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DETERMINATION OF IN-SITU COMPRESSIVE STRENGTH OF PRECAST CONCRETE GIRDERS

Final Report

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Abstract

Verification of field compressive strength of precast concrete girders from 52 bridges in seven counties in California are presented. Non-destructive Testing (NDT) methods used are Proceq's Silver Schmidt Rebound Hammer and Ultrasonic Pulse Velocity (UPV) and James Instruments' Windsor Pin and Windsor Probe Systems. NDT tests were performed on concrete walls, slabs, and cylinders constructed under ambient and laboratory curing conditions at San Jose State University. Data from the laboratory testing in combination with data supplied by the manufacturer of the NDT equipment were utilized to develop strength prediction charts for the different bridge girders. Concrete cores from five selected bridges were taken, and compressive strength and NDT tests were performed and analyzed. Results obtained from the cores with the bridge prediction data were compared to verify accuracy of the predictions. The American Concrete Institute (ACI) 209 equation was utilized, and modified equations are proposed for more accurate bridge strength predictions.

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1.0 Problem Statement

Caltrans is seeking a way to verify field compressive strength of precast concrete girders from several bridges in the state of California. In-situ data will be used to obtain reliable estimates of concrete strengths needed to increase capacity recognition. Non-destructive Testing (NDT) methods and field core specimens will be utilized to evaluate the strength of the girders. Additionally, seismic/strengthening upgrades on bridges can be assessed more accurately with the field-testing data.

2.0 Executive Summary

This report summarizes tasks completed for the project “Determination of In-situ Compressive Strength of Precast Concrete Girders,” for the period 03/01/2016 to 12/31/2017.

52 bridges in seven counties in the state of California were selected in consultation with Caltrans. NDT methods were performed on the bridges, utilizing Proceq’s Silver Schmidt Rebound Hammer, Proceq’s Ultrasonic Pulse Velocity (UPV), James Instruments’ Windsor Pin Penetration System, and James Instruments’ Windsor Probe System to determine their compressive strength.

Concrete cylinders (6x12 in.), slabs (24x18x4 in. and 24x18x8 in.), and retaining walls (9 ft wide x 6 ft height x 8 in. thickness) were constructed at San Jose State University to calibrate the NDT equipment. The data collected from all the laboratory testing in combination with data supplied by the manufacturer of the NDT equipment were utilized to develop strength prediction charts for the different bridge girders. The specimens were cured under three different environments: engineering courtyard at ambient temperature, engineering structural laboratory at a controlled temperature of 71°F, and the concrete laboratory curing chamber at 71°F, and 100% relative humidity (RH). The specimens were periodically tested up to 180 days using the Silver Schmidt Rebound Hammer, UPV, Windsor Pin Penetration, and Windsor Probe to determine their compressive strength. Concrete cylinders (4x8 in. and 6x12 in.) and cores (3.75x8 in.) taken from concrete slabs were tested for their compressive strength.

Concrete cores from five selected bridges in Santa Clara County and San Bernardino County were taken, and compressive strength and NDT tests were performed and analyzed. Results obtained from the cores with the bridge prediction data were compared to verify accuracy of the predictions. The ACI 209 equation was utilized to check the accuracy of the strength predictions. Modifications to the ACI 209 equation are proposed for more accurate bridge strength predictions.

3.0 Literature Review

3.1 Ultrasonic Pulse Velocity Test

The UPV involves the measure of travel time of an ultrasonic pulse to pass through a known distance of concrete. This method is applied to determine the relative condition of concrete based on measured pulse velocity.

Unruh [1] states that there is currently no reliable nondestructive method for determining the strength of concrete. However, ultrasonic pulse velocity and rebound hammer are two methods that shown to be promising in estimating compressive strength.

Although the UPV test measures critical characteristics over the service life of a structure, there are a number of factors and conditions that can affect the accuracy of the results. The paper by Lorenzi [2] suggests the use of artificial neural networks as an easier, more accurate method of estimating concrete characteristics, density and compressive strength.

Trtnik [3] states that although the UPV method is used to assess concrete properties, it is very difficult to accurately evaluate the concrete compressive strength with this method since the ultrasonic pulse velocity values are affected by a number of factors, which do not necessarily influence the concrete compressive strength in the same way or to the same extent. These factors include the influence of aggregate, initial concrete temperature, type of cement, environmental temperature, and water to cement ratio. Artificial neural network modeling the velocity-strength relationship provides a more reliable estimate of the compressive strength of concrete by using only the ultrasonic pulse velocity value and some mix parameters of concrete.

Impact echo and ultrasonic pulse velocity tests were performed in investigating quality assurance of the repair done on an I-beam bridge girder on a concrete bridge located east of Interstate 70, east of Denver, Colorado. Promboon [4] preliminarily used impact echo to detect internal cracks at each test point. Then, once an internal crack was detected, the ultrasonic pulse velocity test with angular paths were performed to provide more information on the location and extent of the unfilled cracks. With a combination of both methods, concrete conditions can be rated on a more precise and accurate level, with more confidence.

Compressive strength cannot be assessed solely from the performance of the ultrasonic pulse velocity test due to the fact that too many factors affect the ultrasonic pulse velocity measurement. Some of these factors include moisture content, temperature of concrete, path length, shape and size of specimen, and effect of reinforcing bars. Combining the use of rebound hammer and the ultrasonic pulse velocity method can better predict the compressive strength of concrete [5].

In a study by Huang [6], when combining the rebound hammer and the ultrasonic pulse velocity methods, regression models are used to predict the compressive strength of the concrete. However, the available regression models are not sufficiently valid due to the limited range of data used for their calibration. This paper proposes a probabilistic multivariable linear regression

model to predict the compressive strength using the measurements obtained from the combination of both methods and additional concrete properties.

In a study by Lin [7], the ultrasonic pulse velocity measurement and compressive strength tests were carried out at the concrete age of 1, 3, 7, 14, and 28 days for concrete specimens with different water-cement ratios and coarse aggregate content by weight. A clear relationship curve was drawn, verifying that it is suitable to predict concrete strength from the ultrasonic pulse velocity values.

3.2 Pull-out Test

The pull out test is based on the principle that the force required to pull out a cone of steel embedded in concrete is proportional to the strength of concrete.

As a result of much research throughout the past 30 years by many countries, such as Russia, the US, Canada and Denmark, it was discovered that there is a linear relationship between the pullout force and the compressive strength. Because of its usefulness, many countries have standardized the pullout test [8].

Various NDT tests were investigated to determine the best method to give the compressive strength of cores. The highest degree of correlation is for the pullout test followed by that for the CAPO (cut and pullout) test and rebound test, probe penetration test, and pulse velocity test [9].

The paper by Bishr [10] reports the results of a study carried out to estimate the accuracy and reliability of the pullout test for assessment of the in-situ compressive strength of concrete made with three water-cement ratios, two cement contents and two different types of aggregates. The compressive strength of both cast and cored cylindrical specimens was statistically correlated with the pullout force. It can be concluded that the linear relationship between the compressive strength and the pullout force was very significant and totally independent of the mixture design variables. There is a high potential of the pullout test to determine the compressive strength of concrete with a high degree of reliability.

3.3 Silver Schmidt Rebound Hammer Test

The Silver Schmidt Rebound Hammer Test involves a rebound hammer being pressed against the surface of a concrete structure. Thereafter, the hammer will read back the rebound number or index along a graduated scale, which assesses the surface hardness. The surface hardness is correlated with the compressive strength of the concrete. This correlation can be displayed graphically.

From studies undertaken in Australia and Scotland, it would appear that the combination of performing both the rebound hammer and ultrasonic pulse velocities tests, the confidence in estimating the strength of in-situ concrete is much higher [11].

The experimental investigation by Jaggerwal [12] showed that a good co-relation exists between compressive strength and rebound numbers/ index. As long as non-destructive testing is

performed periodically and consistently on the same girder of a bridge, the confidence level of the compressive strength of that structure is much higher. A combination of multiple non-destructive tests helps further assess the strength and durability. The results of this experiment verified that there is a strong co-relation between compressive strength and the rebound hammer. Nevertheless, rebound hammer could be used alone to determine the compressive strength of the structures.

The nondestructive tests, rebound hammer, pulse velocity and core tests, were compared by Henao [13] in terms of correction factors for estimating compressive strength and the effect of variables, such as casting direction, sample location, core diameter, core moisture conditions, concrete strength, and congested reinforcement. The findings revealed significant differences in the way some of these variables and correction factors for estimating strength affect the strength measurements.

3.4 Windsor Probe Test

The Windsor probe simulates a gun where a plug, resembling a bullet, is fired into the concrete and the distance into which the plug penetrates into the concrete is measured and correlated to the compressive strength of concrete.

After evaluating the use of the Windsor probe test on thirteen mixes with strength varying between 2240 and 18,820 psi, it was found that the Windsor probe test is capable of predicting the in situ compressive strength of normal and high strength concrete up to 17,080 psi [14].

3.5 Windsor Pin Penetration Test

The Windsor pin penetration test involves a spring loaded hammer that drives a small pin into a concrete surface and the depth the pin penetrates is correlated with the compressive strength of the concrete.

The paper by Masoumi [15] discusses visual inspections of 200 reinforced concrete bridges in Turkey and non-destructive testing applications performed on 10 bridges, which were most deficient. Penetration resistance, ultrasonic pulse velocity, rebar locator and reinforcement corrosion tests are performed on different elements of reinforced concrete bridges and the results are compared with the results of visual inspections. Almost perfect correlations are observed between results of nondestructive tests and condition states based on visual inspections. The Windsor pin test is applied 45 times on different bridge elements of 10 existing bridges. There is a good correlation between Windsor pin results and condition states which are obtained based on visual inspections.

After testing for compressive strength using the nail penetration method on 18 different concrete mixtures, the measured compressive strength values were compared to other NDT techniques; including Schmidt rebound hammer, ultrasonic pulse velocity, and Windsor probe. Selcuk [16] found that the nail penetration test can reliably estimate the compressive strength of a wide range of in-place concrete.

The pin penetration test was used to relate the early age strength of hardened concrete and mortar in the laboratory. It was found that the pin penetration tester can be used successfully, under laboratory conditions, to determine the compressive strength of concrete cylinders and mortar slabs at early age from 10 hours up to 28 days. For concrete and mortar cylinders, slabs and cubes with a compressive strength of up to 27.6 MPa (4000 psi), the pin penetration test readings were found to be linearly related to the compressive strength [17].

3.6 Impact Echo Test

The Impact Echo Test is based on the use of impact-generated stress (sound) waves that propagate through concrete and are reflected by internal flaws and external surfaces. Impact-echo can be used to determine the location and extent of flaws such as cracks.

In a study by Pessiki [18], the use of the impact-echo method to nondestructively estimate the in-place strength of concrete is more appropriately limited to the estimation of early-age strength. Operating experience with the impact-echo technique by Limaye [19] has shown that, within known limitations, the technique can provide a rapid nondestructive means for performing certain concrete condition surveys.

Impact-echo testing was performed by Tinkey [20] on the webs of two box girders with different amounts of deterioration. Because the P-wave peaks are determined by the persons performing the impact-echo test, the results come out to be biased. This method can be improved by coming up with and following a certain reliable standard that chooses the P-wave peaks to test. A more standard procedure for impact-echo testing should be further researched before implementation, since the test is subjective.

3.7 Selected NDT tests

After evaluating the six NDT tests, it was decided to use the following tests:

1. Silver Schmidt Rebound Hammer
2. Ultrasonic Pulse Velocity
3. Windsor Pin Penetration
4. Windsor Probe

The pull-out test was evaluated; however, it is not practical to use for bridge girders evaluation because of height accessibility limitations. The impact echo test was considered, however, it is not a proven method to determine in-situ compressive strength.

4.0 Description of Tasks

In situ NDT tests were performed on 52 bridge girders in Contra Costa County, Fresno County, Los Angeles County, Placer County, San Bernardino County, Santa Clara County, and Ventura County. Table 4 shows the number of bridge girders tested in each county. Four NDT tests that were performed to accurately calibrate for the concrete strength of the bridge girders were Proceq's Silver Schmidt Rebound Hammer, Proceq's Ultrasonic Pulse Velocity (UPV), James Instruments' Windsor Pin Penetration System, and James Instruments' Windsor Probe System.

A concrete mix was supplied by Star Concrete to cast a variety of specimens at San Jose State University. Table 1 shows the mix design used. Specimens constructed were concrete cylinders (6x12 in.), slabs (24x18x4 in. and 24x18x8 in.), and retaining walls (9 ft wide x 6 ft height x 8 in. thickness). 4x8 in. cores were taken from the 24x18x8 in. slabs, while NDT tests were performed on the 24x18x4 in. slabs, retaining walls, and cylinders.

Table 2 lists all the specimens on which the Silver Schmidt Rebound Hammer, UPV, Windsor Pin Penetration, and Windsor Probe tests were performed. Specimens in three Groups A, B, and C were cast and cured with different environmental conditions: Group A was cured at the SJSU building courtyard at ambient temperature, Group B was cured at the SJSU engineering structural laboratory at a controlled temperature of 71°F, and Group C was cured in the SJSU concrete laboratory at 71°F, and 100% relative humidity (RH).

Table 3 shows the frequency at which the NDT tests were performed. The collected data from all the specimens in Groups A, B, and C were combined with data supplied by the manufacturer of the NDT equipment to generate calibration charts for estimating the compressive strengths of the bridge girders.

Core samples were taken on three bridges in Santa Clara County and two bridges in San Bernardino County. Table 5 shows the schedule for taking cores on the five bridges. Compressive strength and NDT tests were performed on the core specimens to verify the NDT bridge compressive strength predictions.

To check the accuracy of the strength predictions, the existing ACI 209 equation was utilized. The equation will be described in Section 6.0.

5.0 Test Results for Laboratory Specimens, Calibration Charts for Bridges, and Core Specimens

Compression tests were performed over a period of 180 days on the 6x12 in. cylinders, 4x8 in. cylinders in Groups A, B, and C and 3.75x8 in. cores taken from the slabs in Groups A and C. NDT tests performed on all the cylinders, slabs, and walls were the Silver Schmidt Rebound Hammer, UPV, Windsor Pin Penetration, and Windsor Probe tests. Charts were developed for strength predictions for the Silver Schmidt Rebound Hammer, UPV, Windsor Pin Penetration, and Windsor Probe systems using the data collected from the laboratory testing and data supplied by the manufacturer for the NDT equipment.

5.1 Compressive Strength Test Results

Appendix A contains all compressive strength test results that were performed in accordance with ASTM C-39. Table A-1 contains the compression results for the 6x12 in. cylinders. Table A-2 contains the compression test results for the 4x8 in. cylinders. Outliers marked with the asterisk “*” were ignored when calculating the average compressive strength.

Figures A-1 and A-2 show the ratio between the strength of the 6x12 in. cylinders to the 4x8 in. cylinders. Figure A-3 shows the strength versus age of each tested cylinder in all three groups, while Figure A-4 shows the average strength versus age for each group. At 180 days, all cylinders had an average compressive strength ranging from 6,700 psi to 7,800 psi.

Table A-3 compares the average cylinder strengths to the core cylinder strength obtained from the slabs. The data from Table A-3 is also plotted in Figure A-5. In general, the 6x12 in. cylinders had a higher strength than the cores and 4x8 in. cylinders.

All strength data from this section in combination with data supplied by the manufacturer of the NDT equipment were utilized to develop strength prediction charts.

5.2 Rebound Hammer Test Results

Appendix B contains readings on cylinders (6x12 in.), slabs, and retaining walls obtained from the Proceq Silver Schmidt Rebound Hammer. Tables B-1 to B-3 contain the Rebound hammer test results from the cylinders, slabs, and retaining walls for Group A. Tables B-4 to B-6 contain the Rebound hammer results for cylinders, slabs, and the retaining wall for Group B. Tables B-7 and B-8 contain the Rebound hammer readings taken for cylinders and the slab in Group C. The data for the cylinders in Tables B-1, B-4, and B-7 were adjusted using the cylinder form factor (0.8) found in the Silver Schmidt Rebound Hammer user manual. Figures B-1 to B-8 show plots of the compressive strength versus the Rebound numbers for all tested specimens in all three groups with data provided by the Silver Schmidt Manufacturer Proceq. The Rebound values (Q) steadily increased for all plotted data in the range from 28 (Q) to 53 (Q), where the "Q"-value equals the rebound velocity divided by inbound velocity, which represents the physical rebound coefficient.

5.3 Ultrasonic Pulse Velocity Test Results

Appendix C contains readings on cylinders (6x12 in.), slabs, and retaining walls obtained from the Ultrasonic Pulse Velocity (UPV) tests. The tests were performed utilizing the Proceq Pundit 200 PL device. Tables C-1 to C-3 contain the UPV test results from the cylinders, slabs, and retaining walls for Group A. Tables C-4 to C-6 contain the UPV results for cylinders, slabs, and the retaining walls for Group B. Tables C-7 and C-8 contain the UPV readings taken for cylinders and the slab in Group C.

The data from Tables C-1 to C-8 with the data provided by the manufacturer to aid in the estimation of the compressive strength are plotted in Figures C-1 to C-8. The UPV test results exponentially increased as compressive strength increased. The UPV values ranged from 14,000 ft/s to 16,400 ft/s.

5.4 Windsor Pin Penetration Test Results

Appendix D contains all the data gathered when performing Pin Penetration test using the James Instruments Windsor Pin Test System. The micrometer used to measure the depth of each pin

penetration measures the exposed length of the pin. The readings were taken on cylinders (6x12 in.), slabs, and retaining walls in three groups. Tables D-1 to D-3 contain the pin penetration test results from the cylinders, slabs, and retaining walls for Group A. Tables D-4 to D-6 contain the pin penetration test results for cylinders, slabs, and retaining wall for Group B. Tables D-7 and D-8 contain the pin penetration test results taken from the cylinders and slab in Group C.

The data from Tables D-1 to D-8 with the corresponding compressive strength values obtained from the cylinders, slabs, and retaining walls are plotted in Figures D-1 to D-8. The trend for each of the set of results showed an increase in pin readings with time. After 180 days, the exposed pin readings ranged from 823×10^{-3} in. to 857×10^{-3} in. Results for the exposed pin readings for a given specimen at a given age often deviated by 3×10^{-3} in.

5.5 Windsor Probe Test Results

Appendix E contains the data gathered when performing the Windsor Probe test on the retaining walls cured in Groups A and B. The Windsor probe test measures the length of exposed probe after it has been embedded in the concrete.

Tables E-1 and E-2 contain the exposed probe and compressive strength for both retaining walls. Figure E-1 shows the exposed probe length (in.) versus specimen age in days, while Figure E-2 shows the average exposed probe length versus specimen age in days. Figure E-3 shows the relationship between time versus the compressive strength. Figures E-4 to E-6 show the relationship between exposed probe length (in.) and the compressive strength (psi) from the Windsor Probe Standard power table provided by James Instruments. Using the Windsor Probe Test, the compressive strength for the retaining walls A and B were both in the range of 5,900-6,400 psi. These compressive strength values are lower than those obtained from testing the 6x12 in. cylinders at the same age.

5.6 Strength Predictions for Bridges

Appendix F contains charts developed for strength predictions for the Silver Schmidt Rebound Hammer, the UPV, the Windsor Pin, and the Windsor Probe system. Data obtained from the laboratory testing in combination with the data supplied by the manufacturer for the NDT equipment were combined and utilized for strength prediction.

Figures F-1 to F-4 contain the charts showing equations from the Proceq's data, SJSU data, and their combination. Tables F-1 to F-7 contain strength predictions for all seven counties using the combined equation from the charts. The combined equations were used for all equipment, except for the Windsor Pin predictions. As shown in the tables, predicted UPV compressive strength data were in some cases below the design strength, as noted by “*”. It is not clear why this problem occurs, however, it may be related to the reinforcement bar layout in the structure; even after bar scanning was performed. Therefore, UPV will not be included in the Mean strength calculations or in the Standard Deviation calculations, as noted by “***”.

5.7 Core Samples

Core specimens were taken on selected bridges from two counties to further verify the accuracy of the compressive strength predictions made from the Silver Schmidt Rebound Hammer, UPV, Windsor Pin, and Windsor Probe Systems. Table 5 shows the list of selected bridges utilized. Tables F-8 to F-10 contain the compressive strength of core samples taken from three bridges in Santa Clara County. Tables F-11 and F-12 contain the compressive strength of core samples taken from two bridges in San Bernardino County. The percentage between parenthesis next to the compressive strength values for the core and all the NDT equipment predictions represent the percentage increase or decrease from the NDT bridge prediction. The percentage between parenthesis under the compressive strength values for the core and all the NDT equipment predictions represent the percent increase or decrease of the core from the individual equipment predictions.

A summary of the core specimen results is given in Table F-13. The table shows that the ratio of the average percent increase in strength of the bridge over the percent increase of the core was 1.30. Therefore, 70 percent of the predicted bridge NDT strength was calculated to make more realistic predictions, as seen in the far right column on Table F-13. Table F-14 shows the bridge NDT compressive strength predictions and their standard deviations of $\sigma-2\text{StDev}$, $\sigma-\text{StDev}$, $\sigma+\text{StDev}$, and $\sigma+2\text{StDev}$. Table F-14 shows that the average core compressive strengths fall between $\sigma-\text{StDev}$ and $\sigma+\text{StDev}$ of the averaged NDT compressive strength prediction. The UPV prediction results were below the design strength and they were excluded from the average. The UPV compressive strength values on the cores were more realistic than the predictions on the bridges, which mean the reinforcing strands may have some influence on the final value of the UPV prediction.

6.0 ACI 209 Equation and Modified Equations

In order to predict the strength of the bridges, the ACI 209 equation [21] was utilized to check the accuracy of the strength predictions over time for the bridge girders.

Figure F-5 shows the age ranges for the different bridges and the correlating percent increase in their design strength as predicted by the NDT tests. It can be observed that bridges around 10 years old showed at least 20 percent increase from their design compressive strength, and bridges around 50 years old showed at least 40 percent increase from their design compressive strength. A proposed equation, shown below, from ACI Committee 209 to predict compressive strength over time for concrete made with Type I cement and cured at 70°F was used to make strength predictions for the bridges:

t = Compressive strength prediction
= Design strength of the bridge
t = Time in days

Figure F-6 shows the comparison of strength prediction versus age between 70%NDT and the ACI 209 equation. It can be observed that the ACI 209 equation is more accurate in predicting bridge strength older than 50 years, but not for younger bridges, where the strength predictions were over estimated.

After calibrating the data, the following two modified equations were proposed. The first modified equation was utilized to predict compressive strength of bridges younger than 15 years, while the other modified equation was utilized to predict compressive strength of bridges older than 15 years. The modified equations can be summarized as follows:

For bridges younger than 15 years:

For bridges older than 15 years:

This equation is based on limited data points for the ages between 15 to 50 years.

Figure F-7 shows the compressive strength predictions versus age from both modified equations. The equations were compared with the 70%NDT predicted compressive strength values. It can be observed that the compressive strength values obtained from the 70%NDT gives a better correlation with the modified equation predictions.

Figure F-8 shows the percent increase or decrease between the ACI 209 equation and the 70%NDT predictions, while Figure F-9 shows a similar comparison, but utilizing the modified ACI 209 equations. The values from Figures F-8 and F-9 were compared in Tables F-15 and F-16.

Table F-15 shows the percent increase or decrease of the ACI 209 equation compressive strength predictions from the 70%NDT strength predictions. The positive percentage represent an over estimation prediction while the negative percentage represents an under estimation prediction. The average percent for all the bridges at all ages was -1 percent, average for bridges younger than 15 years was 32 percent, average for bridges older than 15 years was -3 percent, and average for bridges older than 50 years was 1 percent. The 32 percent average over estimation for bridges younger than 15 years confirms that the ACI 209 equation is not the best choice to use for younger bridges. On the other hand, the 1 percent average over estimation for bridges over 50 years shows that the ACI 209 equation is useful for predicting compressive strength for older bridges.

Table F-16 shows the percent increase or decrease of the modified ACI 209 equation compressive strength predictions from the 70%NDT strength predictions. The average percent for all the bridges at all ages was 1 percent, average for bridges younger than 15 years was 6 percent, average for bridges older than 15 years was 2 percent, and average for bridges older than 50 years was 6 percent. The 2 percent average over estimation for bridges over 15 years confirms that the modified ACI 209 equation is a better choice to use for bridges older than 15 years. The

6 percent average over estimation for bridges younger than 15 years shows that the modified ACI 209 equation is also a better choice to use for younger bridges.

Finally, Table F-17 shows the summary percentage values from Tables F-15 and F-16. The table shows that the ACI 209 equation can give a good compressive strength prediction for bridges older than 50 years. On the other hand, the modified ACI 209 equations can be a better choice for predicting compressive strength for bridges at all ages. There was limited data to evaluate bridges between 15 and 50 years old, and therefore, the modified ACI 209 equations can be further improved if data are available for this age range.

7.0 Conclusions

The following conclusions can be made from this study:

- (1) In several cases, the UPV prediction results were below the design strength. Therefore, they were excluded from the analysis.
- (2) Core compressive strength values of the cores taken from five selected bridges fell between mean-StDev and mean+StDev of the predicted averaged NDT bridge values, excluding the UPV.
- (3) The Windsor Probe strength prediction was typically higher than those strengths obtained from the Silver Schmidt and Windsor Pin predictions on the bridges.
- (4) The percentage increase in strength of the bridges can be better predicted with core compressive strength values when taking 70% of the averaged compressive strength predictions obtained from the Silver Schmidt, Windsor Probe, and Windsor Pin tests.
- (5) In-situ precast concrete girders that were approximately 10 years old exhibited at least 20% increase in their design compressive strength.
- (6) In-situ precast concrete girders that were approximately 50 years old exhibited at least 40% increase from their design compressive strength.
- (7) The following modified equations are proposed for bridge compressive strength predictions:

| | | |
|----------------------------|-------|-----------------------|
| Modified ACI 209 Equations | _____ | Younger than 15 years |
| | _____ | Older than 15 years |

- (8) Caltrans is seeking a way to verify field compressive strength of precast concrete girders from several bridges in the state of California. In-situ testing data and modified prediction equations, obtained from this study, will help Caltrans to reliably estimate the concrete strength needed to increase capacity recognition of the bridges. Additionally, seismic/strengthening upgrades on bridges can be assessed more accurately with the field-testing data provided.

Table 1: Ready Mix Design Ordered from Star Concrete



San Jose Plant • 1404 So. 7th St., San Jose, CA 95112

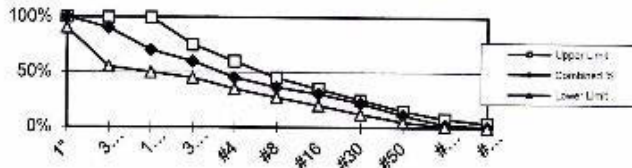
Ph: (408) 947-0669 • Fax: (408) 947-0434

Contractor: San Jose State
Project:
Concrete Mix Design: 10.2 sk 1/2"
Mix Design Number: 10212WR
Date: 9/14/2016
Use : High Strength
Plant: San Jose, CA

Mechanical analyses percent passing U.S. standard sieves

| Sieve | 1 1/2" | 1" | 3/4" | 1/2" | 3/8" | #4 | #8 | #16 | #30 | #50 | #100 | #200 |
|---------------|--------|------|------|------|------|-----|-----|-----|-----|-----|------|------|
| 1" x #4 | 100% | 100% | 82% | 46% | 27% | 1% | 0% | 0% | 0% | 0% | 0% | 0% |
| Concrete Sand | 100% | 100% | 100% | 100% | 100% | 99% | 81% | 68% | 49% | 25% | 6% | 2% |
| Combined | 100% | 100% | 90% | 70% | 60% | 45% | 36% | 31% | 22% | 11% | 3% | 1% |

Sack Content: 10.20 sk equiv.
 Specified Strength: High Strength
 W/Cm Ratio: 0.34
 Slump: 4.00 +/-1"
 Cement Type: Type II/V



| Material | | Specific Gravity | Density lb/ft ³ | S.S.D. Weight | Vol. ft ³ |
|-----------------------|---------------|------------------|----------------------------|---------------|----------------------|
| 1/2" X #4 | 60.0% | 2.88 | 179.71 | 1752 lb | 9.75 |
| Concrete Sand | 40.0% | 2.78 | 173.47 | 1128 lb | 6.50 |
| Cement, Type II/V | 89% | 3.15 | 196.56 | 853 lb | 4.34 |
| Slag, 120 Grade | 0% | 2.92 | 182.21 | 0 lb | 0.00 |
| Pozzolan, Class F Ash | 11% | 2.32 | 144.77 | 105 lb | 0.73 |
| 39.5 Gallons Water | | 1.00 | 62.40 | 329 lb | 5.27 |
| Entrapped Air | 1.5% | | | | 0.41 |
| 322N | | | | 31 oz/yd | |
| Admix 2 | | | | 0.0 oz/yd | |
| Admix 3 | | | | 0 oz/yd | |
| Total | Unit Weight = | 154.4 pcf | | 4168 lb | 27.00 |

Table 2: List of Specimens Tested

| Specimen | Group A (Courtyard) | Group B (Lab) | Group C (Humidity Room) | Total Quantity |
|--------------------|---------------------|---------------|-------------------------|----------------|
| Retaining Wall | 1 | 1 | 0 | 2 |
| 6x12 in. Cylinders | 36 | 36 | 36 | 108 |
| 4x8 in. Cylinders | 36 | 36 | 36 | 108 |
| 24x18x4 in. Slabs | 3 | 3 | 3 | 9 |
| 24x18x8 in. Slabs | 1 | 1 | 1 | 3 |

Table 3: NDT Testing Schedule

| Date | Concrete Age (days) |
|-------------|----------------------------|
| 10/18/2016 | 1 |
| 10/20/2016 | 3 |
| 10/24/2016 | 7 |
| 10/31/2016 | 14 |
| 11/7/2016 | 21 |
| 11/14/2016 | 28 |
| 11/21/2016 | 35 |
| 11/28/2016 | 42 |
| 12/12/2016 | 56 |
| 1/15/2017 | 90 |
| 2/14/2017 | 120 |
| 4/15/2017 | 180 |

Table 4: NDT Tests Performed on Bridges in Seven Counties

| County | Number of Bridge Girders Tested | Number of Cores Taken |
|----------------|--|------------------------------|
| Contra Costa | 7 | - |
| Fresno | 6 | - |
| Los Angeles | 8 | - |
| Placer | 7 | - |
| San Bernardino | 8 | 4 – (Two Bridges) |
| Santa Clara | 9 | 6 – (Three Bridges) |
| Ventura | 7 | - |
| | Total = 52 | Total = 10 |

Table 5: Core Samples Schedule

| Date | Bridge No. | County |
|-------------|-------------------|----------------|
| 6/1/2017 | 37C0031 | Santa Clara |
| 6/13/2017 | 37 0218 | Santa Clara |
| 6/21/2017 | 37 0149 | Santa Clara |
| 7/27/2017 | 54 1277L | San Bernardino |
| 7/27/2017 | 54 1278R | San Bernardino |

Appendix A

Compression Test Results for Cylinders and Cores

Table A-1: 6x12 in. Cylinder Compression Strengths

| | Group A 6x12 in. Cylinders | | | Group B 6x12 in. Cylinders | | | Group C 6x12 in. Cylinders | | |
|------------|----------------------------|---------------|-----------|----------------------------|---------------|-----------|----------------------------|---------------|-----------|
| | Strength (psi) | Average (psi) | Std. Dev. | Strength (psi) | Average (psi) | Std. Dev. | Strength (psi) | Average (psi) | Std. Dev. |
| 1 | 2608* | 3219 | 405 | 3655 | 3487 | 157 | 2750* | 3269 | 334 |
| | 3021 | | | 3463 | | | 3121 | | |
| | 3417 | | | 3344 | | | 3417 | | |
| 3 | 4598 | 4648 | 209 | 4804 | 4833 | 130 | 4826 | 4622 | 181 |
| | 4469 | | | 4975 | | | 4479 | | |
| | 4878 | | | 4720 | | | 4563 | | |
| 7 | 5502 | 5484 | 99 | 5365 | 5150 | 191 | 5243 | 5059 | 357 |
| | 5378 | | | 5000 | | | 5285 | | |
| | 5573 | | | 5085 | | | 4648 | | |
| 14 | 5883 | 5680 | 276 | 5460 | 5715 | 505 | 5357 | 5383 | 44 |
| | 5366 | | | 6297 | | | 5433 | | |
| | 5791 | | | 5389 | | | 5359 | | |
| 21 | 6445 | 6322 | 194 | 6103 | 6226 | 169 | 6203 | 5789 | 362 |
| | 6423 | | | 6419 | | | 5533 | | |
| | 6099 | | | 6155 | | | 5631 | | |
| 28 | 6185 | 6356 | 257 | 6394 | 6403 | 113 | 6539* | 6034 | 317 |
| | 6232 | | | 6597* | | | 6156 | | |
| | 6651 | | | 6411 | | | 5911 | | |
| 35 | 6549 | 6425 | 146 | 5994* | 6314 | 192 | 5982 | 6346 | 395 |
| | 6463 | | | 6260 | | | 6766 | | |
| | 6264 | | | 6368 | | | 6291 | | |
| 42 | 6351* | 6474 | 280 | 6594 | 6460 | 269 | 5905* | 6574 | 475 |
| | 6203 | | | 6635 | | | 6297 | | |
| | 6745 | | | 6150 | | | 6851 | | |
| 56 | 7003 | 6621 | 455 | 6834 | 6910 | 225 | 7058 | 6925 | 167 |
| | 6742 | | | 7163 | | | 7100* | | |
| | 6117 | | | 6732 | | | 6792 | | |
| 90 | 7239 | 7045 | 168 | 7014 | 7065 | 287 | 7044 | 6993 | 76 |
| | 6947 | | | 7554* | | | 6941 | | |
| | 6948 | | | 7116 | | | 6896* | | |
| 120 | 7275 | 7207 | 171 | 6919 | 7054 | 269 | 7579 | 7382 | 330 |
| | 7012 | | | 6651* | | | 7185 | | |
| | 7333 | | | 7189 | | | 7841* | | |
| 180 | 7431 | 7880 | 397 | 7817 | 7835 | 113 | 7297 | 7501 | 211 |
| | 8023 | | | 7641 | | | 7704 | | |
| | 8185 | | | 7852 | | | 7406 | | |

*Outlier not plotted or used to calculate average

Table A-2: 4x8 in. Cylinder Compression Strength

| | Group A 4x8 in. Cylinders | | | Group B 4x8 in. Cylinders | | | Group C 4x8 in. Cylinders | | |
|------------|---------------------------|---------------|-----------|---------------------------|---------------|-----------|---------------------------|---------------|-----------|
| | Strength (psi) | Average (psi) | Std. Dev. | Strength (psi) | Average (psi) | Std. Dev. | Strength (psi) | Average (psi) | Std. Dev. |
| 1 | 3470 | 3284 | 454 | 3180 | 3357 | 176 | 2300* | 3334 | 642 |
| | 2566* | | | 3533 | | | 3570 | | |
| | 3099 | | | 3356 | | | 3099 | | |
| 3 | 3140* | 4610 | 849 | 4228 | 4071 | 282 | 4662 | 4628 | 44 |
| | 4586 | | | 3746 | | | 4643 | | |
| | 4635 | | | 4240 | | | 4579 | | |
| 7 | 4791 | 4891 | 183 | 4613 | 4551 | 274 | 4723 | 4851 | 186 |
| | 4780 | | | 4789 | | | 5065 | | |
| | 5103 | | | 4252 | | | 4766 | | |
| 14 | 5338 | 5503 | 155 | 5086 | 5335 | 226 | 5542 | 5430 | 98 |
| | 5527 | | | 5395 | | | 5387 | | |
| | 5645 | | | 5525 | | | 5360 | | |
| 21 | 6251* | 5899 | 223 | 6659* | 6271 | 254 | 6478 | 6329 | 212 |
| | 5989 | | | 6389 | | | 6590* | | |
| | 5808 | | | 6152 | | | 6180 | | |
| 28 | 5450* | 5844 | 273 | 5442* | 6081 | 369 | 6224 | 6181 | 61 |
| | 5692 | | | 6059 | | | 6111 | | |
| | 5995 | | | 6102 | | | 6209 | | |
| 35 | 6098 | 6175 | 187 | 2594** | 6240 | 2112 | 5911* | 6175 | 207 |
| | 6252 | | | 6068 | | | 6315 | | |
| | 5880* | | | 6412 | | | 6034 | | |
| 42 | 6487 | 6462 | 75 | 6181 | 5931 | 221 | 6124 | 6219 | 360 |
| | 6437 | | | 5765 | | | 6617 | | |
| | 6585* | | | 5846 | | | 5917 | | |
| 56 | 6502 | 6377 | 452 | 5864 | 5942 | 125 | 6284 | 6162 | 142 |
| | 6252 | | | 6086 | | | 6007 | | |
| | 5625* | | | 5877 | | | 6196 | | |
| 90 | 6783* | 6557 | 186 | 6842 | 6303 | 475 | 6704 | 6688 | 352 |
| | 6690 | | | 5947 | | | 7032 | | |
| | 6424 | | | 6120 | | | 6328 | | |
| 120 | 6156 | 6587 | 427 | 6473 | 6506 | 592 | 6685 | 7075 | 346 |
| | 6595 | | | 5931 | | | 7197 | | |
| | 7010 | | | 7113 | | | 7344 | | |
| 180 | 6731 | 7055 | 706 | 6635 | 6793 | 357 | 7514 | 7495 | 70 |
| | 7864 | | | 6542 | | | 7554 | | |
| | 6569 | | | 7201 | | | 7418 | | |

