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

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

By

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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

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Thesis Approval

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This thesis prepared by

James M. Bristow

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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

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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
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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.

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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.

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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.

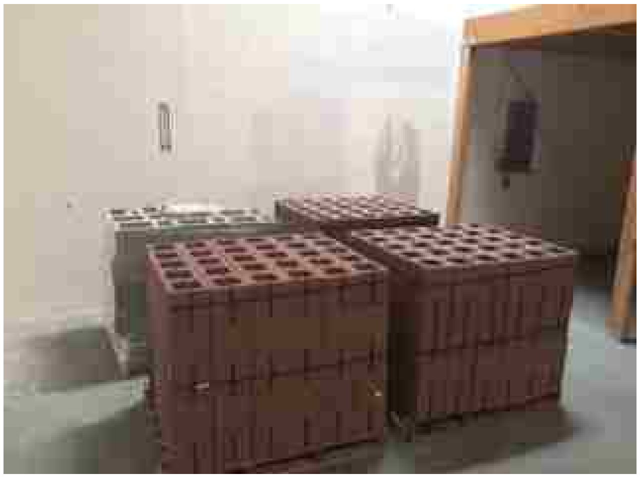


Figure 1- Blocks as delivered by manufacturer

Figure 2- Blocks laid in order for prism construction

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.

Figure 4- Consolidation of Grout

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.

Figure 5- Curing of Specimens

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.

Set 1- 2500 PSI at 4" Slump		Set 2- 4500 PSI at 4" Slump		Set 3- 4500 at 10" Slump	
Specimen #	Corrected Strength (PSI)	Specimen #	Corrected Strength (PSI)	Specimen #	Corrected Strength (PSI)
1a	2486	1a	3604	1a	2362
1b	2279	1b	3811	1b	2680
1c	2451	1c	3973	1c	2527
2a	2599	2a	3751	2a	2735
2b	2219	2b	4119	2b	2367
2c	2503	2c	3099	2c	2808
3a	2080	3a	3269	3a	3219
3b	2250	3b	3360	3b	2258
3c	2809	3c	3420	3c	2452
4a	2416	4a	3873	4a	2377
4b	2146	4b	3533	4b	2391
4c	2486	4c	3652	4c	2846
5a	2285	5a	3543	5a	2942
5b	2466	5b	3526	5b	3038
5c	2716	5c	4011	5c	2871
6a	2566	6a	3794	6a	3213
6b	2642	6b	3410	6b	3186
6c	2527	6c	3840	6c	2900
7a	2261	7a	3680	7a	2783
7b	1964	7b	3174	7b	2819
7c	2619	7c	3380	7c	2141
8a	2620	8a	3785	8a	2894
8b	2310	8b	3415	8b	2183
8c	2171	8c	3325	8c	2389
9a	2332	9a	3618	9a	1994
9b	2504	9b	3404	9b	2212
9c	2301	9c	2927	9c	1832
10a	2250	10a	3329	10a	2362
10b	2621	10b	3123	10b	2585
10c	2578	10c	3322	10c	2215

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.

Set 1- 2500 PSI at 4" Slump		Set 2- 4500 PSI at 4" Slump		Set 3- 4500 at 10" Slump	
Specimen #	Corrected Strength (PSI)	Specimen #	Corrected Strength (PSI)	Specimen #	Corrected Strength (PSI)
1a	4298	1a	9083	1a	5436
1b	4052	1b	7271	1b	5894
1c	4191	1c	8654	1c	5150
2a	4458	2a	8461	2a	6228
2b	4830	2b	8400	2b	6546
2c	4769	2c	7630	2c	5963
3a	4756	3a	8295	3a	5970
3b	4040	3b	7958	3b	5646
3c	4974	3c	8566	3c	5693
4a	4147	4a	7505	4a	6165
4b	4249	4b	8041	4b	6262
4c	4497	4c	7824	4c	5786
5a	4814	5a	8012	5a	5788
5b	4861	5b	8571	5b	6358
5c	4674	5c	7854	5c	5900
6a	4651	6a	7367	6a	5764
6b	4786	6b	8358	6b	5424
6c	4908	6c	7088	6c	5989
7a	4451	7a	6704	7a	6320
7b	4620	7b	7889	7b	6157
7c	4204	7c	8377	7c	6417
8a	4537	8a	7242	8a	6239
8b	4194	8b	8116	8b	6593
8c	4887	8c	7731	8c	6765
9a	4828	9a	7861	9a	6391
9b	4614	9b	7671	9b	5827
9c	4856	9c	7523	9c	6353
10a	4643	10a	8121	10a	5940
10b	4527	10b	6996	10b	6137
10c	4600	10c	7272	10c	6452

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

Figure 8- “Invalid” Slump Test Due to Very High Slump Flow

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:

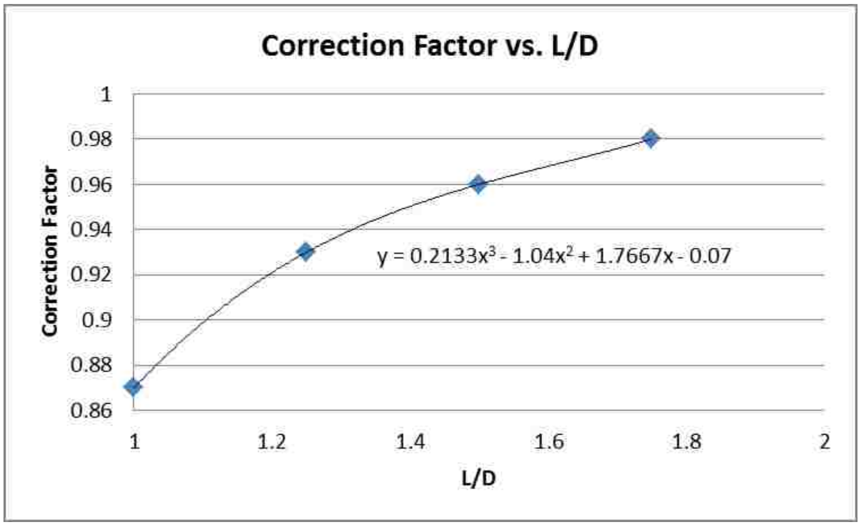


Figure 9 - Linear Interpolation Graph for Grout

Prism linear interpolation for correction factors:

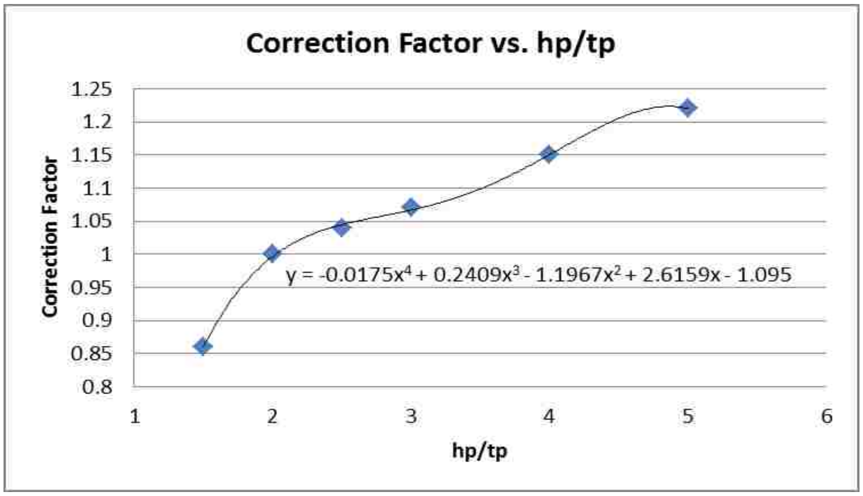


Figure 10 - Linear Interpolation Graph for Prisms

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		
	Actual Grout Strength (PSI)	Resulting Prism Strength (PSI)
Low	6704	2927
Mean	7881	3536
High	9083	4119
2500 PSI at 4" Slump		
	Actual Grout Strength (PSI)	Resulting Prism Strength (PSI)
Low	4040	1964
Mean	4564	2415
High	4974	2809
4500 PSI at 10" Slump		
	Actual Grout Strength (PSI)	Resulting Prism Strength (PSI)
Low	5150	1832
Mean	6052	2586
High	6765	3219

Table 3 - Summary of Low, Mean and High Compressive Strength Results for Grout

The following table outlines the input parameters of the statistical analysis:

Parameters of Statistical Analysis							
Grout Type	G or M	n	Mean	Median	sd	Min	Max
2500PSI4	FprimeG	30	4564	4617	278	4040	4974
4500PSI10	FprimeG	30	6052	6063	375	5150	6765
4500PSI4	FprimeG	30	7881	7875	558	6704	9083
2500PSI4	FprimeM	30	2415	2459	202	1964	2809
4500PSI10	FprimeM	30	2586	2556	369	1832	3219
4500PSI4	FprimeM	30	3536	3529	290	2927	4119

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.

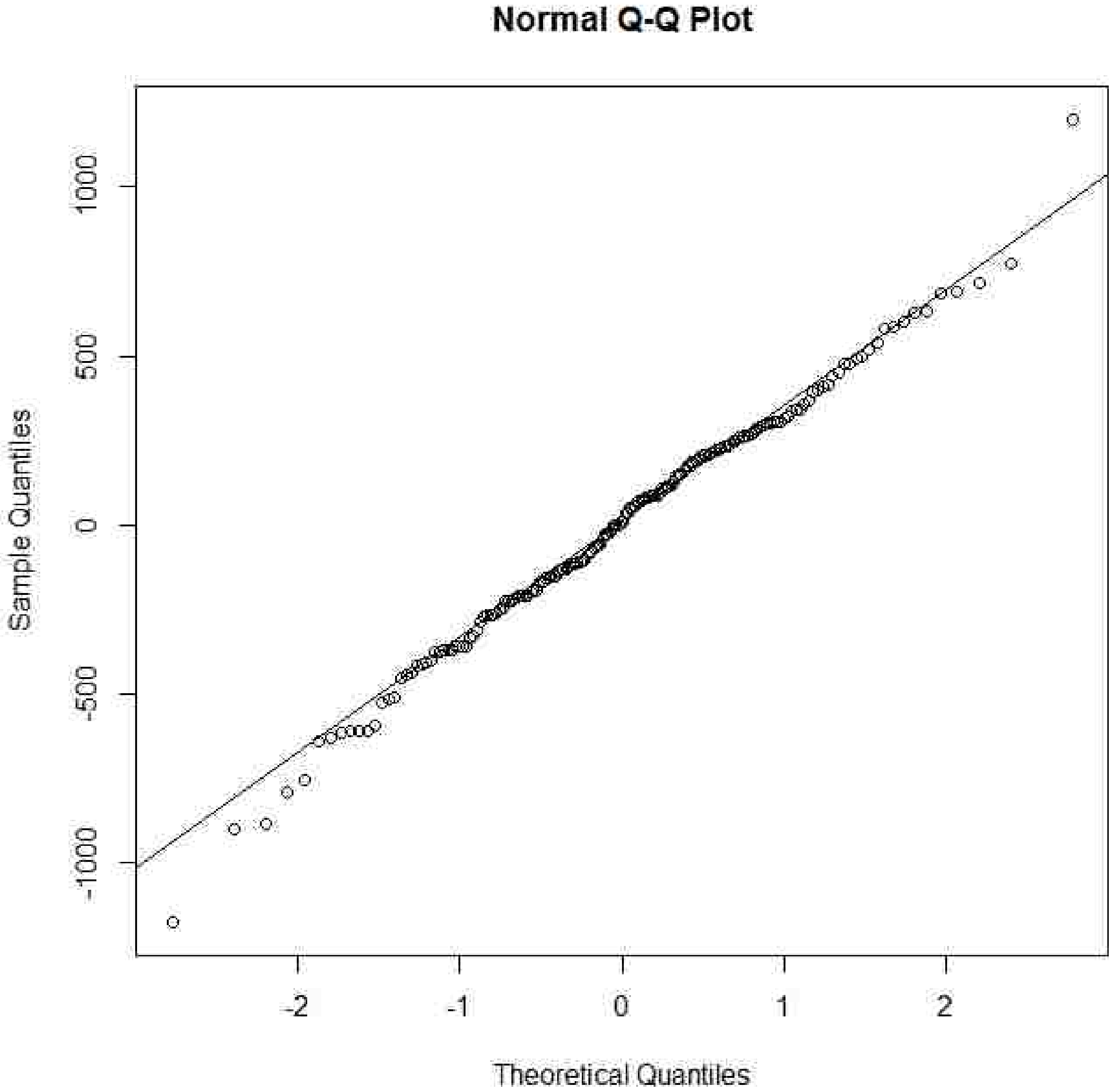


Figure 11- Normal Q-Q Plot

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, p-value = 0.304 > 0.05; 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.

