Re-evaluation of Acceptance Testing Criteria for Structural Masonry Using the Prism Test Method

James Bristow
University of Nevada, Las Vegas, James.Bristow@novageotech.com

Follow this and additional works at: https://digitalscholarship.unlv.edu/thesesdissertations
Part of the Civil Engineering Commons, Engineering Science and Materials Commons, Geotechnical Engineering Commons, and the Materials Science and Engineering Commons

Repository Citation
https://digitalscholarship.unlv.edu/thesesdissertations/2950

This Thesis is brought to you for free and open access by Digital Scholarship@UNLV. It has been accepted for inclusion in UNLV Theses, Dissertations, Professional Papers, and Capstones by an authorized administrator of Digital Scholarship@UNLV. For more information, please contact digitalscholarship@unlv.edu.
RE-EVALUATION OF ACCEPTANCE TESTING CRITERIA FOR STRUCTURAL MASONRY USING THE PRISM TEST METHOD

By

James M. Bristow

Bachelor of Science – Civil Engineering
University of Nevada, Las Vegas
2008

A thesis submitted in partial fulfillment
of the requirements of the

Master of Science in Engineering – Civil and Environmental Engineering

Department of Civil and Environmental Engineering and Construction
Howard R. Hughes College of Engineering
The Graduate College

University of Nevada, Las Vegas
May 2017
This thesis prepared by

James M. Bristow

entitled

Re-evaluation of Acceptance Testing Criteria for Structural Masonry Using the Prism Test Method

is approved in partial fulfillment of the requirements for the degree of

Master of Science in Engineering – Civil and Environmental Engineering
Department of Civil and Environmental Engineering and Construction

Moses Karakouzian, Ph.D.  
Examination Committee Chair

Kathryn Hausbeck Korgan, Ph.D.  
Graduate College Interim Dean

Pramen P. Shrestha, Ph.D.  
Examination Committee Member

Douglas Rigby, Ph.D.  
Examination Committee Member

Vernon Hodge, Ph.D.  
Graduate College Faculty Representative
ABSTRACT

RE-EVALUATION OF ACCEPTANCE TESTING CRITERIA FOR STRUCTURAL MASONRY USING THE PRISM TEST METHOD

By

James M. Bristow, P.E.

Dr. Moses Karakouzian, Committee Chair
Professor of Civil and Environmental Engineering
University of Nevada, Las Vegas

The current acceptance criteria for structural masonry in accordance with International Building Code allows for the prism test method to be used. However, without a proper understanding of the effects of variable material properties such as individual masonry unit compressive strength and the various material moduli of elasticity, as well as the effect of field conditions on the unit’s performance, masonry prisms may “fail” to reach the design compressive strength ($f'_m$).

By identifying causes of failure and evaluating the failure magnitude, it is concluded that when the masonry prism test method is utilized for acceptance testing of as-built masonry structures, additional testing should be performed on the grout in order to fully understand the influence that grout strength and possible grout deformation on the concrete masonry unit during
the uniaxial compression test. If grout and block characteristics indicate it is appropriate, some combination of the unit test method and the prism test method may be appropriate to provide a determining reliability of test result implications. Alternatively, a complete re-evaluation of the prism test method and its applicability to acceptance criteria for structural masonry may be appropriate.
ACKNOWLEDGEMENTS

I would like to thank Dr. Moses Karakouzian for his dedication to the education of engineers from all walks of life.

I would like to thank my grandmother, Barbara Bristow, a lifelong educator and the one who created the inquisitive soul that I maintain to be.

I would like to thank Chad Hirschi and the rest of the Hirschi Masonry family for the support of the masonry industry and unrelenting need for material truth.

I would like to thank the Camarenos and others from JC Masonry for their continued support and guidance through the means and methods.

I would like to thank NOVA Las Vegas for their donations of time and resources that made this research possible.

I would like to thank my partner, Taylor Marie, for her continued support of my personal and professional goals.
TABLE OF CONTENTS

ABSTRACT ........................................................................................................................................ iii
ACKNOWLEDGEMENTS .................................................................................................................. v
TABLE OF CONTENTS .................................................................................................................. vi
LIST OF TABLES ............................................................................................................................ vii
LIST OF FIGURES ........................................................................................................................ viii
INTRODUCTION ........................................................................................................................... 1
BACKGROUND AND LITERATURE REVIEW ........................................................................ 4
METHODOLOGY AND MATERIALS ............................................................................................ 7
FINDINGS AND ANALYSIS ......................................................................................................... 14
CONCLUSIONS AND RECOMMENDATIONS ............................................................................ 30
APPENDIX 1: MATERIALS SPECIFICATIONS ....................................................................... 35
APPENDIX 2: RAW DATA .......................................................................................................... 46
REFERENCES ............................................................................................................................. 52
CURRICULUM VITAE ................................................................................................................ 53
LIST OF TABLES

Table 1 - Prism Compressive Strength Results ................................................................. 14
Table 2 - Grout Compressive Strength Results ................................................................. 15
Table 3 - Summary of Low, Mean and High Compressive Strength Results for Grout .......... 20
Table 4 - Descriptive Statistics of Data By Grout Type and Factor ................................. 21
Table 5 - Statistical Output for Ratios .............................................................................. 28
LIST OF FIGURES

Figure 1- Blocks as delivered by manufacturer ................................................................. 8
Figure 2- Blocks laid in order for prism construction ........................................................ 8
Figure 3- Placement of Grout ......................................................................................... 10
Figure 4- Consolidation of Grout ................................................................................... 11
Figure 5- Curing of Specimens ...................................................................................... 11
Figure 6- Example of Prism Testing in Compression Machine ...................................... 12
Figure 7- Slump Measurement by ACI Technician ........................................................... 16
Figure 8- “Invalid” Slump Test Due to Very High Slump Flow ....................................... 17
Figure 9 - Linear Interpolation Graph for Grout .............................................................. 19
Figure 10 - Linear Interpolation Graph for Prisms ............................................................ 20
Figure 11- Normal Q-Q Plot .......................................................................................... 22
Figure 12 - Two- Way Interaction Plot .......................................................................... 24
Figure 13- Normal Q-Q Plot for “Ratio Data Sets” ......................................................... 26
Figure 14- One-Way ANOVA Plot for Ratios ................................................................. 27
Figure 15- Cross Section Area of Prism Testable Surface ............................................. 29
INTRODUCTION

Hollow concrete masonry units (CMU) are used both nationwide and around the world as literal building blocks. CMU blocks provide the formwork for the walls, the architectural details needed for design implementation and the structural capacity needed to withstand applied loads. However, when the CMU blocks and the associated composite masonry system incorporated into the structures do not meet the required structural capacities, designers are forced to reevaluate (and oftentimes, redesign), the systems that have been relied upon. Many times, these acceptance testing results are not fully available until weeks or months after the materials have been covered up, loaded or otherwise built into the project.

The purpose of this study is to reevaluate the current use of the prism test method to verify compressive strength of the masonry prism ($f'_m$) and its use as acceptance criteria for structural CMU applications. Test specimens created under field conditions and tested in a laboratory setting provide for a comparison of CMU prisms created using three different coarse aggregate grout materials, each with dramatically different consistency and ultimate compressive strength ($f'_g$).

Over the years, as various codes have been nationally and internationally published and adopted, the prism test method has gained commercial popularity due to the simplicity it offers for material evaluation in Quality Assurance and Quality Control programs. Currently, the International Building Code (2015) offers three levels of “special inspections” to the QA/QC program. Level A provides for an in-depth document review of the material supplier data, which generally includes grout mix design, proposed mortar specifications, proposed block specifications and performance history for each of the proposed materials. Level B generally allows the masonry subcontractor to mix mortar, lay block, as well as install reinforcement and
embeds all with a periodic inspection requirement, thus preventing definitive testing frequencies from occurring. Observation of grout placement into the hollow cells of the CMU is a continuous inspection, so that grout materials, mechanical consolidation, conformity to temperature and moisture requirements, and other real-time, critical parameters are complied with. Finally, Level C provides generally for the continuous inspection of mixing of mortar, placement of block and installation of grout. Level B and C also include the document review outlined above for Level A. It is further noted that Level C is only required during construction of “critical” structures, or those facilities deemed to be critical to the community in an emergency.

Most structures in the United States do not fall into the “critical” category according to their designers, and thus, Level B inspections have become the most-often specified level for masonry QA/QC. Accordingly, a special inspector is rarely present during the mixing of mortar, placement of mortar, installation of block or placement of reinforcement. Due to the absent overlap in presence between the masonry subcontractor and inspector/masonry testing technician during the wall construction process, the prism test method has surpassed the unit test method for verification of the masonry material properties. Furthermore, the masonry prism test method can be used to verify skill level of the mason performing the work, which the unit test method cannot.

This thesis is divided into four chapters. The first chapter describes past research, current acceptance criteria testing and some of the challenges presented by the current condition. This chapter also includes the results of literature review of previously-formed conclusions regarding CMU testing methods and related acceptance criteria. The second chapter introduces the testing methodology used to reevaluate the prism testing method with specific materials, including an
outline of the variables, conditions and materials used. The third chapter presents the findings of
the testing, with an analysis of the effect of the variables and conditions on the results. Lastly,
the fourth chapter provides the conclusions and recommendations, which includes a
recommendation for further study and experimentation.
BACKGROUND AND LITERATURE REVIEW

The prism test method is often relied upon for confirmation of $f'm$, the design strength of the CMU composite system, while other important data sets, such as the elastic modulus, are simply derived from the corresponding compressive strength test results. The composite nature of this test method, with its utilization of block, grout, mortar, as well as the skill of the tradesman, inherently presents substantial variability. Previous research suggests that both unit strength and mortar strength have a significant effect on prism strength, although little research found discusses variation in grout strength and its corresponding effect on resulting prism strength. Furthermore, the failure modes and mechanisms of prisms are not fully understood and continuous improvement of the testing and evaluation of structural masonry is needed (Atkinson et al, 1985).

The prism strength of grouted prisms ($f'm$) is calculated by obtaining the ultimate failure load in uniaxial compression and dividing it by the gross cross-sectional area of the prism. Current practices for this determination include a stacked hollow CMU configuration, separated by a (horizontal) mortar bed joint, with grout placed and consolidated within the vertically aligned cells. Mortar is typically struck flush with the face of the block and interior mortar projections are removed by hand. Once consolidated in place, the grout is struck flush at the top surface, although it is “best practice” to leave the grout slightly higher than the top surface to allow for likely shrinkage of grout. Furthermore, after the initial consolidation, it is recommended that a second application of consolidating vibration be applied within a few minutes of the initial consolidation to assist the block with absorption of free water from the grout and to increase bond of grout to inside faces of the block.

Past and current masonry codes provide for the adoption and application of universal
correction factors based on prism geometry. Specifically, the height-to-width (least lateral dimension, which may be called “width” or “thickness”) ratio attempts to correct for the scaling effect of the relatively small test specimen as it relates to in-place, as-built masonry walls. It also limits the potential for slenderness effects on the prism test results (Hegemier et al, 1977).

A few relevant conclusions from previous research include:

1. Sample size has a significant effect on prism test results. Simplified, larger stacked unit configuration (3-4 coarses or “Wallette” samples) tend to produce more precise results as compared to smaller stacked (2 coarses) unit or single unit configurations (Kingsley et al, 1992).

2. Mortar type and mortar compressive strength has a low to negligible effect on prism strength in most configurations. However, with high-strength prism assemblies (f’m = 4000 PSI and higher), mortar strength and type has a more visible effect on prism strength (Baur et al, 1978).

3. Compressive strength testing for units is affected by the moisture content of the block; units that have been wetted for up to 7 days prior to testing will likely be approximately 85% weaker in resulting compressive strength than its drier counterpart. For prisms, blocks should not be allowed to be wetted or in a moist condition prior to use in prism assembly (Nichols et al, 2007).

4. A decreased end restraint of the prism during loading can dramatically decrease the ultimate compressive strength of the prism (Kingsley et al, 1992).

5. The skill level and variability of the tradesman can have a variable effect on prism compressive strength (Miller et al, 1978).
6. The unit test method, as compared to the prism test method, creates inherently conservative analysis of the in-situ performance of structural masonry (NCMA, MR-37, 2012).
METHODOLOGY AND MATERIALS

For this research, all prisms were constructed by the same professional mason. The same tools were used and the same process for assembly was followed. To mitigate the effects of slenderness on f’m results within this research, a target h/t ratio of 2.0 was established (i.e. 2 single blocks stacked on top of each other with a single horizontal mortar joint). Saw-cutting of the ends was kept to a minimum to reduce the effect of universal correction factors for prism geometry, yet was relied upon to produce smooth ends for capping. Capping of the prisms was achieved using a molten sulfur compound in accordance with ASTM C1552 (ASTM, 2015) and a capping jig with a bullseye level to ensure level and plumb capping was achieved. Each end of the prism was capped in this manner. During loading, this capping material was in direct contact with the top and bottom platens of the compressive strength testing apparatus. Block and mortar source was consistent for all prism sets. Furthermore, grout source, strength, and mix design were selected as the principal variables. The purpose of the testing was to evaluate the variability in grout testing results in ready-mix coarse aggregate grout, evaluate the effect of ensuing grout compressive strength and to calculate the modulus of elasticity from the resulting prism compressive strength.

The materials used for the research included two pallets of uniformly-colored Type N hollow cell precision CMU, measuring approximately 8 inches by 8 inches by 8 inches, which were manufactured and delivered in a single batch. The reported compressive strength of the block from the manufacturer was 1900 PSI. For the sake of this investigation, it was assumed that block, manufactured in a controlled commercial environment, and certified by the manufacturer for material properties, had a minimum actual compressive strength as reported by manufacturer. Once received, the CMU block was randomly split into three batches to be used
in prism assembly; this was done to ensure that the multiple loads of block from the supplier were not introducing an unintended variable. During sampling, preparation, curing and other processes, blocks were stored in moisture and temperature-controlled laboratory space to ensure block curing and condition at time of use were consistent. Block specifications, as presented by the manufacturer, are presented within Appendix 1 of this report.

![Figure 1- Blocks as delivered by manufacturer](image1)

![Figure 2- Blocks laid in order for prism construction](image2)
The masonry mortar used for the prism construction was a pre-blended, bagged masonry mortar, consisting of Type S cement, lime and sand, with a manufacturer-reported compressive strength of 1900 PSI. Mortar joints were maintained at ½” to 5/8” and all joints were struck flush. As indicated by previous sources (NCMA, MR-37, 2012), mortar compressive strength most often presents a significant effect on high-strength prism samples rather than with prisms designed to achieve a code minimum strength. Thus, mortar compressive strength as reported by the manufacturer has been assumed as accurate and was relied on within this investigation. Mortar specifications, as presented by the manufacturer, are presented within Appendix 1 of this report.

Three different commercially-produced coarse aggregate grout mix designs and batches were used to construct the three corresponding batches of prisms; each batch of prisms was constructed using only one of the three grout mix designs, and the material was delivered in a revolving drum truck mixer. Grout batch size was 2 cubic yards for each of the three grout deliveries and slump was specified for each batch; slump was measured at time of delivery and was recorded and/or modified as required for desired slump. The three grout batches delivered to the research site consisted of materials designed for resulting compressive strength of grout (f’g) of 4500 PSI and 2500 PSI, with two batches of the 2500 PSI material delivered at two dramatically different water-to-cement ratios for comparative purposes. Grout was conveyed from the tailgate of the ready-mix truck into a wheelbarrow and transported to the flat surface where prisms were assembled and bagged. Grout compressive strength test specimens were constructed alongside corresponding prism test specimens; each grout sample consisted of consecutive scoops from the wheelbarrow (after the wheelbarrow sample was thoroughly mixed by hand) and into the lined cylindrical sample form. It is acknowledged that the cylindrical grout specimen forms used (manufactured block forms) are not ASTM approved in this format.
(uncalibrated), however, since the relevant data presented by the method used is more focused on precision rather than accuracy, the investigation presents the data with this limitation. Alternatively, the “pin-wheel” method could be used in the future if more accurate grout compressive strength data is required, or a calibration of the cylindrical masonry molds could be performed to establish base-line absorption and net effect values for the resulting cylindrical grout specimens.