* Outlier not plotted or used to calculate average

**Specimen failed at Cap

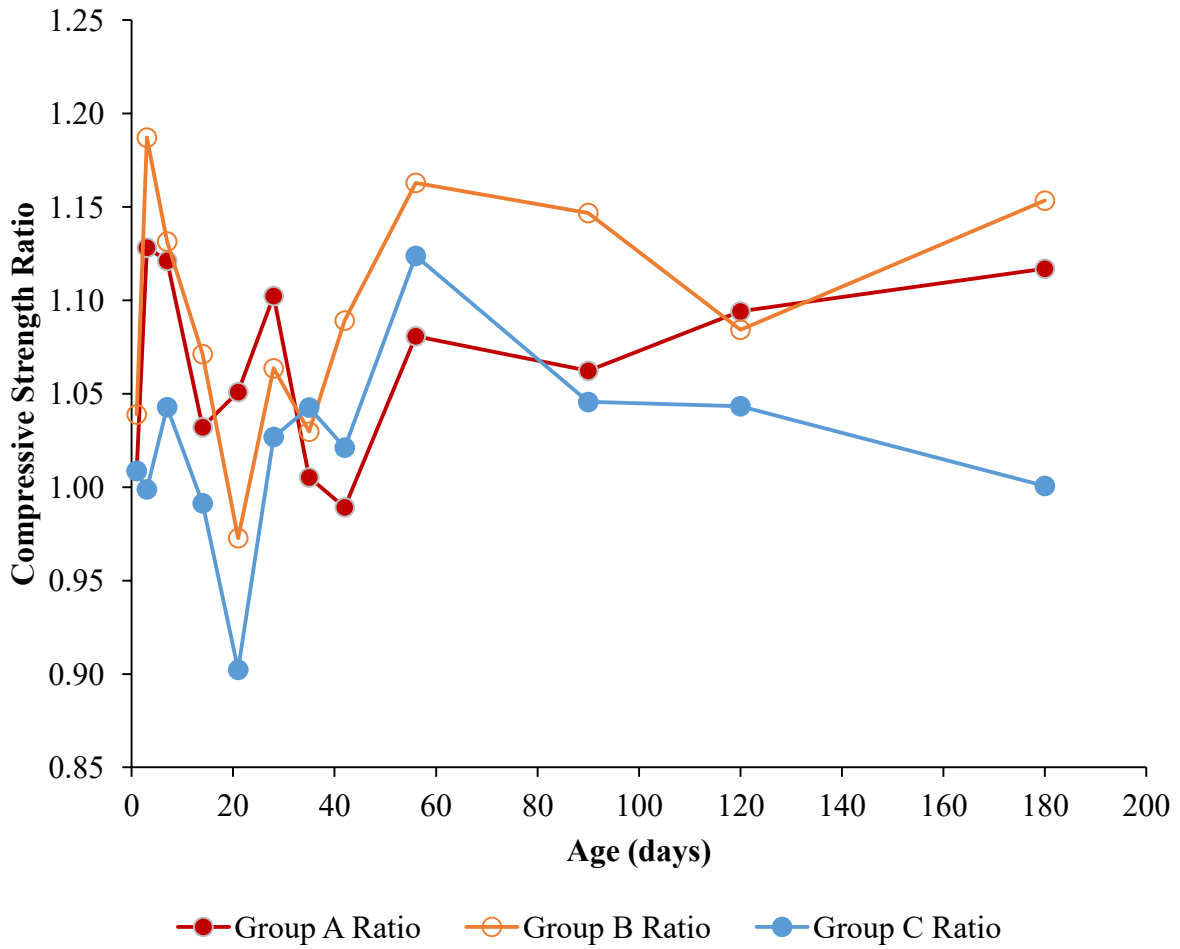


Figure A-1: Ratio of 6x12 in./4x8 in. Cylinder Strength vs. Age (days)

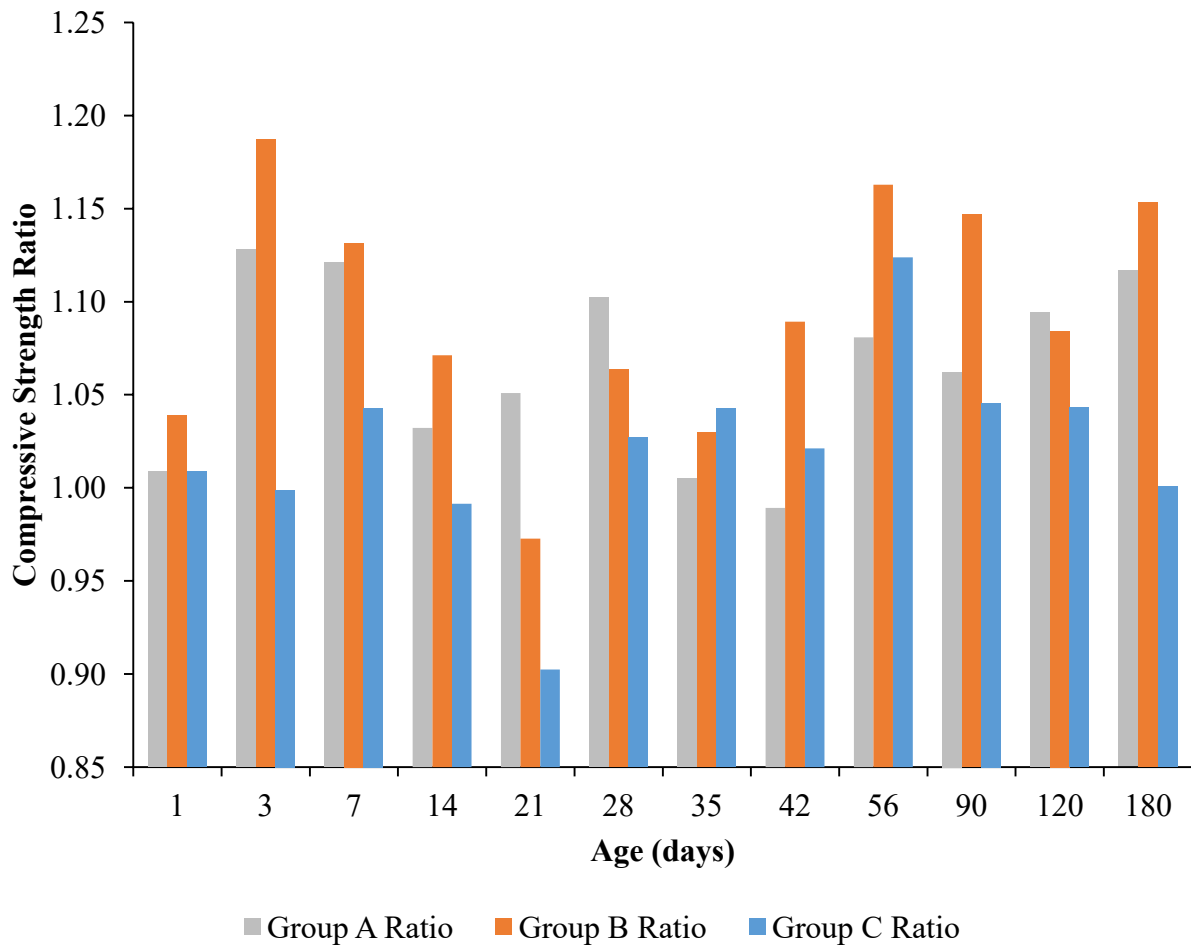


Figure A-2: Ratio of 6x12 in./4x8 in. Cylinder Strength vs. Age (days)

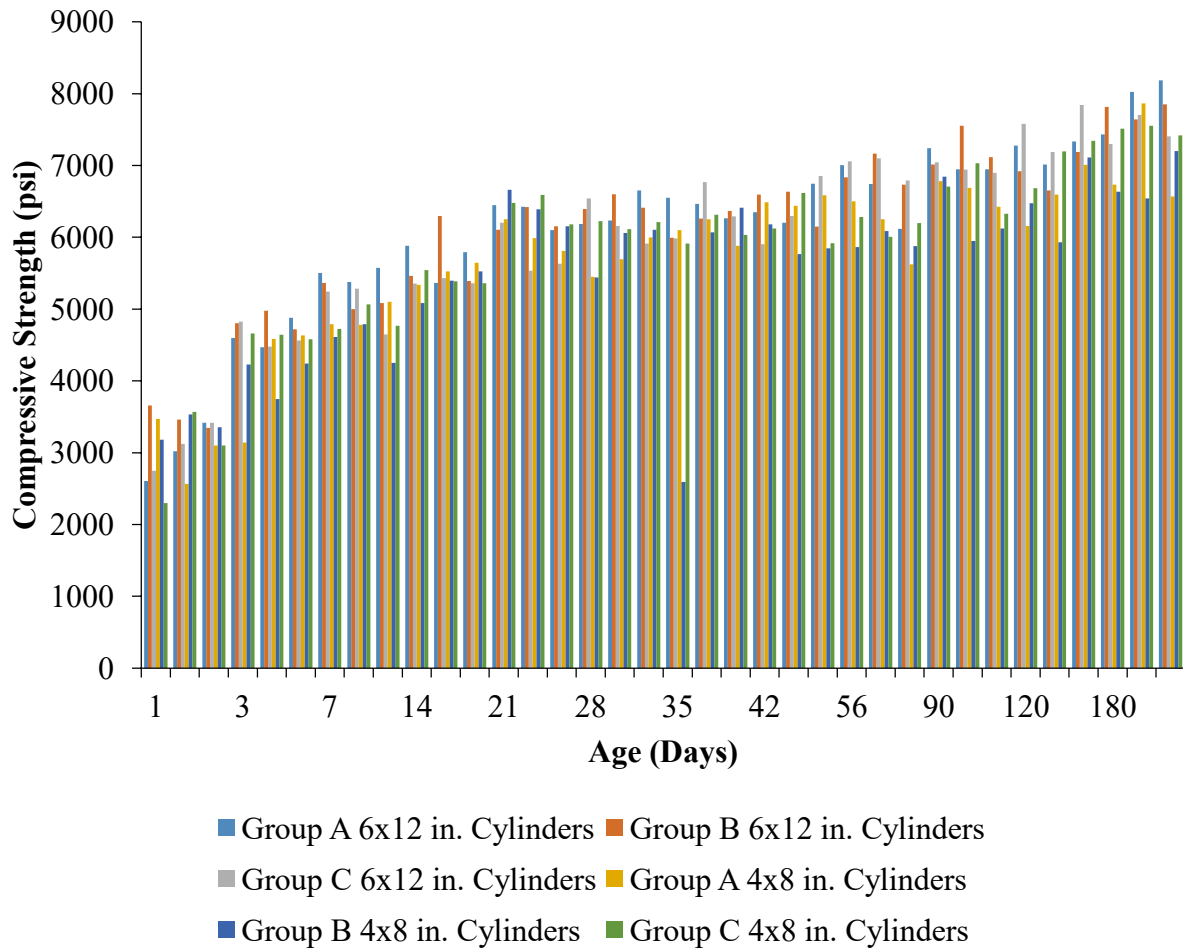


Figure A-3: Compressive Strength for all Cylinders (psi) vs. Age (days)

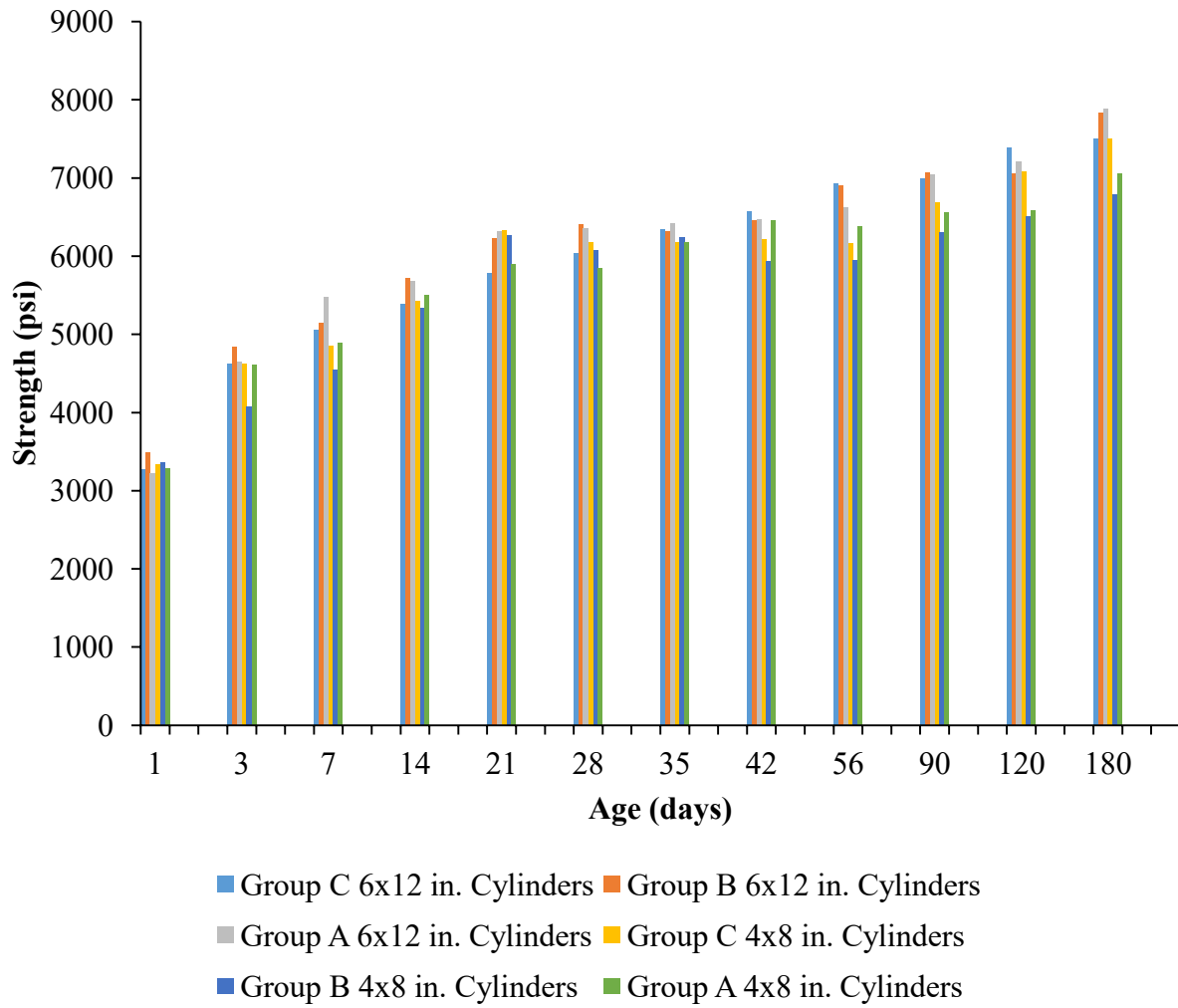


Figure A-4: Average Compressive Strength for all Cylinders (psi) vs. Age (days)

Table A-3: Slabs Core Strength & Cylinder Strength

| Age (Days) | Group A Slab Core (psi) | Group C Slab Core (psi) | Group A 6x12 in. Cylinder (psi) | Group C 6x12 in. Cylinder (psi) | Group A 4x8 in. Cylinder (psi) | Group C 4x8 in. Cylinder (psi) |
|------------|-------------------------|-------------------------|---------------------------------|---------------------------------|--------------------------------|--------------------------------|
| 14 | 4487 | 4580 | 5680 | 5383 | 5503 | 5430 |
| 21 | 4740 | 5401 | 6322 | 5789 | 5899 | 6329 |
| 35 | 5522 | 5685 | 6425 | 6346 | 5844 | 6175 |
| 56 | 6303 | 5719 | 6621 | 6925 | 6377 | 6162 |
| 90 | 6865 | 6328 | 7045 | 6993 | 6557 | 6688 |
| 120 | 5791 | 5953 | 7207 | 7382 | 6587 | 7075 |
| 180 | 6624 | 7187 | 7880 | 7501 | 7055 | 7495 |

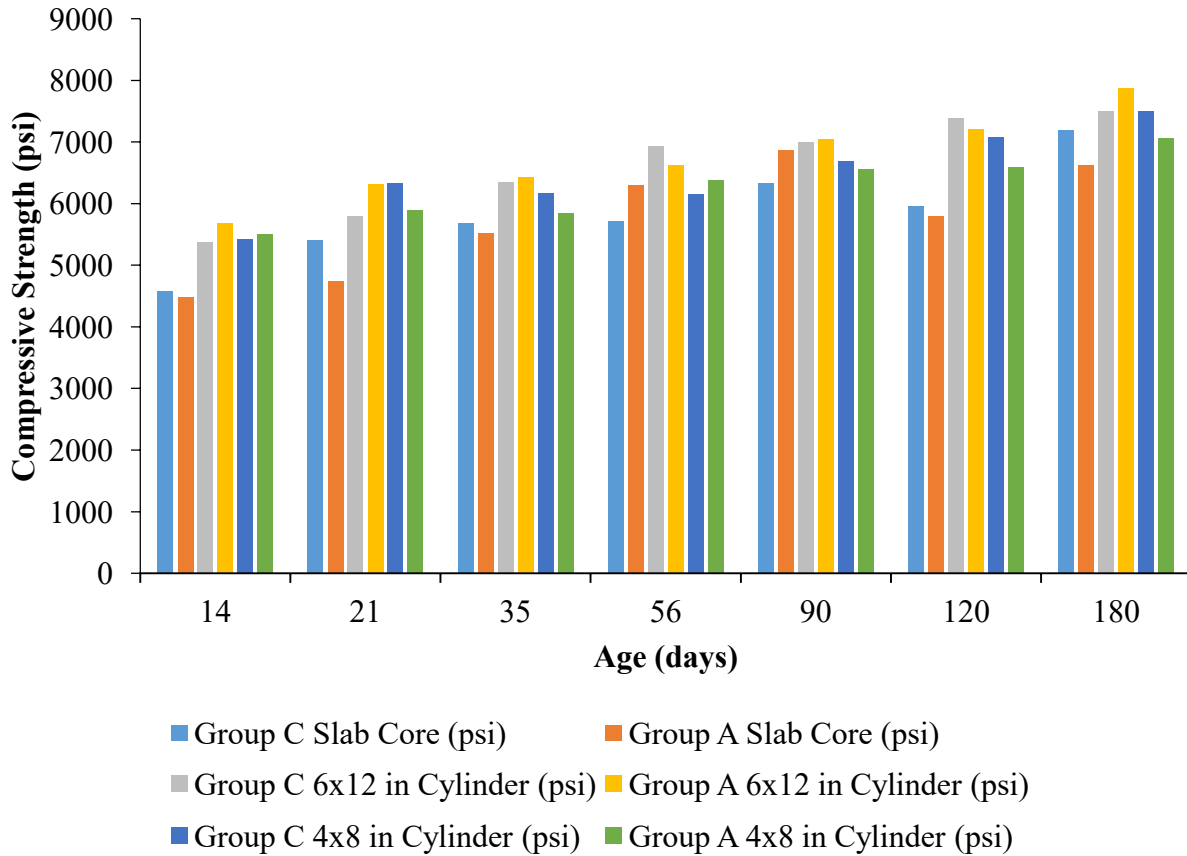


Figure A-5: Core and Cylinder Compressive Strength (psi) vs. Age (days)

Appendix B

Rebound Hammer Test Results for Cylinders, Slabs, and Retaining Walls

Table B-1: Rebound Values for 6x12 in. Group A Cylinders

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 35 | | | Day 42 | | | Day 56 | | | Day 90 | | | Day 120 | | | Day 180 | | |
|----------------------------|-------|-------|-------|--------|--------|--------|--------|------|------|--------|------|------|--------|------|------|--------|------|------|---------|------|------|---------|------|------|
| 6x12 in. Str. (psi) | 3219 | 4648 | 5484 | 5680 | 6322 | 6356 | 6549 | 6463 | 6264 | 6594 | 6635 | 6150 | 7003 | 6742 | 6117 | 7239 | 6948 | 6947 | 7275 | 7012 | 7333 | 7431 | 8023 | 8185 |
| | 39.0 | 51.5 | 45.5 | 57.5 | 57.5 | 57.5 | 60.5 | 61 | 60 | 61.0 | 61.5 | 60.5 | 62.5 | 63.5 | 63.0 | 65.5 | 63.5 | 65.0 | 60.0 | 64.5 | 63.5 | 65.5 | 64.5 | 61 |
| | 45.0 | 53.5 | 57.5 | 55.5 | 54 | 58.0 | 62.5 | 60.5 | 57 | 65.5 | 62.5 | 62.0 | 63.0 | 61.5 | 63.0 | 63.5 | 67.5 | 61.0 | 61.5 | 62.0 | 63.5 | 64 | 64.5 | 64.5 |
| | 40.0 | 51.0 | 58.5 | 59.0 | 57.5 | 56.0 | 65.5 | 59.5 | 61.5 | 55.5 | 65.0 | 60.5 | 62.5 | 62.5 | 61.0 | 61.5 | 64.0 | 64.0 | 59.5 | 66.5 | 63.0 | 66.5 | 66 | 67 |
| | 41.5 | 53.5 | 55.0 | 60.5 | 57 | 59.0 | 6 | 60.5 | 58.5 | 64.5 | 62.5 | 62.0 | 59 | 61.5 | 60.5 | 58.5 | 64.5 | 62.5 | 62.5 | 64.0 | 61.0 | 69.5 | 68.5 | 64.5 |
| | 46.0 | 49.5 | 53.5 | 55.5 | 56.5 | 58.0 | 57.5 | 62 | 66 | 60.0 | 63.5 | 62.5 | 62.5 | 59.0 | 62.0 | 61.0 | 63.5 | 65.0 | 64.5 | 65.0 | 59.5 | 67.5 | 64 | 64.5 |
| | 42.0 | 51.0 | 53.0 | 53.0 | 59.5 | 58.0 | 57 | 61 | 63 | 66.0 | 62.5 | 60.0 | 61 | 59.5 | 62.5 | 65.0 | 60.5 | 64.0 | 63.0 | 64.0 | 62.0 | 65.5 | 65 | 67 |
| | 48.5 | 50.5 | 52.0 | 54.5 | 56 | 57.5 | 61.5 | 60 | 59 | 62.5 | 64.0 | 61.0 | 59 | 62.5 | 68.5 | 60.0 | 60.5 | 64.0 | 63.5 | 62.5 | 62.0 | 62 | 64 | 66 |
| | 43.5 | 51.0 | 52.0 | 57.0 | 51 | 57.0 | 63 | 56.5 | 61 | 60.0 | 63.0 | 63.0 | 64 | 59.0 | 61.5 | 59.5 | 59.0 | 62.5 | 62.5 | 62.5 | 65.5 | 63 | 66 | 66 |
| | 42.5 | 48.5 | 53.5 | 56.0 | 57.5 | 54.0 | 61 | 57.5 | 61.5 | 61.0 | 61.5 | 62.0 | 59 | 62.5 | 63.5 | 64.0 | 64.0 | 63.0 | 64.5 | 63.0 | 61.5 | 66 | 65 | 63.5 |
| | 46.5 | 50.5 | 56.5 | 59.5 | 56.5 | 55.5 | 58.5 | 57.5 | 61.5 | 60.0 | 62.5 | 61.0 | 60 | 60.5 | 63.0 | 62.5 | 69.5 | 61.0 | 62.5 | 65.0 | 61.5 | 68 | 64.5 | 64 |
| | 41.0 | 49.5 | 61.0 | 58.0 | 60 | 56.0 | 59.5 | 58.5 | 58.5 | 60.5 | 63.0 | 64.5 | 60.5 | 65.5 | 63.0 | 63.5 | 60.0 | 60.0 | 62.5 | 64.5 | 64.0 | 64 | 65 | 62.5 |
| | 41.0 | 53.5 | 50.5 | 58.0 | 61.5 | 57.0 | 57 | 61 | 60.5 | 61.5 | 61.0 | 63.0 | 62 | 59.0 | 62.5 | 61.0 | 57.5 | 59.5 | 61.0 | 63.5 | 59.0 | 67 | 62 | 66 |
| | 44.0 | 51.0 | 53.0 | 58.0 | 54.5 | 57.5 | 60 | 61 | 61 | 62.5 | 61.0 | 59.0 | 68 | 59.0 | 62.5 | 57.5 | 59.5 | 62.0 | 63.5 | 60.0 | 60.0 | 67 | 63.5 | 64.5 |
| | 44.0 | 48.5 | 56.0 | 56.0 | 58 | 56.0 | 60 | 61.5 | 61 | 63.0 | 62.0 | 61.5 | 61.5 | 63.0 | 64.5 | 63.5 | 63.0 | 61.5 | 60.0 | 63.0 | 61.5 | 64 | 67 | 63.5 |
| | 41.5 | 52.0 | 57.0 | 58.5 | 57.5 | 58.0 | 58 | 59.5 | 58.5 | 61.0 | 61.0 | 60.5 | 60 | 63.0 | 63.0 | 62.5 | 56.0 | 62.5 | 69.0 | 61.0 | 60.0 | 67.5 | 65 | 65 |
| *Average | 43.1 | 51.0 | 54.3 | 57.1 | 57.0 | 57.0 | 56.5 | 59.8 | 60.6 | 61.6 | 62.4 | 61.5 | 61.6 | 61.4 | 62.9 | 61.9 | 62.2 | 62.5 | 62.7 | 63.4 | 61.8 | 65.8 | 65.0 | 64.6 |
| **Adjusted Average | 34 | 41 | 43 | 46 | 46 | 46 | 45 | 48 | 48 | 49 | 50 | 49 | 49 | 49 | 50 | 50 | 50 | 50 | 50 | 51 | 49 | 53 | 52 | 52 |

**Adjusted Average = Average x Form factor of standard cylinders (i.e. 0.8)

**Adjusted Average will be used for the graphs

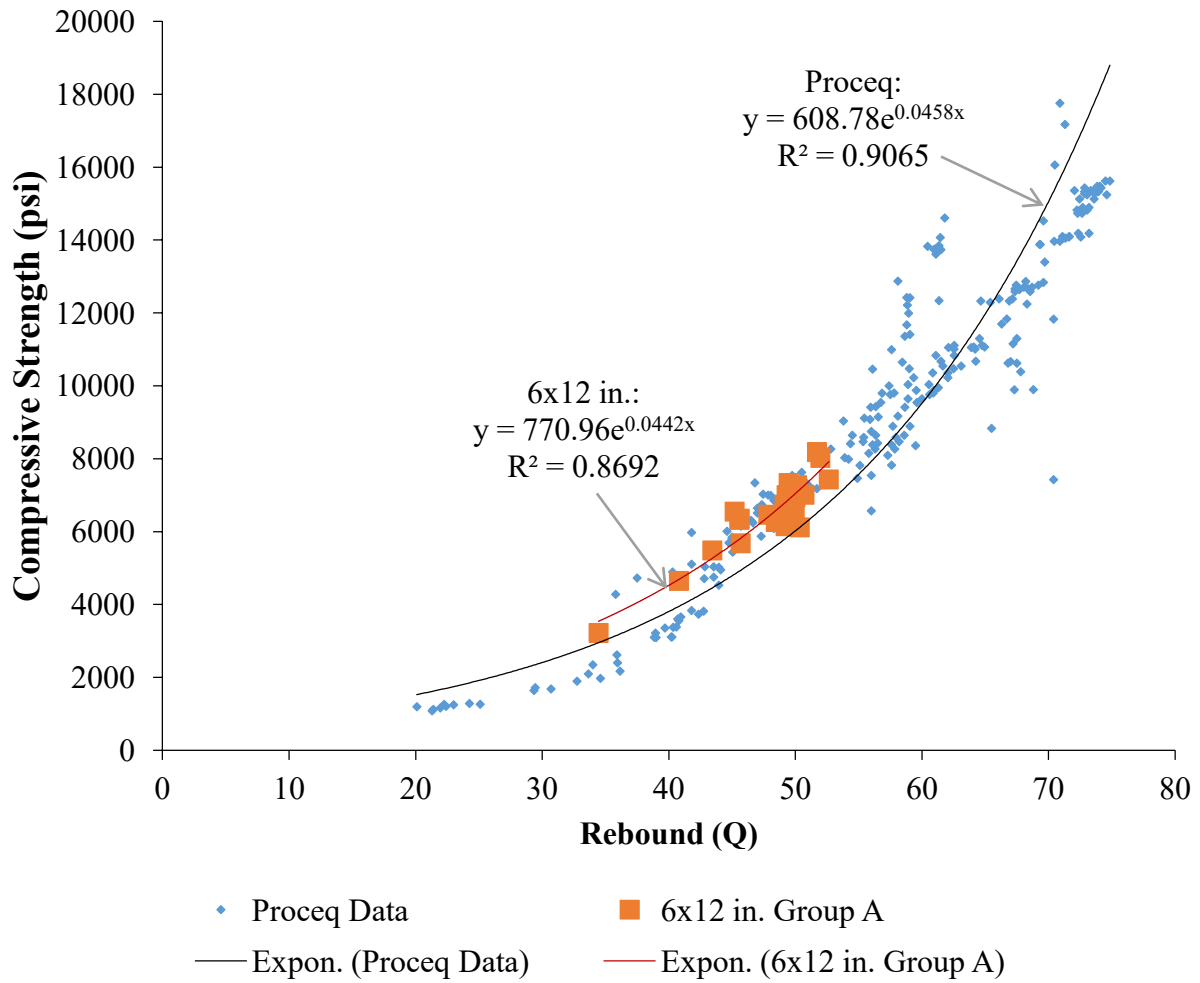


Figure B-1: Rebound Value (Q) vs. Compressive Strength (psi) for Group A 6x12 in. Cylinders

Table B-2: Rebound Values for 24x18x4 in. Slab A

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 42 | Day 56 | Day 90 | Day 120 | Day 180 |
|----------------------------|-------|-------|-------|--------|--------|--------|--------|--------|--------|---------|---------|
| 6x12 in. Str. (psi) | 3219 | 4648 | 5484 | 5680 | 6322 | 6356 | 6474 | 6621 | 7045 | 7207 | 7880 |
| Core Str. (psi) | | | | 4487 | 4740 | | | 6303 | 6865 | 5791 | 6624 |
| | 40.0 | 48.0 | 46.5 | 61.5 | 43.5 | 55.0 | 61.5 | 56.5 | 62.5 | 62.0 | 56 |
| | 43.0 | 46.0 | 49.5 | 54.5 | 43 | 55.5 | 59.5 | 57.5 | 61.5 | 61.0 | 57 |
| | 41.0 | 49.5 | 56.0 | 54.5 | 48 | 55.5 | 58.5 | 60.5 | 60.0 | 60.5 | 59.5 |
| | 43.5 | 47.0 | 54.0 | 56.5 | 43 | 58.0 | 60.0 | 56.0 | 60.5 | 51.0 | 61 |
| | 40.0 | 45.5 | 56.0 | 49.0 | 44.5 | 52.0 | 58.0 | 56.0 | 61.0 | 60.5 | 55.5 |
| | 42.0 | 42.0 | 49.0 | 49.5 | 45 | 55.5 | 57.5 | 60.0 | 57.5 | 59.5 | 64 |
| | 44.0 | 45.0 | 44.5 | 49.5 | 45.5 | 52.0 | 57.5 | 61.5 | 60.5 | 60.5 | 61.5 |
| | 42.0 | 45.0 | 54.0 | 56.5 | 45.5 | 55.5 | 58.0 | 57.0 | 61.5 | 59.5 | 56 |
| | 42.5 | 47.5 | 56.0 | 45.5 | 52.5 | 52.0 | 61.5 | 58.5 | 66.0 | 62.0 | 64 |
| | 39.5 | 40.5 | 50.0 | 51.5 | 46.5 | 55.5 | 57.0 | 59.0 | 62.0 | 59.5 | 63 |
| | 41.0 | 45.5 | 52.5 | 46.0 | 43 | 56.5 | 58.0 | 62.5 | 57.0 | 61.0 | 56 |
| | 41.0 | 41.5 | 49.0 | 50.0 | 45 | 54.0 | 62.0 | 54.0 | 62.0 | 56.5 | 62 |
| | 44.0 | 46.0 | 50.0 | 56.0 | 45 | 53.5 | 60.0 | 60.0 | 60.0 | 58.0 | 64.5 |
| | 38.0 | 47.5 | 53.0 | 55.5 | 47 | 51.5 | 61.0 | 58.5 | 59.0 | 58.5 | 60 |
| | 43.5 | 48.0 | 2.5 | 55.5 | 47 | | 57.0 | 56.0 | 57.0 | 58.5 | 61 |
| *Average | 41.7 | 45.6 | 48.2 | 52.8 | 45.6 | 54.4 | 59.1 | 58.2 | 60.5 | 59.2 | 60.1 |
| **Adjusted Average | 33 | 37 | 39 | 42 | 36 | 44 | 47 | 47 | 48 | 47 | 48 |

*Average = Rebound Value (Q)

**Adjusted Average = Average x Form factor of standard cylinders (i.e. 0.8)

**Adjusted Average will be used for the graphs

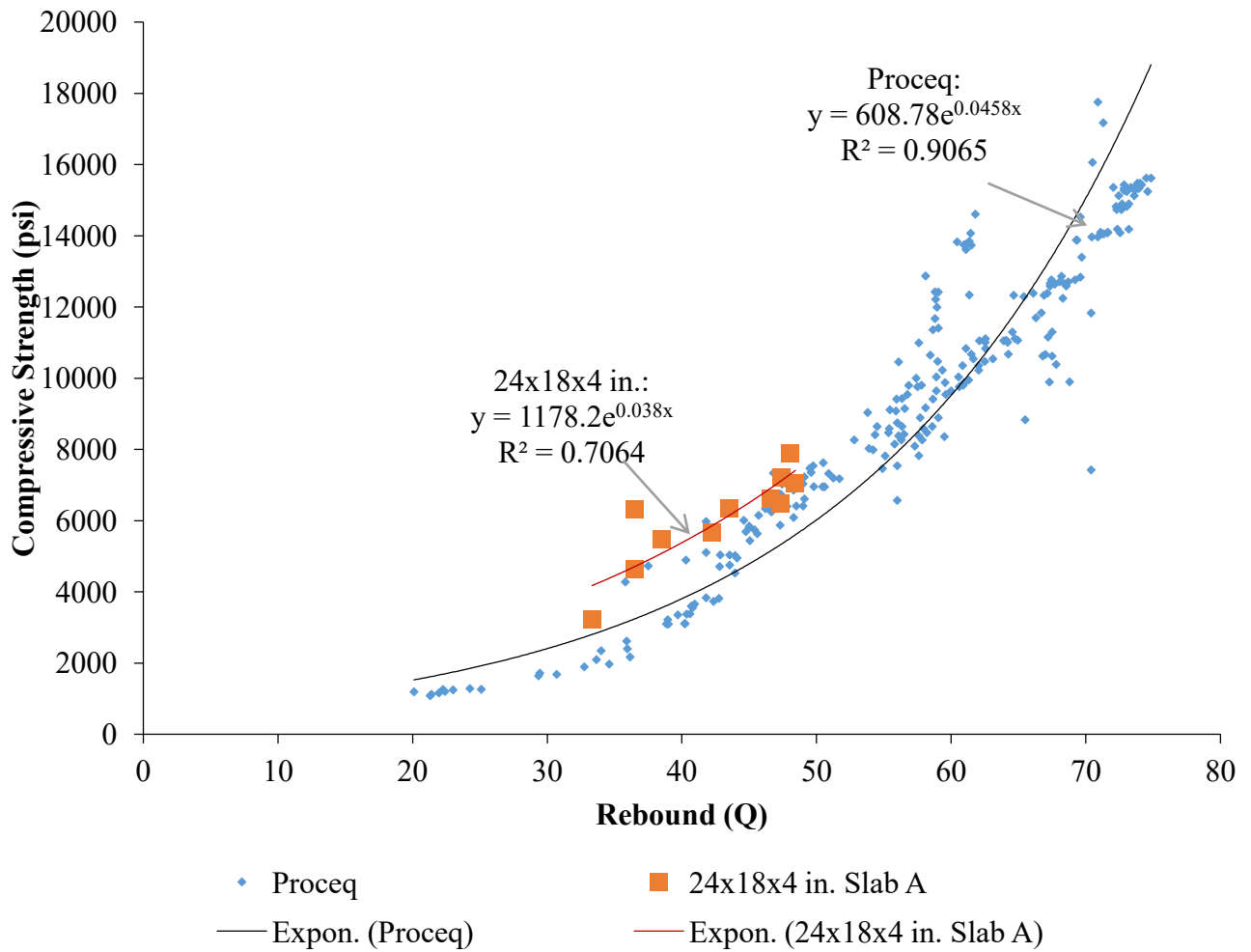


Figure B-2: Rebound Value (Q) vs. Compressive Strength (psi) for 24x18x4 in. Slab A

