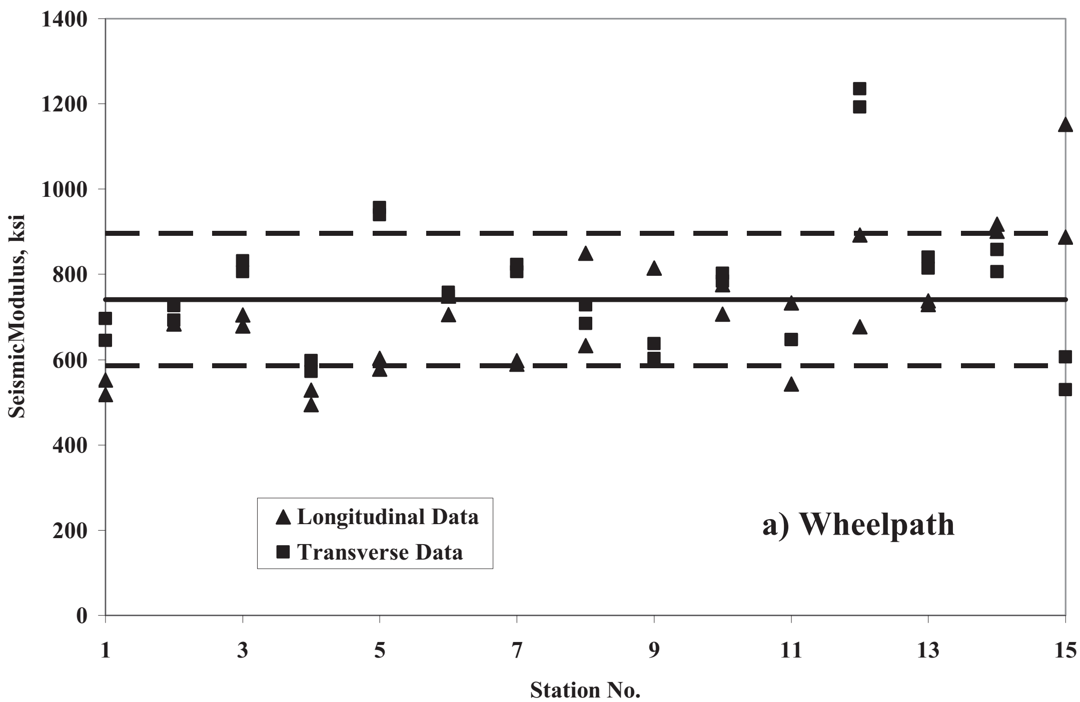
The gradations seem to be fairly uniform within each site and between the sites. Large variability in the fines contents (i.e. materials passing No. 200 sieve) is apparent. Given the small amounts of fines present in the gradation, this can be due to experimental error during the sieving operations.

PSPA MODULI

The average moduli obtained at each site adjusted for temperature are reflected in Table 3. Point-by-point variation in moduli can be found graphically in Figures 6.2 through 6.7 and numerically in Appendix C. Typical time records, phase spectra and dispersion curves from the core locations at each site as seen in the PSPA software are included in Appendix D.

Table 3. Seismic Moduli Obtained from PSPA at Different Sites.

Site	Seismic Modulus					
	Wheel path		Midlane		Overall	
	Average, ksi	COV, %	Average, Ksi	COV, %	Average, ksi	COV, %
1	741	20.9%	794	18.8%	767	20.1%
2	1645	35.8%	1280	30.6%	1463	36.3%
3	1964	13.8%	1967	12.2%	1965	13.0%
4	1104	44.0%	1119	41.8%	1112	42.7%
5	1811	18.5%	1849	17.9%	1830	18.2%
6	1795	29.2%	1648	32.0%	1721	30.8%



