An *IPRF* Research Report

Innovative Pavement Research Foundation

Airport Concrete Pavement Technology Program

Report IPRF-01-G-002-03-4

Precision Statement for ASTM C-78, Flexural Testing, Airfield Concrete

Programs Management Office
5420 Old Orchard Road
Skokie, IL 60077

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Precision Statement for ASTM C-78, Flexural Testing, Airfield Concrete

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LIST OF ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
ACPA	American Concrete Pavement Association
AMRL	AASHTO Materials Reference Library
ANOVA	Analysis of Variance
ASTM	American Society of Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
NRMCA	National Ready-Mix Concrete Association
PCA	Portland Cement Association
TRIS	Transportation Research Information System

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1 INTRODUCTION.

1.1 BACKGROUND.

The uniformity of concrete material properties, particularly strength, is important to the performance of concrete infrastructure elements, and in particular airfield pavements. Since airfield pavement design methods rely on assumptions about concrete flexural strength as a primary level input, it is vital that the actual in-place concrete comply with these assumptions. In addition, to achieve consistent performance and avoid random performance problems associated with variation in the actual concrete placed, it is important that the material used be uniform in strength and other properties directly related to performance. Consequently, the airfield industry has relied upon flexural strength testing as the means for specifying and accepting airfield concrete, as discussed by Rapol [1].

However, far too often, variability in test results is encountered in the course of trying to complete projects. Reported flexural strength test results frequently exhibit excessive variability, and since there are numerous potential sources for this variability, disputes arise and resolution processes are necessary to close out project payment. Even then, there may be lingering questions about the compliance of the strength and uniformity of the concrete included in the work which cannot reasonably be definitively answered. Contractors may endure payment penalties as the result of sample molding, handling and testing not directly under their control, rather than as a result of concrete production, which is directly under their control. Consequently, this can be a big issue in the airfield and other infrastructure industries that utilize flexural strength requirements to control work.

The problem associated with the use of flexural strength testing is that while defined testing procedures and related precision statement information are available for laboratory controlled specimens, no documented attempt to measure the impact and determine a precision statement for field cured concrete flexural specimens exists. There are several potential sources of variability, and perhaps error, which can show up in reported flexural strength results. Foremost among these are potential variability in the molding of test specimens, initial curing methods, transporting to a final curing facility, and the actual testing of the samples. Included in this list of potential problem areas are both mechanical and human factors. Procedural practices and errors may indeed play a large part in the derivation of unacceptable flexural strength test results, even if there is no real strength and variability problem with the actual concrete in the placement. For example, individual technician practices in molding and testing specimens can potentially affect reported strength results. Even though specific molding procedures are required of ACI certified technicians, it is known that individual practices can affect results. Similarly, even though a specific range of loading rate is specified in the testing procedure, it is known that this portion of the testing process is often violated to speed up the testing process, and increase productivity. Further, the care exercised in handling and transporting flexural beam specimens can have a major impact on whether sample specimens are damaged prior to testing. Likewise, care in insuring that adequate curing procedures are followed can prevent unacceptable test results.

1.2 OBJECTIVE.

The objective of this study is to provide some quantification of the collective impact of these sources of potential variability by generating flexural beam samples and test results within the parameters of a test plan. An experimental test plan was developed to generate flexural beam strength test results which were useful in the determination of a precision statement for multiple field-cured flexural strength specimens, as determined from inter-laboratory testing from a single concrete batch. Following the development of test results for a single concrete batch tested by 12 individual laboratories, two additional concrete batches at different target strength values were produced and tested following the same testing procedures. All concrete was produced from a single source with the same materials, and tested for flexure strength using tightly monitored experimental procedures.

2 LITERATURE REVIEW.

The subject of variability of concrete flexural beams can be broken into two components: concrete variability and testing variability. Each of these components has factors which need to be examined in detail to isolate their relative importance to variability. The subject of concrete variability includes each of the materials, measuring and mixing; while these items are important to overall variability, they are beyond the scope of this effort. The field factors and testing variability is of particular importance in this work.

Practically every day, important decisions are made based upon the concrete flexural test data. For those making these decisions and those affected by these decisions it is vital to understand the accuracy and quality of that data so that correct judgments can be made. When doubt exists about the quality of test data, disputes can arise over the decisions that are made. The basis for this doubt can be an abnormal group of test results or a large within-test variation between companion flexural beam specimens.

In order to better understand flexural beam testing variation, a literature review was conducted looking at published and non-published information focusing on important factors. This literature review considered information from agency, academic, and industry sources. A brief summary of key elements of the literature review is provided here. The search reviewed sources from the:

- American Association of State Highway and Transportation Officials (AASHTO)
- American Concrete Institute (ACI)
- American Concrete Pavement Association (ACPA)
- American Society of Testing and Materials (ASTM)
- Federal Aviation Administration (FAA)
- Federal Highway Pavement Technology Library
- Forney, Inc.
- National Ready-Mix Concrete Association (NRMCA)
- Portland Cement Association (PCA)
- Rainhart, Inc.
- Testmark, Inc.
- Transportation Research Information System (TRIS)

2.1 VARIABILITY OF FLEXURAL STRENGTH

The FAA discusses statistical quality acceptance criteria which cover, among other items, strength of flexural beams [1]. An assumed 55 psi standard deviation is used for flexural strength acceptance. The FAA assumes this value is “not unreasonable” for process control parameters and acceptance [2]. However, field usage of the ASTM C-78 and the associated ASTM C-31 has demonstrated that variation of the testing process itself can have a variance greatly exceeding the assumed 55 psi standard deviation [3]. Analysis has shown that two flexural strength test results from the same batch of concrete can be expected to vary by as much as 100 psi and not be considered suspect 95 percent of the time [1].

A Federal Highway Administration (FHWA) report references work by Darter of an analysis of relative standard deviation of portland cement concrete pavements, which separated variation into three components — sampling, testing, and material [4a-d]. For the five pavement projects reported, the sampling and testing components of variation were larger (52 to 57 percent) compared to the concrete materials variation (48 to 43 percent) on three of the projects. On the remaining two projects, the variation of sampling and testing were less than (36 to 40) percent the variation of the concrete materials (60 to 64 percent). This analysis of variation was conducted on compressive cylinder test data, which is regarded as less variable than flexural beam test data, but still indicates a very significant component of variation is contained within sampling and testing. This FHWA report includes a table proposed by Greer for guidelines to rate flexural beam testing into three grades—"Excellent to Good, Good to Fair, and Fair to Poor"—depending on the within-test variation.

For flexural strength determined with third-point loading, Carresquillo found that, other mix factors constant, both the standard deviation and the coefficient of variation are dependent upon the strength level [5].

2.2 RELEVANT ASTM STANDARDS GOVERNING MAKING AND TESTING FLEXURAL BEAMS.

- *ASTM C-31 (AASHTO T-23) "Making and Curing Concrete Test Specimens in the Field"* covers procedures for flexural beam specimen molding (and consolidation), curing (and protection), and transporting (and protection) to the laboratory with no precision statement [6].

- *ASTM C-78 (AASHTO T-97) "Flexural Strength of Concrete* (Using Simple Beam with Third-Point Loading)" covers procedures for testing, calculating, reporting and a precision statement for single operator coefficient of variation (5.7%) and multi-laboratory coefficient of variation (7.0%) [7].

2.3 AREAS FOR IMPROVEMENT AND ADDITIONAL RESEARCH REGARDING FLEXURAL BEAM TESTING.

Early studies on flexural beam sizes, loading rates, central versus third point loading, and the "weakest link theory" of failure provide insights into variability and other fundamental factors [8]. A reduction of approximately 30 percent was observed when the depth of the beam was increased from 3 in. to 8 in. for a span-depth ratio of 3, but other effects were small. Increasing the rate of stress increase (loading rate) from 20 to 1,140 lb per sq. in. per minute resulted in an increase of about 15 percent in the modulus of rupture. Central loading gave results about 20 to 25 percent higher than third-point loading, but the results were less uniform (more variable).

ACPA's position paper cites the specific need to improve the quality of flexural testing. The position paper makes a recommendation to change specifications to base acceptance on compressive tests [9]. When the change to compressive tests are not possible, they recommend referee testing and an active partnership between the agency (or agent) and contractor to conduct strength testing.

FAA recognizes that sometimes disputes arise as to the validity of the flexural strength test results [10]. They provide guidance for referee testing when doubt exists as to the validity of the field tests. Improper specimen preparation or curing, mishandling of test beams, improper testing techniques, uncalibrated testing machines, and similar factors are often cited as reasons for questioning the flexural strength test results. The referee testing effort is conducted in order to develop further information on the in-situ concrete. The referee tests have been used to modify decisions that would have resulted from flexural tests alone.

Other authors have stated the need for additional research and improvements on the field fabrication and subsequent testing of flexural concrete beams as a result of high variability, and suggest that the data point to a need for a review of current (flexural) testing procedures [11, 12, 13, and 14].

A comparison between the precision statements contained in ASTM C-78 (5.7% for beams) with ASTM C-39 (2.4%/2.9% compressive cylinders) indicates that the coefficient of variation is about double for beams compared to cylinders.

Greer reported a special analysis of within-batch flexural beam variation [15]. An evaluation of the flexural beam data based on nine test results from the same batch tested at the same age showed a range of results of 90 psi. By making different groups of three results from each of the individual nine results, he was able to show that the data itself is very sensitive to which individual test results are used. This demonstrates the high within-test variability of this process.

NRMCA reported that flexural beam standard deviations of 40 to 80 psi indicated good testing control, and values over 100 psi indicated testing problems [16].

Despite the reported variability of flexural strength testing of concrete beams, the fact remains that it is the most direct measurement of the relevant design property. Therefore, it is important to better understand, quantify, and control this variability to the extent possible.

2.4 FIELD AND MATERIAL FACTORS WHICH INCREASE VARIATION IN BEAM MOLDING, HANDLING, AND CURING.

From the literature, the following factors were identified as important effects on variability when making and testing beams:

Consolidation of the specimen. Poorly compacted concrete will produce lower strength. Slipform paving mixes, in accordance with P501 guidance, have between .5 and 1.5 inches of slump [11]. Consolidation of these low slump concretes in test specimens is more difficult than consolidation of more moderate slump concrete. Difficulties in consolidation can be related directly to lower strength and weight in flexural specimens.

Flexural beam variability increases with increases in nominal maximum size of coarse aggregate [11].

Flexural beam variability increased as the quantity of coarse aggregate is increased [11]. Concrete mixes with larger coarse sizes and quantities are often developed for concrete paving to reduce shrinkage and improve economy.

Flexural strength of concrete is extremely sensitive to the moisture distribution within the specimen. ASTM C-31 emphasizes: "Relatively small amounts of surface drying of flexural specimens can induce tensile stresses in the extreme fibers that will markedly reduce the indicated flexural strength."[6] Protection of the flexural specimens from early drying until the time of testing is an important factor in controlling variation. PCA reported on flexural beam specimens from seven days through 20 years under five different curing conditions [17]. Abrupt changes between moist and dry conditions were observed to cause 20 to 30 percent decreases in flexural strength.

Flexural test specimens can be greatly affected by jostling, changes in temperature, and exposure to drying, particularly within the first 24 hours after casting." The PCA suggests compressive-strength tests be used to monitor concrete quality after a mix-specific empirical relationship is developed in the laboratory to avoid problems associated with flexural-strength testing in the field [13].

Non-compliance with the ASTM C-31 initial curing requirements is often the case on projects and will contribute to reduced strength and increased variability of flexural test results. Greer noted "Concrete specimens made in Atlanta in winter may be placed in a box with a light bulb to keep them from freezing; however, the temperature is not controlled [15]. In addition, the concrete specimens are seldom, if ever, maintained below 80°F on hot summer days." NRMCA reported on the effects of non-standard curing temperatures on strength of concrete [18]. While this work was on concrete cylinders, the same principles would apply to concrete beams. Strength losses of 22 percent at 28 days were noted for concrete initially cured below or above the specified 60-80°F for the first 48 hours. The comparative strength losses at 90 days were less (10 to 16 percent) in this same study due to non-standard curing temperatures.

ACI 214 "Evaluation of Strength Test Results of Concrete" currently only deals with variability of compressive cylinders [19]. However, the concepts identified provide a useful list of factors that would affect variation in flexural beams including:

- Improper sampling procedures
- Variations due to fabrication techniques; handling, storing of newly made specimens
- Poor quality, damaged, or distorted molds
- Changes in curing; temperature variation, variable moisture control, delays in transportation of specimens to the laboratory, delays in beginning standard curing
- Poor testing procedures; specimen preparation, test procedure, uncalibrated testing equipment

2.5 TESTING VARIABILITY FACTORS.

Rate of loading, calibration, test equipment evaluation. ASTM specifies a "constant rate" between 125 and 175 psi until rupture occurs [6]. Various types of testing equipment are used to conduct flexural beam testing in the field [20, 21]. Often, beam testing is conducted with hydraulic testing equipment primarily designed for high-hydraulic loads (compressive testing) modified with a "flexural beam attachment." This equipment is often operated at 10 percent or less of its rated capacity. Maintaining the correct control on rate-of-loading can be difficult with this type of equipment. While not required by the P-501 specification, testing equipment manufacturers offer equipment specifically designed and developed to meet the lower rate-of-loading control requirements for testing flexural concrete beams [20, 21]. This equipment either has electronic control of the rate-of- loading or provides the operator with real-time "load pace" information, thus reducing operator error and provides a record of rate-of-load and peak stress for each beam tested. Use of this type of equipment would likely reduce this potential source of variation.

Several states have developed specifications that address these test equipment and operator issues [22, 23, 24]. These requirements allow the use of test equipment developed only for the testing of flexural beams, including evaluation and calibration requirements.

Pre-testing moisture control. Several authors caution that even small amounts of surface drying occurring immediately prior to testing of flexural specimens can markedly reduce the strength [11, 15, 16]. Beams must be continuously kept moist until the time of test.

Pre-loading gap determination. Strict procedures are required to identify and correct any gap deviations prior to fully loading the specimen [7].

2.6 SUMMARY.

The literature review examined the reported potential causes of variability in flexural strength test results, particularly from the work of Greer, Wright, and Carasquillo [14, 15, 7, and 5]. Many factors were identified which could affect flexural strength test results. Improved decision making regarding the quality on in-situ concrete is possible when these factors are better quantified and understood by all parties involved. Most of the variability factors identified for concrete flexural beams will result in a lower identified strength in the test specimen. Identified factors include material factors, field factors and testing parameters.

Conclusions from the literature indicate the following three items are important field factors which contribute to flexural beam test result variability.

- Specimen preparation/consolidation
- Initial cure deficiencies (temperatures)
- Rough handling/transportation

The following three additional factors relate to the testing process itself. It is believed that these three factors have been addressed within the existing precision statement for laboratory specimens.