Table B-3: Rebound Values for Retaining Wall A

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 42 | Day 56 | Day 90 | Day 120 | Day 180 |
|----------------------------|--------------|--------------|--------------|---------------|---------------|---------------|---------------|---------------|---------------|----------------|----------------|
| 6x12 in. Str. (psi) | 3219 | 4648 | 5484 | 5680 | 6322 | 6356 | 6474 | 6621 | 7045 | 7207 | 7880 |
| | 34.0 | 50.5 | 46.5 | 43.5 | 44.0 | 45.0 | 50.0 | 49.5 | 51.5 | 53.0 | 53 |
| | 35.5 | 42.0 | 40.5 | 49.0 | 46.0 | 44.5 | 49.5 | 54.0 | 51.5 | 54.5 | 55.5 |
| | 36.5 | 39.5 | 46.5 | 42.5 | 47.0 | 44.5 | 52.0 | 48.0 | 53.0 | 57.0 | 56.5 |
| | 35.5 | 42.0 | 40.0 | 43.0 | 44.5 | 43.0 | 48.5 | 53.5 | 57.5 | 56.0 | 55 |
| | 38.5 | 42.0 | 42.0 | 43.5 | 45.5 | 42.0 | 52.0 | 50.0 | 54.0 | 53.0 | 55 |
| | 36.5 | 42.0 | 48.5 | 45.0 | 44.5 | 46.0 | 51.5 | 50.5 | 52.0 | 56.0 | 56 |
| | 37.0 | 47.5 | 49.0 | 43.5 | 47.0 | 48.0 | 50.5 | 51.5 | 57.5 | 53.5 | 54 |
| | 38.0 | 53.5 | 41.0 | 47.0 | 48.0 | 49.0 | 50.5 | 45.0 | 52.0 | 54.0 | 52 |
| | 35.5 | 46.0 | 41.5 | 48.0 | 45.5 | 44.5 | 47.5 | 50.5 | 56.5 | 54.5 | 54.5 |
| | 40.0 | 38.5 | 45.0 | 43.5 | 44.0 | 50.5 | 47.5 | 49.0 | 53.5 | 53.0 | 52 |
| | 39.0 | 40.0 | 43.5 | 43.5 | 45.0 | 47.0 | 47.0 | 52.0 | 55.5 | 58.5 | 52 |
| | 34.5 | 40.0 | 42.5 | 45.0 | 45.5 | 47.5 | 48.0 | 51.0 | 53.0 | 57.0 | 53.5 |
| | 39.5 | 40.0 | 43.5 | 46.5 | 45.0 | 48.5 | 47.5 | 51.5 | 55.5 | 53.5 | 58.5 |
| | 36.5 | 39.5 | 44.0 | 45.0 | 44.0 | | 47.0 | 55.0 | 51.5 | 59.5 | 59 |
| | 38.5 | 40.5 | 46.5 | 42.5 | 44.0 | | 46.5 | 55.0 | 52.5 | 56.0 | 53.5 |
| *Average | 37.0 | 42.9 | 44.0 | 44.7 | 45.3 | 46.2 | 49.0 | 51.1 | 53.8 | 55.3 | 54.7 |
| **Adjusted Average | 30 | 34 | 35 | 36 | 36 | 37 | 39 | 41 | 43 | 44 | 44 |

*Average = Rebound Value (Q)

**Adjusted Average = Average x Form factor of standard cylinders (i.e. 0.8)

**Adjusted Average will be used for the graphs

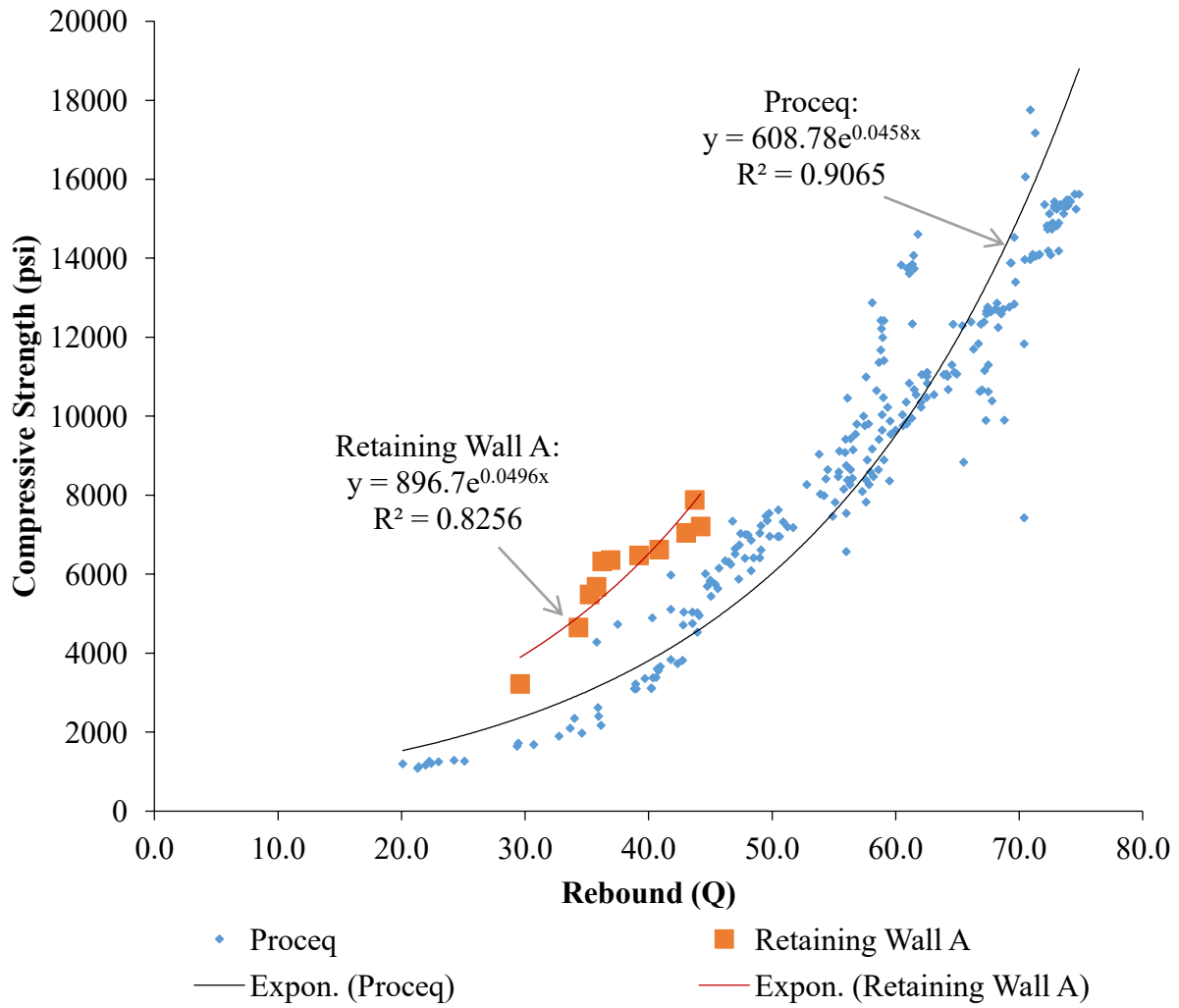


Figure B-3: Rebound Value (Q) vs. Compressive Strength (psi) for Retaining Wall A

Table B-4: Rebound Values for Group B 6x12 in. Cylinders

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 35 | | | Day 42 | | | Day 56 | | | Day 90 | | | Day 120 | | | Day 180 | | |
|----------------------------|-------|-------|-------|--------|--------|--------|--------|------|------|--------|------|------|--------|------|------|--------|------|------|---------|------|------|---------|------|------|
| 6x12 in. Str. (psi) | 3487 | 4833 | 5150 | 5715 | 6226 | 6403 | 5994 | 6260 | 6368 | 6351 | 6203 | 6745 | 6834 | 7163 | 6732 | 7014 | 7554 | 7116 | 6919 | 6651 | 7189 | 7817 | 7641 | 7852 |
| | 40.0 | 47.5 | 55.5 | 56.0 | 54 | 58.0 | 58.5 | 56 | 60 | 59.0 | 60.0 | 62.0 | 61.0 | 63.5 | 60.0 | 59.5 | 66.5 | 64.0 | 63.5 | 66.5 | 64.5 | 64.5 | 65 | 65 |
| | 41.0 | 46.5 | 54.0 | 54.0 | 59.5 | 58.0 | 59 | 57 | 61 | 65.0 | 59.5 | 61.5 | 63.0 | 58.5 | 59.5 | 65.5 | 65.0 | 62.5 | 62.0 | 63.5 | 64.0 | 65 | 61.5 | 68 |
| | 40.0 | 44.5 | 55.0 | 55.0 | 54.5 | 60.0 | 64.5 | 62 | 56.5 | 61.5 | 61.5 | 61.5 | 61.0 | 62.5 | 64.5 | 64.5 | 69.5 | 61.0 | 60.0 | 64.0 | 59.0 | 64.5 | 67 | 63.5 |
| | 42.5 | 44.0 | 49.0 | 57.5 | 53 | 61.5 | 61 | 56.5 | 60 | 62.0 | 60.5 | 60.5 | 60.0 | 64.5 | 68.0 | 63.0 | 62.0 | 60.0 | 62.5 | 61.5 | 55.5 | 64.5 | 62.5 | 66.5 |
| | 47.5 | 54.0 | 55.0 | 55.0 | 55.5 | 58.0 | 63 | 57.5 | 60.5 | 63.5 | 61.0 | 61.0 | 64.0 | 66.0 | 64.5 | 64.0 | 66.0 | 64.5 | 66.0 | 62.5 | 61.5 | 67.5 | 63.5 | 61 |
| | 47.0 | 49.0 | 58.0 | 60.0 | 58 | 60.5 | 63.5 | 63 | 63.5 | 62.5 | 59.0 | 63.5 | 63.0 | 64.0 | 63.5 | 60.5 | 65.0 | 66.5 | 65.5 | 59.5 | 65.0 | 65 | 64 | 67 |
| | 41.0 | 46.0 | 55.5 | 60.0 | 56.5 | 62.5 | 61 | 63 | 61 | 61.0 | 4.0 | 59.0 | 63.0 | 62.5 | 60.5 | 61.0 | 60.0 | 65.5 | 63.5 | 62.0 | 62.0 | 69 | 66 | 67 |
| | 41.0 | 53.0 | 52.5 | 55.0 | 59.5 | 58.0 | 62 | 60 | 57.5 | 60.0 | 63.5 | 64.0 | 62.0 | 60.0 | 60.0 | 61.5 | 65.0 | 64.5 | 64.5 | 64.0 | 60.0 | 64.5 | 65 | 63 |
| | 43.0 | 51.5 | 56.0 | 58.5 | 51.5 | 58.5 | 62.5 | 58.5 | 61.5 | 63.5 | 63.0 | 61.5 | 59.5 | 60.0 | 64.0 | 63.5 | 67.0 | 61.5 | 61.5 | 60.0 | 64.0 | 65.5 | 66 | 67.5 |
| | 38.5 | 52.0 | 50.5 | 57.0 | 57 | 60.0 | 58 | 62 | 62.5 | 61.5 | 62.0 | 60.0 | 62.0 | 64.0 | 65.0 | 61.5 | 69.0 | 66.0 | 60.5 | 62.0 | 63.5 | 67 | 65 | 69 |
| | 43.5 | 47.5 | 54.5 | 58.5 | 55 | 58.0 | 63.5 | 64 | 59 | 62.5 | 59.5 | 59.0 | 63.0 | 62.5 | 62.0 | 62.5 | 65.0 | 62.5 | 64.5 | 61.5 | 63.5 | 65.5 | 64.5 | 63 |
| | 41.5 | 51.5 | 55.0 | 58.5 | 55 | 61.0 | 61 | 60 | 61 | 64.0 | 63.5 | 62.0 | 63.5 | 62.0 | 65.0 | 65.5 | 67.0 | 60.0 | 61.5 | 65.0 | 62.0 | 69.5 | 60.5 | 66.5 |
| | 45.5 | 48.0 | 52.5 | 61.0 | 51.5 | 59.0 | 63.5 | 64 | 5 | 59.0 | 61.5 | 59.0 | 60.0 | 60.5 | 66.0 | 60.0 | 62.0 | 61.0 | 61.5 | 62.5 | 64.5 | 69.5 | 67 | 63 |
| | 41.5 | 52.5 | 56.0 | 56.5 | 51.5 | 59.0 | 59 | 63 | 61.5 | | 62.5 | 61.0 | 62.5 | 63.5 | 63.0 | 65.5 | 65.0 | 66.0 | 63.0 | 61.0 | 63.5 | 65.5 | 65.5 | 65 |
| | 45.5 | 45.0 | 54.5 | 56.5 | 52 | 59.0 | 58 | 61 | 62.5 | | 63.5 | 62.0 | 63.5 | 66.5 | 62.5 | 60.0 | 66.0 | 61.5 | 63.5 | 60.5 | 59.5 | 67 | 62 | 67 |
| | 40.0 | 48.5 | 55.0 | | | 61.0 | 59 | 61 | 58 | | | | | | 59.0 | | | | | | | | | |
| | 40.5 | 51.0 | 54.0 | | | 58.0 | | | | | | | | | | | | | | | | | | |
| *Average | 42.3 | 48.9 | 54.3 | 57.3 | 54.9 | 59.4 | 61.1 | 60.5 | 56.9 | 61.9 | 57.6 | 61.2 | 62.1 | 62.7 | 62.9 | 62.5 | 65.3 | 63.1 | 62.9 | 62.4 | 62.1 | 66.3 | 64.3 | 65.5 |
| **Adjusted Average | 34 | 39 | 43 | 46 | 44 | 48 | 49 | 48 | 46 | 50 | 46 | 49 | 50 | 50 | 50 | 50 | 52 | 51 | 50 | 50 | 50 | 53 | 51 | 52 |

*Average = Rebound Value (Q)

**Adjusted Average = Average x Form factor of standard cylinders (i.e. 0.8)

**Adjusted Average will be used for the graphs

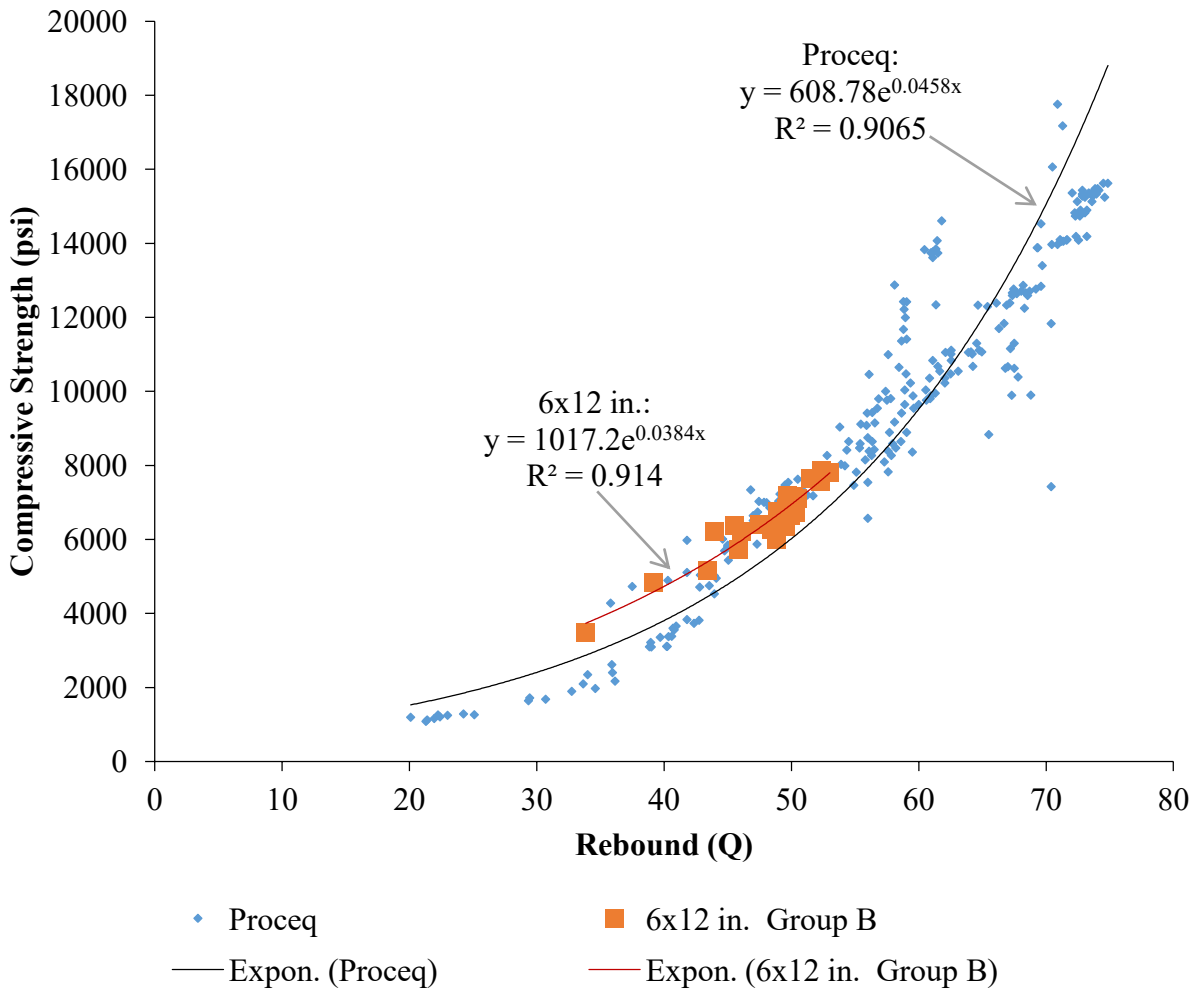


Figure B-4: Rebound Value (Q) vs. Compressive Strength (psi) for Group B 6x12 in. Cylinders

Table B-5: Rebound Values for 24x18x4 in. Slab B

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 42 | Day 56 | Day 90 | Day 120 | Day 180 |
|----------------------------|-------|-------|-------|--------|--------|--------|---------|--------|--------|---------|---------|
| 6x12 in. Str. (psi) | 3487 | 4833 | 5150 | 5715 | 6226 | 6403 | 6459.67 | 6910 | 7065 | 7054 | 7770 |
| | 35.5 | 37.0 | 42.0 | 47.0 | 45 | 43.5 | 48.5 | 48.0 | 51 | 51.0 | 58 |
| | 36.5 | 38.5 | 43.5 | 43.0 | 45 | 42.5 | 53.5 | 48.0 | 58.0 | 55.0 | 56.5 |
| | 38.0 | 44.0 | 38.0 | 41.5 | 48 | 49.5 | 48.5 | 50.5 | 53.5 | 54.0 | 57.5 |
| | 37.5 | 35.5 | 42.0 | 50.5 | 45 | 46.5 | 45.0 | 52.5 | 60.5 | 59.0 | 63 |
| | 36.0 | 43.0 | 45.5 | 42.5 | 48 | 46.5 | 43.0 | 51.0 | 54.5 | 57.5 | 60 |
| | 35.0 | 34.0 | 41.5 | 50.0 | 44.5 | 48.5 | 49.5 | 54.0 | 58.0 | 54.5 | 52.5 |
| | 35.0 | 38.0 | 38.0 | 46.0 | 45 | 45.5 | 54.0 | 52.5 | 59.0 | 57.0 | 57.5 |
| | 36.5 | 34.0 | 36.0 | 49.0 | 45.5 | 49.0 | 50.0 | 52.5 | 56.5 | 61.0 | 61 |
| | 33.5 | 34.5 | 46.0 | 47.5 | 45.5 | 46.5 | 47.5 | 49.0 | 55.5 | 58.0 | 57.5 |
| | 37.5 | 40.5 | 45.0 | 49.0 | 52.5 | 48.0 | 51.0 | 53.0 | 60.5 | 55.5 | 59 |
| | 35.0 | 42.5 | 35.5 | 45.0 | 46.5 | 47.5 | 46.5 | 51.5 | 55.0 | 56.0 | 56.5 |
| | 34.5 | 35.0 | 49.0 | 48.0 | 45 | 50.5 | 47.5 | 49.0 | 54.0 | 63.0 | 59 |
| | 37.5 | 36.5 | 42.0 | 50.5 | 47 | 46.0 | 46.0 | 53.0 | 57.0 | 54.0 | 60 |
| | 34.5 | 38.5 | 38.0 | 53.5 | 47 | 48.5 | 46.5 | 52.0 | 56.0 | 54.5 | 57.5 |
| | 35.5 | 40.5 | 42.5 | 54.0 | 47 | 48.0 | 46.5 | 54.5 | 53.5 | 52.5 | 59.5 |
| | | | | | | | | 54.5 | | | |
| *Average | 35.9 | 38.1 | 41.6 | 47.8 | 46.4 | 47.1 | 48.2 | 51.6 | 56.5 | 56.2 | 58.3 |
| **Adjusted Average | 29 | 31 | 33 | 38 | 37 | 38 | 39 | 41 | 45 | 45 | 47 |

*Average = Rebound Value (Q)

**Adjusted Average = Average x Form factor of standard cylinders (i.e. 0.8)

**Adjusted Average will be used for the graphs

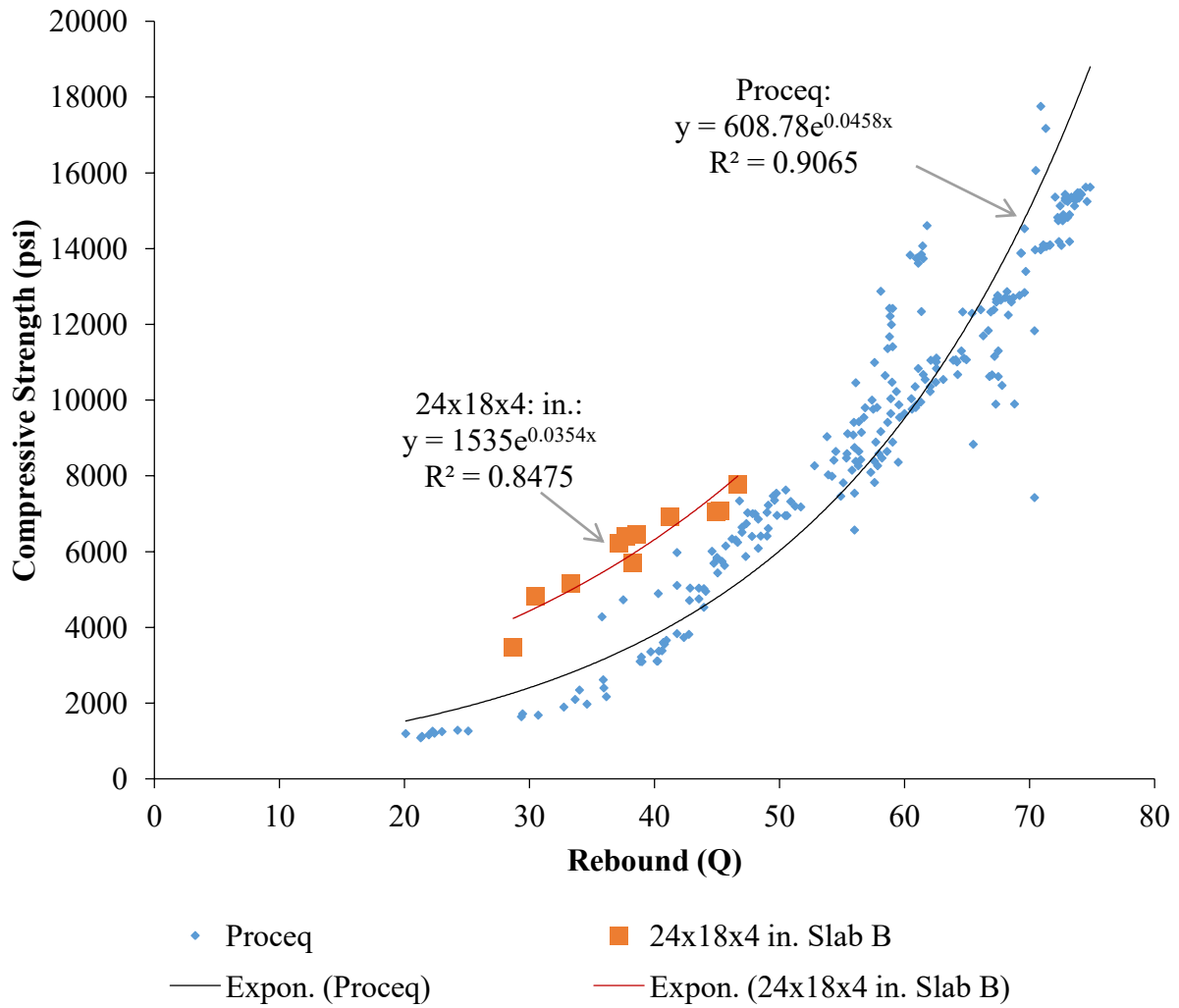


Figure B-5: Rebound Value (Q) vs. Compressive Strength (psi) for 24x18x4 in. Slab B

Table B-6: Rebound Values for Retaining Wall B

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 42 | Day 56 | Day 90 | Day 120 | Day 180 |
|----------------------------|-------|-------|-------|--------|--------|--------|--------|--------|--------|---------|---------|
| 6x12 in. Str. (psi) | 3487 | 4833 | 5150 | 5715 | 6226 | 6403 | 6460 | 6910 | 7065 | 7054 | 7770 |
| | 35.0 | 39.5 | 39.5 | 42.0 | 45 | 47.0 | 50.0 | 51.0 | 51.5 | 51.5 | 50.5 |
| | 34.0 | 37.5 | 40.0 | 42.5 | 54.5 | 43.5 | 50.0 | 51.0 | 54.0 | 49.5 | 53.5 |
| | 35.5 | 38.5 | 40.0 | 44.5 | 46.5 | 47.0 | 49.0 | 49.5 | 51.0 | 51.5 | 59 |
| | 37.5 | 39.0 | 40.5 | 42.0 | 47.5 | 47.0 | 47.5 | 46.0 | 52.0 | 48.5 | 58.5 |
| | 36.5 | 38.0 | 39.5 | 46.0 | 47 | 47.5 | 48.0 | 56.5 | 53.0 | 55.5 | 53.5 |
| | 36.0 | 38.5 | 40.5 | 40.5 | 45.5 | 44.0 | 46.5 | 47.0 | 50.5 | 59.0 | 56.5 |
| | 36.0 | 37.5 | 39.5 | 42.5 | 46.5 | 47.5 | 49.0 | 46.0 | 51.0 | 54.0 | 56 |
| | 35.0 | 36.5 | 38.5 | 40.0 | 47 | 44.5 | 50.5 | 45.0 | 52.5 | 56.5 | 50 |
| | 35.5 | 36.5 | 51.0 | 42.5 | 46 | 43.5 | 46.5 | 47.5 | 49.5 | 53.0 | 52 |
| | 37.0 | 35.5 | 40.0 | 40.0 | 44.5 | 45.5 | 45.5 | 49.0 | 52.0 | 51.5 | 53 |
| | 34.0 | 35.5 | 38.5 | 41.0 | 46.5 | 43.0 | 48.0 | 48.5 | 56.5 | 51.0 | 54 |
| | 38.0 | 37.5 | 38.0 | 41.0 | 42.5 | 47.0 | 45.5 | 49.0 | 50.5 | 56.0 | 50.5 |
| | 33.0 | 38.5 | 46.0 | 41.5 | 46.5 | | 44.5 | 48.5 | 50.0 | 56.5 | 56 |
| | 32.5 | 42.0 | 39.0 | 42.0 | 46.5 | | 46.0 | 49.0 | 52.5 | 59.0 | 55 |
| | 34.5 | 37.5 | 39.5 | | | | 47.5 | 51.5 | 57.0 | 52.5 | 51.5 |
| | 36.5 | 38.5 | | | | | | 49.0 | | | |
| | 34.5 | | | | | | | | | | |
| *Average | 35.4 | 37.9 | 40.7 | 42.0 | 46.6 | 45.6 | 47.6 | 49.0 | 52.2 | 53.7 | 54.0 |
| **Adjusted Average | 28 | 30 | 33 | 34 | 37 | 36 | 38 | 39 | 42 | 43 | 43 |

*Average = Rebound Value (Q)

**Adjusted Average = Average x Form factor of standard cylinders (i.e. 0.8)

**Adjusted Average will be used for the graphs

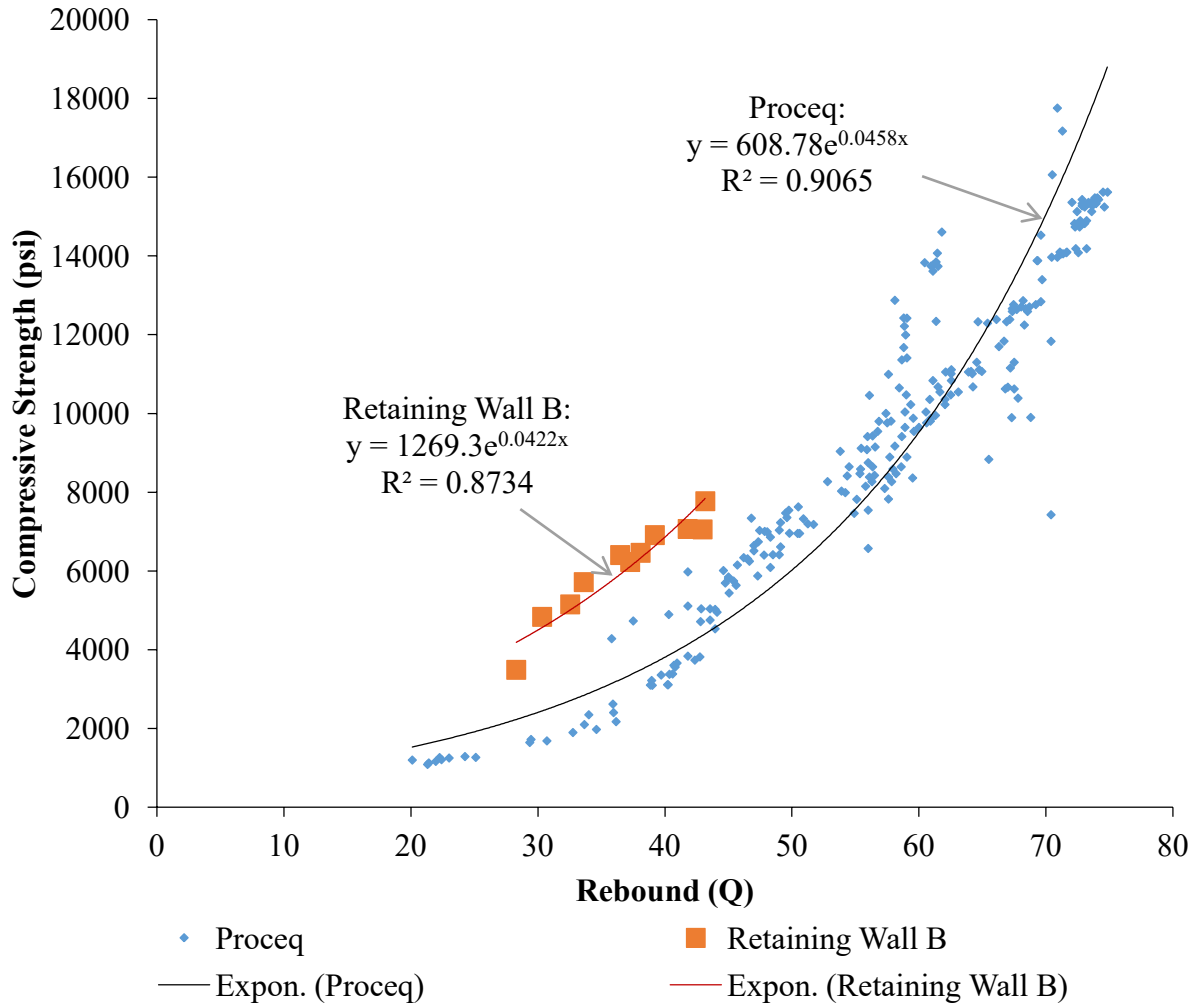


Figure B-6: Rebound Value (Q) vs. Compressive Strength (psi) for Retaining Wall B

Table B-7: Rebound Values for Group C 6x12 in. Cylinders

| | Day1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 35 | | | Day 42 | | | Day 56 | | | Day 90 | | | Day 120 | | | Day 180 | | |
|----------------------------|------|-------|-------|--------|--------|--------|--------|------|------|--------|------|------|--------|------|------|--------|------|------|---------|------|------|---------|------|------|
| 6x12 in. Str. (psi) | 3269 | 4622 | 5059 | 5383 | 5789 | 6034 | 5982 | 6766 | 6291 | 6297 | 5917 | 6851 | 7058 | 7100 | 6792 | 6896 | 7044 | 6941 | 7579 | 7185 | 7841 | 7297 | 7704 | 7406 |
| | 45.5 | 53.0 | 53.0 | 56.0 | 61 | 62.0 | 59 | 61.5 | 59 | 64.0 | 60.5 | 61.0 | 62.5 | 59.0 | 55.5 | 64.0 | 60.5 | 63.5 | 66.5 | 68.0 | 61.0 | 67.5 | 65.5 | 63.5 |
| | 41.5 | 51.5 | 55.0 | 59.0 | 60 | 60.5 | 61 | 60.5 | 58.5 | 61.0 | 61.0 | 61.5 | 64.5 | 60.0 | 61.5 | 63.5 | 60.0 | 67.5 | 59.5 | 65.5 | 64.0 | 69.5 | 63.5 | 65 |
| | 43.5 | 51.5 | 56.0 | 57.0 | 62.5 | 60.0 | 61.5 | 60.5 | 58.5 | 63.0 | 64.5 | 62.0 | 61.0 | 61.5 | 64.5 | 64.0 | 64.0 | 60.0 | 61.0 | 64.5 | 63.5 | 65 | 66 | 68 |
| | 45.5 | 55.0 | 55.0 | 56.0 | 58.5 | 61.5 | 62.5 | 60.5 | 62 | 61.0 | 64.4 | 60.5 | 55.0 | 66.5 | 65.5 | 62.5 | 65.0 | 63.5 | 66.5 | 64.0 | 66.5 | 66 | 65 | 67 |
| | 40.0 | 50.5 | 55.5 | 59.5 | 61 | 61.0 | 61.5 | 59.5 | 60 | 60.0 | 61.0 | 62.0 | 62.0 | 56.0 | 64.5 | 63.0 | 62.5 | 62.5 | 65.0 | 64.0 | 64.0 | 65.5 | 64.5 | 64.5 |
| | 41.0 | 55.0 | 54.0 | 57.5 | 60 | 58.5 | 59 | 60.5 | 61.5 | 59.0 | 64.0 | 63.0 | 61.5 | 64.5 | 63.0 | 60.0 | 63.0 | 64.0 | 64.5 | 63.5 | 63.0 | 66.5 | 65.5 | 65 |
| | 42.0 | 48.5 | 50.5 | 56.0 | 55.5 | 58.0 | 63 | 61.5 | 59 | 60.0 | 62.0 | 60.5 | 63.0 | 61.5 | 58.5 | 60.0 | 65.0 | 65.0 | 61.5 | 64.5 | 63.0 | 64.5 | 66 | 66.5 |
| | 43.5 | 50.5 | 55.5 | 56.0 | 57 | 64.5 | 61 | 58 | 58.5 | 63.0 | 63.0 | 61.5 | 62.5 | 59.0 | 61.5 | 60.5 | 63.0 | 67.0 | 67.5 | 66.0 | 65.0 | 63.5 | 61.5 | 62.5 |
| | 43.0 | 49.0 | 55.0 | 56.5 | 59 | 60.0 | 63 | 62 | 61.5 | 58.5 | 65.0 | 58.5 | 63.0 | 63.5 | 60.5 | 62.5 | 66.0 | 63.5 | 64.0 | 63.0 | 67.0 | 64.5 | 64.5 | 63 |
| | 46.0 | 51.0 | 55.0 | 57.0 | 60.5 | 61.0 | 62.5 | 59 | 62 | 63.0 | 58.5 | 63.0 | 65.0 | 63.5 | 66.5 | 61.0 | 65.5 | 63.0 | 59.5 | 61.5 | 65.5 | 68.5 | 65.5 | 66.5 |
| | 43.0 | 48.5 | 52.5 | 56.0 | 56.5 | 59.5 | 61 | 60.5 | 59.5 | 59.5 | 61.0 | 59.5 | 66.5 | 63.0 | 62.0 | 59.5 | 64.5 | 62.5 | 64.5 | 67.0 | 62.5 | 64.5 | 66.5 | 61.5 |
| | 38.5 | 49.0 | 54.5 | 55.5 | 59.5 | 60.5 | | | | 66.0 | 63.0 | 62.0 | 61.5 | 59.5 | 64.5 | 62.5 | 62.5 | 67.5 | 67.5 | 63.5 | 65.0 | 68 | 64 | 67.5 |
| | 42.0 | 52.5 | 51.5 | 55.5 | 60 | 64.0 | | | | 61.0 | 63.5 | 59.0 | 61.0 | 62.0 | 62.0 | 63.0 | 65.5 | 66.0 | 64.5 | 65.5 | 65.0 | 68 | 61.5 | 69.5 |
| | 44.0 | 54.5 | 54.0 | 56.5 | 61 | 60.5 | | | | 64.0 | 60.0 | 59.0 | 58.5 | 65.5 | 58.5 | 63.5 | 63.5 | 63.0 | 62.0 | 64.5 | 68.5 | 67.5 | 67 | 66.5 |
| | 44.0 | 53.0 | 55.0 | 58.5 | | 59.0 | | | | 62.0 | 62.0 | 60.0 | 60.5 | 64.0 | 59.5 | 61.0 | 61.5 | 65.0 | 64.5 | 63.5 | 67.0 | 63.5 | 66.5 | 66 |
| *Average | 42.9 | 51.5 | 54.1 | 56.8 | 59.4 | 60.7 | 61.4 | 60.4 | 60.0 | 61.7 | 62.2 | 60.9 | 61.9 | 61.9 | 61.9 | 62.0 | 63.5 | 64.2 | 63.9 | 64.6 | 64.7 | 66.2 | 64.9 | 65.5 |
| **Adjusted Average | 34 | 41 | 43 | 45 | 48 | 49 | 49 | 48 | 48 | 49 | 50 | 49 | 49 | 50 | 49 | 50 | 51 | 51 | 51 | 52 | 52 | 53 | 52 | 52 |