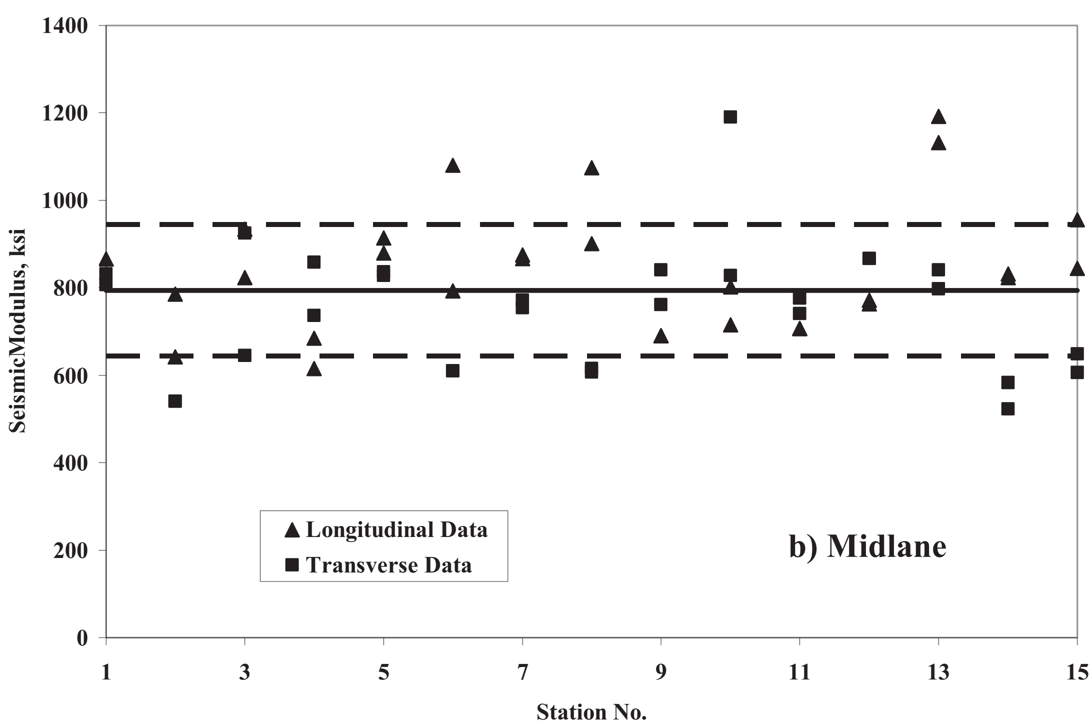


Figure 25. Graph. Variation in Modulus with PSPA along Site 1.