- Specimen surface drying prior to testing
- Rate of loading deviations
- Pre-loading gap determination and correction

A number of material factors were also indicated by the literature to increase flexural beam variability. These factors include increases in nominal maximum size of coarse aggregate and increased quantity of coarse aggregate. The flexural strength of concrete is also extremely sensitive to the moisture distribution within the specimen.

Therefore, the results of this literature review identify the first three field factors—specimen preparation, curing control, and handling during transportation—as being very important in obtaining good flexural strength test results. Improved decision making regarding the quality of in-situ concrete will be possible when these factors are better quantified and understood by the parties involved in flexural beam sampling and testing. Controlling these factors was thus given priority in the development of the experimental plan.

3 EXPERIMENT DESIGN.

For development of the experiment design, review and full consideration was given to the relevant ASTM standards, including:

- C-31-06 *Making and Curing Concrete Test Specimens in the Field* [6],
- C-78-02 *Flexural Strength of Concrete* [7],
- C-802 *Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods for Construction Materials* [25], and
- C-670 *Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials* [26].

There were less than 10 labs AASHTO Materials Reference Library (AMRL) certified for ASTM C78 testing within a suitable transportation circumference of the concrete production facility selected for the experiment. In order to accommodate this, the six available certified labs were each asked to make eight beams, meeting the minimum number of six beams each required according to C-802, with additional beams in case unrepresentative specimens were identified, or one of the laboratories failed to meet the requirements of the experiment.

In addition, six labs with the C78 testing capabilities, but without current AMRL certification for the test, were included, also each making eight beams, under the same assumptions. For anticipated levels of variability reported in the literature, this would enable an adequate data pool to determine if the certified and not-certified labs produced flexural strength results that were statistically different. In the event that the results were not different, the results from all labs could be pooled to achieve the recommended minimum of 10 participating laboratories [8].

The experimental matrix was expanded to include three different concrete mixes with different target flexural strength values. The original mix tested was one previously used by the supplier for FAA work at the Erie, PA airport. This mix was found to produce approximately 950 psi flexural strength at 28 days. The goal for the second and third concrete mixes was to target flexural strengths of 750 psi and 550 psi to provide a range of strength results.

4 TEST SPECIMEN PRODUCTION, HANDLING, AND TESTING.

The concrete mixes were developed in accordance with FAA P-501 specification requirements. For the flexural strength experiment, the mixes were produced at a single batching facility, using the same materials with revisions in the mix proportions to achieve different target strengths. The original seven sack mix provided strength higher than desired, so it was determined that the most effective means for reducing the strength was to reduce the cement content for mixes two and three. Thus, mix two contained six sacks of cement, and mix three contained five sacks. These mixes were batched consistent with slipform paving criteria. Mix one was batched at 3/4 in. slump. This was found to result in inadequate time to mold all samples without affecting the results. This is subsequently discussed further. As an adjustment, mix two was batched at 2 in. initial slump, which was found to provide better test results. The water content for mix three was increased further as a precaution against having a harsh mix with the lower cement factor, and to help keep strength values low.

Prior to testing, a scope of work (Appendix A) and subcontract agreement were sent to each testing laboratory. Signed subcontract agreements were obtained before the field experiment could be undertaken. On batching day the technicians from all participating laboratories were assembled and reviewed an ACI training video (figure 1) on flexural beam casting and testing [27]. This was followed by a discussion of factors the assembled technicians had witnessed, and which they believed could cause variability in test results.

FIGURE 1. TECHNICIANS ASSEMBLED FOR ASTM C78 REVIEW AND FIELD TECHNICIAN VARIABILITY FACTORS DISCUSSION

Variations in testing and handling identified by the technicians included: casting beams on an incline, leaving specimens uncovered and exposed to the elements during cure, early stripping to produce results in less than two days, striking specimens with hard objects such as metal hammers or reinforcing bars to remove beam forms, "tossing" of specimens into a pickup truck, and transporting beams unprotected in the back of a pickup truck. While not all of these events witnessed by the technicians are seen frequently, actions which result in rough handling such as improper mold removal and unprotected transport were considered to be more prevalent than the problem of not having adequate cover during curing.

4.1 ROUND ONE TESTING.

Concrete was batched on July 7th, 2009 in Erie, Pennsylvania at the Austin/ServAll batch plant. The concrete mix parameters are shown in table 1. Laboratory technicians were gathered from Pennsylvania, Ohio, and New York, and had varying travel distances from three miles up to 140 miles. Laboratories from the Pittsburgh, Cleveland, and Buffalo areas had access to the production plant via interstate highways, so reasonable travel times on the order of two hours maximum were anticipated. Among the labs, six were AMRL certified specifically for ASTM C78 testing and six were not. Several of the labs had additional certifications for concrete testing, but the research team used the C78 AMRL certification as a variable to evaluate uniformity between certified and not-certified labs.

TABLE 1. CONCRETE BATCH PARAMETERS PER CUBIC YARD FOR ROUND ONE

Target Strength (psi)	Type 1 Cement (lb)	#57 Limestone (lb)	Concrete Sand (lb)	Water, Includes Agg. Moisture (lb)	Air (%)	Water/ Cement Ratio	Unit Weight (lb/cu.ft.)
700	658	1700	1195	263	6	0.40	141.30

On batching day, the test batch was cast inside the concrete supplier's garage facility where the samples were protected from sun and direct wind, as shown in figure 2. The 12 technicians molded eight test specimens each. The concrete was batched at 11:15 a.m. and provided in truck number 51. The truck was given instructions to drive around locally for 20 minutes prior to discharge to simulate delivery to a paving operation. The outside air temperature was 80°F while the indoor temperature was 74°F. Humidity readings were taken at the time of casting with outdoor humidity of 48.9% and indoor humidity of 52.8%. Discharge of the concrete batch began at 11:46 a.m. with uniformity testing completed at 12:14 p.m. The results of uniformity testing for slump, air, temperature, and unit weight are provided in table 2. Casting of specimens started after uniformity testing was completed and finished at 1:32 p.m. Four-mil plastic sheeting was placed on top of the beams to maintain the beam moisture condition during curing and to protect the beam surfaces from any dust rendered airborne by the casting activities. Beams were left where they had been cast for initial field cure. Doors to the garage were kept closed overnight to simulate being placed in an area on site that is protected from wind and direct exposure to sunlight. The garage area used for the experiment was normally used as truck storage, so to protect the beams from truck traffic, large concrete blocks were placed at the entrance to prevent vehicles from entering. A security fence enclosing the garage prevented tampering by the general public.

FIGURE 2. CASTING IN CONCRETE SUPPLIER'S GARAGE FACILITY

TABLE 2. RESULTS OF UNIFORMITY TESTING FOR SLUMP, AIR, TEMPERATURE, AND UNIT WEIGHT

Test Sample Number and Timing	Slump (in)	Air (%)	Unit Weight (lb/cu.ft.)
1-Before Travel	1.00	5.4	NA
2-First Third	0.75	4.5	146.6
3-Second Third	0.75	4.5	147
4-Last Third	0.75	4.4	147.6

The specimens were field cured for two days at the casting site. After the two-day field cure, but within the 48 hours specified by ASTM, the 12 laboratory technicians returned to the site to strip the molds and place all beams in temperature-controlled water baths for the remainder of the 27 days before pick up. The specimens were control cured in limewater bath tanks, inside the garage facility, consistent with the ASTM C31 specification (72°F ± 3). The curing tanks were galvanized steel tanks typical of those used by testing laboratories nationwide, with a multi-tank recirculation system to ensure limewater temperature uniformity across all tanks (figure 3). A climate-controlled enclosure was built around the curing tanks using 2-in.-thick styrofoam board insulation to ensure that curing conditions were kept at optimal levels while the garage temperature fluctuated during the curing period. A portable air conditioning unit was inserted into the styrofoam chamber to maintain even temperature (figure 4). After all beams were placed in the curing tanks, additional styrofoam board was placed in front of the tanks as well as on top of the enclosure, creating a room that was sectioned off from the remaining garage facility. As an added means of moisture retention, a 4-mil layer of plastic was draped over the entire enclosure. Temperature fluctuations observed in figure 5 for the first 48-hour period ranged from 61°F to 78°F. With the enclosure in place, the variations in air temperature around the tanks were reduced as shown in figure 6. During the curing period, a member of the research team examined the integrity of the curing enclosure by removing the plastic sheeting, top panels of Styrofoam board, and the front panels of Styrofoam board at least once a week, and found that the enclosure was effectively maintaining temperature and moisture levels.

FIGURE 3. CURING TANKS SHOWN WITH SINGLE PUMP RECIRCULATION SYSTEM INSTALLED

FIGURE 4. AIR CONDITIONING UNIT INSTALLED IN STYROFOAM ENCLOSURE

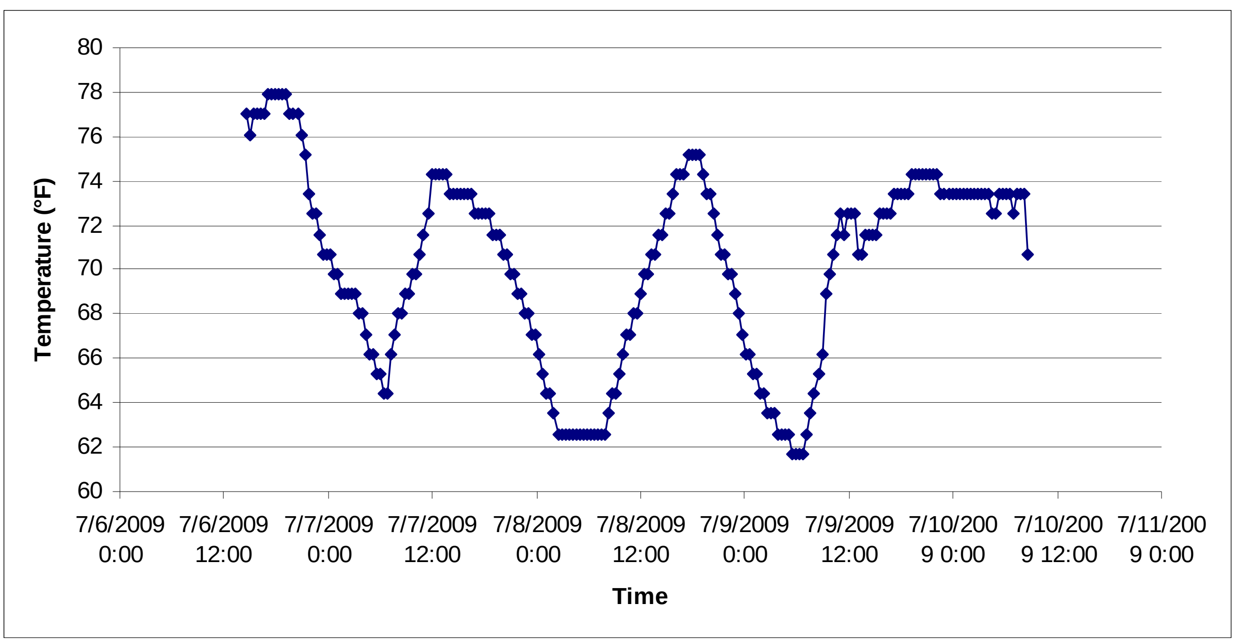

FIGURE 5. TEMPERATURE OF CURING ENCLOSURE DURING INITIAL CURE

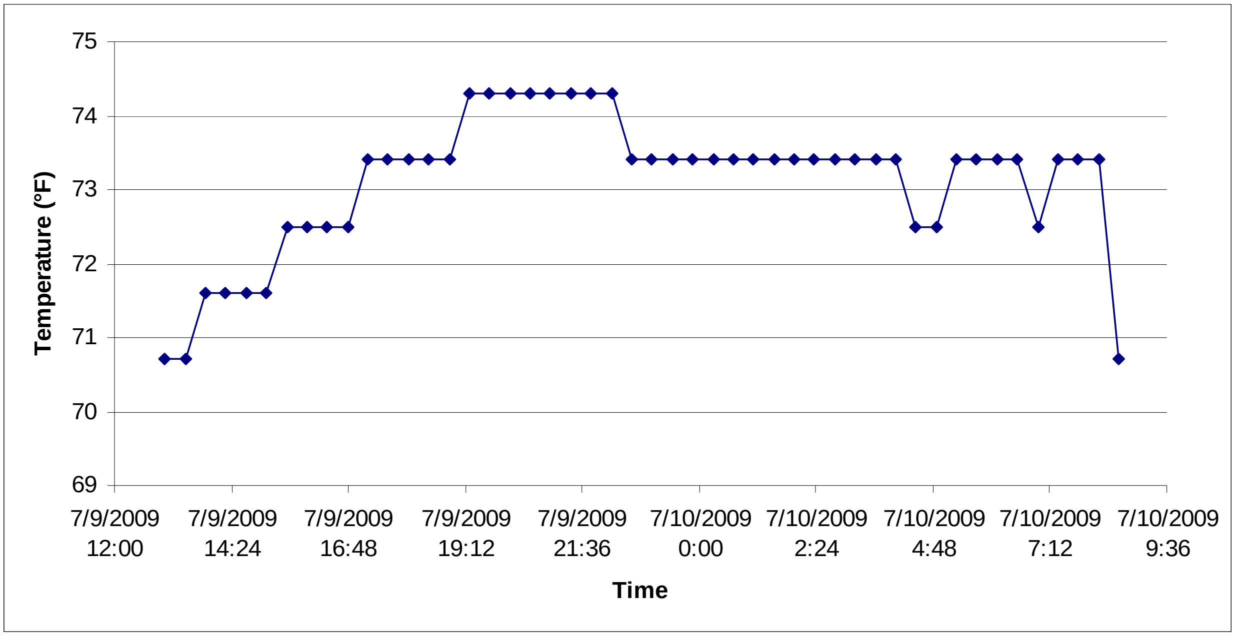

FIGURE 6. EXAMPLE TEMPERATURE VARIATIONS WITHIN STYROFOAM CURING ENCLOSURE

The technicians returned on the 27th day after casting to pick up the specimens and transported them to their individual labs for testing. All specimens were then placed in water bath cure tanks at the individual laboratories for a minimum of 20 hours prior to testing on the 28th day. Protective transportation boxes were provided to the technicians for moving the beams to their own labs. The boxes were constructed of 0.75-in plywood, and lined with 4-mil plastic sheets and carpet scraps to pad the specimens during transportation, as shown in figure 7. Care was taken to assure the specimens remained in cure while being transported to the individual laboratories for testing by soaking the carpet in the limewater curing tanks before the carpet and beams were placed in the curing boxes.

A data collection form was designed by the research team, and provided to each laboratory with specific instructions for data collection. The specific information requested, including loading rate, gap measurement, beam size, beam weight, moisture condition, temperature, and other information about the test conditions, is shown on the modified laboratory data sheet in figure 8. The completed sheets, in a consolidated form with lab-identification information removed, are included in Appendix B.