*Average = Rebound Value(Q)

**Adjusted Average = Average x Form factor of standard cylinders (i.e. 0.8)

**Adjusted Average will be used for the graphs

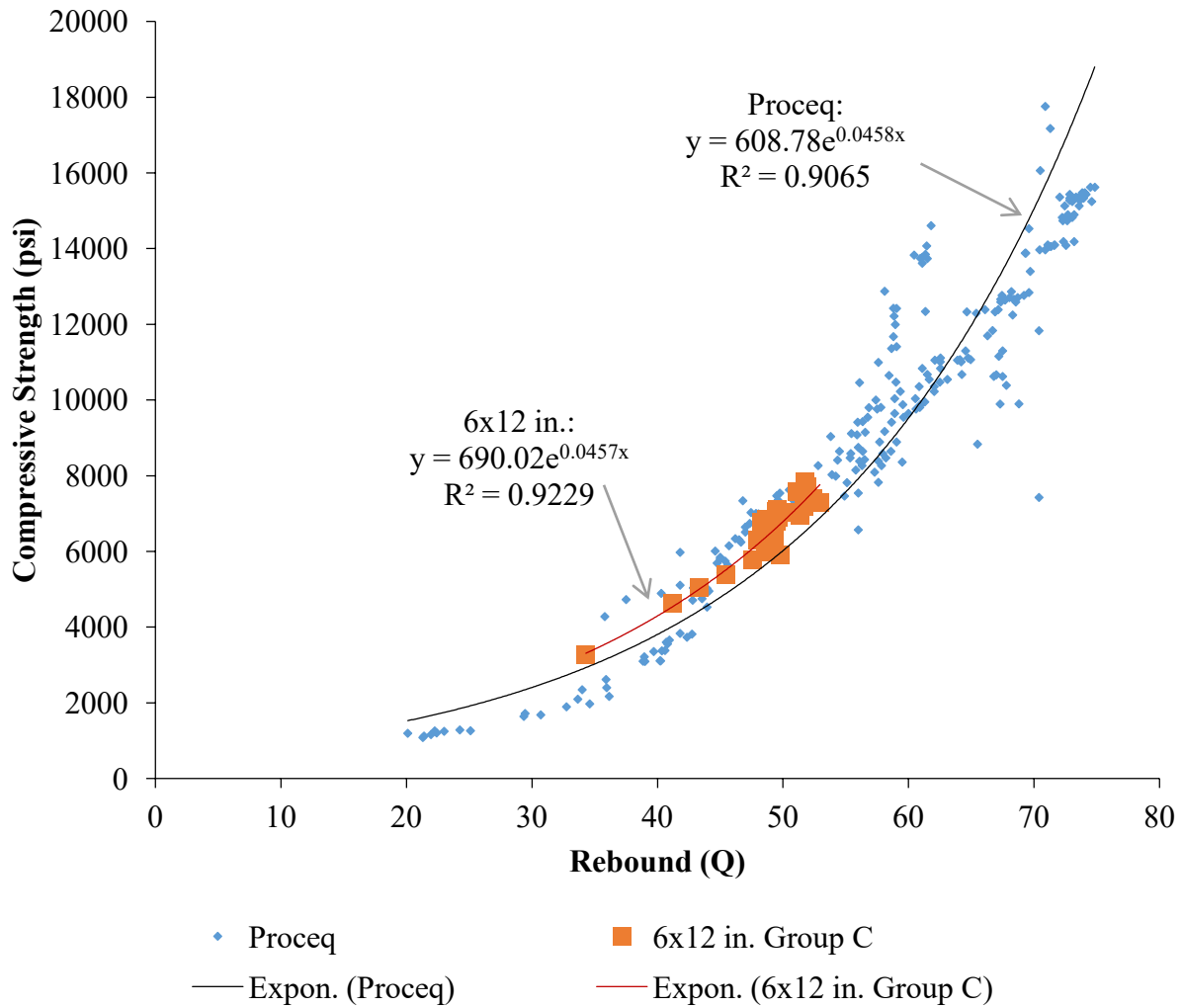


Figure B-7: Rebound Value (Q) vs. Compressive Strength (psi) for Group C 6x12 in. Cylinders

Table B-8: Rebound Values for 24x18x4 in. Slab C

| | Day1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 42 | Day 56 | Day 90 | Day 120 | Day 180 |
|----------------------------|------|-------|-------|--------|--------|--------|--------|--------|--------|---------|---------|
| 6x12 in. Str. (psi) | 3269 | 4622 | 5059 | 5383 | 5789 | 6034 | 6574 | 6925 | 6993 | 7382 | 7469 |
| Core Str. (psi) | | | | 4580 | 5401 | | | 5719 | 6328 | 5953 | 7187 |
| | 36.5 | 46.0 | 55.5 | 62.5 | 60.5 | 61.5 | 61.0 | 64.0 | 66.5 | 64.0 | 59 |
| | 34.0 | 51.5 | 51.5 | 57.5 | 56.5 | 62.0 | 58.5 | 60.0 | 63.5 | 61.5 | 69 |
| | 42.5 | 45.5 | 54.0 | 57.0 | 58.5 | 57.0 | 60.0 | 63.5 | 66.0 | 66.5 | 60.5 |
| | 40.5 | 49.0 | 52.5 | 50.0 | 58 | 62.0 | 59.0 | 62.0 | 67.0 | 63.0 | 58 |
| | 37.5 | 44.5 | 55.5 | 51.0 | 60 | 56.0 | 60.0 | 60.0 | 63.5 | 62.5 | 68.5 |
| | 36.5 | 47.0 | 53.0 | 51.0 | 61 | 60.0 | 63.0 | 59.5 | 62.0 | 62.5 | 69.5 |
| | 42.5 | 55.5 | 51.5 | 54.5 | 60.5 | 59.5 | 57.5 | 62.0 | 65.0 | 61.0 | 67 |
| | 42.0 | 41.0 | 51.0 | 55.5 | 59 | 59.5 | 57.0 | 54.5 | 61.0 | 57.5 | 63 |
| | 39.0 | 41.5 | 53.5 | 51.5 | 60.5 | 56.0 | 59.0 | 59.0 | 65.5 | 62.5 | 67 |
| | 39.0 | 49.0 | 55.0 | 50.0 | 60.5 | 58.5 | 61.5 | 61.5 | 64.5 | 63.5 | 66 |
| | 37.0 | 49.0 | 55.0 | 52.0 | 58 | 58.5 | 60.5 | 63.0 | 61.5 | 61.5 | 67.5 |
| | 42.0 | 48.0 | 51.5 | 53.0 | 60.5 | 52.0 | 57.5 | 63.0 | 60.5 | 64.5 | 63 |
| | | 51.5 | 48.5 | 51.0 | 60 | | 59.0 | 59.0 | 64.5 | 56.0 | 59 |
| | | 47.5 | 54.5 | | 60.5 | | 60.5 | 64.0 | 65.5 | 61.5 | 59.5 |
| | | | | | | | 57.5 | 61.0 | 69.0 | 57.0 | 63.5 |
| *Average | 39.1 | 47.6 | 53.0 | 53.6 | 59.6 | 58.5 | 59.4 | 61.1 | 64.4 | 61.7 | 64.0 |
| **Adjusted Average | 31 | 38 | 42 | 43 | 48 | 47 | 48 | 49 | 51 | 49 | 51 |

*Average = Rebound Value (Q)

**Adjusted Average = Average x Form factor of standard cylinders (i.e. 0.8)

**Adjusted Average will be used for the graphs

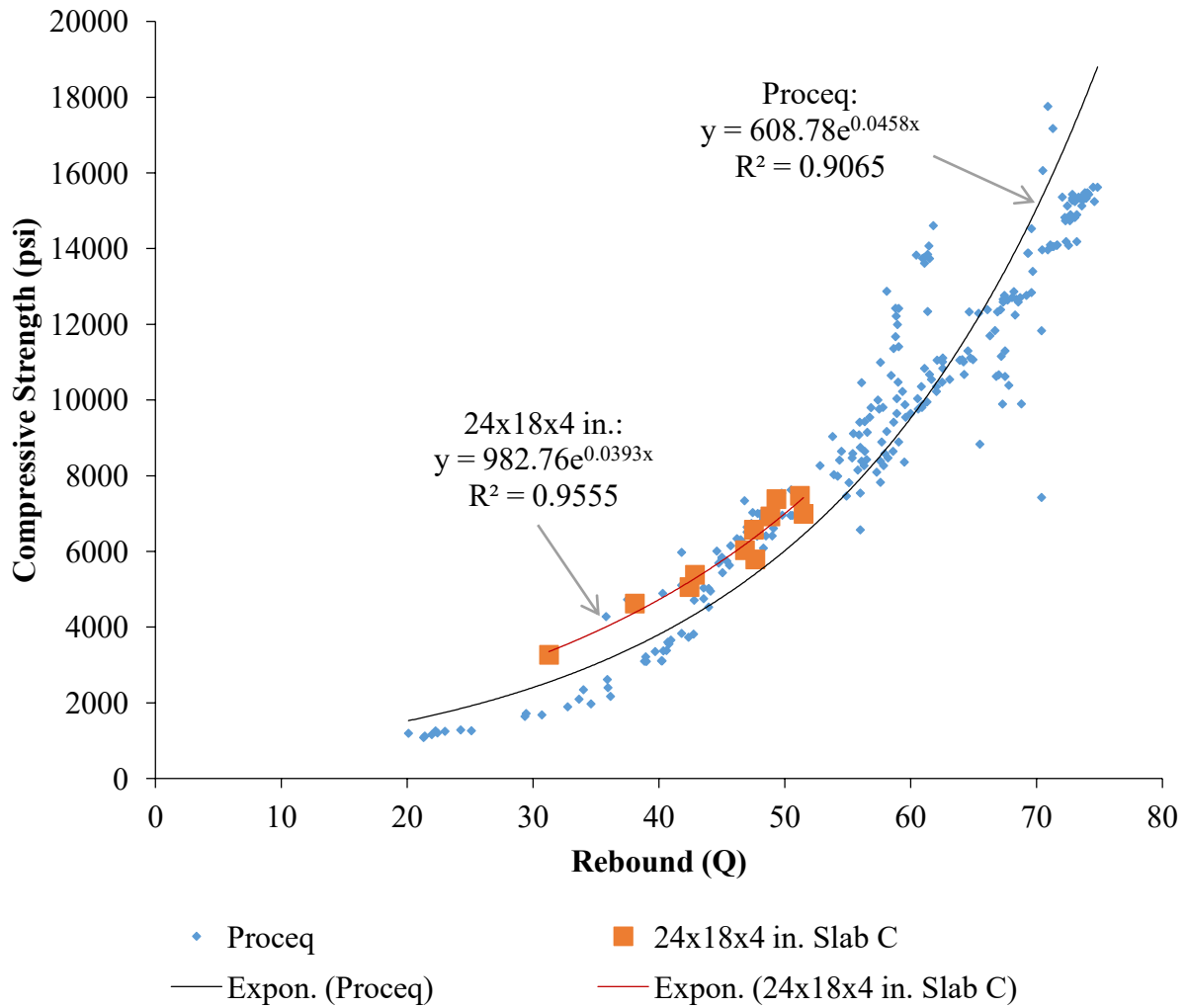


Figure B-8: Rebound Value (Q) vs. Compressive Strength (psi) for 24x18x4 in. Slab C

Appendix C

Ultrasonic Pulse Velocity Test Results for Cylinders, Slabs, and Retaining Walls

Table C-1: Ultrasonic Pulse Velocity (UPV) Test results for Group A 6x12 in. Cylinders (ft/s)

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 35 | | | Day 42 | | | Day 56 | | | Day 90 | | | Day 120 | | | Day 180 | | |
|----------------------------|-------|-------|-------|--------|--------|--------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|---------|-------|-------|---------|-------|-------|
| 6x12 in. Str. (psi) | 3219 | 4648 | 5484 | 5680 | 6322 | 6356 | 6549 | 6463 | 6264 | 6594 | 6635 | 6150 | 7003 | 6742 | 6117 | 7239 | 6948 | 6947 | 7275 | 7012 | 7333 | 7431 | 8023 | 8185 |
| | 14986 | 14803 | 15514 | 15858 | 15709 | 15408 | 16549 | 16463 | 16264 | 15883 | 15959 | 15934 | 15808 | 15909 | 15538 | 15959 | 16114 | 16010 | 16088 | 15442 | 15985 | 16404 | 15959 | 16431 |
| | 14265 | 14847 | 15490 | 15883 | 15758 | 15504 | 16098 | 16252 | 15880 | 15883 | 15959 | 15883 | 15985 | 15934 | 15883 | 15883 | 16114 | 16010 | 16114 | 15371 | 16088 | 16271 | 15883 | 16404 |
| | 14234 | 14825 | 15466 | 15909 | 15833 | 15456 | 16065 | 16042 | 15965 | 15909 | 15985 | 15934 | 16010 | 15909 | 15858 | 15883 | 16140 | 16010 | 16166 | 15371 | 15959 | 16244 | 15909 | 16377 |
| | 14388 | 14825 | 15490 | 15883 | 15808 | 15601 | 16067 | 16067 | 15990 | 15808 | 15985 | 1959 | 15934 | 15934 | 15883 | 15883 | 16114 | 15985 | 16166 | 15758 | 16010 | 16192 | 15808 | 16404 |
| | 14451 | 14847 | 15442 | 15883 | 15808 | 15674 | 16042 | 16067 | 15864 | 15858 | 15959 | 15959 | 15909 | 15909 | 15858 | 15858 | 16140 | 16062 | 16114 | 15684 | 16062 | 16010 | 15783 | 16244 |
| | | 14875 | 15442 | 15883 | 15808 | 15337 | 16016 | 16016 | 15889 | 15858 | 15883 | 15985 | 15909 | 15934 | 15883 | 15883 | 16140 | 16062 | 16140 | 15660 | 16010 | 16114 | 15734 | 16324 |
| | | 14825 | 15490 | 15883 | 15833 | 15291 | 15889 | 16067 | 15914 | 15858 | 15909 | 15959 | 15909 | 15909 | 15883 | 15858 | 16114 | 16062 | 16140 | 15660 | 16036 | 16088 | | 16140 |
| | | | 15418 | 15783 | 15858 | 15798 | 15914 | 16016 | 15965 | 15909 | 15959 | | 15833 | 15883 | 15883 | 15808 | 16088 | 16114 | 16140 | | 15883 | 16062 | | 16166 |
| | | | | | | | 16042 | 16042 | 15965 | | | | | | | 15684 | | 16114 | | 15959 | | | | |
| Average | 14465 | 14835 | 15469 | 15871 | 15802 | 15509 | 16076 | 16115 | 15966 | 15871 | 15950 | 13945 | 15912 | 15915 | 15834 | 15877 | 16072 | 16039 | 16131 | 15564 | 15999 | 16173 | 15846 | 16311 |

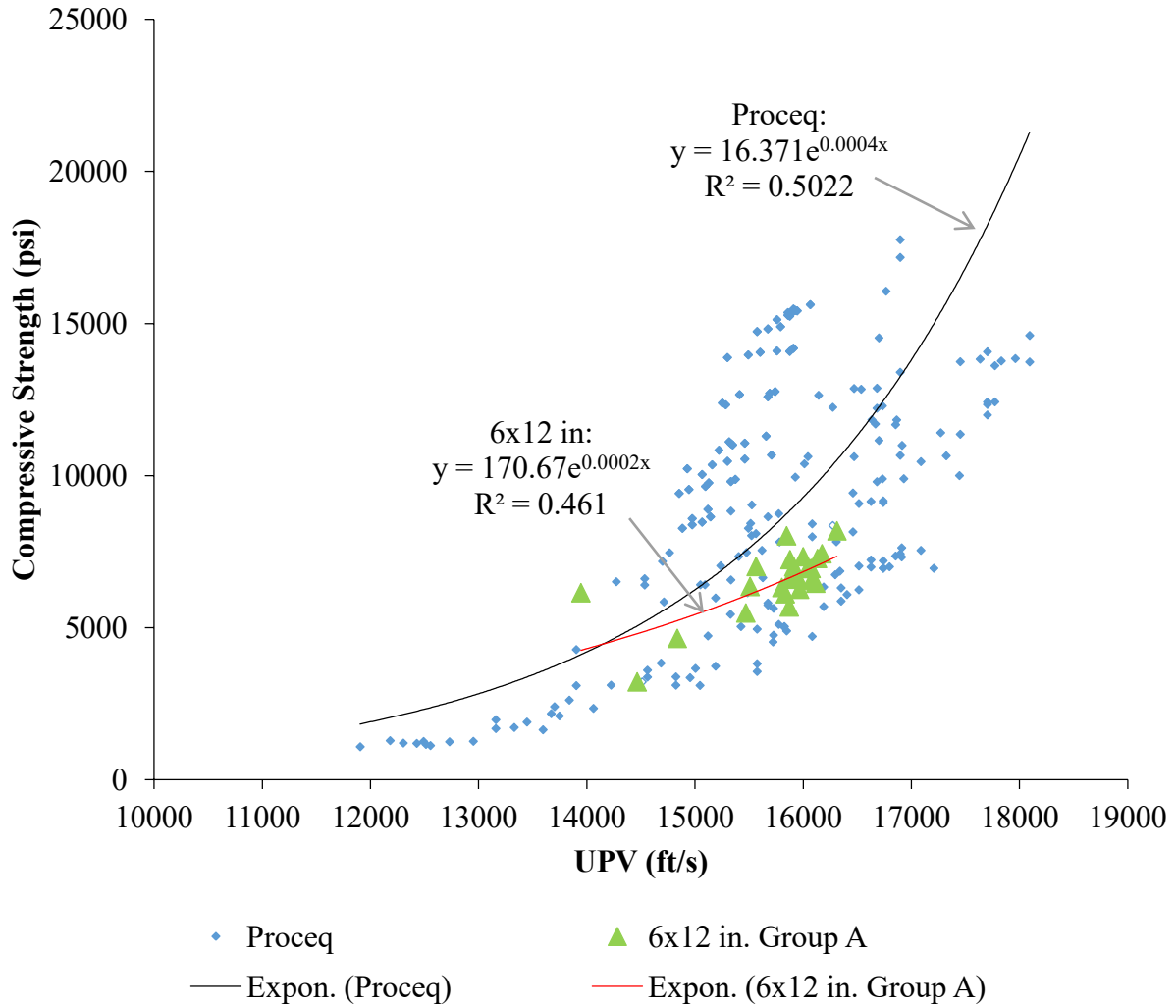


Figure C-1: UPV (ft/s) vs. Compressive Strength (psi) for Group A 6x12 in. Cylinders

Table C-2: UPV Test results for 24x18x4 in. Slab A (ft/s)

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 42 | Day 56 | Day 90 | Day 120 | Day 180 |
|----------------------------|--------------|--------------|--------------|---------------|---------------|---------------|---------------|---------------|---------------|----------------|----------------|
| 6x12 in. Str. (psi) | 3219 | 4648 | 5484 | 5680 | 6322 | 6356 | 6474 | 6621 | 7045 | 7207 | 7880 |
| Core Strength (psi) | | | | 4487 | 4740 | | | 6303 | 6865 | 5791 | 6624 |
| | 14231 | 13429 | 15213 | 15275 | 15337 | 15496 | 15974 | 15806 | 15291 | 15005 | 15346 |
| | 14286 | 14313 | 15060 | 15213 | 15291 | 15625 | 15974 | 15707 | 15823 | 15989 | 15268 |
| | 14437 | 13405 | 15136 | 15198 | 15182 | 15528 | 15974 | 15658 | 15856 | 15917 | 14860 |
| | 14563 | 13441 | 15213 | 15228 | 15167 | 15432 | 15974 | 15641 | 15806 | 15877 | 14993 |
| | 14409 | 14663 | 15182 | 15121 | 15244 | 15544 | 15907 | 15576 | 15823 | 15745 | 14919 |
| | 14606 | 14881 | 15322 | 15030 | 18091 | 15658 | 15924 | 15560 | 15823 | 15714 | 15160 |
| | 14634 | 14881 | 15167 | 15075 | 15091 | 15593 | 15957 | 15512 | 15806 | 15661 | 15222 |
| | 14563 | 14570 | 15030 | | 15275 | 15228 | 15971 | 15544 | | 15753 | 15114 |
| | 14620 | 14695 | | | 15030 | 15432 | | | | 15707 | 15206 |
| | 14563 | 14667 | | | | | | | | | |
| Average | 14491 | 14295 | 15165 | 15163 | 15523 | 15504 | 15957 | 15626 | 15747 | 15708 | 15121 |

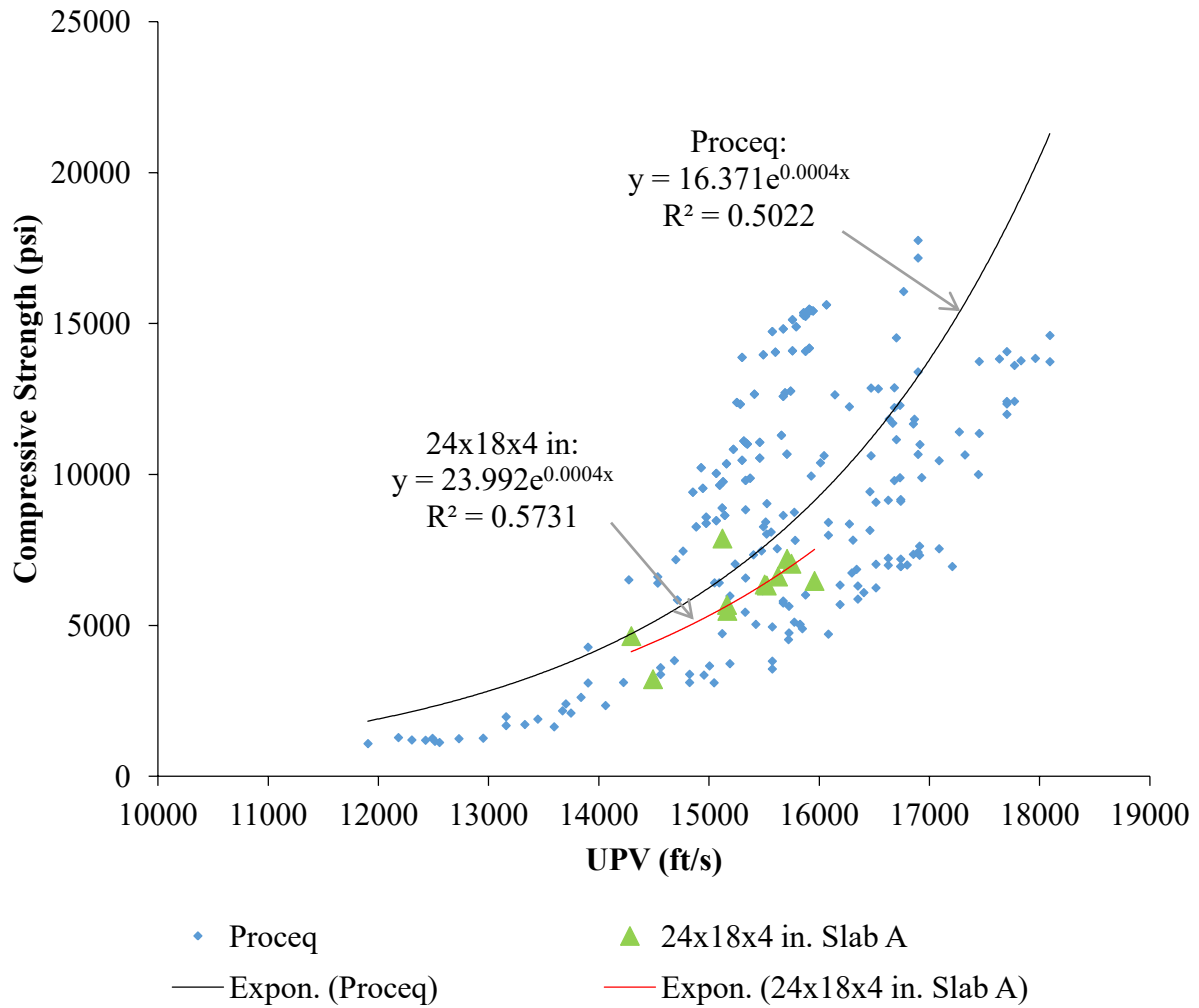


Figure C-2: UPV (ft/s) vs. Compressive Strength (psi) for 24x18x4 in. Slab A

Table C-3: UPV Test Results for Retaining Wall A (ft/s)

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 42 | Day 90 | Day 120 | Day 180 |
|--------------------------------|--------------|--------------|--------------|---------------|---------------|---------------|---------------|---------------|----------------|----------------|
| 6x12 in. Str. (psi) | 3219 | 4648 | 5484 | 5680 | 6322 | 6356 | 6474 | 7045 | 7207 | 7880 |
| | 13130 | 14080 | 14444 | 14045 | 14460 | 14447 | 14004 | 14269 | 15187 | 14231 |
| | 13130 | 14110 | 14444 | 14045 | 14490 | 14454 | 14066 | 14237 | 14908 | 14200 |
| | 13048 | 14261 | 14509 | 14013 | 14490 | 14679 | 14066 | 14140 | 15116 | 14110 |
| | 13186 | 14261 | 14509 | 13982 | 14490 | 14747 | 14128 | 14077 | 15012 | 14261 |
| | 13103 | 13904 | 14381 | 13982 | 14579 | 14713 | 14159 | 14140 | 15081 | 14080 |
| | 13021 | 14021 | 14444 | 13951 | 14549 | 14747 | 14159 | 14077 | 15081 | 14170 |
| | 12913 | 13992 | 14444 | | 14459 | 14815 | 14066 | 14045 | 15116 | 14080 |
| | 13021 | 14110 | | | | 14884 | | | 15258 | |
| | 13075 | 14080 | | | | | | | 15258 | |
| | | 14110 | | | | | | | | |
| Average | 13070 | 14093 | 14454 | 14003 | 14502 | 14686 | 14093 | 14141 | 15113 | 14162 |

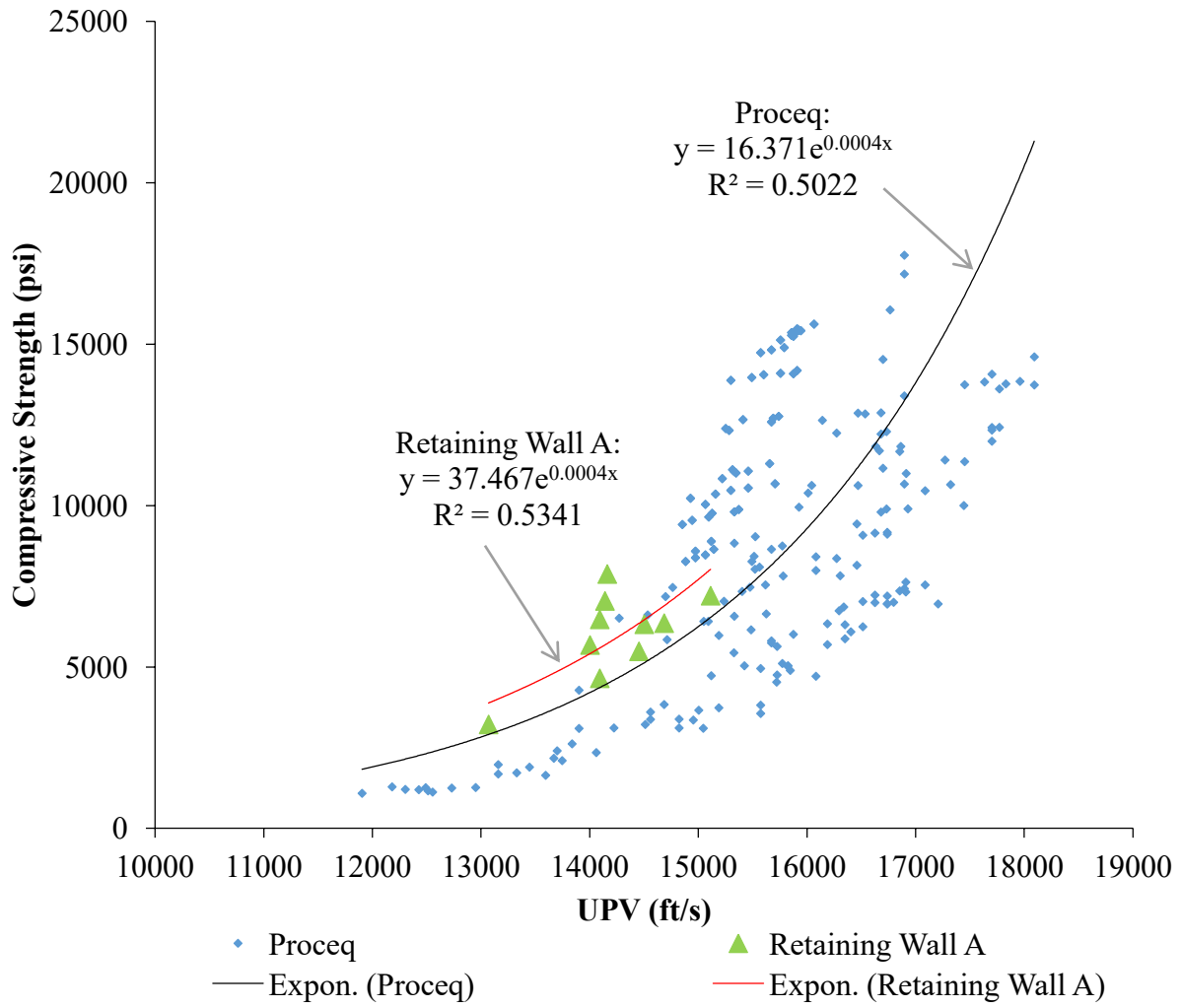


Figure C-3: UPV (ft/s) vs. Compressive Strength (psi) for Retaining Wall A

Table C-4: UPV Test Results for Group B 6x12 in. Cylinders (ft/s)

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 35 | | | Day 42 | | | Day 56 | | | Day 90 | | | Day 120 | | | Day 180 | | | |
|----------------------------|-------|-------|-------|--------|--------|--------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|---------|-------|-------|---------|-------|-------|-------|
| 6x12 in. Str. (psi) | 3487 | 4833 | 5150 | 5715 | 6226 | 6403 | 5994 | 6260 | 6368 | 6351 | 6203 | 6745 | 6834 | 7163 | 6732 | 7014 | 7116 | 7554 | 6919 | 6651 | 7189 | 7817 | 7641 | 7852 | |
| | 13898 | 15093 | 15684 | 15783 | 15635 | 15823 | 15994 | 16088 | 16368 | 16035 | 15985 | 15758 | 15909 | 16062 | 15783 | 16192 | 16271 | 16114 | 16271 | 16324 | 16218 | 16088 | 16036 | 16351 | |
| | 13956 | 15002 | 15684 | 15758 | 15611 | 15873 | 16068 | 16088 | 16088 | 16010 | 15883 | 15709 | 15883 | 16010 | 15758 | 16218 | 16271 | 16114 | 16192 | 16324 | 16218 | 16192 | 16114 | 16431 | |
| | 14015 | 14980 | 15684 | 15709 | 15635 | 15898 | 15985 | 16036 | 16088 | 15959 | 15883 | 15883 | 16088 | 16062 | 15562 | 16192 | 16297 | 16114 | 16114 | 16324 | 16166 | 16114 | 16062 | 16271 | |
| | 13995 | 15093 | 15635 | 15758 | 15562 | 15873 | 16010 | 15934 | 16036 | 15959 | 15934 | 15934 | 16140 | 16036 | 15758 | 16244 | 16297 | 16114 | 16088 | 16244 | 16192 | 16218 | 16036 | 16192 | |
| | 14074 | 15093 | 15635 | 15709 | 15635 | 15898 | 16010 | 15959 | 16088 | 15985 | 15883 | 15959 | 16114 | 15985 | 15783 | 16244 | 16297 | 16140 | 16088 | 16192 | 16114 | 16297 | 16166 | 16324 | |
| | 13802 | 15070 | 15684 | 15684 | 15611 | 15898 | 15985 | 15934 | 16036 | 16010 | 15909 | 15909 | 16140 | 16036 | 15808 | 16192 | 16271 | 16114 | 16062 | 16244 | 16062 | 16351 | 16140 | 16377 | |
| | 13898 | | 15564 | 15635 | 15635 | 15848 | 16010 | 15934 | 16036 | 15959 | | 15959 | 16114 | 16010 | 15783 | 16218 | 16297 | 16140 | 16062 | 16244 | 16062 | 16377 | 16192 | 16540 | |
| | | | 15684 | 15611 | 15611 | | | | | 15959 | | 16036 | | 16062 | 15934 | 15758 | 16218 | 16324 | 16114 | 16010 | 16271 | 16062 | 16377 | 16218 | 16458 |
| | | | 15635 | | | | | | | 15909 | | | | 16088 | | 16271 | 16297 | | 16010 | 16218 | 15985 | | 16218 | 16458 | |
| Average | 13948 | 15055 | 15654 | 15706 | 15617 | 15873 | 15992 | 15996 | 16097 | 15988 | 15913 | 15873 | 16060 | 16017 | 15749 | 16221 | 16291 | 16121 | 16100 | 16265 | 16120 | 16252 | 16131 | 16378 | |

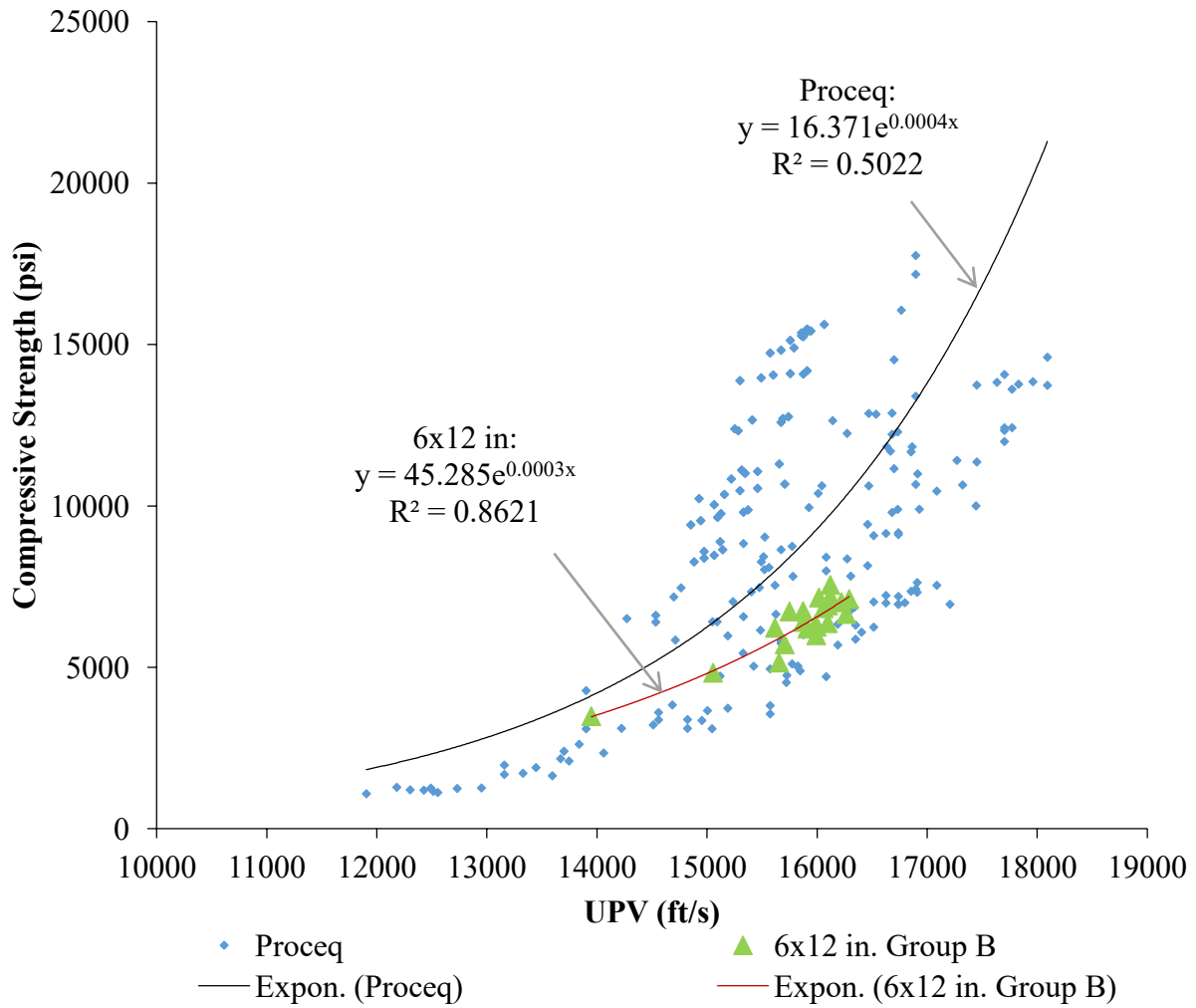


Figure C-4: UPV (ft/s) vs. Compressive Strength (psi) for Group B 6x12 in. Cylinders