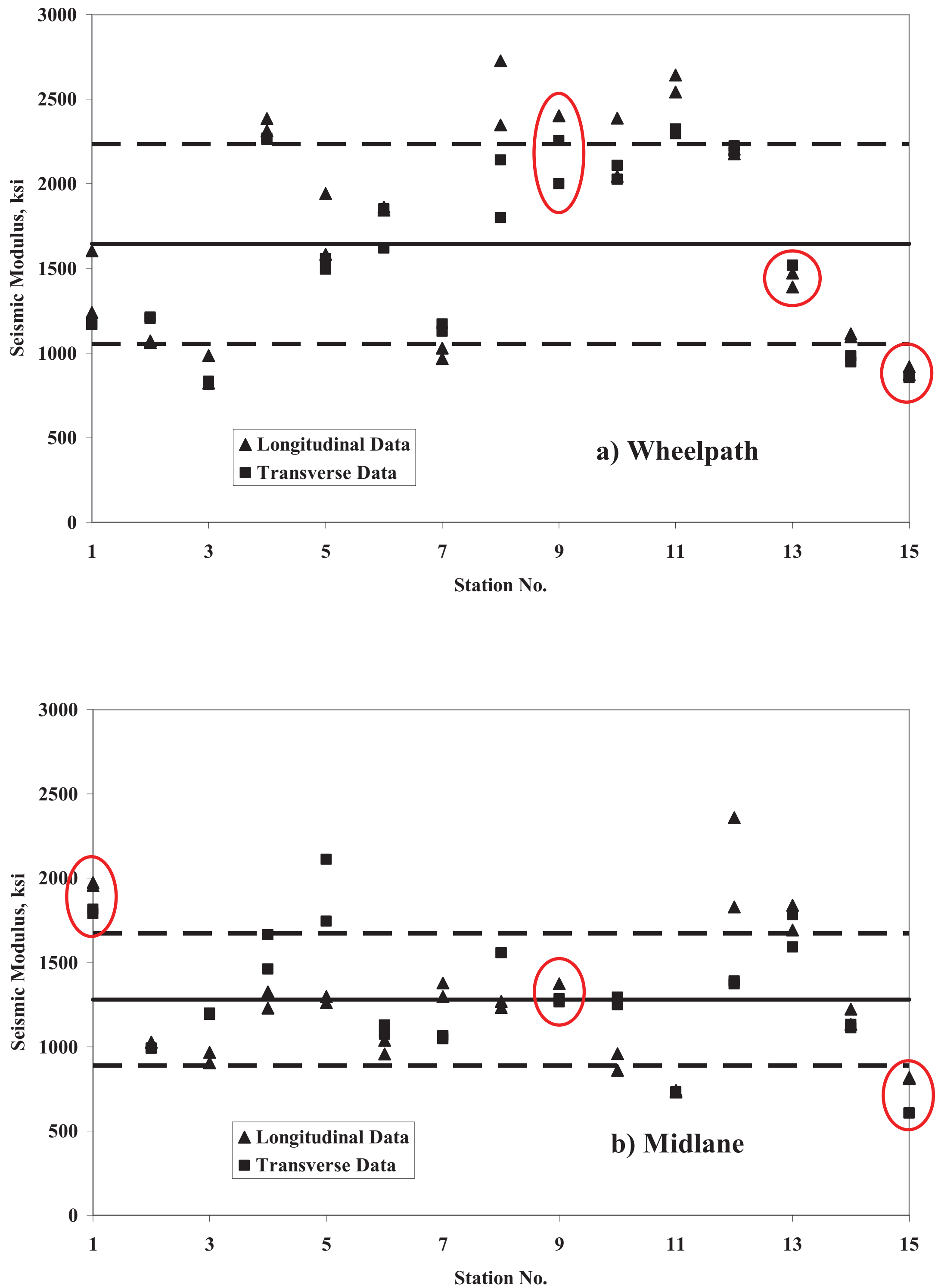


Figure 26. Graph. Variation in Modulus with PSPA along Site 2.

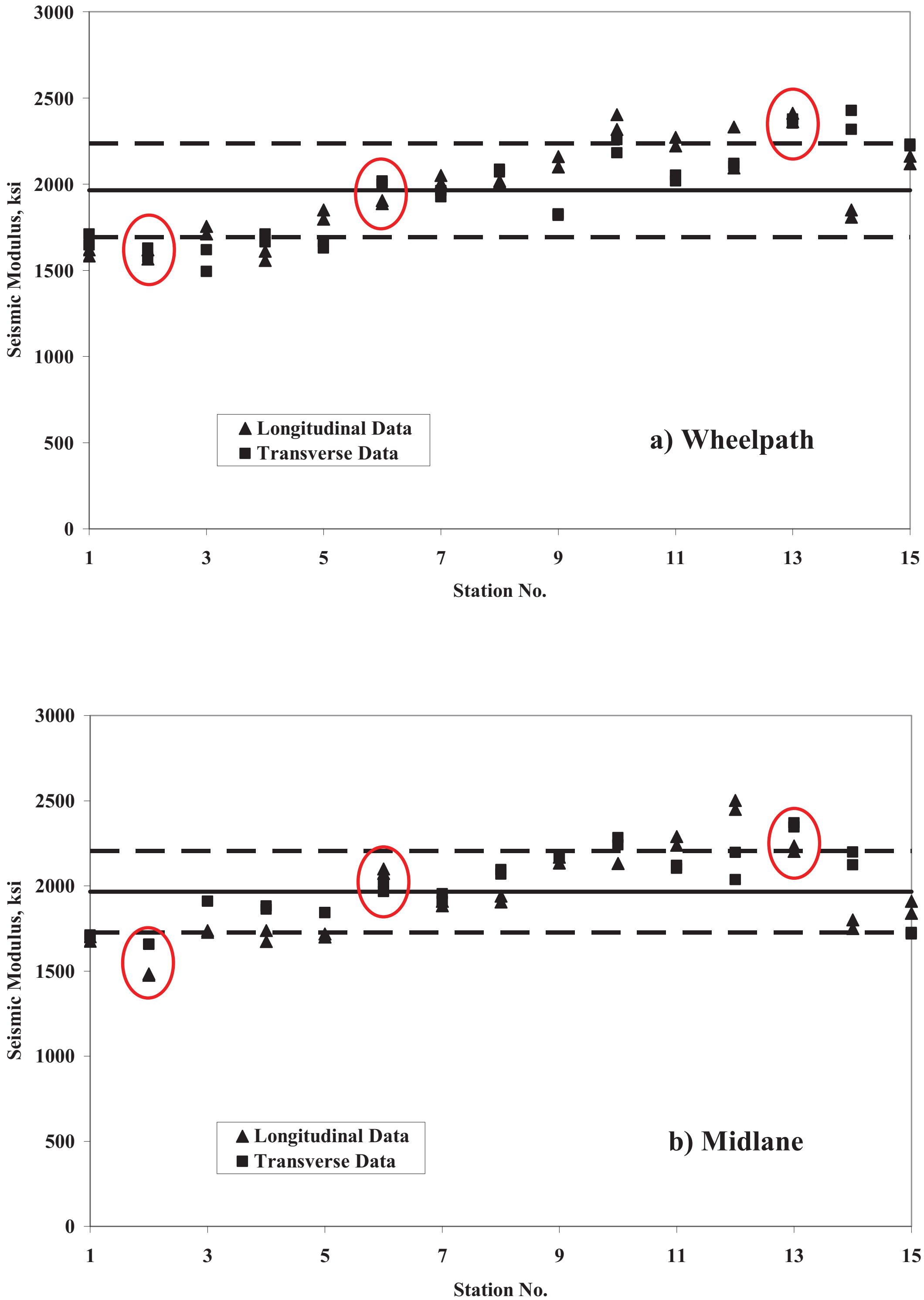


Figure 27. Graph. Variation in Modulus with PSPA along Site 3.