Figure 3- Placement of Grout

Once the cylindrical grout specimens were cast and rodded for consolidation, the prism specimens were then filled using the same conveyance method. Once grouted, the prisms were consolidated using a hand-held mechanical vibrator with a ¾” vibrating end; approximately 3 minutes after the initial consolidation, grout in the prism specimens was consolidated using the same tool a second time. Upon completion of the second consolidation, the top surface of the masonry prisms was struck to produce a raised grout surface of approximately ¼” above the top of the block to allow for grout shrinkage during curing. Upon finishing the top surface, both the grout and prism test specimens were sealed in bags for curing.
After 26 days of curing in the moisture and temperature-controlled warehouse, grout samples were removed from the bags and broken free from the CMU molds and lining. The top and bottom surfaces of the grout cylinders were cut smooth using a large diameter wet-saw. On the 27th day, after having been cut and dried, grout samples were capped using molten sulfur compound. Similarly, after 26 days of curing, prism samples were removed from the bags.

The top and bottom surfaces of the masonry prisms were cut clean and flat; cutting was kept to a minimum to align with research objectives that sought to minimize variability in test results.
caused by varying correction factors. On the 27th day, after being cut and dried, prisms were capped using the molten sulfur compound. Grout and prism samples were tested in uniaxial compression on the 28th day from initial casting, using a 500K Gilson compression machine with the Gilson-provided top platens, bottom platens and spacers (3 inch steel top and bottom platens used for prisms to ensure even load application and no platen deformation, as required).

**Figure 6- Example of Prism Testing in Compression Machine**

Compressive strength values were reported to the whole unit as displayed by the digital data display on the compression testing machine. For the sake of reducing rounding effect in the data set, the ASTM recommendation for rounding to the nearest 5 PSI or 10 PSI (depending on the specific material being testing and the ASTM being referenced) was not used in the research reporting.
The primary objectives during testing included:

1. Monitoring and evaluating the consistency in grout slump as compared to requested slump with ready-mix supplier, to replicate field conditions.

2. Monitoring and recording the effect of grout slump and corresponding water/cement ratio on grout strength.

3. Monitoring and describing the visual failure indicators during prism and grout cylinder uniaxial compression testing.

4. Identifying limiting commonalities between prism strength and proposed corresponding full-scale wall strength, as appropriate.
FINDINGS AND ANALYSIS

All prism test results are presented herein in the table below, showing corrected strengths for prism geometry in accordance with applicable ASTM.

<table>
<thead>
<tr>
<th>Specimen #</th>
<th>Corrected Strength (PSI)</th>
<th>Specimen #</th>
<th>Corrected Strength (PSI)</th>
<th>Specimen #</th>
<th>Corrected Strength (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>2486</td>
<td>1a</td>
<td>3604</td>
<td>1a</td>
<td>2362</td>
</tr>
<tr>
<td>1b</td>
<td>2279</td>
<td>1b</td>
<td>3811</td>
<td>1b</td>
<td>2680</td>
</tr>
<tr>
<td>1c</td>
<td>2451</td>
<td>1c</td>
<td>3973</td>
<td>1c</td>
<td>2527</td>
</tr>
<tr>
<td>2a</td>
<td>2599</td>
<td>2a</td>
<td>3751</td>
<td>2a</td>
<td>2735</td>
</tr>
<tr>
<td>2b</td>
<td>2219</td>
<td>2b</td>
<td>4119</td>
<td>2b</td>
<td>2367</td>
</tr>
<tr>
<td>2c</td>
<td>2503</td>
<td>2c</td>
<td>3099</td>
<td>2c</td>
<td>2808</td>
</tr>
<tr>
<td>3a</td>
<td>2080</td>
<td>3a</td>
<td>3269</td>
<td>3a</td>
<td>3219</td>
</tr>
<tr>
<td>3b</td>
<td>2250</td>
<td>3b</td>
<td>3360</td>
<td>3b</td>
<td>2258</td>
</tr>
<tr>
<td>3c</td>
<td>2809</td>
<td>3c</td>
<td>3420</td>
<td>3c</td>
<td>2452</td>
</tr>
<tr>
<td>4a</td>
<td>2416</td>
<td>4a</td>
<td>3873</td>
<td>4a</td>
<td>2377</td>
</tr>
<tr>
<td>4b</td>
<td>2146</td>
<td>4b</td>
<td>3533</td>
<td>4b</td>
<td>2391</td>
</tr>
<tr>
<td>4c</td>
<td>2486</td>
<td>4c</td>
<td>3652</td>
<td>4c</td>
<td>2846</td>
</tr>
<tr>
<td>5a</td>
<td>2285</td>
<td>5a</td>
<td>3543</td>
<td>5a</td>
<td>2942</td>
</tr>
<tr>
<td>5b</td>
<td>2466</td>
<td>5b</td>
<td>3526</td>
<td>5b</td>
<td>3038</td>
</tr>
<tr>
<td>5c</td>
<td>2716</td>
<td>5c</td>
<td>4011</td>
<td>5c</td>
<td>2871</td>
</tr>
<tr>
<td>6a</td>
<td>2566</td>
<td>6a</td>
<td>3794</td>
<td>6a</td>
<td>3213</td>
</tr>
<tr>
<td>6b</td>
<td>2642</td>
<td>6b</td>
<td>3410</td>
<td>6b</td>
<td>3186</td>
</tr>
<tr>
<td>6c</td>
<td>2527</td>
<td>6c</td>
<td>3840</td>
<td>6c</td>
<td>2900</td>
</tr>
<tr>
<td>7a</td>
<td>2261</td>
<td>7a</td>
<td>3680</td>
<td>7a</td>
<td>2783</td>
</tr>
<tr>
<td>7b</td>
<td>1964</td>
<td>7b</td>
<td>3174</td>
<td>7b</td>
<td>2819</td>
</tr>
<tr>
<td>7c</td>
<td>2619</td>
<td>7c</td>
<td>3380</td>
<td>7c</td>
<td>2141</td>
</tr>
<tr>
<td>8a</td>
<td>2620</td>
<td>8a</td>
<td>3785</td>
<td>8a</td>
<td>2894</td>
</tr>
<tr>
<td>8b</td>
<td>2310</td>
<td>8b</td>
<td>3415</td>
<td>8b</td>
<td>2183</td>
</tr>
<tr>
<td>8c</td>
<td>2171</td>
<td>8c</td>
<td>3325</td>
<td>8c</td>
<td>2389</td>
</tr>
<tr>
<td>9a</td>
<td>2332</td>
<td>9a</td>
<td>3618</td>
<td>9a</td>
<td>1994</td>
</tr>
<tr>
<td>9b</td>
<td>2504</td>
<td>9b</td>
<td>3404</td>
<td>9b</td>
<td>2212</td>
</tr>
<tr>
<td>9c</td>
<td>2301</td>
<td>9c</td>
<td>2927</td>
<td>9c</td>
<td>1832</td>
</tr>
<tr>
<td>10a</td>
<td>2250</td>
<td>10a</td>
<td>3329</td>
<td>10a</td>
<td>2362</td>
</tr>
<tr>
<td>10b</td>
<td>2621</td>
<td>10b</td>
<td>3123</td>
<td>10b</td>
<td>2585</td>
</tr>
<tr>
<td>10c</td>
<td>2578</td>
<td>10c</td>
<td>3322</td>
<td>10c</td>
<td>2215</td>
</tr>
</tbody>
</table>

Table 1 - Prism Compressive Strength Results
All corresponding grout test results are presented herein in the table below, showing corrected strengths in accordance with applicable ASTM.

<table>
<thead>
<tr>
<th>Specimen #</th>
<th>Corrected Strength (PSI)</th>
<th>Specimen #</th>
<th>Corrected Strength (PSI)</th>
<th>Specimen #</th>
<th>Corrected Strength (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>4298</td>
<td>1a</td>
<td>9083</td>
<td>1a</td>
<td>5436</td>
</tr>
<tr>
<td>1b</td>
<td>4052</td>
<td>1b</td>
<td>7271</td>
<td>1b</td>
<td>5894</td>
</tr>
<tr>
<td>1c</td>
<td>4191</td>
<td>1c</td>
<td>8654</td>
<td>1c</td>
<td>5150</td>
</tr>
<tr>
<td>2a</td>
<td>4458</td>
<td>2a</td>
<td>8461</td>
<td>2a</td>
<td>6228</td>
</tr>
<tr>
<td>2b</td>
<td>4830</td>
<td>2b</td>
<td>8400</td>
<td>2b</td>
<td>6546</td>
</tr>
<tr>
<td>2c</td>
<td>4769</td>
<td>2c</td>
<td>7630</td>
<td>2c</td>
<td>5963</td>
</tr>
<tr>
<td>3a</td>
<td>4756</td>
<td>3a</td>
<td>8295</td>
<td>3a</td>
<td>5970</td>
</tr>
<tr>
<td>3b</td>
<td>4040</td>
<td>3b</td>
<td>7958</td>
<td>3b</td>
<td>5646</td>
</tr>
<tr>
<td>3c</td>
<td>4974</td>
<td>3c</td>
<td>8566</td>
<td>3c</td>
<td>5693</td>
</tr>
<tr>
<td>4a</td>
<td>4147</td>
<td>4a</td>
<td>7505</td>
<td>4a</td>
<td>6165</td>
</tr>
<tr>
<td>4b</td>
<td>4249</td>
<td>4b</td>
<td>8041</td>
<td>4b</td>
<td>6262</td>
</tr>
<tr>
<td>4c</td>
<td>4497</td>
<td>4c</td>
<td>7824</td>
<td>4c</td>
<td>5786</td>
</tr>
<tr>
<td>5a</td>
<td>4814</td>
<td>5a</td>
<td>8012</td>
<td>5a</td>
<td>5788</td>
</tr>
<tr>
<td>5b</td>
<td>4861</td>
<td>5b</td>
<td>8571</td>
<td>5b</td>
<td>6358</td>
</tr>
<tr>
<td>5c</td>
<td>4674</td>
<td>5c</td>
<td>7854</td>
<td>5c</td>
<td>5900</td>
</tr>
<tr>
<td>6a</td>
<td>4651</td>
<td>6a</td>
<td>7367</td>
<td>6a</td>
<td>5764</td>
</tr>
<tr>
<td>6b</td>
<td>4786</td>
<td>6b</td>
<td>8358</td>
<td>6b</td>
<td>5424</td>
</tr>
<tr>
<td>6c</td>
<td>4908</td>
<td>6c</td>
<td>7088</td>
<td>6c</td>
<td>5989</td>
</tr>
<tr>
<td>7a</td>
<td>4451</td>
<td>7a</td>
<td>6704</td>
<td>7a</td>
<td>6320</td>
</tr>
<tr>
<td>7b</td>
<td>4620</td>
<td>7b</td>
<td>7889</td>
<td>7b</td>
<td>6157</td>
</tr>
<tr>
<td>7c</td>
<td>4204</td>
<td>7c</td>
<td>8377</td>
<td>7c</td>
<td>6417</td>
</tr>
<tr>
<td>8a</td>
<td>4537</td>
<td>8a</td>
<td>7242</td>
<td>8a</td>
<td>6239</td>
</tr>
<tr>
<td>8b</td>
<td>4194</td>
<td>8b</td>
<td>8116</td>
<td>8b</td>
<td>6593</td>
</tr>
<tr>
<td>8c</td>
<td>4887</td>
<td>8c</td>
<td>7731</td>
<td>8c</td>
<td>6765</td>
</tr>
<tr>
<td>9a</td>
<td>4828</td>
<td>9a</td>
<td>7861</td>
<td>9a</td>
<td>6391</td>
</tr>
<tr>
<td>9b</td>
<td>4614</td>
<td>9b</td>
<td>7671</td>
<td>9b</td>
<td>5827</td>
</tr>
<tr>
<td>9c</td>
<td>4856</td>
<td>9c</td>
<td>7523</td>
<td>9c</td>
<td>6353</td>
</tr>
<tr>
<td>10a</td>
<td>4643</td>
<td>10a</td>
<td>8121</td>
<td>10a</td>
<td>5940</td>
</tr>
<tr>
<td>10b</td>
<td>4527</td>
<td>10b</td>
<td>6996</td>
<td>10b</td>
<td>6137</td>
</tr>
<tr>
<td>10c</td>
<td>4600</td>
<td>10c</td>
<td>7272</td>
<td>10c</td>
<td>6452</td>
</tr>
</tbody>
</table>

Table 2 - Grout Compressive Strength Results
Ready-mix grout delivery was the first major variable explored in this research. This was anticipated although certainly not expected to the degree encountered. In an effort to replicate field-constructed conditions for the prism samples, ready-mix concrete trucks with grout batched using conventional batching equipment, scales, and computers were used to produce the grout materials. Variability in the delivered slump of the grout batches was significant; for the first mix, a 4500 PSI design, a slump of 5 inches was ordered and a 3.75 inch slump was measured once the material arrived at the research site. For the second batch, which was a 2500 PSI design, a slump of 5 inches was ordered and a slump of 4 inches was measured at the research site. For the third batch, which was a 4500 PSI design, a slump of 7 inches was ordered and the material arrived with a slump that could not be measured in accordance with applicable ASTM for vertical slump due to three consecutive failed slump tests due to material falling off of the plate; however, for sake of reporting for this research, a 10” slump is reported. All slump tests were conducted by the same technician possessing the American Concrete Institute’s Field Technician Level 1 certification in accordance with industry standards.

![Figure 7- Slump Measurement by ACI Technician](image)
Compressive strengths for the grout cylinders were considerably higher than their commercially-advertised strengths. Expectedly so, this was exaggerated especially when the water-cement ratio was held at a lower value than represented by the mix design (resultant was lower slump). For example, the 4500 PSI grout delivered at a 3.75-inch slump and placed at a 4-inch slump (water added from truck tank) resulted with compressive strengths ranging from approximately 6700 PSI to 9080 PSI; the strength range for the 2500 PSI mix at 4 inch slump was similarly elevated, with a range of approximately 4050 PSI to nearly 4975 PSI. Although these results are expected in theory (factors of safety from mix design methodology) yet perhaps more so than expected, even the high slump material resulted in a grout compressive strength significantly higher than commercially advertised. The 4500 PSI grout placed with a 10-inch slump resulted in a compressive strength range of 5150 PSI to 6765 PSI. Furthermore, grout strength variability was substantially more than expected.