Table C-5: UPV Test Results for 24x18x4 in. Slab B (ft/s)

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 42 | Day 56 | Day 90 | Day 120 | Day 180 |
|----------------------------|--------------|--------------|--------------|---------------|---------------|---------------|---------------|---------------|---------------|----------------|----------------|
| 6x12 in. Str. (psi) | 3487 | 4833 | 5150 | 5715 | 6226 | 6403 | 6460 | 6910 | 7065 | 7054 | 7770 |
| | 13991 | 14822 | 15835 | 16484 | 16224 | 16566 | 16434 | 16785 | 16998 | 15228 | 15075 |
| | 13830 | 14111 | 15973 | 16208 | 16353 | 16600 | 16550 | 16717 | 16464 | 15337 | 15091 |
| | 14208 | 14995 | 15865 | 15988 | 16304 | 16583 | 6684 | 16717 | 16497 | 15213 | 15121 |
| | 14143 | 14937 | 14719 | 15911 | 16337 | 16566 | 16208 | 16717 | 16398 | 15228 | 15091 |
| | 14169 | 14951 | 15850 | 16098 | 16418 | 16550 | 16717 | 16684 | 16414 | 15244 | 15121 |
| | 14118 | 14981 | 15988 | 15957 | 16353 | 16550 | 16684 | 16700 | 16365 | 15198 | 15152 |
| | 14067 | 14951 | 16004 | 15881 | 16467 | 16517 | 16633 | 16768 | 16332 | 15198 | 15152 |
| | | | 16145 | | | | | 16684 | 16266 | 15198 | |
| | | | 16161 | | | | | | 16283 | 15167 | |
| Average | 14075 | 14821 | 15838 | 16075 | 16351 | 16562 | 15130 | 16722 | 16446 | 15223 | 15115 |

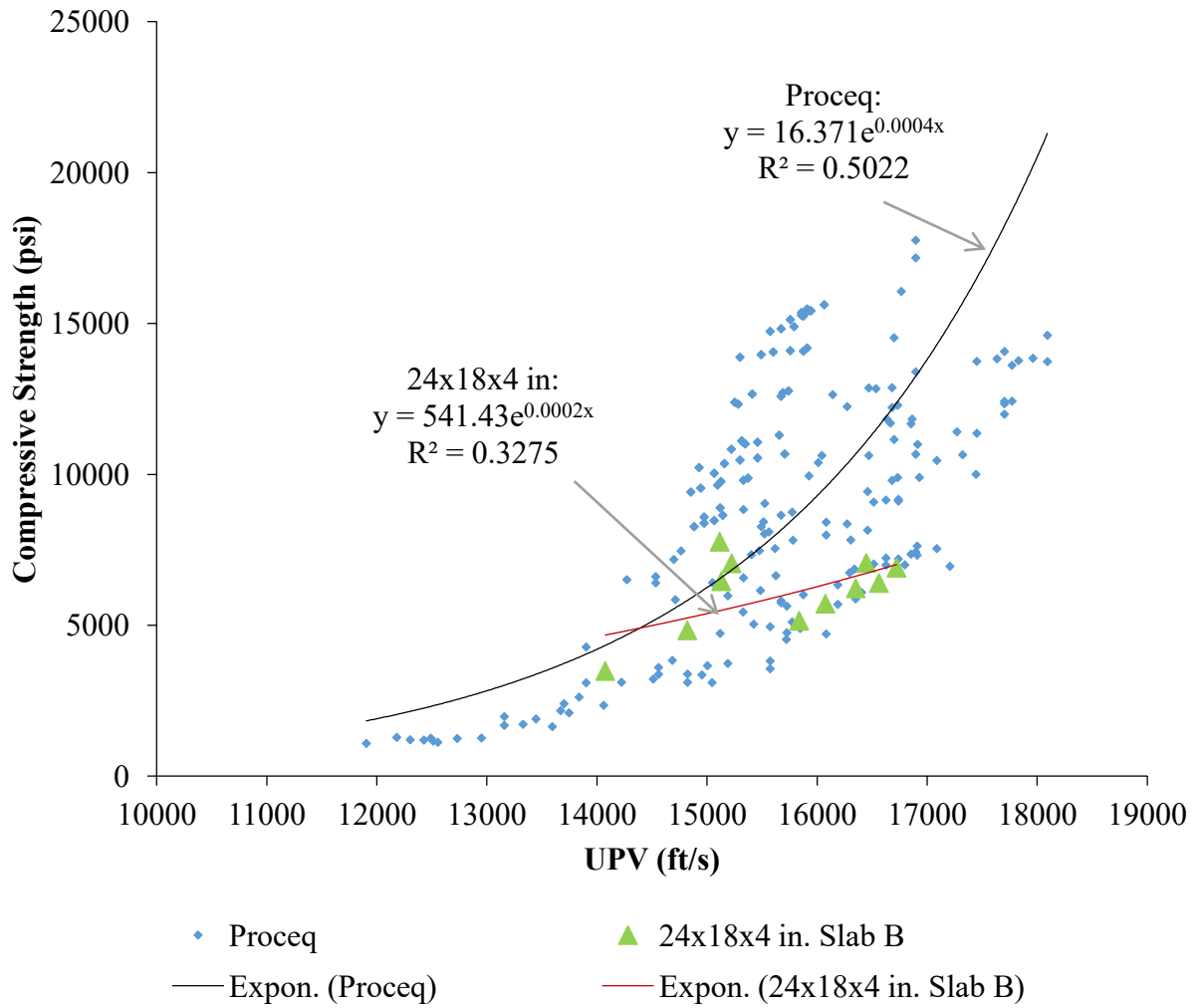


Figure C-5: UPV (ft/s) vs. Compressive Strength (psi) for 24x18x4 in. Slab B

Table C-6: UPV Test Results for Retaining Wall B (ft/s)

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 42 | Day 56 | Day 90 | Day 120 | Day 180 |
|--------------------------------|--------------|--------------|--------------|---------------|---------------|---------------|---------------|---------------|---------------|----------------|----------------|
| 6x12 in. Str. (psi) | 3487 | 4833 | 5150 | 5715 | 6226 | 6403 | 6460 | 6910 | 7065 | 7054 | 7770 |
| | 12399 | 13550 | 14245 | 14345 | 14345 | 14141 | 14874 | 14303 | 14658 | 14568 | 14555 |
| | 12399 | 13524 | 14303 | 14286 | 14028 | 14028 | 14968 | 14332 | 14598 | 14598 | 14253 |
| | 12249 | 13418 | 14332 | 14315 | 14028 | 14028 | 14719 | 14390 | 14568 | 14598 | 14078 |
| | 12509 | 13444 | 14332 | 14286 | 14266 | 14028 | 14843 | 14361 | 14449 | 14568 | 14049 |
| | 12553 | 13471 | 14390 | 14286 | 14285 | 14141 | 14781 | 14303 | 14568 | 14598 | 14224 |
| | 12443 | 13471 | 14132 | 14286 | 14317 | 14217 | 14781 | 14390 | 14449 | 14479 | 14020 |
| | 12421 | 13471 | 14188 | 14345 | | 14285 | 14925 | 14303 | 14449 | 14508 | 14224 |
| | 12487 | 14170 | 14217 | 14256 | | 14137 | 14937 | 14245 | | 14449 | |
| | 12421 | | | 14227 | | | | | | 14508 | |
| Average | 12431 | 13565 | 14267 | 14292 | 14212 | 14126 | 14854 | 14328 | 14534 | 14542 | 14200 |

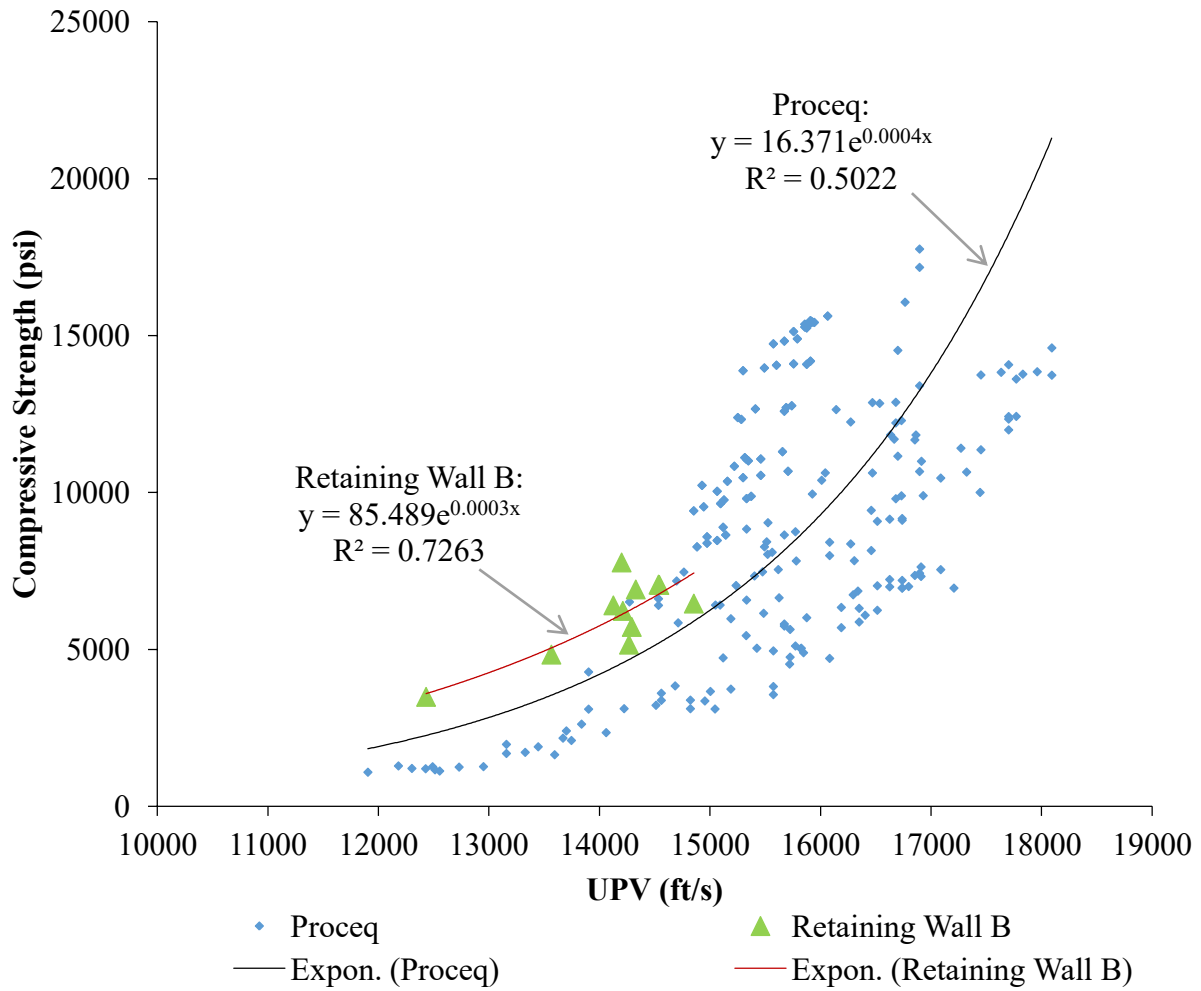


Figure C-6: UPV (ft/s) vs. Compressive Strength (psi) for Retaining Wall B

Table C-7: UPV Test Results for Group C 6x12 in. Cylinders (ft/s)

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 35 | | | Day 42 | | | Day 56 | | | Day 90 | | | Day 120 | | | Day 180 | |
|----------------------------|-------|-------|-------|--------|--------|--------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|---------|-------|-------|---------|-------|
| 6x12 in. Str. (psi) | 3269 | 4622 | 5059 | 5383 | 5789 | 6034 | 5982 | 6766 | 6291 | 6297 | 5917 | 6851 | 7058 | 7100 | 6792 | 6896 | 7044 | 6941 | 7579 | 7185 | 7841 | 7297 | 7704 |
| | 14094 | 14970 | 15674 | 15704 | 15699 | 16026 | 15873 | 16155 | 16000 | 16088 | 15959 | 16010 | 16234 | 16313 | 16207 | 16129 | 16367 | 16340 | 16026 | 16026 | 15823 | 16502 | 16420 |
| | 13995 | 15015 | 15647 | 15552 | 15699 | 16051 | 15873 | 16181 | 16051 | 16088 | 15985 | 16010 | 16234 | 16287 | 16181 | 16129 | 16313 | 16367 | 16051 | 15773 | 16026 | 16529 | 16529 |
| | 13917 | 15993 | 15699 | 15601 | 15699 | 16077 | 15898 | 16207 | 16000 | 16088 | 15959 | 15985 | 16260 | 16287 | 16340 | 16155 | 16260 | 16393 | 16026 | 15974 | 16207 | 16502 | 16340 |
| | 13898 | 15015 | 15674 | 15752 | 15699 | 15949 | 15873 | 16207 | 16000 | 16088 | 15959 | 15985 | 16260 | 16287 | 16367 | 16181 | 16234 | 16367 | 15848 | 15873 | 16207 | 16393 | 16447 |
| | 13898 | 14993 | 15674 | 15552 | 15773 | 16000 | 15848 | 16207 | 16000 | 16114 | 15909 | 16010 | 16287 | 16260 | 16367 | 16181 | 16181 | 16367 | 16051 | 16026 | 16000 | 16103 | 16340 |
| | 13907 | 15015 | 15699 | 15625 | 15773 | 16051 | 15870 | 16207 | 16000 | 16114 | 15959 | 15985 | 16287 | 16313 | 16393 | 16103 | 16260 | 16393 | 16077 | 15848 | 15723 | 16722 | 16287 |
| | 13897 | 15015 | 15576 | 15601 | 15773 | 16103 | 15823 | 16207 | 16000 | 16100 | 15959 | 16010 | 16234 | 16313 | 16393 | 16207 | 16234 | 16313 | 16181 | 16181 | 15601 | 16393 | 16077 |
| | | | | | 15823 | | | | 15924 | 16144 | 15959 | 16010 | 16234 | 16313 | 16367 | | 16260 | 16313 | 16026 | 16103 | 15748 | 16234 | 16207 |
| | | | | | | | | | | | 15985 | | | 16260 | 16340 | | | | | | 15552 | 16393 | 16129 |
| | | | | | | | | | | | | | | | | | | | | | | 16287 | 16260 |
| Average | 13944 | 15145 | 15663 | 15627 | 15742 | 16037 | 15865 | 16196 | 15997 | 16103 | 15959 | 16001 | 16254 | 16293 | 16328 | 16155 | 16264 | 16357 | 16036 | 15976 | 15876 | 16406 | 16304 |

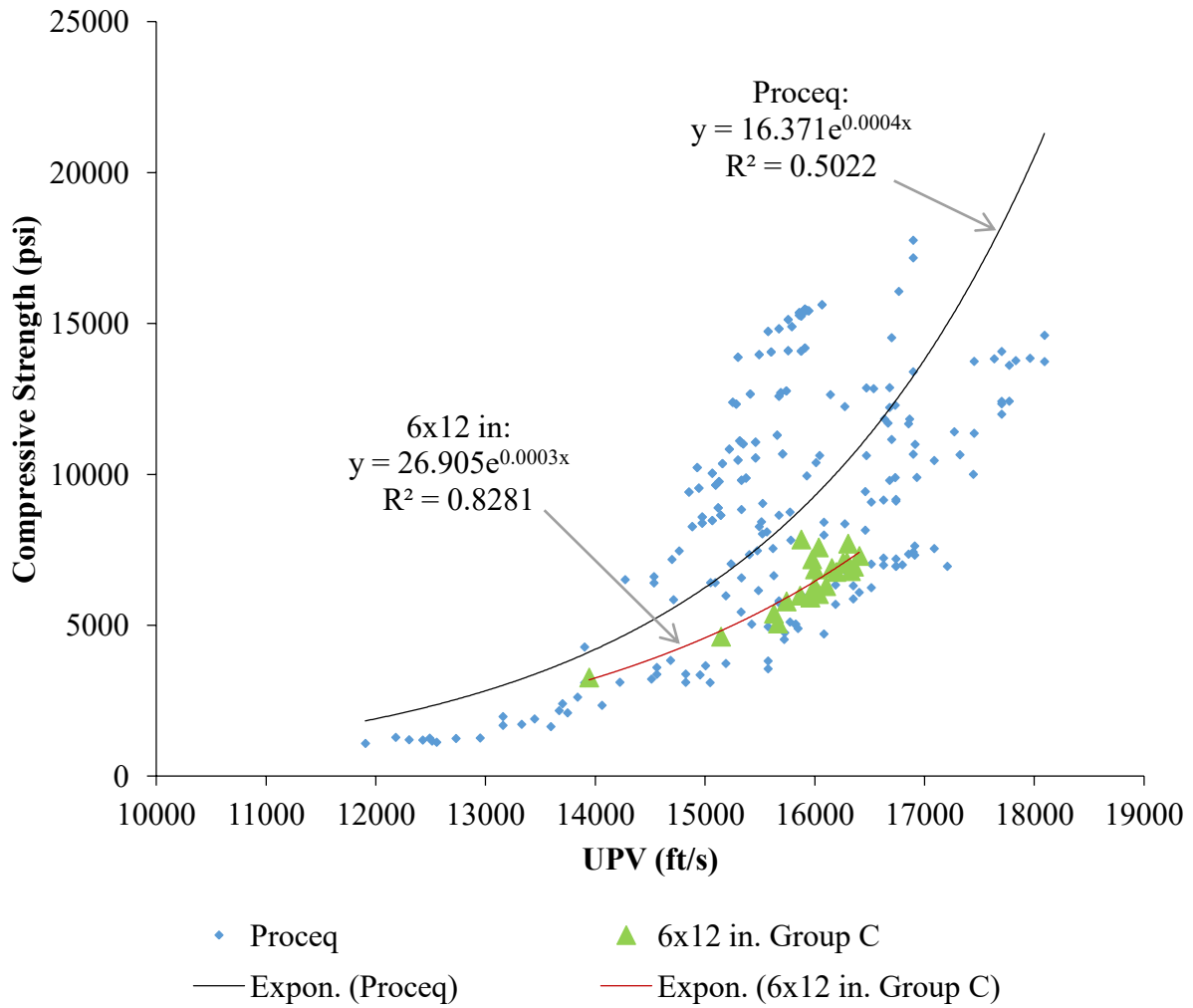


Figure C-7: UPV (ft/s) vs. Compressive Strength (psi) for Group C 6x12 in. Cylinders

Table C-8: UPV Test Results for 24x18x4 in. Slab C (ft/s)

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 42 | Day 56 | Day 90 | Day 120 | Day 180 |
|----------------------------|--------------|--------------|--------------|---------------|---------------|---------------|---------------|---------------|---------------|----------------|----------------|
| 6x12 in. Str. (psi) | 3269 | 4622 | 5059 | 5383 | 5789 | 6034 | 6574 | 6925 | 6993 | 7382 | 7469 |
| Core Strength (psi) | | | | 4580 | 5401 | | | 5719 | 6328 | 5953 | 7187 |
| | 13953 | 15121 | 15448 | 15690 | 15789 | 15690 | 16112 | 15823 | 16465 | 15560 | 15991 |
| | 13979 | 15152 | 15448 | 15658 | 15789 | 15690 | 16146 | 15806 | 16287 | 15740 | 16199 |
| | 14218 | 15000 | 15464 | 15740 | 15823 | 15213 | 16164 | 15707 | 16304 | 16026 | 15873 |
| | 14286 | 15136 | 15512 | 15823 | 15823 | 15244 | 15890 | 15512 | 16216 | 15873 | 16112 |
| | 14272 | 15060 | 15464 | 15773 | 15839 | 15259 | 16077 | 15560 | 16322 | 15806 | 16112 |
| | 14245 | 15121 | 15496 | 15806 | 15873 | 15353 | 16094 | 15641 | 16287 | 15690 | 16199 |
| | 14245 | 15045 | 15448 | | 15890 | 15890 | 16199 | 15609 | 16216 | 15723 | 16322 |
| | 14231 | 15015 | | | 15890 | | | 15432 | 16164 | 15625 | |
| | 14231 | 15045 | | | | | | | | | |
| | | 15212 | | | | | | | | | |
| Average | 14184 | 15091 | 15469 | 15748 | 15840 | 15477 | 16097 | 15636 | 16283 | 15755 | 16115 |

Appendix D

Windsor Pin Penetration Test Results for Cylinders, Slabs, and Retaining Walls

Table D-1: Pin Penetration Test Results for Group A 6x12 in. Cylinders (in.x10⁻³)

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 35 | | | Day 42 | | | Day 56 | | | Day 90 | | | Day 120 | | | Day 180 | |
|---------------------------|-------|-------|-------|--------|--------|--------|--------|------|------|--------|------|------|--------|------|------|--------|------|------|---------|------|------|---------|------|
| 6x12 in. Str (psi) | 3219 | 4648 | 5484 | 5680 | 6322 | 6356 | 6549 | 6463 | 6264 | 6594 | 6635 | 6150 | 7003 | 6742 | 6117 | 7239 | 6948 | 6947 | 7275 | 7012 | 7333 | 7431 | 8023 |
| | 757 | 771 | 809 | 819 | 814 | 864 | 834 | 849 | 863 | 802 | 849 | 856 | 824 | 861 | 806 | 814 | 832 | 841 | 834 | 850 | 834 | 857 | 851 |
| | 776 | 809 | 798 | 849 | 854 | 836 | 854 | 824 | 860 | 804 | 829 | 869 | 831 | 804 | 814 | 899 | 875 | 838 | 880 | 827 | 835 | 874 | 876 |
| | 822 | 787 | 858 | 824 | 842 | 848 | 856 | 847 | 864 | 809 | 812 | 820 | 851 | 851 | 810 | 816 | 868 | 855 | 850 | 863 | 860 | 837 | 810 |
| | 839 | 834 | 812 | 814 | 820 | 826 | 835 | 821 | 750 | 814 | 837 | 831 | | 841 | 827 | 839 | 841 | | 826 | 807 | 828 | 831 | 867 |
| | 813 | 811 | 811 | 824 | 818 | 878 | | | | 803 | | | | | 819 | | | | | 832 | | | |
| | 817 | 788 | 801 | 837 | 816 | 840 | | | | 846 | | | | | | | | | | | | | |
| | 771 | 770 | 803 | | 818 | 842 | | | | | | | | | | | | | | | | | |
| | 818 | 777 | 801 | | 840 | | | | | | | | | | | | | | | | | | |
| | 824 | 798 | | | | | | | | | | | | | | | | | | | | | |
| Average | 804 | 794 | 812 | 828 | 828 | 848 | 845 | 835 | 834 | 813 | 832 | 844 | 835 | 839 | 815 | 842 | 854 | 845 | 848 | 836 | 839 | 850 | 851 |

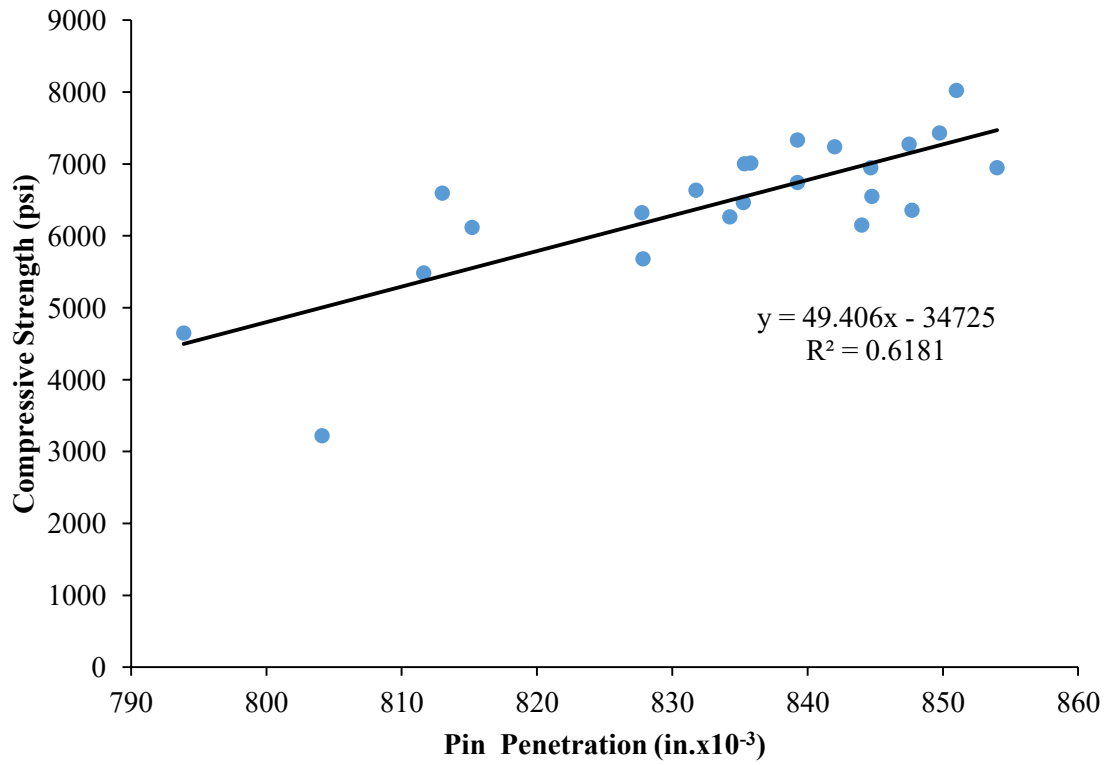


Figure D-1: Pin Penetration (in.x10⁻³) vs. Compressive Strength (psi) for Group A 6x12 in. Cylinders

Table D-2: Pin Penetration Test Results for 24x18x4 in. Slab A (in.x10⁻³)

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 42 | Day 56 | Day 120 | Day 180 |
|----------------------------|-------|-------|-------|--------|--------|--------|--------|--------|---------|---------|
| 6x12 in. Str (psi) | 3219 | 4648 | 5484 | 5680 | 6322 | 6356 | 6474 | 6621 | 7207 | 7880 |
| Core Strength (psi) | | | | 4487 | 4740 | | | 6303 | 5791 | 6624 |
| | 773 | 824 | 829 | 834 | 829 | 821 | 834 | 832 | 834 | 824 |
| | 778 | 805 | 818 | 809 | 856 | 835 | 804 | 852 | 819 | 848 |
| | 749 | 814 | 816 | 797 | 842 | 867 | 807 | 859 | 828 | 835 |
| | 767 | 807 | 819 | 831 | 829 | 824 | 826 | 837 | 829 | 839 |
| | 754 | 768 | 807 | 839 | 843 | 824 | 809 | 824 | 814 | 856 |
| | 764 | 785 | 823 | 826 | | | 812 | 867 | | 833 |
| | | | | | | | 834 | | | |
| | | | | | | | 829 | | | |
| | | | | | | | 851 | | | |
| Average | 764 | 801 | 819 | 823 | 840 | 834 | 823 | 845 | 825 | 839 |

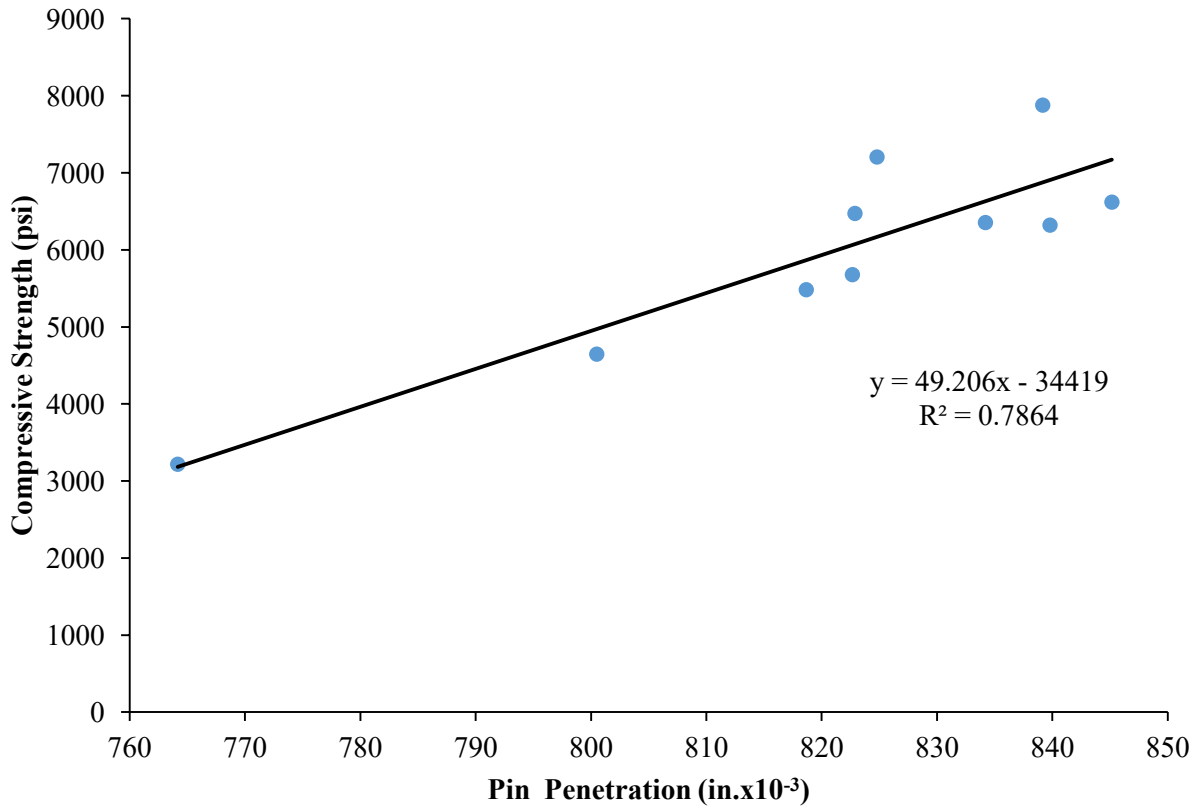


Figure D-2: Pin Penetration (in.x10⁻³) vs. Compressive Strength (psi) for 24x18x4 in. Slab A

Table D-3: Pin Penetration Test Results for Retaining Wall A (in.x10⁻³)

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 28 | Day 42 | Day 56 | Day 120 | Day 180 |
|---------------------------|-------|-------|-------|--------|--------|--------|--------|---------|---------|
| 6x12 in. Str (psi) | 3219 | 4648 | 5484 | 5680 | 6356 | 6474 | 6621 | 7207 | 7880 |
| | 792 | 798 | 812 | 819 | 830 | 801 | 852 | 846 | 824 |
| | 803 | 820 | 803 | 836 | 821 | 829 | 849 | 834 | 836 |
| | 757 | 793 | 831 | 825 | 888 | 846 | 841 | 835 | 829 |
| | 767 | 821 | 814 | 806 | 838 | 821 | 829 | 800 | 827 |
| | 734 | 779 | 798 | 834 | 834 | 834 | 830 | 826 | 807 |
| | 786 | 871 | 827 | 830 | 813 | 813 | 835 | | 829 |
| | 783 | 797 | 814 | | | 812 | | | |
| | 776 | | 807 | | | | | | |
| | 776 | | | | | | | | |
| | 777 | | | | | | | | |
| Average | 775 | 811 | 813 | 825 | 837 | 822 | 839 | 828 | 825 |

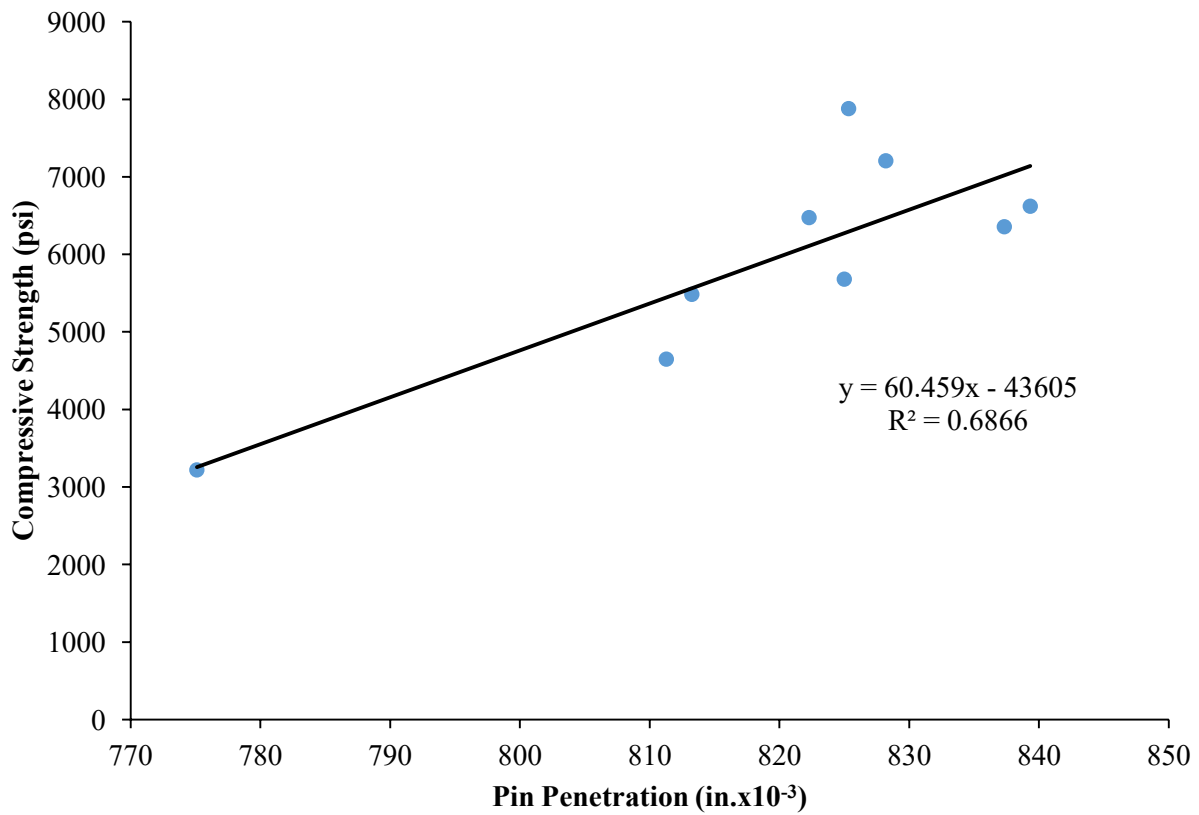


Figure D-3: Pin Penetration (in.x10⁻³) vs. Compressive Strength (psi) for Retaining Wall A

Table D-4: Pin Penetration Test Results for Group B 6x12 in. Cylinders (in.x10⁻³)

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 35 | | | Day 42 | | | Day 56 | | | Day 90 | | | Day 120 | | | Day 180 | | |
|---------------------------|-------|-------|-------|--------|--------|--------|--------|------|------|--------|------|------|--------|------|------|--------|------|------|---------|------|------|---------|------|------|
| 6x12 in. Str (psi) | 3487 | 4833 | 5150 | 5715 | 6226 | 6403 | 5994 | 6260 | 6368 | 6351 | 6203 | 6745 | 6834 | 7163 | 6732 | 7014 | 7116 | 7554 | 6919 | 6651 | 7189 | 7817 | 7641 | 7852 |
| | 774 | 831 | 829 | 813 | 825 | 831 | 829 | 823 | 811 | 819 | 814 | 861 | 841 | 835 | 834 | 842 | 839 | 820 | 842 | 866 | 859 | 867 | 811 | 832 |
| | 754 | 806 | 803 | 815 | 839 | 869 | 852 | 822 | 813 | 809 | 837 | 812 | 831 | 838 | 852 | 854 | 813 | 856 | 828 | 846 | 871 | 849 | 827 | 839 |
| | 781 | 829 | 809 | 816 | 840 | 844 | 839 | 841 | 823 | 829 | 834 | 820 | 840 | 801 | 853 | 848 | 854 | 847 | 831 | 852 | 877 | 854 | 834 | 849 |
| | 776 | 804 | 814 | 817 | 825 | 822 | | 862 | 824 | 824 | 809 | 857 | | 815 | | | 846 | | | | | | 845 | |
| | 784 | 798 | 802 | 839 | 859 | 847 | | 817 | 851 | | 833 | | | 836 | | | | | | | | | 837 | |
| | 741 | 814 | 852 | 843 | | 846 | | | | | | | | | | | | | | | | | | |
| | 779 | | 807 | 844 | | | | | | | | | | | | | | | | | | | | |
| | | | 804 | 847 | | | | | | | | | | | | | | | | | | | | |
| | | | | 874 | | | | | | | | | | | | | | | | | | | | |
| | | | | 877 | | | | | | | | | | | | | | | | | | | | |
| | | | | 881 | | | | | | | | | | | | | | | | | | | | |
| Average | 770 | 814 | 815 | 842 | 838 | 843 | 840 | 833 | 830 | 820 | 825 | 838 | 837 | 825 | 846 | 848 | 838 | 841 | 834 | 855 | 869 | 857 | 831 | 840 |