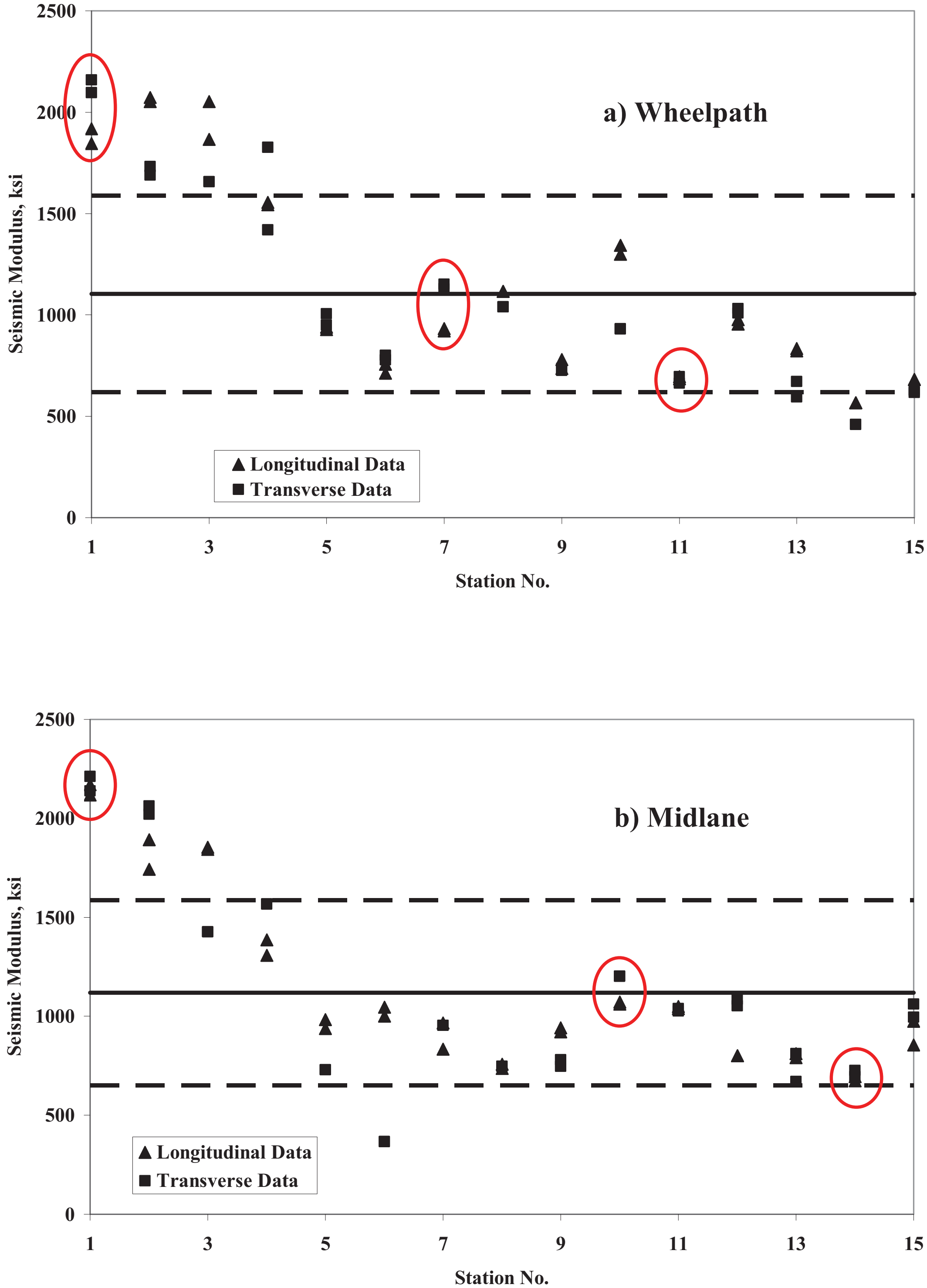
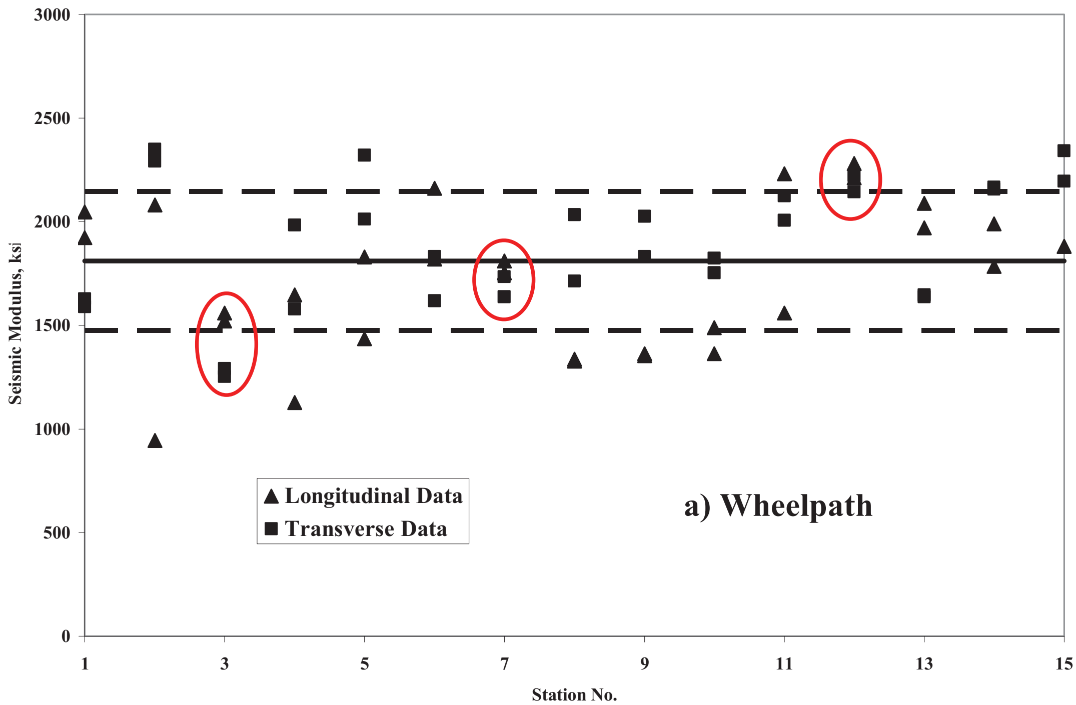


