PEM DATA PLOTS

The PEM project included shadow testing performed by state agencies, the research team, and the FHWA MCTC, where PEM tests were run concurrently with the local department of transportation. The following are data plots from the sampling and testing.

Fresh Properties – Unit Weight Plots

Figure 35 shows scatter plots of unit weight test results versus date for bridge and pavement projects. While it is difficult to see correlation or trends, the scatter plot provides a glimpse of the number of total tests taken.

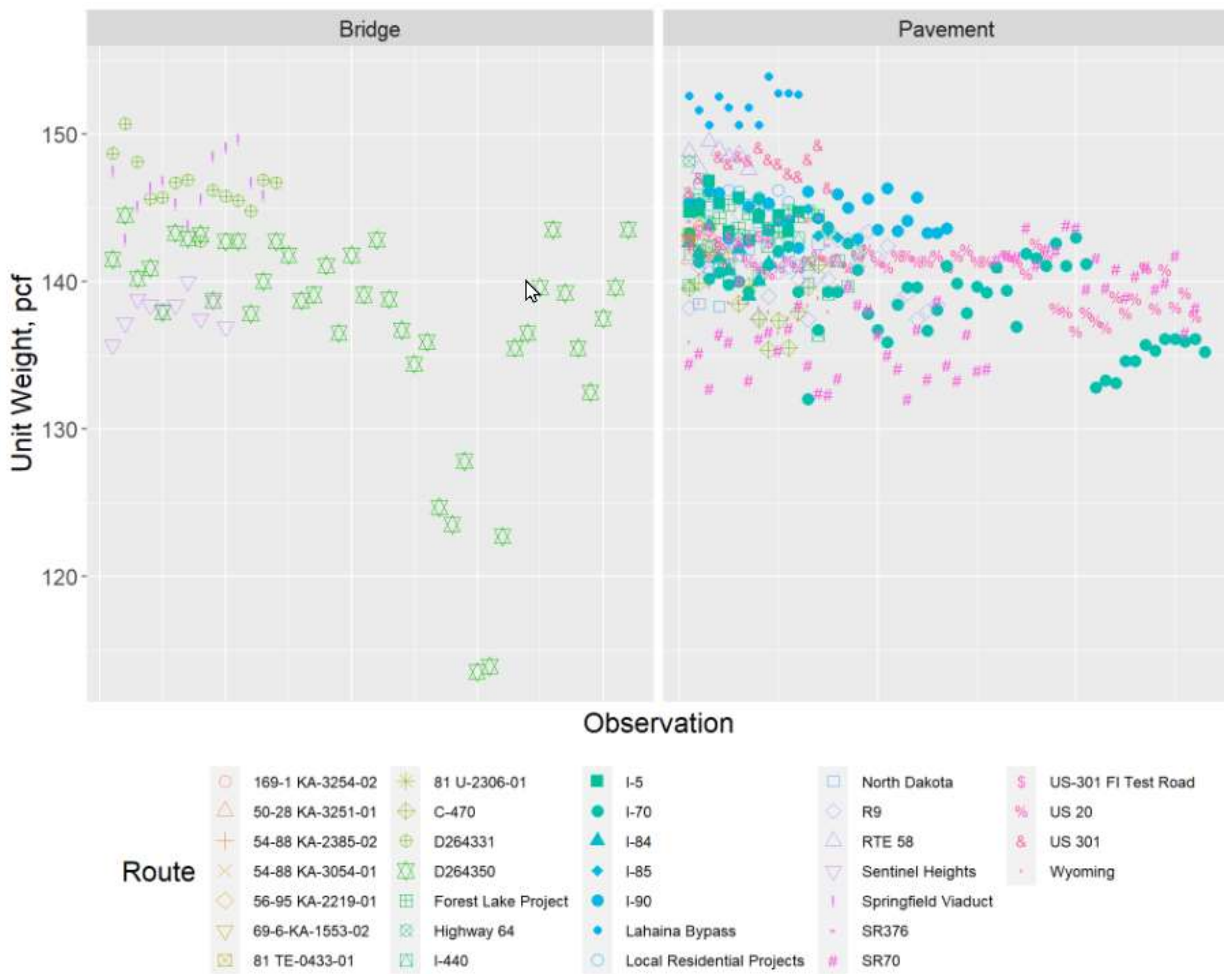

Figure 1. Unit weight scatter data for bridges and pavements

Figure 36 shows the unit weight test results over time. Data plots that result in a horizontal line indicate a consistent and uniform mixture based on consistent weights.

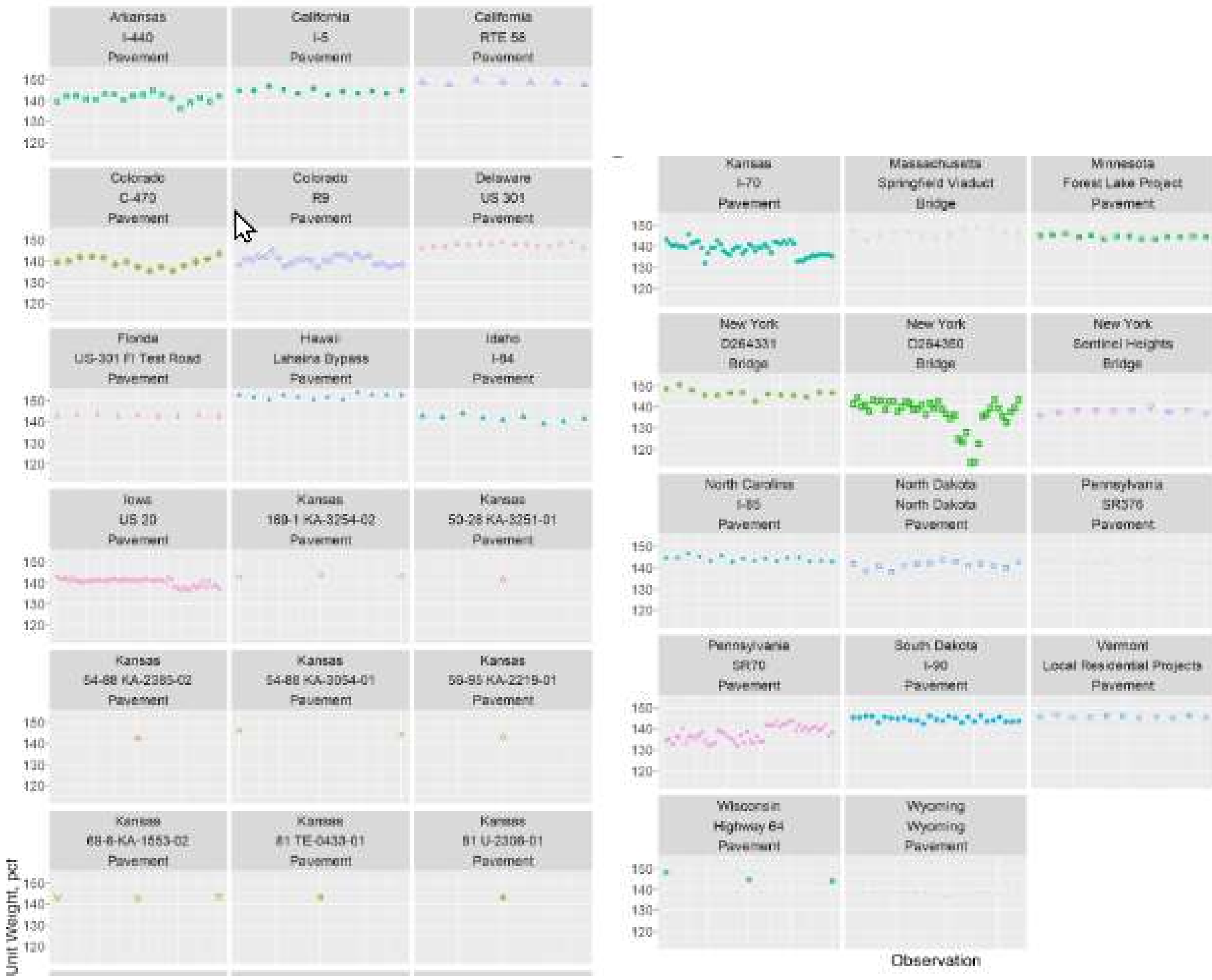

Figure 2. Unit weight data from various locations

Figure 37 is a box and whisker plot showing unit weights for all pavements. This figure allows for comparison between different projects. The box and whisker plot is a way of showing data that provides the lower and upper quartiles, the interquartile (where 50% of the data are found), and the median value.

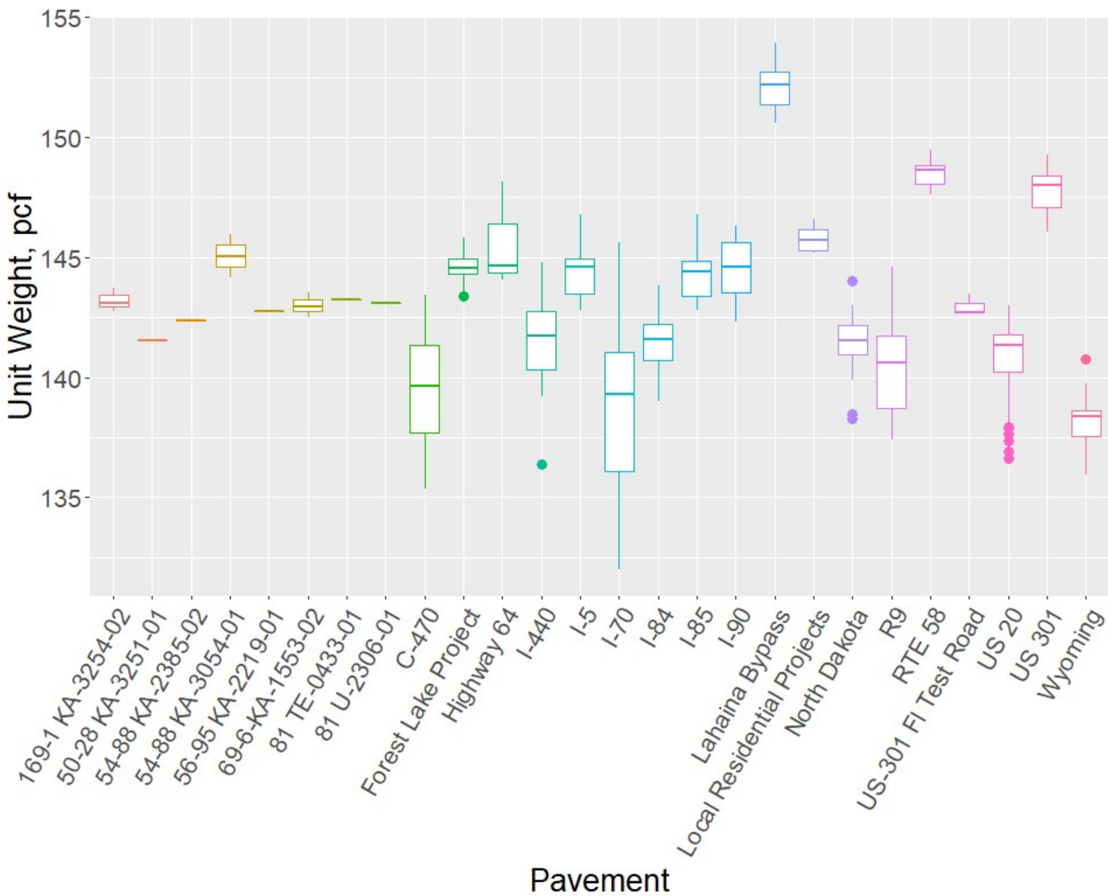

Figure 3. Unit weight box and whisker data for pavements

Figure 38 shows the box and whisker plots for unit weight versus date on bridge projects.

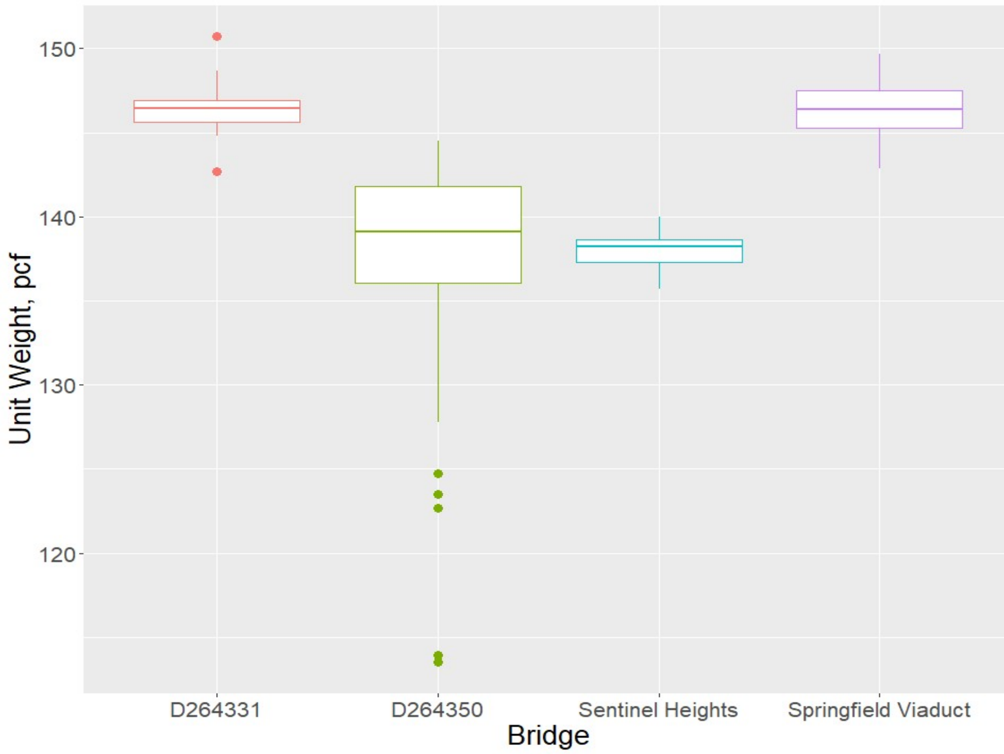

Figure 4. Unit weight box and whisker data for bridges

Fresh Properties – SAM and Air Content Plots

The following figures represent SAM test results and air content testing. SAM_Air represents air content determined by the SAM. Air_Content represent air content determined by the Type B meter. Figure 39 is a box and whisker plot showing SAM numbers for pavement projects, while Figure 40 is a box and whisker plot showing SAM numbers for bridge projects. The horizontal lines indicate a SAM value of 0.3 and a value of 0.2. This figure allows for SAM number to be compared among several projects, with some projects having more variability than others.