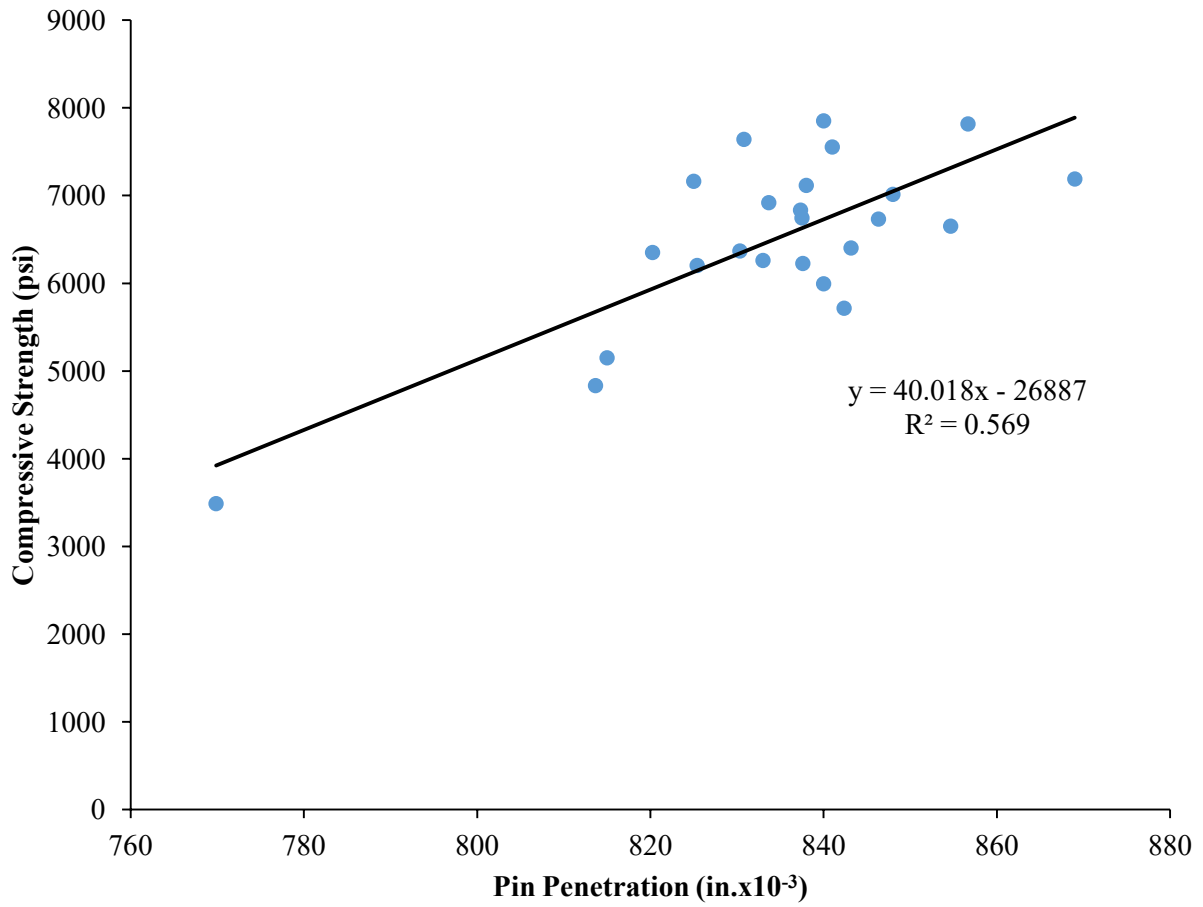


Figure D-4: Pin Penetration (in.x10⁻³) vs. Compressive Strength (psi) for Group B 6x12 in. Cylinders

Table D-5: Pin Penetration Test Results for 24x18x4 in. Slab B (in.x10⁻³)

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 42 | Day 56 | Day 120 | Day 180 |
|---------------------------|-------|-------|-------|--------|--------|--------|--------|--------|---------|---------|
| 6x12 in. Str (psi) | 3487 | 4833 | 5150 | 5715 | 6226 | 6403 | 6460 | 6910 | 7054 | 7770 |
| | 781 | 754 | 756 | 806 | 837 | 845 | 797 | 820 | 823 | 827 |
| | 786 | 747 | 750 | 827 | 825 | 831 | 860 | 838 | 820 | 832 |
| | 751 | 766 | 749 | 834 | 817 | 865 | 829 | 819 | 868 | 837 |
| | 783 | 726 | 746 | 804 | 833 | 823 | 810 | 812 | 830 | 858 |
| | 749 | 759 | 729 | 824 | 825 | 821 | 805 | 795 | 854 | 829 |
| | 722 | | 732 | 799 | 829 | 826 | 838 | 834 | | 818 |
| | | | | | | | 851 | 804 | | 836 |
| | | | | | | | 807 | 832 | | |
| Average | 762 | 750 | 744 | 816 | 828 | 835 | 825 | 819 | 839 | 834 |

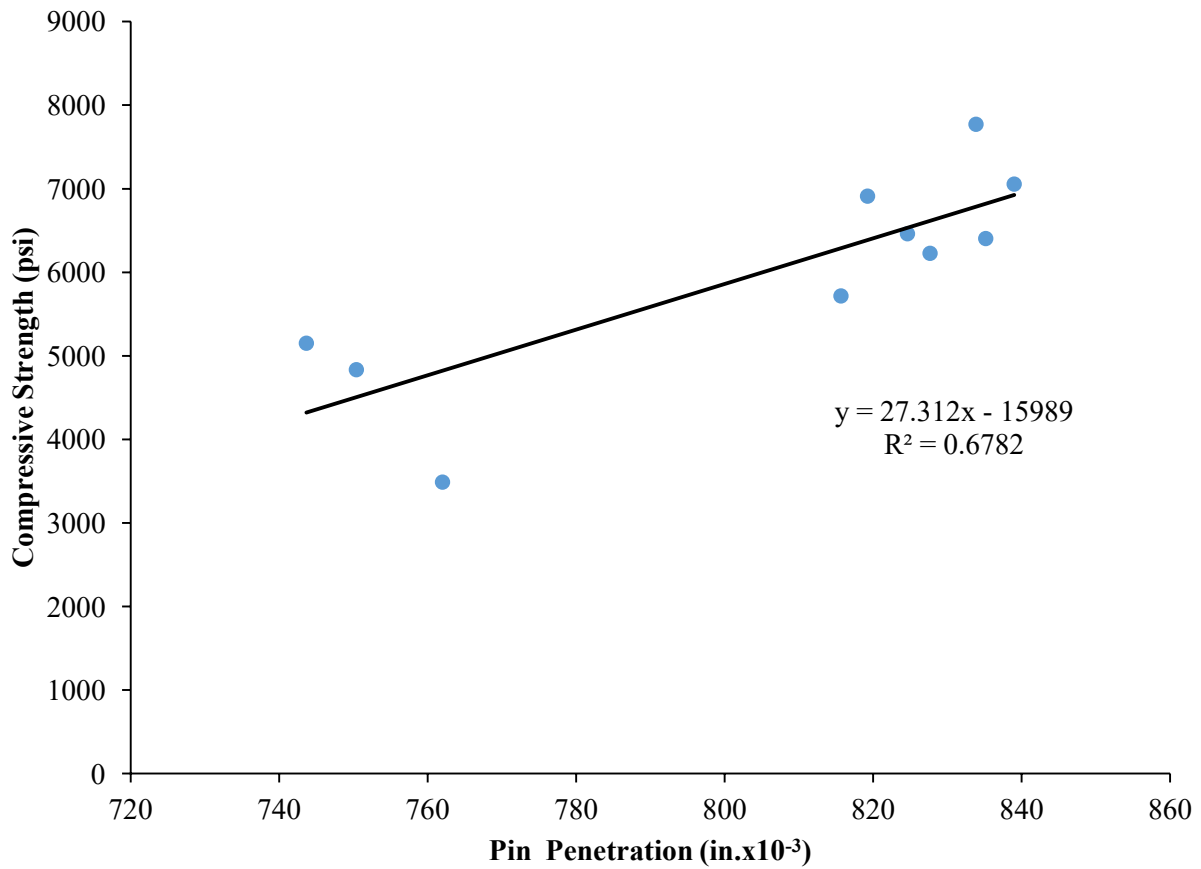


Figure D-5: Pin Penetration (in.x10⁻³) vs. Compressive Strength (psi) for 24x18x4 in. Slab B

Table D-6: Pin Penetration Test Results for Retaining Wall B (in.x10⁻³)

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 42 | Day 56 | Day 120 | Day 180 |
|---------------------------|-------|-------|-------|--------|--------|--------|--------|--------|---------|---------|
| 6x12 in. Str (psi) | 3487 | 4833 | 5150 | 5715 | 6226 | 6403 | 6460 | 6910 | 7054 | 7770 |
| | 712 | 761 | 749 | 801 | 836 | 859 | 813 | 850 | 835 | 860 |
| | 707 | 776 | 771 | 787 | 841 | 826 | 810 | 818 | 808 | 830 |
| | 703 | 782 | 768 | 793 | 804 | 819 | 811 | 815 | 854 | 811 |
| | 732 | 738 | 774 | 778 | 831 | 837 | 826 | 819 | 864 | 823 |
| | 698 | 742 | 756 | 784 | 829 | 829 | 799 | 815 | 845 | 822 |
| | 702 | 757 | 753 | 781 | 837 | | 793 | 814 | | 845 |
| | 691 | 768 | | | | | | | | |
| Average | 706 | 761 | 762 | 787 | 830 | 834 | 809 | 822 | 841 | 832 |

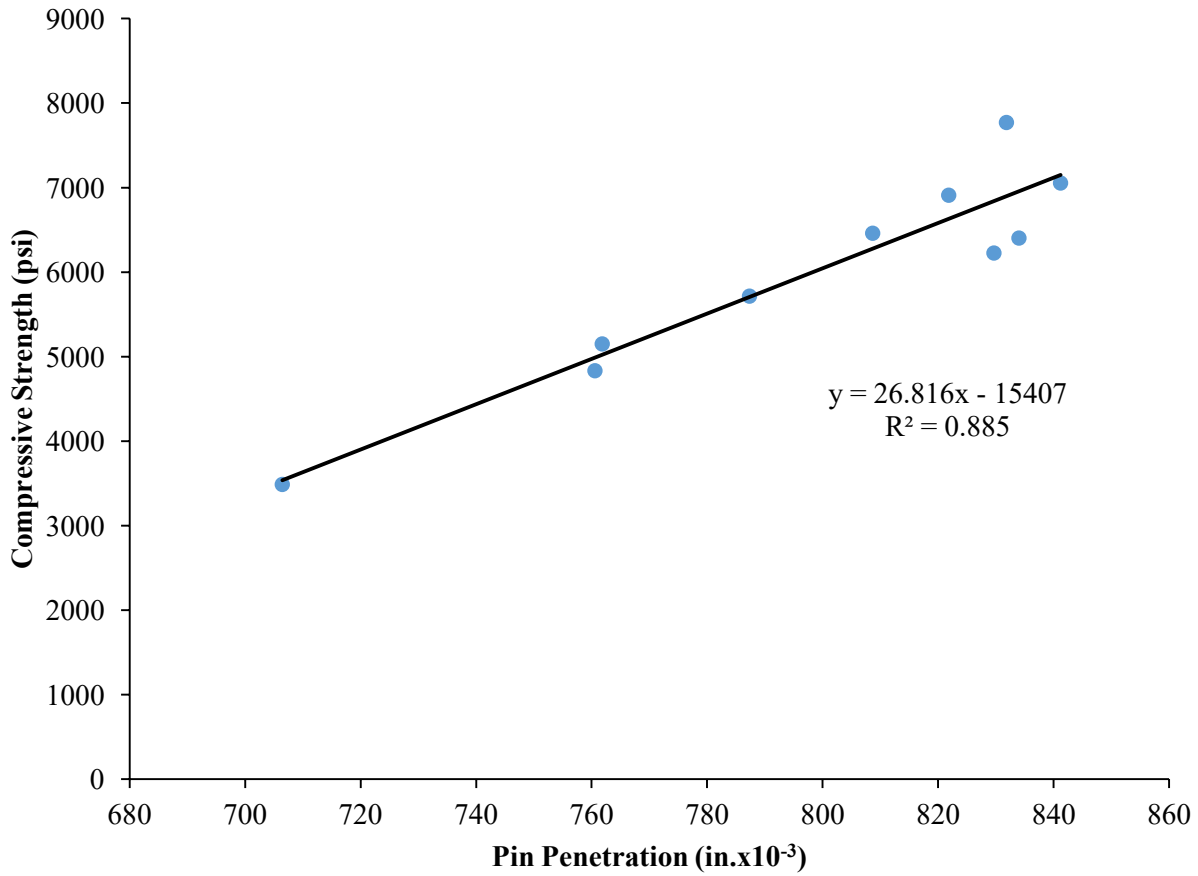


Figure D-6: Pin Penetration (in.x10⁻³) vs. Compressive Strength (psi) for Retaining Wall B

Table D-7: Pin Penetration Test Results for Group C 6x12 in. Cylinders (in.x10⁻³)

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 35 | | | Day 42 | | | Day 56 | | | Day 90 | | | Day 120 | | | Day 180 | | |
|---------------------------|-------|-------|-------|--------|--------|--------|--------|------|------|--------|------|------|--------|------|------|--------|------|------|---------|------|------|---------|------|------|
| 6x12 in. Str (psi) | 3269 | 4622 | 5059 | 5383 | 5789 | 6034 | 5982 | 6766 | 6291 | 6297 | 5917 | 6851 | 7058 | 7100 | 6792 | 6896 | 7044 | 6941 | 7579 | 7185 | 7841 | 7297 | 7704 | 7406 |
| | 771 | 815 | 831 | 819 | 873 | 878 | 810 | 829 | 852 | 881 | 831 | 858 | 834 | 834 | 854 | 820 | 849 | 837 | 834 | 854 | 875 | 839 | 860 | 861 |
| | 820 | 842 | 815 | 826 | 867 | 845 | 837 | 824 | 826 | 815 | 816 | 854 | 773 | 836 | 834 | 815 | 844 | 836 | 837 | 824 | 831 | 821 | 826 | 863 |
| | 833 | 823 | 804 | 824 | 831 | 844 | 845 | 821 | 839 | 812 | 876 | 861 | 839 | 831 | 804 | 856 | 837 | 829 | 844 | 821 | 875 | 804 | 846 | 847 |
| | 832 | 821 | 832 | 821 | 839 | 848 | 848 | | | 809 | 822 | 832 | 846 | | 827 | | | | | | | 836 | 842 | |
| | 807 | 809 | 798 | 829 | 837 | 834 | 875 | | | 857 | 849 | 815 | | | | | | | | | | 843 | | |
| | 809 | 829 | 854 | | 824 | | | | | | | | | | | | | | | | | | | |
| | 856 | 823 | 824 | | 875 | | | | | | | | | | | | | | | | | | | |
| | 758 | 798 | 823 | | | | | | | | | | | | | | | | | | | | | |
| | 834 | | | | | | | | | | | | | | | | | | | | | | | |
| | 817 | | | | | | | | | | | | | | | | | | | | | | | |
| Average | 814 | 820 | 823 | 824 | 849 | 850 | 843 | 825 | 839 | 835 | 839 | 844 | 823 | 834 | 830 | 830 | 843 | 834 | 838 | 833 | 860 | 829 | 844 | 857 |

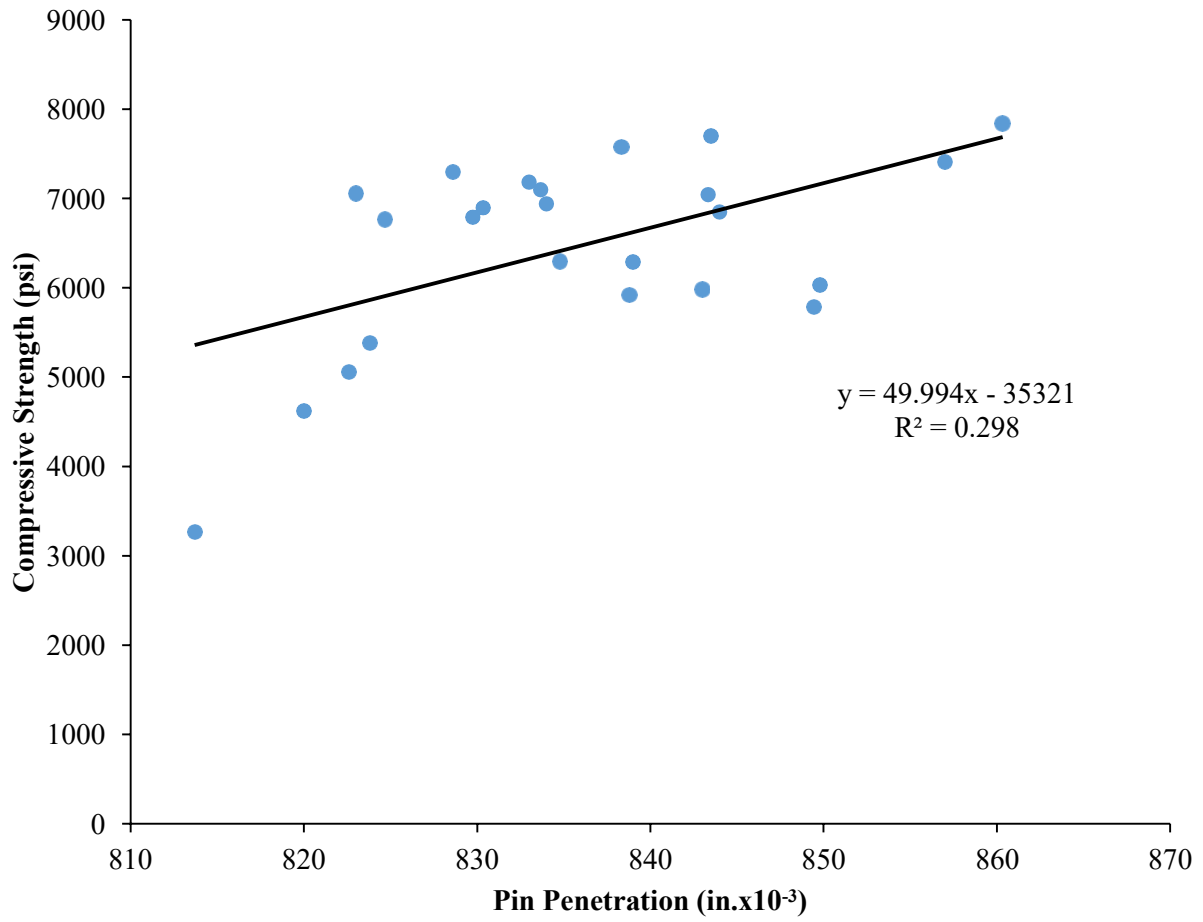


Figure D-7: Pin Penetration (in.x10⁻³) vs. Compressive Strength (psi) for Group C 6x12 in. Cylinders

Table D-8: Pin Penetration Test Results for 24x18x4 in. Slab C (in.x10⁻³)

| | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 42 | Day 56 | Day 120 | Day 180 |
|----------------------------|-------|-------|-------|--------|--------|--------|--------|--------|---------|---------|
| 6x12 in. Str (psi) | 3269 | 4622 | 5059 | 5383 | 5789 | 6034 | 6574 | 6925 | 7382 | 7469 |
| Core Strength (psi) | | | | 4580 | 5401 | | | 5719 | 5953 | 7187 |
| | 781 | 773 | 801 | 837 | 804 | 879 | 876 | 812 | 835 | 841 |
| | 786 | 776 | 807 | 834 | 819 | 806 | 828 | 809 | 814 | 801 |
| | 751 | 759 | 826 | 831 | 833 | 848 | 839 | 862 | 834 | 827 |
| | 783 | 778 | 807 | 839 | 812 | 834 | 834 | 822 | 811 | 821 |
| | 749 | 767 | 824 | 826 | 854 | 832 | 846 | 865 | 891 | 831 |
| | 722 | 751 | 806 | 809 | 831 | | 838 | 831 | 859 | 818 |
| | | | | | | | | 832 | | |
| Average | 762 | 767 | 812 | 829 | 826 | 840 | 844 | 833 | 841 | 823 |

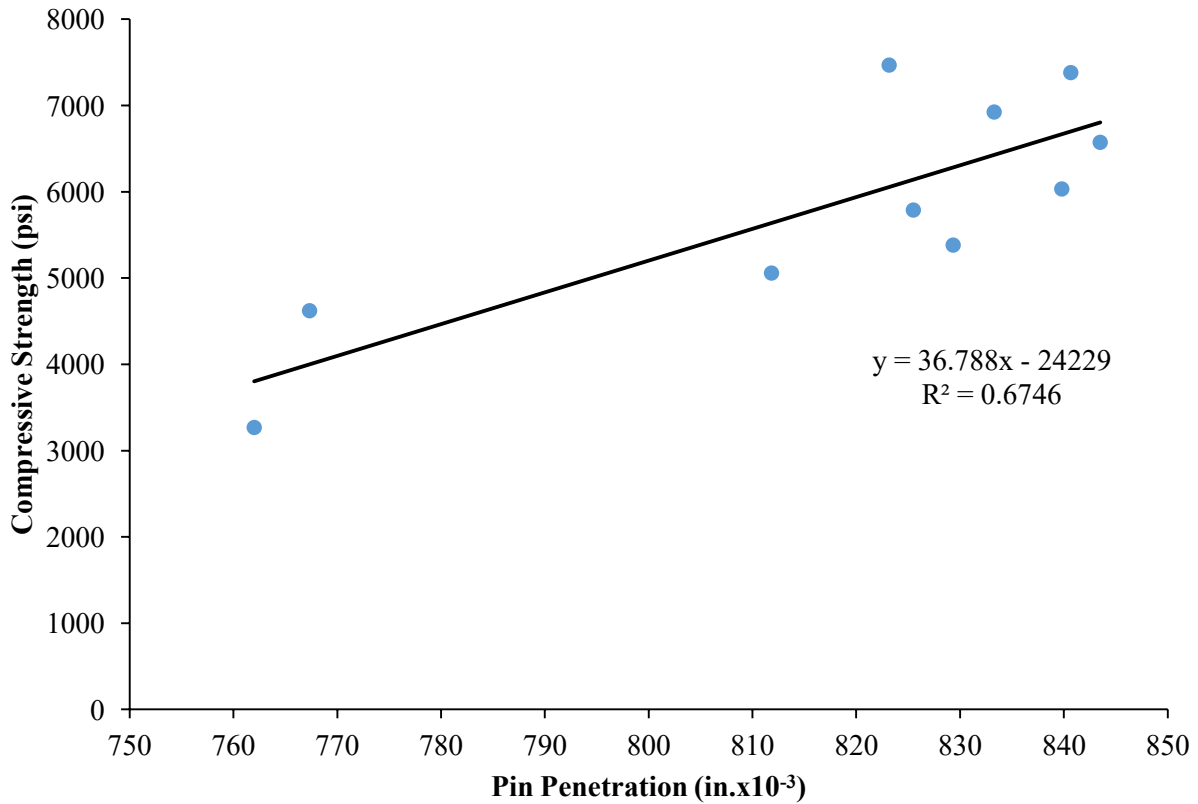


Figure D-8: Pin Penetration (in.x10⁻³) vs. Compressive Strength (psi) for 24x18x4 in. Slab C

Appendix E

Windsor Probe Penetration Results for Retaining Walls

Table E-1: Windsor Probe Test Results for Retaining Wall A

| Age (Days) | Exposed Probe | Average Exposed Probe (in.) | Str. (psi) | Average Str. (psi) | Std. Dev |
|-------------------|----------------------|------------------------------------|-------------------|---------------------------|-----------------|
| 7 | 1.71 | 1.78 | 2256 | 2890 | 0.07 |
| | 1.72 | | 2336 | | |
| | 1.86 | | 3524 | | |
| | 1.86 | | 3524 | | |
| | 1.77 | | 2812 | | |
| 14 | 2.07* | 1.92 | 5425* | 4119 | 0.10 |
| | 1.88 | | 3762 | | |
| | 1.96 | | 4475 | | |
| 21 | 1.81* | 1.93 | 3128* | 4159 | 0.08 |
| | 1.96 | | 4475 | | |
| | 1.89 | | 3842 | | |
| 28 | 1.91 | 1.95 | 4000 | 4343 | 0.03 |
| | 1.96 | | 4475 | | |
| | 1.97 | | 4555 | | |
| 42 | 2.05 | 2.01 | 5189 | 4845 | 0.04 |
| | 1.97 | | 4555 | | |
| | 2.00 | | 4792 | | |
| 56 | 2.08 | 2.09 | 5505 | 5611 | 0.02 |
| | 2.09 | | 5585 | | |
| | 2.11 | | 5743 | | |
| 90 | 2.14 | 2.12 | 6059 | 5822 | 0.03 |
| | 2.08 | | 5505 | | |
| | 2.13 | | 5901 | | |
| 120 | 2.28 | 2.15 | 7248 | 6007 | 0.11 |
| | 2.08 | | 5189 | | |
| | 2.09 | | 5585 | | |
| 180 | 2.09 | 2.18 | 5585 | 6403 | 0.08 |
| | 2.24 | | 6931 | | |
| | 2.22 | | 6693 | | |

*Data not used

Table E-2: Windsor Probe Test Results for Retaining Wall B

| Age (Days) | Exposed Probe | Average Exposed Probe (in.) | Str. (psi) | Average Str. (psi) | Std. Dev |
|-------------------|----------------------|------------------------------------|-------------------|---------------------------|-----------------|
| 7 | 1.56 | 1.62 | 910 | 1465 | 0.10 |
| | 1.53 | | 672 | | |
| | 1.76 | | 2654 | | |
| | 1.57 | | 1069 | | |
| | 1.68 | | 2020 | | |
| 14 | 1.76* | 1.92 | 2654* | 4045 | 0.01 |
| | 1.93 | | 4169 | | |
| | 1.91 | | 3921 | | |
| 21 | 2.04 | 2.05 | 5109 | 5109 | 0.02 |
| | 2.08 | | 5505* | | |
| | 2.04 | | 5109 | | |
| 28 | 2.14* | 1.96 | 5981* | 4476 | 0.01 |
| | 1.97 | | 4555 | | |
| | 1.95 | | 4396 | | |
| 42 | 1.93 | 2.00 | 4258 | 4605 | 0.06 |
| | 2.05 | | 5267* | | |
| | 2.02 | | 4951 | | |
| 56 | 1.87 | 1.92 | 5505 | 5545 | 0.05 |
| | 1.96 | | 5585 | | |
| | 1.92 | | 5743* | | |
| 90 | 2.07 | 2.06 | 5425 | 5399 | 0.02 |
| | 2.06 | | 5347 | | |
| | 2.04 | | 5425 | | |
| 120 | 2 | 2.02 | 4792* | 5109 | 0.03 |
| | 2.06 | | 5347 | | |
| | 2.01 | | 4871 | | |
| 180 | 2.21 | 2.16 | 6615 | 5981 | 0.05 |
| | 2.15 | | 6139 | | |
| | 2.12 | | 5823 | | |

*Data not used

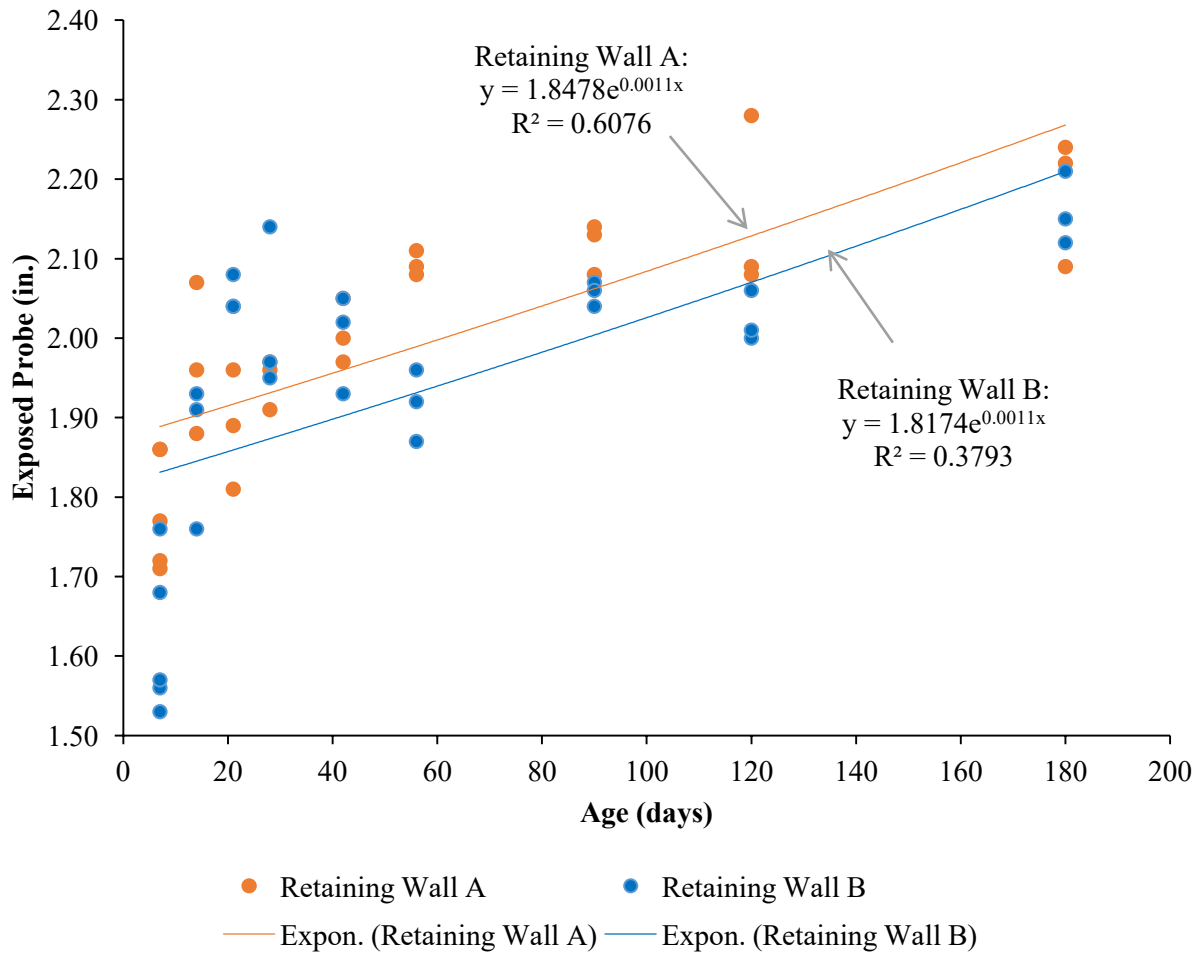


Figure E-1: Length of Exposed Probe (in.) vs. Age (days) for Retaining Walls A&B

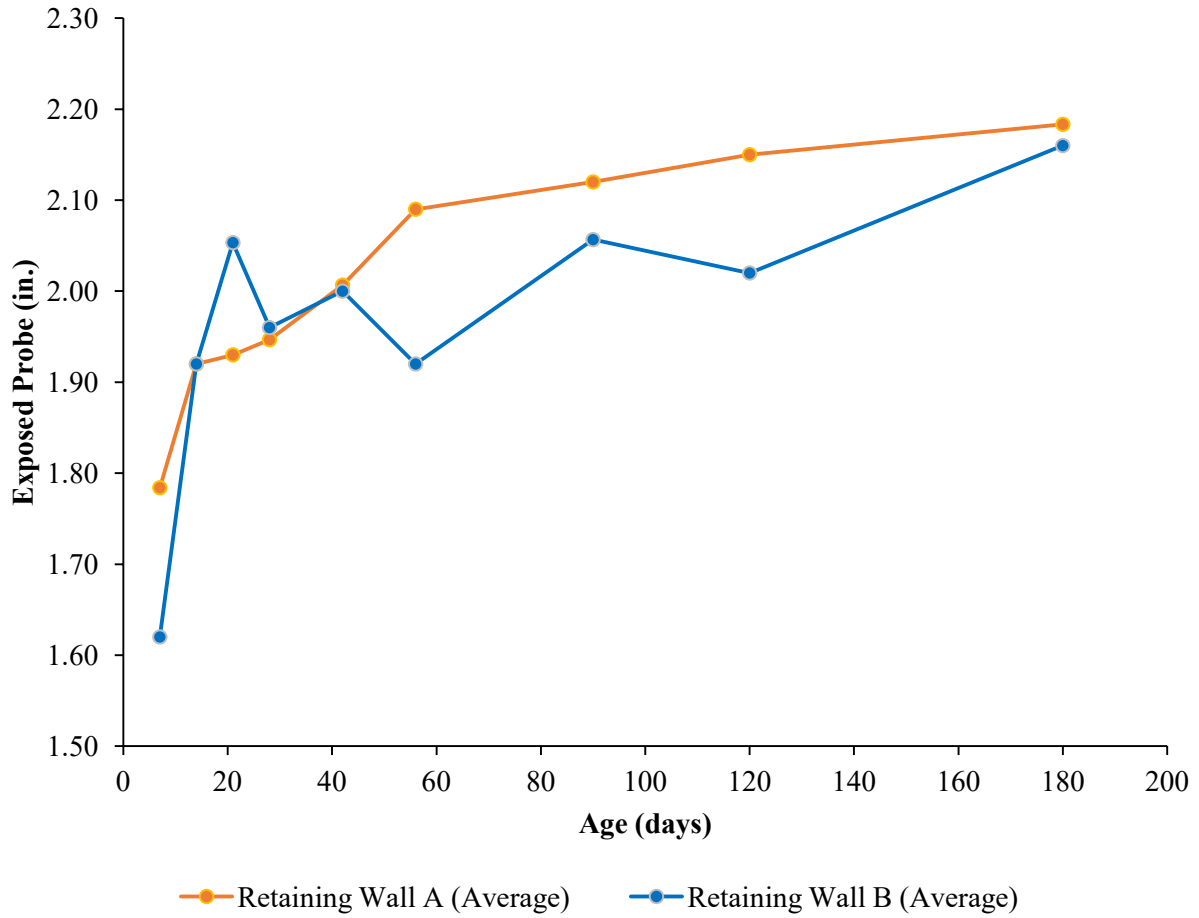


Figure E-2: Average Length of Exposed Probe (in.) vs. Age (days) for Retaining Walls A&B