Figure 28. Graph. Variation in Modulus with PSPA along Site 4.



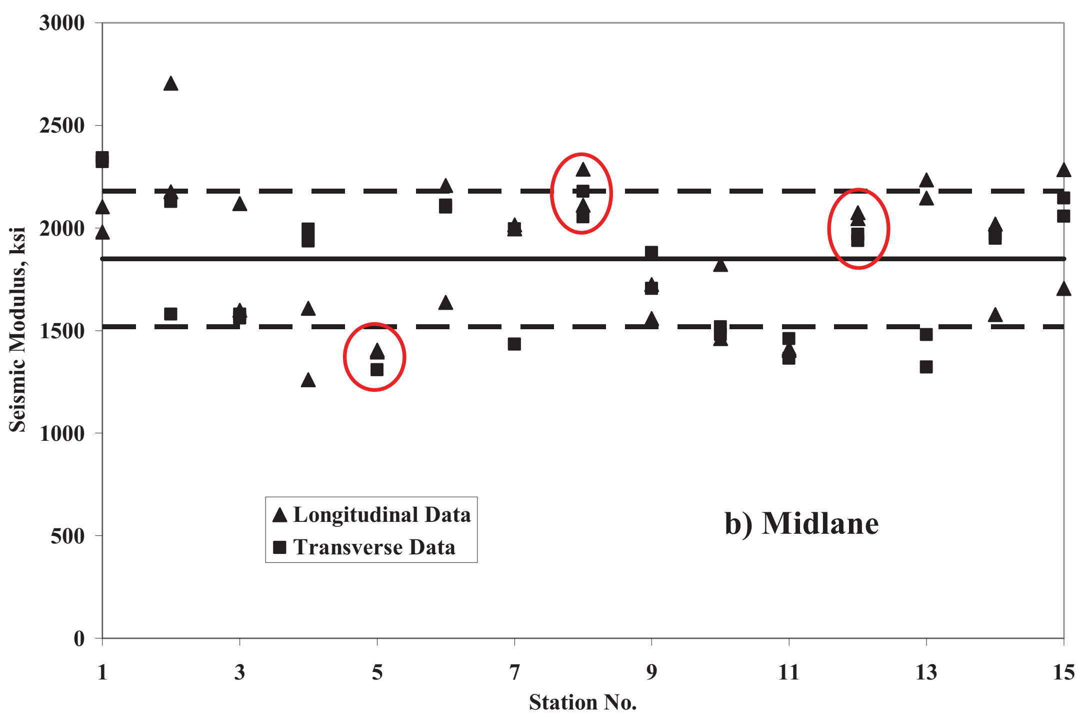


Figure 29. Graph. Variation in Modulus with PSPA along Site 5.