Two-way Interaction Plot

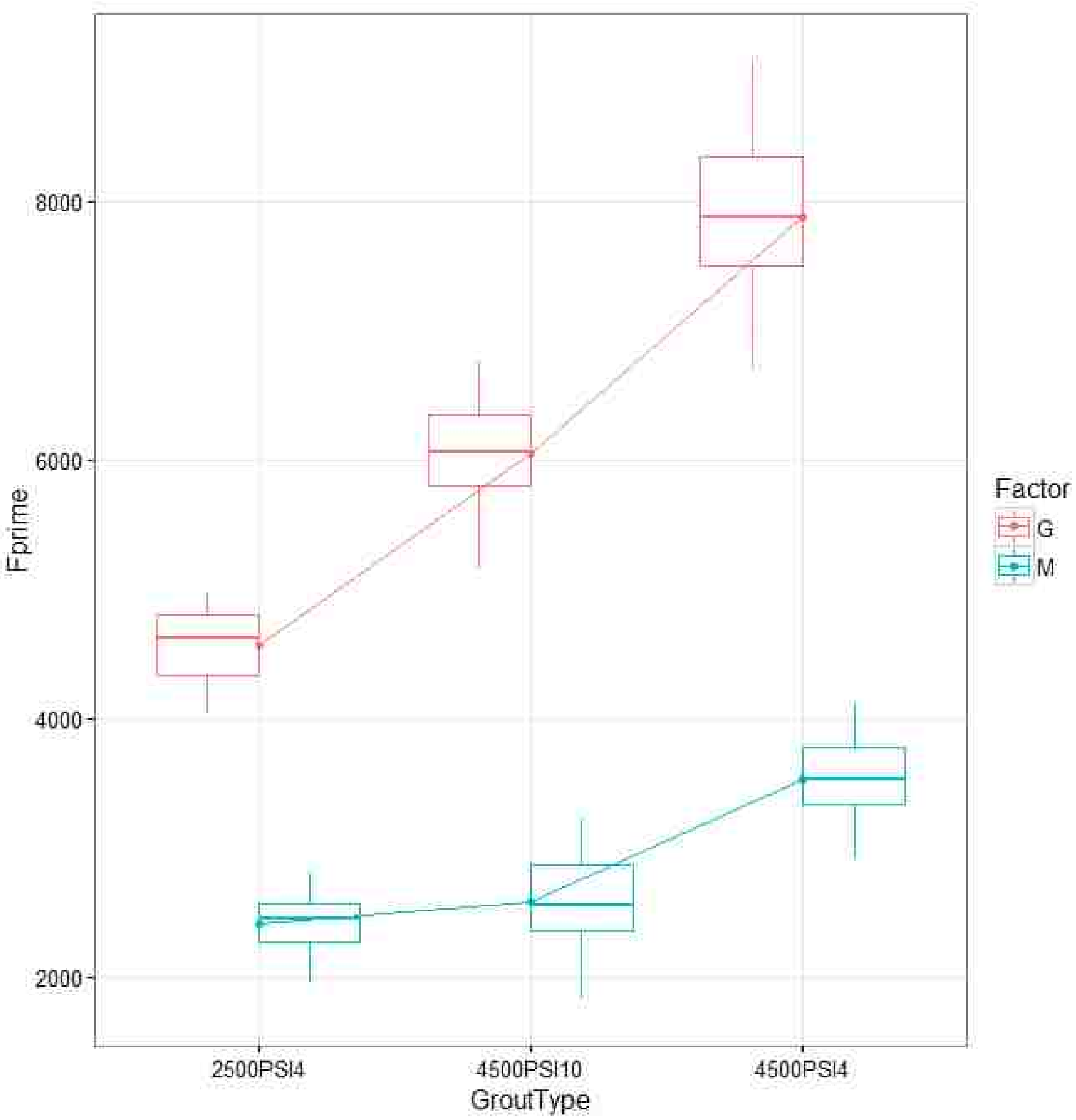


Figure 12 - Two- Way Interaction Plot

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.

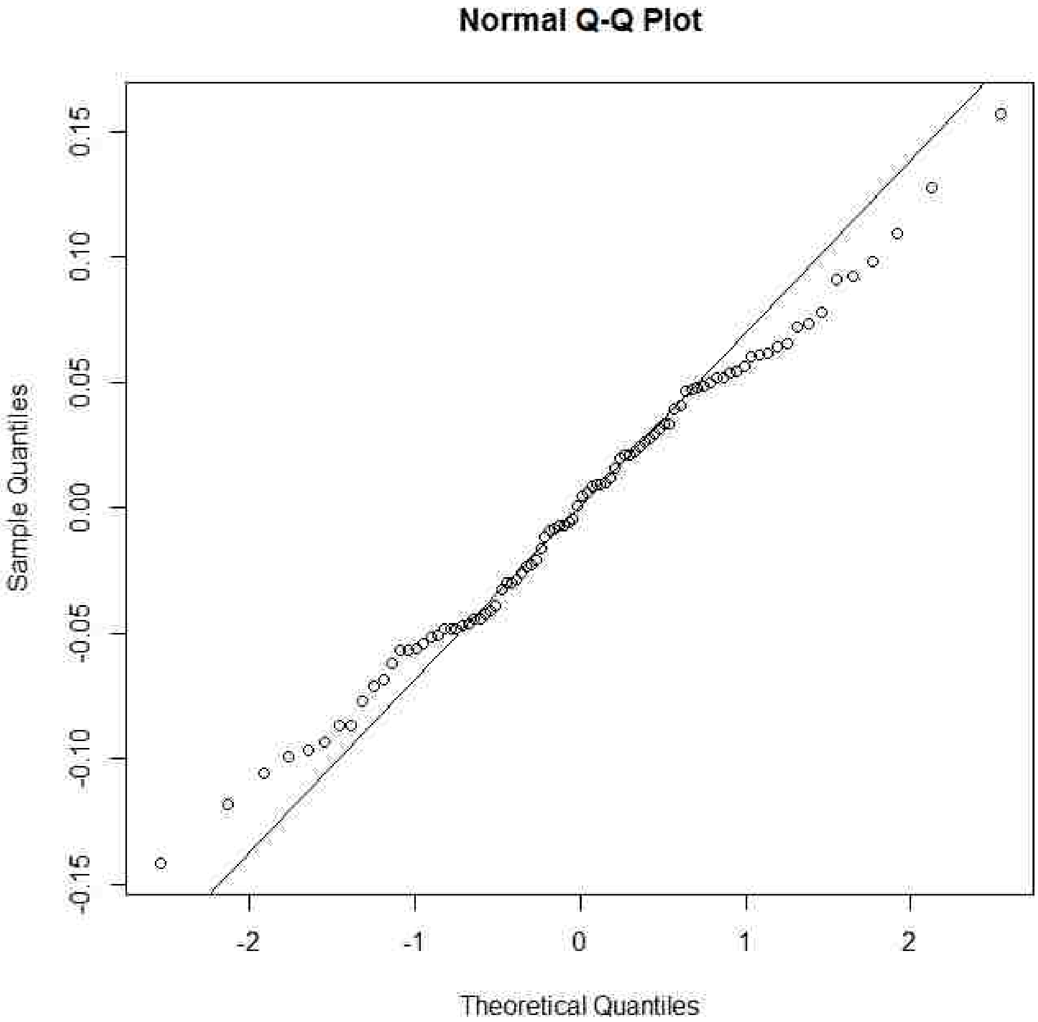


Figure 13- Normal Q-Q Plot for "Ratio Data Sets"

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-value = 0.9365> 0.05; 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

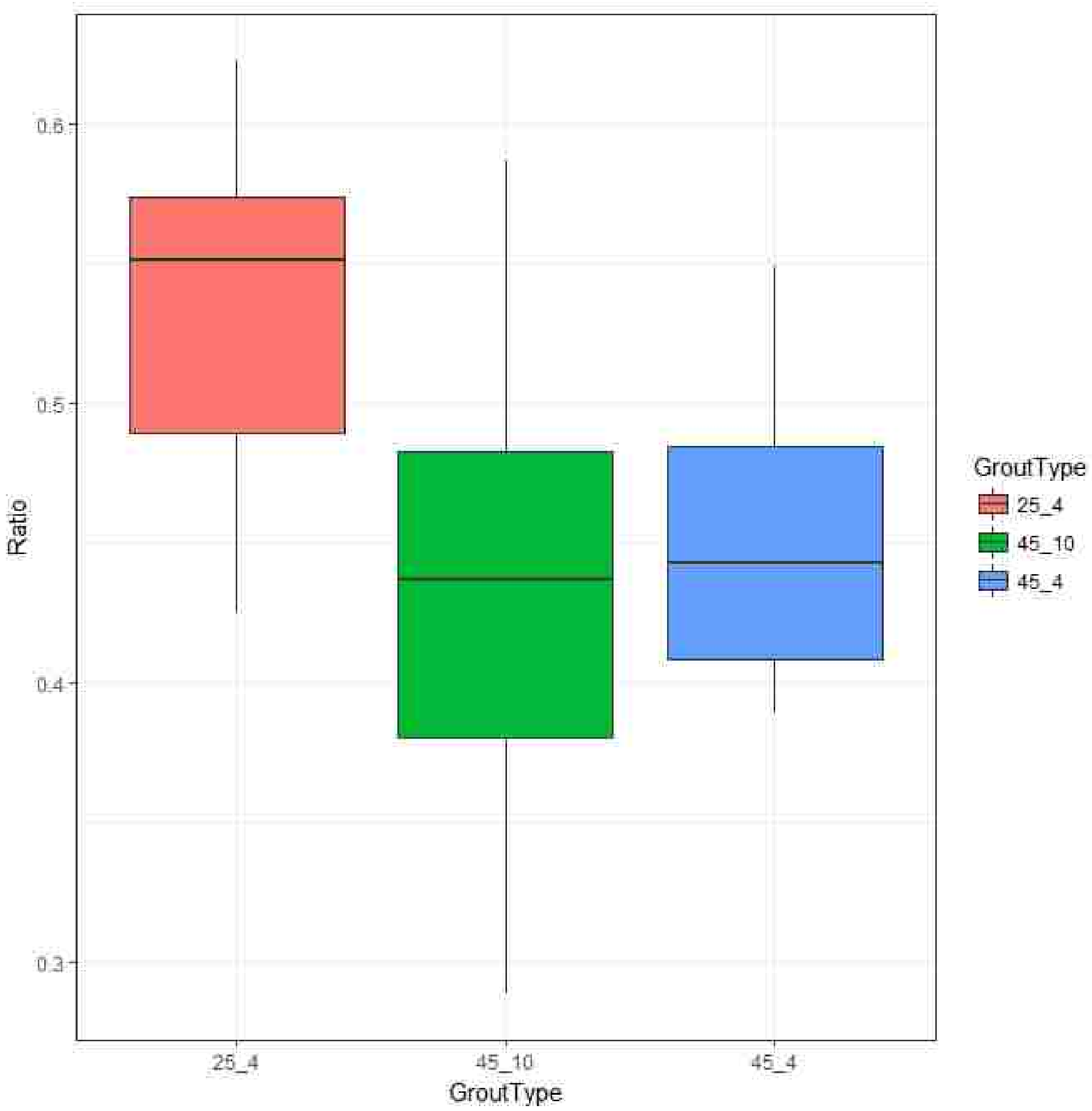


Figure 14- One-Way ANOVA Plot for Ratios

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.

	Estimate	SE	t-value	P-value
(Intercept)	0.53	0.01	49.05	0.00
GroutType45_10	-0.10	0.02	-6.58	0.00
GroutType45_4	-0.08	0.02	-5.24	0.00

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.

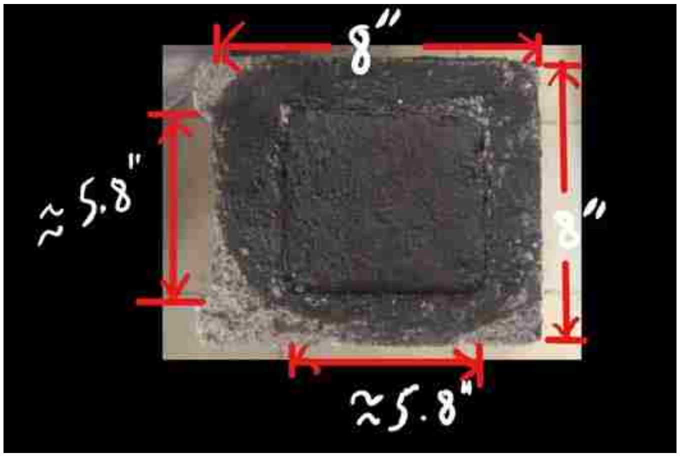


Figure 15- Cross Section Area of Prism Testable Surface

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 ANDS 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:

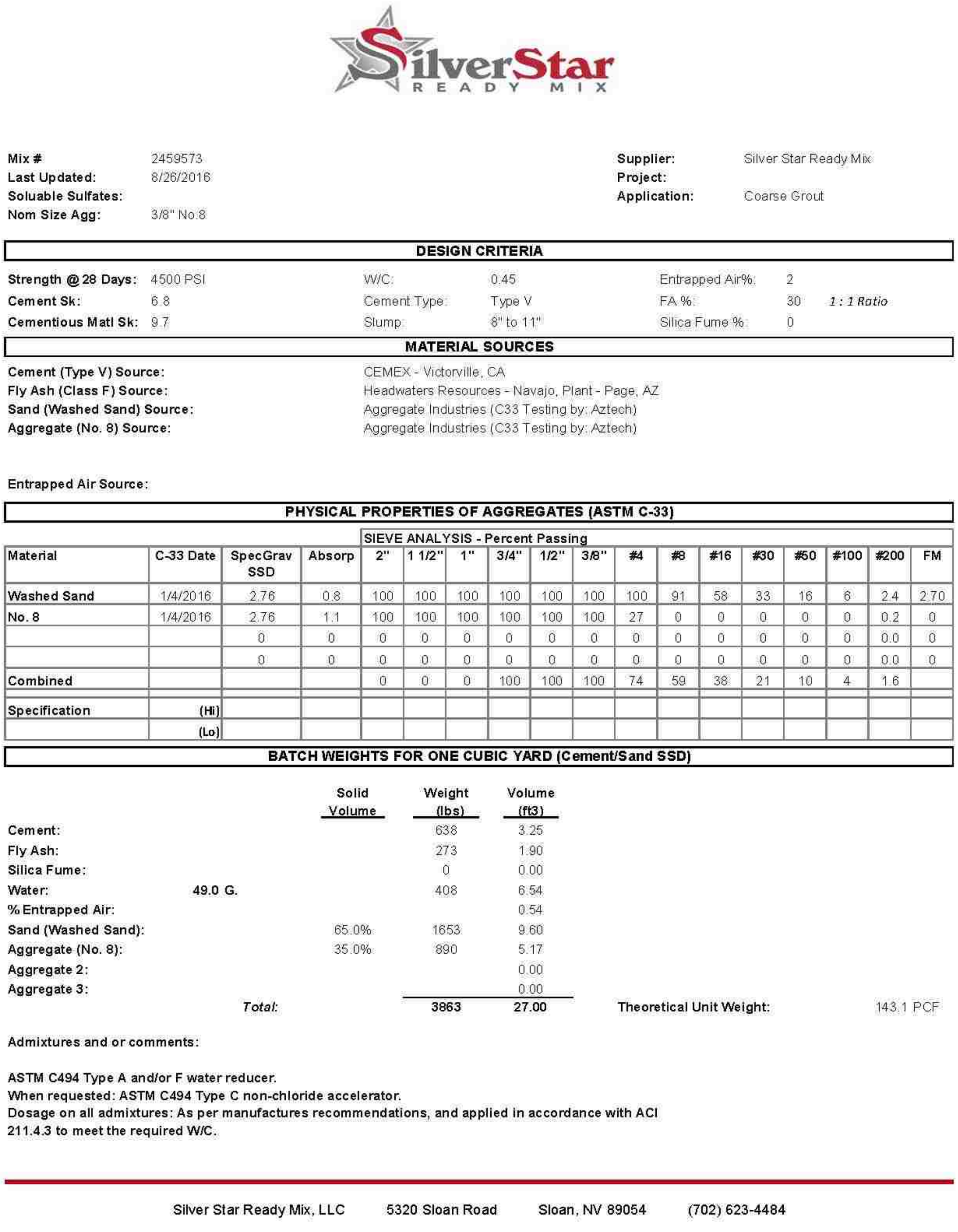
1. What is the variability of prism compressive strength when using all code-minimum values for f'm, f'g and mortar compressive strength, with the only variable being the water-to-cement ratio within the grout (similar to the variation herein between the 4500 PSI grout at 4" and 10" but using code-minimum 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