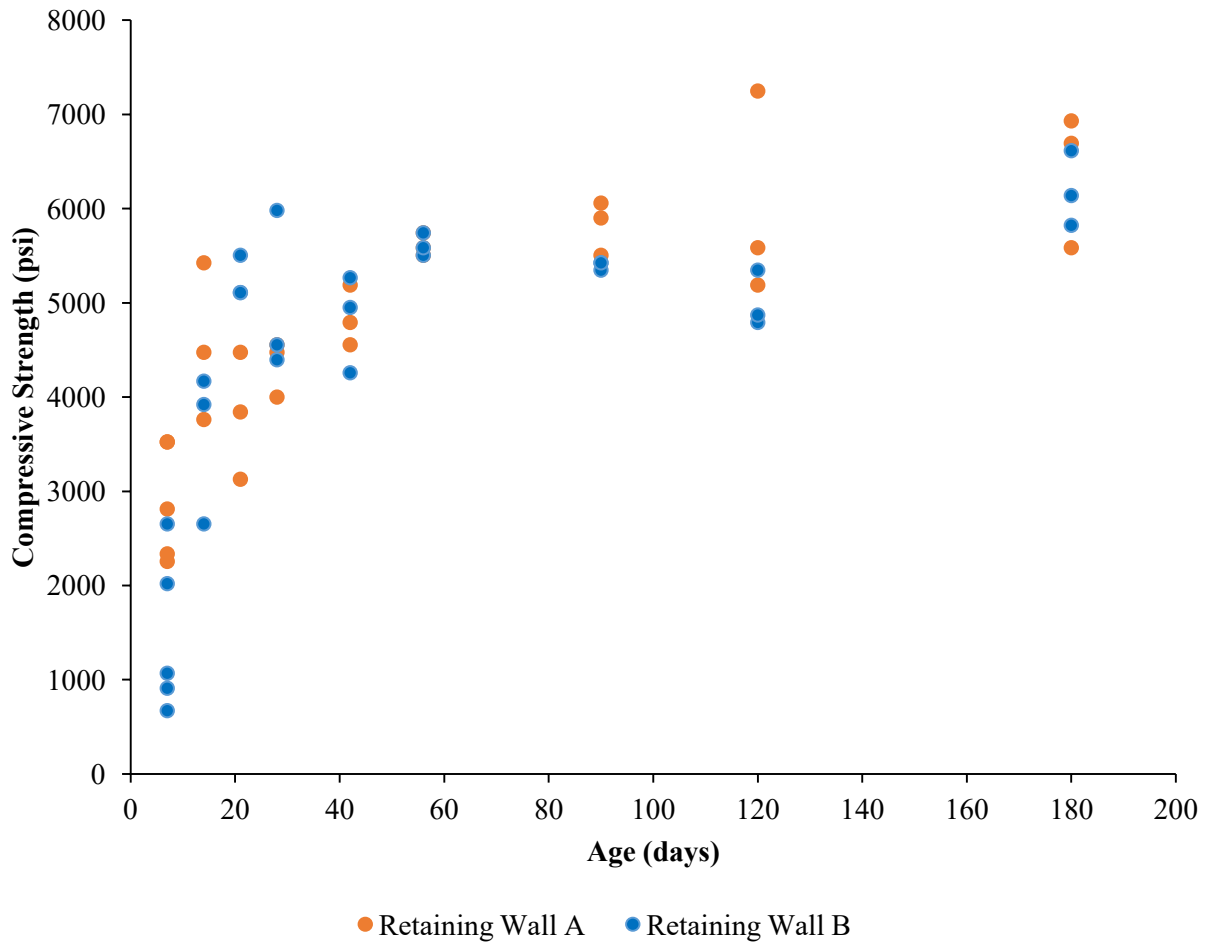


Figure E-3: Compressive Strength (psi) vs. Age (days) for Retaining Walls A&B

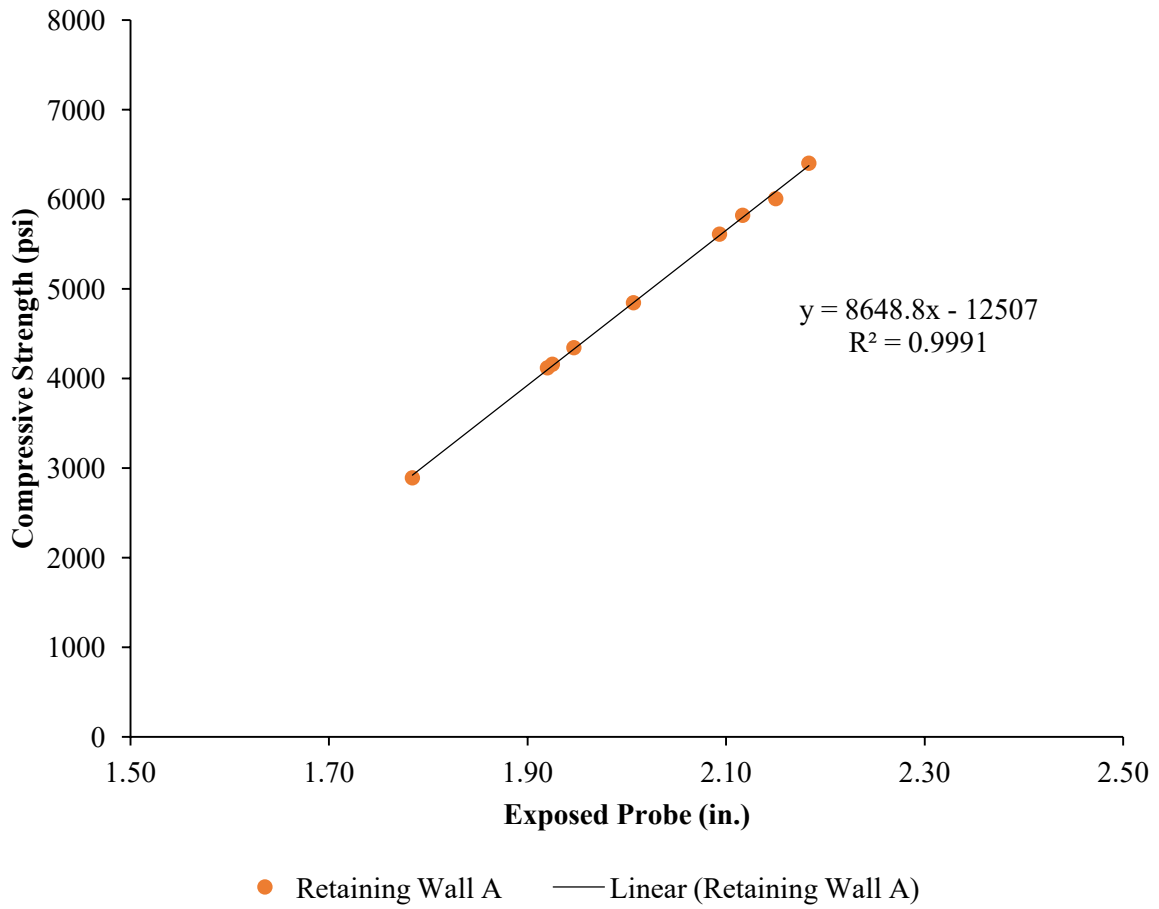


Figure E-4: Average Exposed Probe (in.) vs. Average Compressive Strength (psi) for Retaining Wall A

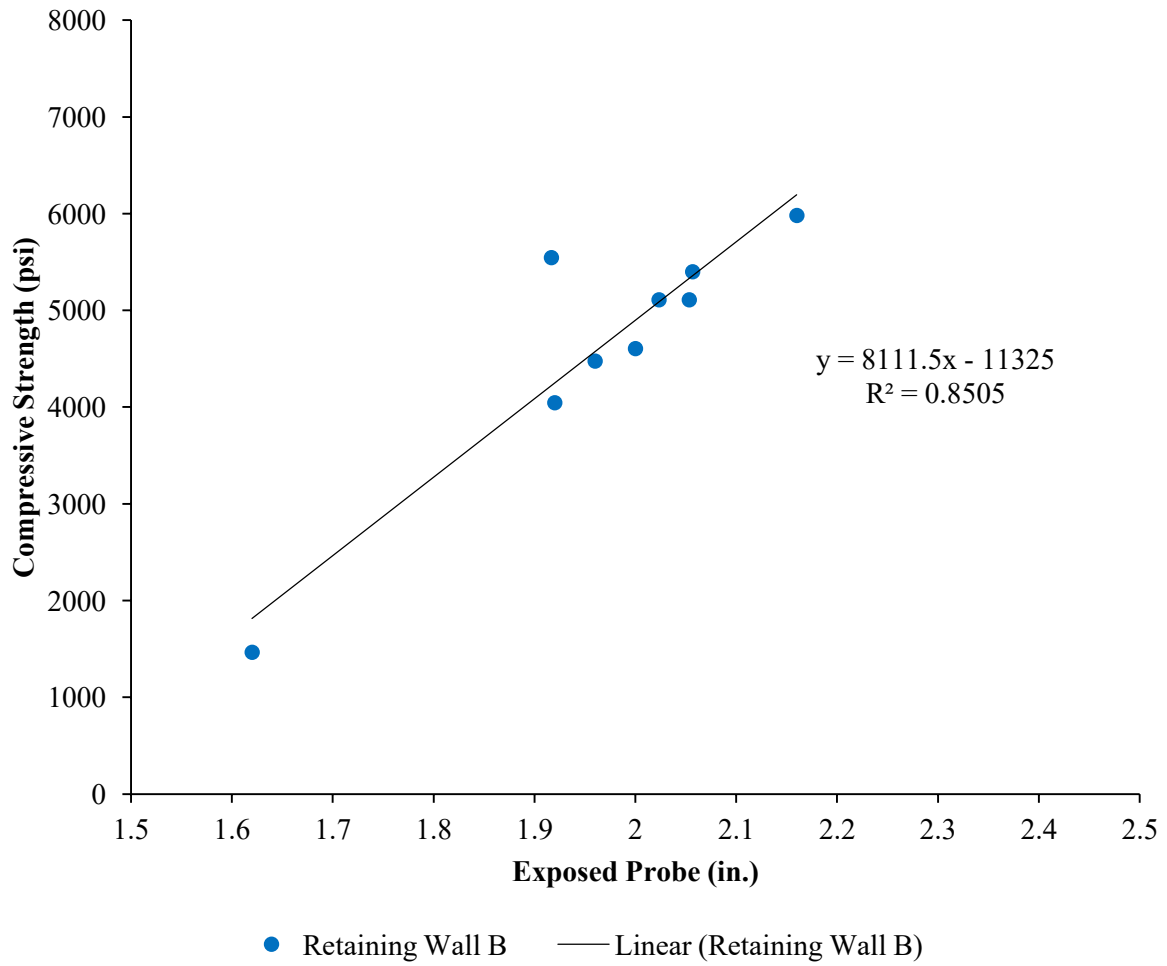


Figure E-5: Average Exposed Probe (in.) vs. Average Compressive Strength (psi) for Retaining Wall B

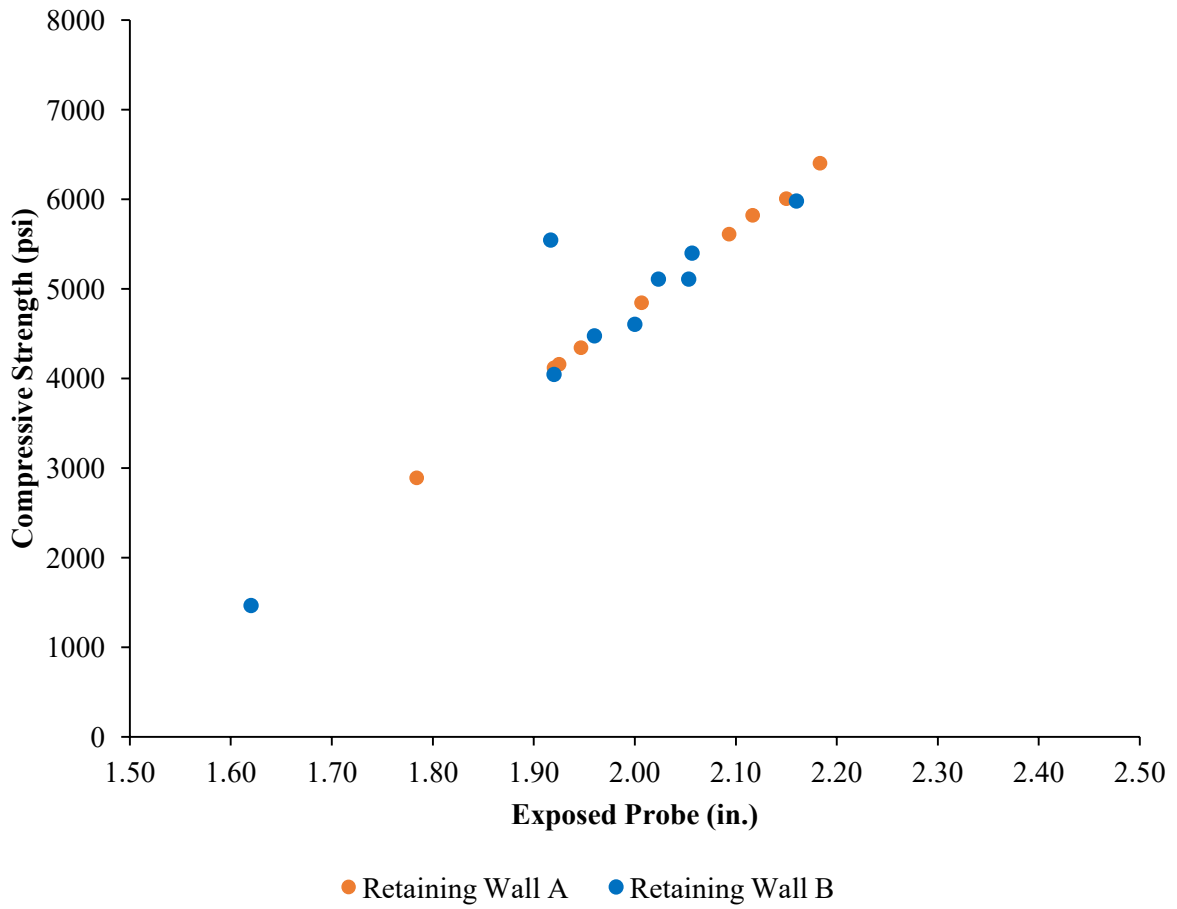


Figure E-6: Exposed Probe (in.) vs. Average Compressive Strength (psi) for Retaining Walls A&B

Appendix F

**Strength Prediction Charts for the
Rebound Hammer, UPV, Windsor
Pin, and Windsor Probe systems
and tables for all seven counties**

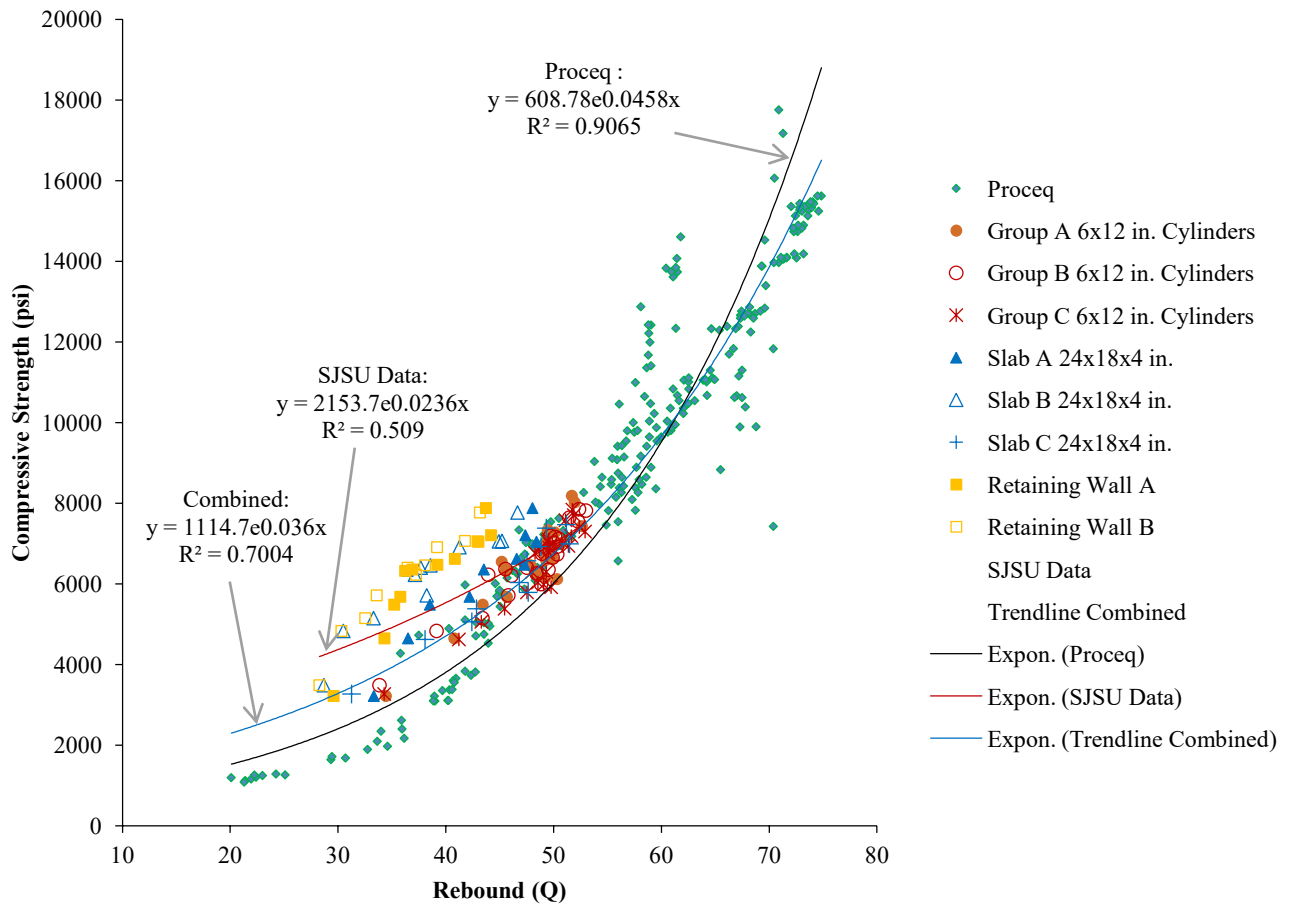


Figure F-1: Strength Prediction Chart for the Silver Schmidt Rebound Hammer

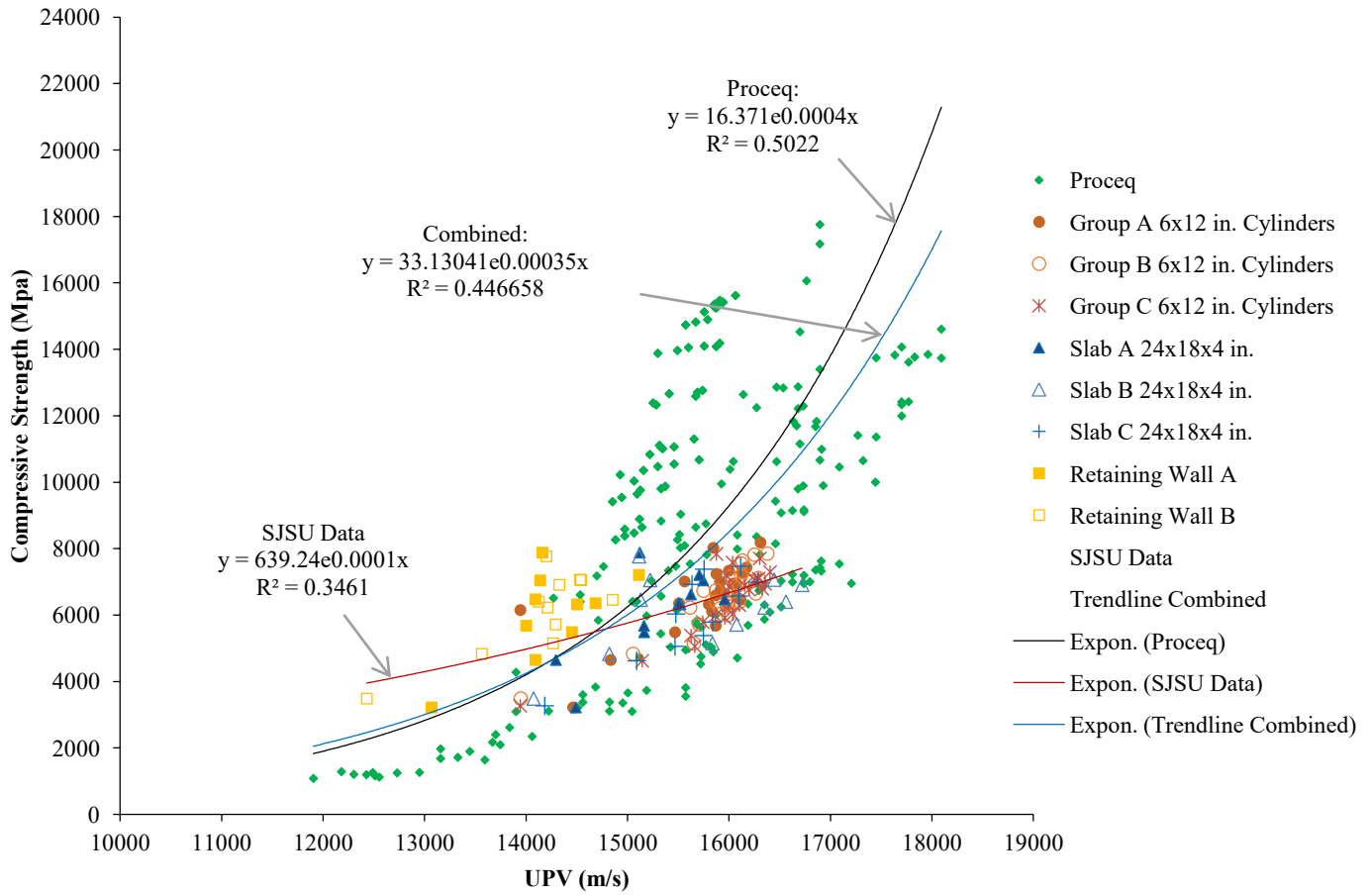


Figure F-2: Strength Prediction Chart for the Ultrasonic Pulse Velocity (UPV)

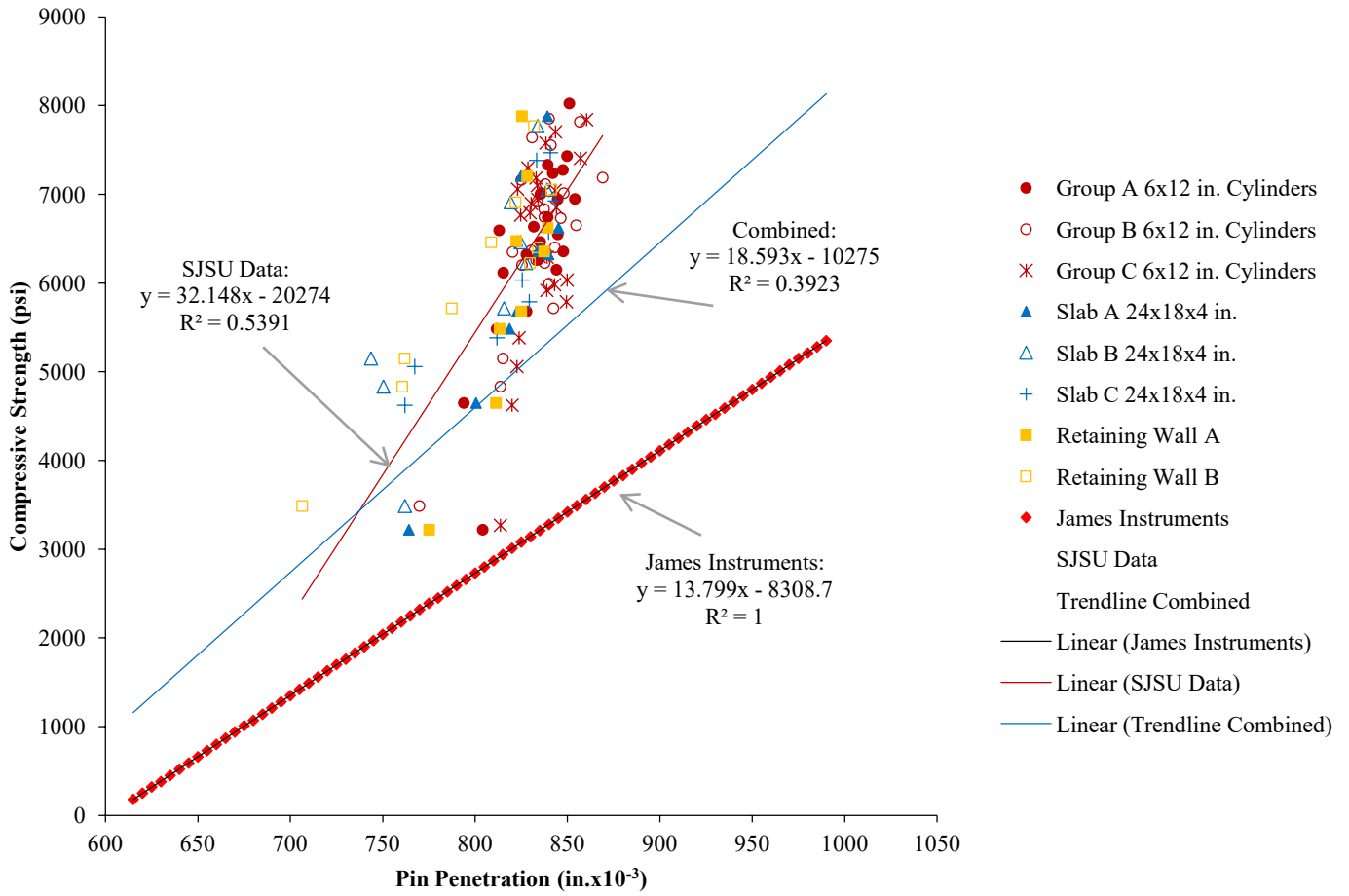


Figure F-3: Strength Prediction Chart for the Windsor Pin Penetration System

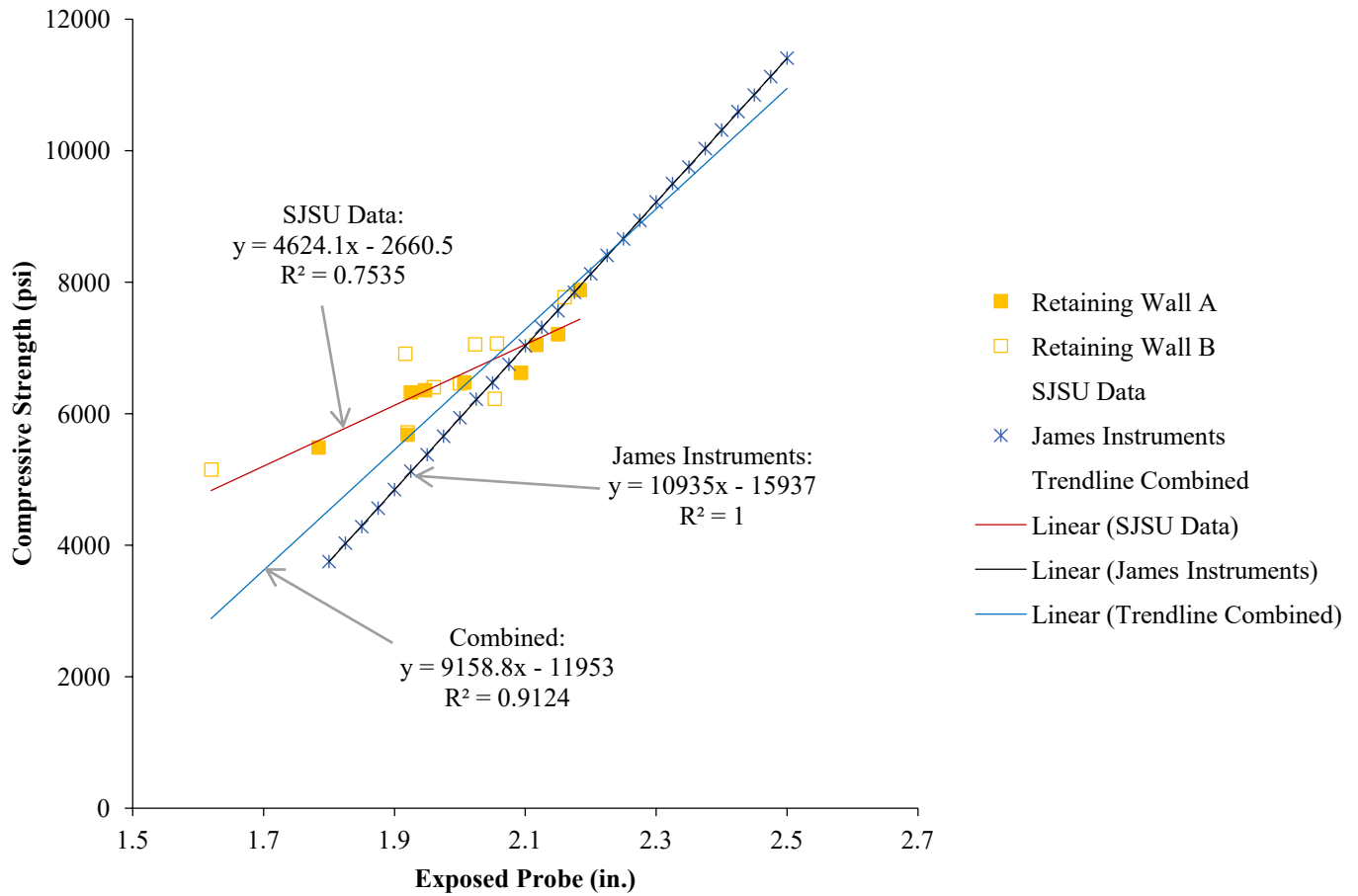


Figure F-4: Strength Prediction Chart for the Windsor Probe System

Table F-1: Contra Costa County Strength Predictions

| Bridge No. (Date Built) | Design Strength (psi) | Silver Schmidt (psi) | Windsor Pin (psi) | Windsor Probe (psi) | UPV (psi) | **Mean (σ) | Min | Max | % Increase (Mean σ) | $\sigma_{\bar{A}}$ 2StDev | $\sigma_{\bar{A}}$ 1StDev | σ_{+} 1StDev | σ_{+} 2StDev | StDev (psi) |
|-------------------------|-----------------------|----------------------|-------------------|---------------------|-----------|---------------------|------|------|-----------------------------|---------------------------|---------------------------|---------------------|---------------------|-------------|
| 28C0189R (1966) | 5500 | 8760 | 6634 | 8471 | 5539 | 7955 | 6634 | 8760 | 45 | 5649 | 6802 | 9108 | 10261 | 1153 |
| 28C0189L (1966) | 5500 | 8255 | 7289 | 8105 | 3613* | 7883 | 7289 | 8255 | 43 | 6843 | 7363 | 8403 | 8923 | 520 |
| 28C0087 (1965) | 5800 | 8614 | 7148 | 8960 | 3457* | 8241 | 7148 | 8960 | 42 | 6317 | 7279 | 9202 | 10164 | 962 |
| 28C0094 (1965) | 4500 | 7915 | 7084 | 9906 | 2500* | 8302 | 7084 | 9906 | 84 | 5401 | 6852 | 9752 | 11202 | 1450 |
| 28C0091L (1964) | 4700 | 8289 | 6891 | 9326 | 3272* | 8169 | 6891 | 9326 | 74 | 5725 | 6947 | 9391 | 10613 | 1222 |
| 28C0167 (1980) | 5000 | 6664 | 6377 | 9631 | 3444* | 7557 | 6377 | 9631 | 51 | 3954 | 5756 | 9359 | 11161 | 1802 |
| 28C0085 (1975) | 4000 | 8411 | 7052 | 8815 | 4705 | 8093 | 7052 | 8815 | 102 | 6245 | 7169 | 9016 | 9940 | 924 |
| Average | 5000 | 8130 | 6925 | 9030 | 3790 | 8028 | 6925 | 9093 | 63 | 5733 | 6881 | 9176 | 10323 | 1147 |

Table F-2: Fresno County Strength Predictions

| Bridge No. (Date Built) | Design Strength (psi) | Silver Schmidt (psi) | Windsor Pin (psi) | Windsor Probe (psi) | UPV (psi) | **Mean (σ) | Min | Max | % Increase (Mean σ) | $\sigma_{\bar{A}}$ 2StDev | $\sigma_{\bar{A}}$ 1StDev | σ_{+} 1StDev | σ_{+} 2StDev | StDev (psi) |
|-------------------------|-----------------------|----------------------|-------------------|---------------------|-----------|---------------------|------|------|-----------------------------|---------------------------|---------------------------|---------------------|---------------------|-------------|
| 42C0136 (1963) | 6000 | 8301 | 7373 | 9685 | 4633* | 8453 | 7373 | 9685 | 41 | 6127 | 7290 | 9616 | 10779 | 1163 |
| 42 0355 (1966) | 6000 | 8263 | 7180 | 8807 | 4081* | 8084 | 7180 | 8807 | 35 | 6427 | 7256 | 8912 | 9740 | 828 |
| 42 0272 (1967) | 6000 | 7796 | 6891 | 9227 | 3725* | 7971 | 6891 | 9227 | 33 | 5616 | 6794 | 9149 | 10327 | 1178 |
| 42 0270 (1967) | 6000 | 8082 | 6827 | 9181 | 6605 | 8030 | 6827 | 9181 | 34 | 5674 | 6852 | 9208 | 10386 | 1178 |
| 42C0649 (2006) | 6000 | 6264 | 6827 | 7670 | 4125* | 6920 | 6264 | 7670 | 15 | 5505 | 6212 | 7628 | 8335 | 708 |
| 42C0009 (1975) | 4000 | 7879 | 6827 | 9094 | 3655* | 7933 | 6827 | 9094 | 98 | 5664 | 6799 | 9068 | 10202 | 1135 |
| Average | 5667 | 7764 | 6988 | 8944 | 4471 | 7898 | 6894 | 8944 | 43 | 5836 | 6867 | 8930 | 9961 | 1031 |

Table F-3: Los Angeles County Strength Predictions

| Bridge No. (Date built) | Design Strength (psi) | Silver Schmidt (psi) | Windsor Pin (psi) | Windsor Probe (psi) | UPV (psi) | **Mean (σ) | Min | Max | % Increase (Mean σ) | σ -2StDev | σ -1StDev | σ +1StDev | σ +2StDev | StDev (psi) |
|-------------------------|-----------------------|----------------------|-------------------|---------------------|-----------|---------------------|------|-------|-----------------------------|------------------|------------------|------------------|------------------|-------------|
| 53C1457 (1961) | 5000 | 8166 | 7245 | 9845 | 3862* | 8418 | 7245 | 9845 | 68 | 5782 | 7100 | 9737 | 11055 | 1318 |
| 53 0851 (1969) | 4000 | 8401 | 7052 | 9692 | 4135 | 8382 | 7052 | 9692 | 110 | 5741 | 7061 | 9702 | 11022 | 1320 |
| 53 2032R (1970) | 4000 | 7241 | 7438 | 9295 | 4540 | 7991 | 7241 | 9295 | 100 | 5725 | 6858 | 9125 | 10258 | 1133 |
| 53 2032L (1970) | 4000 | 7521 | 7438 | 9967 | 3472* | 8309 | 7438 | 9967 | 108 | 5435 | 6872 | 9745 | 11182 | 1437 |
| 53 1681 (1965) | 4500 | 7558 | 7502 | 9601 | 1962* | 8220 | 7502 | 9601 | 83 | 5829 | 7024 | 9416 | 10612 | 1196 |
| 53C1261 (1964) | 4000 | 8872 | 7438 | 10181 | 3708* | 8830 | 7438 | 10181 | 121 | 6086 | 7458 | 10202 | 11574 | 1372 |
| 53 2030R (1970) | 5000 | 8322 | 7663 | 10547 | 3508* | 8844 | 7663 | 10547 | 77 | 5821 | 7332 | 10355 | 11867 | 1511 |
| 53 2030L (1970) | 4500 | 8086 | 7470 | 10120 | 3821* | 8558 | 7470 | 10120 | 90 | 5785 | 7172 | 9945 | 11332 | 1387 |
| Average | 4375 | 8021 | 7405 | 9906 | 3626 | 8444 | 7381 | 9906 | 94 | 5775 | 7110 | 9779 | 11113 | 1334 |

Table F-4: Placer County Strength Predictions

| Bridge No. (Date built) | Design Strength (psi) | Silver Schmidt (psi) | Windsor Pin (psi) | Windsor Probe (psi) | UPV (psi) | **Mean (σ) | Min | Max | % Increase (Mean σ) | σ -2StDev | σ -1StDev | σ +1StDev | σ +2StDev | StDev (psi) |
|-------------------------|-----------------------|----------------------|-------------------|---------------------|-----------|---------------------|------|-------|-----------------------------|------------------|------------------|------------------|------------------|-------------|
| 19 0128 (1973) | 4000 | 7692 | 7373 | 9601 | 3703* | 8222 | 7373 | 9601 | 106 | 5813 | 7018 | 9427 | 10631 | 1204 |
| 19 0130 (1973) | 4000 | 9070 | 7084 | 9295 | 4510 | 8483 | 7084 | 9295 | 112 | 6049 | 7266 | 9700 | 10917 | 1217 |
| 19 0062 (1967) | 4300 | 8455 | 7502 | 8960 | 5592 | 8306 | 7502 | 8960 | 93 | 6825 | 7565 | 9046 | 9786 | 740 |
| 19 0131 (1966) | 4300 | 8967 | 7566 | 9906 | 5310 | 8813 | 7566 | 9906 | 105 | 6458 | 7636 | 9991 | 11168 | 1177 |
| 19 0085 (1966) | 4300 | 8507 | 7598 | 9601 | 5577 | 8569 | 7598 | 9601 | 99 | 6563 | 7566 | 9571 | 10574 | 1003 |
| 19 0040 (1961) | 4000 | 8363 | 7405 | 11127 | 2549* | 8965 | 7405 | 11127 | 124 | 5100 | 7033 | 10898 | 12830 | 1933 |
| 19C0047 (1966) | 4000 | 8455 | 7470 | 9906 | 6986 | 8610 | 7470 | 9906 | 115 | 6159 | 7385 | 9836 | 11061 | 1226 |
| Average | 4129 | 8501 | 7428 | 9771 | 4889 | 8567 | 7428 | 9771 | 108 | 6138 | 7353 | 9781 | 10995 | 1214 |

Table F-5: San Bernardino County Strength Predictions

| Bridge No. (Date built) | Design Strength (psi) | Silver Schmidt (psi) | Windsor Pin (psi) | Windsor Probe (psi) | UPV (psi) | **Mean (σ) | Min | Max | % Increase (Mean σ) | σ -2StDev | σ -1StDev | σ +1StDev | σ +2StDev | StDev (psi) |
|-------------------------|-----------------------|----------------------|-------------------|---------------------|-----------|---------------------|------|------|-----------------------------|------------------|------------------|------------------|------------------|-------------|
| 54C0157 (1978) | 4500 | 8075 | 7084 | 9570 | 3838* | 8243 | 7084 | 9570 | 83 | 5740 | 6991 | 9495 | 10746 | 1252 |
| 54C0101 (1967) | 4850 | 6287 | 6795 | 9845 | 2115* | 7642 | 6287 | 9845 | 58 | 3793 | 5718 | 9567 | 11491 | 1925 |
| 54C0067 (1961) | 5700 | 7260 | 7341 | 9692 | 2679* | 8098 | 7260 | 9692 | 42 | 5335 | 6716 | 9479 | 10861 | 1382 |
| 54 0769R (1968) | 4300 | 8173 | 7341 | 9753 | 2676* | 8423 | 7341 | 9753 | 96 | 5972 | 7197 | 9648 | 10873 | 1225 |
| 54 1277R (2007) | 6000 | 8005 | 7433 | 9790 | 3958* | 7627 | 6188 | 9022 | 27 | 4629 | 6128 | 9126 | 10625 | 1499 |
| 54 1278L (2007) | 6000 | 7732 | 7245 | 8929 | 5753* | 7969 | 7245 | 8929 | 33 | 6235 | 7102 | 8835 | 9702 | 867 |
| 54 1278R (2007) | 5000 | 7722 | 7018 | 9039 | 4538* | 7034 | 6143 | 8028 | 41 | 4772 | 5903 | 8165 | 9297 | 1132 |
| 54 1277L (2007) | 6000 | 7850 | 7470 | 9243 | 5026* | 8188 | 7470 | 9243 | 36 | 6320 | 7254 | 9121 | 10055 | 934 |
| Average | 5294 | 7679 | 7218 | 9439 | 3916 | 7788 | 6735 | 9113 | 48 | 5220 | 6504 | 9073 | 10357 | 1285 |