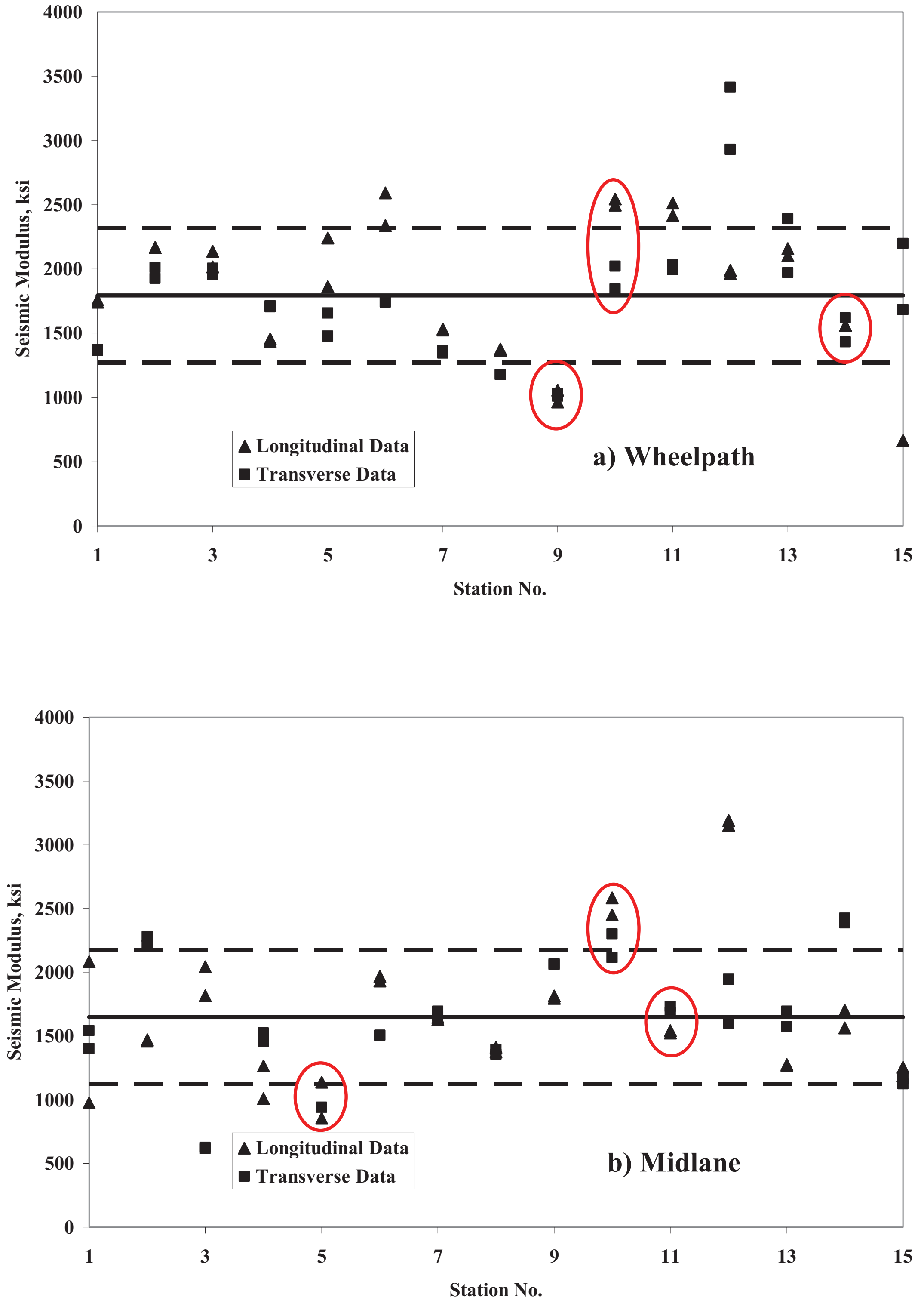


Figure 30. Graph. Variation in Modulus with PSPA along Site 6.

The variations in PSPA modulus along the wheel path and midlane for Site 1 are shown in Figure 25. As indicated before, the top layer at this site was a thin double surface treatment. The average seismic modulus at this site is about 760 ksi which translates to an approximate design modulus of about 250 ksi. This value seems to be reasonable for such a surface. The coefficient of variation is about 20% which reflects the quality anticipated from surface treatment.

At site 2, as reflected in Table 3, the average seismic modulus is about 1460 ksi. The variations in PSPA modulus along the site are shown in Figure 26. For the wheel path, the first three and last two points exhibit lower moduli with the middle points generally being significantly stiffer. Along the midlane, the moduli are more uniform and generally lower than the wheel path. This trend is typically observed on the older pavements, where the vehicular traffic would typically consolidate the material in the wheel path. The VTM for the wheel path, as shown in Table 5 is about 2% whereas for the midlane the VTM is closer to 4%. The observed point-to-point variability is also normal for aged pavements that contain micro-cracking and have experienced consolidation.