FIGURE 7. TRANSPORTATION BOXES LINED WITH WET CARPET

The initial concrete mix was batched at a low water cement ratio representative of slipform paving (3/4 in.). However, the technicians were not able to complete the molding of all specimens within the 90-minute time allotted in the ASTM C31 test procedure. Due to the extended casting period and the low water cement ratio, the mix began to set up and thus became too stiff to cast quality beam specimens. Each technician cast four beams first, and then subsequently cast four additional beams. As a result, some of the beams from the second sequence were identified as poorly consolidated, and were excluded from the final analysis. The project team was aware of the problem at the time of casting, and beams with known voids or poor consolidation were specially marked during stripping. While marking for poor consolidation, the research team observed that all beams with known voids or poor consolidation could be visually distinguished from the higher quality beams based on visible surface voids and exposed aggregate, as illustrated in figure 9.

Upon initial inspection, the research team found that all labs had at least 4 good beams. The beam densities for these specimens were found to differ from those samples of similar dimensions, further confirming the molding problem. The resulting flexural strengths from these beams were consistently and significantly lower than for the unmarked beams. Therefore, the poorly consolidated beams were all excluded from the subsequent statistical analysis.

C-78 Amplified Data Report

Lab. ID Number	Beam ID Number	(*1) Beam Weight	Ambient Temperature at Time of Test	Time Between Removal from Cure & Start of Test (<20 min.)	(*2) Moisture Condition (Photo)	GAP Measurement (load applying blocks)	GAP Measurement (at support blocks)	Average Width to the Nearest .05 inch	Average Depth to the nearest .05 inch	Span Length in Inches	Rate of Loading (attach chart if available)	Max. Applied Load (lbs)	MOR to nearest 5 PSI	(*3) Location Of Fracture (Photo)	1 Hour Oven Dried Moisture Content of Broken Sample at 110°F ±5° (%)	Note Defects: if capped if ground if shims used Addl. Comments use reverse & identify by Beam ID #

(*1) Beam Weight: Measure to nearest 1/10 lb.

(*2) Moisture Condition Definitions (include photo): SD = Surface Dry SM = Surface Moist SW = Surface Wet

(*3) Location Of Fracture (include photo): Measure inches from short end of beam to bottom of fracture

Curing History:			
Transportation Time (hrs/mins):		Transportation Miles:	

Field Technician ID Signature ______________ Printed Name ______________ Date Conducted ______________

Lab Technician ID Signature ______________ Printed Name ______________ Date Conducted ______________

FIGURE 8. AMPLIFIED DATA RECORDING WORKSHEET AS SUPPLIED TO THE TESTING LABORATORIES

FIGURE 9. LAB 12 BEAM WITH KNOWN VOIDS AND POOR CONSOLIDATION

Detailed photos obtained subsequent to the testing showed that all 8 beams from lab 4 were poorly consolidated, as shown in figures 10 and 11. Therefore, all lab 4 beams were removed from the final analysis of data for the first concrete batch.

FIGURE 10. LAB 4 BEAM 1 VOIDS AND POOR CONSOLIDATION

FIGURE 11. LAB 4 BEAM 7 VOIDS AND POOR CONSOLIDATION

4.2 ROUND TWO TESTING.

The second concrete batch was cast with only six sacks of cement (table 3). Casting took place at the same location in Erie, PA on October 20, 2009 with 10 of the initial 12 laboratories present. On October 20th, one of the laboratories was unable to travel to the site because of unexpected scheduling conflicts and illness, so eight sample specimens were cast for them by another technician. The laboratory that was not able to make the round two batch day was still responsible for stripping and testing of the samples cast for them and all duties required for round three. Lab 3 was not able to participate in rounds two and three and so the research team decided to remove the data from Lab 3 from all rounds of testing. Thus, 11 of the original labs renewed their work agreement for the experimental testing in rounds two and three.

TABLE 3. CONCRETE BATCH PARAMETERS FOR ROUND TWO

Target Strength (psi)	Type 1 Cement (lb)	#57 Limestone (lb)	Concrete Sand (lb)	Water, Includes Agg. Moisture (lb)	Air (%)	Water/ Cement Ratio	Unit Weight (lb/cu.ft.)
650	564	1732	1315	237	6	0.42	141.81

In round two of concrete batching and testing, specimens were cast using the same procedure outlined in round one with some variances as presented herein. Ready mix truck number 171 was used for round two, and the "transport" time was reduced to five minutes, to make additional time available for molding to mitigate the concrete set up problems experienced in round one.

Labs were also instructed to complete beams as shovels and vibrators became available to reduce the casting time for each beam.

Since it was later in the year, environmental conditions for rounds two and three differed from those of round one. The round two concrete was batched at 12:15 p.m. and the outside air temperature was 55°F, while the indoor temperature was 50°F. Discharge of the concrete batch began at 12:30 p.m. with uniformity testing completed at 12:44 p.m. The results of uniformity testing for slump, air, temperature, and unit weight can be found in table 4. Casting of specimens started after uniformity testing was completed and was finished at 1:12 p.m. The beams were protected from exposure and tampering in the same way as round one with plastic placed on the beam surface, a closed garage door and all the protections provided by the concrete blocks and security gate. Temperatures inside the building were monitored using high-low thermometers at several locations around the garage and a high temperature of 72°F and a low temperature of 61°F were observed during field cure. An anticipated overnight low air temperature of 45°F was mitigated using the overhead heating system in the garage facility and by opening and closing the garage doors.

The completed sheets, in a consolidated form with lab-identification information removed, are included in Appendix C.

TABLE 4. RESULTS OF UNIFORMITY TESTING FOR SLUMP, AIR, TEMPERATURE, AND UNIT WEIGHT

Test Sample Number and Timing	Slump (in)	Air (%)	Unit Weight (lb/cu.ft.)
1-Before Travel	2	6.4	NA
2-Add 6 Gallons	0.75	5.4	NA
3-First Third	1.75	5.4	143.84
4-Second Third	1.75	5.2	147.44
5-Last Third	1.5	5.2	143.04

4.3 ROUND THREE TESTING.

The technicians returned to Erie on October 22, 2009. The specimens from the second round were stripped, and placed in the temperature controlled limewater bath cure tanks. The tanks were maintained within the styrofoam insulated space as they were in round one, but water heaters were installed in place of the air conditioning unit to maintain the C31 temperature range of 72°±3°F. Water was circulated among the tanks by a re-circulating system that was expanded from that installed in round one.

Following the stripping of round two beams, cleaning and reassembly of beam molds, the third concrete batch was produced with five sacks of cement to further reduce the strength. In addition, the water content was slightly increased to protect against having problems with the mix being harsh and stiffening prematurely. The concrete batch weights can be found in table 5. The concrete was provided in truck number 200 in the same fashion as the second round. Eight gallons of additional water was added to increase slump to the target 2-in. value. The batch time for round three was 12:42 p.m. with an outside temperature of 66°F and indoor temperature of 60°F. Initial discharge was at 1:10 p.m. with uniformity testing completed at 1:20 p.m. The results of uniformity testing for slump, air, temperature, and unit weight can be found in table 6. The technicians again molded eight specimens for testing, and placed them in field cure, as with the previous rounds. The high temperature observed in the garage during the field cure of round three beams was 70°F, and the low was 60°F.

TABLE 5. CONCRETE BATCH PARAMETERS FOR ROUND THREE

Target Strength (psi)	Type 1 Cement (lb)	#57 Limestone (lb)	Concrete Sand (lb)	Water, Includes Agg. Moisture (lb)	Air (%)	Water/ Cement Ratio	Unit Weight (lb/cu.ft.)
500	470	1735	1533	207	6	0.44	143.01

TABLE 6. RESULTS OF UNIFORMITY TESTING FOR SLUMP, AIR, TEMPERATURE, AND UNIT WEIGHT

Test Sample Number and Timing	Slump (in)	Air (%)	Unit Weight (lb/cu.ft.)
1-Before Travel	1.25	5.5	NA
2-Add 8 Gallons	1.5	5.9	142.64
3-Second Third	1.50	5.6	143.44
4-Last Third	1.00	5.6	139.44

The technicians returned to Erie on October 24, 2009 to strip the round three specimens, and place them in the cure tanks with those from round two. The curing tanks were then enclosed with the 2-in. styrofoam board insulation with several maximum-minimum thermometers to monitor the air temperature around the curing tanks. Curing temperature was monitored manually for rounds 2 and 3 because the electronic sensor installed for that purpose failed. Therefore, the data was collected at intervals of several days to limit the trips to the site. The temperature range of the curing tanks during round two and three curing was recorded from 72°F to 75°F.

Technicians picked up the beam specimens from round two on November 16, 2009 and from round three on November 18, 2009. Actual testing of the samples at the individual laboratories was carried out on November 17 and November 19. Results of C78 beam testing were reported to the research team within three weeks of testing due to the Thanksgiving holiday.

The completed sheets, in a consolidated form with lab-identification information removed, are included in Appendix D.

5 ANALYSIS OF FLEXURAL TEST RESULTS.

5.1 FIRST ROUND RESULTS.

5.1.1 Summary and Descriptive Statistics for First Round.

The data submitted from the ten laboratories were collected and summarized. The data were then analyzed from several perspectives, including within-laboratory variation, between-laboratory variation, and overall data variability. The tabulated data were converted to an entirely numerical format for statistical analysis, using data codes for non-numeric notations from the laboratory worksheets.

For the simplest and most consistent analysis, and to avoid any concerns about apparent elimination of outliers due to the consolidation problems, only the first four beams were used from each laboratory in the final analysis. This also avoids an unbalanced experiment with different numbers of beams from different laboratories, as suggested by ASTM C-802 [25]. The reported flexural strength results for those beams are shown in table 7.

After excluding the poorly consolidated beams, the results from the certified and not-certified labs were found to be indistinguishable in terms of both mean and variability at the 95 percent confidence level. The mean flexural strength reported by the not-certified labs was 878 psi, with a standard deviation of 43 psi. The mean flexural strength reported by the certified labs was 847 psi, with a standard deviation of 47 psi. Therefore, an adequate number of laboratories and beams were still available for analysis, despite the consolidation problems. For the subsequent analysis of the first round data, the results from the certified and not-certified labs were pooled.

TABLE 7. FIRST ROUND FLEXURAL STRENGTH RESULTS FOR TEN LABS, FOUR BEAMS

Lab ID	Flexural Strength (psi)					Within Lab Variance	Within Lab Standard Deviation
	a	b	c	d	Average		
1	790	820	815	785	803	308	18
2	880	870	960	900	903	1625	40
5	820	880	935	800	859	3740	61
6	890	895	910	890	896	90	9
7	875	895	840	810	855	1417	38
8	730	781	875	805	798	3630	60
9	880	900	945	920	911	773	28
10	785	835	825	960	851	5723	76
11	770	895	910	890	866	4190	65
12	850	925	850	785	853	3275	57

The following parameters were calculated as per the provisions of ASTM C-802, with supplemental summary statistics provided:

- The overall average flexural strength was 859 psi, with laboratories reporting values between 798 psi and 911 psi.
- Within-laboratory standard deviations varied from 9 psi to 76 psi, with an average within-laboratory standard deviation of 47 psi.
- The pooled within-laboratory variance was 2477 $(psi)^2$.
- The variance of laboratory averages was determined to be 1458 $(psi)^2$, and the standard deviation of laboratory averages was 38 psi.
- The between-laboratory component of variance was 839 $(psi)^2$, which is significantly less than the within-laboratory variance.

5.1.2 Investigation of Agreement of Variances.

In addition to the finding that there was not a significant difference between the certified and not-certified labs in terms of either mean or variability, it was also important to verify that the variances were reasonably the same in the different laboratories. This does not mean that the variances must be the same, but that they must meet statistical tests. The variances for the individual laboratories are plotted in figure 12. The certified labs are shown on the shaded bars, and the not-certified labs on the unshaded bars. The ratio of the largest variance to the sum of variances is 0.2310, which is less than maximum allowable value for 10 laboratories and 4 replicates (upper 5% level) of 0. 3733.

Unreasonably low variances for a laboratory were also investigated. The ratio of the highest to lowest variance was 64, which is less than the allowable value (upper 5% level) of 104. Therefore, based upon the first round of testing, all laboratories could be included in the estimates of precision.

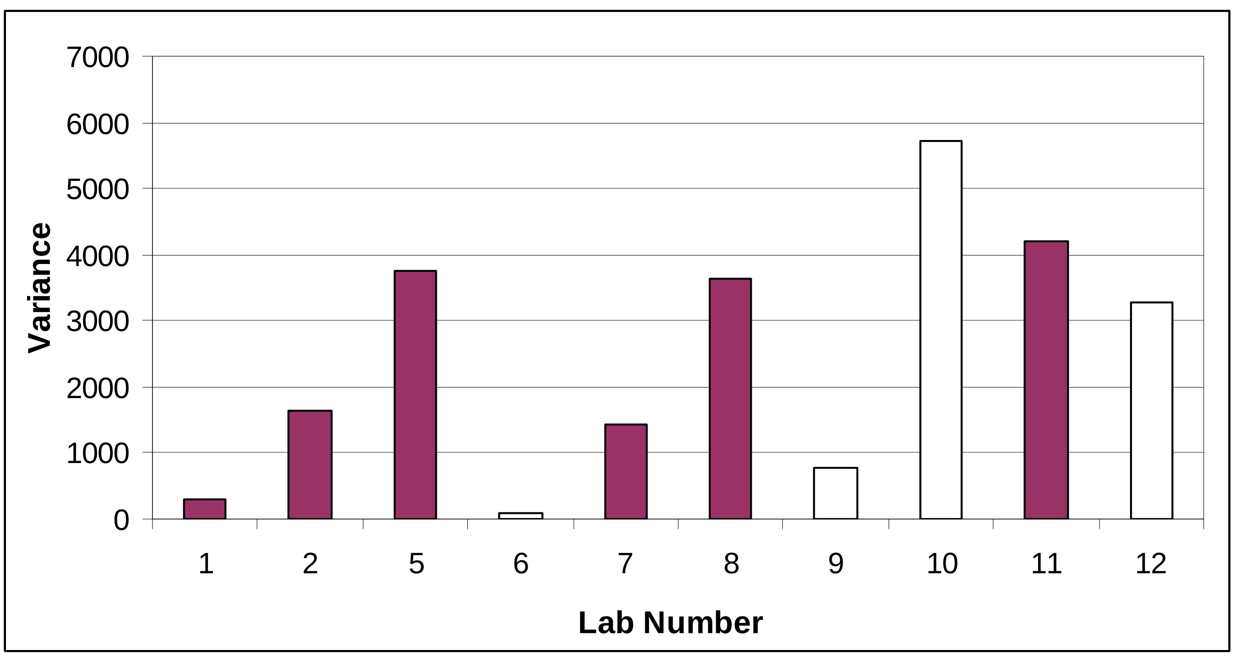

FIGURE 12. VARIANCE OF FIRST ROUND FLEXURAL STRENGTH (PSI) BY LAB NUMBER

5.1.3 Linear Regression for First Round.

Linear regression relating the recorded variables (from the data worksheets) to the reported flexural strength for each beam was conducted for the results from the first four beams, and also for all beams without consolidation problems. Within the controlled ranges maintained within this experiment for the recorded variables, only the ambient temperature at the time of testing was found to have a statistically significant impact on the reported flexural strength.