statistical 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



SilverStar READY MIX

Mix #	2459573	**Supplier:**	Silver Star Ready Mix
Last Updated:	8/26/2016	**Project:**	
Soluable Sulfates:		**Application:**	Coarse Grout
Nom Size Agg:	3/8" No.8		

DESIGN CRITERIA

Strength @ 28 Days:	4500 PSI	W/C:	0.45	Entrapped Air%:	2	
Cement Sk:	6.8	Cement Type:	Type V	FA %:	30	*1 : 1 Ratio*
Cementious Matl Sk:	9.7	Slump:	8" to 11"	Silica Fume %:	0	

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: Aztech)
Aggregate (No. 8) Source:	Aggregate Industries (C33 Testing by: Aztech)

Entrapped Air Source:

PHYSICAL PROPERTIES OF AGGREGATES (ASTM C-33)

				SIEVE ANALYSIS - Percent Passing													
Material	**C-33 Date**	**SpecGrav SSD**	**Absorp**	**2"**	**1 1/2"**	**1"**	**3/4"**	**1/2"**	**3/8"**	**#4**	**#8**	**#16**	**#30**	**#50**	**#100**	**#200**	**FM**
Washed Sand	1/4/2016	2.76	0.8	100	100	100	100	100	100	100	91	58	33	16	6	2.4	2.70
No. 8	1/4/2016	2.76	1.1	100	100	100	100	100	100	27	0	0	0	0	0	0.2	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
Combined				0	0	0	100	100	100	74	59	38	21	10	4	1.6	
Specification	**(Hi)**																
	(Lo)																

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

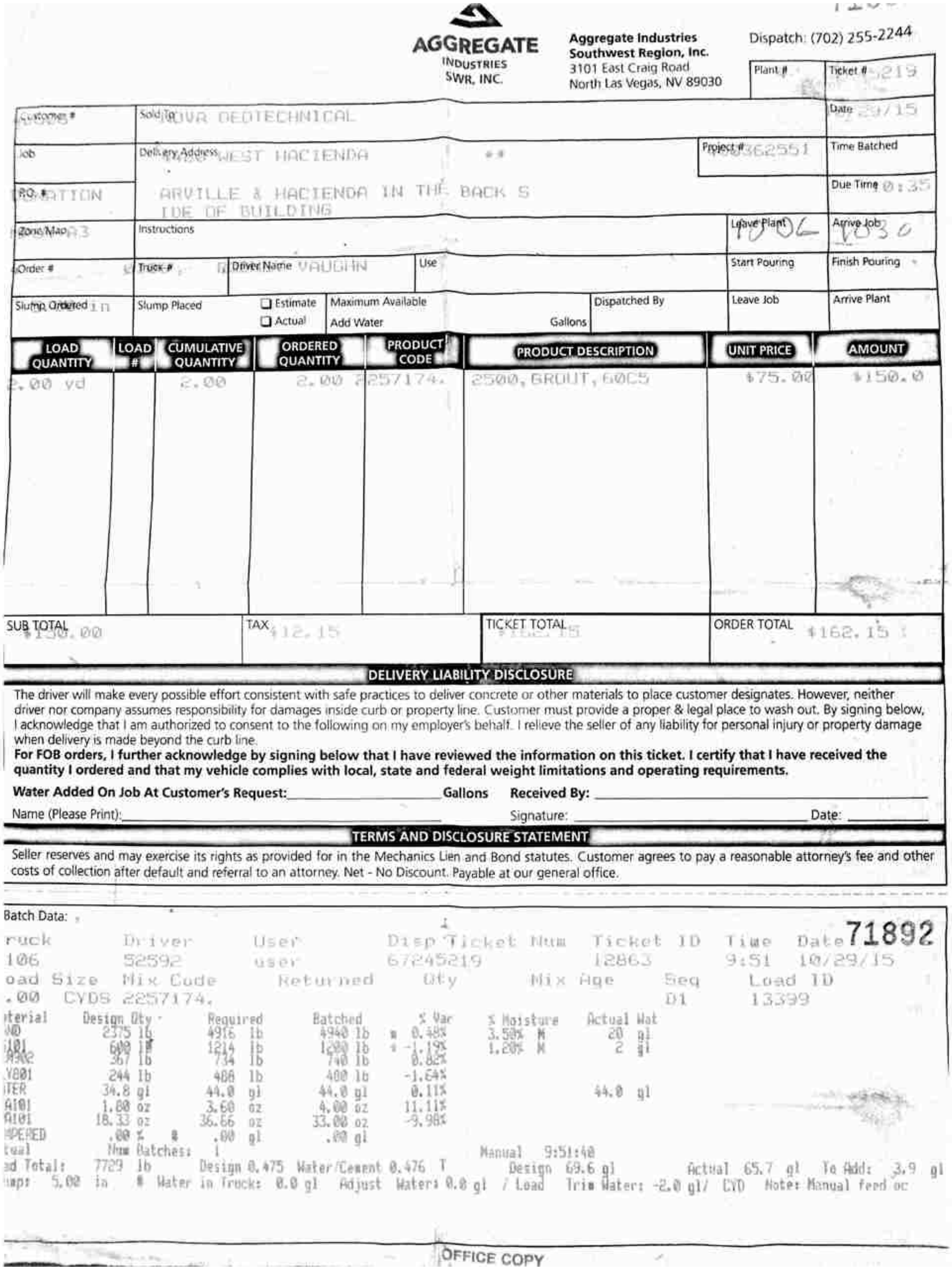
		Solid Volume	**Weight (lbs)**	**Volume (ft3)**
Cement:			638	3.25
Fly Ash:			273	1.90
Silica Fume:			0	0.00
Water:	**49.0 G.**		408	6.54
% Entrapped Air:				0.54
Sand (Washed Sand):		65.0%	1653	9.60
Aggregate (No. 8):		35.0%	890	5.17
Aggregate 2:				0.00
Aggregate 3:				0.00
	Total:		**3863**	**27.00**

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 manufactures recommendations, and applied in accordance with ACI 211.4.3 to meet the required W/C.

Silver Star Ready Mix, LLC 5320 Sloan Road Sloan, NV 89054 (702) 623-4484



AGGREGATE INDUSTRIES SWR, INC.

Aggregate Industries
Southwest Region, Inc.
3101 East Craig Road
North Las Vegas, NV 89030

Dispatch: (702) 255-2244

Plant #
Ticket # 219
Customer #
Sold To NOVA GEOTECHNICAL
Date 29/15
Job
Delivery Address WEST HACIENDA **
Project # 362551
Time Batched
P.O. # ATION
ARVILLE & HACIENDA IN THE BACK S
IDE OF BUILDING
Due Time 0:35
Zone/Map A3
Instructions
Leave Plant 1006
Arrive Job 1030
Order #
Truck #
Driver Name VAUGHN
Use
Start Pouring
Finish Pouring
Slump Ordered in
Slump Placed
☐ Estimate
☐ Actual
Maximum Available
Add Water
Gallons
Dispatched By
Leave Job
Arrive Plant

LOAD QUANTITY	LOAD #	CUMULATIVE QUANTITY	ORDERED QUANTITY	PRODUCT CODE	PRODUCT DESCRIPTION	UNIT PRICE	AMOUNT
2.00 yd		2.00	2.00	2257174.	2500, GROUT, 60C5	$75.00	$150.0

SUB TOTAL $150.00
TAX $12.15
TICKET TOTAL $162.15
ORDER TOTAL $162.15

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 driver nor company assumes responsibility for damages inside curb 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 I 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: ____________

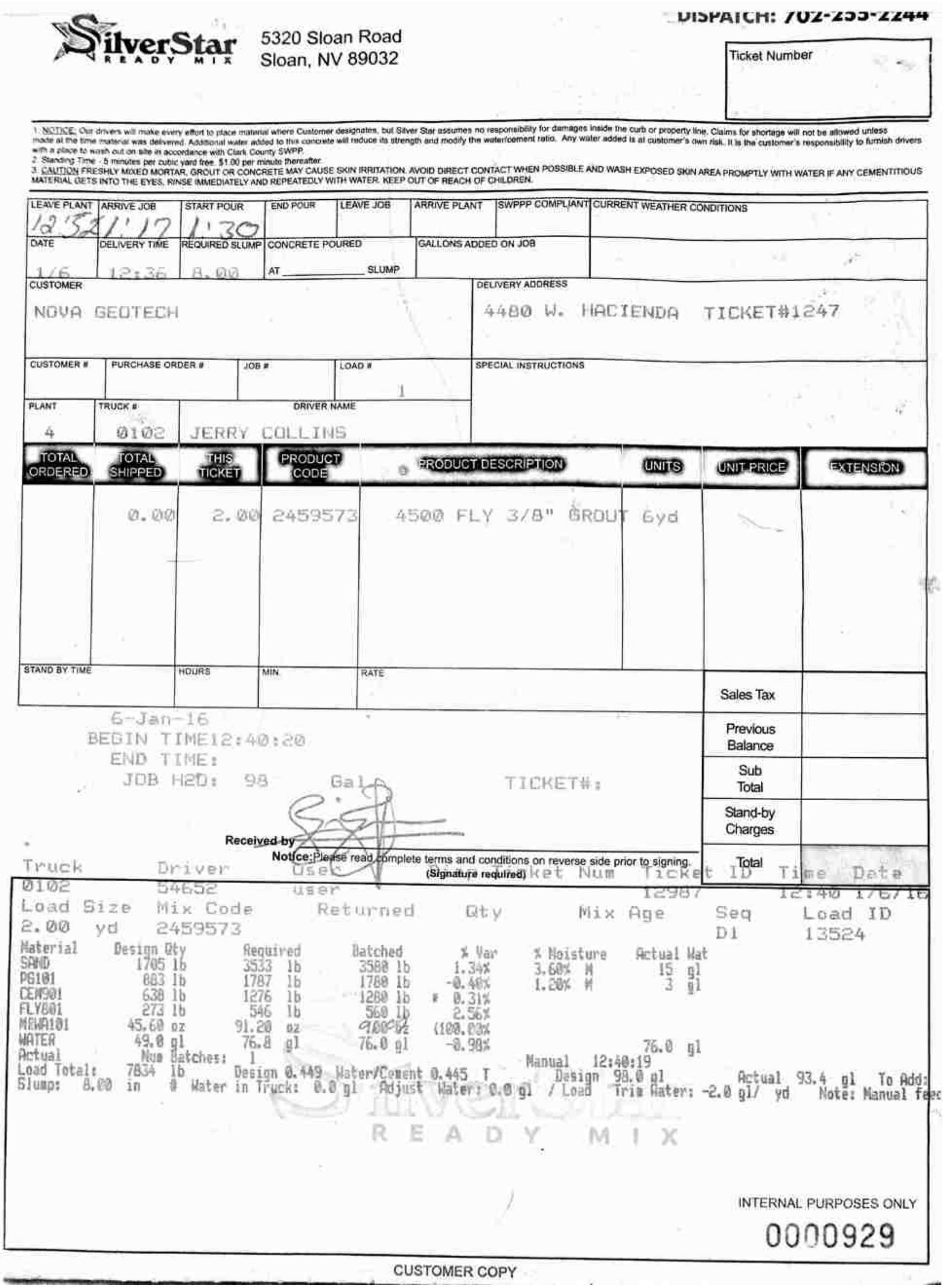
TERMS AND DISCLOSURE STATEMENT

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: 71892

```
ruck          Driver        User          Disp Ticket Num    Ticket ID    Time     Date
106           52592         user          67245219           12863        9:51     10/29/15
oad Size   Mix Code           Returned       Qty          Mix Age        Seq       Load ID
.00   CYDS 2257174.                                                      01        13399
terial     Design Qty       Required      Batched       % Var     % Moisture   Actual Wat
ND          2375 lb          4916 lb      4940 lb    *  0.48%     3.50% M        20 gl
101          600 lb          1214 lb      1200 lb    + -1.19%     1.20% M         2 gl
R902         367 lb           734 lb       740 lb       0.82%
Y801         244 lb           408 lb       400 lb      -1.64%
TER         34.8 gl          44.0 gl      44.0 gl       0.11%                  44.0 gl
A101        1.80 oz          3.60 oz      4.00 oz      11.11%
A101       18.33 oz         36.66 oz     33.00 oz      -9.98%
PERED        .00 %   *        .00 gl       .00 gl
tual        Num Batches:  1                                   Manual   9:51:40
d Total:   7729 lb      Design 0.475  Water/Cement 0.476  T     Design  69.6 gl        Actual  65.7 gl   To Add:   3.9 gl
mp:    5.00 in    * Water in Truck:  0.0 gl   Adjust  Water: 0.0 gl  / Load   Trim Water: -2.0 gl/  CYD   Note: Manual feed oc
```

OFFICE COPY



DISPATCH: 702-255-2244

SilverStar READY MIX

5320 Sloan Road
Sloan, NV 89032

Ticket Number

1. NOTICE: Our drivers will make every effort to place material where Customer designates, but Silver Star assumes no responsibility for damages inside the curb or property line. Claims for shortage will not be allowed unless made at the time material was delivered. Additional water added to this concrete will reduce its strength and modify the water/cement ratio. Any water added is at customer's own risk. It is the customer's responsibility to furnish drivers with a place to wash out on site in accordance with Clark County SWPP.
2. Standing Time - 5 minutes per cubic yard free. $1.00 per minute thereafter.
3. CAUTION FRESHLY MIXED MORTAR, GROUT OR CONCRETE MAY CAUSE SKIN IRRITATION. AVOID DIRECT CONTACT WHEN POSSIBLE AND WASH EXPOSED SKIN AREA PROMPTLY WITH WATER IF ANY CEMENTITIOUS MATERIAL GETS INTO THE EYES, RINSE IMMEDIATELY AND REPEATEDLY WITH WATER. KEEP OUT OF REACH OF CHILDREN.