Contrary to Site 2, Site 3 exhibits fairly uniform behavior along the site (see Figure 27). This trend is also anticipated because Site 3 was newly constructed. The average seismic moduli along the wheel path and the midlane are fairly close since the site is not extensively trafficked. The quality of construction can be observed in Figure 27. The first half of the site demonstrates consistently lower moduli perhaps because of compaction efforts. This increase in modulus was not only apparent on the PSPA results but also on seismic tests performed on cores.

Site 4 consists of 2 in. of overlay over an old ACP. An inspection of cores (see Figure 46) and dispersion curves (see Appendix D) indicated that at the beginning of the section the overlay is thicker as compared to the remainder of the section. The inspection of the cores also indicated that the original ACP is of poor quality. The variations in PSPA modulus along the wheel path and midlane are shown in Figure 28. The moduli along the section are initially high. Past Point 5, the moduli are much lower than the initial points, indicating the lower quality materials. The close relationship, between the observed quality of the cores and the results from the PSPA is a good indication of the usefulness of the PSPA in determining the properties of an AC layer.

Site 5 again consists of 2 in. of overlay over a recycled asphalt layer. The average PSPA modulus at this site is about 1830 ksi with a coefficient of variation of about 18%. The variations in PSPA modulus along the wheel path and midlane are shown in Figure 29. The variation is rather random along the site, indicating variability in the properties of the recycled ACP layer. Also the moduli in the longitudinal and transverse directions at some points, especially along wheel path, are different, maybe demonstrating directionality of compactions of recycled materials.

Finally, the results from PSPA at Site 6 are shown in Figure 30. This site consisted of an old, cracked, road. As anticipated the coefficient of variation is rather high at about 31%. The average modulus of the wheel path is greater than the midlane, once again because of consolidation of the ACP under traffic.

DESIGN MODULI

The individual master curves from the cores subjected to resilient modulus are included in Appendix E. The procedure to obtain the design modulus was described in Chapter 5. The average master curve parameters associated with Equation 3.1 for each site are included in Table 4. The coefficient of determination, the R^2 value, associated with each curve fit is also included in the table. All R^2 values are greater than 0.94 indicating good agreement between the fitted curve and the data obtained from lab and field testing.

Based on these average master curve parameters, the average design moduli were obtained and reported in Table 4. For Site 1, the simplified procedure advocated by Aouad et al. (1993) was used because the cores where too thin for actual resilient modulus tests. The approximate design modulus for this site is about 250 ksi. For the other five sites, the modulus varied from about 500 ksi to 800 ksi.

Table 4. Design Moduli Obtained from Integration of Lab and PSPA Tests at Different Sites.

Site	Average Master Curve Parameters					Average Design Modulus, ksi
	δ	α	β	γ	R^2	
1	Specimens too thin for Testing					250*
2	-3.100	6.967	-1.600	0.147	0.978	713
3	-3.300	6.800	-1.600	0.390	0.960	523
4	-2.988	6.813	-1.600	0.119	0.944	582
5	-3.338	7.115	-1.600	0.228	0.981	709
6	-2.950	6.833	-1.600	0.160	0.977	811

* Based on simplified Method

COMPARISON OF CORE MODULI WITH PSPA MODULI

A comparison of the seismic moduli obtained with the ultrasonic device on the cores and the PSPA moduli obtained at the respective core location is presented in Figure 31. In general, close agreement between the two moduli was observed. The exception is Core 4 for Site 2 that contained micro-cracks and Core 1 of Site 4 that was badly stripped (see picture of cores in Appendix A). To further quantify the comparison between the two moduli, they are plotted against one another in Figure 32. The differences between the two moduli are generally less than 20%. The reasons for differences, aside from any experimental errors are itemized in Chapter 5.