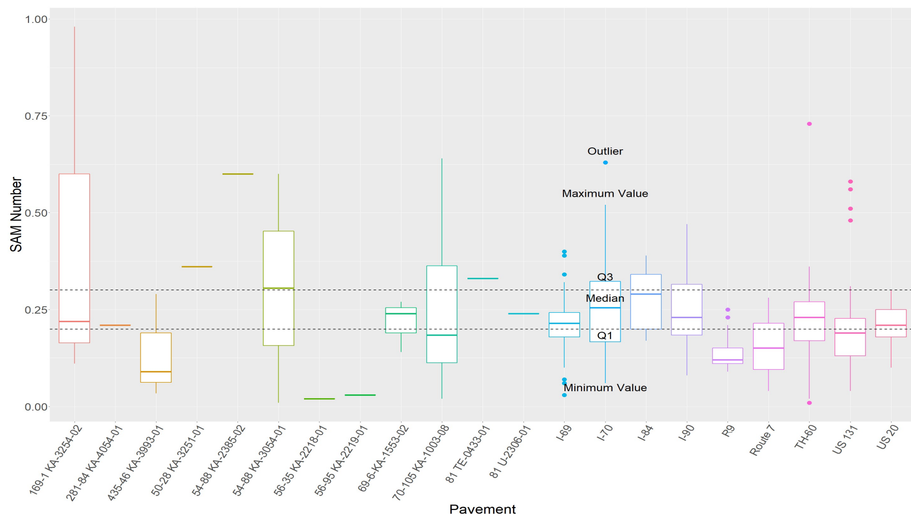

Figure 5. SAM box and whisker data for pavements

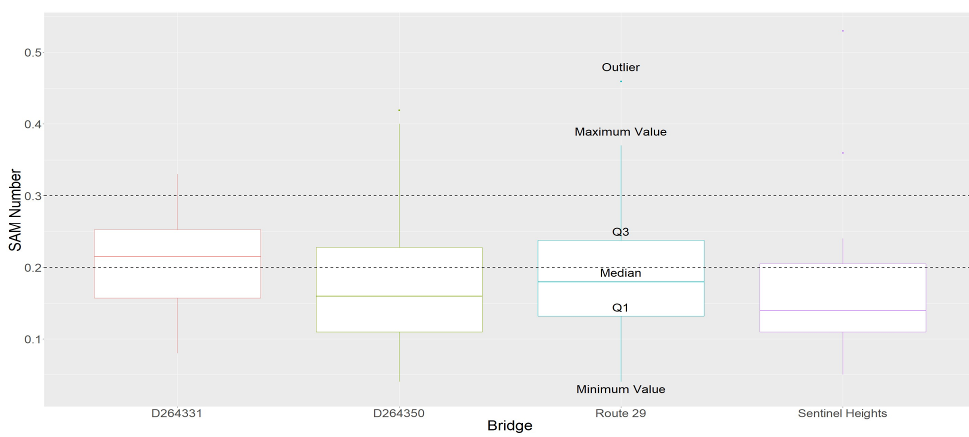

Figure 6. SAM box and whisker data for bridges

Figures 41 and 42 show SAM numbers versus date for various projects. Separating the data into individual projects allows the data to be compared between projects, and the outlier data, or any data not found on a horizontal line, can be observed. Variability in the results may warrant further investigation.

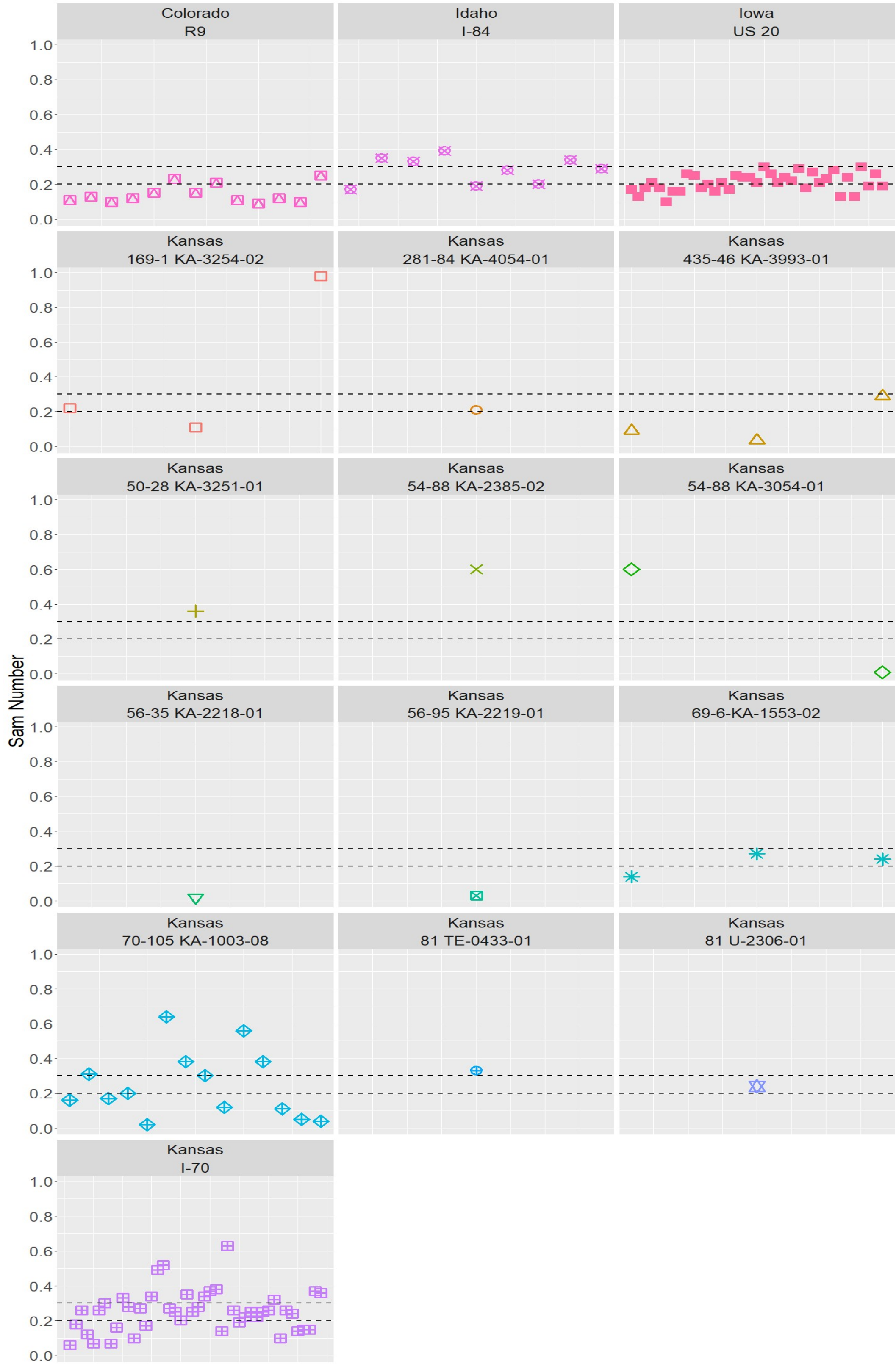

Figure 7. SAM data for various locations

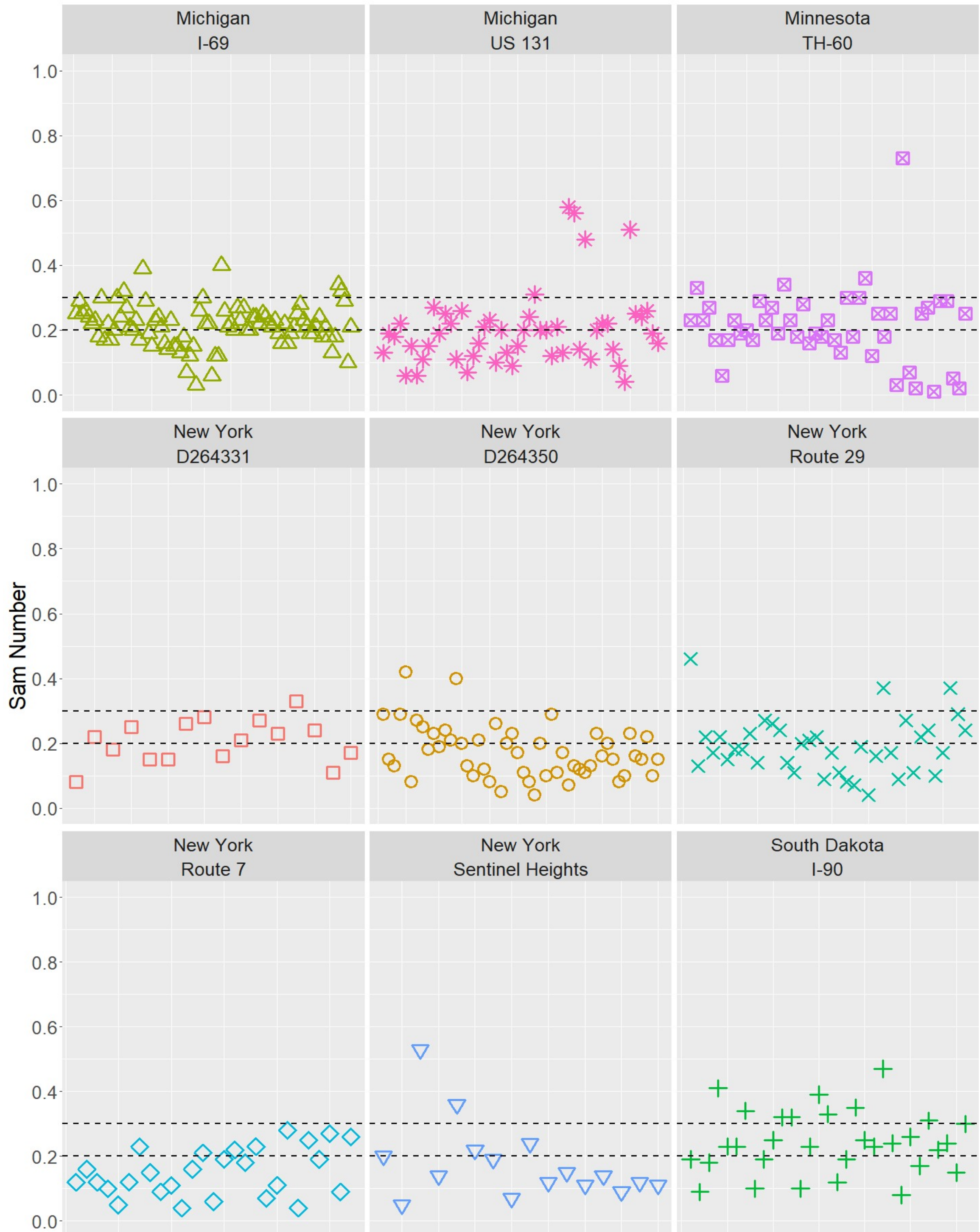

Figure 8. SAM data for various locations (continued)

Figure 43 is a SAM scatter plot for all pavement projects, and Figure 44 is a SAM scatter plot for all bridge projects. While it is difficult to see correlations or trends, the scatter plots provide a glimpse of the total number of tests taken.

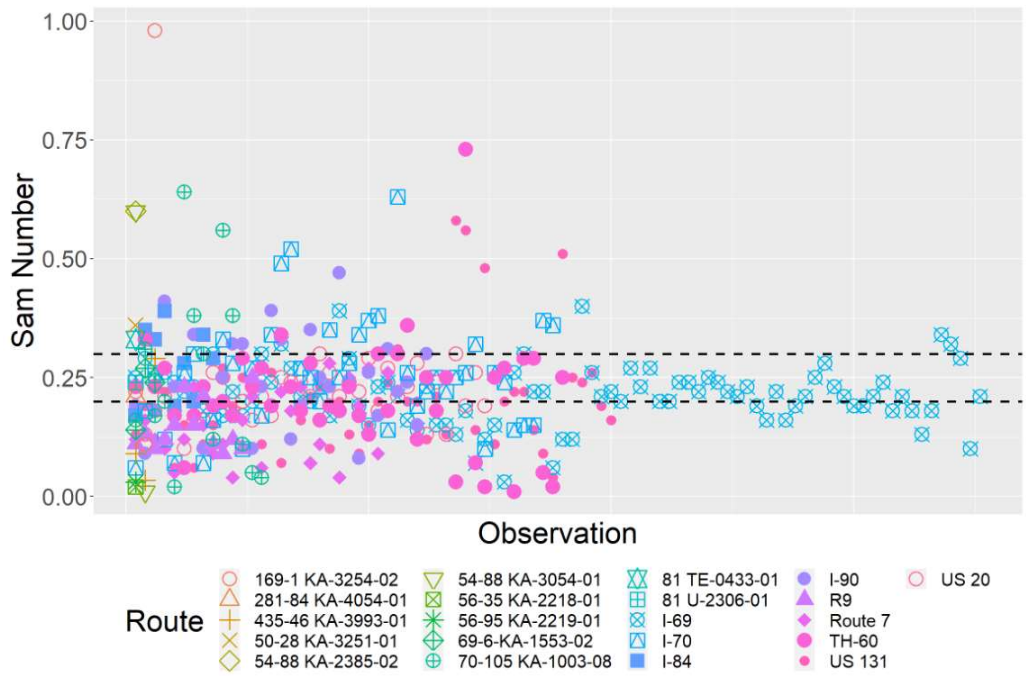

Figure 9. SAM scatter data for pavements

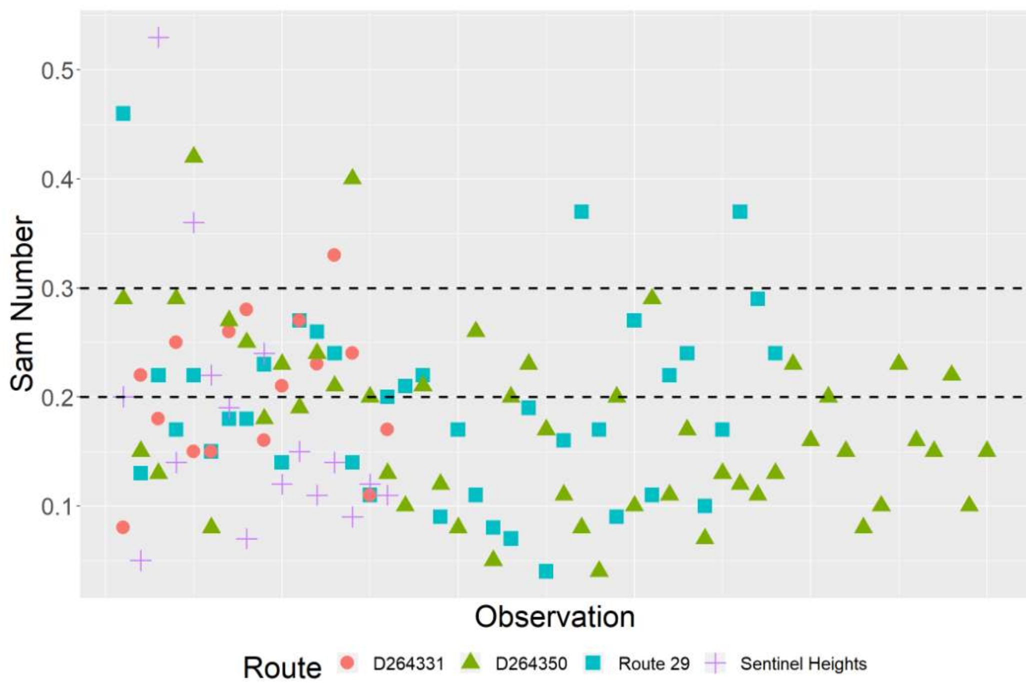

Figure 10. SAM scatter data for bridges

Figure 45 is a box and whisker plot of air content taken by the Type B meter for all pavement projects, and Figure 46 is a box and whisker plot of air content taken by the Type B meter for all bridge projects.