5.2 ANALYSIS OF SECOND ROUND RESULTS.

5.2.1 Summary and Descriptive Statistics for Second Round.

For the second round beams, no visual or testing parameters caused any beams to be eliminated from the analysis. To verify that there was not a progressive decrease in beam quality, analysis of variance was performed, comparing the statistical results of using only the first 4 beams, versus using all 8 beams. There was not a statistically significant difference between using 4 or 8 beams per lab in the analysis, at the 95% confidence level, verifying the observations during molding.

However, the results from the certified and not-certified labs were found to be significantly different in terms of both mean and variance for the second round, at the 95 percent confidence level. The summary statistics are therefore presented in this section both for the certified and not-certified labs separately, and then pooled.

5.2.1.1 Certified Labs, Second Round.

The flexural strength test results for round 2, from the certified labs, are summarized in table 8. The following bullets provide parameters that were calculated as per the provisions of ASTM C-802, with supplemental summary statistics provided.

TABLE 8. SECOND ROUND FLEXURAL STRENGTH RESULTS FOR SIX CERTIFIED LABS, EIGHT BEAMS

Lab ID	Flexural Strength (psi)									Within Lab Variance	Within Lab Standard Deviation
	a	b	c	d	e	f	d	h	Average		
1	835	850	745	770	805	830	820	795	806	1241	35
2	965	925	950	930	950	935	920	850	928	1221	35
5	780	740	785	825	870	815	925	815	819	3260	57
7	780	805	755	730	710	830	745	860	777	2671	52
8	755	800	860	815	720	800	855	785	799	2213	47
11	855	815	830	870	740	830	720	835	812	2864	54

- The overall average flexural strength for certified labs was 824 psi, with laboratories reporting values between 777 psi and 928 psi.
- Within-laboratory standard deviations for certified labs varied from 35 psi to 57 psi, with an average within-laboratory standard deviation of 47 psi.

- The pooled within-laboratory variance for certified labs was 2245 $(psi)^2$.
- The variance of laboratory averages for certified labs was determined to be 2837 $(psi)^2$, and the standard deviation of laboratory averages was 53 psi.
- The between-laboratory component of variance for certified labs was 2556 $(psi)^2$.

5.2.1.2 Not-Certified Labs, Second Round.

The flexural strength test results for round 2, from the not-certified labs, are summarized in table 9. The following bullets provide parameters that were calculated as per the provisions of ASTM C802, with supplemental summary statistics provided.

TABLE 9. SECOND ROUND FLEXURAL STRENGTH RESULTS FOR FIVE NOT-CERTIFIED LABS, EIGHT BEAMS

Lab ID	Flexural Strength (psi)									Within Lab Variance	Within Lab Standard Deviation
	a	b	c	d	e	f	d	h	Average		
4	1015	1085	1030	905	935	885	865	825	943	8257	91
6	1035	1030	1055	1030	1060	1115	1205	1060	1074	3570	60
9	945	935	925	780	830	805	935	825	873	4714	69
10	888	780	735	785	740	845	750	705	779	3721	61
12	925	980	880	835	1000	940	875	875	914	3284	57

- For not-certified labs, the overall average flexural strength was 916 psi, with ranges from 779 psi to 1074 psi.
- For not-certified labs, within-laboratory standard deviations varied from 57 psi to 91 psi, with an average within-laboratory standard deviation of 68 psi.
- The pooled within-laboratory variance for not-certified labs was 4709 $(psi)^2$.
- The variance of laboratory averages for not-certified labs was determined to be 11,606 $(psi)^2$, and the standard deviation of laboratory averages was 108 psi.
- The between-laboratory component of variance was 11,017 $(psi)^2$.

5.2.1.3 All Labs, Second Round.

The flexural strength test results for round 2, from all labs—certified and not-certified—were pooled for analysis, with the caution that the results from the certified and not-certified labs were statistically different. The following bullets provide parameters that were calculated as per the provisions of ASTM C802, with supplemental summary statistics provided.

- The overall average flexural strength for all labs was 866 psi, with reported values ranging from 777 psi to 1074 psi.
- Within-laboratory standard deviations varied from 35 psi to 91 psi, with an average within-laboratory standard deviation of 56 psi.
- The pooled within-laboratory variance for all labs was 3365 $(psi)^2$.
- The variance of laboratory averages was determined to be 8,408 $(psi)^2$, and the standard deviation of laboratory averages was 92 psi.

- The between-laboratory component of variance was 7988 $(psi)^2$, which is significantly greater than the within-laboratory variance.

5.2.2 Investigation of Agreement of Variances.

For the second round, the variances for the individual laboratories are plotted in figure 13. The certified labs are shown on the shaded bars, and the not-certified labs on the unshaded bars. For all results pooled, the ratio of the largest variance (for lab 4) to the sum of variances is 0.2231, which is less than the maximum allowable value for 11 laboratories and 6 replicates (upper 5% level) of 0.2810. The variance of lab 4 is well within the acceptable range, however. Furthermore, if the data from the certified and not-certified labs are separated, then all laboratories meet the criterion for large variances.

Unreasonably low variances for a laboratory were also investigated. The ratio of the highest to lowest variance was 7, which is less than the maximum allowable value for 6 replicates (upper 5% level) of 28. If certified and not-certified labs are considered separately, then the ratios of highest to lowest variances are 2.5 and 2.7, which are well within the acceptable range.

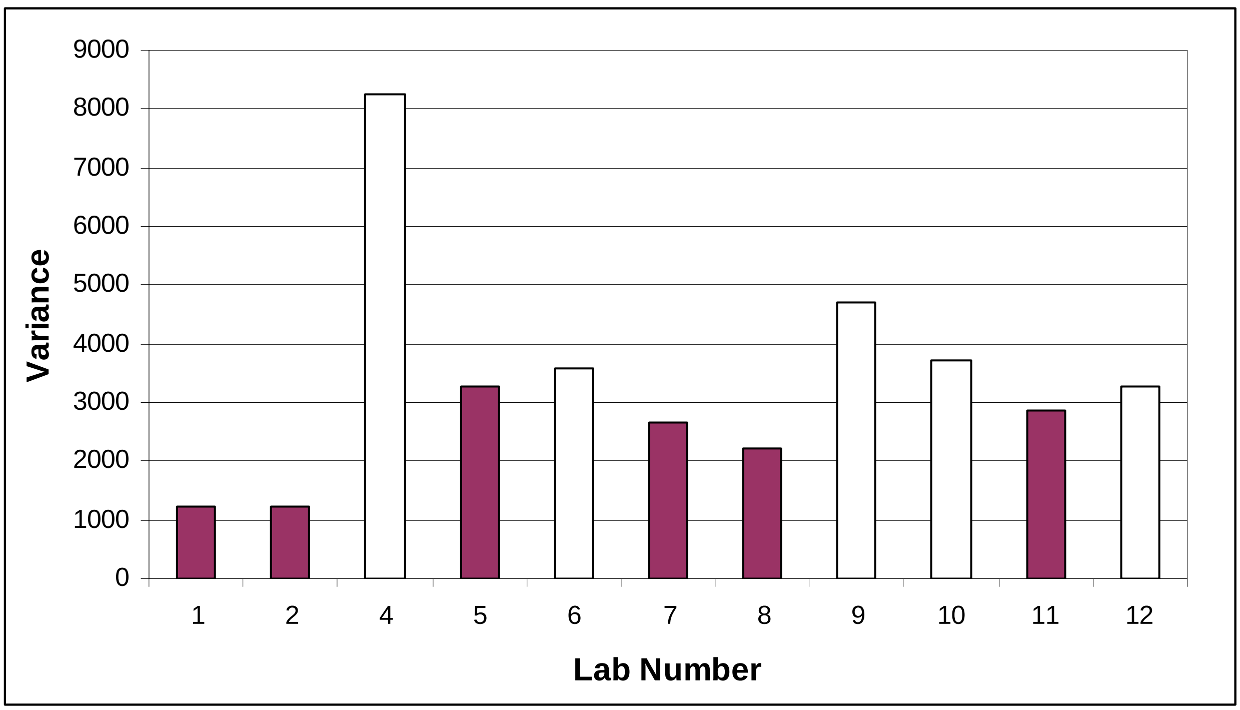

FIGURE 13. VARIANCE OF SECOND ROUND FLEXURAL STRENGTH (PSI) BY LAB NUMBER (CERTIFIED LABS ARE SHADED)

5.2.3 Linear Regression for Second Round.

Linear regression relating the recorded variables (from the data worksheets) to the reported flexural strength for each beam was conducted for all 8 beams from each laboratory. Within the controlled ranges maintained within this experiment for the recorded variables, the variable with the strongest relationship to reported flexural strength was the indicator for certified and not-certified labs, 1 or 0, respectively. Transport time/distance and moisture condition were also significant variables.

5.3 ANALYSIS OF THIRD ROUND RESULTS.

5.3.1 Summary and Descriptive Statistics for Third Round.

For the third round beams, no visual parameters caused any beams to be eliminated from analysis. However, the beam designated as "e" that was molded, transported and tested by lab 8, is a suspicious outlier. Since no physical reason was recorded, there was not a basis for discarding this result. It is included in the remaining analysis. Statistically, at the 95 percent confidence level, the results using all 8 beams or only the first 4 beams were not significantly different.

However, the results from the certified and not-certified labs were found to be significantly different in terms of both mean and variance for the third round, at the 95 percent confidence level. The summary statistics are therefore presented in this section both for the certified and not-certified labs separately, and then pooled.

5.3.1.1 Certified Labs, Third Round.

The flexural strength test results for round 3, from the certified labs, are summarized in table 10. The following parameters were calculated as per the provisions of ASTM C-802, with supplemental summary statistics provided:

- The overall average flexural strength for certified labs was 724 psi, with laboratories reporting values ranging from 659 psi to 810 psi.
- Within-laboratory standard deviations for certified labs varied from 15 psi to 95 psi, with an average within-laboratory standard deviation of 42 psi.
- The pooled within-laboratory variances for certified laboratories was 2463 $(psi)^2$.
- The variance of laboratory averages for certified labs was determined to be 4710 $(psi)^2$, and the standard deviation of laboratory averages was 69 psi.
- The between-laboratory component of variance for certified labs was 4402 $(psi)^2$.

TABLE 10. THIRD ROUND FLEXURAL STRENGTH RESULTS FOR SIX CERTIFIED LABS, EIGHT BEAMS

Lab ID	Flexural Strength (psi)									Within Lab Variance	Within Lab Standard Deviation
	a	b	c	d	e	f	d	h	Average		
1	665	720	670	665	710	660	705	730	691	810	28
2	780	870	725	880	835	800	820	770	810	2721	52
5	770	645	760	720	705	700	720	690	714	1563	40
7	670	655	685	690	625	650	655	675	663	450	21
8	695	705	655	695	430	730	675	685	659	9020	95
11	820	785	805	825	795	805	825	800	808	214	15

5.3.1.2 Not-Certified Labs, Third Round.

The flexural strength test results for round 3, from the not-certified labs, are summarized in table 11. The following bullets provide parameters that were calculated as per the provisions of ASTM C802, with supplemental summary statistics provided.

TABLE 11. THIRD ROUND FLEXURAL STRENGTH RESULTS FOR FIVE NOT-CERTIFIED LABS, EIGHT BEAMS

Lab ID	Flexural Strength (psi)									Within Lab Variance	Within Lab Standard Deviation
	a	b	c	d	e	f	d	h	Average		
4	1050	975	865	830	930	910	915	820	912	5821	76
6	750	705	735	705	750	720	730	700	724	403	20
9	720	695	720	780	815	700	760	770	745	1821	43
10	610	630	620	790	700	760	640	680	679	4498	67
12	840	700	810	765	750	705	785	790	768	2378	49

- For not-certified labs, the overall average flexural strength was 766 psi, ranging from 679 psi to 912 psi.
- For not-certified labs, within-laboratory standard deviations varied from 20 psi to 76 psi, with an average within-laboratory standard deviation of 51 psi.
- The pooled within-laboratory variances for not-certified laboratories was 2,984 $(psi)^2$.
- The variance of laboratory averages for not-certified labs was determined to be 7,767 $(psi)^2$, and the standard deviation of laboratory averages was 88 psi.
- The between-laboratory component of variance for not-certified labs was 7,394$(psi)^2$, which is substantially greater than the within-lab variability.

5.3.1.3 All Labs, Third Round.

The flexural strength test results for round 3, from all labs—certified and not-certified—were pooled for analysis, with the caution that the results from the certified and not-certified labs were statistically different. The following bullets provide parameters that were calculated as per the provisions of ASTM C802, with supplemental summary statistics provided.

- The overall average flexural strength for all labs was 743 psi, with reported values ranging from 659 psi to 912 psi.
- Within-laboratory standard deviations varied from 15 psi to 95 psi, with an average within-laboratory standard deviation of 46 psi.
- The pooled within-laboratory variance for all labs was 2700 $(psi)^2$.
- The variance of laboratory averages was determined to be 5,935 $(psi)^2$, and the standard deviation of laboratory averages was 77 psi.
- The between-laboratory component of variance was 5,598 $(psi)^2$, which is significantly greater than the within-laboratory variance.

5.3.2 Investigation of Agreement of Variances.

For the third round, the variances for the individual laboratories are plotted in figure 14. The certified labs are shown by the shaded bars and the not-certified labs by the unshaded bars. For all results pooled, the ratio of the largest individual laboratory variance (lab 8) to the sum of variances is 0.3034, which is slightly greater than the maximum allowable value of 0.2810 for 11 laboratories and 6 replicates (upper 5% level). Furthermore, if the data from the certified and not-certified labs are separated, interestingly only the not-certified lab group meets the criteria for large variances. For only the certified labs, the ratio is 0.6104, as compared to the maximum allowable value of 0.4447 for 6 laboratories and 6 replicates (upper 5% level). For not-certified labs, the value is 0.3901, as compared to the maximum allowable value of 0.5065 for 5 laboratories and 6 replicates (upper 5% level).