LEAVE PLANT 12:52	ARRIVE JOB 1:17	START POUR 1:30	END POUR	LEAVE JOB	ARRIVE PLANT	SWPPP COMPLIANT	CURRENT WEATHER CONDITIONS
DATE 1/6	DELIVERY TIME 12:36	REQUIRED SLUMP 8.00	CONCRETE POURED AT ______ SLUMP		GALLONS ADDED ON JOB		

CUSTOMER NOVA GEOTECH	DELIVERY ADDRESS 4480 W. HACIENDA TICKET#1247

CUSTOMER #	PURCHASE ORDER #	JOB #	LOAD # 1	SPECIAL INSTRUCTIONS

PLANT 4	TRUCK # 0102	DRIVER NAME JERRY COLLINS

TOTAL ORDERED	TOTAL SHIPPED	THIS TICKET	PRODUCT CODE	PRODUCT DESCRIPTION	UNITS	UNIT PRICE	EXTENSION
	0.00	2.00	2459573	4500 FLY 3/8" GROUT	6yd		

STAND BY TIME	HOURS	MIN.	RATE

Sales Tax	
Previous Balance	
Sub Total	
Stand-by Charges	
Total	

6-Jan-16
BEGIN TIME12:40:20
END TIME:
JOB H2O: 98 Gal TICKET#:

Received by

Notice: Please read complete terms and conditions on reverse side prior to signing.
(Signature required)

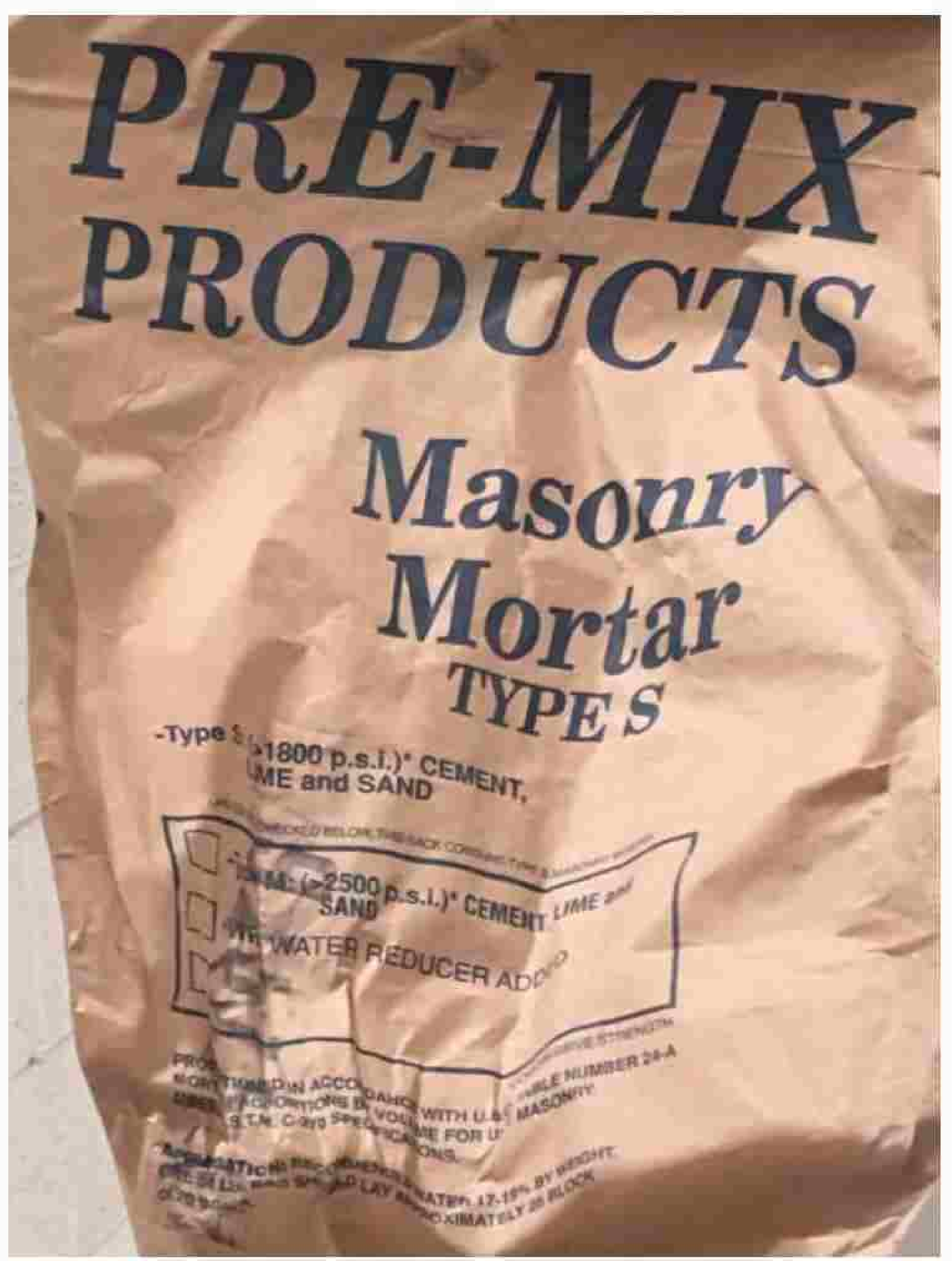
```
Truck    Driver   User    Ticket Num   Ticket ID   Time   Date
0102     54652    user    12987                    12:40  1/6/16
Load Size   Mix Code   Returned   Qty   Mix Age   Seq   Load ID
2.00  yd    2459573                               D1    13524
Material   Design Qty   Required    Batched    % Var     % Moisture   Actual Wat
SAND        1705 lb     3533  lb    3580 lb     1.34%    3.60%  M     15  gl
PG101        883 lb     1787  lb    1780 lb    -0.40%    1.20%  M      3  gl
CEM901       638 lb     1276  lb    1280 lb  *  0.31%
FLY801       273 lb      546  lb     560 lb     2.56%
MRWA101    45.60 oz    91.20  oz    90.0 oz  (100.03%
WATER       49.0 gl     76.8  gl    76.0 gl    -0.98%                 76.0  gl
Actual        Num Batches:  1                           Manual   12:40:19
Load Total:  7834  lb      Design 0.449  Water/Cement 0.445  T    Design  98.0 gl         Actual  93.4  gl   To Add:
Slump:   8.00  in    # Water in Truck:  0.0 gl   Adjust  Water: 0.0 gl  / Load   Trim Water: -2.0 gl/  yd    Note: Manual fee
```

READY MIX

INTERNAL PURPOSES ONLY

0000929

CUSTOMER COPY


PRE-MIX
PRODUCTS
Masonry
Mortar
TYPE S
-Type S (>1800 p.s.i.)* CEMENT, LIME and SAND
(>2500 p.s.i.)* CEMENT LIME and SAND
WATER REDUCER ADDED
TABLE NUMBER 24-A
IN ACCORDANCE WITH U.S. MASONRY
PROPORTIONS BY VOLUME FOR U
S.T.M. C-270 SPECIFICATIONS.
17-19% BY WEIGHT
APPROXIMATELY 28 BLOCK

Ingredients:

MORTAR INGREDIENTS MAY CONSIST OF SOME OF THE FOLLOWING

PORTLAND CEMENT: ASTM C150 normal grey or colored as required for project conditions
TYPE II - V
BLENDED CEMENT: ASTM C595, for general or high-strength uses
AGGREGATES (sand): ASTM C144, for standard masonry type, clean
HYDRATED LIME: ASTM C207, Type S
MORTAR COLORS: ASTM C979, (pure mineral colors)

DANGER

Superlite an Oldcastle® company

Date: **3/269/2015**
To:
Through: **Hirschi Masonry**
Project: **Nova**
Subject: **Material Certification – Concrete Masonry Units**

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	**Date Received:**	9/16/14
Project Name:	Quality Control	**Project Number:**	303753001
CMU Type:	8x8x16 Medium Weight Standard Hollow Loadbearing Block		
Laboratory Sample No.:	26111		

Compression Units

		Unit No. 1	Unit No. 2	Unit No. 3	Average	ASTM C90 Spec.
Width (in.)	Top	7.6	7.6	7.6		
	Bottom	7.6	7.6	7.6		
	Average	7.6	7.6	7.6	7.6	
Height (in.)	Face 1	7.6	7.6	7.6		
	Face 2	7.6	7.6	7.6		
	Average	7.6	7.6	7.6	7.6	
Length (in.)	Face 1	15.6	15.6	15.6		
	Face 2	15.6	15.6	15.6		
	Average	15.6	15.6	15.6	15.6	
Minimum Face Shell Thickness (in.)	Face 1	1.31	1.30	1.30		
	Face 2	1.30	1.30	1.29		
	Average	1.31	1.30	1.30	1.30	1.25 Minimum
Average Minimum Web Thickness (in.)	Web 1	1.26	1.27	1.28		
	Web 2 / 3	1.09/1.27	1.08/1.28	1.08/1.26		
	Average	1.21	1.21	1.21	1.21	1.00 Minimum
Equivalent Web Thickness (in./ft.)		2.78	2.79	2.78	2.78	2.25 Minimum
Equivalent Thickness (in.)		--	--	--	--	
Maximum Load (lbf)		170425	166620	176585	--	
Gross Area Tested (in.^{2})		118.6	118.6	118.6	118.6	
Gross Compressive Strength (psi)		1440	1400	1490	1440	
Net Volume Tested (ft.^{3})		0.27	0.27	0.27	0.27	
Net Area Tested (in.^{2})		60.45	60.45	60.45	60.45	
Net Compressive Strength (psi)		2820	2770	2930	2840	Min. 1700 Indiv. 1900 Avg. of 3

Absorption Units

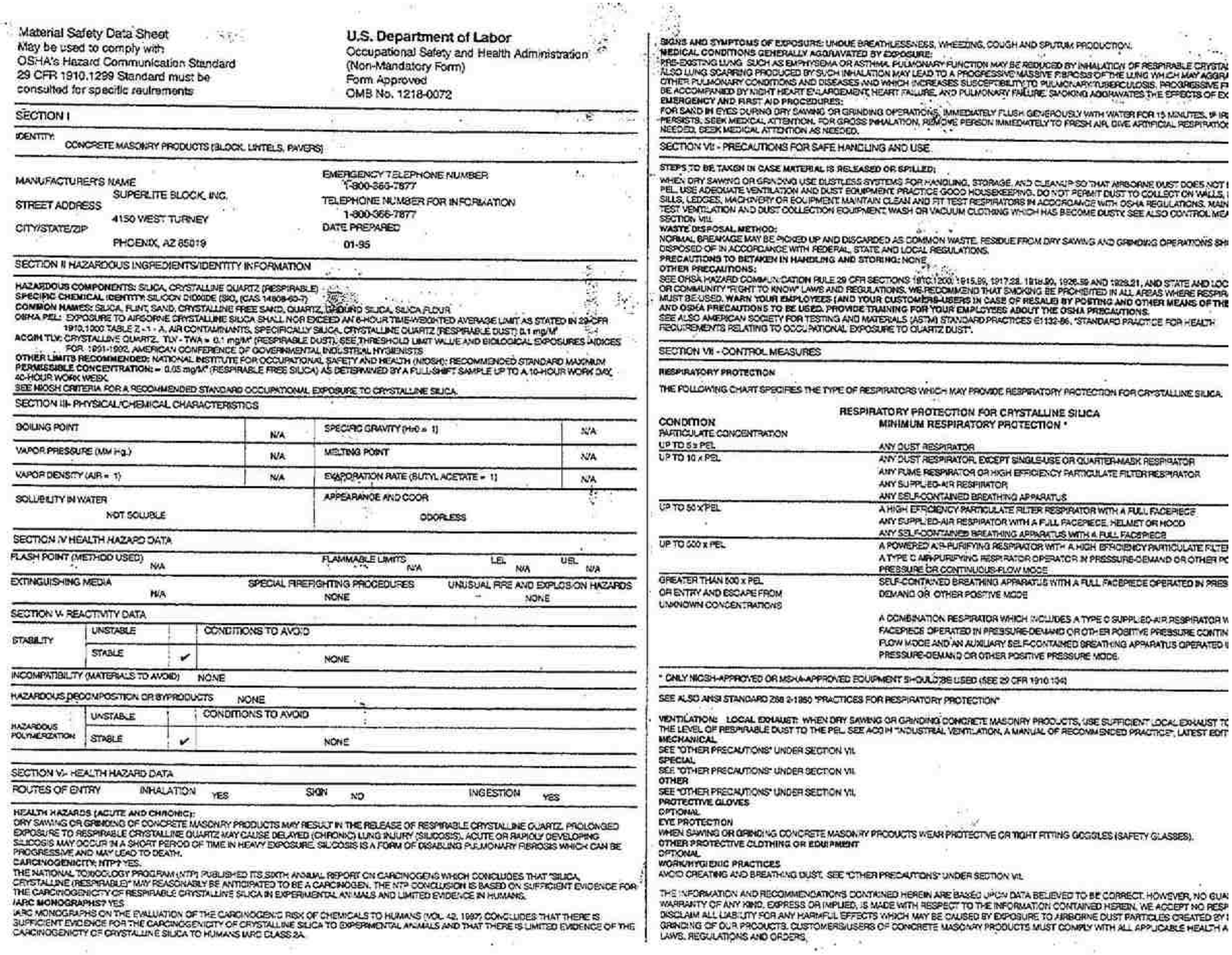
	Unit No. 4	Unit No 5	Unit No. 6	Average	ASTM C90 Spec.
Received Weight (lb.)	31.51	31.33	31.46	31.43	
Saturated Weight (lb.)	34.14	34.03	34.10	34.09	
Oven Dry Weight (lb.)	31.18	31.00	31.13	31.10	
Immersed Weight (lb.)	17.55	17.53	17.55	17.54	
Absorption (%)	9.5	9.8	9.5	9.6	
Absorption (pcf)	11.1	11.5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

Samples prepared and tested in accordance with ASTM C-140.