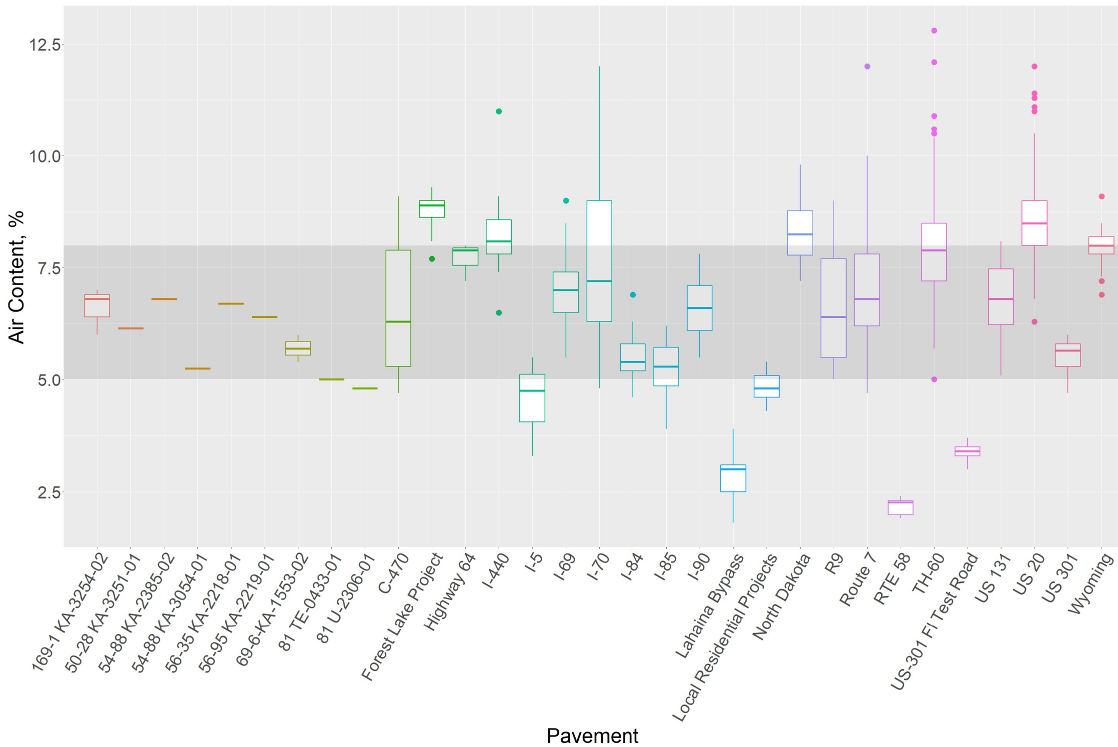

Figure 11. Air content box and whisker for pavements

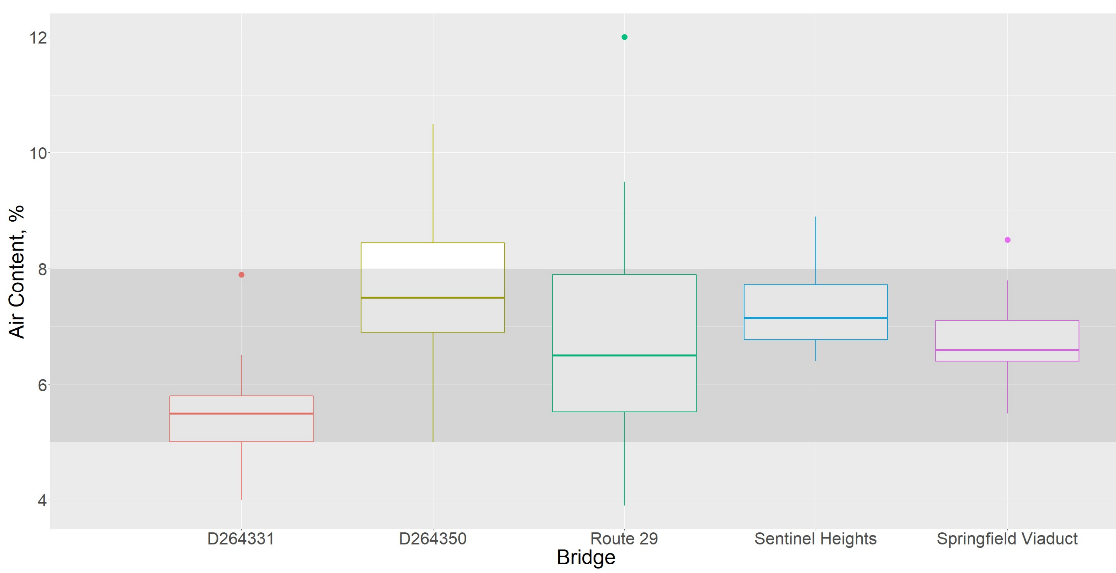

Figure 12. Air content box and whisker for bridges

Figure 47 shows air content as determined by the Type B meter versus date in scatter plots for bridge projects (left) and pavements (right). The shaded region between 5% and 8% represents the range of acceptable air content per AASHTO R 101.

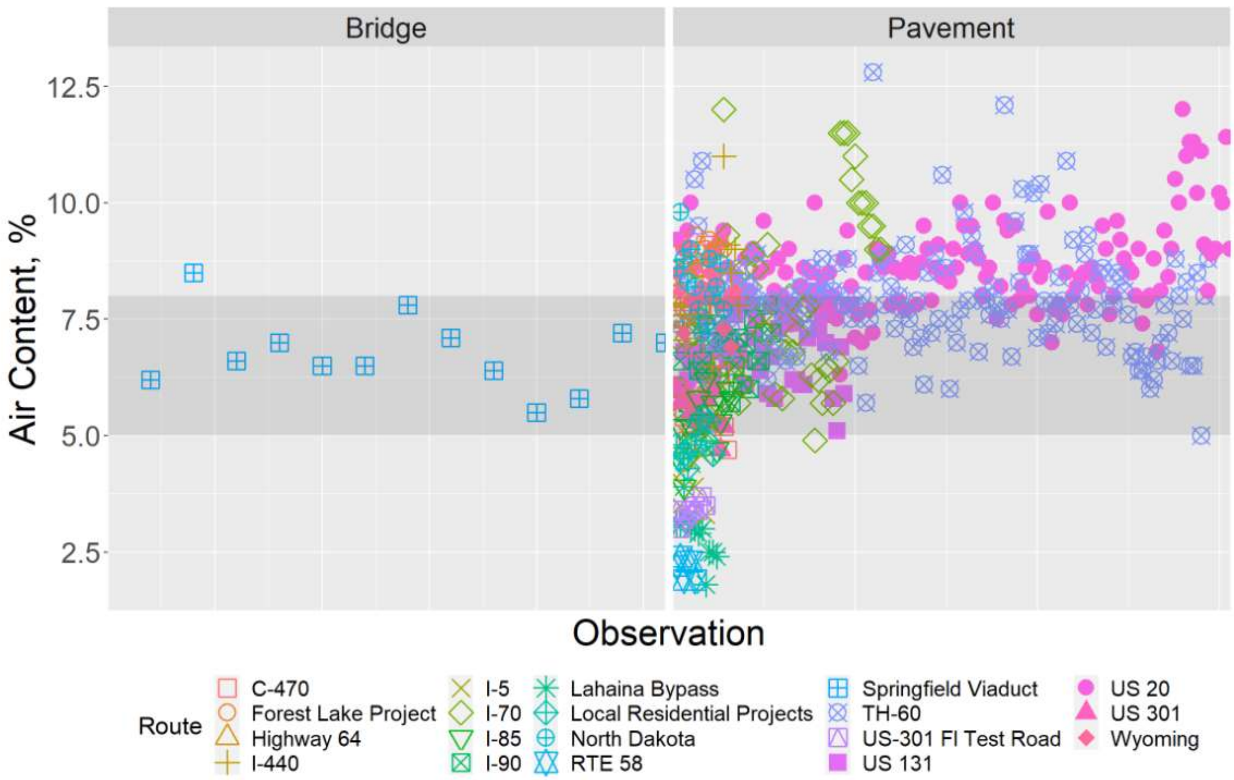

Figure 13. Air content scatter data for bridges (left) and pavements (right)

Figure 48 shows the air content determined by the Type B meter (Air_Content) and the air content determined by the SAM (SAM_Air) for various projects. The y-axis is the air content, and the x-axis is the observations. The expected standard deviation based on ASTM standards for the air content determined by the Type B meter and the air content determined by the SAM is 0.29%. This means that expected variation, within a 95% confidence interval, can vary by 0.58% for laboratory measurements. Variability between the two results can be caused by many factors, including differences in the location of the air test (at the batch plant versus at the paver), calibration of equipment, and other factors.

Figure 49 shows air content determined by the Type B meter for various projects. The y-axis is the air content, and the x-axis is the observations. Some locations with low air content values (Hawaii and Florida) are representative of mixtures that do not require a specified air content for freeze-thaw durability.

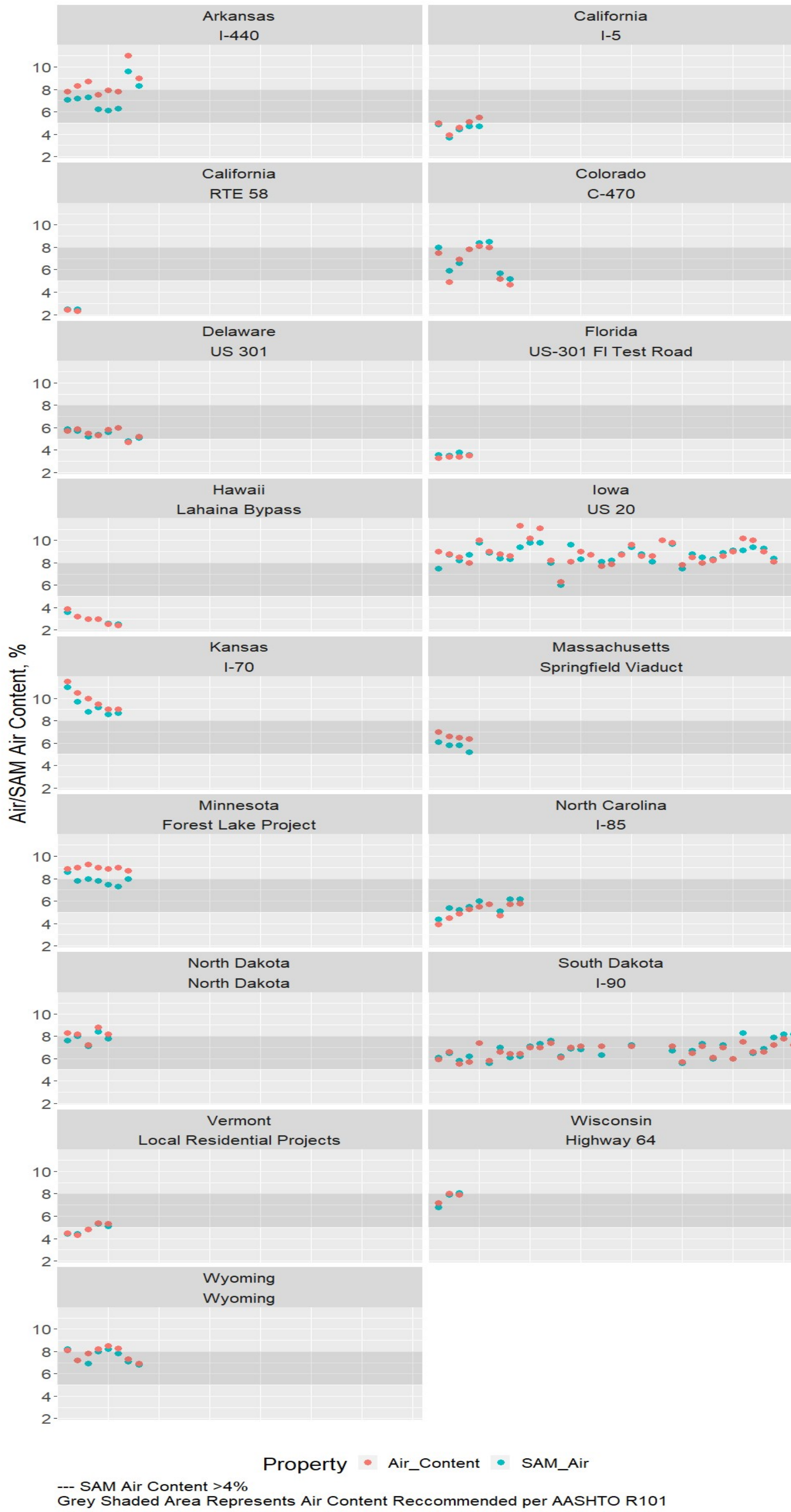

Figure 14. Air content measured by Type B meter (Air_Content) and SAM (SAM_Air) for various locations

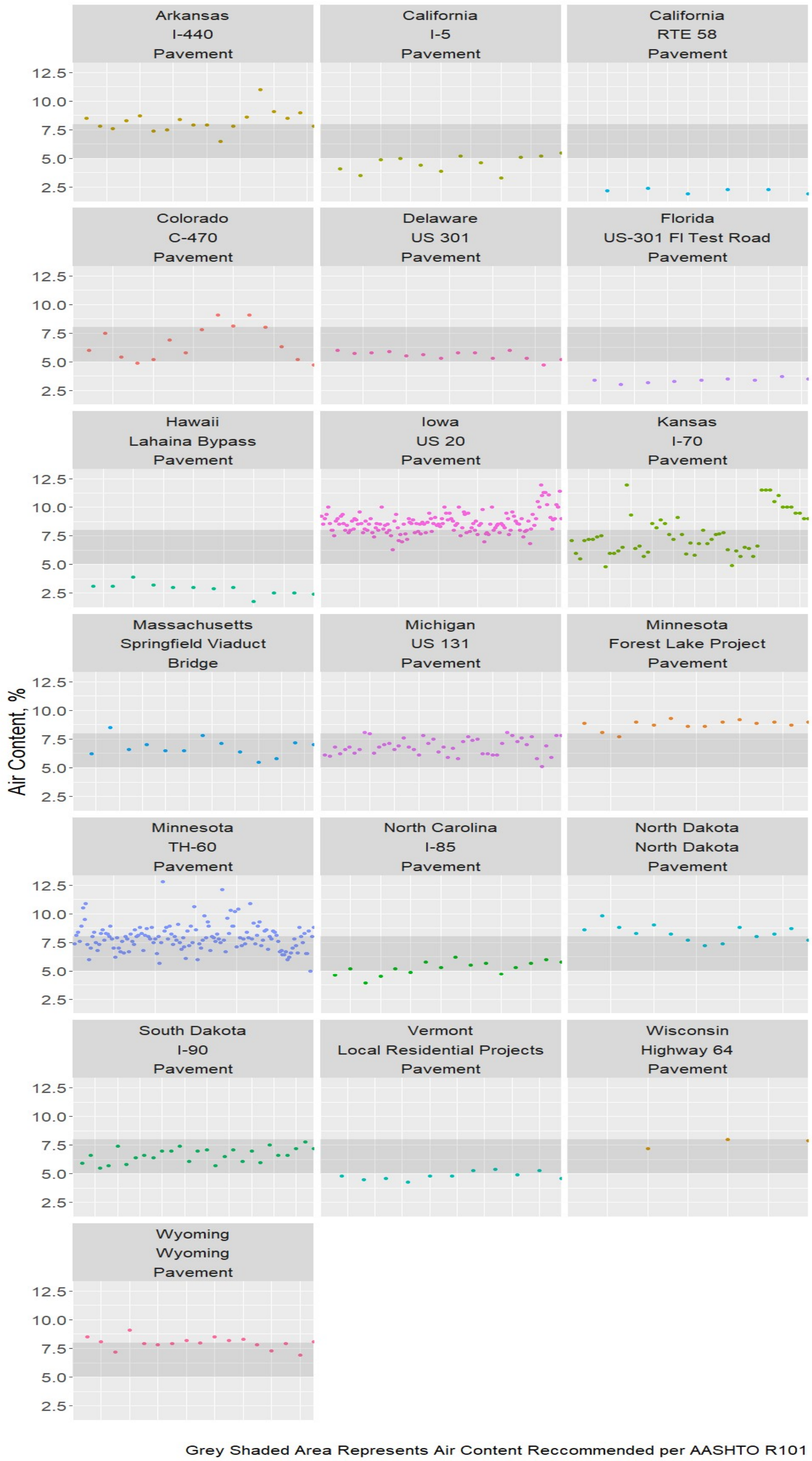

Figure 15. Air content measured by Type B meter (Air_Content) for various locations

Figure 50 illustrates a histogram of all of the SAM data gathered in this pooled fund project. The suggested limits of 0.20 and 0.30 are shown by two black vertical lines. A normal distribution curve is shown to highlight how the data are distributed. Since the data are normally distributed, it is appropriate to calculate an average and standard deviation.