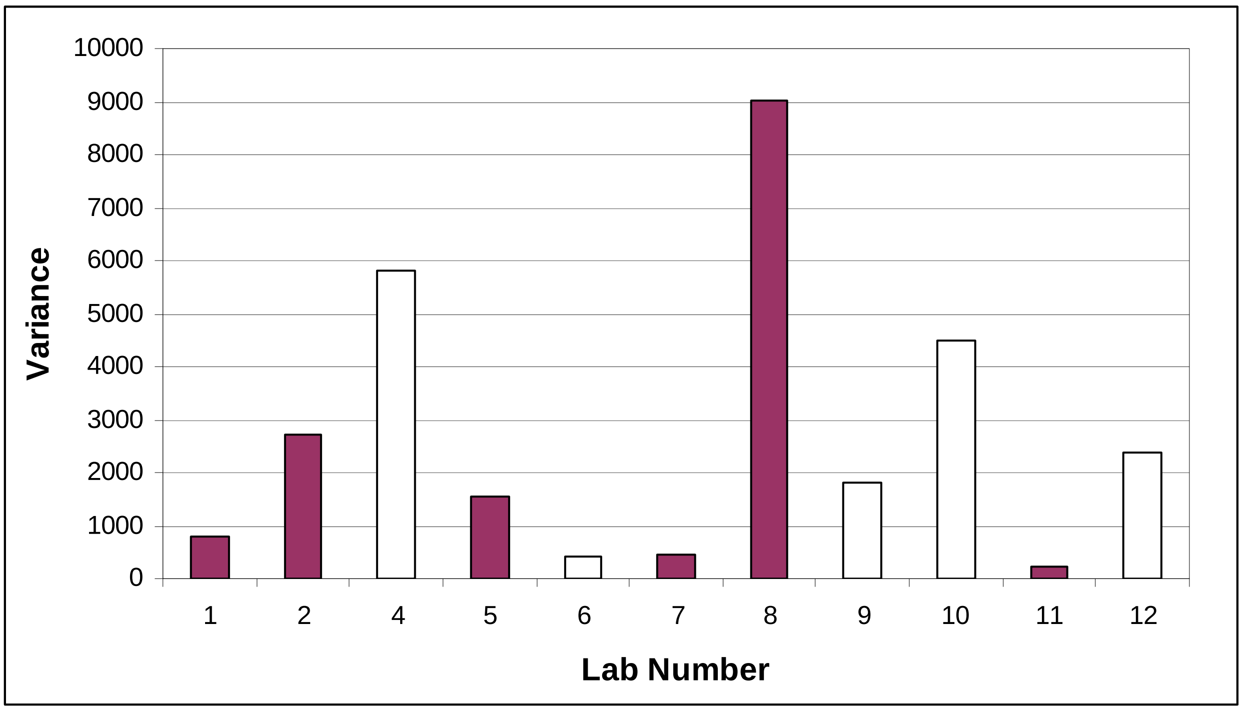

FIGURE 14. VARIANCE OF THIRD ROUND FLEXURAL STRENGTH (PSI) BY LAB NUMBER (CERTIFIED LABS ARE SHADED)

Unreasonably low variances identified for a laboratory were also investigated. The ratio of the highest to the lowest variance was 42, which is greater than the maximum allowable value of 28 for 6 replicates (upper 5% level). If certified and not-certified labs are considered separately, then the ratios of highest to lowest variances are 42 and 14, respectively. The maximum allowable value for 6 labs and 6 replicates (upper 5% level), as applies to the certified labs is 19. The maximum allowable value for 5 labs and 6 replicates (upper 5% level), as applies to the not-certified labs is 16. Thus, the certified labs are outside the maximum allowable range, while the not-certified labs are below the maximum allowable range.

The flexural strength test results for round 3 fail most of the agreement and consistency checks suggested in ASTM C802. This does not inherently mean that the data must be discarded, but does necessitate a careful assessment of why the results are so erratic. If this happens for multiple materials, then it suggests a reassessment of aspects of the test method may be required.

5.3.3 Linear Regression for Third Round.

Linear regression relating the recorded variables (from the data worksheets) to the reported flexural strength for each beam was conducted for the results from all beams. Within the controlled ranges maintained within this experiment for the recorded variables, the variable with the strongest relationship to reported flexural strength was loading rate at the time of test. However, for this round of testing, many of the testing variables, as well as moisture conditions and transport variables, were significant. One notable item is that the certified/not-certified indicator was not found to be significant in this linear regression analysis. The probable reason is the overall erratic behavior of this round of material and testing.

5.4 COMPARISON OF CERTIFIED AND NOT-CERTIFIED LABS FOR ALL ROUNDS.

The testing results from all three rounds was pooled (using only 4 beams from round 1), and separated by certification status. Analysis of variance (ANOVA) was conducted to check whether there is a significant difference between certified labs and not-certified labs for all pooled data. The results confirmed the anticipated findings from the analysis of the individual rounds. The mean and variance from the not-certified group are higher than those from the certified group, indicating that there might be a significant difference between them. The ANOVA confirms this assumption with a p-value significantly smaller than the value of 0.05 to indicate a difference at the 95% confidence level.

5.5 DEVELOPMENT AND SUMMARY OF ESTIMATES OF PRECISION.

There were several complicating factors in developing the estimates of precision:

- Laboratory 3 was eliminated, because they could not participate in rounds 2 and 3.
- Consolidation problems caused only the first 4 beams to be consistently viable for use from round 1. For the most consistency, only the first 4 beams should be used from all rounds. However, this does not take advantage of the full pool of data. (It also eliminates the one extreme outlier.)
- Laboratory 4 had consolidation problems for all 8 round one beams. However, they did participate in the subsequent rounds.
- For rounds 2 and 3, there is a statistically significant difference in both the mean and variability of results from the certified and not-certified labs. Will pooling those results make a significant difference in the final estimates of precision?
- The results from round 3 exceed the ASTM C802 consistency of variance limits.
- The average strengths from the three rounds do not cover the desirable range.

Therefore, the tables for estimates of precision were developed for four case scenarios, as shown in tables 12 through 19.

5.5.1 Case a: Round 1 (1^{st} 4 Beams), Rounds 2 and 3 (8 Beams from Certified Labs Only).

TABLE 12. AVERAGE, COMPONENTS OF VARIANCE, AND VARIANCES FOR ROUND 1 (4 BEAMS), CERTIFIED LABS ONLY FOR ROUNDS 2 AND 3 (8 BEAMS)

Round	Average	Components of Variance $(psi)^2$		Variance $(psi)^2$	
		Within-Laboratory	Between-Laboratory	Within-Laboratory	Between-Laboratory
3	724	2463	4402	2463	6865
2	824	2245	2556	2245	4801
1	859	2477	839	2477	3316

TABLE 13. AVERAGE, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIANCES FOR ROUND 1 (4 BEAMS), CERTIFIED LABS ONLY FOR ROUNDS 2 AND 3 (8 BEAMS)

Round	Average	Standard Deviation $(psi)^2$		Coefficient of Variation $(psi)^2$	
		Within-Laboratory	Between-Laboratory	Within-Laboratory	Between-Laboratory
3	724	50	83	6.9	11.4
2	824	47	69	5.8	8.4
1	859	50	58	5.8	6.7

5.5.2 Case b: Round 1 (1^{st} 4 Beams), Rounds 2 and 3 (8 Beams from Not-Certified Labs Only).

TABLE 14. AVERAGE, COMPONENTS OF VARIANCE, AND VARIANCES FOR ROUND 1 (4 BEAMS), NOT-CERTIFIED LABS FOR ROUNDS 2 AND 3 (8 BEAMS)

Round	Average	Components of Variance $(psi)^2$		Variance $(psi)^2$	
		Within-Laboratory	Between-Laboratory	Within-Laboratory	Between-Laboratory
3	766	2984	7394	2984	10378
1	859	2477	839	2477	3316
2	916	4709	11017	4709	15726

TABLE 15. AVERAGE, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIANCES FOR ROUND 1 (4 BEAMS), NOT-CERTIFIED LABS FOR ROUNDS 2 AND 3 (8 BEAMS)

Round	Average	Standard Deviation $(psi)^2$		Coefficient of Variation $(psi)^2$	
		Within-Laboratory	Between-Laboratory	Within-Laboratory	Between-Laboratory
3	766	55	102	7.1	13.3
1	859	50	58	5.8	6.7
2	916	69	125	7.5	13.7

5.5.3 Case c: Round 1 (1st 4 Beams), Rounds 2 and 3 (8 Beams).

TABLE 16. AVERAGE, COMPONENTS OF VARIANCE, AND VARIANCES FOR ROUND 1 (4 BEAMS), ROUNDS 2 AND 3 (8 BEAMS)

Round	Average	Components of Variance $(psi)^2$		Variance $(psi)^2$	
		Within-Laboratory	Between-Laboratory	Within-Laboratory	Between-Laboratory
3	743	2700	5598	2700	8298
1	859	2477	839	2477	3316
2	866	3365	7988	3365	11353

TABLE 17. AVERAGE, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIANCES FOR ROUND 1 (4 BEAMS), ROUNDS 2 AND 3 (8 BEAMS)

Round	Average	Standard Deviation $(psi)^2$		Coefficient of Variation $(psi)^2$	
		Within-Laboratory	Between-Laboratory	Within-Laboratory	Between-Laboratory
3	743	52	91	7.0	12.3
1	859	50	58	5.8	6.7
2	866	58	107	6.7	12.3

5.5.4 Case d: Rounds 1, 2 and 3 (1st 4 Beams).

TABLE 18. AVERAGE, COMPONENTS OF VARIANCE, AND VARIANCES FOR ALL TEST ROUNDS, 4 BEAMS

Round	Average	Components of Variance $(psi)^2$		Variance $(psi)^2$	
		Within-Laboratory	Between-Laboratory	Within-Laboratory	Between-Laboratory
3	747	3050	5691	3050	8741
1	859	2477	839	2477	3316
2	872	2506	8124	2506	10630

TABLE 19. AVERAGE, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIANCES FOR ALL TEST ROUNDS, FOUR BEAMS

Round	Average	Standard Deviation $(psi)^2$		Coefficient of Variation $(psi)^2$	
		Within-Laboratory	Between-Laboratory	Within-Laboratory	Between-Laboratory
3	747	55	93	7.4	12.5
1	859	50	58	5.8	6.7
2	872	50	103	5.7	11.8

5.6 ANALYSIS OF ADDITIONAL MIXTURE PROPERTIES.

Based on the results to this point, further analysis of the mixes was considered to be appropriate. The approach taken was to look at proportions of mix components to determine if any of the three mixes used in the experiment violated any of the standard practice guidelines contained in ACI 211. The mix components are provided in Table 20. Comparisons in this section are based on all samples for all laboratories not previously described as being discarded from the study.

TABLE 20. MIXTURE PROPORTIONS AND RATIOS COMPARED TO VARIANCE

Round	Cement (lbs)	Fine Aggregate (lbs)	Coarse Aggregate (lbs)	Fine Aggregate/ Cement Ratio	Coarse Aggregate/ Fine Aggregate Ratio	Case c: Within Lab Variance $(psi)^2$	Volume (yd^3)	Normalized Cement Content (lbs/yd^3)
1	658	1195	1700	1.82	1.42	2477	0.996	660.7
2	564	1315	1732	2.33	1.32	3365	1.018	554.1
3	470	1533	1735	3.26	1.13	2700	1.048	448.6

Figure 15 provides the relationship for the three mixes between the standard deviation of flexural strength test results and the cement content. The figure shows similar within-laboratory standard deviation for the three concrete batches produced for rounds one, two, and three of the testing. The between-laboratory standard deviation of the strength test results for the mixes used in rounds 2 and 3 are considerably higher than these of round 1, with the round 2 mix having higher standard deviation values than round 3. An observation from this figure is that the high cement content in the round 1 mix has the lowest standard deviation of strength test results of the three mixes. This is potentially the result of more thorough coating of the fine aggregate particles in the mix by the cement.

Figure 16 shows the relationship between standard deviation of flexural strength test results and the fine aggregate/cement content ratio for the three mixes. The standard deviation results for the three mixes tested demonstrate trends similar to those in Figure 15. The within-laboratory standard deviation is relatively constant for all three mixes. The between-laboratory standard deviation of flexural strength test results again increases for the round 2 and 3 mixes, with round 2 having the largest standard deviation.

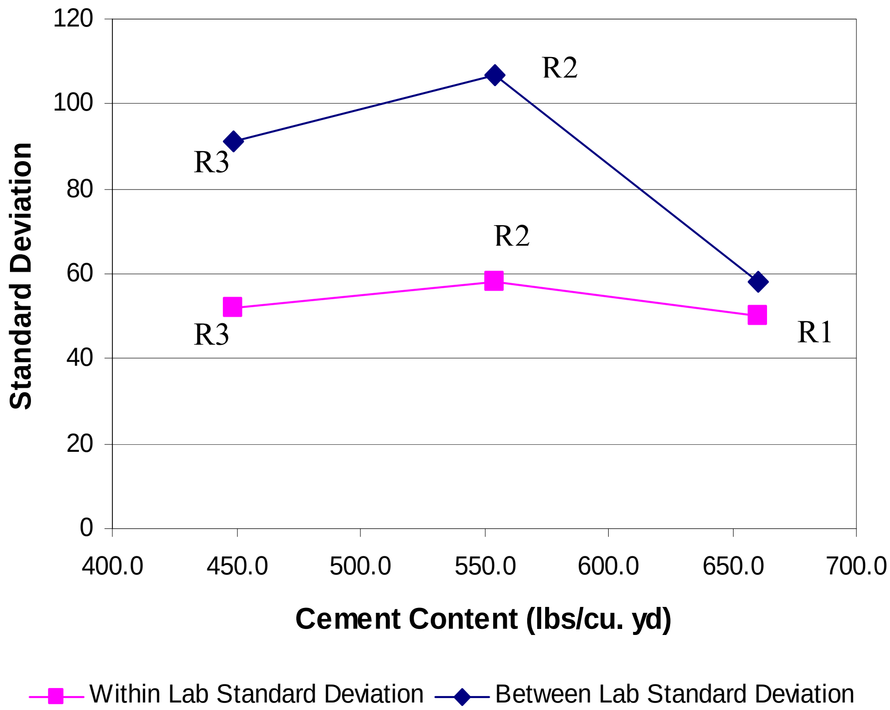

FIGURE 15. ANALYSIS OF CEMENT CONTENT VS. FLEXURAL STRENGTH STANDARD DEVIATION

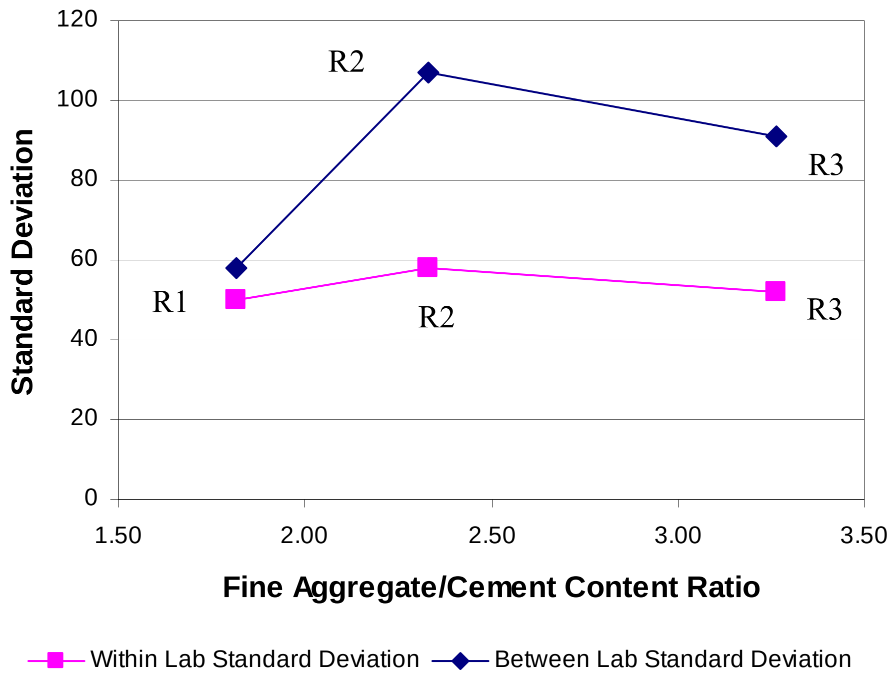

FIGURE 16. ANALYSIS OF THE FINE AGGREGATE/CEMENT CONTENT RATIO VS. FLEXURAL STRENGTH STANDARD DEVIATION

Figure 17 provides the relationship for the three mixes between standard deviation of flexural strength test results and the coarse to fine aggregate ratio. The within-laboratory standard deviation values for the three mixes are once again observed to be similar. The plot also shows again that the concrete used in round 1 has significantly smaller between-laboratory standard deviation than the mixes for rounds 2 and 3, with the round 2 mix having the largest standard deviation. These trends again illustrate that the round 1 mix has smaller between-laboratory standard deviation than the mixes for rounds 2 and 3.