Compressive strength for corresponding prisms effectively refuted the possible concept that the composite sample may be as strong as its strongest component. Instead, the resulting values for compressive strength of the prism test for the 4500 PSI grouted prism with 4-inch
slump ranged only from 2927 PSI to 4119 PSI. Similarly, the 4500 PSI grouted prism with 10-inch slump ranged from only 1832 PSI to 3219 PSI. Finally, the 2500 PSI grouted prisms with 4-inch slump ranged from 1964 PSI to just over 2800 PSI. As required by the applicable ASTMS (C39 and C1314), specimen compressive strength results were corrected for L/D and hp/tp for cylinders and prisms, respectively.
Linear interpolation was used in order to determine correction factors not provided by the applicable ASTM.

| Cylinder Correction Factor Table from ASTM C39 |
| L/D   | 1.75 | 1.5 | 1.25 | 1  |
| Correction | 0.98 | 0.96 | 0.93 | 0.87 |

| Prism Correction Factor Table from ASTM C1314 |
| hp/tp | 1.5 | 2 | 2.5 | 3 | 4 | 5 |
| Correction | 0.86 | 1 | 1.04 | 1.07 | 1.15 | 1.22 |

Grout Linear Interpolation for correction factors:

![Correction Factor vs. L/D](image)

**Figure 9 - Linear Interpolation Graph for Grout**

Prism linear interpolation for correction factors:
A simple summary of the low, mean and high results for each data set (each mix design at specific slump) is provided herein:

### 4500 PSI at 4" Slump

<table>
<thead>
<tr>
<th>Actual Grout Strength (PSI)</th>
<th>Resulting Prism Strength (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>6704</td>
</tr>
<tr>
<td>Mean</td>
<td>7881</td>
</tr>
<tr>
<td>High</td>
<td>9083</td>
</tr>
</tbody>
</table>

### 2500 PSI at 4" Slump

<table>
<thead>
<tr>
<th>Actual Grout Strength (PSI)</th>
<th>Resulting Prism Strength (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>4040</td>
</tr>
<tr>
<td>Mean</td>
<td>4564</td>
</tr>
<tr>
<td>High</td>
<td>4974</td>
</tr>
</tbody>
</table>

### 4500 PSI at 10" Slump

<table>
<thead>
<tr>
<th>Actual Grout Strength (PSI)</th>
<th>Resulting Prism Strength (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>5150</td>
</tr>
<tr>
<td>Mean</td>
<td>6052</td>
</tr>
<tr>
<td>High</td>
<td>6765</td>
</tr>
</tbody>
</table>

Table 3 - Summary of Low, Mean and High Compressive Strength Results for Grout
The following table outlines the input parameters of the statistical analysis:

<table>
<thead>
<tr>
<th>Grout Type</th>
<th>G or M</th>
<th>n</th>
<th>Mean</th>
<th>Median</th>
<th>sd</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>2500PSI4</td>
<td>FprimeG</td>
<td>30</td>
<td>4564</td>
<td>4617</td>
<td>278</td>
<td>4040</td>
<td>4974</td>
</tr>
<tr>
<td>4500PSI10</td>
<td>FprimeG</td>
<td>30</td>
<td>6052</td>
<td>6063</td>
<td>375</td>
<td>5150</td>
<td>6765</td>
</tr>
<tr>
<td>4500PSI4</td>
<td>FprimeG</td>
<td>30</td>
<td>7881</td>
<td>7875</td>
<td>558</td>
<td>6704</td>
<td>9083</td>
</tr>
<tr>
<td>2500PSI4</td>
<td>FprimeM</td>
<td>30</td>
<td>2415</td>
<td>2459</td>
<td>202</td>
<td>1964</td>
<td>2809</td>
</tr>
<tr>
<td>4500PSI10</td>
<td>FprimeM</td>
<td>30</td>
<td>2586</td>
<td>2556</td>
<td>369</td>
<td>1832</td>
<td>3219</td>
</tr>
<tr>
<td>4500PSI4</td>
<td>FprimeM</td>
<td>30</td>
<td>3536</td>
<td>3529</td>
<td>290</td>
<td>2927</td>
<td>4119</td>
</tr>
</tbody>
</table>

Table 4 - Descriptive Statistics of Data By Grout Type and Factor

A Q-Q multiplicative model analysis was used to determine if data sets are normally distributed. As shown by the following Q-Q Plot, the residuals from the multiplicative model plot along the normal distribution based line, so residuals appear to be normally distributed.
Figure 11- Normal Q-Q Plot

Using the Shapiro-Wilk’s Test of Normality analysis on residuals from the multiplicative model, the following result and conclusion is obtained:

\[ W = 0.99081, \text{ p-value} = 0.304 > 0.05; \text{ Concludes that residuals are normally distributed.} \]
As suggested by the individual test results and supported by the summary table, when the grout slump and water-to-cement ratio is held below the design slump for the specific mix design, the resulting grout compressive strength can be as much as 100% higher than the design compressive strength. Moreover, as grout compressive strength increases, resulting prism strength increases. However, as shown by the Two-Way plot, it becomes clear that the higher grout strengths do not create an equitable or directly proportional strength gain to the corresponding prisms.
As displayed by Figure 12 and the Two-Way Interaction Plot, the prism and grout samples at each corresponding compressive strength do not interact the same (the lines are not parallel). In order to analyze this interaction further, the individual test ratio between grout and
corresponding prism test was evaluated and compared using similar statistical analysis. For example, “prism1/grout1” creates a ratio, “prism 12/grout 12” creates a similar ratio, and so on for the n = 30 data set for each of the three groups. Those ratios then create average ratios for further analysis.

Another Q-Q multiplicative model analysis was used to determine if ratio data sets are normally distributed. As shown by the following Q-Q Plot, the residuals from the multiplicative model plot along the normal distribution based line, so residuals appear to be normally distributed.
Using the Shapiro-Wilk’s Test of Normality analysis on residuals from the multiplicative model, the following result and conclusion is obtained:

\[ W = 0.99338, \ p\text{-value} = 0.9365 > 0.05; \text{ Concludes that residuals are normally distributed.} \]
Reliance on an One-Way ANOVA with the prism-to-grout ratios creates another valuable demonstration of the influences of the grout strength on the composite prism strength. As shown in Figure 14 below, the ratio mean drops dramatically as the grout strength increases.

One-Way ANOVA for Ratios

![One-Way ANOVA Plot for Ratios](image)

**Figure 14- One-Way ANOVA Plot for Ratios**
The table below includes the results from the statistical analysis that was conducted to determine the relevancy of the differences in the data set, which included and F-statistic = 24.18 and Degrees of Freedom = 2 and 87.

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>0.53</td>
<td>0.01</td>
<td>49.05</td>
<td>0.00</td>
</tr>
<tr>
<td>GroutType45_10</td>
<td>-0.10</td>
<td>0.02</td>
<td>-6.58</td>
<td>0.00</td>
</tr>
<tr>
<td>GroutType45_4</td>
<td>-0.08</td>
<td>0.02</td>
<td>-5.24</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Table 5- Statistical Output for Ratios

Since both grout type 4500 at 4” slump and 4500 at 10” are statistically significant (P-value < 0.05), we can conclude that the 2500 at 4” slump data set has the largest mean ratio. Perhaps most important, the mean ratios are statistically different from one another.

The failure mode of the prisms tested were monitored and recorded. The prisms constructed using 4500 PSI grout (design strength) placed with a 4 inch slump resulted in a “6” failure mode more than 75% more often than in the two other sets. Using ASTM C1314 break mode classification, the “6” failure mode is a shear break along a linear plane in the prism (ASTM, 2015). Furthermore, face shell separation, noted as failure mode “7”, was more than five times more likely to occur within the high-slump data set than the lower slump counterparts.

During analysis of the grout and prism compressive strengths, the geometry of the specimens and importance of uniformity in loading became more relevant. In geometric terms, if material modulus did not have an effect on composite compressive strength, the ratio of area of grout- to- area of composite testable surface should equal the ratio of composite strength to grout strength. For purposes of this analysis, the total testable area of the precision unit half-blocks used was 65.77 square inches and the grout column within the prism was calculated as 33.64, for
a ratio of 0.512. Figure 15 below provides for a general summary of dimensions in a graphical representation.

![Figure 15- Cross Section Area of Prism Testable Surface](image)

Furthermore, face-shell spallation, as defined and measured by Hegemier et al in Prism Tests for the Compressive Strength of Concrete Masonry, was observed as a continual phenomenon throughout testing, although there seemed to be an unmeasured variability on frequency, magnitude or other comparable parameters (Hegemier, 1977).
CONCLUSIONS AND RECOMMENDATIONS

In conventional concrete placement, standard practice dictates that the concrete slump and water-to-cement ratio are kept as low as possible while still providing for acceptable workability. However, in structural masonry construction, this practice can prove detrimental to the prism results, as demonstrated within this research. Functionally, by maintaining a lower than designed slump and water-to-cement ratio, it is clear that a higher compressive strength of grout occurs. However, the resulting prism strength gain from the decreased water-to-cement ratio is not proportional to that of the grout strength gain. Instead, an 1800 PSI reduction in grout strength caused by the increase in slump from 4 inches to 10 inches resulted in an average prism strength reduction of 1000 PSI. Both of the 4500 PSI grout mixes illustrate this clearly, as the ratios of prism to grout are adversely affected by the strength gain of the grout.

In this research, the block strength, source and thus, modulus was maintained as a static physical characteristic. As a result of this research, it is concluded that increasing elastic modulus of the grout certainly has a detrimental effect on strength gain of the composite system. For efficient and equitable distribution of strength gain in a design, the block modulus must also increase as the grout modulus increases or the grout modulus should be held down through the increase of the water to cement ratio (indicated by higher slump). When the modulus of the block and the modulus of the grout are equal, the ratio of the testable surfaces of the composite prism and the grout should equal the mean ratio of the compressive strength of the composite sample to the corresponding grout sample. As the modulus of the grout increases and the block remains static, the difference between ratio of geometry and ratio of strength diverge. For example, the ratio of the geometry is 0.511; the mean ratio for the 2500 at 4’’ set was
approximately 0.53, suggesting that the moduli of the grout and block were very close in this set. However, for the 4500 sets, the mean ratio fell dramatically to below 0.45 for each, proving the influence of the “bulging” deformation of the grout column on the block.

One of the consistent conflicts with masonry subcontractors in structural masonry construction is the second application of vibratory consolidation. Through this process, there was not a single prism that resulted in a compressive strength of less than 1500 PSI (code minimum), yet low prism breaks tend to occur more often than low concrete break results (research of local commercial laboratory testing results show that low results occur as often as 1 in 20 in prism testing but only 1 in 300 in concrete testing, on average). It is recommended that additional investigation regarding single consolidation versus consolidation/reconsolidation, perhaps an iteration of the investigatory procedure outlined herein, may result in lower compressive strength results for prisms. This may assist with further determining the cause of axial compressive strength failures when construction design teams are using the prism test method for acceptance criteria.

For this investigation, supplier-provided specifications, including “material compressive strength” was assumed to be accurate. Specifically, mortar compressive strength and block compressive strength were used herein as reported by the manufacturer. Although, as previously mentioned, mortar compressive strength variability has minimal effect on prisms with target compressive strength at or only moderately above code minimums, the block compressive strength may have a significant effect on the resulting prism compressive strength. Additional investigation regarding this possible variability, within regional manufacturing of CMU, should be completed in order to evaluate the possible net effect it may have on acceptance criteria using the prism test method.
Creating a laboratory test that adequately represents field processes is not always the intent of an ASTM test method. For example, with the concrete cylinder compressive strength test, acceptance criteria requires curing in ideal conditions (curing room with moisture and temperature controls in place) while field-placed materials experience a wide variety of conditions. However, in creating a more directly-applicable compressive strength test, it is proposed that a lateral restraint installed on the compressive strength testing machine, which would restrain the specimen from deforming in one axis. This lateral restraint should be designed to prevent bending or other specimen deformation, and more importantly, to eliminate the triaxial stress and strain component of the test, which cannot be effectively evaluated at current time. To this effect, the cast masonry prism becomes a “wall coupon” and more truly represents its performance within the wall; for instances when the testing methodology seeks to establish acceptance criteria for in-place materials, this representation relevance should be an important aspect. Additional research and testing should be performed in this field.

Lastly, as demonstrated by this research, significant added value is offered when a set of compressive strength grout specimens is cast alongside each prism set. With the prism test method for $f_{m}$ verification, very little resulting information is available for the compressive strength of the grout, except that $f_{g}$ can be assumed to be approximately 2 times the corresponding $f_{m}$. Little or no QA/QC value is added to the construction process through this raw assumption though. Where this becomes most evident is when prisms fail to meet the required compressive strength during QA/QC testing. For example, within this investigation, the mean prism strength result was 2586 PSI for the high slump grouted prisms, and the corresponding grout mean compressive strength was 6052. If the prism compressive strength had been 1400 PSI (which is lower than the code-minimum of 1500 PSI for structural masonry), the
corresponding grout compressive strength expected through this established relationship would be 2800 PSI. This demonstrates that more likely than not, the grout compressive strength is acceptable while the composite masonry prism strength is not acceptable. To further verify this, once the grout is placed inside of the wall, industry standards suggest that the best method to confirm acceptable f’g has been achieved is through the use of destructive coring and extraction of grout cores from the wall. As proposed above, the grout will, far more often than not, result in acceptable compressive strength values for the grout. However, that does not necessarily indicate that the f’m has been achieved. By casting a partner set of grout cylinders alongside the prism set, a new acceptance criteria of f’g and f’m partnering verification should provide adequate information to the design and construction team to affirm that the materials are in fact installed as designed and built (by mix designers, block manufacturers, mortar suppliers, structural engineers, architects and by the masons alike).

As expected, more questions than answers resulted from this research. The following additional research questions and proposed research methodologies were noted during the research and conclusion formation:

1. What is the variability of prism compressive strength when using all code-minimum values for f’m, f’g and mortar compressive strength, with the only variable being the water-to-cement ratio within the grout (similar to the variation herein between the 4500 PSI grout at 4” and 10” but using code-minimum grout strength of 2000 PSI)?
2. Does the block failure, which occurred within this research long-before the grout failure, add substantially to the prism strength if stronger block is used to fabricate the prism? For example, if the grout strength is held constant and block strength is varied, are
strategic results similar to those found within this research?

3. What is the net effect of a single consolidation of the grout column versus the code-required consolidation and re-consolidation, with regard to face-shell spallation frequency and magnitude?

4. What is the net effect of field-curing for 24 hours followed by lab curing (consistent with industry standards) versus lab-curing the entire life of the specimen?

5. What is the net effect of transporting the prism specimens to the laboratory in a high-level controlled fashion versus transporting them with a low-level of security and care?

6. What is the ultimate difference in using the pin-wheel method (using a standard block) and the grout cylinder block, keeping absorption, block strength and block moisture content equal, to reconsider validity and/or applicability of each method for field preparation of grout cylinders?