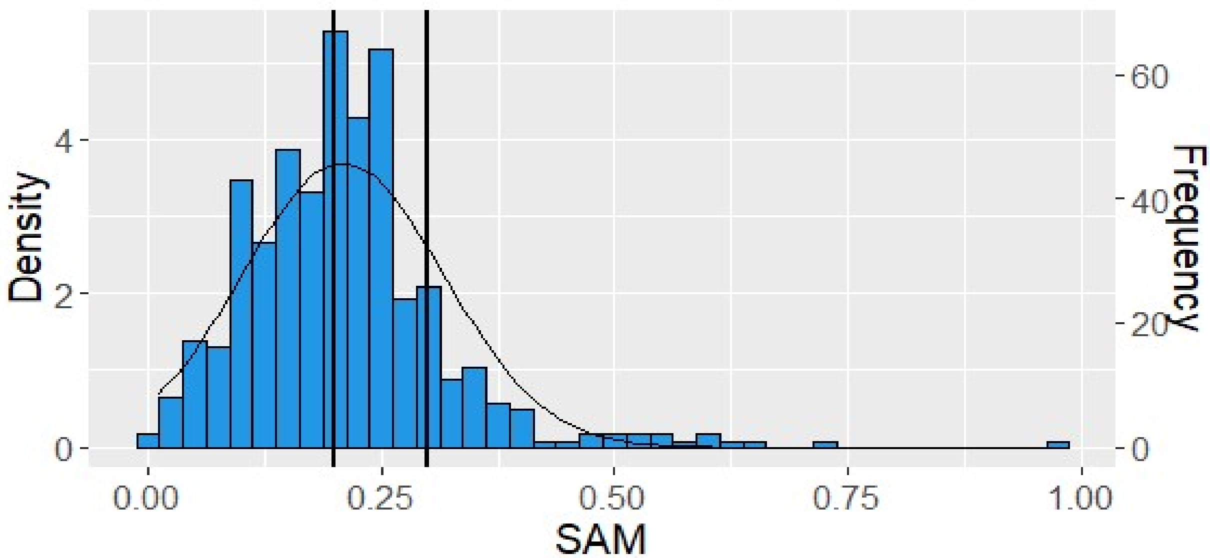

Figure 16. SAM histogram for all projects

The results show the following:

- The average SAM number was 0.21.
- Approximately 50% of the data were above the recommended 0.20 limit.
- Approximately 14% of the data were above 0.30.

The 0.30 limit is the recommended limit for freeze-thaw durability. This means that roughly one out of every six measurements made had a SAM number above this limit, and therefore freeze-thaw durability is a concern for these mixtures; that is, if this concrete becomes saturated and freezes, freeze-thaw damage is expected.

One reason for the higher SAM numbers in Figure 50 is that these were measurements made in the field based on existing specifications. These projects did not require a target SAM number in the mixture design stage. For example, the current AASHTO R 101 document requires the SAM number to be less than 0.20 in the mixture design stage and then sets a limit of 0.30 for the field. The data set from NYSDOT is unique in that the SAM was required to be less than 0.20 in the mixture design stage. These data are shown in Figure 51.

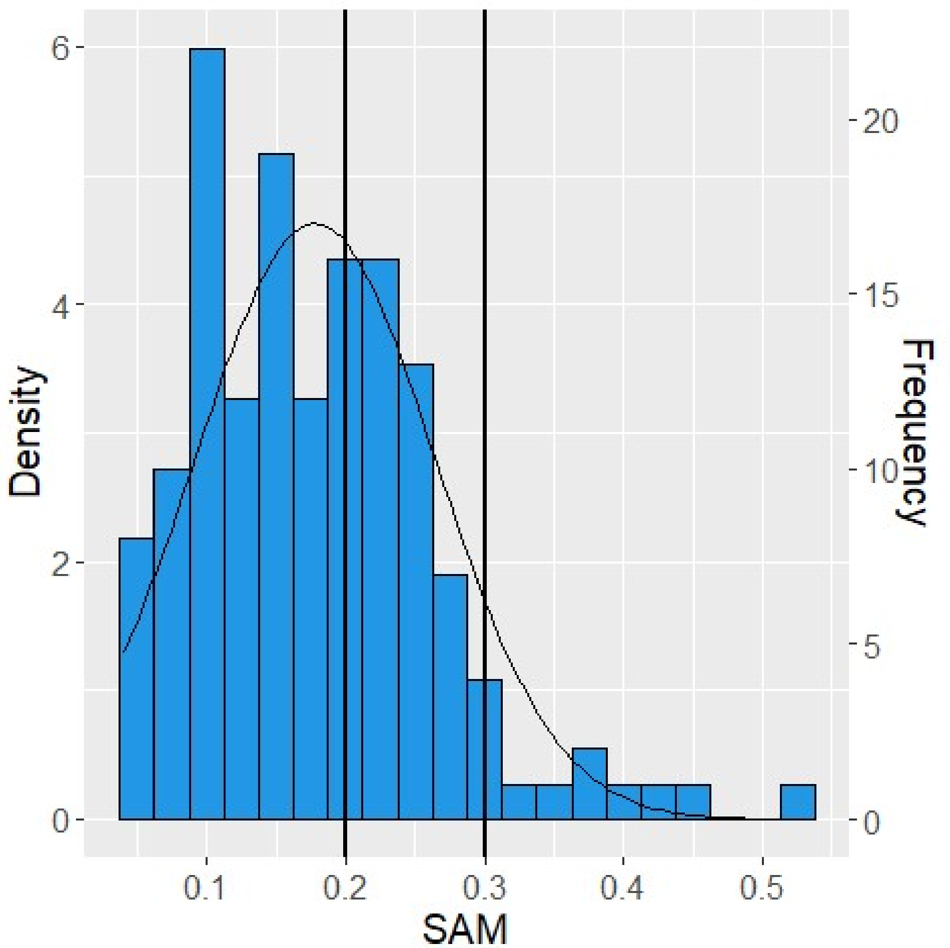

Figure 51. SAM histogram for all New York projects

When comparing the histograms in Figures 50 and 51, the values in Figure 51 are located more to the left, indicating lower SAM numbers. The average SAM number in Figure 51 is 0.18, and it was required that mixtures be designed to have a SAM number less than 0.20 on average. This is important because only 5% of the data in Figure 51 have SAM numbers above 0.30.

Figure 52 shows the difference in the air content as determined by the Type B air meter and the SAM. The difference between the air content from the Type B air meter and the SAM was on average 0.1%, with a standard deviation of 0.58%. The published standard deviation between the two is 0.29%. The reasons for the higher standard deviation in these measurements could be differences in calibration between the meters or the fact that the tests were performed in different locations. Previous laboratory and field studies have shown that the Type B meter and the SAM give nearly equivalent air contents and lower standard deviations than what is shown in this work.

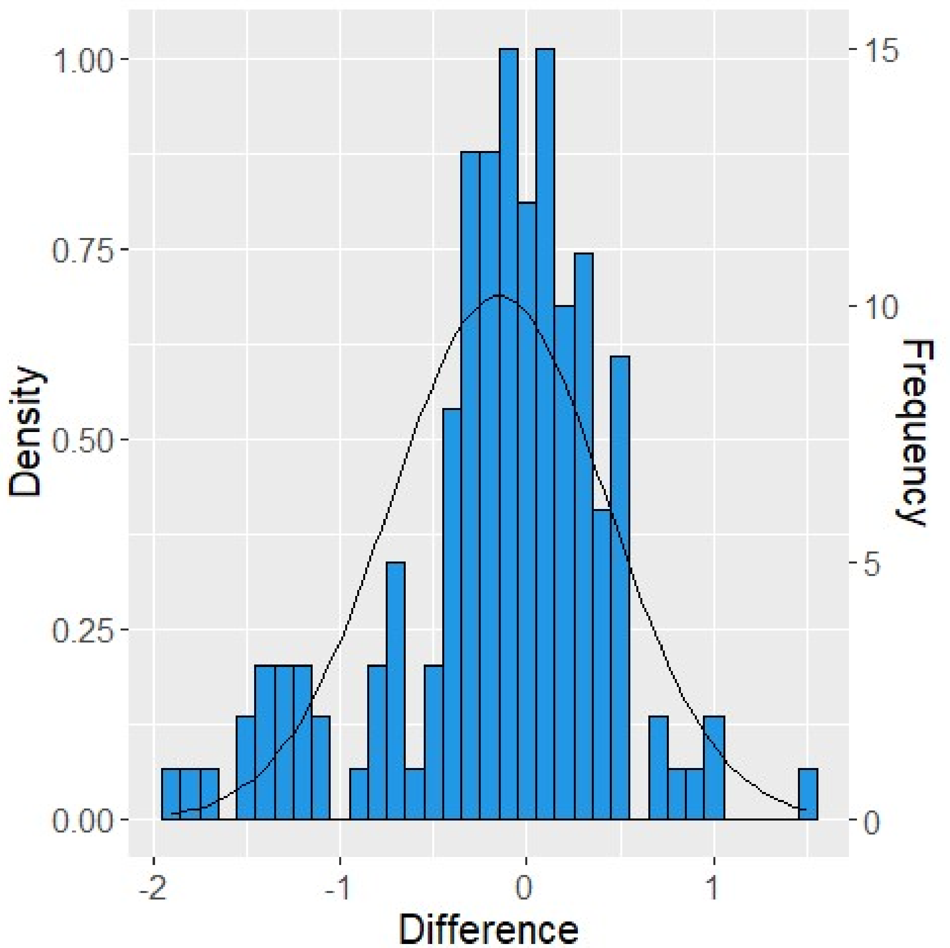

Figure 52. Difference between SAM_Air and Air_Content measured with Type B meter

Hardened Properties – Hardened Air Relationships

The following figures represent data from hardened concrete testing. Figure 53 shows relationships between air content as determined from hardened testing (Hard_Air), the Type B meter (Fresh_Air), and the SAM (SAM_Air). Figure 54 shows the relationship between Fresh_Air and Hard_Air. The y-axis in Figures 53 and 54 is air content, while the x-axis is the observations.