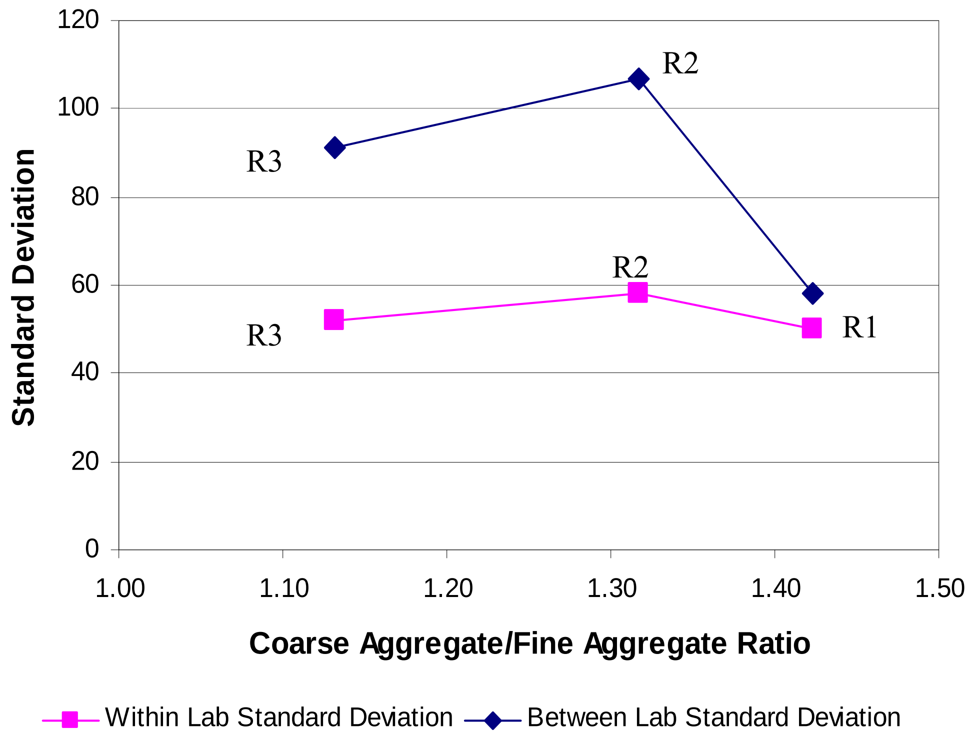

FIGURE 17. ANALYSIS OF THE COARSE AGGREGATE/FINE AGGREGATE RATIO VS. FLEXURAL STRENGTH STANDARD DEVIATION

Figures 18, 19, and 20 provide the cement efficiency, defined as flexural strength (psi) per pound of cement contained in the three mixes based on the strength results of all beams from the individual laboratories. In addition to the computed value of cement efficiency, the mean value of results for each concrete mix is provided. It can be observed from these plots that the effectiveness of the cement in the mix for round 1 is less efficient than for the other two mixes. This is intuitive, since the cement factor for this mix is quite high. The other two batches appear to be similar in cement efficiency, even though the mix for round three has one less sack of cement than that for round 2.

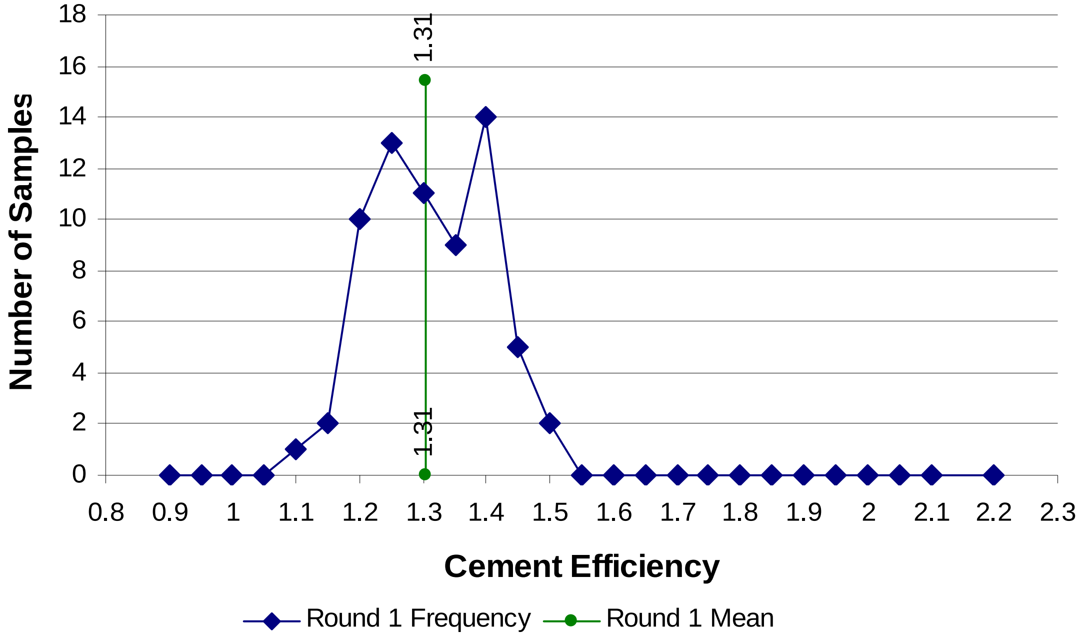

FIGURE 18. ROUND 1 CEMENT EFFICIENCY HISTOGRAM

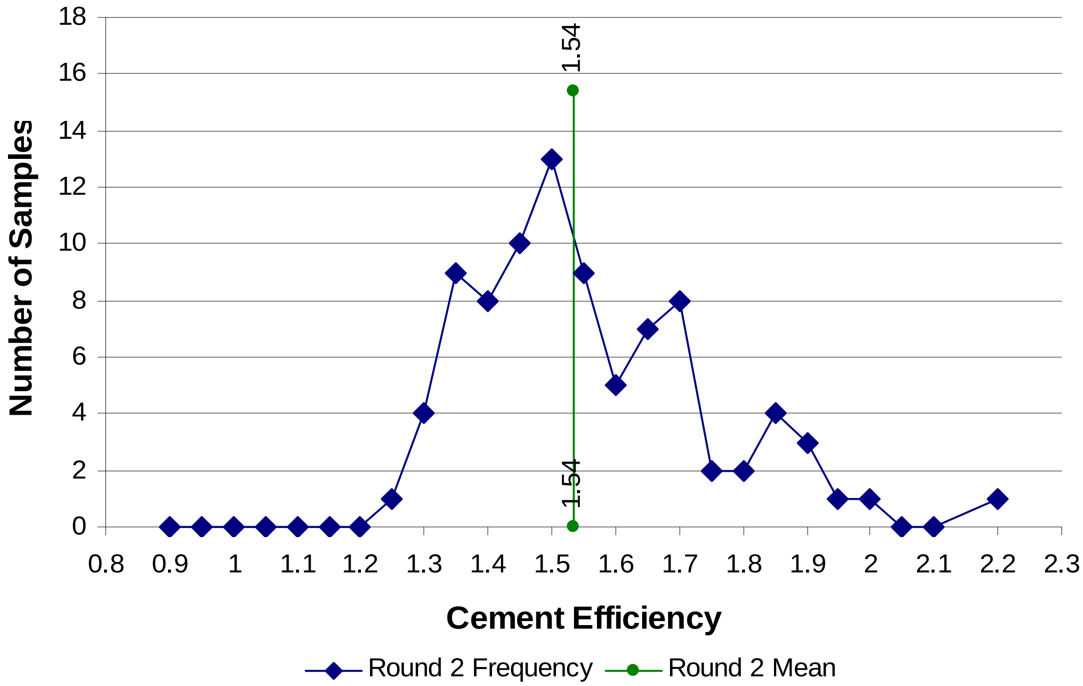

FIGURE 19. ROUND 2 CEMENT EFFICIENCY HISTOGRAM

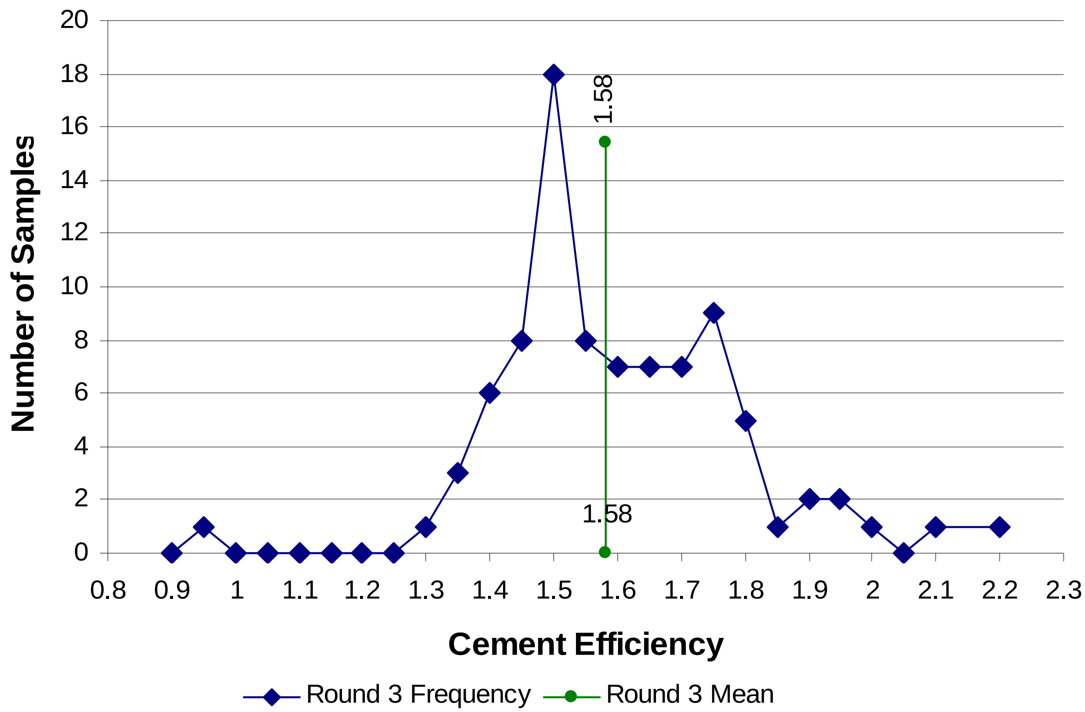

FIGURE 20. ROUND 3 CEMENT EFFICIENCY HISTOGRAM

An observation from these mix material analyses is that while the round 1 mix, which was the material previously used by the supplier for FAA work, resulted in the lowest standard deviations for both the within and between laboratory cases, this condition does not necessarily result in the best performing concrete for use in concrete pavements. The round 2 mix, which would be considered to have a more normal cement content resulted in the highest standard deviations, although the differences between within laboratory mix standard deviations is not considered to be significant. Further reducing the cement content in the round 3 mix with an accompanying increase in fine aggregate resulted in a relative decrease in standard deviation values, simultaneous with a small increase in cement efficiency. This may be the consequence of an improvement in the effectiveness of the mix constituents.

To clarify, the data used in this section include all data for all beams not previously removed because the samples were suspect. The intention of these analyses was to capture the mix component relationships to flexural strength, with the objective of identifying any influencing factors.

6 FINDINGS AND RECOMMENDATIONS.

6.1 RECOMMENDED PRECISION STATEMENT FOR FIELD-CURED BEAMS.

The current precision statement for ASTM C78-08, for laboratory specimens, is as follows:

> The coefficient of variation of test results has been observed to be dependent on the strength level of the beams. The single operator coefficient of variation has been found to be 5.7%. Therefore, results of two properly conducted tests by the same operator on beams made from the same batch sample should not differ from each other by more than 16%. The multi-laboratory coefficient of variation has been found to be 7.0%. Therefore, results of two different laboratories on beams made from the same batch sample should not differ from each other by more than 19%.

Within the range of flexural strength values in this experiment, and with the corresponding differences in mix proportioning, the strong relationship between strength and standard deviation assumed by the current statement was not observed. Other testing and material factors apparently predominated. These strength values are also fairly typical for FAA P501 mixes, although greater than required. Therefore, the precision statement was written in terms of a limiting standard deviation, rather than in terms of coefficient of variation.

In developing the statement below, consideration was primarily given to the certified labs, with the results pooled only from the certified and not-certified labs for Round 1, where there was not a statistically significant difference between them. This provided an adequate number of specimens for analysis in each round, although the distribution of those specimens across labs differs between rounds. This situation is summarized as Case a in Tables 12 and 13. Because only six certified labs were available, greater statistical confidence can be placed in the within-laboratory results from this experiment than in the between-laboratory results.

Therefore, for field-cured beams, a modified precision statement for flexural strength based upon standard deviation was developed using the definitions in ASTM C 670. The pooled variance across mixes was obtained by taking the square root of the average of the batch variances. Then, the maximum acceptable difference between two results obtained on beams from the same material should not differ by more than $2\sqrt{2}$ multiplied by the standard deviation. The recommended statement for flexural strength testing according to C78 for field-cured beams is as follows:

> The single operator standard deviation has been found to be 50 psi. Therefore, results of two properly conducted tests by the same operator on beams made from the same batch sample should not differ from each other by more than 140 psi. The multi-laboratory standard deviation has been found to be 70 psi. Therefore, results of two different laboratories on beams made from the same batch sample should not differ from each other by more than 200 psi.