Table F-6: Santa Clara County Strength Predictions

| Bridge No. (Date built) | Design Strength (psi) | Silver Schmidt (psi) | Windsor Pin (psi) | Windsor Probe (psi) | UPV (psi) | Mean (σ) | Min | Max | % Increase (Mean σ) | σ ̄ 2StDev | σ ̄ 1StDev | σ +1StDev | σ +2StDev | StDev (psi) |
|-------------------------|-----------------------|----------------------|-------------------|---------------------|-----------|-------------------|------|-------|-----------------------------|-------------------|-------------------|------------------|------------------|-------------|
| 37C0031 (1972) | 3500 | 8299 | 6791 | 10143 | 5311 | 8411 | 6791 | 10143 | 140 | 5054 | 6733 | 10090 | 11768 | 1678 |
| 37 0247 (1966) | 4000 | 8165 | 7116 | 8135 | 3372* | 7805 | 7116 | 8165 | 95 | 6611 | 7208 | 8402 | 9000 | 597 |
| 37 0246 (1966) | 4000 | 7797 | 7245 | 9295 | 3316* | 8112 | 7245 | 9295 | 103 | 5990 | 7051 | 9174 | 10235 | 1061 |
| 37 0253 (1966) | 4000 | 7513 | 6409 | 9173 | 6974 | 7698 | 6409 | 9173 | 92 | 4915 | 6307 | 9090 | 10481 | 1392 |
| 37 0218 (1965) | 4000 | 8394 | 7653 | 9860 | 4911 | 8636 | 7653 | 9860 | 132 | 6367 | 7502 | 9770 | 10905 | 1135 |
| 37 0217 (1965) | 4500 | 8393 | 7180 | 9433 | 7733 | 8335 | 7180 | 9433 | 85 | 6081 | 7208 | 9463 | 10590 | 1127 |
| 37C0082 (1961) | 5000 | 8721 | 7245 | 9356 | 1644* | 8441 | 7245 | 9356 | 69 | 6274 | 7357 | 9524 | 10608 | 1083 |
| 37C0074 (1964) | 4500 | 9094 | 7277 | 9570 | 3569* | 8647 | 7277 | 9570 | 92 | 6226 | 7437 | 9857 | 11068 | 1210 |
| 37 0149 (1965) | 4000 | 8402 | 7493 | 4869 | 5481 | 6921 | 4869 | 8402 | 73 | 3252 | 5086 | 8756 | 10590 | 1835 |
| Average | 4167 | 8317 | 7252 | 8969 | 5887 | 8164 | 6944 | 9326 | 101 | 5714 | 6939 | 9390 | 10615 | 1225 |

Table F-7: Ventura County Strength Predictions

| Bridge No. (Date built) | Design Strength (psi) | Silver Schmidt (psi) | Windsor Pin (psi) | Windsor Probe (psi) | UPV (psi) | Mean (σ) | Min | Max | % Increase (Mean σ) | $\sigma_{\bar{A}}$ 2StDev | $\sigma_{\bar{A}}$ 1StDev | σ_{+} 1StDev | σ_{+} 2StDev | StDev (psi) |
|-------------------------|-----------------------|----------------------|-------------------|---------------------|-----------|-------------------|------|------|-----------------------------|---------------------------|---------------------------|---------------------|---------------------|-------------|
| 52 0280L (1966) | 4750 | 7308 | 7213 | 9845 | 3356* | 8122 | 7213 | 9845 | 71 | 5135 | 6629 | 9615 | 11108 | 1493 |
| 52 0280R (1966) | 4750 | 7355 | 6923 | 9845 | 1291* | 8041 | 6923 | 9845 | 69 | 4887 | 6464 | 9618 | 11195 | 1577 |
| 52 0270 (1964) | 4500 | 6012 | 7116 | 9418 | 1639* | 7515 | 6012 | 9418 | 67 | 4040 | 5778 | 9253 | 10990 | 1737 |
| 52 C0043 (1990) | 4100 | 7720 | 7116 | 8807 | 3913* | 7881 | 7116 | 8807 | 92 | 6168 | 7024 | 8738 | 9595 | 857 |
| 52 0239 (1963) | 5000 | 7576 | 7084 | 7647 | 3469* | 7435 | 7084 | 7647 | 49 | 6822 | 7129 | 7742 | 8048 | 306 |
| 52C0051 (1960) | 5500 | 7782 | 7180 | 9326 | 3851* | 8096 | 7180 | 9326 | 47 | 5883 | 6989 | 9203 | 10310 | 1107 |
| 52 0049 (1994) | 6000 | 7624 | 7116 | 9112 | 3125* | 7951 | 7116 | 9112 | 33 | 5876 | 6914 | 8988 | 10026 | 1037 |
| Average | 4943 | 7340 | 7107 | 9143 | 2949 | 7863 | 6949 | 9143 | 61 | 5545 | 6704 | 9022 | 10182 | 1159 |

Table F-8: Santa Clara County Bridge 37C0031 Core Specimen Results

| Bridge | Design Strength (psi) | Core Compressive Strength (psi) | Silver Schmidt (psi) | Windsor Pin (psi) | UPV (psi) | Windsor Probe (psi) | Mean (σ) of Silver Schmidt and Windsor Pin (psi) |
|------------------|-----------------------|---------------------------------|--------------------------|--------------------------|-------------------------|---------------------|---|
| Bridge | 3500 | - | 8299 | 6791 | 5311 | 10143 | 7545** |
| Core 1 | | 6865 | 6994 (-16%)* (2%)** | 6819 (0.4%)* (-1%)** | 6198 (17%)* (-10%)** | - | 6906 (-8.5%)** (1%)** |
| Core 2 | | 8008 | 6622 (-20%)* (-17%)** | - | 7903 (49%)* (-1%)** | - | 6622 (-12.2%)** (-17%)** |
| Average of Cores | | 7437 | 6808 (-18%)* (-8%)** | 6819 (0.41%)* (-1%)** | 7051 (33%)* (-6%)** | - | 6764 (-10.4%)** (-8%)** |

*The percentage between parenthesis represents the percentage increase/decrease of the core from the bridge NDT prediction

**Silver Schmidt + Windsor Pin

***The percentage at bottom represents the percent increase/decrease of the core from the individual equipment prediction



Table F-9: Santa Clara County Bridge 37 0218 Core Specimen Results

| Bridge | Design Strength (psi) | Core Compressive Strength (psi) | Silver Schmidt (psi) | Windsor Pin (psi) | UPV (psi) | Windsor Probe (psi) | Mean (σ) of Silver Schmidt and Windsor Pin (psi) |
|------------------|-----------------------|---------------------------------|--------------------------|------------------------|--------------------------|---------------------|---|
| Bridge | 4000 | - | 8369 | 7373 | 3880 | 9509 | 7871 |
| Core 1 | | 5870 | 7153 (-15%)* (22%)*** | 7657 (4%)* (30%)*** | 7109 (83%)* (21%)*** | - | 7405 (-6%)* (26%)*** |
| Core 2 | | 6020 | 7150 (-15%)* (18%)*** | 7745 (5%)* (29%)*** | 7932 (104%)* (32%)*** | - | 7448 (-6%)* (23%)*** |
| Average of Cores | | 5945 | 7152 (-15%)* (20%)*** | 7701 (4%)* (30%)*** | 7520 (94%)* (26%)*** | | 7426 (-6%)* (25%)*** |

*The percentage between parenthesis represents the percentage increase/decrease of the core from the bridge NDT prediction

**Silver Schmidt + Windsor Pin

***The percentage at bottom represents the percent increase/decrease of the core from the individual equipment prediction

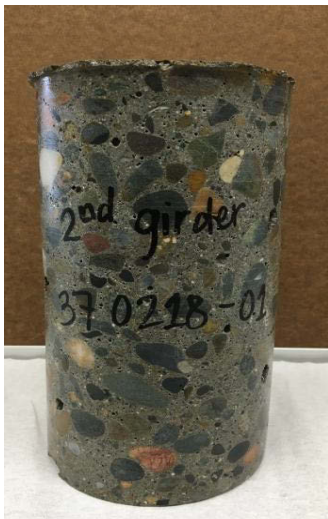


Table F-10: Santa Clara County Bridge 37 0149 Core Specimen Results

| | Design Strength (psi) | Core Compressive Strength (psi) | Silver Schmidt (psi) | Windsor Pin (psi) | UPV (psi) | Windsor Probe (psi) | Mean (σ) of Silver Schmidt and Windsor Pin (psi) |
|------------------|-----------------------|---------------------------------|--------------------------|-------------------------|-------------------------|---------------------|---|
| Bridge | 4000 | - | 8402 | 7493 | 5481 | 4869 | 7948** |
| Core 1 | | 8236 | 6888 (-18%)* (-16%)** | 7377 (-2%)* (-10%)** | 5705 (4%)* (-31%)** | - | 7132 (-10%)** (-13%)** |
| Core 2 | | 8353 | 6446 (-23%)* (-23%)** | 7079 (-6%)* (-15%)** | 6232 (14%)* (-25%)** | - | 6762 (-15%)** (-19%)** |
| Average of Cores | | 8295 | 6667 (-21%)* (-20%)** | 7228 (-4%)* (-13%)** | 5968 (9%)* (-28%)** | - | 6947 (-13%)** (-16%)** |

*The percentage between parenthesis represents the percentage increase/decrease of the core from the bridge NDT prediction
 **Silver Schmidt + Windsor Pin
 ***The percentage at bottom represents the percent increase/decrease of the core from the individual equipment prediction



Table F-11: San Bernardino County Bridge 54 1277R Core Specimen Results

| | Design Strength (psi) | Core Compressive Strength (psi) | Silver Schmidt (psi) | Windsor Pin (psi) | UPV (psi) | Windsor Probe (psi) | Mean (σ) of Silver Schmidt and Windsor Pin (psi) |
|------------------|-----------------------|---------------------------------|--------------------------|--------------------------|-------------------------|---------------------|---|
| Bridge | 6000 | - | 7756 | 7277 | 3898 | 9790 | 7517** |
| Core 1 | | 7599 | 6390 (-18%)* (-16%)** | 7255 (-0.3%)* (-5%)** | 6609 (70%)* (-13%)** | - | 6823 (-9%)** (-10%)** |
| Core 2 | | 7787 | 6588 (-15%)* (-15%)** | 6969 (-4%)* (-11%)** | 6735 (73%)* (-14%)** | - | 6801 (-10%)** (-13%)** |
| Average of Cores | | 7693 | 6489 (-16%)* (-16%)** | 6672 (-2%)* (-8%)** | 7112 (71%)* (-13%)** | - | 6801 (-10%)** (-12%)** |

*The percentage between parenthesis represents the percentage increase/decrease of the core from the bridge NDT prediction

**Silver Schmidt + Windsor Pin

***The percentage at bottom represents the percent increase/decrease of the core from the individual equipment prediction

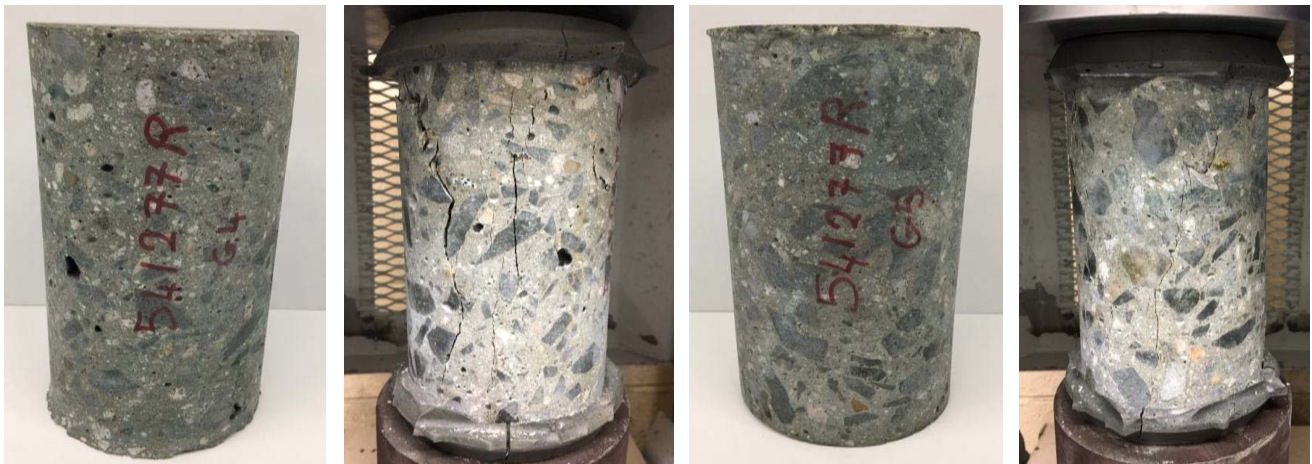


Table F-12: San Bernardino County Bridge 54 1278R Core Specimen Results

| | Design Strength (psi) | Core Compressive Strength (psi) | Silver Schmidt (psi) | Windsor Pin (psi) | UPV (psi) | Windsor Probe (psi) | Mean (σ) of Silver Schmidt and Windsor Pin (psi) |
|------------------|-----------------------|---------------------------------|--------------------------|--------------------------|-------------------------|---------------------|---|
| Bridge | | - | 7722 | 7020 | 3608 | 9039 | 7371** |
| Core 1 | 5000 | 7998 | 5782 (-25%)* (-28%)** | 6850 (-2%)* (-14%)** | 7718 (114%)* (-3%)** | - | 6316 (-14%)** (-21%)** |
| Core 2 | | 7611 | 6181 (-20%)* (-19%)** | 7237 (3%)* (-5%)** | 8395 (133%)* (10%)** | - | 6709 (-9%)** (-12%)** |
| Average of Cores | | 7805 | 5981 (-23%)* (-23%)** | 7043 (0.3%)* (-10%)** | 8057 (123%)* (3%)** | - | 6512 (-12%)** (-16%)** |

*The percentage between parenthesis represents the percentage increase/decrease of the core from the bridge NDT prediction
 **Silver Schmidt + Windsor Pin
 ***The percentage at bottom represents the percent increase/decrease of the core from the individual equipment prediction



Table F-13: Summary of Core Specimen Results

| Bridge No. | Design Strength (psi) | Average Core Compressive Strength (psi) | Predicted Bridge NDT Strength (psi) | Bridge $\sigma - \bar{\Delta}$ StDev (psi) | Bridge $\sigma - \bar{\Delta}$ StDev (psi) | Bridge $\sigma + 1$ StDev (psi) | Bridge $\sigma + 2$ StDev (psi) | % Increase Core & Design Strength | % Increase Bridge NDT & Design Strength | % Increase Bridge / % Increase Core | 70% Predicted Bridge NDT Strength (psi) |
|------------|-----------------------|---|-------------------------------------|--|--|---------------------------------|---------------------------------|-----------------------------------|---|-------------------------------------|---|
| 37C0031 | 3500 | 6966 | 8411 | 5054 | 6733 | 10090 | 11768 | 99 | 140 | 1.41 | 5888 |
| 37 0218 | 4000 | 5945 | 8636 | 6367 | 7502 | 9770 | 10905 | 49 | 132 | 2.69 | 6045 |
| 37 0149 | 4000 | 8295 | 6921 | 3252 | 5086 | 8756 | 10590 | 107 | 73 | 0.68 | 4845 |
| 54 1277R | 6000 | 7693 | 7627 | 4629 | 6128 | 9126 | 10625 | 28 | 27 | 0.96 | 5339 |
| 54 1278R | 5000 | 7805 | 7034 | 4772 | 5903 | 8165 | 9297 | 56 | 41 | 0.73 | 4924 |
| Average | | | | | | | | | | 1.30 | |

Table F-14: Summary of Core Specimen Results

| Bridge No. | Bridge Age (years) | Design Strength (psi) | Average Core Compressive Strength (psi) | Predicted Bridge NDT Strength (psi) | Bridge NDT $\sigma_{\bar{A}}$ 2StDev (psi) | Bridge NDT $\sigma_{\bar{A}}$ StDev (psi) | Bridge NDT $\sigma+1$ StDev (psi) | Bridge NDT $\sigma+2$ StDev (psi) |
|-----------------|--------------------|-----------------------|---|-------------------------------------|--|---|-----------------------------------|-----------------------------------|
| 37C0031 (1972) | 45 | 3500 | 6966 | 8411 | 5054 | 6733 | 10090 | 11768 |
| 37 0218 (1965) | 52 | 4000 | 5945 | 8636 | 6367 | 7502 | 9770 | 10905 |
| 37 0149 (1965) | 52 | 4000 | 8295 | 6921 | 3252 | 5086 | 8756 | 10590 |
| 54 1277R (2007) | 10 | 6000 | 7693 | 7627 | 4629 | 6128 | 9126 | 10625 |
| 54 1278R (2007) | 10 | 5000 | 7805 | 7034 | 4772 | 5903 | 8165 | 9297 |

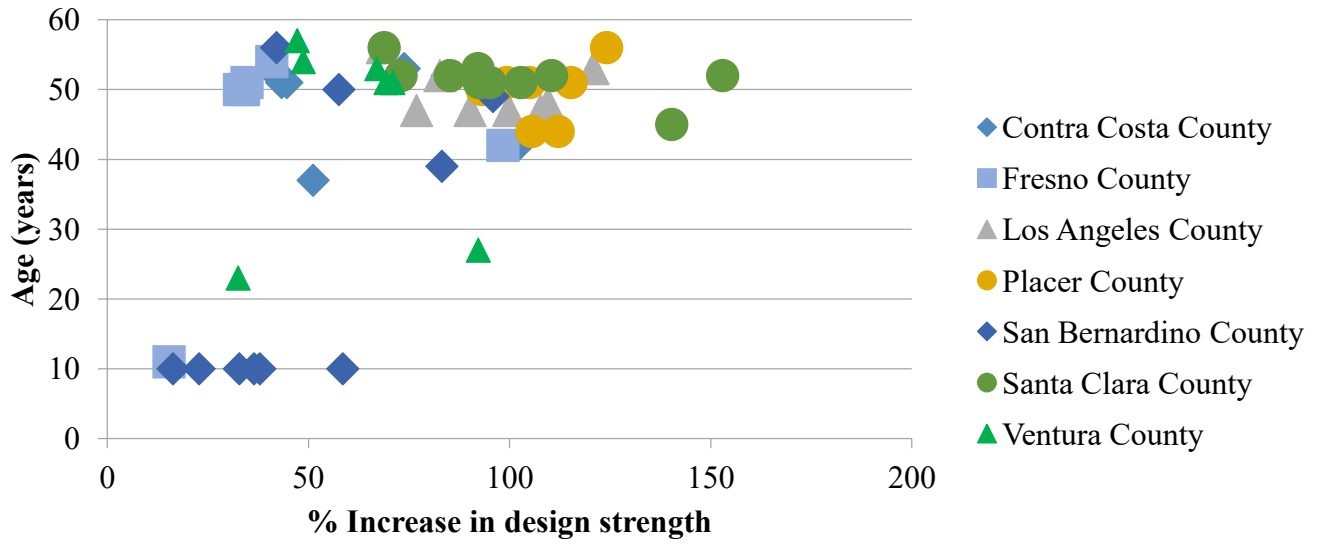


Figure F-5: Age vs. %Increase from Design Strength As Predicted By NDT Predictions

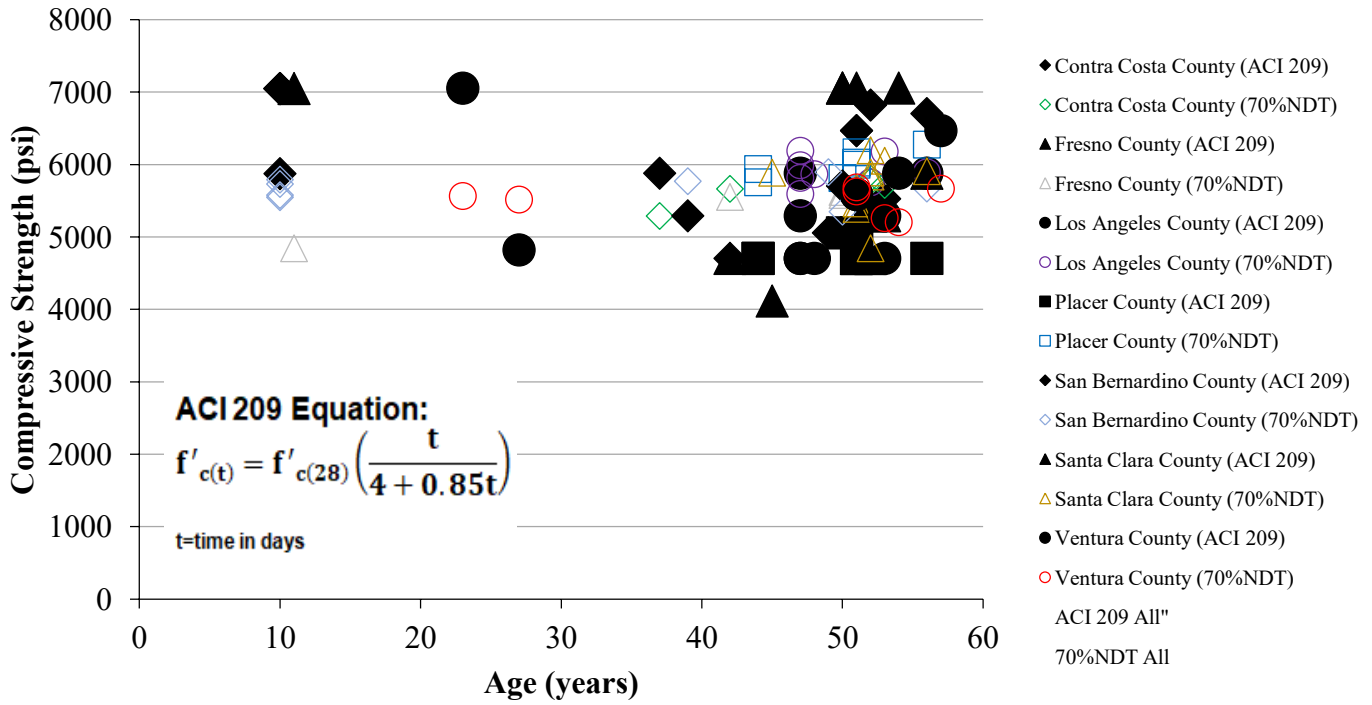


Figure F-6: Comparison of Strength Prediction vs. Age Between 70%NDT and ACI 209 Equation

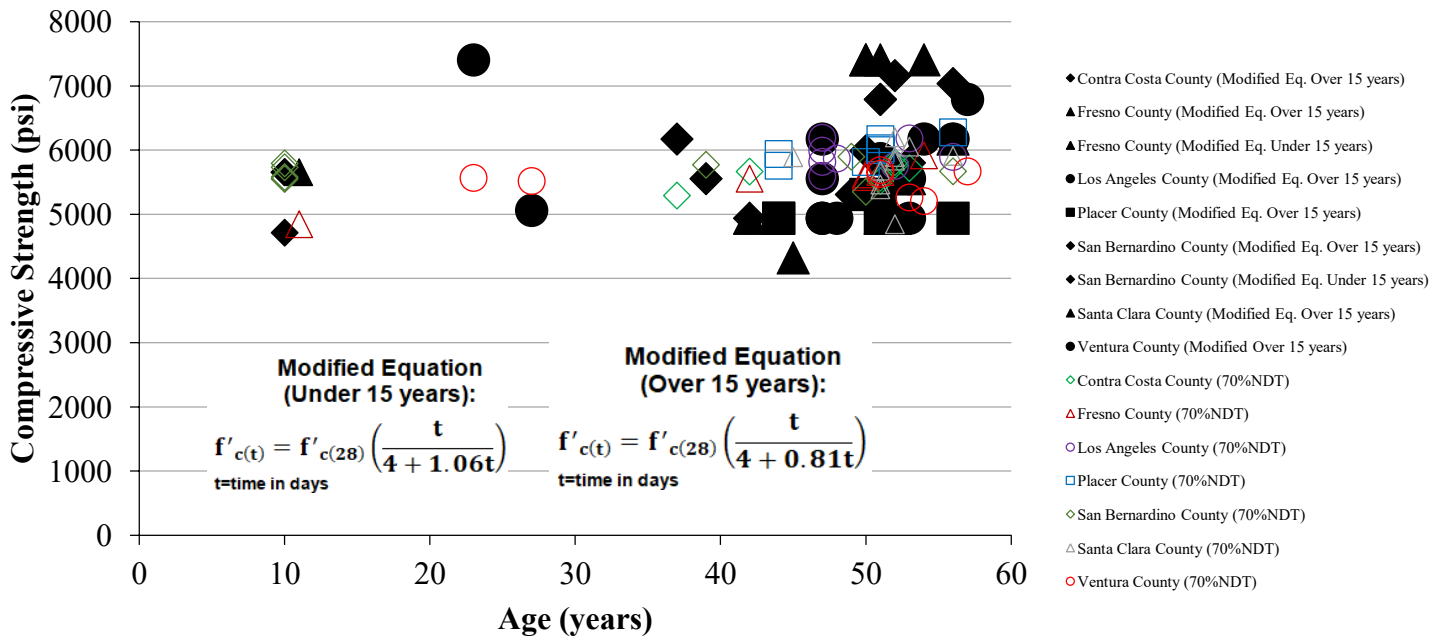


Figure F-7: Comparison of Strength Prediction vs. Age of Modified Equation Predictions

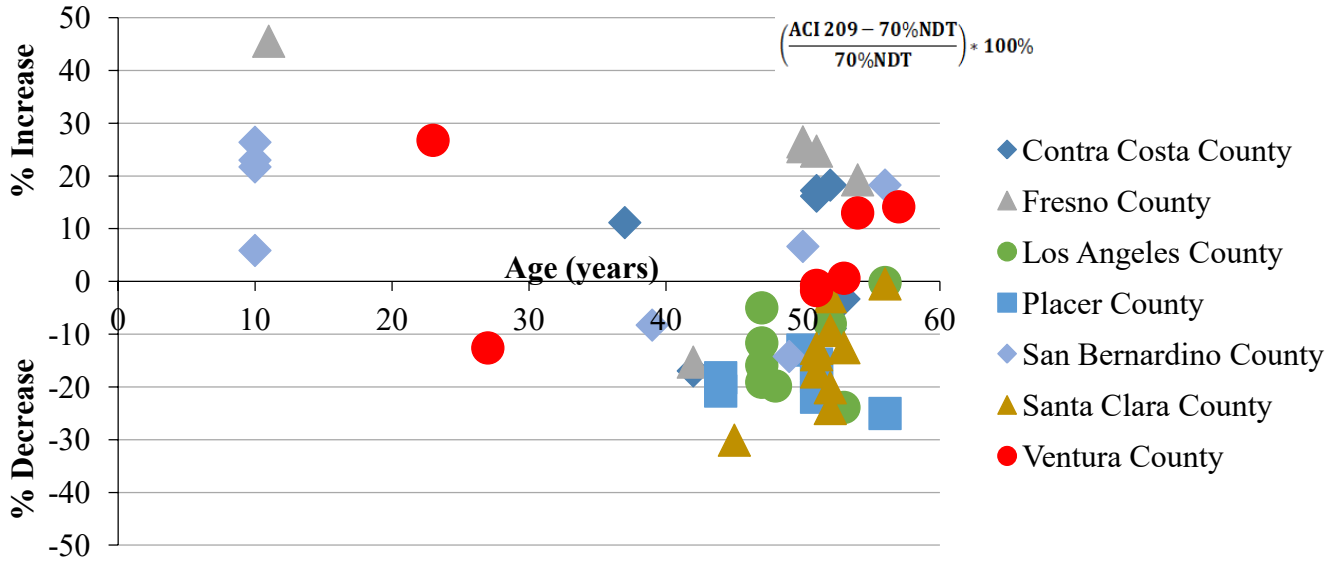


Figure F-8: %Increase or Decrease of ACI 209 Equation from 70%NDT Strength Predictions

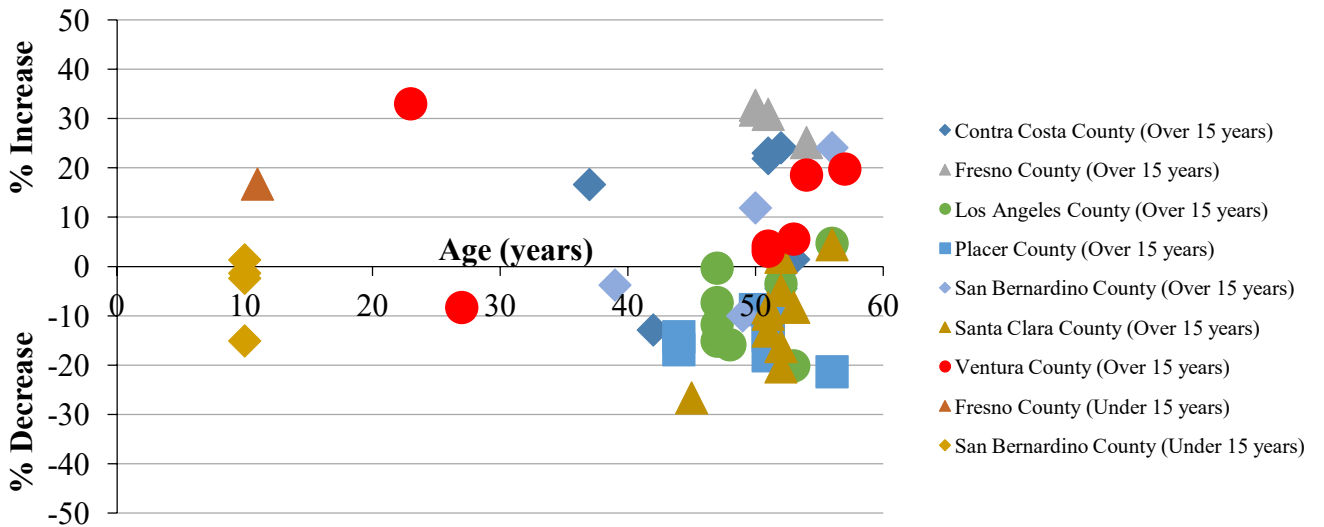


Figure F-9: %Increase or Decrease of Modified Equations from 70%NDT Strength Predictions

**Table F-15: Percent Increase or Decrease of ACI 209 Equation From 70%NDT
Compressive Strength Predictions**

| County | Contra Costa | Fresno | Los Angeles | Placer | San Bernardino | Santa Clara | Ventura |
|-----------------|------------------------|------------------------|-------------------------|------------------------|-------------------------|-------------------------|-------------------------|
| | 16% (51) (28C0189R) | 19% (54) (42C0136) | 0.2% (56) (53C1457) | -18% (44) (19 0128) | -8% (39) (54C0157) | -30% (45) (37C0031) | -2% (51) (52 0280L) |
| | 17% (51) (28C0189L) | 25% (51) (42 0355) | -20% (48) (53 0851) | -21% (44) (19 0130) | 7% (50) (54C0101) | -14% (51) (37 0247) | -1% (51) (52 0280R) |
| | 18% (52) (28C0087) | 26% (50) (42 0272) | -16% (47) (53 2032R) | -13% (50) (19 0062) | 18% (56) (54C0067) | -17% (51) (37 0246) | 1% (53) (52 0270) |
| | -9% (52) (28C0094) | 26% (50) (42 0270) | -19% (47) (53 2032L) | -18% (51) (19 0131) | -14% (49) (54 0769R) | -13% (51) (37 0253) | -13% (27) (52 C0043) |
| | -3% (53) (28C0091L) | 46% (11) (42C0649) | -8% (52) (53 1681) | -16% (51) (19 0085) | 22% (10) (54 1277R) | -22% (52) (37 0218) | 13% (54) (52 0239) |
| | 11% (37) (28C0167) | -15% (42) (42C0009) | -24% (53) (53C1261) | -25% (56) (19 0040) | 26% (10) (54 1278L) | -9% (52) (37 0217) | 14% (57) (52C0051) |
| | -17% (42) (28C0085) | | -5% (47) (53 2030R) | -22% (51) (19C0047) | 6% (10) (54 1278R) | -0.5% (56) (37C0082) | 27% (23) (52 0049) |
| | | | -12% (47) (53 2030L) | | 23% (10) (54 1277L) | -13% (53) (37C0074) | |
| | | | | | | -3% (52) (37 0149) | |
| ACI 209 Average | 5% | 21% | -13% | -19% | 10% | -14% | 6% |
| | -1% | | | | | | |
| Under 15 years | - | 46% | - | - | 19% | - | - |
| Average | 32% | | | | | | |
| Over 15 years | 5% | 16% | -13% | -19% | 1% | -14% | 6% |
| Average | -3% | | | | | | |
| Over 50 years | 8% | 24% | -11% | -19% | 12% | -13% | 5% |
| Average | 1% | | | | | | |

ACI 209 Equation:

$$f'_{c(t)} = f'_{c(28)} \left(\frac{t}{4 + 0.85t} \right)$$

+Over estimation

-Under estimation

t=time in days

**Table F-16: Percent Increase or Decrease of Modified ACI 209 Equations From 70%NDT
Compressive Strength Predictions**

| County | Contra Costa | Fresno | Los Angeles | Placer | San Bernardino | Santa Clara | Ventura |
|---------------------------------------|------------------------|------------------------|--------------------------|------------------------|-------------------------|------------------------|------------------------|
| | 22% (51) (28C0189R) | 25% (54) (42C0136) | 5% (56) (53C1457) | -14% (44) (19 0128) | -4% (39) (54C0157) | -27% (45) (37C0031) | 3% (51) (52 0280L) |
| | 23% (51) (28C0189L) | 31% (51) (42 0355) | -16% (48) (53 0851) | -17% (44) (19 0130) | 12% (50) (54C0101) | -10% (51) (37 0247) | 4% (51) (52 0280R) |
| | 24% (52) (28C0087) | 33% (50) (42 0272) | -12% (47) (53 2032R) | -9% (50) (19 0062) | 24% (56) (54C0067) | -13% (51) (37 0246) | 6% (53) (52 0270) |
| | -4% (52) (28C0094) | 32% (50) (42 0270) | -15% (47) (53 2032L) | -14% (51) (19 0131) | -10% (49) (54 0769R) | -8% (51) (37 0253) | -8% (27) (52 C0043) |
| | 1% (53) (28C0091L) | 17% (11) (42C0649) | -3% (52) (53 1681) | -12% (51) (19 0085) | -2% (10) (54 1277R) | -18% (52) (37 0218) | 19% (54) (52 0239) |
| | 17% (37) (28C0167) | -11% (42) (42C0009) | -20% (53) (53C1261) | -21% (56) (19 0040) | 1% (10) (54 1278L) | -20% (52) (37 0217) | 20% (57) (52C0051) |
| | -13% (42) (28C0085) | | -0.3% (47) (53 2030R) | -18% (51) (19C0047) | -15% (10) (54 1278R) | -5% (56) (37C0082) | 33% (23) (52 0049) |
| | | | -7% (47) (53 2030L) | | -1% (10) (54 1277L) | 4% (53) (37C0074) | |
| | | | | | | -8% (52) (37 0149) | |
| ACI 209 (Modified) Average | 10% | 21% | -9% | -15% | 1% | -10% | 11% |
| | 1% | | | | | | |
| Under 15 years Average | - | 17% | - | - | -4% | - | - |
| | 6% | | | | | | |
| Over 15 years Average | 10% | 22% | -9% | -15% | 6% | -10% | 11% |
| | 2% | | | | | | |
| Over 50 years Average | 13% | 30% | -6% | -15% | 18% | -8% | 10% |
| | 6% | | | | | | |

Modified Eq. <15 years:

$$f'_{c(t)} = f'_{c(28)} \left(\frac{t}{4 + 1.06t} \right)$$

t=time in days

Modified Eq. >15 years:

$$f'_{c(t)} = f'_{c(28)} \left(\frac{t}{4 + 0.81t} \right)$$

t=time in days

+Over estimation
 -Under estimation

Table F-17: Average Percent Increase or Decrease of ACI 209 Equation and Modified ACI 209 Equations From 70%NDT Compressive Strength Prediction Comparison

| | Under 15 years | Over 15 years | Over 50 years | All Ages |
|--------------------|----------------|---------------|---------------|----------|
| ACI 209 | 32% | -3% | 1% | -1% |
| Modified Equations | 6% | 2% | 6% | 1% |

ACI 209 Equation:

$$f'_{c(t)} = f'_{c(28)} \left(\frac{t}{4 + 0.85t} \right)$$

t=time in days

**Modified Equation
(Under 15 years):**

$$f'_{c(t)} = f'_{c(28)} \left(\frac{t}{4 + 1.06t} \right)$$

t=time in days

**Modified Equation
(Over 15 years):**

$$f'_{c(t)} = f'_{c(28)} \left(\frac{t}{4 + 0.81t} \right)$$

t=time in days

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