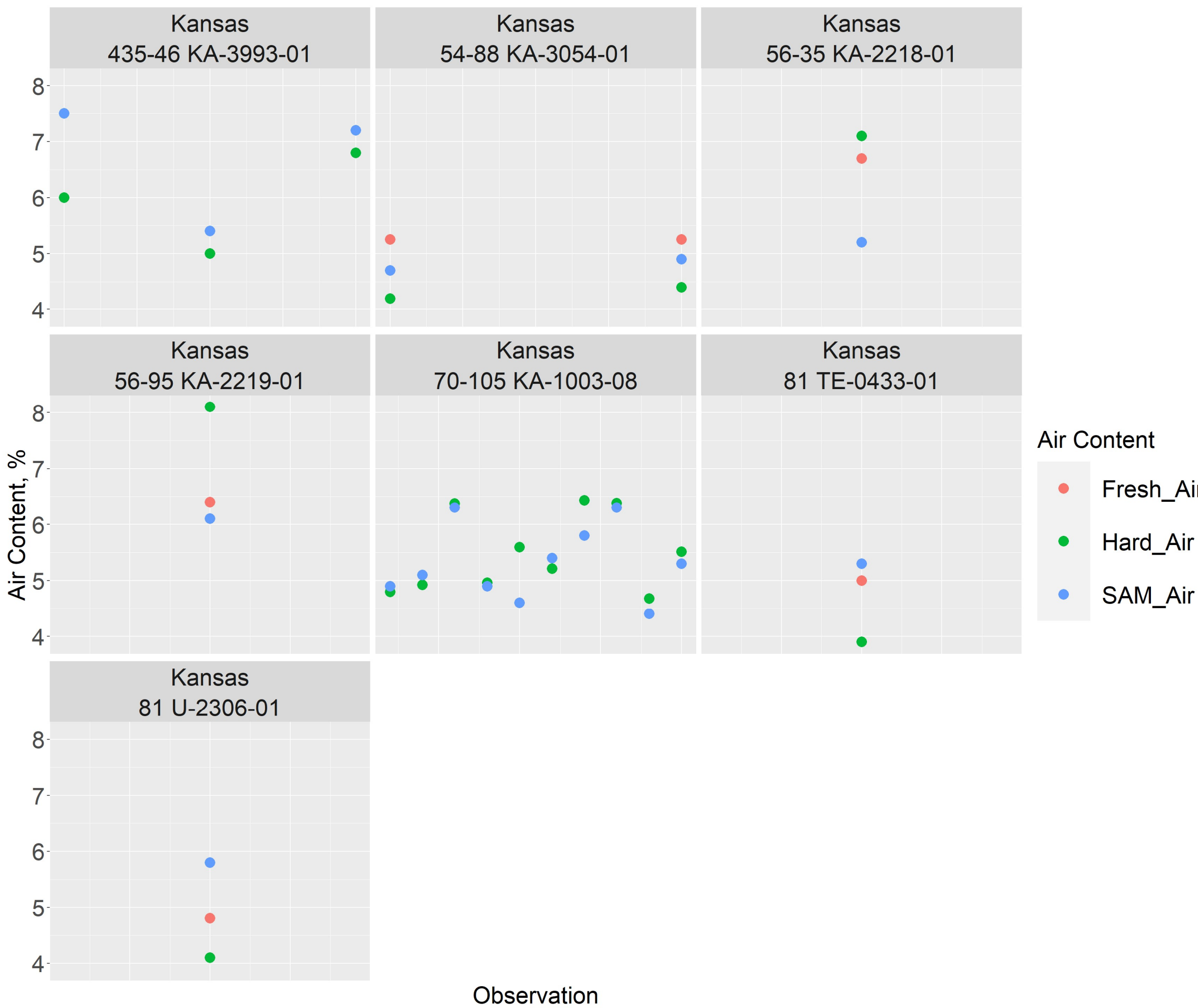

Figure 53. Fresh air, hardened air, and SAM air

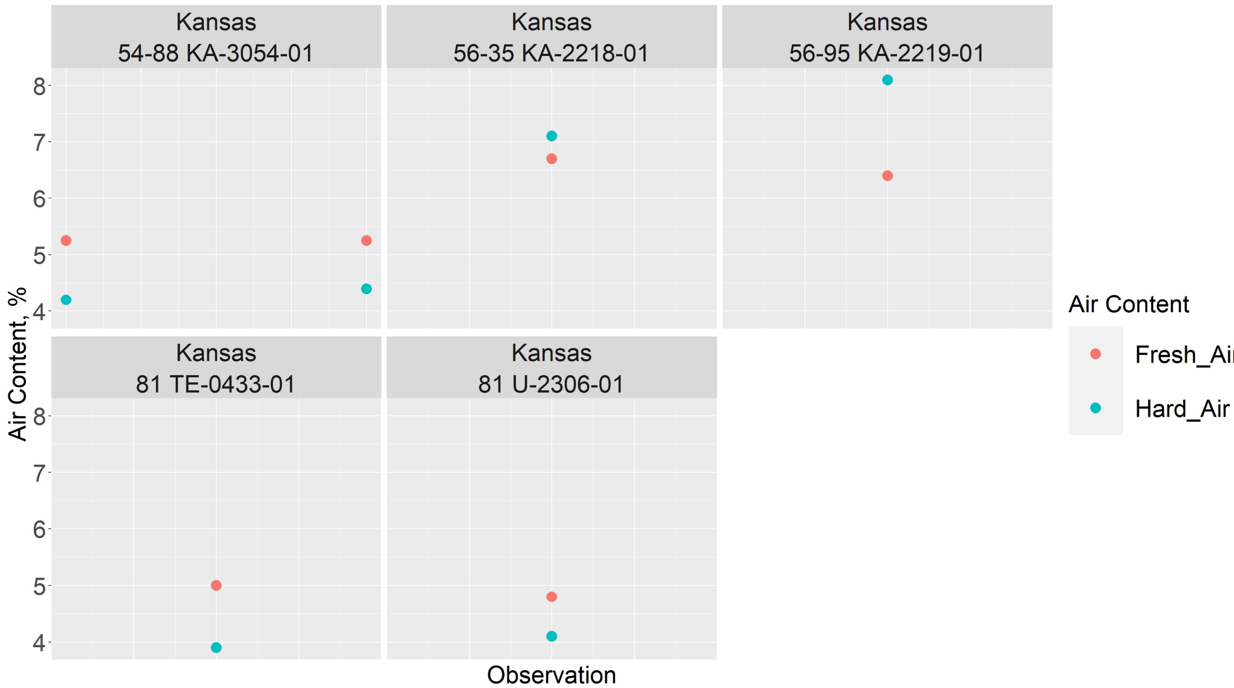

Figure 17. Fresh and hardened air content

One finding from the data review process was that if more data were provided, more plots could be developed with relationships similar to those in Figure 53.

Figure 55 shows the relationship between the SAM and hardened air, with the y-axis showing SAM number.

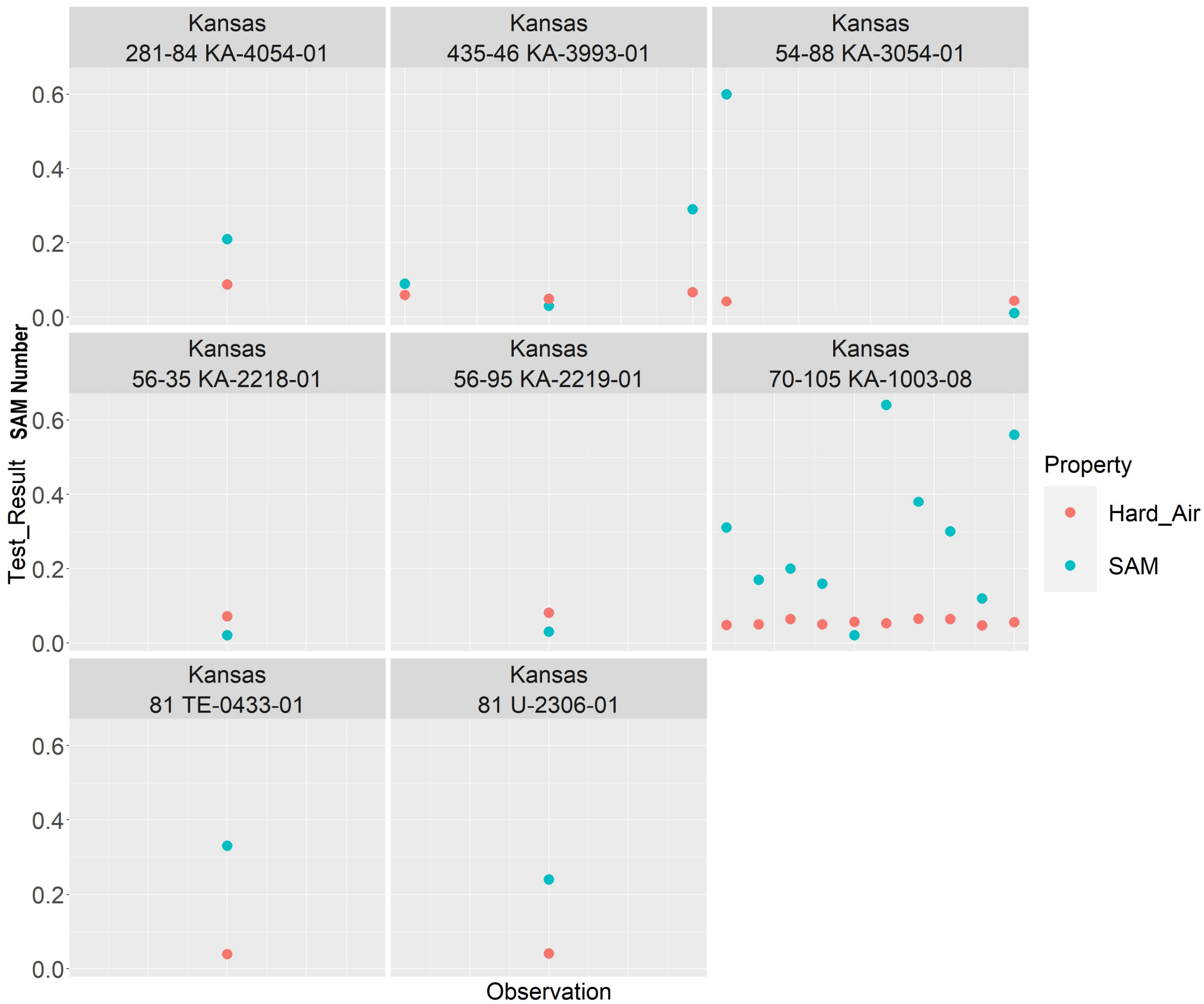

Figure 55. Hardened air and SAM

Figure 56 shows the relationship between the SAM and hardened air, with the y-axis showing units of inches.

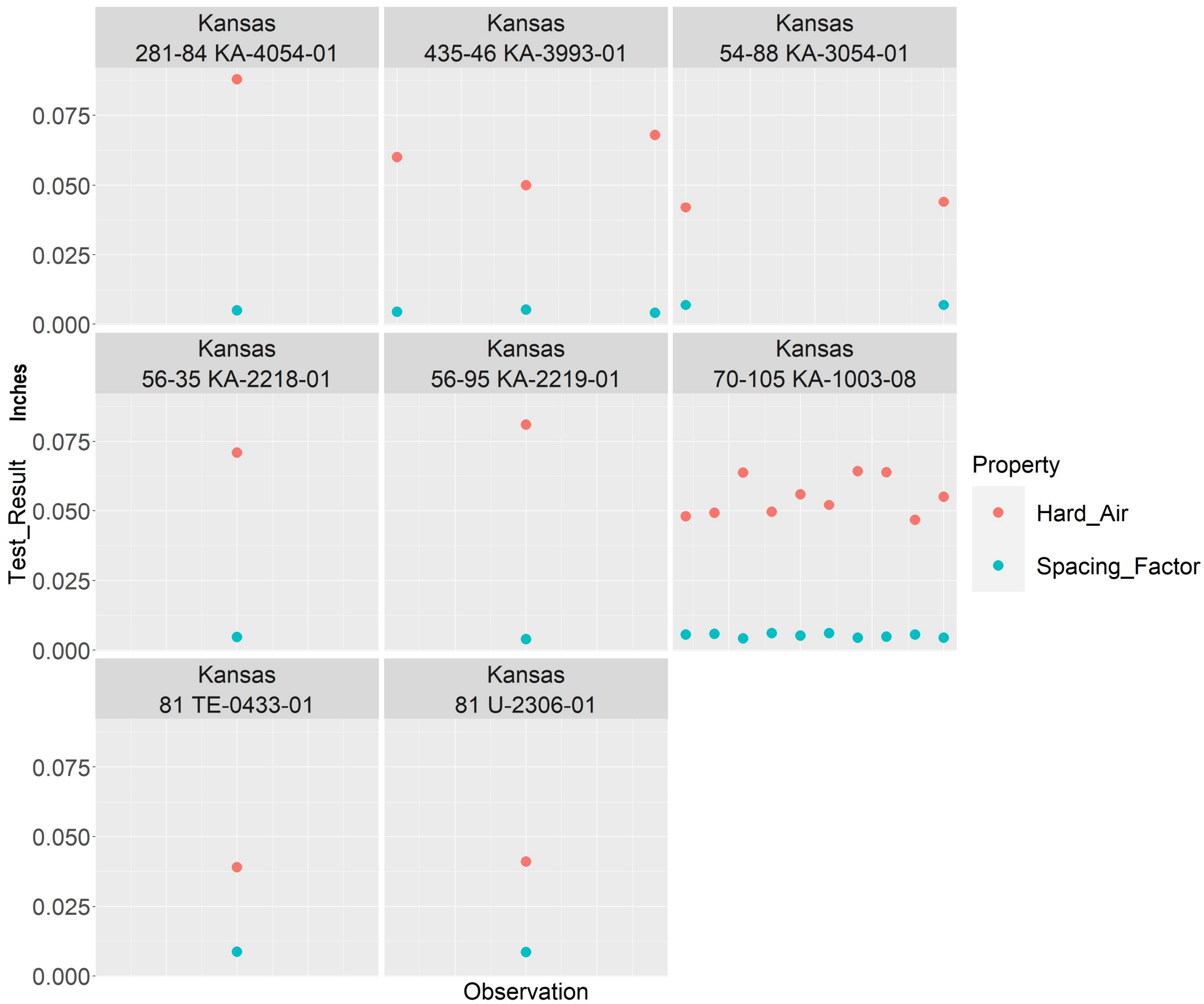

Figure 56. Hardened air and spacing factor

Figure 57 shows a scatter plot of hardened air results, and Figure 58 shows hardened air results based on various projects.

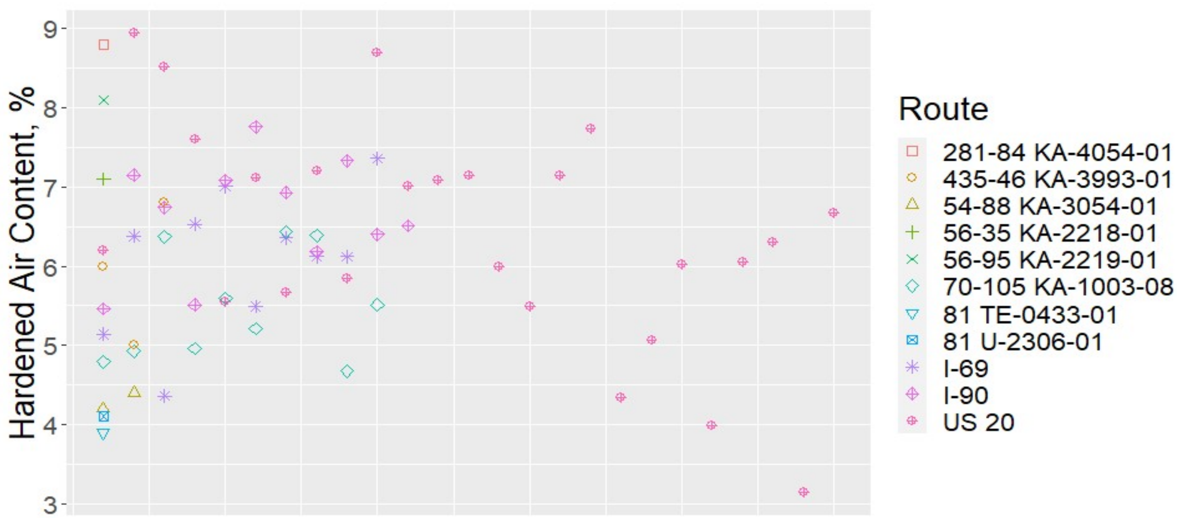

Figure 57. Scatter data for hardened air content

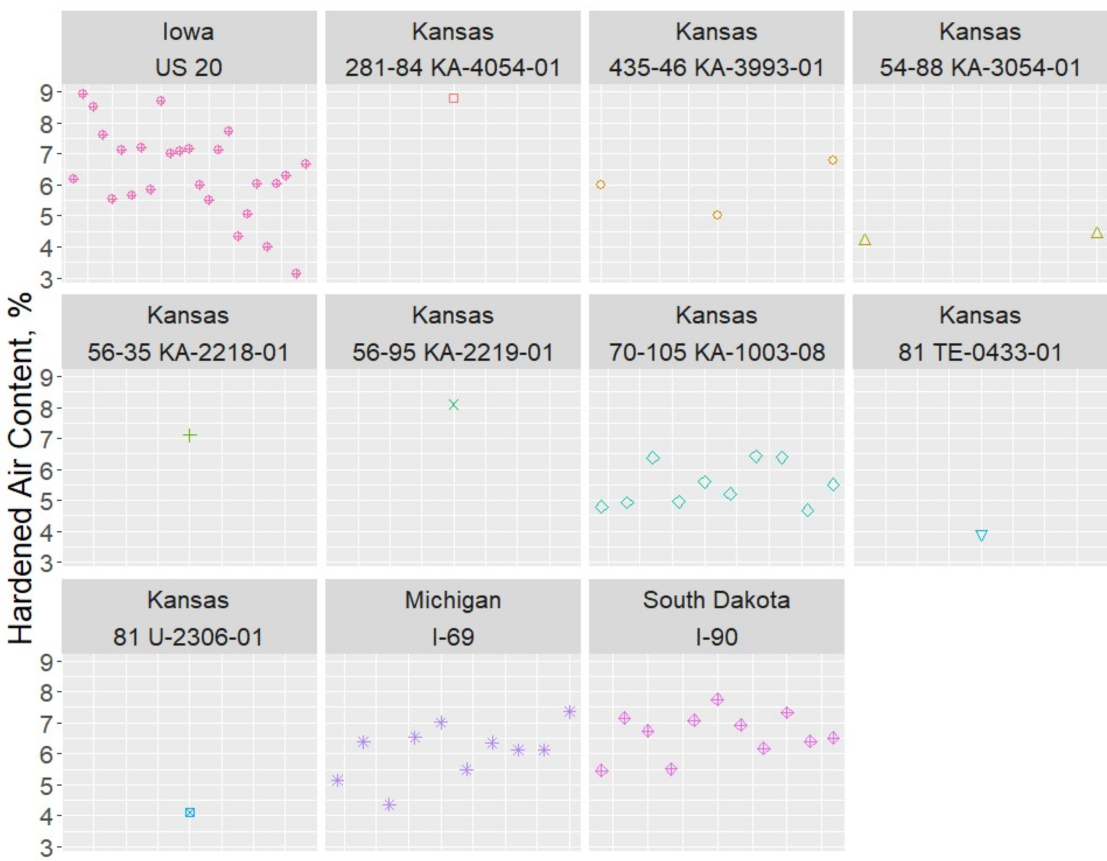

Figure 58. Hardened air content for various locations

Figure 59 shows box and whisker plots for hardened air on various projects.