PROFESSIONAL ENGINEER-STATE OF NEVADA
ALISHA F. AUCH
Exp: 12/31/14
CIVIL
No. 20697

10/13/14

Ninyo & Moore



Material Safety Data Sheet
May be used to comply with
OSHA's Hazard Communication Standard
29 CFR 1910.1299 Standard must be
consulted for specific reuirements

U.S. Department of Labor
Occupational Safety and Health Administration
(Non-Mandatory Form)
Form Approved
OMB No. 1218-0072

SECTION I

IDENTITY: CONCRETE MASONRY PRODUCTS (BLOCK, LINTELS, PAVERS)

MANUFACTURER'S NAME SUPERLITE BLOCK, INC.
STREET ADDRESS 4150 WEST TURNEY
CITY/STATE/ZIP PHOENIX, AZ 85019

EMERGENCY TELEPHONE NUMBER 1-800-366-7877
TELEPHONE NUMBER FOR INFORMATION 1-800-366-7877
DATE PREPARED 01-95

SECTION II HAZARDOUS INGREDIENTS/IDENTITY INFORMATION

HAZARDOUS COMPONENTS: SILICA, CRYSTALLINE QUARTZ (RESPIRABLE)
SPECIFIC CHEMICAL IDENTITY: SILICON DIOXIDE (SiO_2) (CAS 14808-60-7)
COMMON NAMES: SILICA, FLINT, SAND, CRYSTALLINE FREE SAND, QUARTZ, GROUND SILICA, SILICA FLOUR
OSHA PEL: EXPOSURE TO AIRBORNE CRYSTALLINE SILICA SHALL NOR EXCEED AN 8-HOUR TIME-WEIGHTED AVERAGE LIMIT AS STATED IN 29 CFR 1910.1000 TABLE Z - 1 - A, AIR CONTAMINANTS, SPECIFICALLY SILICA, CRYSTALLINE QUARTZ (RESPIRABLE DUST) 0.1 mg/M³
ACGIH TLV: CRYSTALLINE QUARTZ. TLV - TWA = 0.1 mg/M³ (RESPIRABLE DUST). SEE THRESHOLD LIMIT VALUE AND BIOLOGICAL EXPOSURES INDICES FOR 1991-1992, AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS
OTHER LIMITS RECOMMENDED: NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH): RECOMMENDED STANDARD MAXIMUM **PERMISSIBLE CONCENTRATION:** = 0.05 mg/M³ (RESPIRABLE FREE SILICA) AS DETERMINED BY A FULL-SHIFT SAMPLE UP TO A 10-HOUR WORK DAY, 40-HOUR WORK WEEK.
SEE NIOSH CRITERIA FOR A RECOMMENDED STANDARD OCCUPATIONAL EXPOSURE TO CRYSTALLINE SILICA.

SECTION III- PHYSICAL/CHEMICAL CHARACTERISTICS

BOILING POINT	N/A	SPECIFIC GRAVITY (H_2O = 1)	N/A
VAPOR PRESSURE (MM Hg.)	N/A	MELTING POINT	N/A
VAPOR DENSITY (AIR = 1)	N/A	EVAPORATION RATE (BUTYL ACETATE = 1)	N/A
SOLUBILITY IN WATER NOT SOLUBLE		APPEARANCE AND ODOR ODORLESS	

SECTION IV HEALTH HAZARD DATA

FLASH POINT (METHOD USED) N/A
FLAMMABLE LIMITS N/A LEL N/A UEL N/A
EXTINGUISHING MEDIA N/A
SPECIAL FIREFIGHTING PROCEDURES NONE
UNUSUAL FIRE AND EXPLOSION HAZARDS NONE

SECTION V- REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID
	STABLE	✓	NONE
INCOMPATIBILITY (MATERIALS TO AVOID)	NONE		
HAZARDOUS DECOMPOSITION OR BYPRODUCTS	NONE		
HAZARDOUS POLYMERIZATION	UNSTABLE		CONDITIONS TO AVOID
	STABLE	✓	NONE

SECTION VI- HEALTH HAZARD DATA

ROUTES OF ENTRY INHALATION YES SKIN NO INGESTION YES

HEALTH HAZARDS (ACUTE AND CHRONIC):
DRY SAWING OR GRINDING OF CONCRETE MASONRY PRODUCTS MAY RESULT IN THE RELEASE OF RESPIRABLE CRYSTALLINE QUARTZ. PROLONGED EXPOSURE TO RESPIRABLE CRYSTALLINE QUARTZ MAY CAUSE DELAYED (CHRONIC) LUNG INJURY (SILICOSIS). ACUTE OR RAPIDLY DEVELOPING SILICOSIS MAY OCCUR IN A SHORT PERIOD OF TIME IN HEAVY EXPOSURE. SILICOSIS IS A FORM OF DISABLING PULMONARY FIBROSIS WHICH CAN BE PROGRESSIVE AND MAY LEAD TO DEATH.
CARCINOGENICITY: NTP? YES.
THE NATIONAL TOXICOLOGY PROGRAM (NTP) PUBLISHED ITS SIXTH ANNUAL REPORT ON CARCINOGENS WHICH CONCLUDES THAT "SILICA, CRYSTALLINE (RESPIRABLE)" MAY REASONABLY BE ANTICIPATED TO BE A CARCINOGEN. THE NTP CONCLUSION IS BASED ON SUFFICIENT EVIDENCE FOR THE CARCINOGENICITY OF RESPIRABLE CRYSTALLINE SILICA IN EXPERIMENTAL ANIMALS AND LIMITED EVIDENCE IN HUMANS.
IARC MONOGRAPHS? YES
IARC MONOGRAPHS ON THE EVALUATION OF THE CARCINOGENIC RISK OF CHEMICALS TO HUMANS (VOL. 42, 1987) CONCLUDES THAT THERE IS SUFFICIENT EVIDENCE FOR THE CARCINOGENICITY OF CRYSTALLINE SILICA TO EXPERIMENTAL ANIMALS AND THAT THERE IS LIMITED EVIDENCE OF THE CARCINOGENICTY OF CRYSTALLINE SILICA TO HUMANS IARC CLASS 2A.

SIGNS AND SYMPTOMS OF EXPOSURE: UNDUE BREATHLESSNESS, WHEEZING, COUGH AND SPUTUM PRODUCTION.
MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE:
PRE-EXISTING LUNG SUCH AS EMPHYSEMA OR ASTHMA. PULMONARY FUNCTION MAY BE REDUCED BY INHALATION OF RESPIRABLE CRYSTA
ALSO LUNG SCARRING PRODUCED BY SUCH INHALATION MAY LEAD TO A PROGRESSIVE MASSIVE FIBROSIS OF THE LUNG WHICH MAY AGGRA
OTHER PULMONARY CONDITIONS AND DISEASES AND WHICH INCREASES SUSCEPTIBILITY TO PULMONARY TUBERCULOSIS. PROGRESSIVE F
BE ACCOMPANIED BY NIGHT HEART ENLARGEMENT, HEART FAILURE, AND PULMONARY FAILURE. SMOKING AGGRAVATES THE EFFECTS OF EX
EMERGENCY AND FIRST AID PROCEDURES:
FOR SAND IN EYES DURING DRY SAWING OR GRINDING OPERATIONS, IMMEDIATELY FLUSH GENEROUSLY WITH WATER FOR 15 MINUTES. IF IR
PERSISTS, SEEK MEDICAL ATTENTION. FOR GROSS INHALATION, REMOVE PERSON IMMEDIATELY TO FRESH AIR, GIVE ARTIFICIAL RESPIRATIO
NEEDED, SEEK MEDICAL ATTENTION AS NEEDED.

SECTION VII - PRECAUTIONS FOR SAFE HANDLING AND USE

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED:
WHEN DRY SAWING OR GRINDING USE DUSTLESS SYSTEMS FOR HANDLING, STORAGE, AND CLEANUP SO THAT AIRBORNE DUST DOES NOT
PEL. USE ADEQUATE VENTILATION AND DUST EQUIPMENT. PRACTICE GOOD HOUSEKEEPING. DO NOT PERMIT DUST TO COLLECT ON WALLS,
SILLS, LEDGES, MACHINERY OR EQUIPMENT. MAINTAIN CLEAN AND FIT TEST RESPIRATORS IN ACCORDANCE WITH OSHA REGULATIONS. MAIN
TEST VENTILATION AND DUST COLLECTION EQUIPMENT. WASH OR VACUUM CLOTHING WHICH HAS BECOME DUSTY. SEE ALSO CONTROL MEA
SECTION VIII.
WASTE DISPOSAL METHOD:
NORMAL BREAKAGE MAY BE PICKED UP AND DISCARDED AS COMMON WASTE. RESIDUE FROM DRY SAWING AND GRINDING OPERATIONS SH
DISPOSED OF IN ACCORDANCE WITH FEDERAL, STATE AND LOCAL REGULATIONS.
PRECAUTIONS TO BETAKEN IN HANDLING AND STORING: NONE
OTHER PRECAUTIONS:
SEE OHSA HAZARD COMMUNICATION RULE 29 CFR SECTIONS 1910.1200, 1915.99, 1917.28, 1918.90, 1926.59 AND 1928.21, AND STATE AND LOC
OR COMMUNITY "RIGHT TO KNOW" LAWS AND REGULATIONS. WE RECOMMEND THAT SMOKING BE PROHIBITED IN ALL AREAS WHERE RESPIR
MUST BE USED. **WARN YOUR EMPLOYEES (AND YOUR CUSTOMERS-USERS IN CASE OF RESALE) BY POSTING AND OTHER MEANS OF THE**
AND OSHA PRECAUTIONS TO BE USED. PROVIDE TRAINING FOR YOUR EMPLOYEES ABOUT THE OSHA PRECAUTIONS.
SEE ALSO AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) STANDARD PRACTICES E1132-86, "STANDARD PRACTICE FOR HEALTH REQUIREMENTS RELATING TO OCCUPATIONAL EXPOSURE TO QUARTZ DUST".

SECTION VIII - CONTROL MEASURES

RESPIRATORY PROTECTION

THE FOLLOWING CHART SPECIFIES THE TYPE OF RESPIRATORS WHICH MAY PROVIDE RESPIRATORY PROTECTION FOR CRYSTALLINE SILICA.