A systemic analysis is required when composite testing is utilized, whereas the current methodology aims to establish composite understanding using independent components. With a combination of the revised approach outlined in the conclusions, it is possible to establish the next step in holistic acceptance criteria for composite structural masonry construction. By analyzing $f_g$ and $f_m$ simultaneously, and by specifically acknowledging effects of modulus of elasticity, sample deformation and composite interaction, this new approach would aim to bring all parties involved to the same table. This new acceptance criteria methodology would provide the confidence needed by all parties to be truly comfortable with the end product.
APPENDIX 1: MATERIALS SPECIFICATIONS

Silver Star Ready Mix

Mix #: 245973
Last Updated: 8/28/2016
Soluble Sulfates: 3/8" No.8
Nom Size Agg: 3/8" No.8

Supplier: Silver Star Ready Mix
Project: Application: Coarse Grout

DESIGN CRITERIA

<table>
<thead>
<tr>
<th>Strength @ 28 Days:</th>
<th>4500 PSI</th>
<th>W/C:</th>
<th>0.45</th>
<th>Entrapped Air%:</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement Sk:</td>
<td>6.8</td>
<td>Cement Type:</td>
<td>Type V</td>
<td>FA %:</td>
<td>30</td>
</tr>
<tr>
<td>Cementitious Mat Sk:</td>
<td>9.7</td>
<td>Stump:</td>
<td>9&quot; to 11&quot;</td>
<td>Silica Fume %:</td>
<td>0</td>
</tr>
</tbody>
</table>

MATERIAL SOURCES

Cement (Type V) Source: CEMEX - Victorville, CA
Fly Ash (Class F) Source: Headwaters Resources - Navajo Plant, Page, AZ
Sand (Washed Sand) Source: Aggregate Industries (C33 Testing by: Atech)
Aggregate (No. 8) Source: Aggregate Industries (C33 Testing by: Atech)

Entrained Air Source:

PHYSICAL PROPERTIES OF AGGREGATES (ASTM C-33)

<table>
<thead>
<tr>
<th>Material</th>
<th>C-33 Date</th>
<th>SpecGrav</th>
<th>Absorp</th>
<th>2&quot;</th>
<th>1 1/2&quot;</th>
<th>1&quot;</th>
<th>3/4&quot;</th>
<th>1/2&quot;</th>
<th>3/8&quot;</th>
<th>#4</th>
<th>#8</th>
<th>#16</th>
<th>#30</th>
<th>#50</th>
<th>#100</th>
<th>#200</th>
<th>FM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washed Sand</td>
<td>1/4/2018</td>
<td>2.78</td>
<td>0.8</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>91</td>
<td>58</td>
<td>33</td>
<td>18</td>
<td>6</td>
<td>2.4</td>
</tr>
<tr>
<td>No.8</td>
<td>1/4/2018</td>
<td>2.78</td>
<td>1.1</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>27</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Combined</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>74</td>
<td>59</td>
<td>38</td>
<td>21</td>
<td>10</td>
<td>4</td>
<td>1.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specification</td>
<td>[H]</td>
<td>[B]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BATCH WEIGHTS FOR ONE CUBIC YARD (Cement/Sand SSD)

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>630</td>
<td>3.25</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>273</td>
<td>1.90</td>
</tr>
<tr>
<td>Silica Fume</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Water</td>
<td>49.0 G.</td>
<td>0.54</td>
</tr>
<tr>
<td>Total</td>
<td>3863</td>
<td>27.30</td>
</tr>
</tbody>
</table>

Theoretical Unit Weight: 143.1 PCF

Admixtures and/or comments:

ASTM C494 Type A and/or F water reducer.
When requested: ASTM C494 Type C non-chloride accelerator.
Dosage on all admixtures: As per manufacturer’s recommendations, and applied in accordance with ACI 211.4.3 to meet the required W/C.

Silver Star Ready Mix, LLC 6320 Sloan Road Sloan, NY 89054 (702) 623-4484
### Aggregate Industries
Southwest Region, Inc.
3101 East Craig Road
North Las Vegas, NV 89030

<table>
<thead>
<tr>
<th>Customer #</th>
<th>SOUTHWEST HACIENDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Job</td>
<td>ARVILLE &amp; HACIENDA IN THE BACK S</td>
</tr>
<tr>
<td>Instructions</td>
<td>USE OF BUILDING</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Order #</th>
<th>Truck #</th>
<th>Driver Name</th>
<th>Vaughn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stump Ordered</th>
<th>Stump Placed</th>
<th># Estimate</th>
<th># Actual</th>
<th>Maximum Available</th>
<th>Add Water</th>
<th>Gallons Dispatched</th>
<th>Leave Job</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Load

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Cumulative Quantity</th>
<th>Order Quantity</th>
<th>Product Code</th>
<th>Load ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>250000001,000</td>
<td>106</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product Description</th>
<th>Unit Price</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>250000001,000</td>
<td>$50.00</td>
<td>$100.00</td>
</tr>
</tbody>
</table>

### Delivery Liability Disclosure

The driver will make every possible effort consistent with safe practices to deliver concrete or other materials to place customer designates. However, neither Aggregate nor company assumes responsibility for damages inside curbs or property line. Customer must provide a proper & legal place to wash out. By signing below, I acknowledge that I am authorized to consent to the following on my employer's behalf. I relieve the seller of any liability for personal injury or property damage when delivery is made beyond the curb line.

For FOB orders, I further acknowledge by signing below that I have reviewed the information on this ticket. I certify that I have received the quantity ordered and that my vehicle complies with local, state and federal weight limitations and operating requirements.

Water Added On Job At Customer's Request: Gallons Received By: 

Name (Please Print): ____________________________ Signature: ____________________________ Date: ____________________________

### Terms and Disclosure Statement

Seller reserves and may exercise its rights as provided for in the Mechanics Lien and Bond statutes. Customer agrees to pay a reasonable attorney's fee and other costs of collection after default and referral to an attorney. Net - No Discount. Payable at our general office.

Batch Data:

<table>
<thead>
<tr>
<th>Batch</th>
<th>Driver</th>
<th>User</th>
<th>Disp</th>
<th>Ticket Num</th>
<th>Ticket ID</th>
<th>Time Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>106</td>
<td>52992</td>
<td>user</td>
<td>67245219</td>
<td>12862</td>
<td>9:51 10/29/15</td>
<td></td>
</tr>
</tbody>
</table>

### Material

<table>
<thead>
<tr>
<th>TBA</th>
<th>Design Qty</th>
<th>Required</th>
<th>Batches</th>
<th>% Var</th>
<th>% Moisture</th>
<th>Actual Wet</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>250 lb</td>
<td>491 lb</td>
<td>4940 lb</td>
<td>0.48%</td>
<td>5.58%</td>
<td>20 q</td>
</tr>
<tr>
<td>100</td>
<td>500 lb</td>
<td>734 lb</td>
<td>1000 lb</td>
<td>-1.19%</td>
<td>1.20%</td>
<td>4 q</td>
</tr>
<tr>
<td>100</td>
<td>244 lb</td>
<td>468 lb</td>
<td>460 lb</td>
<td>-1.6%</td>
<td>44.0%</td>
<td>40 q</td>
</tr>
<tr>
<td>100</td>
<td>36.0 gl</td>
<td>44.0 gl</td>
<td>44.0 gl</td>
<td>0.11%</td>
<td>44.0 gl</td>
<td>40 q</td>
</tr>
<tr>
<td>100</td>
<td>36.0 oz</td>
<td>36.0 oz</td>
<td>33.00 oz</td>
<td>0.00%</td>
<td>33.00 oz</td>
<td>40 q</td>
</tr>
<tr>
<td>100</td>
<td>100 ct</td>
<td>100 ct</td>
<td>100 ct</td>
<td>0.00%</td>
<td>100 ct</td>
<td>40 q</td>
</tr>
</tbody>
</table>

Note: Manual Feed 39.
<table>
<thead>
<tr>
<th>LEVELED PLANT</th>
<th>ARRIVE JOB</th>
<th>START POUR</th>
<th>END POUR</th>
<th>LEAVE JOB</th>
<th>ARRIVE PLANT</th>
<th>SHIPPED</th>
<th>CURRENT WEATHER CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/5/17</td>
<td>12:30</td>
<td>0.00</td>
<td></td>
<td>12:30</td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CUSTOMER**

NOVA GEOTECH

**DELIVERY ADDRESS**

4400 W. HACIENDA  TICKET # 1247

**CUSTOMER #**

PURCHASE ORDER #

**JOB #**

LOAD #

**PRODUCTS SHIPPED**

<table>
<thead>
<tr>
<th>PRODUCT CODE</th>
<th>PRODUCT DESCRIPTION</th>
<th>UNITS</th>
<th>UNIT PRICE</th>
<th>EXTENSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>2459573</td>
<td>4500 FLY 3/8&quot; GROUT</td>
<td>6yd</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**STAND BY TIME**

6-Jan-16

**BEgin TIME:** 12:40:20

**END TIME:** 12:40:20

**TRUCK #**

0102

**DRIVER NAME**

JERRY COLLINS

**Sales Tax**

Previous Balance

Sub Total

Stand-by Charges

Total

**INTERNAL PURPOSES ONLY**

0000929
PRE-MIX PRODUCTS

Masonry Mortar

Type S

- Type S (â¥1800 p.s.i.) CEMENT, LIME and SAND

This sack contains Type S Masonry Mortar.

- Type M (â¥2500 p.s.i.) CEMENT, LIME and SAND

- WATER REDUCER ADDED

Proportioned in accordance with U.A. MASONRY. 
Mix for proportions by volume for U.A. MASONRY.

Application: Recommended pre-blend dry bag and lay water 17-18% by weight.
Approximately 25 blocks per 25 lb. bag.
The Concrete Masonry Units produced by Superlite, Oldcastle for the subject project are certified to meet the requirements of ASTM Standards C90-12 when properly sampled and tested by a qualified laboratory using ASTM Test Method C140.

Concrete Masonry Units will conform to the characteristics outlined in ASTM C90 Table 2, Density Classification for Medium Weight units.

If Unit Strength Method of determining compressive strength of each wythe of masonry (TMS602-11, 1.4, B.2) is specified, the Concrete Masonry Units will have minimum net compressive strength (for design $f'$m) of 1,900psi (1,500psi) when using Type M or S Mortar.

Concrete Masonry Units will not contain integral water repellant admixtures.

Per ASTM Standard C90, “the purchaser or authorized representative shall be accorded proper facilities to inspect and sample the units at the place of manufacture from the lots ready for delivery.” Sampling and testing of Concrete Masonry Units contractually required by the project plans and/or specifications, or those conformance tests required by building code, will be performed by the owner or the general contractor as outlined in TMS602-11, 1.6.

Sincerely,

Lacie Slevin  
Assistant Site Manager  
Oldcastle, Superlite Block
CONCRETE MASONRY UNIT CONFORMANCE TEST DATA

Client: Superlite  
Project Name: Quality Control  
CMU Type: 8x8x16 Medium Weight Standard Hollow Loadbearing Block  
Laboratory Sample No.: 26111  
Date Received: 9/16/04  
Project Number: 303235001

### Compression Units

<table>
<thead>
<tr>
<th>Width (in.)</th>
<th>Top</th>
<th>Unit No. 2</th>
<th>Unit No. 3</th>
<th>Average</th>
<th>ASTM C90 Spec.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7.6</td>
<td>7.6</td>
<td>7.6</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>Bottom</td>
<td>7.6</td>
<td>7.6</td>
<td>7.6</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>7.6</td>
<td>7.6</td>
<td>7.6</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>Height (in.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Face 1</td>
<td>7.6</td>
<td>7.6</td>
<td>7.6</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>Face 2</td>
<td>7.6</td>
<td>7.6</td>
<td>7.6</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>7.6</td>
<td>7.6</td>
<td>7.6</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>Length (in.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Face 1</td>
<td>15.6</td>
<td>15.6</td>
<td>15.6</td>
<td>15.6</td>
<td>12.5 Minimum</td>
</tr>
<tr>
<td>Face 2</td>
<td>15.6</td>
<td>15.6</td>
<td>15.6</td>
<td>15.6</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>15.6</td>
<td>15.6</td>
<td>15.6</td>
<td>15.6</td>
<td></td>
</tr>
<tr>
<td>Minimum Face Shell Thickness (in.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Face 1</td>
<td>1.31</td>
<td>1.30</td>
<td>1.30</td>
<td>1.30</td>
<td>1.25 Minimum</td>
</tr>
<tr>
<td>Face 2</td>
<td>1.30</td>
<td>1.30</td>
<td>1.29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>1.31</td>
<td>1.30</td>
<td>1.30</td>
<td>1.30</td>
<td></td>
</tr>
<tr>
<td>Average Minimum Web Thickness (in.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Web 1</td>
<td>1.26</td>
<td>1.27</td>
<td>1.28</td>
<td>1.28</td>
<td>1.00 Minimum</td>
</tr>
<tr>
<td>Web 2/3</td>
<td>1.09/1.27</td>
<td>1.08/1.28</td>
<td>1.08/1.26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>1.21</td>
<td>1.21</td>
<td>1.21</td>
<td>1.21</td>
<td></td>
</tr>
<tr>
<td>Equivalent Web Thickness (in./ft.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.25 Minimum</td>
</tr>
<tr>
<td>Equivalent Thickness (in.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Load (lb.)</td>
<td>170425</td>
<td>166620</td>
<td>176585</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Gross Area Tested (in.²)</td>
<td>118.6</td>
<td>118.6</td>
<td>118.6</td>
<td>118.6</td>
<td></td>
</tr>
<tr>
<td>Gross Compressive Strength (psi)</td>
<td>1440</td>
<td>1400</td>
<td>1490</td>
<td>1440</td>
<td></td>
</tr>
<tr>
<td>Net Volume Tested (ft.³)</td>
<td>0.27</td>
<td>0.27</td>
<td>0.27</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>Net Area Tested (in.²)</td>
<td>60.45</td>
<td>60.45</td>
<td>60.45</td>
<td>60.45</td>
<td></td>
</tr>
<tr>
<td>Net Compressive Strength (psi)</td>
<td>2820</td>
<td>2770</td>
<td>2930</td>
<td>2840</td>
<td>Min. 1700 Indiv. 1900 Avg. of 3</td>
</tr>
</tbody>
</table>

### Absorption Units

<table>
<thead>
<tr>
<th>Received Weight (lb.)</th>
<th>Unit No. 4</th>
<th>Unit No. 5</th>
<th>Unit No. 6</th>
<th>Average</th>
<th>ASTM C90 Spec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>31.51</td>
<td>31.33</td>
<td>31.46</td>
<td>31.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34.14</td>
<td>34.03</td>
<td>34.10</td>
<td>34.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31.18</td>
<td>31.00</td>
<td>31.13</td>
<td>31.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.55</td>
<td>17.53</td>
<td>17.55</td>
<td>17.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absorption (%)</td>
<td>9.5</td>
<td>9.8</td>
<td>9.5</td>
<td>9.6</td>
<td></td>
</tr>
<tr>
<td>Absorption (pcf)</td>
<td>11.1</td>
<td>11.5</td>
<td>11.2</td>
<td>11.3</td>
<td>Max. 17 Indiv. -15 Avg. of 3</td>
</tr>
<tr>
<td>Moisture Content (%)</td>
<td>11.1</td>
<td>10.9</td>
<td>11.1</td>
<td>11.1</td>
<td></td>
</tr>
<tr>
<td>Density (pcf)</td>
<td>117.3</td>
<td>117.2</td>
<td>117.4</td>
<td>117.3</td>
<td></td>
</tr>
</tbody>
</table>

Ninja & Moore

Sample prepared and tested in accordance with ASTM C-461.
August 18, 2016

Certificate of Analysis/QC Results

600 CAPPING COMPOUND – 2 HR. COMPRESSIVE STRENGTH TESTING – ASTM C817

<table>
<thead>
<tr>
<th>Lot #072116</th>
<th>Lot #080516</th>
<th>Lot #081016</th>
<th>Lot #081116</th>
</tr>
</thead>
<tbody>
<tr>
<td>8,622</td>
<td>8,235</td>
<td>8,835</td>
<td>8,171</td>
</tr>
<tr>
<td>8,459</td>
<td>8,205</td>
<td>8,859</td>
<td>8,046</td>
</tr>
<tr>
<td>8,604</td>
<td>8,285</td>
<td>8,804</td>
<td>8,051</td>
</tr>
<tr>
<td>8,561 psi</td>
<td>8,242 psi</td>
<td>8,833 psi</td>
<td>8,090 psi</td>
</tr>
</tbody>
</table>

The above results were obtained under laboratory conditions.