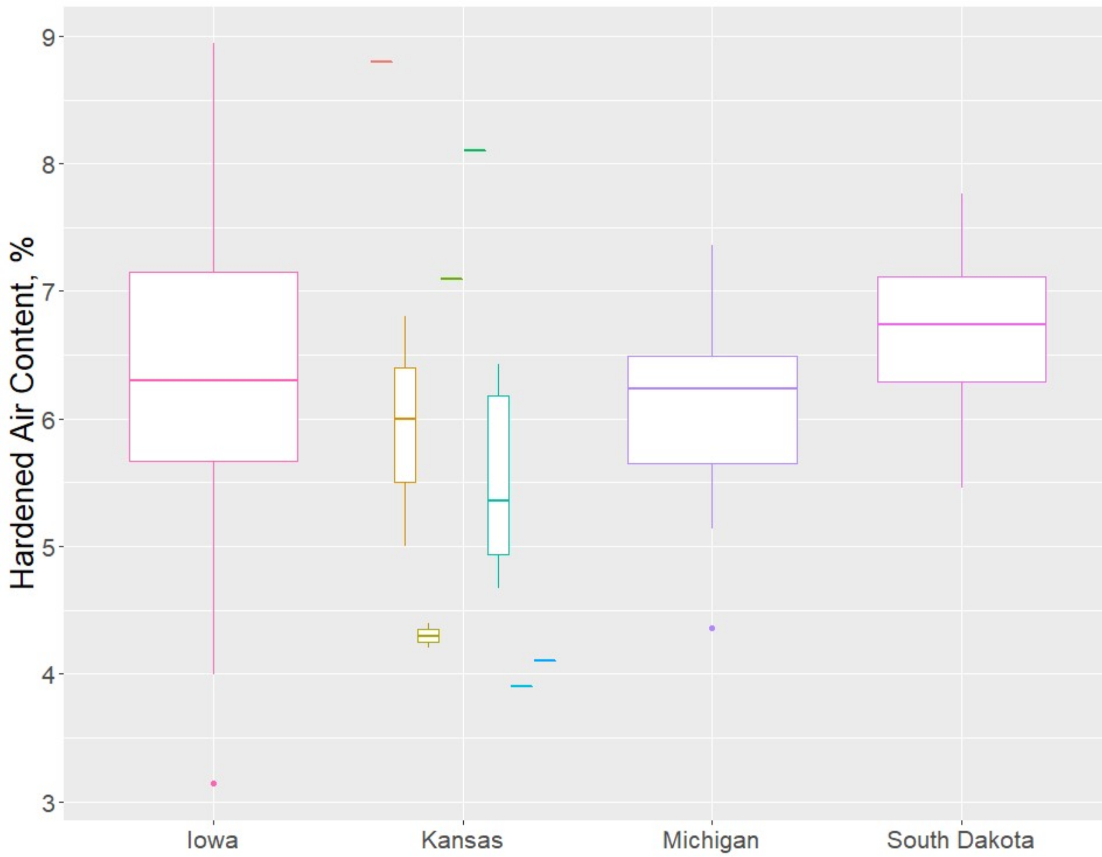

Figure 59. Box and whisker data for hardened air for various locations

Hardened Properties – Compressive and Flexural Strength Plots

Figure 60 shows 7-day, 28-day, and 56-day compressive strength results for various locations. The x-axis is the casting date.

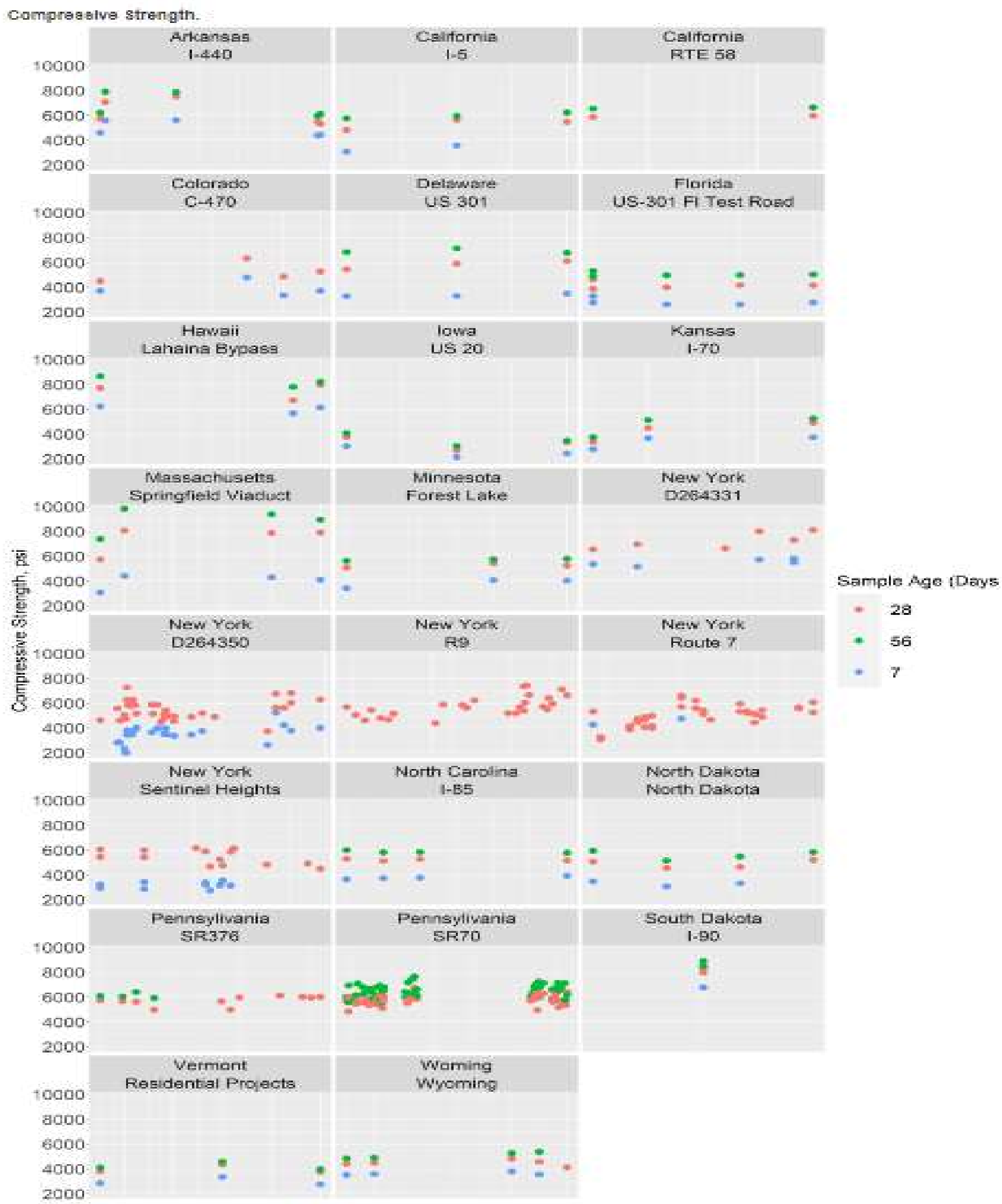

Figure 60. Compressive strength for various locations

Figure 61 shows 28-day flexural strength values for a few projects, while Figure 62 shows a scatter plot of compressive strength values at various days for bridge projects (left) and pavement projects (right). Figure 63 shows the same data separated for various projects.

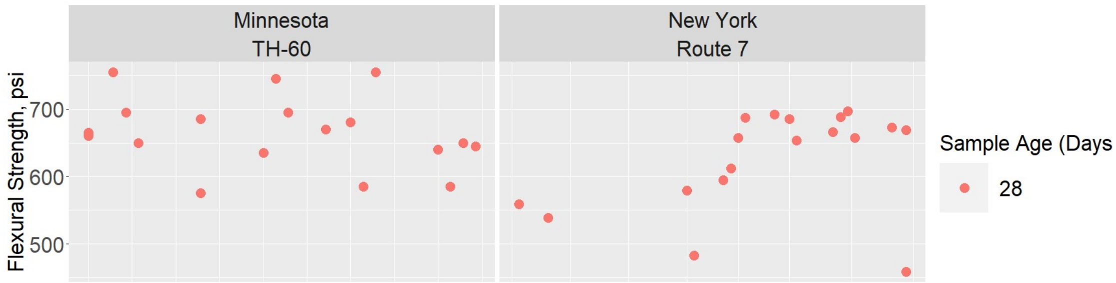

Figure 61. Flexural strength for various locations

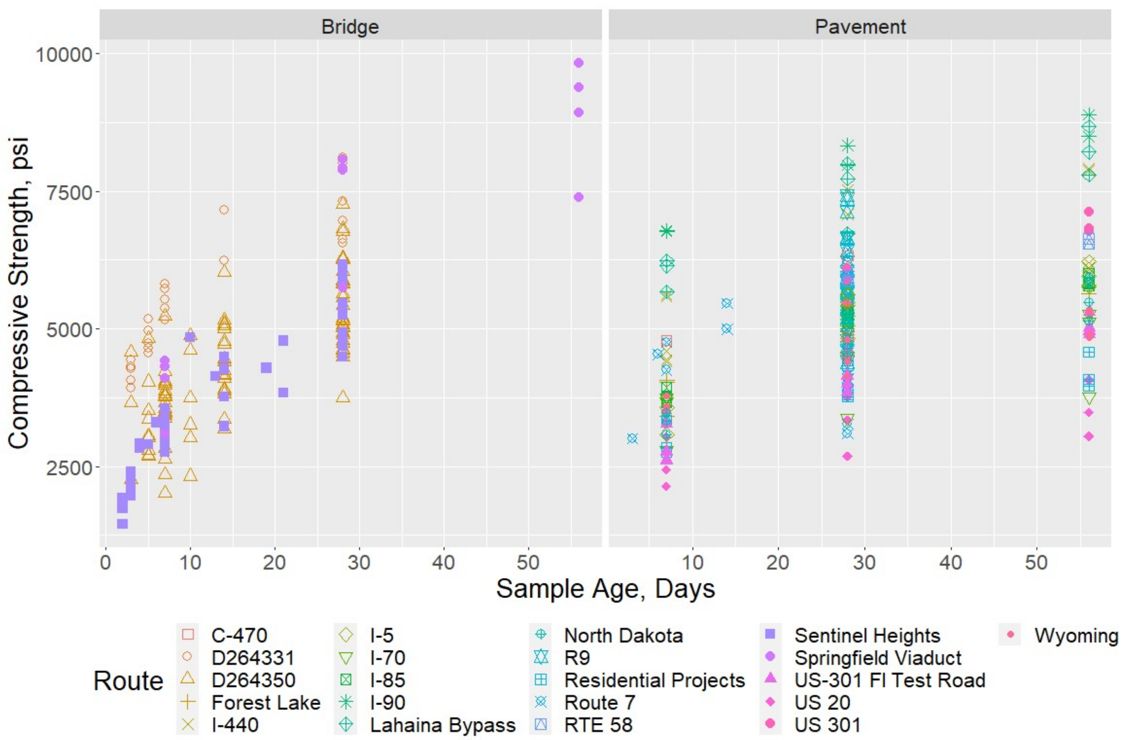

Figure 62. Scatter data for compressive strength for bridges (left) and pavements (right)

Figure 63. Compressive strength data for pavements at various locations

Figure 64 shows flexural strength scatter data versus sample age in days for a few projects, while Figure 65 shows the same data separated into two graphs.

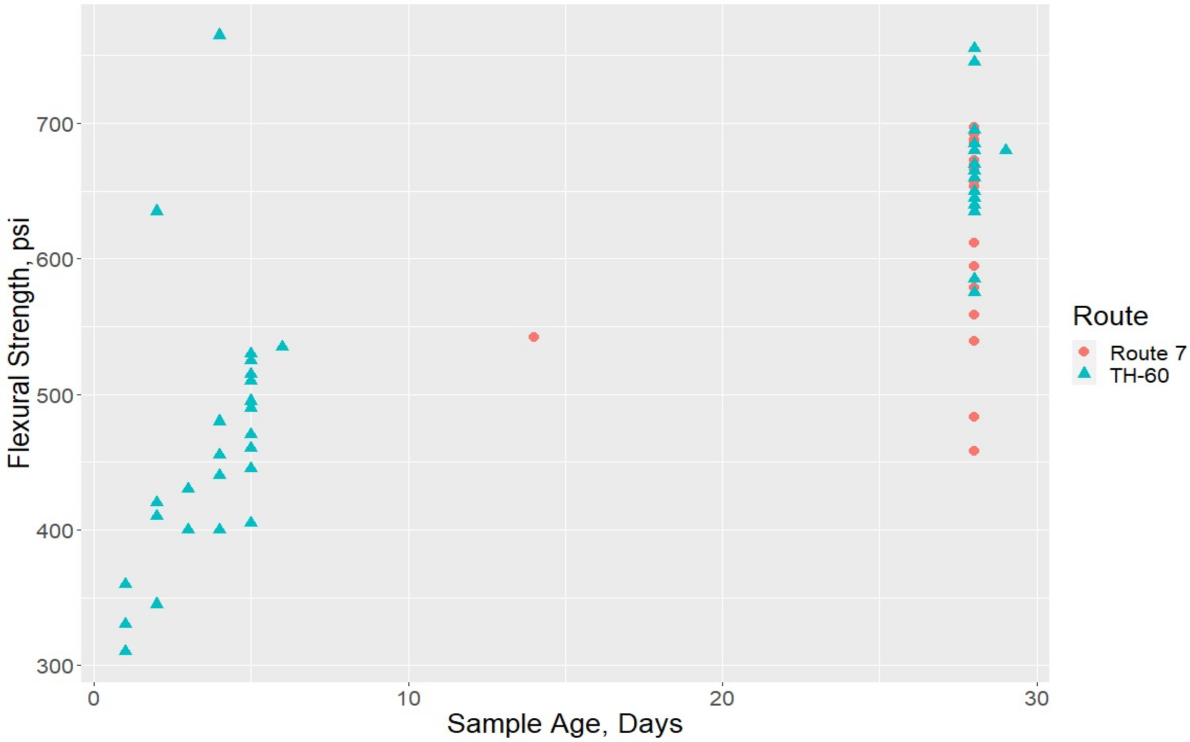

Figure 64. Flexural strength data for pavements

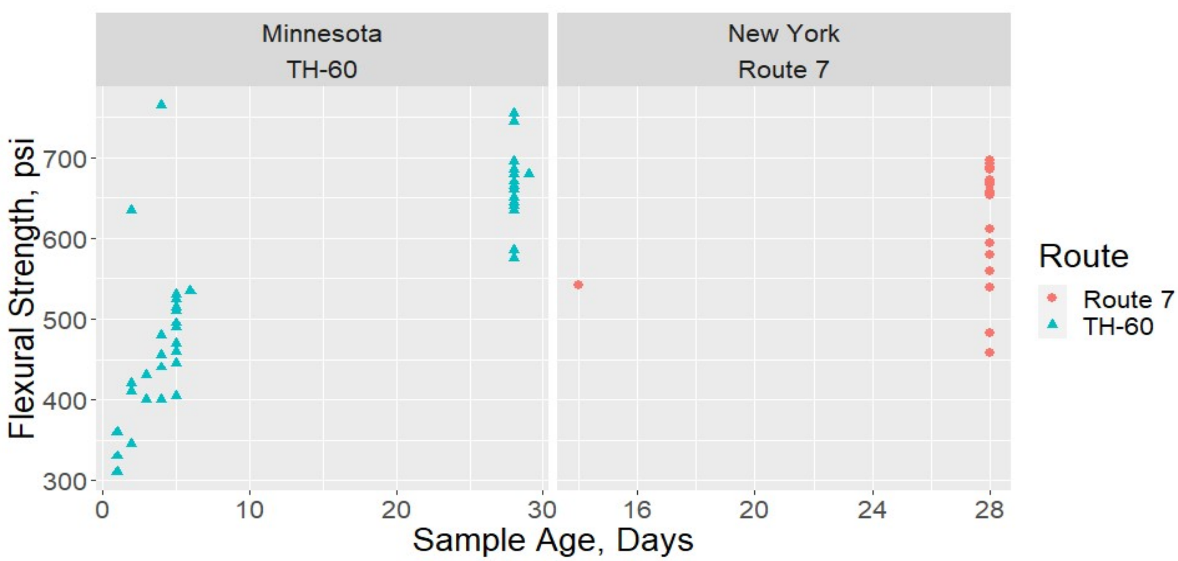

Figure 65. Flexural strength data for pavements at various locations

Figure 66 shows scatter data for resistivity versus compressive strength, with the y-axis having units of kOhm-cm. While one would expect that higher strength is consistent with higher resistivity, adding cement to a mixture does not inherently increase durability, and in many instances doing so may have the opposite result.