RESPIRATORY PROTECTION FOR CRYSTALLINE SILICA

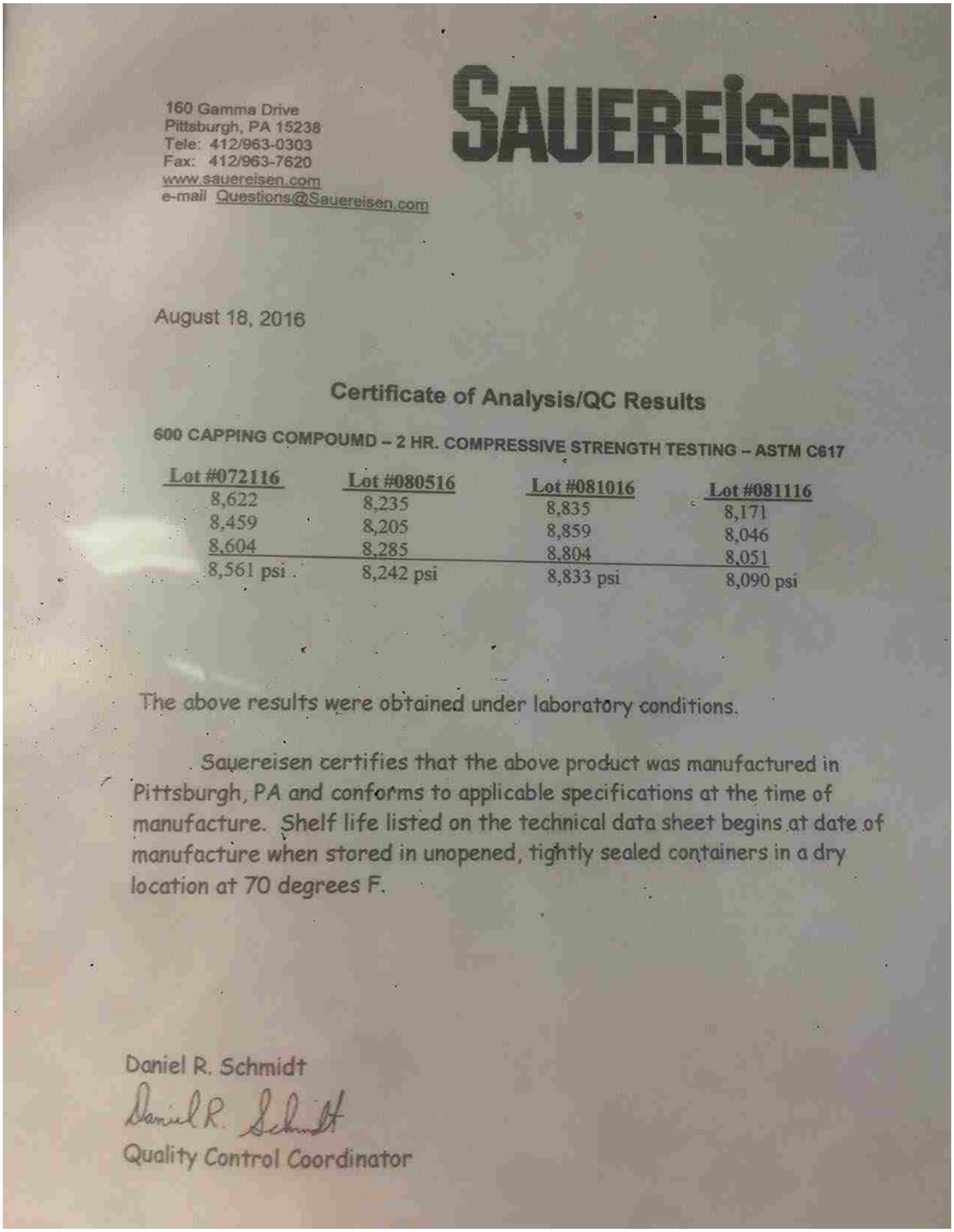
CONDITION PARTICULATE CONCENTRATION	**MINIMUM RESPIRATORY PROTECTION ***
UP TO 5 x PEL	ANY DUST RESPIRATOR
UP TO 10 x PEL	ANY DUST RESPIRATOR, EXCEPT SINGLE-USE OR QUARTER-MASK RESPIRATOR ANY FUME RESPIRATOR OR HIGH EFFICIENCY PARTICULATE FILTER RESPIRATOR ANY SUPPLIED-AIR RESPIRATOR ANY SELF-CONTAINED BREATHING APPARATUS
UP TO 50 x PEL	A HIGH EFFICIENCY PARTICULATE FILTER RESPIRATOR WITH A FULL FACEPIECE ANY SUPPLIED-AIR RESPIRATOR WITH A FULL FACEPIECE, HELMET OR HOOD ANY SELF-CONTAINED BREATHING APPARATUS WITH A FULL FACEPIECE
UP TO 500 x PEL	A POWERED AIR-PURIFYING RESPIRATOR WITH A HIGH EFFICIENCY PARTICULATE FILTE A TYPE C AIR-PURIFYING RESPIRATOR OPERATOR IN PRESSURE-DEMAND OR OTHER PO PRESSURE OR CONTINUOUS-FLOW MODE
GREATER THAN 500 x PEL OR ENTRY AND ESCAPE FROM UNKNOWN CONCENTRATIONS	SELF-CONTAINED BREATHING APPARATUS WITH A FULL FACEPIECE OPERATED IN PRES DEMAND OR OTHER POSITIVE MODE A COMBINATION RESPIRATOR WHICH INCLUDES A TYPE C SUPPLIED-AIR RESPIRATOR W FACEPIECE OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE CONTIN FLOW MODE AND AN AUXILIARY SELF-CONTAINED BREATHING APPARATUS OPERATED I PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE.

* ONLY NIOSH-APPROVED OR MSHA-APPROVED EQUIPMENT SHOULD BE USED (SEE 29 CFR 1910.134)

SEE ALSO ANSI STANDARD Z88 2-1980 "PRACTICES FOR RESPIRATORY PROTECTION"

VENTILATION: LOCAL EXHAUST: WHEN DRY SAWING OR GRINDING CONCRETE MASONRY PRODUCTS, USE SUFFICIENT LOCAL EXHAUST TO
THE LEVEL OF RESPIRABLE DUST TO THE PEL. SEE ACGIH "INDUSTRIAL VENTILATION, A MANUAL OF RECOMMENDED PRACTICE", LATEST EDIT
MECHANICAL
SEE "OTHER PRECAUTIONS" UNDER SECTION VII.
SPECIAL
SEE "OTHER PRECAUTIONS" UNDER SECTION VII.
OTHER
SEE "OTHER PRECAUTIONS" UNDER SECTION VII.
PROTECTIVE GLOVES
OPTIONAL
EYE PROTECTION
WHEN SAWING OR GRINDING CONCRETE MASONRY PRODUCTS WEAR PROTECTIVE OR TIGHT FITTING GOGGLES (SAFETY GLASSES).
OTHER PROTECTIVE CLOTHING OR EQUIPMENT
OPTIONAL
WORK/HYGIENIC PRACTICES
AVOID CREATING AND BREATHING DUST. SEE "OTHER PRECAUTIONS" UNDER SECTION VII.

THE INFORMATION AND RECOMMENDATIONS CONTAINED HEREIN ARE BASED UPON DATA BELIEVED TO BE CORRECT. HOWEVER, NO GUA
WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, IS MADE WITH RESPECT TO THE INFORMATION CONTAINED HEREIN. WE ACCEPT NO RESP
DISCLAIM ALL LIABILITY FOR ANY HARMFUL EFFECTS WHICH MAY BE CAUSED BY EXPOSURE TO AIRBORNE DUST PARTICLES CREATED BY
GRINDING OF OUR PRODUCTS. CUSTOMERS/USERS OF CONCRETE MASONRY PRODUCTS MUST COMPLY WITH ALL APPLICABLE HEALTH A
LAWS, REGULATIONS AND ORDERS.



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SAUEREISEN

August 18, 2016

Certificate of Analysis/QC Results

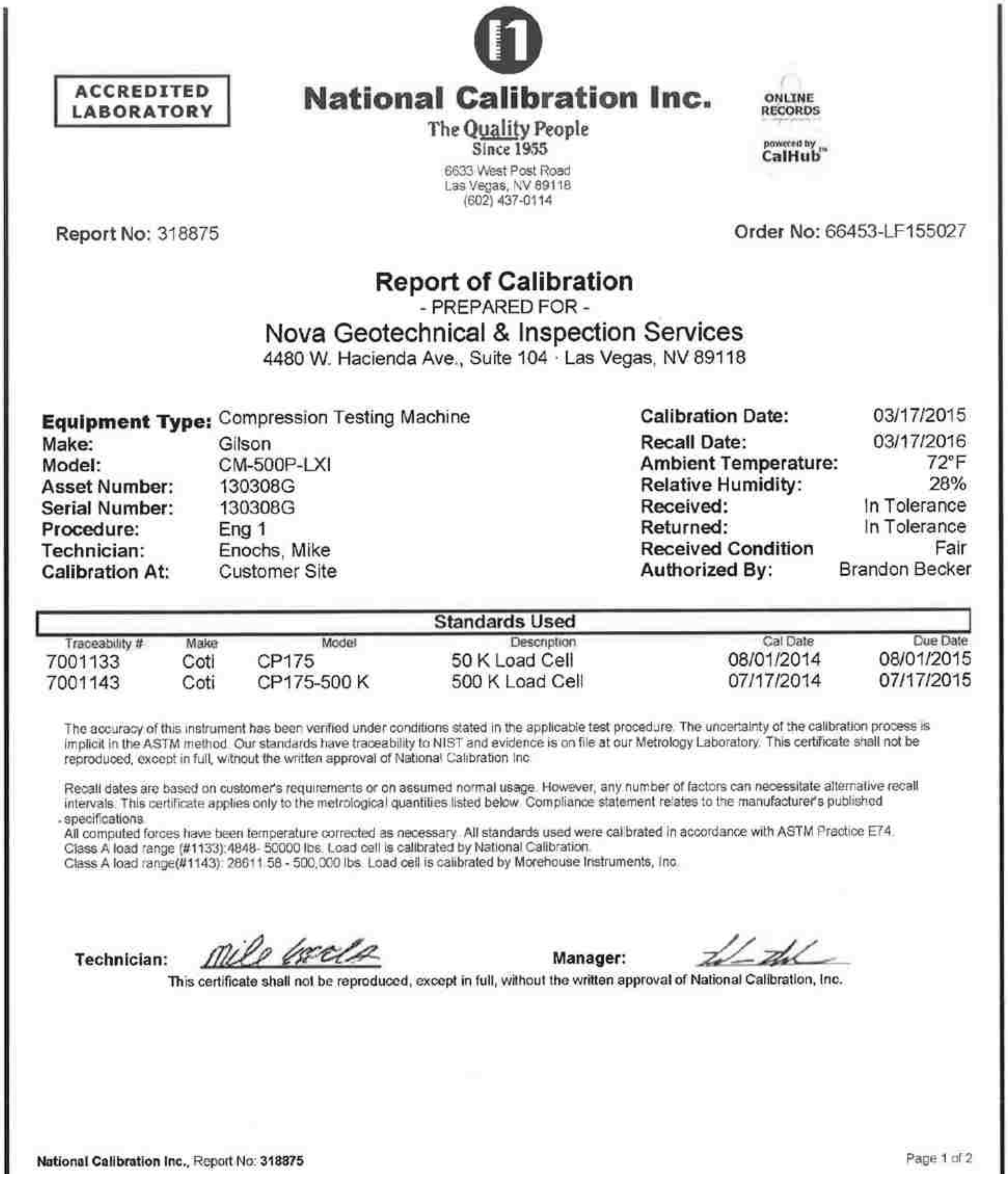
600 CAPPING COMPOUMD – 2 HR. COMPRESSIVE STRENGTH TESTING – ASTM C617

Lot #072116	Lot #080516	Lot #081016	Lot #081116
8,622	8,235	8,835	8,171
8,459	8,205	8,859	8,046
8,604	8,285	8,804	8,051
8,561 psi	8,242 psi	8,833 psi	8,090 psi

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
Daniel R. Schmidt
Quality Control Coordinator



ACCREDITED
LABORATORY

National Calibration Inc.

The Quality People
Since 1955

6633 West Post Road
Las Vegas, NV 89118
(602) 437-0114

ONLINE
RECORDS

powered by
CalHub™

Report No: 318875

Order No: 66453-LF155027

Report of Calibration

- PREPARED FOR -

Nova Geotechnical & Inspection Services
4480 W. Hacienda Ave., Suite 104 · Las Vegas, NV 89118

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

Standards Used

Traceability #	Make	Model	Description	Cal Date	Due Date
7001133	Coti	CP175	50 K Load Cell	08/01/2014	08/01/2015
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 computed forces have been temperature corrected as necessary. All standards used were calibrated in accordance with ASTM Practice E74.
Class A load range (#1133):4848- 50000 lbs. Load cell is calibrated by National Calibration.
Class A load range(#1143): 28611.58 - 500,000 lbs. Load cell is calibrated by Morehouse Instruments, Inc.

Technician:

Manager:

This certificate shall not be reproduced, except in full, without the written approval of National Calibration, Inc.

National Calibration Inc., Report No: **318875**

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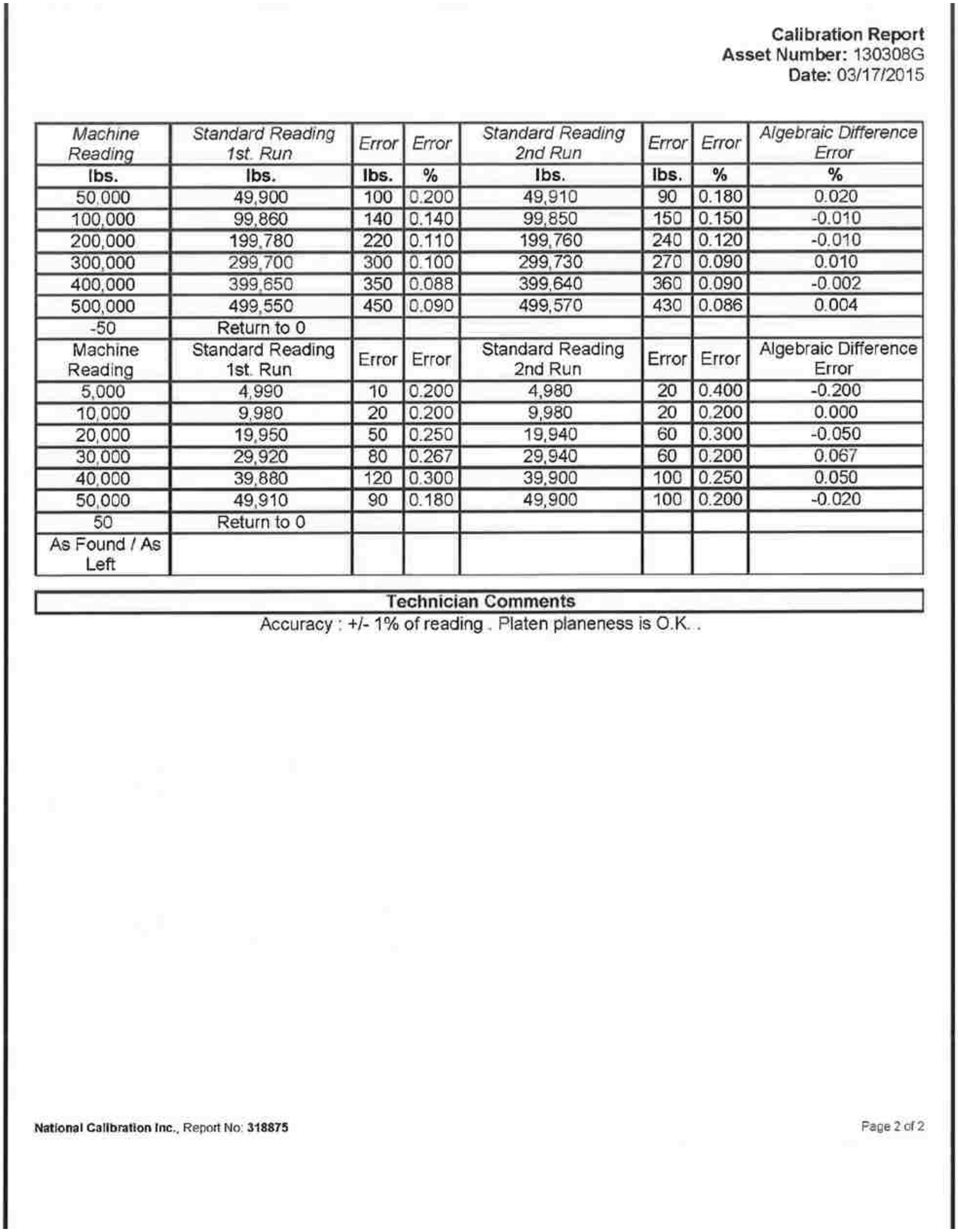