Sauereisen certifies that the above product was manufactured in Pittsburgh, PA and conforms to applicable specifications at the time of manufacture. Shelf life listed on the technical data sheet begins at date of manufacture when stored in unopened, tightly sealed containers in a dry location at 70 degrees F.

Daniel R. Schmidt

Quality Control Coordinator
Report of Calibration
- PREPARED FOR -
Nova Geotechnical & Inspection Services
4480 W. Hacienda Ave., Suite 104 - Las Vegas, NV 89118

<table>
<thead>
<tr>
<th>Equipment Type:</th>
<th>Compression Testing Machine</th>
<th>Calibration Date:</th>
<th>03/17/2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make:</td>
<td>Gilson</td>
<td>Recall Date:</td>
<td>03/17/2016</td>
</tr>
<tr>
<td>Model:</td>
<td>CM-500P-LXI</td>
<td>Ambient Temperature:</td>
<td>72°F</td>
</tr>
<tr>
<td>Asset Number:</td>
<td>130308G</td>
<td>Relative Humidity:</td>
<td>28%</td>
</tr>
<tr>
<td>Serial Number:</td>
<td>130308G</td>
<td>Received:</td>
<td>In Tolerance</td>
</tr>
<tr>
<td>Procedure:</td>
<td>Eng 1</td>
<td>Returned:</td>
<td>In Tolerance</td>
</tr>
<tr>
<td>Technician:</td>
<td>Enochs, Mike</td>
<td>Received Condition</td>
<td>Fair</td>
</tr>
<tr>
<td>Calibration At:</td>
<td>Customer Site</td>
<td>Authorized By:</td>
<td>Brandon Becker</td>
</tr>
</tbody>
</table>

| Standards Used |
|-----------------|-----------------|-----------------|--------|
| Traceability #  | Make | Model  | Description | Call Date | Due Date |
| 7001133         | Coti  | CP175  | 50 K Load Cell | 08/01/2014 | 09/01/2015 |
| 7001143         | Coti  | CP175-500 K | 500 K Load Cell | 07/17/2014 | 07/17/2015 |

The accuracy of this instrument has been verified under conditions stated in the applicable test procedure. The uncertainty of the calibration process is implicit in the ASTM method. Our standards have traceability to NIST and evidence is on file at our Metrology Laboratory. This certificate shall not be reproduced, except in full, without the written approval of National Calibration, Inc.

Recall dates are based on customer's requirements or on assumed normal usage. However, any number of factors can necessitate alternative recall intervals. This certificate applies only to the metrological quantities listed below. Compliance statement relates to the manufacturer's published specifications.

All recorded forces have been temperature corrected as necessary. All standards used were calibrated in accordance with ASTM Practice E74.

Class A load range (#1143): 2661.15 - 50,000 lbs. Load cell is calibrated by National Calibration.

Technician: 
Manager: 

This certificate shall not be reproduced, except in full, without the written approval of National Calibration, Inc.
<table>
<thead>
<tr>
<th>Machine Reading</th>
<th>Standard Reading 1st Run</th>
<th>Error</th>
<th>Error</th>
<th>Standard Reading 2nd Run</th>
<th>Error</th>
<th>Error</th>
<th>Algebraic Difference Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>lbs.</td>
<td>lbs.</td>
<td>%</td>
<td>lbs.</td>
<td>lbs.</td>
<td>%</td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>50,000</td>
<td>49,900</td>
<td>0.200</td>
<td>49,910</td>
<td>0.180</td>
<td>0.020</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100,000</td>
<td>99,860</td>
<td>0.140</td>
<td>99,850</td>
<td>0.150</td>
<td>-0.010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200,000</td>
<td>199,780</td>
<td>0.110</td>
<td>199,760</td>
<td>0.120</td>
<td>-0.010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>300,000</td>
<td>299,700</td>
<td>0.100</td>
<td>299,730</td>
<td>0.090</td>
<td>0.010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>400,000</td>
<td>399,650</td>
<td>0.088</td>
<td>399,640</td>
<td>0.090</td>
<td>-0.002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500,000</td>
<td>499,550</td>
<td>0.090</td>
<td>499,570</td>
<td>0.086</td>
<td>0.004</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Machine Reading**

<table>
<thead>
<tr>
<th>Standard Reading 1st Run</th>
<th>Error</th>
<th>Error</th>
<th>Standard Reading 2nd Run</th>
<th>Error</th>
<th>Error</th>
<th>Algebraic Difference Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>lbs.</td>
<td></td>
<td></td>
<td>lbs.</td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>5,000</td>
<td>4,990</td>
<td>0.200</td>
<td>4,980</td>
<td>0.400</td>
<td>-0.200</td>
<td></td>
</tr>
<tr>
<td>10,000</td>
<td>9,980</td>
<td>0.200</td>
<td>9,980</td>
<td>0.200</td>
<td>0.200</td>
<td></td>
</tr>
<tr>
<td>20,000</td>
<td>19,940</td>
<td>0.250</td>
<td>19,940</td>
<td>0.300</td>
<td>-0.050</td>
<td></td>
</tr>
<tr>
<td>30,000</td>
<td>29,920</td>
<td>0.267</td>
<td>29,940</td>
<td>0.200</td>
<td>0.067</td>
<td></td>
</tr>
<tr>
<td>40,000</td>
<td>39,860</td>
<td>0.300</td>
<td>39,900</td>
<td>0.250</td>
<td>0.050</td>
<td></td>
</tr>
<tr>
<td>50,000</td>
<td>49,910</td>
<td>0.180</td>
<td>49,500</td>
<td>0.200</td>
<td>-0.020</td>
<td></td>
</tr>
</tbody>
</table>

**As Found / As Left**

**Technician Comments**

Accuracy: +/- 1% of reading. Platen planeness is O.K.
## Grout Cylinder (4" Diameter) Results

<table>
<thead>
<tr>
<th>Specimen #</th>
<th>Cylinder Diameter (inches)</th>
<th>Cylinder Area (sq inches)</th>
<th>Cylinder Length After Prep (inches)</th>
<th>Load (lbs)</th>
<th>Strength (PSI)</th>
<th>L/D</th>
<th>Correction Factor</th>
<th>Corrected Strength (PSI)</th>
<th>Fracture Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>3.96</td>
<td>12.32</td>
<td>6.86</td>
<td>114340</td>
<td>9284</td>
<td>1.73</td>
<td>0.98</td>
<td>9083</td>
<td>3</td>
</tr>
<tr>
<td>1b</td>
<td>3.94</td>
<td>12.19</td>
<td>6.78</td>
<td>90700</td>
<td>7430</td>
<td>1.72</td>
<td>0.98</td>
<td>7271</td>
<td>3</td>
</tr>
<tr>
<td>1c</td>
<td>4.01</td>
<td>12.61</td>
<td>7.03</td>
<td>111526</td>
<td>8810</td>
<td>1.25</td>
<td>0.88</td>
<td>8654</td>
<td>3</td>
</tr>
<tr>
<td>2a</td>
<td>3.99</td>
<td>12.50</td>
<td>7.11</td>
<td>107656</td>
<td>8610</td>
<td>1.78</td>
<td>0.88</td>
<td>8461</td>
<td>3</td>
</tr>
<tr>
<td>2b</td>
<td>3.94</td>
<td>12.19</td>
<td>7.33</td>
<td>1031360</td>
<td>6470</td>
<td>1.86</td>
<td>0.99</td>
<td>6000</td>
<td>3</td>
</tr>
<tr>
<td>2c</td>
<td>4.02</td>
<td>12.69</td>
<td>7.23</td>
<td>98390</td>
<td>7792</td>
<td>1.80</td>
<td>0.98</td>
<td>7630</td>
<td>3</td>
</tr>
<tr>
<td>3a</td>
<td>3.91</td>
<td>12.01</td>
<td>7.3</td>
<td>100460</td>
<td>8367</td>
<td>1.87</td>
<td>0.99</td>
<td>8295</td>
<td>3</td>
</tr>
<tr>
<td>3b</td>
<td>3.97</td>
<td>12.38</td>
<td>7.38</td>
<td>99450</td>
<td>8544</td>
<td>1.86</td>
<td>0.99</td>
<td>7958</td>
<td>3</td>
</tr>
<tr>
<td>3c</td>
<td>3.97</td>
<td>12.38</td>
<td>7.76</td>
<td>1055750</td>
<td>8543</td>
<td>1.95</td>
<td>1.06</td>
<td>8556</td>
<td>3</td>
</tr>
<tr>
<td>4a</td>
<td>4.08</td>
<td>13.07</td>
<td>7.44</td>
<td>90440</td>
<td>7666</td>
<td>1.82</td>
<td>0.99</td>
<td>7505</td>
<td>3</td>
</tr>
<tr>
<td>4b</td>
<td>3.97</td>
<td>12.38</td>
<td>7.4</td>
<td>100410</td>
<td>8113</td>
<td>1.86</td>
<td>0.99</td>
<td>8041</td>
<td>3</td>
</tr>
<tr>
<td>4c</td>
<td>4.01</td>
<td>12.63</td>
<td>7.5</td>
<td>99630</td>
<td>7889</td>
<td>1.87</td>
<td>0.99</td>
<td>7834</td>
<td>3</td>
</tr>
<tr>
<td>5a</td>
<td>3.97</td>
<td>12.38</td>
<td>7.49</td>
<td>99660</td>
<td>8062</td>
<td>1.89</td>
<td>0.99</td>
<td>8012</td>
<td>3</td>
</tr>
<tr>
<td>5b</td>
<td>3.96</td>
<td>12.32</td>
<td>7.29</td>
<td>105780</td>
<td>8670</td>
<td>1.84</td>
<td>0.99</td>
<td>8571</td>
<td>3</td>
</tr>
<tr>
<td>5c</td>
<td>4.01</td>
<td>12.63</td>
<td>7.55</td>
<td>99660</td>
<td>7997</td>
<td>1.88</td>
<td>0.99</td>
<td>7854</td>
<td>3</td>
</tr>
<tr>
<td>6a</td>
<td>3.99</td>
<td>12.50</td>
<td>7.32</td>
<td>93340</td>
<td>7457</td>
<td>1.83</td>
<td>0.99</td>
<td>7367</td>
<td>3</td>
</tr>
<tr>
<td>6b</td>
<td>3.93</td>
<td>12.13</td>
<td>7.37</td>
<td>102160</td>
<td>8422</td>
<td>1.88</td>
<td>0.99</td>
<td>8358</td>
<td>3</td>
</tr>
<tr>
<td>6c</td>
<td>4.04</td>
<td>12.82</td>
<td>7.46</td>
<td>91860</td>
<td>7166</td>
<td>1.85</td>
<td>0.99</td>
<td>7688</td>
<td>3</td>
</tr>
<tr>
<td>7a</td>
<td>4.1</td>
<td>13.20</td>
<td>7.43</td>
<td>89800</td>
<td>6802</td>
<td>1.81</td>
<td>0.99</td>
<td>6704</td>
<td>3</td>
</tr>
<tr>
<td>7b</td>
<td>4.02</td>
<td>12.69</td>
<td>7.63</td>
<td>100620</td>
<td>7928</td>
<td>1.90</td>
<td>1.00</td>
<td>7809</td>
<td>3</td>
</tr>
<tr>
<td>7c</td>
<td>3.94</td>
<td>12.19</td>
<td>7.45</td>
<td>102730</td>
<td>8426</td>
<td>1.89</td>
<td>0.99</td>
<td>8177</td>
<td>3</td>
</tr>
<tr>
<td>8a</td>
<td>4.11</td>
<td>13.17</td>
<td>7.18</td>
<td>98040</td>
<td>7390</td>
<td>1.75</td>
<td>0.98</td>
<td>7242</td>
<td>3</td>
</tr>
<tr>
<td>8b</td>
<td>3.94</td>
<td>12.19</td>
<td>7.15</td>
<td>100176</td>
<td>8232</td>
<td>1.81</td>
<td>0.99</td>
<td>8116</td>
<td>3</td>
</tr>
<tr>
<td>8c</td>
<td>3.99</td>
<td>12.50</td>
<td>7.25</td>
<td>98030</td>
<td>7840</td>
<td>1.82</td>
<td>0.99</td>
<td>7731</td>
<td>3</td>
</tr>
<tr>
<td>9a</td>
<td>3.98</td>
<td>12.44</td>
<td>6.97</td>
<td>99990</td>
<td>8021</td>
<td>1.75</td>
<td>0.98</td>
<td>7861</td>
<td>3</td>
</tr>
<tr>
<td>9b</td>
<td>3.91</td>
<td>12.13</td>
<td>3.2</td>
<td>94330</td>
<td>7667</td>
<td>1.83</td>
<td>0.99</td>
<td>7611</td>
<td>3</td>
</tr>
<tr>
<td>9c</td>
<td>3.95</td>
<td>12.25</td>
<td>7.28</td>
<td>93330</td>
<td>7608</td>
<td>1.84</td>
<td>0.99</td>
<td>7323</td>
<td>3</td>
</tr>
<tr>
<td>10a</td>
<td>3.98</td>
<td>12.44</td>
<td>7.48</td>
<td>101760</td>
<td>8170</td>
<td>1.88</td>
<td>0.99</td>
<td>8121</td>
<td>3</td>
</tr>
<tr>
<td>10b</td>
<td>4.08</td>
<td>13.07</td>
<td>7.18</td>
<td>93360</td>
<td>7133</td>
<td>1.76</td>
<td>0.98</td>
<td>6996</td>
<td>3</td>
</tr>
<tr>
<td>10c</td>
<td>3.99</td>
<td>12.50</td>
<td>7.14</td>
<td>92460</td>
<td>7395</td>
<td>1.79</td>
<td>0.98</td>
<td>7222</td>
<td>3</td>
</tr>
</tbody>
</table>
## Grout Cylinder (4" Diameter) Results

\[
g = 0.213 \times 10^{-6} \times 1.0962 \times 0.57
\]