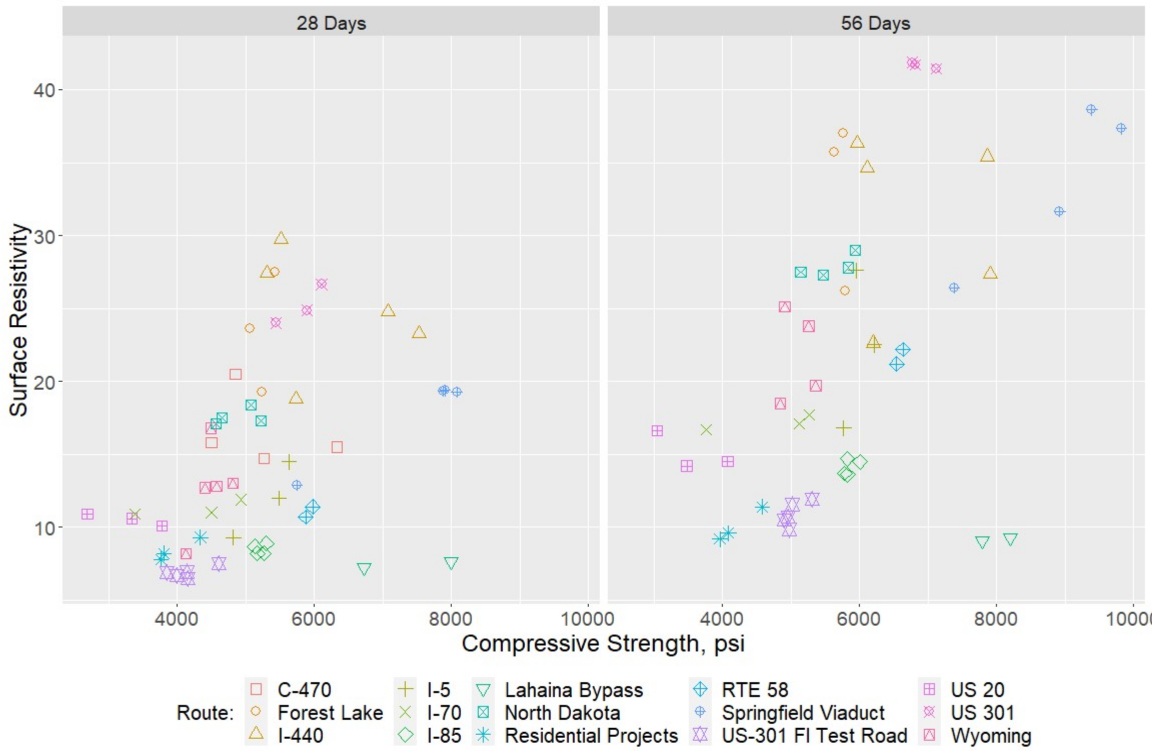

Figure 66. Scatter data for surface resistivity versus compressive strength

Hardened Properties – Formation Factor and Surface Resistivity Plots

Figure 67 shows the formation factor versus sample age in days. Although the data show a general increase in formation factor from left to right over time, the last three data points indicate potential erroneous test results.

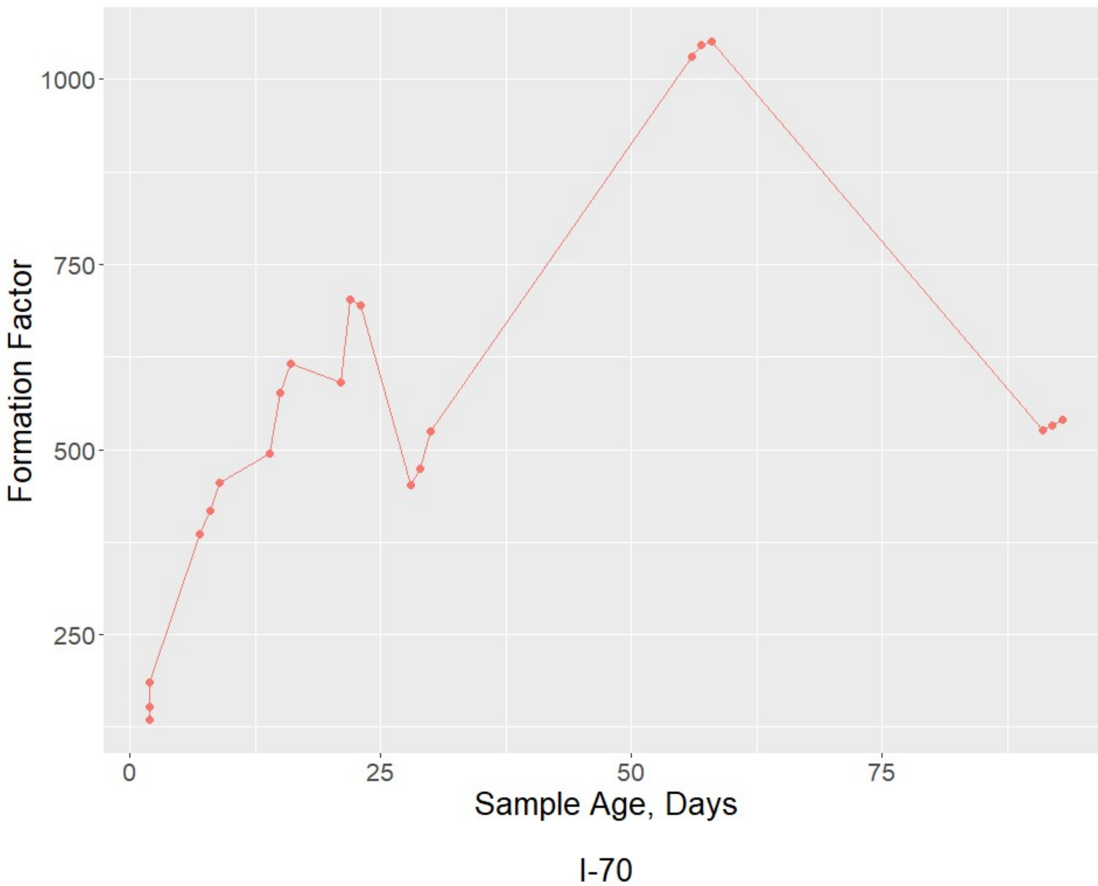

Figure 67. Formation factor versus age

Figure 68 shows the same data as Figure 66 separated into various projects. One conclusion that can be drawn is that the data from samples that underwent lime water conditioning exhibit higher variability than data from samples conditioned by other methods.

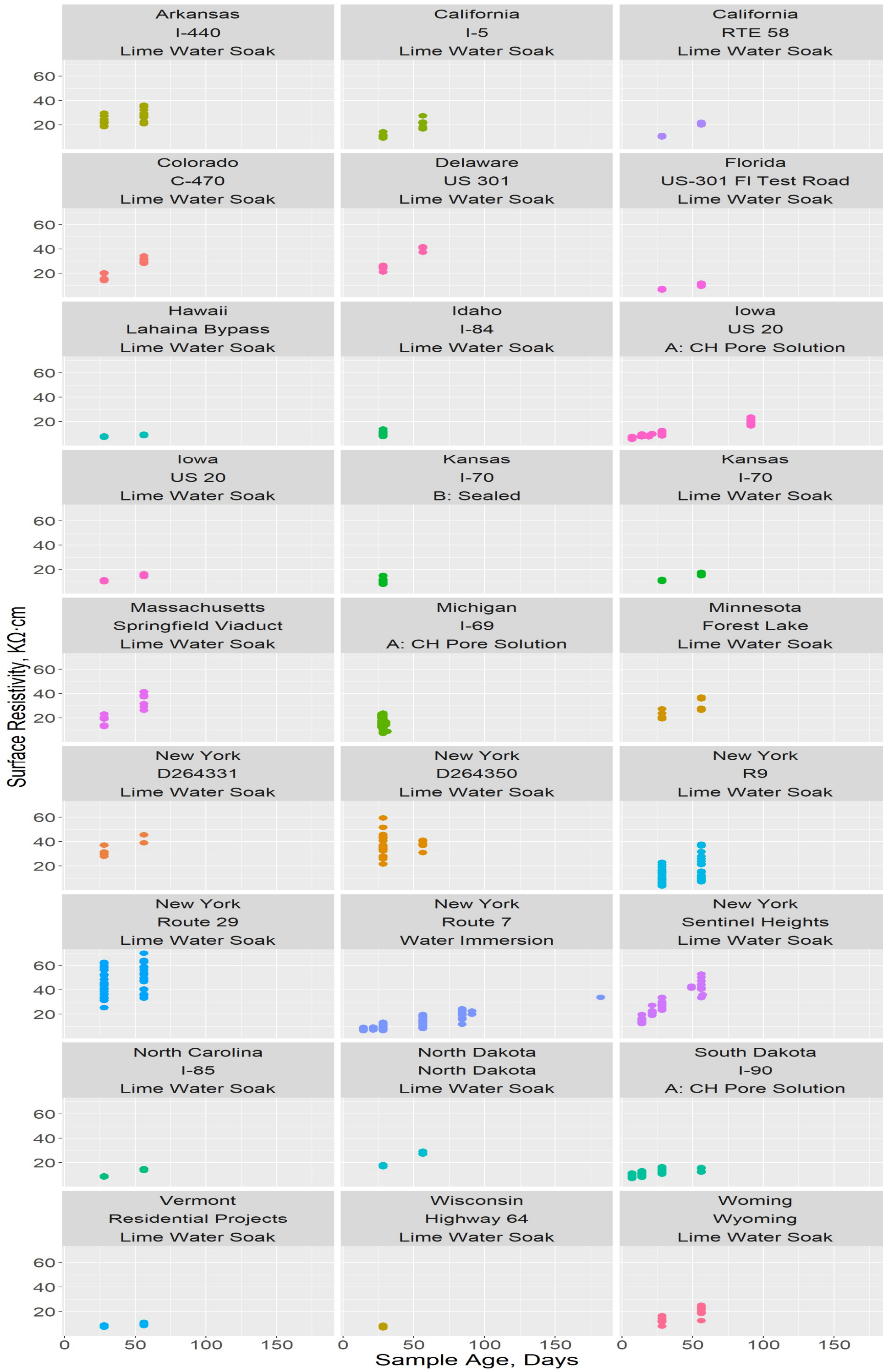

Figure 68. Surface resistivity versus age for various locations

Figure 69 shows resistivity data based on various conditioning methods. Again, it is evident that samples conditioned with lime water show a higher variability in the resistivity results.

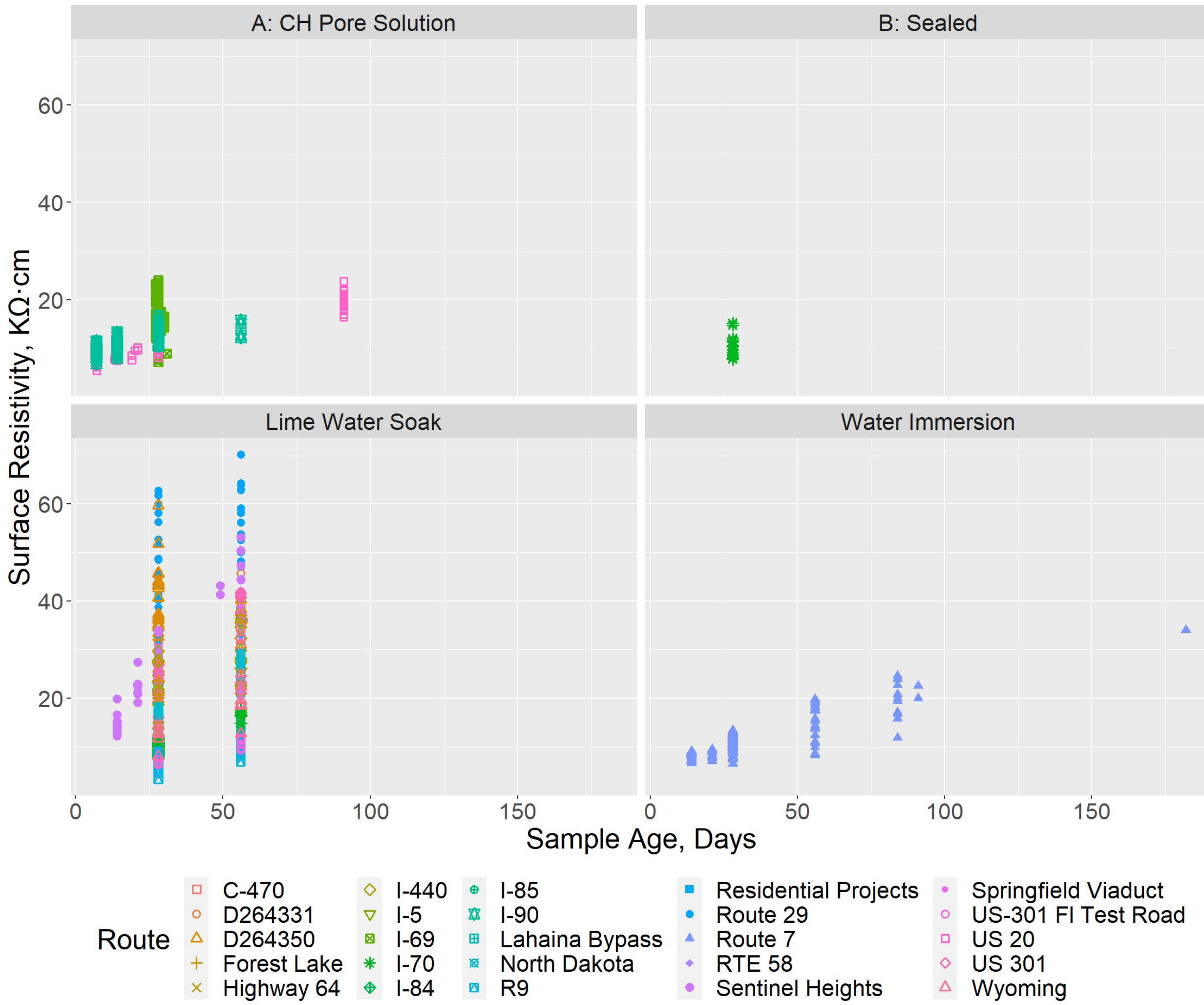

Figure 69. Surface resistivity versus age by various conditioning methods

Figure 70 shows box and whisker plots for the resistivity of samples conditioned by various methods.