Calibration Report
Asset Number: 130308G
Date: 03/17/2015

Machine Reading	*Standard Reading 1st. Run*	*Error*	*Error*	*Standard Reading 2nd Run*	*Error*	*Error*	*Algebraic Difference Error*
lbs.	**lbs.**	**lbs.**	**%**	**lbs.**	**lbs.**	**%**	**%**
50,000	49,900	100	0.200	49,910	90	0.180	0.020
100,000	99,860	140	0.140	99,850	150	0.150	-0.010
200,000	199,780	220	0.110	199,760	240	0.120	-0.010
300,000	299,700	300	0.100	299,730	270	0.090	0.010
400,000	399,650	350	0.088	399,640	360	0.090	-0.002
500,000	499,550	450	0.090	499,570	430	0.086	0.004
-50	Return to 0						
Machine Reading	Standard Reading 1st. Run	Error	Error	Standard Reading 2nd Run	Error	Error	Algebraic Difference Error
5,000	4,990	10	0.200	4,980	20	0.400	-0.200
10,000	9,980	20	0.200	9,980	20	0.200	0.000
20,000	19,950	50	0.250	19,940	60	0.300	-0.050
30,000	29,920	80	0.267	29,940	60	0.200	0.067
40,000	39,880	120	0.300	39,900	100	0.250	0.050
50,000	49,910	90	0.180	49,900	100	0.200	-0.020
50	Return to 0						
As Found / As Left							

Technician Comments

Accuracy : +/- 1% of reading . Platen planeness is O.K. .

National Calibration Inc., Report No: **318875**

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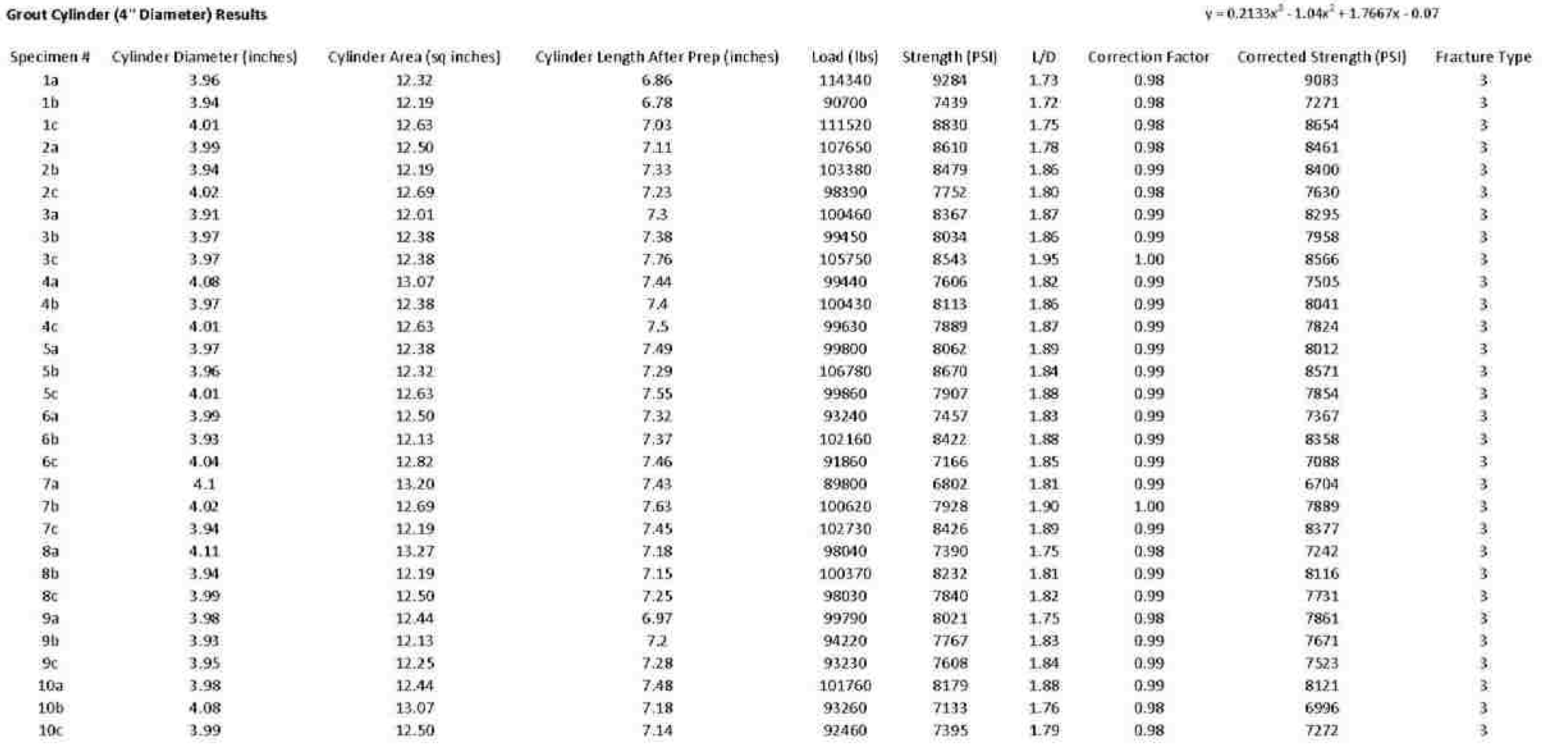
APPENDIX 2: RAW DATA

4500 PSI at 4 Inch Slump



Grout Cylinder (4" Diameter) Results

$y = 0.2133x^3 - 1.04x^2 + 1.7667x - 0.07$

Specimen #	Cylinder Diameter (inches)	Cylinder Area (sq inches)	Cylinder Length After Prep (inches)	Load (lbs)	Strength (PSI)	L/D	Correction Factor	Corrected Strength (PSI)	Fracture Type
1a	3.96	12.32	6.86	114340	9284	1.73	0.98	9083	3
1b	3.94	12.19	6.78	90700	7439	1.72	0.98	7271	3
1c	4.01	12.63	7.03	111520	8830	1.75	0.98	8654	3
2a	3.99	12.50	7.11	107650	8610	1.78	0.98	8461	3
2b	3.94	12.19	7.33	103380	8479	1.86	0.99	8400	3
2c	4.02	12.69	7.23	98390	7752	1.80	0.98	7630	3
3a	3.91	12.01	7.3	100460	8367	1.87	0.99	8295	3
3b	3.97	12.38	7.38	99450	8034	1.86	0.99	7958	3
3c	3.97	12.38	7.76	105750	8543	1.95	1.00	8566	3
4a	4.08	13.07	7.44	99440	7606	1.82	0.99	7505	3
4b	3.97	12.38	7.4	100430	8113	1.86	0.99	8041	3
4c	4.01	12.63	7.5	99630	7889	1.87	0.99	7824	3
5a	3.97	12.38	7.49	99800	8062	1.89	0.99	8012	3
5b	3.96	12.32	7.29	106780	8670	1.84	0.99	8571	3
5c	4.01	12.63	7.55	99860	7907	1.88	0.99	7854	3
6a	3.99	12.50	7.32	93240	7457	1.83	0.99	7367	3
6b	3.93	12.13	7.37	102160	8422	1.88	0.99	8358	3
6c	4.04	12.82	7.46	91860	7166	1.85	0.99	7088	3
7a	4.1	13.20	7.43	89800	6802	1.81	0.99	6704	3
7b	4.02	12.69	7.63	100620	7928	1.90	1.00	7889	3
7c	3.94	12.19	7.45	102730	8426	1.89	0.99	8377	3
8a	4.11	13.27	7.18	98040	7390	1.75	0.98	7242	3
8b	3.94	12.19	7.15	100370	8232	1.81	0.99	8116	3
8c	3.99	12.50	7.25	98030	7840	1.82	0.99	7731	3
9a	3.98	12.44	6.97	99790	8021	1.75	0.98	7861	3
9b	3.93	12.13	7.2	94220	7767	1.83	0.99	7671	3
9c	3.95	12.25	7.28	93230	7608	1.84	0.99	7523	3
10a	3.98	12.44	7.48	101760	8179	1.88	0.99	8121	3
10b	4.08	13.07	7.18	93260	7133	1.76	0.98	6996	3
10c	3.99	12.50	7.14	92460	7395	1.79	0.98	7272	3

2500 PSI at 4 Inch Slump

Grout Cylinder (4" Diameter) Results

$y = 0.2133x^3 - 1.04x^2 + 1.7667x - 0.07$

Specimen #	Cylinder Diameter (inches)	Cylinder Area (sq inches)	Cylinder Length After Prep (inches)	Load (lbs)	Strength (PSI)	L/D	Correction Factor	Corrected Strength (PSI)	Fracture Type
1a	3.99	12.50	6.37	55535	4442	1.60	0.97	4298	5
1b	3.95	12.25	6.13	51495	4202	1.55	0.96	4052	5
1c	4.01	12.63	6.51	54580	4322	1.62	0.97	4191	2
2a	4.01	12.63	6.44	58140	4604	1.61	0.97	4458	5
2b	3.97	12.38	6.37	61745	4988	1.60	0.97	4830	5
2c	4	12.57	5.77	62775	4995	1.44	0.95	4769	2
3a	3.98	12.44	7.07	60240	4842	1.78	0.98	4756	5
3b	4.02	12.69	6.85	52535	4139	1.70	0.98	4040	5
3c	3.99	12.50	6.45	64170	5132	1.62	0.97	4974	5
4a	4.01	12.63	6.13	54425	4309	1.53	0.96	4147	2
4b	4	12.57	6.72	54815	4362	1.68	0.97	4249	2
4c	4	12.57	6.8	57915	4609	1.70	0.98	4497	5
5a	3.98	12.44	6.67	61495	4943	1.68	0.97	4814	2
5b	4	12.57	6.73	62695	4989	1.68	0.97	4861	2
5c	3.97	12.38	6.22	59935	4842	1.57	0.97	4674	2
6a	3.96	12.32	6.41	59085	4797	1.62	0.97	4651	5
6b	3.98	12.44	6.22	61690	4959	1.56	0.97	4786	5
6c	3.94	12.19	6.24	61895	5077	1.58	0.97	4908	2
7a	3.98	12.44	6.6	56945	4577	1.66	0.97	4451	2
7b	4	12.57	5.99	60480	4813	1.50	0.96	4620	5
7c	4.01	12.63	5.97	55360	4383	1.49	0.96	4204	5
8a	3.99	12.50	6.19	58835	4705	1.55	0.96	4537	2
8b	3.98	12.44	6.44	53825	4326	1.62	0.97	4194	5
8c	3.99	12.50	7.19	62060	4963	1.80	0.98	4887	2
9a	3.96	12.32	6.46	61280	4976	1.63	0.97	4828	2
9b	4.01	12.63	6.23	60420	4784	1.55	0.96	4614	2
9c	3.98	12.44	6.04	62835	5051	1.52	0.96	4856	2
10a	3.99	12.50	6.93	59310	4743	1.74	0.98	4643	2
10b	4.02	12.69	6.39	59405	4680	1.59	0.97	4527	2
10c	4.02	12.69	6.45	60295	4750	1.60	0.97	4600	2