<table>
<thead>
<tr>
<th>Specimen #</th>
<th>Cylinder Diameter (inches)</th>
<th>Cylinder Area (sq inches)</th>
<th>Cylinder Length After Prep (inches)</th>
<th>Load (lbs)</th>
<th>Strength (PSI)</th>
<th>L/D</th>
<th>Correction Factor</th>
<th>Corrected Strength (PSI)</th>
<th>Fracture Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>3.09</td>
<td>12.25</td>
<td>6.27</td>
<td>55335</td>
<td>4442</td>
<td>1.60</td>
<td>0.97</td>
<td>4290</td>
<td>5</td>
</tr>
<tr>
<td>1b</td>
<td>3.05</td>
<td>12.25</td>
<td>6.28</td>
<td>54885</td>
<td>4202</td>
<td>1.55</td>
<td>0.97</td>
<td>4032</td>
<td>5</td>
</tr>
<tr>
<td>1c</td>
<td>4.01</td>
<td>12.63</td>
<td>6.51</td>
<td>54530</td>
<td>4322</td>
<td>1.62</td>
<td>0.97</td>
<td>4191</td>
<td>2</td>
</tr>
<tr>
<td>2a</td>
<td>4.01</td>
<td>12.63</td>
<td>6.44</td>
<td>58146</td>
<td>4604</td>
<td>1.61</td>
<td>0.97</td>
<td>4438</td>
<td>5</td>
</tr>
<tr>
<td>2b</td>
<td>3.07</td>
<td>12.58</td>
<td>6.57</td>
<td>51745</td>
<td>4938</td>
<td>1.60</td>
<td>0.97</td>
<td>4830</td>
<td>5</td>
</tr>
<tr>
<td>2c</td>
<td>4</td>
<td>12.57</td>
<td>5.77</td>
<td>52775</td>
<td>4995</td>
<td>1.46</td>
<td>0.95</td>
<td>4769</td>
<td>2</td>
</tr>
<tr>
<td>3a</td>
<td>3.08</td>
<td>12.44</td>
<td>7.07</td>
<td>62246</td>
<td>4842</td>
<td>1.78</td>
<td>0.98</td>
<td>4756</td>
<td>5</td>
</tr>
<tr>
<td>3b</td>
<td>4.02</td>
<td>12.69</td>
<td>6.85</td>
<td>52533</td>
<td>4139</td>
<td>1.70</td>
<td>0.98</td>
<td>4040</td>
<td>5</td>
</tr>
<tr>
<td>3c</td>
<td>3.99</td>
<td>12.50</td>
<td>6.45</td>
<td>54170</td>
<td>5132</td>
<td>1.62</td>
<td>0.97</td>
<td>4974</td>
<td>5</td>
</tr>
<tr>
<td>4a</td>
<td>4.01</td>
<td>12.63</td>
<td>6.43</td>
<td>54425</td>
<td>4808</td>
<td>1.53</td>
<td>0.96</td>
<td>4177</td>
<td>2</td>
</tr>
<tr>
<td>4b</td>
<td>4</td>
<td>12.57</td>
<td>6.72</td>
<td>54815</td>
<td>4362</td>
<td>1.60</td>
<td>0.97</td>
<td>4209</td>
<td>2</td>
</tr>
<tr>
<td>4c</td>
<td>4</td>
<td>12.57</td>
<td>6.8</td>
<td>57915</td>
<td>4608</td>
<td>1.70</td>
<td>0.98</td>
<td>4497</td>
<td>5</td>
</tr>
<tr>
<td>5a</td>
<td>3.08</td>
<td>12.44</td>
<td>6.67</td>
<td>61495</td>
<td>4443</td>
<td>1.68</td>
<td>0.97</td>
<td>4814</td>
<td>2</td>
</tr>
<tr>
<td>5b</td>
<td>4</td>
<td>12.57</td>
<td>6.73</td>
<td>52605</td>
<td>4958</td>
<td>1.68</td>
<td>0.97</td>
<td>4881</td>
<td>2</td>
</tr>
<tr>
<td>5c</td>
<td>3.97</td>
<td>12.38</td>
<td>6.22</td>
<td>59935</td>
<td>4442</td>
<td>1.57</td>
<td>0.97</td>
<td>4674</td>
<td>2</td>
</tr>
<tr>
<td>6a</td>
<td>3.96</td>
<td>12.32</td>
<td>6.41</td>
<td>59695</td>
<td>4797</td>
<td>1.62</td>
<td>0.97</td>
<td>4651</td>
<td>5</td>
</tr>
<tr>
<td>6b</td>
<td>3.98</td>
<td>12.44</td>
<td>6.22</td>
<td>51690</td>
<td>4559</td>
<td>1.56</td>
<td>0.97</td>
<td>4786</td>
<td>5</td>
</tr>
<tr>
<td>6c</td>
<td>3.94</td>
<td>12.19</td>
<td>6.24</td>
<td>51893</td>
<td>3677</td>
<td>1.28</td>
<td>0.97</td>
<td>4908</td>
<td>2</td>
</tr>
<tr>
<td>7a</td>
<td>3.08</td>
<td>12.44</td>
<td>6.6</td>
<td>56845</td>
<td>4577</td>
<td>1.66</td>
<td>0.97</td>
<td>4851</td>
<td>2</td>
</tr>
<tr>
<td>7b</td>
<td>4</td>
<td>12.57</td>
<td>5.98</td>
<td>60640</td>
<td>4813</td>
<td>1.59</td>
<td>0.96</td>
<td>4620</td>
<td>5</td>
</tr>
<tr>
<td>7c</td>
<td>4.01</td>
<td>12.63</td>
<td>5.97</td>
<td>55560</td>
<td>4383</td>
<td>1.49</td>
<td>0.96</td>
<td>4204</td>
<td>5</td>
</tr>
<tr>
<td>8a</td>
<td>3.99</td>
<td>12.50</td>
<td>6.39</td>
<td>58835</td>
<td>4705</td>
<td>1.55</td>
<td>0.96</td>
<td>4537</td>
<td>2</td>
</tr>
<tr>
<td>8b</td>
<td>3.98</td>
<td>12.44</td>
<td>6.44</td>
<td>53835</td>
<td>4328</td>
<td>1.62</td>
<td>0.97</td>
<td>4134</td>
<td>5</td>
</tr>
<tr>
<td>8c</td>
<td>3.99</td>
<td>12.50</td>
<td>7.19</td>
<td>62960</td>
<td>4964</td>
<td>1.80</td>
<td>0.98</td>
<td>4857</td>
<td>2</td>
</tr>
<tr>
<td>9a</td>
<td>3.96</td>
<td>12.32</td>
<td>6.86</td>
<td>61380</td>
<td>4676</td>
<td>1.63</td>
<td>0.97</td>
<td>4328</td>
<td>2</td>
</tr>
<tr>
<td>9b</td>
<td>4.01</td>
<td>12.53</td>
<td>5.23</td>
<td>59420</td>
<td>4784</td>
<td>1.55</td>
<td>0.96</td>
<td>4654</td>
<td>2</td>
</tr>
<tr>
<td>9c</td>
<td>3.98</td>
<td>12.44</td>
<td>6.04</td>
<td>52835</td>
<td>3651</td>
<td>1.52</td>
<td>0.96</td>
<td>4856</td>
<td>2</td>
</tr>
<tr>
<td>10a</td>
<td>3.99</td>
<td>12.50</td>
<td>6.93</td>
<td>59510</td>
<td>4743</td>
<td>1.74</td>
<td>0.98</td>
<td>4603</td>
<td>2</td>
</tr>
<tr>
<td>10b</td>
<td>4.02</td>
<td>12.69</td>
<td>6.39</td>
<td>59405</td>
<td>4698</td>
<td>1.59</td>
<td>0.97</td>
<td>4527</td>
<td>2</td>
</tr>
<tr>
<td>10c</td>
<td>4.02</td>
<td>12.69</td>
<td>6.45</td>
<td>60295</td>
<td>4750</td>
<td>1.60</td>
<td>0.97</td>
<td>4600</td>
<td>2</td>
</tr>
</tbody>
</table>
## Grout Cylinder (4" Diameter) Results

<table>
<thead>
<tr>
<th>Specimen #</th>
<th>Cylinder Diameter (inches)</th>
<th>Cylinder Area (sq inches)</th>
<th>Cylinder Length After Prep (inches)</th>
<th>Load (lbs)</th>
<th>Strength (PSI)</th>
<th>1/D</th>
<th>Correction Factor</th>
<th>Corrected Strength (PSI)</th>
<th>Fracture Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>3.06</td>
<td>12.32</td>
<td>6.52</td>
<td>6890.0</td>
<td>5535</td>
<td>1.65</td>
<td>0.97</td>
<td>5636</td>
<td>4</td>
</tr>
<tr>
<td>1b</td>
<td>3.95</td>
<td>12.75</td>
<td>7.46</td>
<td>72670.0</td>
<td>5930</td>
<td>1.89</td>
<td>0.99</td>
<td>5804</td>
<td>5</td>
</tr>
<tr>
<td>1c</td>
<td>3.94</td>
<td>12.19</td>
<td>6.85</td>
<td>64345.0</td>
<td>5261</td>
<td>1.74</td>
<td>0.98</td>
<td>5150</td>
<td>3</td>
</tr>
<tr>
<td>2a</td>
<td>3.95</td>
<td>12.25</td>
<td>6.77</td>
<td>78225.0</td>
<td>6375</td>
<td>1.71</td>
<td>0.98</td>
<td>6228</td>
<td>5</td>
</tr>
<tr>
<td>2b</td>
<td>3.93</td>
<td>12.13</td>
<td>6.72</td>
<td>83320.0</td>
<td>6704</td>
<td>1.71</td>
<td>0.98</td>
<td>6546</td>
<td>5</td>
</tr>
<tr>
<td>2c</td>
<td>4.04</td>
<td>12.82</td>
<td>6.74</td>
<td>78535.0</td>
<td>6126</td>
<td>1.67</td>
<td>0.97</td>
<td>5963</td>
<td>5</td>
</tr>
<tr>
<td>3a</td>
<td>4.11</td>
<td>13.27</td>
<td>6.67</td>
<td>83680.0</td>
<td>6137</td>
<td>1.62</td>
<td>0.97</td>
<td>5920</td>
<td>4</td>
</tr>
<tr>
<td>3b</td>
<td>4.07</td>
<td>13.01</td>
<td>6.7</td>
<td>75605.0</td>
<td>5811</td>
<td>1.65</td>
<td>0.97</td>
<td>5646</td>
<td>3</td>
</tr>
<tr>
<td>3c</td>
<td>3.98</td>
<td>12.44</td>
<td>6.92</td>
<td>72230.0</td>
<td>5815</td>
<td>1.74</td>
<td>0.98</td>
<td>5603</td>
<td>3</td>
</tr>
<tr>
<td>4a</td>
<td>3.94</td>
<td>12.19</td>
<td>7.05</td>
<td>76435.0</td>
<td>6269</td>
<td>1.70</td>
<td>0.98</td>
<td>6165</td>
<td>5</td>
</tr>
<tr>
<td>4b</td>
<td>3.96</td>
<td>12.32</td>
<td>5.91</td>
<td>80340.0</td>
<td>6523</td>
<td>1.50</td>
<td>0.96</td>
<td>6262</td>
<td>3</td>
</tr>
<tr>
<td>4c</td>
<td>4.03</td>
<td>13.14</td>
<td>6.81</td>
<td>78130.0</td>
<td>5947</td>
<td>1.67</td>
<td>0.97</td>
<td>5786</td>
<td>3</td>
</tr>
<tr>
<td>4d</td>
<td>4.01</td>
<td>12.63</td>
<td>7.39</td>
<td>89315.0</td>
<td>5854</td>
<td>1.84</td>
<td>0.99</td>
<td>5788</td>
<td>3</td>
</tr>
<tr>
<td>5a</td>
<td>3.96</td>
<td>12.32</td>
<td>6.52</td>
<td>80605.0</td>
<td>6543</td>
<td>1.65</td>
<td>0.97</td>
<td>6328</td>
<td>5</td>
</tr>
<tr>
<td>5b</td>
<td>3.97</td>
<td>12.38</td>
<td>6.16</td>
<td>75740.0</td>
<td>6139</td>
<td>1.55</td>
<td>0.96</td>
<td>5900</td>
<td>5</td>
</tr>
<tr>
<td>5c</td>
<td>3.96</td>
<td>12.32</td>
<td>6.59</td>
<td>73765.0</td>
<td>5949</td>
<td>1.61</td>
<td>0.97</td>
<td>5764</td>
<td>3</td>
</tr>
<tr>
<td>6a</td>
<td>3.95</td>
<td>12.25</td>
<td>6.67</td>
<td>68185.0</td>
<td>5564</td>
<td>1.69</td>
<td>0.97</td>
<td>5424</td>
<td>3</td>
</tr>
<tr>
<td>6b</td>
<td>4.03</td>
<td>12.76</td>
<td>6.53</td>
<td>78790.0</td>
<td>6177</td>
<td>1.62</td>
<td>0.97</td>
<td>5989</td>
<td>3</td>
</tr>
<tr>
<td>7a</td>
<td>3.93</td>
<td>12.83</td>
<td>7.39</td>
<td>72705.0</td>
<td>6363</td>
<td>1.88</td>
<td>0.99</td>
<td>6320</td>
<td>6</td>
</tr>
<tr>
<td>7b</td>
<td>3.89</td>
<td>11.08</td>
<td>7.11</td>
<td>74120.0</td>
<td>6237</td>
<td>1.85</td>
<td>0.99</td>
<td>6157</td>
<td>5</td>
</tr>
<tr>
<td>7c</td>
<td>3.94</td>
<td>12.19</td>
<td>7.53</td>
<td>78490.0</td>
<td>6438</td>
<td>1.94</td>
<td>1.00</td>
<td>6417</td>
<td>5</td>
</tr>
<tr>
<td>8a</td>
<td>3.99</td>
<td>12.50</td>
<td>6.29</td>
<td>80745.0</td>
<td>6458</td>
<td>1.58</td>
<td>0.97</td>
<td>6239</td>
<td>5</td>
</tr>
<tr>
<td>8b</td>
<td>3.98</td>
<td>12.44</td>
<td>7.34</td>
<td>82390.0</td>
<td>6567</td>
<td>1.84</td>
<td>0.99</td>
<td>6593</td>
<td>3</td>
</tr>
<tr>
<td>8c</td>
<td>3.91</td>
<td>12.13</td>
<td>7.68</td>
<td>81380.0</td>
<td>6748</td>
<td>1.95</td>
<td>1.00</td>
<td>6765</td>
<td>4</td>
</tr>
<tr>
<td>9a</td>
<td>3.93</td>
<td>12.83</td>
<td>7.19</td>
<td>78530.0</td>
<td>6473</td>
<td>1.83</td>
<td>0.99</td>
<td>6291</td>
<td>5</td>
</tr>
<tr>
<td>9b</td>
<td>4.05</td>
<td>12.88</td>
<td>7.03</td>
<td>76705.0</td>
<td>5954</td>
<td>1.74</td>
<td>0.98</td>
<td>5827</td>
<td>3</td>
</tr>
<tr>
<td>9c</td>
<td>3.97</td>
<td>12.38</td>
<td>7.3</td>
<td>79570.0</td>
<td>6428</td>
<td>1.84</td>
<td>0.99</td>
<td>6333</td>
<td>3</td>
</tr>
<tr>
<td>10a</td>
<td>4.02</td>
<td>12.69</td>
<td>6.35</td>
<td>78175.0</td>
<td>6159</td>
<td>1.55</td>
<td>0.96</td>
<td>5940</td>
<td>3</td>
</tr>
<tr>
<td>10b</td>
<td>4.06</td>
<td>12.95</td>
<td>7.08</td>
<td>81150.0</td>
<td>6767</td>
<td>1.74</td>
<td>0.98</td>
<td>6137</td>
<td>3</td>
</tr>
<tr>
<td>10c</td>
<td>3.94</td>
<td>12.19</td>
<td>6.29</td>
<td>85285.0</td>
<td>6667</td>
<td>1.60</td>
<td>0.97</td>
<td>6452</td>
<td>4</td>
</tr>
</tbody>
</table>