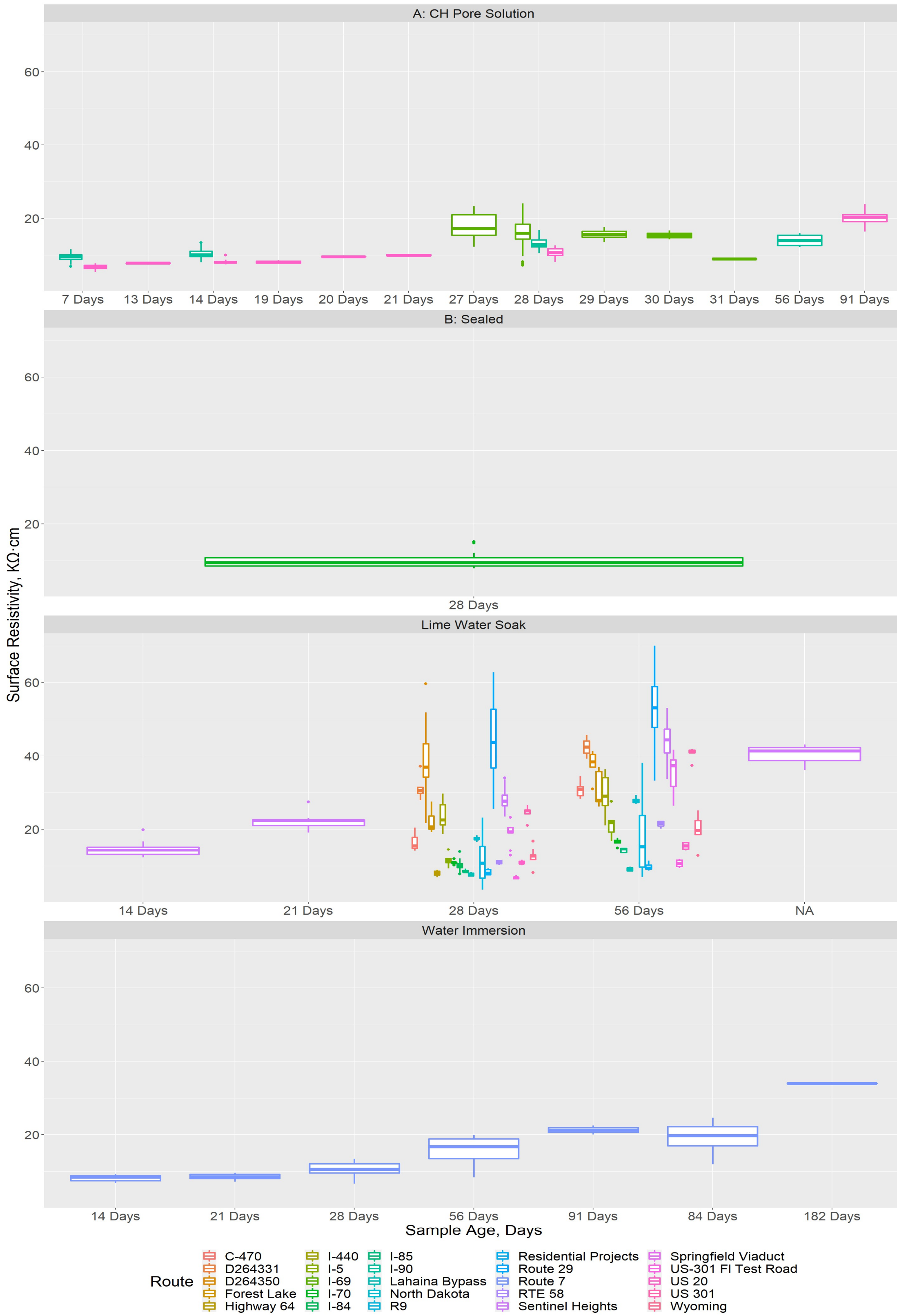

Figure 70. Box and whisker data for surface resistivity versus age for various conditioning methods

Figure 71 shows box and whisker plots for the resistivity of samples conditioned by various methods for various projects.

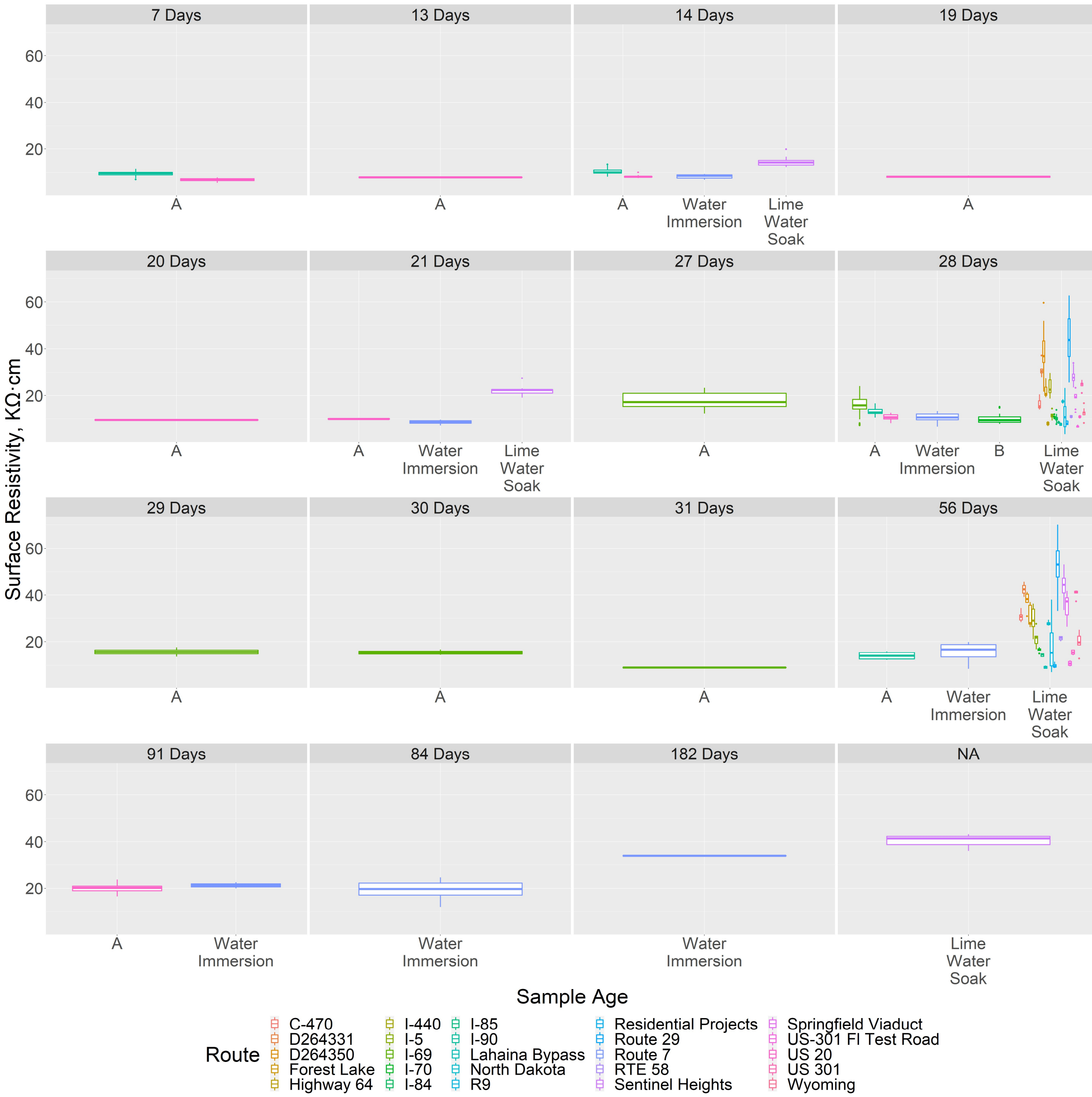

Figure 71. Box and whisker data for surface resistivity versus conditioning method at various ages

Figure 72 shows line plots for resistivity based on various conditioning methods. The data for the samples conditioned in lime water show high variability.

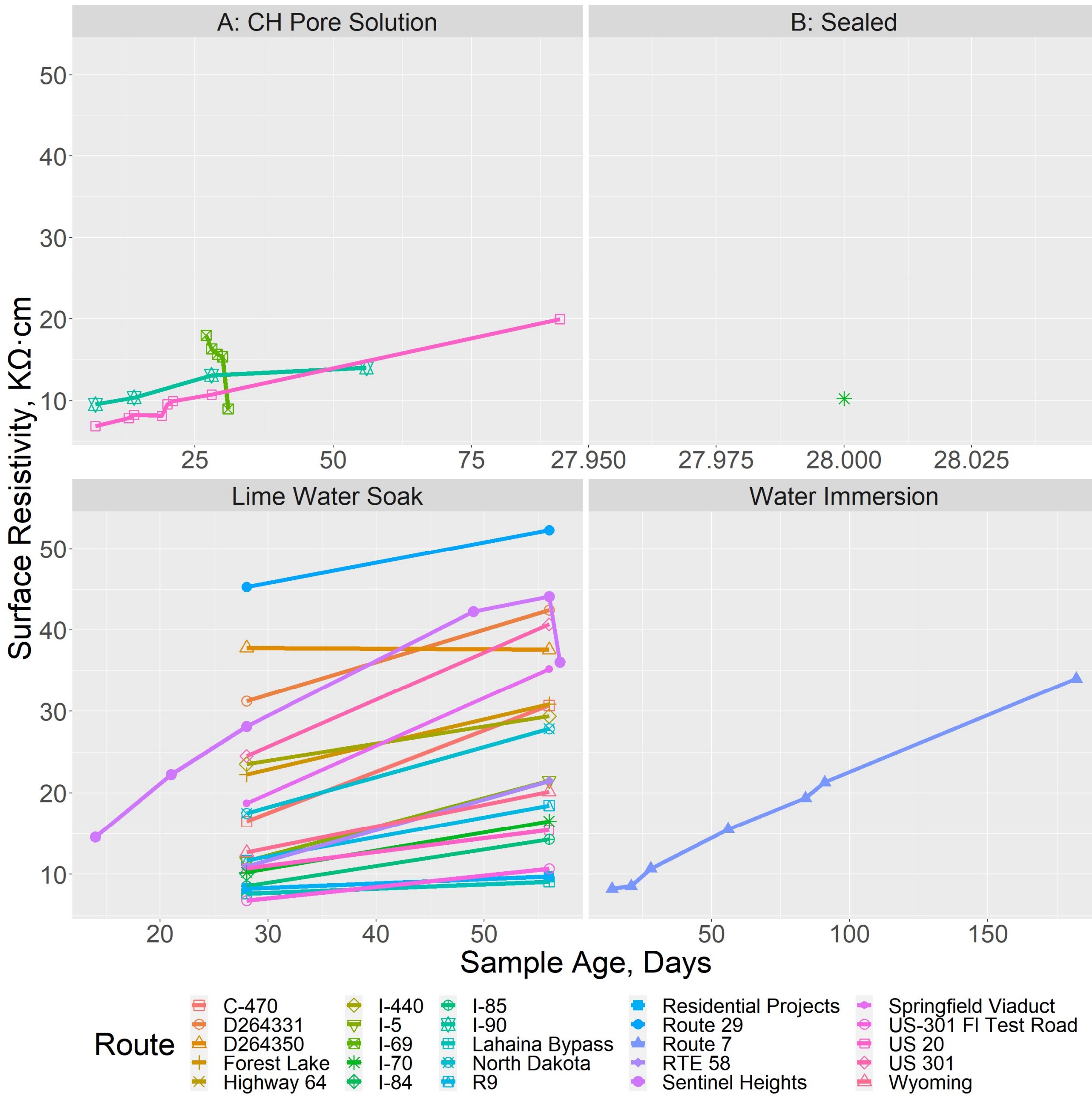

Figure 72. Surface resistivity versus age line data for various conditioning methods

Figure 73 shows the relationship between 56-day resistivity and w/cm ratio. The trendline shows that as the w/cm increases, the resistivity decreases.

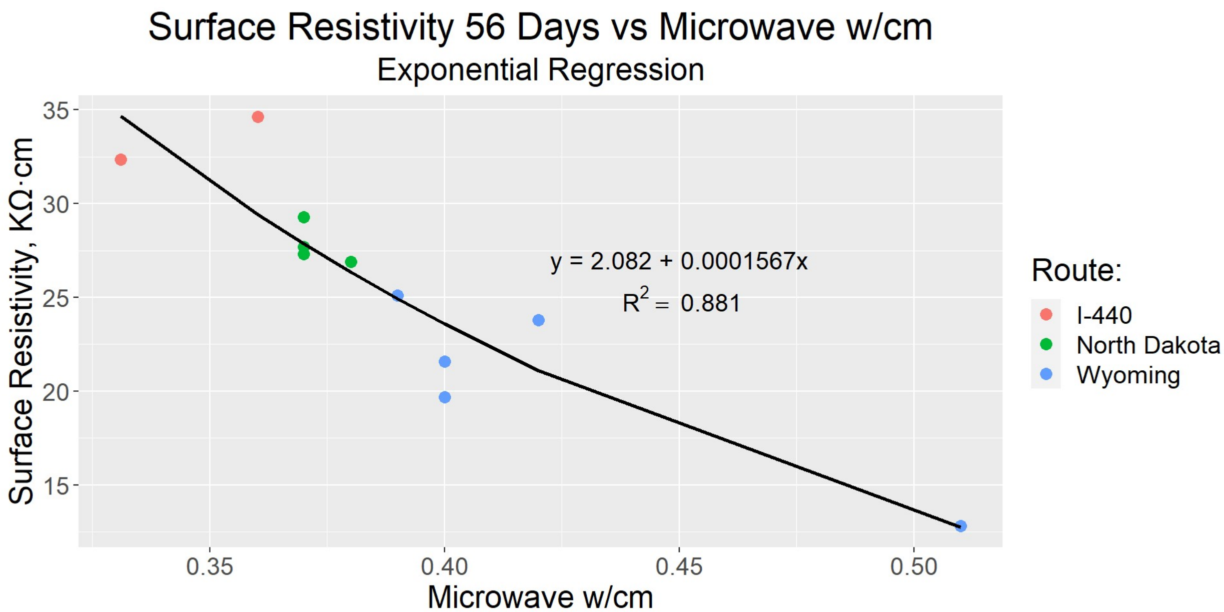

Figure 73. Surface resistivity versus microwave w/cm ratio

Table 16. Fresh properties test count

Number of Projects	40
Air content	37
AVA spacing factor	15
AVA specific surface	11
Box Test	2
Concrete temperature	34
Microwave w/cm ratio	6
Phoenix w/cm ratio	1
SAM	40
SAM air content	32
Slump	35
Unit weight	31
VKelly	2

Table 17. Hardened properties test count

Number of Projects	27
Coefficient of thermal expansion	9
Compressive strength	21
Flexural strength	2
Formation factor	1
F-T durability	1
Hardened air content	1
Maturity meter	1
Resist chloride ion penetration (RCP)	4
Spacing factor	2
Specific surface	1
SR at RCPT age	3
SR sample prep Option A	3
SR sample prep Option B	1
SR sample prep water immersion	2
SR sample prep lime water soak	22