4500 at 10 Inch Slump

Grout Cylinder (4" Diameter) Results

$y = 0.2133x^3 - 1.04x^2 + 1.7667x - 0.07$

Specimen #	Cylinder Diameter (inches)	Cylinder Area (sq inches)	Cylinder Length After Prep (inches)	Load (lbs)	Strength (PSI)	L/D	Correction Factor	Corrected Strength (PSI)	Fracture Type
1a	3.96	12.32	6.52	68910	5595	1.65	0.97	5436	4
1b	3.95	12.25	7.46	72670	5930	1.89	0.99	5894	5
1c	3.94	12.19	6.85	64145	5261	1.74	0.98	5150	3
2a	3.95	12.25	6.77	78125	6375	1.71	0.98	6228	5
2b	3.93	12.13	6.72	81320	6704	1.71	0.98	6546	5
2c	4.04	12.82	6.74	78535	6126	1.67	0.97	5963	5
3a	4.11	13.27	6.67	81680	6157	1.62	0.97	5970	4
3b	4.07	13.01	6.7	75605	5811	1.65	0.97	5646	3
3c	3.98	12.44	6.92	72350	5815	1.74	0.98	5693	3
4a	3.94	12.19	7.05	76435	6269	1.79	0.98	6165	5
4b	3.96	12.32	5.93	80340	6523	1.50	0.96	6262	3
4c	4.09	13.14	6.81	78130	5947	1.67	0.97	5786	3
5a	4.01	12.63	7.39	73935	5854	1.84	0.99	5788	5
5b	3.96	12.32	6.52	80605	6545	1.65	0.97	6358	5
5c	3.97	12.38	6.16	75740	6119	1.55	0.96	5900	5
6a	3.96	12.32	6.39	73265	5949	1.61	0.97	5764	3
6b	3.95	12.25	6.67	68185	5564	1.69	0.97	5424	3
6c	4.03	12.76	6.53	78790	6177	1.62	0.97	5989	3
7a	3.93	12.13	7.39	77205	6365	1.88	0.99	6320	6
7b	3.89	11.88	7.11	74120	6237	1.83	0.99	6157	5
7c	3.94	12.19	7.53	78490	6438	1.91	1.00	6417	5
8a	3.99	12.50	6.29	80745	6458	1.58	0.97	6239	5
8b	3.98	12.44	7.34	82950	6667	1.84	0.99	6593	3
8c	3.93	12.13	7.68	81850	6748	1.95	1.00	6765	4
9a	3.93	12.13	7.19	78520	6473	1.83	0.99	6391	5
9b	4.05	12.88	7.03	76705	5954	1.74	0.98	5827	3
9c	3.97	12.38	7.3	79570	6428	1.84	0.99	6353	3
10a	4.02	12.69	6.25	78175	6159	1.55	0.96	5940	3
10b	4.06	12.95	7.08	81130	6267	1.74	0.98	6137	3
10c	3.94	12.19	6.29	81285	6667	1.60	0.97	6452	4

Prism (8" Block) Results **4500 PSI at 4 Inch Slump** $y = -0.0175x^4 + 0.2409x^3 - 1.1967x^2 + 2.6159x - 1.095$

Specimen #	Average Length (inches)	Average Width (inches)	Prism Area (sq inches)	Average Height (inches)	Load (lbs)	Strength (PSI)	Hp/tp	Correction Factor	Corrected Strength (PSI)	Fracture Type
1a	7.6	7.6	57.76	15	208150	3604	2.0	1.00	3604	5
1b	7.7	7.6	58.52	14.05	230220	3934	1.8	0.97	3811	6
1c	7.6	7.625	57.95	14.8	233260	4025	1.9	0.99	3973	6
2a	7.6	7.575	57.57	15.1	215950	3751	2.0	1.00	3751	6
2b	7.6	7.6	57.76	14.725	241170	4175	1.9	0.99	4119	6
2c	7.6	7.525	57.19	14.7	177250	3099	2.0	1.00	3099	6
3a	7.6	7.625	57.95	14.6	192870	3328	1.9	0.98	3269	6
3b	7.6	7.6	57.76	14.8	196360	3400	1.9	0.99	3360	6
3c	7.625	7.65	58.33	13.9	207470	3557	1.8	0.96	3420	6
4a	7.6	7.575	57.57	14.825	222990	3873	2.0	1.00	3873	6
4b	7.625	7.6	57.95	14	211660	3652	1.8	0.97	3533	6
4c	7.575	7.65	57.95	14.85	214370	3699	1.9	0.99	3652	6
5a	7.575	7.65	57.95	14.65	209020	3607	1.9	0.98	3543	6
5b	7.6	7.65	58.14	14.8	207890	3576	1.9	0.99	3526	5
5c	7.625	7.55	57.57	15.1	230930	4011	2.0	1.00	4011	1
6a	7.6	7.6	57.76	14.975	219130	3794	2.0	1.00	3794	6
6b	7.6	7.6	57.76	15	196980	3410	2.0	1.00	3410	6
6c	7.65	7.625	58.33	14.225	230330	3949	1.9	0.97	3840	6
7a	7.65	7.675	58.71	14.925	218750	3726	1.9	0.99	3680	6
7b	7.625	7.575	57.76	14.9	183300	3174	2.0	1.00	3174	6
7c	7.6	7.65	58.14	14.775	199440	3430	1.9	0.99	3380	6
8a	7.625	7.625	58.14	14.175	226640	3898	1.9	0.97	3785	6
8b	7.575	7.625	57.76	14.65	200530	3472	1.9	0.98	3415	5
8c	7.65	7.65	58.52	14.75	197580	3376	1.9	0.98	3325	5
9a	7.65	7.6	58.14	14.75	213090	3665	1.9	0.99	3618	5
9b	7.625	7.625	58.14	14.625	201360	3463	1.9	0.98	3404	5
9c	7.625	7.625	58.14	14.725	172680	2970	1.9	0.99	2927	3
10a	7.625	7.625	58.14	14.725	196410	3378	1.9	0.99	3329	6
10b	7.65	7.625	58.33	14.725	184860	3169	1.9	0.99	3123	5
10c	7.675	7.65	58.71	14.775	197940	3371	1.9	0.985	3322	6

Prism (8" Block) Results **2500 PSI at 4 Inch Slump** $y = -0.0175x^4 + 0.2409x^3 - 1.1967x^2 + 2.6159x - 1.095$

Specimen #	Average Length (inches)	Average Width (inches)	Prism Area (sq inches)	Average Height (inches)	Load (lbs)	Strength (PSI)	Hp/tp	Correction Factor	Corrected Strength (PSI)	Fracture Type
1a	7.6	7.525	57.19	15.3125	142150	2486	2.0	1.00	2486	4
1b	7.6	7.6	57.76	15.35	131630	2279	2.0	1.00	2279	5
1c	7.5875	7.6125	57.76	15.15	141590	2451	2.0	1.00	2451	6
2a	7.625	7.575	57.76	15.3125	150090	2599	2.0	1.00	2599	6
2b	7.6125	7.6125	57.95	15.3125	128610	2219	2.0	1.00	2219	6
2c	7.6	7.6	57.76	14.2	148610	2573	1.9	0.97	2503	3
3a	7.5875	7.5875	57.57	15.2375	119760	2080	2.0	1.00	2080	5
3b	7.6125	7.6375	58.14	15.4	130800	2250	2.0	1.00	2250	4
3c	7.65	7.625	58.33	14.6875	166420	2853	1.9	0.98	2809	6
4a	7.575	7.575	57.38	15.1875	138650	2416	2.0	1.00	2416	3
4b	7.6625	7.6125	58.33	15.175	125150	2146	2.0	1.00	2146	3
4c	7.65	7.625	58.33	15.225	145030	2486	2.0	1.00	2486	4
5a	7.625	7.6	57.95	15.3625	132440	2285	2.0	1.00	2285	4
5b	7.6	7.675	58.33	15.35	143830	2466	2.0	1.00	2466	7
5c	7.6625	7.6375	58.52	14.775	161190	2754	1.9	0.99	2716	3
6a	7.5	7.5625	56.72	14.5375	147940	2608	1.9	0.98	2566	3
6b	7.5875	7.575	57.48	15.4125	151830	2642	2.0	1.00	2642	2
6c	7.65	7.625	58.33	15.025	147380	2527	2.0	1.00	2527	3
7a	7.5625	7.575	57.29	14.7875	129540	2261	2.0	1.00	2261	2
7b	7.55	7.5875	57.29	14.8	112510	1964	2.0	1.00	1964	6
7c	7.55	7.6	57.38	13.6	157350	2742	1.8	0.95	2619	6
8a	7.5875	7.6	57.67	14.7	153220	2657	1.9	0.99	2620	5
8b	7.55	7.6125	57.47	14.175	136640	2377	1.9	0.97	2310	4
8c	7.575	7.675	58.14	14.675	128560	2211	1.9	0.98	2171	7
9a	7.675	7.625	58.52	14.675	138650	2369	1.9	0.98	2332	4
9b	7.65	7.6	58.14	14.6	148030	2546	1.9	0.98	2504	3
9c	7.65	7.575	57.95	15.2	133340	2301	2.0	1.00	2301	6
10a	7.5875	7.6375	57.95	14.475	133230	2299	1.9	0.98	2250	5
10b	7.6125	7.6375	58.14	14.775	154580	2659	1.9	0.99	2621	6
10c	7.6	7.5875	57.67	14.725	150630	2612	1.9	0.99	2578	4

Prism (8" Block) Results **4500 PSI at 10 Inch Slump**

$y = -0.0175x^4 + 0.2409x^3 - 1.1967x^2 + 2.6159x - 1.095$

Specimen #	Average Length (inches)	Average Width (inches)	Prism Area (sq inches)	Average Height (inches)	Load (lbs)	Strength (PSI)	Hp/tp	Correction Factor	Corrected Strength (PSI)	Fracture Type
1a	7.6	7.65	58.14	15.45	137340	2362	2.0	1.00	2362	3
1b	7.65	7.675	58.71	14.95	159190	2711	1.9	0.99	2680	4
1c	7.6125	7.6625	58.33	15.4625	147430	2527	2.0	1.00	2527	4
2a	7.6875	7.6625	58.91	15.55	161100	2735	2.0	1.00	2735	5
2b	7.7375	7.65	59.19	15.5625	140130	2367	2.0	1.00	2367	3
2c	7.55	7.675	57.95	15.6125	162730	2808	2.0	1.00	2808	5
3a	7.625	7.625	58.14	15.4875	187180	3219	2.0	1.00	3219	3
3b	7.6375	7.7	58.81	15.0625	132810	2258	2.0	1.00	2258	3
3c	7.7125	7.6375	58.90	14.475	147620	2506	1.9	0.98	2452	2
4a	7.6	7.55	57.38	14.925	136380	2377	2.0	1.00	2377	1
4b	7.6125	7.6375	58.14	15.35	139010	2391	2.0	1.00	2391	6
4c	7.6625	7.65	58.62	15.4	166820	2846	2.0	1.00	2846	7
5a	7.625	7.6125	58.05	15.35	170760	2942	2.0	1.00	2942	5
5b	7.6375	7.575	57.85	14.75	177830	3074	1.9	0.99	3038	5
5c	7.6	7.6625	58.24	15.125	167200	2871	2.0	1.00	2871	3
6a	7.65	7.6875	58.81	15.3375	188980	3213	2.0	1.00	3213	5
6b	7.6625	7.5875	58.14	15.3	185240	3186	2.0	1.00	3186	1
6c	7.6125	7.7	58.62	15.3375	169970	2900	2.0	1.00	2900	3
7a	7.6	7.65	58.14	14.85	163900	2819	1.9	0.99	2783	2
7b	7.675	7.6875	59.00	14.625	169750	2877	1.9	0.98	2819	3
7c	7.55	7.525	56.81	15.675	120490	2121	2.1	1.01	2141	3
8a	7.525	7.55	56.81	14.55	166970	2939	1.9	0.98	2894	3
8b	7.6875	7.65	58.81	14.8	130230	2214	1.9	0.99	2183	2
8c	7.6625	7.6125	58.33	15.1	139330	2389	2.0	1.00	2389	7
9a	7.65	7.65	58.52	15.2625	116670	1994	2.0	1.00	1994	7
9b	7.625	7.6125	58.05	15.4	128400	2212	2.0	1.00	2212	3
9c	7.5875	7.6625	58.14	15.3125	106490	1832	2.0	1.00	1832	7
10a	7.625	7.6375	58.24	15.3	137570	2362	2.0	1.00	2362	3
10b	7.7	7.625	58.71	15.6	151780	2585	2.0	1.00	2585	7
10c	7.575	7.65	57.95	15.35	128330	2215	2.0	1.00	2215	4

REFERENCES

Atkinson, R.H., Noland, J.L., Abrams, D.P., and McNary, S., A Deformation Failure Theory for Stacked Bond Prisms. Proceedings of the Third North American Masonry Conference, June 3, 4, 5, 1985.

Hegemier, G.A., Krishnamoorthy, G., Nunn, R.O., Moorthy, T.V., Prism Tests for the Compressive Strength of Concrete Masonry, NSF ENV 74-14818, University of California, San Diego, 1977.

Nichols, J.M. and Tan, Ke Feng, A Treatise of Masonry Testing. Proceedings of the Tenth North American Masonry Conference, June 3-5, 2007.

Baur, John, Noland, J.L. and Chinn, James, Compression Tests of Clay-Unit Stackbond Prisms TMS Journal, June 1978.

Atkinson, R.H., Effect of Loading Platen Thickness on Masonry Unit and Prism Strengths. TMS Journal, August 1991.

Kingsley, G.R., Noland, J.L. and Schuller, M.P., Effect of Slenderness and End Restraint on Masonry Prisms- A Literature Review. TMS Journal, Volume 10, No. 2, February 1992.

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

Hegemier, G.A., Krishnamoorthy, G., Nunn, R.O., Moorthy, T.V., Prism Tests for the Compressive Strength of Concrete Masonry, University of California, San Diego, 1974.

Atkinson, R.H. and Yan, G.G., Results of a Statistical Study of Masonry Deformability, TMS Journal, August 1990.

Atkinson, R.H., Statistical Requirements of Masonry Testing. TMS Journal, August 1992.

Miller, M.E., Hegemier, G.A., and Nunn, R.O., The Influence of Flaws, Compaction and Admixture on the Strength and Elastic Moduli of Concrete Masonry. Report No. AMES/NSF/TR-78/002, University of California, San Diego, 1978.

Annual Book of ASTM Standards, American Society for Testing and Materials, West Conshohocken, PA, 2015.

International Building Code, International Code Council, Washington, DC. 2015

ACI530: Building Code Requirements and Specification for Masonry Structures and Companion Commentaries, American Concrete Institute, Farmington Hills, Michigan, 2015.

CURRICULUM VITAE

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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 amphitheaters, 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