\[ y = 0.2155x^2 - 1.604x + 1.766x \cdot 0.07 \]
<table>
<thead>
<tr>
<th>Specimen #</th>
<th>Average Length [inches]</th>
<th>Average Width [inches]</th>
<th>Prism Area [sq inches]</th>
<th>Average Height [inches]</th>
<th>Load (lbs)</th>
<th>Strength (PSI)</th>
<th>hp/tp</th>
<th>Correction Factor</th>
<th>Corrected Strength [PSI]</th>
<th>Fracture Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>7.6</td>
<td>7.6</td>
<td>57.76</td>
<td>15</td>
<td>208150</td>
<td>3604</td>
<td>2.0</td>
<td>1.00</td>
<td>3664</td>
<td>5</td>
</tr>
<tr>
<td>1b</td>
<td>7.7</td>
<td>7.6</td>
<td>58.52</td>
<td>14.05</td>
<td>280280</td>
<td>3834</td>
<td>1.8</td>
<td>0.97</td>
<td>3811</td>
<td>6</td>
</tr>
<tr>
<td>1c</td>
<td>7.6</td>
<td>7.625</td>
<td>57.95</td>
<td>14.8</td>
<td>233300</td>
<td>4023</td>
<td>1.9</td>
<td>0.99</td>
<td>3973</td>
<td>6</td>
</tr>
<tr>
<td>2a</td>
<td>7.6</td>
<td>7.575</td>
<td>57.57</td>
<td>15.1</td>
<td>219500</td>
<td>3763</td>
<td>2.0</td>
<td>1.00</td>
<td>3275</td>
<td>6</td>
</tr>
<tr>
<td>2b</td>
<td>7.6</td>
<td>7.6</td>
<td>57.26</td>
<td>15.725</td>
<td>241370</td>
<td>4173</td>
<td>1.9</td>
<td>0.99</td>
<td>4119</td>
<td>6</td>
</tr>
<tr>
<td>2c</td>
<td>7.6</td>
<td>7.625</td>
<td>57.10</td>
<td>14.7</td>
<td>272290</td>
<td>3099</td>
<td>2.0</td>
<td>1.00</td>
<td>3099</td>
<td>6</td>
</tr>
<tr>
<td>3a</td>
<td>7.6</td>
<td>7.625</td>
<td>57.95</td>
<td>14.6</td>
<td>292870</td>
<td>3328</td>
<td>1.9</td>
<td>0.98</td>
<td>3269</td>
<td>6</td>
</tr>
<tr>
<td>3b</td>
<td>7.6</td>
<td>7.6</td>
<td>57.76</td>
<td>14.8</td>
<td>263660</td>
<td>3400</td>
<td>1.9</td>
<td>0.99</td>
<td>3560</td>
<td>6</td>
</tr>
<tr>
<td>3c</td>
<td>7.6</td>
<td>7.625</td>
<td>58.33</td>
<td>13.9</td>
<td>264970</td>
<td>3397</td>
<td>1.8</td>
<td>0.96</td>
<td>3420</td>
<td>6</td>
</tr>
<tr>
<td>4a</td>
<td>7.6</td>
<td>7.275</td>
<td>57.27</td>
<td>14.625</td>
<td>2222900</td>
<td>3873</td>
<td>2.0</td>
<td>1.00</td>
<td>3873</td>
<td>6</td>
</tr>
<tr>
<td>4b</td>
<td>7.6</td>
<td>7.6</td>
<td>57.95</td>
<td>14.8</td>
<td>213660</td>
<td>3652</td>
<td>1.8</td>
<td>0.97</td>
<td>3533</td>
<td>6</td>
</tr>
<tr>
<td>4c</td>
<td>7.575</td>
<td>7.6</td>
<td>57.95</td>
<td>14.85</td>
<td>214320</td>
<td>3699</td>
<td>1.9</td>
<td>0.99</td>
<td>3652</td>
<td>6</td>
</tr>
<tr>
<td>5a</td>
<td>7.575</td>
<td>7.6</td>
<td>57.95</td>
<td>14.65</td>
<td>200600</td>
<td>3667</td>
<td>1.9</td>
<td>0.98</td>
<td>3548</td>
<td>6</td>
</tr>
<tr>
<td>5b</td>
<td>7.6</td>
<td>7.6</td>
<td>58.14</td>
<td>14.8</td>
<td>260800</td>
<td>3536</td>
<td>1.9</td>
<td>0.99</td>
<td>3526</td>
<td>5</td>
</tr>
<tr>
<td>5c</td>
<td>7.6</td>
<td>7.55</td>
<td>57.57</td>
<td>15.1</td>
<td>230900</td>
<td>4011</td>
<td>3.0</td>
<td>1.00</td>
<td>4011</td>
<td>1</td>
</tr>
<tr>
<td>6a</td>
<td>7.6</td>
<td>7.6</td>
<td>57.76</td>
<td>14.975</td>
<td>219120</td>
<td>3794</td>
<td>2.0</td>
<td>1.00</td>
<td>3794</td>
<td>6</td>
</tr>
<tr>
<td>6b</td>
<td>7.6</td>
<td>7.6</td>
<td>57.76</td>
<td>15</td>
<td>219680</td>
<td>3410</td>
<td>2.0</td>
<td>1.00</td>
<td>3410</td>
<td>6</td>
</tr>
<tr>
<td>6c</td>
<td>7.65</td>
<td>7.625</td>
<td>58.83</td>
<td>14.225</td>
<td>286300</td>
<td>3941</td>
<td>1.9</td>
<td>0.97</td>
<td>3840</td>
<td>6</td>
</tr>
<tr>
<td>7a</td>
<td>7.65</td>
<td>7.625</td>
<td>58.71</td>
<td>14.925</td>
<td>216790</td>
<td>3236</td>
<td>1.9</td>
<td>0.99</td>
<td>3680</td>
<td>6</td>
</tr>
<tr>
<td>7b</td>
<td>7.625</td>
<td>7.575</td>
<td>57.76</td>
<td>14.9</td>
<td>283860</td>
<td>3174</td>
<td>2.0</td>
<td>1.00</td>
<td>3374</td>
<td>6</td>
</tr>
<tr>
<td>7c</td>
<td>7.6</td>
<td>7.65</td>
<td>58.14</td>
<td>14.775</td>
<td>195400</td>
<td>3430</td>
<td>1.9</td>
<td>0.97</td>
<td>3380</td>
<td>6</td>
</tr>
<tr>
<td>8a</td>
<td>7.6</td>
<td>7.625</td>
<td>58.14</td>
<td>14.175</td>
<td>226640</td>
<td>3898</td>
<td>1.9</td>
<td>0.97</td>
<td>3785</td>
<td>6</td>
</tr>
<tr>
<td>8b</td>
<td>7.575</td>
<td>7.625</td>
<td>57.76</td>
<td>14.65</td>
<td>200530</td>
<td>3472</td>
<td>1.9</td>
<td>0.98</td>
<td>3545</td>
<td>5</td>
</tr>
<tr>
<td>8c</td>
<td>7.65</td>
<td>7.6</td>
<td>58.52</td>
<td>14.7</td>
<td>359580</td>
<td>5336</td>
<td>1.9</td>
<td>0.98</td>
<td>3325</td>
<td>5</td>
</tr>
<tr>
<td>9a</td>
<td>7.65</td>
<td>7.6</td>
<td>58.14</td>
<td>14.75</td>
<td>231090</td>
<td>3665</td>
<td>1.9</td>
<td>0.99</td>
<td>3618</td>
<td>5</td>
</tr>
<tr>
<td>9b</td>
<td>7.625</td>
<td>7.625</td>
<td>58.14</td>
<td>14.825</td>
<td>203160</td>
<td>3463</td>
<td>1.9</td>
<td>0.98</td>
<td>3464</td>
<td>5</td>
</tr>
<tr>
<td>9c</td>
<td>7.625</td>
<td>7.625</td>
<td>58.14</td>
<td>14.725</td>
<td>217680</td>
<td>3970</td>
<td>1.9</td>
<td>0.99</td>
<td>3970</td>
<td>3</td>
</tr>
<tr>
<td>10a</td>
<td>7.625</td>
<td>7.625</td>
<td>58.14</td>
<td>14.725</td>
<td>196410</td>
<td>3378</td>
<td>1.9</td>
<td>0.99</td>
<td>3329</td>
<td>6</td>
</tr>
<tr>
<td>10b</td>
<td>7.65</td>
<td>7.625</td>
<td>58.33</td>
<td>14.725</td>
<td>189860</td>
<td>3166</td>
<td>1.9</td>
<td>0.99</td>
<td>3123</td>
<td>5</td>
</tr>
<tr>
<td>10c</td>
<td>7.675</td>
<td>7.65</td>
<td>58.21</td>
<td>14.775</td>
<td>197940</td>
<td>3371</td>
<td>1.9</td>
<td>0.985</td>
<td>3322</td>
<td>6</td>
</tr>
<tr>
<td>Specimen</td>
<td>Average Length (inches)</td>
<td>Average Width (inches)</td>
<td>Prism Area (sq inches)</td>
<td>Average Height (inches)</td>
<td>Load (lbs)</td>
<td>Strength (PSI)</td>
<td>Hp/fp</td>
<td>Correction Factor</td>
<td>Corrected Strength (PSI)</td>
<td>Fracture Type</td>
</tr>
<tr>
<td>----------</td>
<td>------------------------</td>
<td>-----------------------</td>
<td>-----------------------</td>
<td>-------------------------</td>
<td>-----------</td>
<td>---------------</td>
<td>-------</td>
<td>-----------------</td>
<td>--------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>1a</td>
<td>7.6</td>
<td>7.525</td>
<td>57.59</td>
<td>15.325</td>
<td>142350</td>
<td>2486</td>
<td>7.0</td>
<td>1.00</td>
<td>2486</td>
<td>4</td>
</tr>
<tr>
<td>1b</td>
<td>7.6</td>
<td>7.6</td>
<td>57.76</td>
<td>15.35</td>
<td>131630</td>
<td>2379</td>
<td>7.0</td>
<td>1.00</td>
<td>2379</td>
<td>5</td>
</tr>
<tr>
<td>1c</td>
<td>7.5875</td>
<td>7.625</td>
<td>57.76</td>
<td>15.35</td>
<td>141590</td>
<td>2451</td>
<td>7.0</td>
<td>1.00</td>
<td>2451</td>
<td>6</td>
</tr>
<tr>
<td>2a</td>
<td>7.625</td>
<td>7.755</td>
<td>57.76</td>
<td>15.325</td>
<td>150090</td>
<td>2599</td>
<td>7.0</td>
<td>1.00</td>
<td>2599</td>
<td>6</td>
</tr>
<tr>
<td>2b</td>
<td>7.6325</td>
<td>7.625</td>
<td>57.95</td>
<td>15.325</td>
<td>128610</td>
<td>2219</td>
<td>7.0</td>
<td>1.00</td>
<td>2219</td>
<td>6</td>
</tr>
<tr>
<td>2c</td>
<td>7.6</td>
<td>7.6</td>
<td>57.66</td>
<td>14.2</td>
<td>138610</td>
<td>2575</td>
<td>1.9</td>
<td>0.97</td>
<td>2575</td>
<td>3</td>
</tr>
<tr>
<td>3a</td>
<td>7.5875</td>
<td>7.5875</td>
<td>57.57</td>
<td>15.2375</td>
<td>119760</td>
<td>2080</td>
<td>7.0</td>
<td>1.00</td>
<td>2080</td>
<td>5</td>
</tr>
<tr>
<td>3b</td>
<td>7.6125</td>
<td>7.6375</td>
<td>58.14</td>
<td>15.4</td>
<td>130860</td>
<td>2250</td>
<td>7.0</td>
<td>1.00</td>
<td>2250</td>
<td>4</td>
</tr>
<tr>
<td>3c</td>
<td>7.65</td>
<td>7.625</td>
<td>58.33</td>
<td>14.6875</td>
<td>166420</td>
<td>2833</td>
<td>1.9</td>
<td>0.98</td>
<td>2809</td>
<td>6</td>
</tr>
<tr>
<td>4a</td>
<td>7.575</td>
<td>7.575</td>
<td>57.38</td>
<td>15.1875</td>
<td>138650</td>
<td>2416</td>
<td>2.0</td>
<td>1.00</td>
<td>2416</td>
<td>3</td>
</tr>
<tr>
<td>4b</td>
<td>7.6625</td>
<td>7.6325</td>
<td>58.33</td>
<td>15.175</td>
<td>125130</td>
<td>2146</td>
<td>2.0</td>
<td>1.00</td>
<td>2146</td>
<td>3</td>
</tr>
<tr>
<td>4c</td>
<td>7.65</td>
<td>7.625</td>
<td>58.33</td>
<td>15.225</td>
<td>145030</td>
<td>2486</td>
<td>2.0</td>
<td>1.00</td>
<td>2486</td>
<td>4</td>
</tr>
<tr>
<td>5a</td>
<td>7.625</td>
<td>7.6</td>
<td>57.95</td>
<td>15.3625</td>
<td>132440</td>
<td>2285</td>
<td>7.0</td>
<td>1.00</td>
<td>2285</td>
<td>4</td>
</tr>
<tr>
<td>5b</td>
<td>7.6</td>
<td>7.675</td>
<td>58.33</td>
<td>15.35</td>
<td>343830</td>
<td>2466</td>
<td>2.0</td>
<td>1.00</td>
<td>2466</td>
<td>7</td>
</tr>
<tr>
<td>5c</td>
<td>7.6625</td>
<td>7.6375</td>
<td>58.52</td>
<td>14.775</td>
<td>161390</td>
<td>2754</td>
<td>1.9</td>
<td>0.99</td>
<td>2736</td>
<td>3</td>
</tr>
<tr>
<td>6a</td>
<td>7.5</td>
<td>7.5625</td>
<td>56.72</td>
<td>14.5375</td>
<td>147940</td>
<td>2698</td>
<td>1.9</td>
<td>0.98</td>
<td>2566</td>
<td>3</td>
</tr>
<tr>
<td>6b</td>
<td>7.5875</td>
<td>7.575</td>
<td>57.48</td>
<td>15.4225</td>
<td>155130</td>
<td>2642</td>
<td>2.0</td>
<td>1.00</td>
<td>2642</td>
<td>2</td>
</tr>
<tr>
<td>6c</td>
<td>7.65</td>
<td>7.625</td>
<td>58.33</td>
<td>15.025</td>
<td>147380</td>
<td>2527</td>
<td>2.0</td>
<td>1.00</td>
<td>2527</td>
<td>3</td>
</tr>
<tr>
<td>7a</td>
<td>7.5875</td>
<td>7.575</td>
<td>57.29</td>
<td>14.7875</td>
<td>129540</td>
<td>2261</td>
<td>7.0</td>
<td>1.00</td>
<td>2261</td>
<td>2</td>
</tr>
<tr>
<td>7b</td>
<td>7.55</td>
<td>7.5875</td>
<td>57.29</td>
<td>14.8</td>
<td>112510</td>
<td>1964</td>
<td>7.0</td>
<td>1.00</td>
<td>1964</td>
<td>6</td>
</tr>
<tr>
<td>7c</td>
<td>7.55</td>
<td>7.6</td>
<td>57.38</td>
<td>13.6</td>
<td>153730</td>
<td>2742</td>
<td>1.8</td>
<td>0.95</td>
<td>2619</td>
<td>6</td>
</tr>
<tr>
<td>8a</td>
<td>7.5875</td>
<td>7.6</td>
<td>57.67</td>
<td>14.7</td>
<td>153220</td>
<td>2637</td>
<td>1.9</td>
<td>0.99</td>
<td>2620</td>
<td>5</td>
</tr>
<tr>
<td>8b</td>
<td>7.55</td>
<td>7.6825</td>
<td>57.47</td>
<td>14.175</td>
<td>136640</td>
<td>2377</td>
<td>1.9</td>
<td>0.97</td>
<td>2310</td>
<td>4</td>
</tr>
<tr>
<td>8c</td>
<td>7.575</td>
<td>7.675</td>
<td>58.54</td>
<td>14.675</td>
<td>128560</td>
<td>2211</td>
<td>1.9</td>
<td>0.98</td>
<td>2171</td>
<td>7</td>
</tr>
<tr>
<td>9a</td>
<td>7.675</td>
<td>7.625</td>
<td>58.52</td>
<td>14.675</td>
<td>138650</td>
<td>2369</td>
<td>1.9</td>
<td>0.98</td>
<td>2332</td>
<td>4</td>
</tr>
<tr>
<td>9b</td>
<td>7.65</td>
<td>7.6</td>
<td>58.14</td>
<td>14.6</td>
<td>138030</td>
<td>2546</td>
<td>1.9</td>
<td>0.98</td>
<td>2504</td>
<td>3</td>
</tr>
<tr>
<td>9c</td>
<td>7.65</td>
<td>7.575</td>
<td>57.95</td>
<td>15.2</td>
<td>133340</td>
<td>2301</td>
<td>2.0</td>
<td>1.00</td>
<td>2301</td>
<td>6</td>
</tr>
<tr>
<td>10a</td>
<td>7.5875</td>
<td>7.6375</td>
<td>57.95</td>
<td>14.475</td>
<td>133230</td>
<td>2299</td>
<td>1.9</td>
<td>0.98</td>
<td>2250</td>
<td>5</td>
</tr>
<tr>
<td>10b</td>
<td>7.6125</td>
<td>7.6375</td>
<td>58.14</td>
<td>14.775</td>
<td>154580</td>
<td>2659</td>
<td>1.9</td>
<td>0.99</td>
<td>2621</td>
<td>6</td>
</tr>
<tr>
<td>10c</td>
<td>7.6</td>
<td>7.5875</td>
<td>57.67</td>
<td>14.725</td>
<td>150630</td>
<td>2612</td>
<td>1.9</td>
<td>0.99</td>
<td>2578</td>
<td>4</td>
</tr>
<tr>
<td>Specimen</td>
<td>Average Length (inches)</td>
<td>Average Width (inches)</td>
<td>Prism Area (sq inches)</td>
<td>Average Height (inches)</td>
<td>Load (lbs)</td>
<td>Strength (PSI)</td>
<td>hp/ft</td>
<td>Correction Factor</td>
<td>Corrected Strength (PSI)</td>
<td>Fracture Type</td>
</tr>
<tr>
<td>----------</td>
<td>------------------------</td>
<td>------------------------</td>
<td>------------------------</td>
<td>-------------------------</td>
<td>------------</td>
<td>----------------</td>
<td>-------</td>
<td>-----------------</td>
<td>--------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>1a</td>
<td>7.6</td>
<td>7.65</td>
<td>58.14</td>
<td>15.43</td>
<td>137340</td>
<td>2362</td>
<td>2.0</td>
<td>1.00</td>
<td>2362</td>
<td>3</td>
</tr>
<tr>
<td>1b</td>
<td>7.65</td>
<td>7.675</td>
<td>58.21</td>
<td>14.95</td>
<td>159190</td>
<td>2731</td>
<td>1.9</td>
<td>0.99</td>
<td>2680</td>
<td>4</td>
</tr>
<tr>
<td>1c</td>
<td>7.625</td>
<td>7.625</td>
<td>58.33</td>
<td>15.4625</td>
<td>147410</td>
<td>2527</td>
<td>2.0</td>
<td>1.40</td>
<td>2527</td>
<td>4</td>
</tr>
<tr>
<td>2a</td>
<td>7.6875</td>
<td>7.691</td>
<td>58.91</td>
<td>15.5</td>
<td>161190</td>
<td>2735</td>
<td>2.0</td>
<td>1.60</td>
<td>2735</td>
<td>5</td>
</tr>
<tr>
<td>2b</td>
<td>7.775</td>
<td>7.65</td>
<td>59.19</td>
<td>15.5625</td>
<td>149130</td>
<td>2567</td>
<td>2.0</td>
<td>1.60</td>
<td>2567</td>
<td>3</td>
</tr>
<tr>
<td>3c</td>
<td>7.55</td>
<td>7.675</td>
<td>57.95</td>
<td>15.6125</td>
<td>167730</td>
<td>2808</td>
<td>2.0</td>
<td>1.60</td>
<td>2808</td>
<td>5</td>
</tr>
<tr>
<td>3a</td>
<td>7.625</td>
<td>7.625</td>
<td>58.34</td>
<td>15.4875</td>
<td>187180</td>
<td>3239</td>
<td>2.0</td>
<td>1.60</td>
<td>3219</td>
<td>3</td>
</tr>
<tr>
<td>3b</td>
<td>7.6375</td>
<td>7.2</td>
<td>58.81</td>
<td>15.0625</td>
<td>133410</td>
<td>2138</td>
<td>2.0</td>
<td>1.60</td>
<td>2258</td>
<td>3</td>
</tr>
<tr>
<td>3c</td>
<td>7.7125</td>
<td>7.6375</td>
<td>58.99</td>
<td>14.475</td>
<td>147610</td>
<td>2506</td>
<td>1.9</td>
<td>0.98</td>
<td>2532</td>
<td>2</td>
</tr>
<tr>
<td>4a</td>
<td>7.6</td>
<td>7.55</td>
<td>57.38</td>
<td>14.925</td>
<td>136480</td>
<td>2477</td>
<td>2.0</td>
<td>1.60</td>
<td>2371</td>
<td>1</td>
</tr>
<tr>
<td>4b</td>
<td>7.6125</td>
<td>7.6375</td>
<td>58.34</td>
<td>13.33</td>
<td>139010</td>
<td>2351</td>
<td>2.0</td>
<td>1.60</td>
<td>2391</td>
<td>6</td>
</tr>
<tr>
<td>4c</td>
<td>7.6625</td>
<td>7.6625</td>
<td>58.62</td>
<td>15.4</td>
<td>160820</td>
<td>2846</td>
<td>2.0</td>
<td>1.60</td>
<td>2846</td>
<td>7</td>
</tr>
<tr>
<td>5a</td>
<td>7.623</td>
<td>7.613</td>
<td>58.03</td>
<td>13.33</td>
<td>179060</td>
<td>2942</td>
<td>2.0</td>
<td>1.60</td>
<td>2942</td>
<td>5</td>
</tr>
<tr>
<td>5b</td>
<td>7.6375</td>
<td>7.525</td>
<td>57.85</td>
<td>13.75</td>
<td>172310</td>
<td>3074</td>
<td>2.0</td>
<td>0.99</td>
<td>3038</td>
<td>5</td>
</tr>
<tr>
<td>5c</td>
<td>7.6</td>
<td>7.6625</td>
<td>58.34</td>
<td>15.125</td>
<td>167290</td>
<td>2873</td>
<td>2.0</td>
<td>1.60</td>
<td>2871</td>
<td>3</td>
</tr>
<tr>
<td>6a</td>
<td>7.65</td>
<td>7.6875</td>
<td>58.81</td>
<td>15.3375</td>
<td>188090</td>
<td>3233</td>
<td>2.0</td>
<td>1.60</td>
<td>3213</td>
<td>5</td>
</tr>
<tr>
<td>6b</td>
<td>7.6125</td>
<td>7.5875</td>
<td>58.34</td>
<td>15.3</td>
<td>185940</td>
<td>3186</td>
<td>2.0</td>
<td>1.60</td>
<td>3186</td>
<td>1</td>
</tr>
<tr>
<td>7a</td>
<td>7.6</td>
<td>7.65</td>
<td>58.34</td>
<td>13.85</td>
<td>163980</td>
<td>2839</td>
<td>1.9</td>
<td>0.99</td>
<td>2273</td>
<td>3</td>
</tr>
<tr>
<td>7b</td>
<td>7.675</td>
<td>7.6875</td>
<td>59.09</td>
<td>14.625</td>
<td>169750</td>
<td>2877</td>
<td>1.9</td>
<td>0.98</td>
<td>2819</td>
<td>3</td>
</tr>
<tr>
<td>7c</td>
<td>7.55</td>
<td>7.525</td>
<td>56.81</td>
<td>15.675</td>
<td>128490</td>
<td>2121</td>
<td>2.1</td>
<td>1.61</td>
<td>2143</td>
<td>1</td>
</tr>
<tr>
<td>8a</td>
<td>7.525</td>
<td>7.55</td>
<td>56.81</td>
<td>14.53</td>
<td>160670</td>
<td>2939</td>
<td>1.9</td>
<td>0.98</td>
<td>2894</td>
<td>3</td>
</tr>
<tr>
<td>8b</td>
<td>7.6875</td>
<td>7.65</td>
<td>58.01</td>
<td>14.8</td>
<td>180550</td>
<td>2334</td>
<td>1.9</td>
<td>0.99</td>
<td>2333</td>
<td>2</td>
</tr>
<tr>
<td>8c</td>
<td>7.6625</td>
<td>7.613</td>
<td>58.35</td>
<td>15.1</td>
<td>139330</td>
<td>2385</td>
<td>2.0</td>
<td>1.60</td>
<td>2385</td>
<td>7</td>
</tr>
<tr>
<td>9a</td>
<td>7.65</td>
<td>7.65</td>
<td>58.52</td>
<td>15.2625</td>
<td>116670</td>
<td>1994</td>
<td>2.0</td>
<td>1.60</td>
<td>1994</td>
<td>7</td>
</tr>
<tr>
<td>9b</td>
<td>7.625</td>
<td>7.6375</td>
<td>58.05</td>
<td>15.4</td>
<td>128400</td>
<td>2232</td>
<td>2.0</td>
<td>1.60</td>
<td>2213</td>
<td>3</td>
</tr>
<tr>
<td>9c</td>
<td>7.5875</td>
<td>7.6625</td>
<td>58.14</td>
<td>15.125</td>
<td>106490</td>
<td>1832</td>
<td>2.0</td>
<td>1.60</td>
<td>1832</td>
<td>7</td>
</tr>
<tr>
<td>10a</td>
<td>7.625</td>
<td>7.6375</td>
<td>58.24</td>
<td>15.3</td>
<td>137570</td>
<td>2362</td>
<td>2.0</td>
<td>1.60</td>
<td>2367</td>
<td>3</td>
</tr>
<tr>
<td>10b</td>
<td>7.7</td>
<td>7.625</td>
<td>58.21</td>
<td>15.6</td>
<td>151780</td>
<td>2585</td>
<td>2.0</td>
<td>1.60</td>
<td>2585</td>
<td>7</td>
</tr>
<tr>
<td>10c</td>
<td>7.575</td>
<td>7.65</td>
<td>57.95</td>
<td>15.325</td>
<td>128330</td>
<td>2235</td>
<td>2.0</td>
<td>1.60</td>
<td>2215</td>
<td>4</td>
</tr>
</tbody>
</table>
REFERENCES