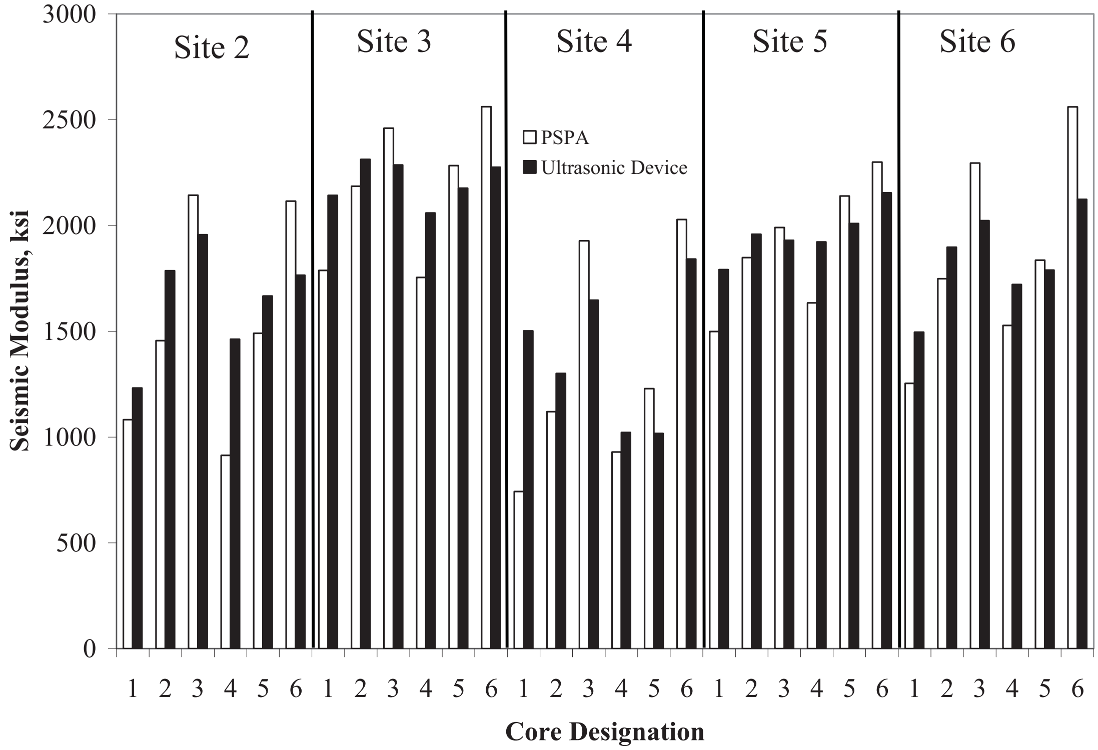


Figure 31. Graph. Comparison of Moduli Obtained by Ultrasonic Device and PSPA at all Sites.

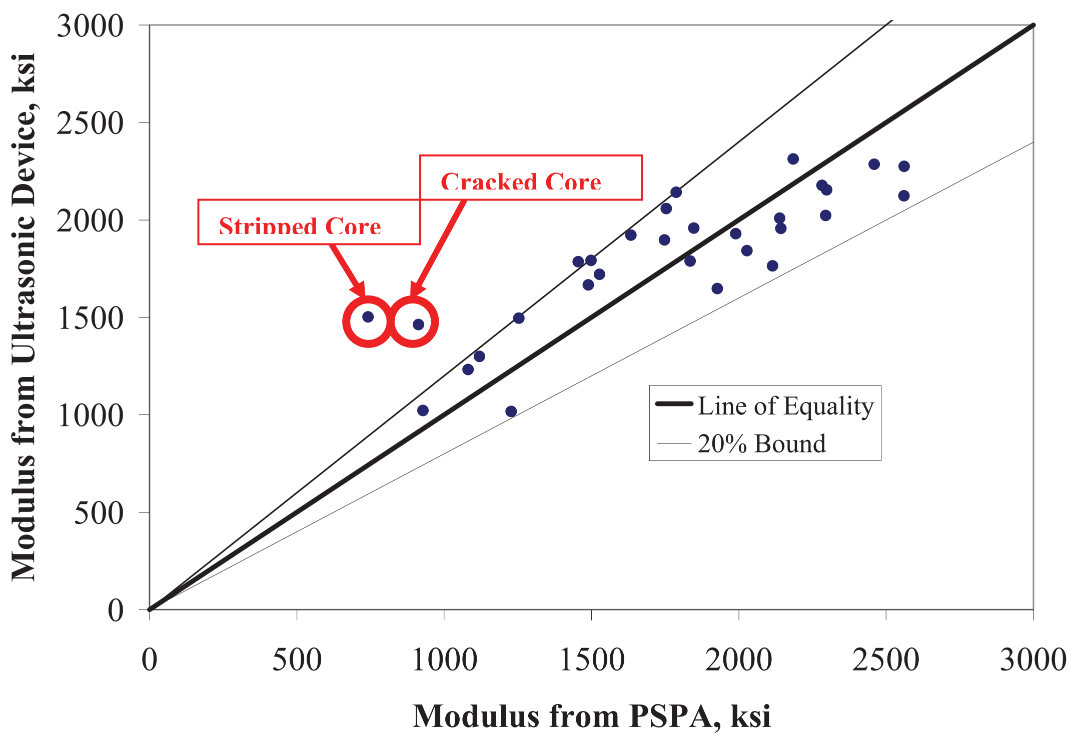


Figure 32. Graph. Variation between Moduli Obtained by Ultrasonic Device and PSPA at all Sites.