6.2 RECOMMENDATIONS FOR ACCEPTANCE TESTING.

From the three concrete batches tested in this project, the current variation of 55 psi standard deviation, as assumed in the P-501 criteria was verified as reasonable. It should also be noted that, from the aspect of practical application, the factors identified from the literature are significant and must be controlled in accordance with the applicable specifications. In fact, the work summarized in this study indicates that excellent control of flexural strength specimens are required to prevent unwarranted variability from appearing in the test results. As previously discussed, there are many potential points in the sample molding, curing, and testing processes to introduce variability if strict adherence to procedures is not accomplished.

Linear regression analysis was performed on the results from each of the three concrete batches in this study. No strong correlations were consistently found to any of the variables recorded by the laboratories, except for temperature at the time of test. Some of the parameters for this study that are specific to field-cured beams, such as transportation distance, had a much wider range of values for this study than would be expected in practice. It should be noted that care was taken to transport the beams carefully, as per the experience of an actual contractor.

It is worth noting that the results obtained occurred even though the research team took extraordinary care to comply with standard procedures for making, transporting, and testing concrete flexural strength beams. This illustrates the importance of carefully following the procedures in actual practice. For example, the research team constructed durable transportation boxes of 3/4 inch plywood, lined with carpet for padding and plastic for moisture retention. Based on the research team's investigation of transportation-related issues, including the experiences of the technicians from the participating laboratories, it is clear that this care should be exercised in actual practice. However, this is often not the case.

Similar emphasis was placed on loading rate as a critical parameter, as a result of the literature search. However, even for this research effort, it was difficult for some laboratories to adequately control loading rate, since they do not have equipment which can do so automatically, or the experience to control it manually. Likewise, consideration of the gap between specimens and the loading equipment was shown to be important in the literature review, but all laboratories were not able to report precise measurements of this parameter.

The test temperature specified is somewhat open in nature, but the test temperature variable within what is considered an acceptable range, was found to influence flexural strength test results. This sensitivity to test temperature is worth noting, and might imply that additional control should be implemented in the standard.

The conclusion from the work conducted during this study is that many factors can affect the results of field-cured flexural beam strength tests. Variability can be reduced by using a high cement content in concrete mixes, but this results in concrete with other undesirable properties such as brittleness. If flexural strength tests are to be used for acceptance and payment, it is vital that careful attention be given to all the details of the molding, curing, transporting, and testing operations involved, to assure the representation of the field-placed concrete is accurate.

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APPENDIX A – SCOPE OF WORK

ASTM C78 LABORATORY SAMPLING AND TESTING PROGRAM

Purpose:
This program involves multiple technicians and laboratories in the making and testing of concrete beam specimens as part of a multiple test facility database which will be used to develop statistical information for flexural strength testing to the ASTM C78 Standard.

Scope:
Each testing laboratory will be asked to provide a currently certified ACI Concrete Field Testing Technician Grade I or equivalent, who will travel to the Austin ServAll facility at 1919 Reed Street, Erie, Pennsylvania in order to sample concrete and make beam specimens in accordance with ASTM C31. Prior to testing, the technician will participate in a review and group discussion of the ASTM C31 and ASTM C78 Test Standards. Concrete will then be delivered to the test site and, after discharge on the ground, the procedure for sampling from paving mixers will be followed. Each technician will than cast (4) beam specimens, resample the concrete, and then cast an additional (4) beam specimens (unless wheelbarrow employed is capable of holding sufficient concrete for the casting of (8) beam specimens). Consolidation of specimens will be by vibration (access to a vibrator will be provided). After casting, beams will be initially cured at a designated test site location for the first 40 to 48 hours.

The technician will return to Austin ServAll between 40 and 48 hours after molding the specimens in order to strip the molds from the beams, ID the beams with indelible markers, and then place the beams in limewater curing tanks provided at the test site.

The technician will again return to Austin ServAll on the morning of the 27th day after casting to pick up the beam specimens and transport them to the testing laboratory. At the testing laboratory, the beams shall be placed into limewater curing at least 20 hours prior to testing in accordance with ASTM C31, Section 10.1.3.2 requirements.

The beam specimens will be tested in strict accordance with ASTM C78 on the 28th day. Technicians conducting the flexural strength testing shall be currently certified to one of the following;

- ACI Concrete Laboratory Testing Technician Grade II
- ACI Concrete Laboratory Testing Technician Level
- ACI Concrete Strength Testing Technician or equivalent

Note: equivalent certification of field or laboratory technicians in this program requires the individual to have passed a written and performance examination for the ASTM C31 and/or the ASTM C78 procedure, as applicable to the activities performed.

A copy of qualification documentation for each technician shall be submitted for inclusion in test program records.

The technician will be asked to record and report the basic information contained in ASTM C78 section 9. “Report” and additional information as follows:

- Rate of loading, ASTM C78, Section 6.3
    - preferably by an automated recorded device (Rainhart or equivalent), attach chart
    - or operator verified rate of loading
- Gap determination as described in ASTM C78, Section 6.2 and actual measurements
- Individual measurements of each specimen after testing as described in ASTM C78, Section 7
- Location of fracture
- Beam photos before and after testing

Payment:
Costs for this work will be paid on a lump sum basis and shall include:

Technician travel to Austin ServAll to make beams and place them in the initial curing location, return between 40 and 48 hours later to strip the beams from the molds, and return on the morning of the 27th day after casting to transport the beams to the testing laboratory.

Beams shall be tested the afternoon of the 28th day in accordance with ASTM C 78. The amplified data test log report will be completed by the field and testing technician as applicable.

Additional Instructions:
It is important for consistency that the laboratories carefully follow the procedures in the referenced ASTM standards, along with the detailed information below.

The technicians must take care to handle and transport the specimens to prevent damage from jarring and prevent moisture loss during transport. Transportation time shall not exceed four hours. Transportation mileage and time shall be recorded and reported on the C78 “Amplified data report.”

Equipment required by field technicians will be (1) shovel, (1) scoop, (8) beam molds, (1) wheel barrow, a water bucket or similar for cleaning, protective equipment and other miscellaneous items.

Equipment provided at the test site will include vibrator(s), initial curing area with plastic coverings, temperature controlled limewater tanks for final curing until pick-up on the 27th day and a beam transportation “box” suitable to transport a minimum of 8 beams meeting the requirements of ASTM C-31.

Prior to arriving on site for the sampling and beam molding, each lab should verify and record the actual mold dimensions per ASTM C31 section 5.3 for standard 6 x 6 in. cross sectional beams. All beam molds shall arrive onsite fully assembled and ready for concrete specimen molding.

APPENDIX B – ROUND ONE DATA SHEETS.

Round	Lab ID Number	Beam ID Number	Suspected Hole or poor consolidation	Beam Weight (lb)	Overall Beam Length (in)	Ambient Temperature at Time of Test (°F)	Time Between Removal From Cure and Start of Test (min)	Moisture Condition	Gap Measurement Application	Gap Measurement Support	Average Width (in)	Average Depth (in)	Span Length (in)	Rate of Loading (psi/min)	Max Applied Load (lb)	Modulus Of Rupture (psi)	Location of Fracture (in)	1 Hour Moisture Loss (%)	Notes:	Curing History	Transport Time (hrs)	Transport Miles (mile)
1	1	1		62.22	20	77.9	7.6	SM	< .004	< .004	5.99	5.99	18	70-210	10030	790	9.00	1.10	ground	24 - 26 Hours in Limewater at 73 F	1.92	108
1	1	2		62.92	20	79.7	2.8	SM	< .004	< .004	6.00	6.21	18	100-200	10490	820	8.50	1.40	ground	24 - 26 Hours in Limewater at 73 F	1.92	108
1	1	3		63.40	20	79.7	4.4	SM	< .004	< .004	5.98	6.23	18	90-225	10330	815	8.50	1.40	ground	24 - 26 Hours in Limewater at 73 F	1.92	108
1	1	4		62.88	20	80.6	2.8	SM	< .004	< .004	6.01	6.20	18	100-180	10060	785	8.25	0.80	ground	24 - 26 Hours in Limewater at 73 F	1.92	108
1	1	5	H	55.88	20	80.6	4.2	SM	< .004	< .004	5.97	6.08	18	100-160	5240	430	8.25	1.50	ground	24 - 26 Hours in Limewater at 73 F	1.92	108
1	1	6	H	56.20	20	79.7	4.5	SM	< .004	< .004	5.98	6.06	18	120-200	4920	405	8.25	1.90	ground	24 - 26 Hours in Limewater at 73 F	1.92	108
1	1	7	H	57.42	20	80.6	4.2	SM	< .004	< .004	5.97	6.07	18	110-180	5370	440	8.50	2.70	ground	24 - 26 Hours in Limewater at 73 F	1.92	108
1	1	8	H	58.84	20	79.7	4.7	SM	< .004	< .004	5.98	6.07	18	110-210	6600	540	8.25	1.30	ground	24 - 26 Hours in Limewater at 73 F	1.92	108
1	2	1		62.20	20	75.3	15.0	SM	<.004	<.004	6.21	6.05	18	120	11110	880	8.75	3.46	Ground/ Shims	at least 20 hours in tank at Office	0.23	3.7
1	2	2		62.20	20	74.8	10.0	SM	<.004	<.004	6.22	6.02	18	120	10860	870	10.31	3.83	Ground/ Shims	at least 20 hours in tank at Office	0.23	3.7
1	2	3		62.00	20	75.1	10.0	SM	<.004	<.004	6.19	6.05	18	120	12080	960	9.88	3.13	Ground/ Shims	at least 20 hours in tank at Office	0.23	3.7
1	2	4		61.80	20	74.9	10.0	SM	<.004	<.004	6.16	6.06	18	120	11320	900	9.06	2.43	Ground/ Shims	at least 20 hours in tank at Office	0.23	3.7
1	2	5		62.30	20	75.0	10.0	SM	<.004	<.004	6.14	6.02	18	120	11100	900	9.69	2.64	Ground/ Shims	at least 20 hours in tank at Office	0.23	3.7
1	2	6		62.80	20	74.8	10.0	SM	<.004	<.004	6.17	6.13	18	120	11700	910	7.63	2.81	Ground/ Shims	at least 20 hours in tank at Office	0.23	3.7
1	2	7		62.00	20	75.0	10.0	SM	<.004	<.004	6.15	6.11	18	120	11280	885	9.75	2.44	Ground/ Shims	at least 20 hours in tank at Office	0.23	3.7
1	2	8		61.90	20	75.2	10.0	SM	<.004	<.004	6.20	6.08	18	120	10790	850	9.56	2.50	Ground/ Shims	at least 20 hours in tank at Office	0.23	3.7
1	3	1		66.00	22	79.0	10.0	SW	0.015	0.013	6.07	6.06	18	150	9500	770	9.80	0.33	Shims	20+ Hours in Limewater at 73 F	2.30	133
1	3	2		65.20	22	79.0	12.0	SW	0.009	0	6.03	5.97	18	150	9900	830	8.30	0.19	Shims	20+ Hours in Limewater at 73 F	2.30	133
1	3	3		65.50	22	79.0	8.0	SW	0.007	0.004	6.01	6.05	18	150	10700	880	9.20	0.17	Shims	20+ Hours in Limewater at 73 F	2.30	133
1	3	4		65.25	22	80.0	10.0	SW	0.003	0	6.07	6.00	18	150	10000	820	8.70	0.19	Shims	20+ Hours in Limewater at 73 F	2.30	133
1	3	5	H	56.00	22	81.0	9.0	SW	0.011	0.007	5.98	5.97	18	150	5000	420	10.00	0.87	Shims	20+ Hours in Limewater at 73 F	2.30	133
1	3	6	H	56.25	22	82.0	9.0	SW	0.005	0.009	6.00	6.04	18	150	4200	350	9.40	0.59	Shims	20+ Hours in Limewater at 73 F	2.30	133
1	3	7	H	55.60	22	78.0	10.0	SW	0.006	0.008	6.01	6.02	18	150	7220	600	8.20	0.84	Shims	20+ Hours in Limewater at 73 F	2.30	133
1	3	8	H	58.90	22	82.0	9.0	SW	0.015	0.013	5.98	6.06	18	150	4920	400	9.00	0.98	Shims	20+ Hours in Limewater at 73 F	2.30	133
1	4	1		60.90	24	74.0	15.0	SM	0.009	0.008	6.10	6.10	18	700	10400	820	7.00	0.46	Shims	24 - 26 Hours in Limewater at 73 F	2.17	115
1	4	2		62.70	24	74.0	15.0	SM	0.006	0.011	6.10	6.15	18	700	10400	820	10.00	0.34	Shims	24 - 26 Hours in Limewater at 73 F	2.17	115
1	4	3		63.40	24	74.0	15.0	SM	0.008	0.012	6.10	6.15	18	700	10500	820	9.75	0.33	Shims	24 - 26 Hours in Limewater at 73 F	2.17	115
1	4	4		62.50	24	74.0	15.0	SM	0.013	0.014	6.00	6.10	18	700	12000	950	8.00	0.44	Shims	24 - 26 Hours in Limewater at 73 F	2.17	115