National Concrete Masonry Association, Research and Development Laboratory, Recalibration of Unit Strength Method for Verifying Compliance of the Specified Compressive Strength of Concrete Masonry. Project # 09-103, July 2, 2012, Publication # MR-37.


CURRICULUM VITAE

JAMES BRISTOW, P.E.
Principal / Project Manager
4480 W Hacienda Avenue Las Vegas, NV 89118
OFFICE (702) 873-3478 · FAX (702) 873-2199 · EMAIL James.Bristow@novageotech.com

PROFILE

James Bristow is an expert in construction materials testing and brings 14 years of industry-specific experience, knowledge and expertise to NOVA’s Management Team. As a UNLV graduate whom double-majored in both Civil Engineering and Political Science, currently working toward his master’s degree in Civil Engineering, James has quickly become the source of knowledge and reference within the engineering community when it comes to materials testing and special inspections. Through his experience in the past decade with acquisition, merger and divesture teams, James has become the primary owner of NOVA and is responsible for the day-to-day management of the business unit.

As an ICC-certified special inspector and member of the Technical Advisory Committee for the International Accreditation Service (IAS), Mr. Bristow began developing his strengths in resolving material interface discrepancies, field-construction errors, and implementing nondestructive, and destructive investigation methods in order to assist contractors, owners, and public entities with resolving major milestone blocks that can occur during construction. Further, Mr. Bristow’s involvement with the local building departments and code councils has allowed him to take an active role in the code development process; he has participated on committees for the Clark County Technical Guidelines, IAS TAC AC291, ICC Evaluation Service for retro-installed anchors, and ACEC’s Subcommittee for Jurisdiction Involvement.

Additionally, Mr. Bristow spent five years managing NOVA’s Quality Control program as the Quality Control Manager. James has provided engineering review and technical oversight on all types of projects including, federal, commercial, residential, academic and industrial. His expertise in the field of engineering has allowed him to assist with problem solving solutions on projects where the client has been able to save time and money

PROFESSIONAL CERTIFICATIONS
State of Nevada, Registered Professional Engineer, No. 22347
ICC Prestressed Concrete Special Inspector
ICC Reinforced Concrete Special Inspector
ICC Structural Masonry Special Inspector
ICC Spray-Applied Fireproofing Special Inspector
ICC Commercial Building Inspector
ICC Structural Steel and Bolting Special Inspector
ACI Field Level 1
OSHA 10

EDUCATION
B.S. Civil Engineering, UNLV (2009)
B.A. Political Science, UNLV (2007)

WORK EXPERIENCE
Downtown Summerlin, Project Manager, Las Vegas, NV

Downtown Summerlin, one of the premier regional mixed-use development sites in the U.S., will be part of a planned urban center which will serve the entire Las Vegas Valley with over 125 shops and restaurants in an open-air shopping environment. This development begins the creation of Downtown Summerlin. When complete, it will include retail, entertainment, office, and multi-family residences, designed to create a vibrant, walkable downtown in the heart of the affluent 22,500-acre master planned community. Mr. Bristow acted as the Quality Assurance Project Engineer/ Senior Inspector and was responsible for coordinating/scheduling all required inspecting for approximately 30 Buildings, attending weekly progress meetings, logging/resolving noncompliance reports, preparing daily reports, monthly summary reports and providing Final Quality Assurance Reports.

City of Pendleton Bachelor Enlisted Quarter’s Package 7 Areas 52 & 62, Engineering Manager of Special Inspections, Camp Pendleton, CA

BEQ Package 7 consisted of four major BEQ structures on two sites and houses over 1,500 marines. Package 7 features an exterior pavilion, two exterior amphitheatres, four community buildings, a 1,600 sq. ft. physical training area, four picnic areas, three bike shelters with 165 bike spaces, a repelling tower, an off-site parking development, and an expansion to the sewer treatment plant. This project was designed with energy and water conservation in mind and a goal of achieving LEED Silver status upon completion. The estimated cost for this major project was $109,578,253, and was completed October 2011.

NOVA was retained to perform testing and inspection for the major CMU structures associated with this project as well as the retaining walls, site utilities, sewer treatment plant and various recreation areas. NOVA also verified compliance with geotechnical report recommendations and project specifications during mass grading, removal documentation, identification and sampling of soils for laboratory testing, observation and testing during fill placement and compaction, precise grading, foundation excavation observation, wall backfill, utility trench backfill, aggregate base and asphalt placement and compaction.

James Bristow acted as the project manager responsible for the scheduling of meetings, inspections and staffing between the client, contractors, and military personnel. Additionally he was accountable for the management of the special inspectors, regulation of the testing requirements, scheduling and the Quality Control budget. Daily QC paperwork was prepared and submitted for Mr. Bristow’s review and acceptance.
OTHER RELEVANT EXPERIENCE

Flood Control Experience CCWRD
  Laughlin Corrosion Mgmt.
  Plan Phase II
  Queens ridge Box Culvert
  Coyote Springs Junction Box & Drop Inlet
  Hard Rock Hotel Central Plant

Building Experience
  Summerlin Hospital
  Federal Justice Tower (ICE)
  Henderson Park Shade Structures
  Clark County Detention Center
  McCarran Airport D-Gates fireproofing
  Date Street Historical Renovation

Transportation Experience
  Pyle Roadway Improvements
  Major Roadways, Summerlin Villages
  Major Roadways, Coyote Springs

Utility Experience
  Major Utilities, Coyote Springs
  Major Utilities, Summerlin Villages
  Floyd Lamb State Park