Round	Lab ID Number	Beam ID Number	Suspected Hole or poor consolidation	Beam Weight (lb)	Overall Beam Length (in)	Ambient Temperature at Time of Test (°F)	Time Between Removal From Cure and Start of Test (min)	Moisture Condition	Gap Measurement Application	Gap Measurement Support	Average Width (in)	Average Depth (in)	Span Length (in)	Rate of Loading (psi/min)	Max Applied Load (lb)	Modulus Of Rupture (psi)	Location of Fracture (in)	1 Hour Moisture Loss (%)	Notes:	Curing History	Transport Time (hrs)	Transport Miles (mile)
1	4	5	H	64.40	24	74.0	15.0	SM	0.006	0.009	6.00	6.00	18	700	7800	680	10.50	0.69	Shims	24 - 26 Hours in Limewater at 73 F	2.17	115
1	4	6	H	57.80	24	74.0	15.0	SM	0.012	0.013	6.00	6.00	18	700	4600	380	10.50	0.76	Shims	24 - 26 Hours in Limewater at 73 F	2.17	115
1	4	7	H	58.20	24	74.0	15.0	SM	0.013	0.009	6.00	6.00	18	700	5800	490	9.50	0.85	Shims	24 - 26 Hours in Limewater at 73 F	2.17	115
1	4	8	H	58.10	24	74.0	15.0	SM	0.008	0.012	6.00	6.00	18	700	4000	350	8.00	0.88	Shims	24 - 26 Hours in Limewater at 73 F	2.17	115
1	5	1		62.20	20	76.0	12.0	SM	<.015	<.015	6.00	6.20	18	125-175	10500	820	9.00	0.68	Shims	24 Hours in Limewater at 73 F	2.00	110
1	5	2		64.20	20	76.0	11.0	SM	<.015	<.015	6.00	6.25	18	125-175	11440	880	8.95	0.64	Shims	24 Hours in Limewater at 73 F	2.00	110
1	5	3		62.90	20	76.0	10.0	SM	<.015	<.015	6.05	6.30	18	125-175	12490	935	9.55	0.77	Shims	24 Hours in Limewater at 73 F	2.00	110
1	5	4		63.30	20	76.0	10.0	SM	<.015	<.015	6.05	6.20	18	125-175	10330	800	8.65	0.72	Shims	24 Hours in Limewater at 73 F	2.00	110
1	5	5	H	57.90	20	76.0	9.0	SM	<.015	<.015	6.00	6.00	18	125-175	6890	575	8.15	0.83	Shims	24 Hours in Limewater at 73 F	2.00	110
1	5	6	H	58.40	20	76.0	10.0	SM	<.015	<.015	6.00	6.10	18	125-175	7610	615	8.35	1.02	Shims	24 Hours in Limewater at 73 F	2.00	110
1	5	7	H	56.50	20	76.0	10.0	SM	<.015	<.015	6.05	6.10	18	125-175	3990	320	9.70	0.92	Shims	24 Hours in Limewater at 73 F	2.00	110
1	5	8	H	57.40	20	76.0	10.0	SM	<.015	<.015	6.00	6.10	18	125-175	5640	455	7.80	1.05	Shims	24 Hours in Limewater at 73 F	2.00	110
1	6	1		62.70	20	81.0	12.0	SM	0.009	0	6.15	6.00	18	125	11030	890	8.50	0.38	Shims	22 hours in tank after arrival in office	1.92	108
1	6	2		61.30	20	81.0	5.0	SM	0.006	0	6.10	5.95	18	120	10670	895	9.25	0.31	Shims	22 hours in tank after arrival in office	1.92	108
1	6	3		64.00	20	81.0	7.0	SM	0.006	0	6.10	6.10	18	170	11410	910	9.75	0.28	Shims	22 hours in tank after arrival in office	1.92	108
1	6	4		62.50	20	81.0	9.0	SM	0.008	0	6.00	6.15	18	150	11200	890	10.00	0.29	Shims	22 hours in tank after arrival in office	1.92	108
1	6	5	H	54.60	20	81.0	7.0	SM	0.01	0.001	6.00	6.00	18	150	6720	560	8.25	1.41	Shims	22 hours in tank after arrival in office	1.92	108
1	6	6	H	59.20	20	81.0	10.0	SM	0.01	0.001	6.05	6.10	18	130	7730	620	9.25	0.68	Shims	22 hours in tank after arrival in office	1.92	108
1	6	7	H	61.30	20	81.0	13.0	SM	0.008	0.002	6.00	6.10	18	180	11510	925	8.50	0.69	Shims	22 hours in tank after arrival in office	1.92	108
1	6	8	H	58.30	20	81.0	8.0	SM	0.01	0.002	6.05	6.05	18	120	8380	675	8.00	1.00	Shims	22 hours in tank after arrival in office	1.92	108
1	7	1		65.80	22	78.3	5.0	SM	<.004	<.004	6.05	6.05	18	150	10745	875	10.10	1.50	None	upon arrival at lab cured at least 23 hours	2.08	107
1	7	2		65.60	22	76.2	5.0	SM	<.004	<.004	6.05	6.00	18	150	10855	895	9.70	1.30	None	upon arrival at lab cured at least 23 hours	2.08	107
1	7	3		65.20	22	79.8	8.0	SM	<.004	<.004(except .5" at 1 edge	6.05	6.00	18	150	10165	840	8.60	0.70	None	upon arrival at lab cured at least 23 hours	2.08	107
1	7	4		65.80	22	80.5	10.0	SM	<.004	>.004 <.015	6.05	6.05	18	150	9970	810	9.30	1.00	Shims	upon arrival at lab cured at least 23 hours	2.08	107
1	7	5	H	61.70	22	80.7	10.0	SM	>.004 <.015	<.004	6.00	6.00	18	150	6740	560	10.50	2.00	Shims	upon arrival at lab cured at least 23 hours	2.08	107
1	7	6	H	59.80	22	82.1	10.0	SM	>.004 <.015	<.004	6.00	6.05	18	150	5170	425	10.10	1.60	Shims	upon arrival at lab cured at least 23 hours	2.08	107
1	7	7	H	61.70	22	81.6	10.0	SM	>.004 <.015	>.004 <.015	5.95	6.00	18	150	7340	615	10.40	1.50	Shims	upon arrival at lab cured at least 23 hours	2.08	107
1	7	8	H	63.40	22	82.3	10.0	SM	>.004 <.015	>.004 <.015	6.00	6.00	18	150	6635	555	9.50	2.00	Shims	upon arrival at lab cured at least 23 hours	2.08	107

Round	Lab ID Number	Beam ID Number	Suspected Hole or poor consolidation	Beam Weight (lb)	Overall Beam Length (in)	Ambient Temperature at Time of Test (°F)	Time Between Removal From Cure and Start of Test (min)	Moisture Condition	Gap Measurement Application	Gap Measurement Support	Average Width (in)	Average Depth (in)	Span Length (in)	Rate of Loading (psi/min)	Max Applied Load (lb)	Modulus Of Rupture (psi)	Location of Fracture (in)	1 Hour Moisture Loss (%)	Notes:	Curing History	Transport Time (hrs)	Transport Miles (mile)
1	8	1		63.30	20	82.0	5.0	SW	.004-.006	.010-.015	6.00	6.10	18	170	9070	730	9.63	2.10	Shims	24 - 26 Hours in Limewater at 73 F	1.92	108
1	8	2		62.80	20	82.0	7.0	SW	.01-.015	< .004	6.00	6.25	18	170	10170	781	9.50	3.10	Shims	24 - 26 Hours in Limewater at 73 F	1.92	108
1	8	3		63.10	20	82.0	8.0	SW	.004-.015	< .004	6.00	6.10	18	170	10850	875	8.63	1.60	Shims	24 - 26 Hours in Limewater at 73 F	1.92	108
1	8	4		62.70	20	82.0	6.0	SW	< .004	< .004	6.00	6.10	18	170	10020	805	9.13	2.40		24 - 26 Hours in Limewater at 73 F	1.92	108
1	8	5	H	61.60	20	82.0	12.0	SW	< .004	< .004	6.00	6.10	18	170	8620	695	8.50	2.10		24 - 26 Hours in Limewater at 73 F	1.92	108
1	8	6	H	60.90	20	82.0	7.0	SW	.010-.015	< .004	6.00	6.00	18	170	8810	735	8.00	2.10	Shims	24 - 26 Hours in Limewater at 73 F	1.92	108
1	8	7	H	60.50	20	82.0	4.0	SW	< .004	< .004	6.00	6.10	18	170	8330	670	8.88	2.40		24 - 26 Hours in Limewater at 73 F	1.92	108
1	8	8	H	61.20	20	82.0	5.0	SW	.004-.006	< .004	6.00	6.00	18	170	8470	705	9.75	3.50	Shims	24 - 26 Hours in Limewater at 73 F	1.92	108
1	9	1		63.05	20	76.0	12.0	SW	0.003	0.004	6.21	5.93	20	120-150	9600	880	Middle	2.90	Ground	24 - 26 Hours in Limewater at 73 F	1.92	108
1	9	2		62.90	20	76.0	14.0	SW	0.003	0.004	6.24	5.90	20	120-150	9800	900	Middle	3.10	Ground	24 - 26 Hours in Limewater at 73 F	1.92	108
1	9	3		63.30	20	75.0	8.0	SW	0.004	0.002	6.28	5.97	20	120-150	10570	945	Middle	2.10	Ground	24 - 26 Hours in Limewater at 73 F	1.92	108
1	9	4		62.60	20	75.0	6.0	SW	0.002	0.002	6.22	5.89	20	120-150	9950	920	Middle	3.00	Ground	24 - 26 Hours in Limewater at 73 F	1.92	108
1	9	5		62.60	20	76.0	14.0	SM	0.003	0.003	6.21	5.96	20	120-150	8940	810	Middle	3.80	Ground	24 - 26 Hours in Limewater at 73 F	1.92	108
1	9	6		62.35	20	76.0	7.0	SW	0.004	0.003	6.28	5.99	20	120-150	9930	880	Middle	3.20	Ground	24 - 26 Hours in Limewater at 73 F	1.92	108
1	9	7		61.70	20	76.0	11.0	SM	0.003	0.004	6.17	5.98	20	120-150	8480	770	Middle	3.50	Ground	24 - 26 Hours in Limewater at 73 F	1.92	108
1	9	8		62.25	20	76.0	13.0	SM	0.004	0.004	6.13	6.02	20	120-150	9190	830	Middle	4.10	Ground	24 - 26 Hours in Limewater at 73 F	1.92	108
1	10	1		62.13	20	74.0	10.3	SM	NA	NA	6.05	6.10	18	120-170	9805	785	10.00	1.00	Ground/ Shims	at least 20 hours curing in Laboratory	2.08	114
1	10	2		62.38	20	75.0	15.5	SM	NA	NA	6.05	6.15	18	120-170	10595	835	8.00	1.70	Ground/ Shims	at least 20 hours curing in Laboratory	2.08	114
1	10	3		61.98	20	73.0	10.1	SW	NA	NA	6.00	6.15	18	120-170	10390	825	8.00	0.90	Ground/ Shims	at least 20 hours curing in Laboratory	2.08	114
1	10	4		61.96	20	72.0	11.3	SW	NA	NA	6.00	6.10	18	120-170	11885	960	9.50	2.20	Ground/ Shims	at least 20 hours curing in Laboratory	2.08	114
1	10	5		62.60	20	75.0	8.2	SM	NA	NA	6.00	6.15	18	120-170	9825	780	9.50	1.60	Ground/ Shims	at least 20 hours curing in Laboratory	2.08	114
1	10	6		62.37	20	74.0	8.1	SM	NA	NA	6.00	6.15	18	120-170	10355	820	9.50	0.70	Ground/ Shims	at least 20 hours curing in Laboratory	2.08	114
1	10	7		63.14	20	75.0	7.9	SM	NA	NA	6.00	6.15	18	120-170	11885	945	9.50	1.50	Ground/ Shims	at least 20 hours curing in Laboratory	2.08	114
1	10	8		63.48	20	75.0	10.8	SM	NA	NA	6.05	6.15	18	120-170	9725	765	9.50	1.80	Ground/ Shims	at least 20 hours curing in Laboratory	2.08	114
1	11	1		61.10	20	78.0	15.0	SM	0	0	6.10	6.10	18	175	9700	770	8.50	0.31	Leather Shims	24 Hours in Limewater at 73+-3 F	3.00	135
1	11	2		62.30	20	78.0	10.0	SM	0	0	6.10	6.10	18	175	11300	895	9.75	0.16	Leather Shims	24 Hours in Limewater at 73+-3 F	3.00	135
1	11	3		61.80	20	78.0	5.0	SM	0	0	6.10	6.10	18	175	11500	910	9.50	0.13	Leather Shims	24 Hours in Limewater at 73+-3 F	3.00	135
1	11	4		62.40	20	78.0	5.0	SM	0	0	6.10	6.10	18	175	11200	890	8.25	0.13	Leather Shims	24 Hours in Limewater at 73+-3 F	3.00	135

Round	Lab ID Number	Beam ID Number	Suspected Hole or poor consolidation	Beam Weight (lb)	Overall Beam Length (in)	Ambient Temperature at Time of Test (°F)	Time Between Removal From Cure and Start of Test (min)	Moisture Condition	Gap Measurement Application	Gap Measurement Support	Average Width (in)	Average Depth (in)	Span Length (in)	Rate of Loading (psi/min)	Max Applied Load (lb)	Modulus Of Rupture (psi)	Location of Fracture (in)	1 Hour Moisture Loss (%)	Notes:	Curing History	Transport Time (hrs)	Transport Miles (mile)
1	11	5		62.30	20	78.0	2.0	SM	0	0	6.10	6.10	18	175	11400	905	9.50	0.26	Leather Shims	24 Hours in Limewater at 73+-3 F	3.00	135
1	11	6		61.40	20	78.0	4.0	SM	0	0	6.10	6.10	18	175	9200	730	9.75	0.31	Leather Shims	24 Hours in Limewater at 73+-3 F	3.00	135
1	11	7		62.50	20	78.0	6.0	SM	0	0	6.10	6.10	18	175	9900	785	8.50	0.34	Leather Shims	24 Hours in Limewater at 73+-3 F	3.00	135
1	11	8		61.30	20	78.0	5.0	SM	0	0	6.15	6.10	18	175	8900	695	8.00	0.26	Leather Shims	24 Hours in Limewater at 73+-3 F	3.00	135
1	12	1		63.55	20	74.0	6.0	SM	NA	NA	6.06	6.03	18	110-190	10420	850	9.50	1.50	No Gap, Filed	21 hours curing in office	0.92	47
1	12	2		63.70	20	74.0	12.0	SM	NA	NA	6.06	6.03	18	110-190	11350	925	9.75	0.70	No Gap, Filed	21 hours curing in office	0.92	47
1	12	3		63.65	20	74.0	10.0	SM	NA	NA	6.03	6.03	18	110-190	10380	850	9.50	1.40	No Gap, Filed	21 hours curing in office	0.92	47
1	12	4		63.40	20	74.0	7.0	SM	NA	NA	6.06	6.06	18	110-190	9760	785	10.00	1.40	No Gap, Filed	21 hours curing in office	0.92	47
1	12	5		63.40	20	74.0	8.0	SM	NA	NA	6.06	6.13	18	110-190	10830	855	9.50	1.40	No Gap, Filed	21 hours curing in office	0.92	47
1	12	6		64.05	20	73.0	10.0	SM	NA	NA	6.25	6.06	18	110-190	10530	825	9.50	1.50	No Gap, Filed	21 hours curing in office	0.92	47
1	12	7		63.70	20	73.0	6.0	SM	NA	NA	6.06	6.06	18	110-190	10530	850	8.25	1.30	No Gap, Filed	21 hours curing in office	0.92	47
1	12	8	H	59.85	20	73.0	9.0	SM	NA	NA	6.00	6.25	18	110-190	8950	685	8.75	1.50	No Gap, Filed	21 hours curing in office	0.92	47

APPENDIX C – ROUND TWO DATA SHEETS.

Round	Lab ID Number	Beam ID Number	Suspected Hole or poor consolidation	Beam Weight (lb)	Overall Beam Length (in)	Ambient Temperature at Time of Test (°F)	Time Between Removal From Cure and Start of Test (min)	Moisture Condition	Gap Measurement Application	Gap Measurement Support	Average Width (in)	Average Depth (in)	Span Length (in)	Rate of Loading (psi/min)	Max Applied Load (lb)	Modulus Of Rupture (psi)	Location of Fracture (in)	1 Hour Moisture Loss (%)	Notes:	Curing History	Transport Time (hrs)	Transport Miles (mile)
2	1	9		61.58	20	66.2	7.6	SM	<.004	<.004	5.95	6.15	18	85-210	10460	835	7.30	0.80	ground	24 - 26 Hours in Limewater at 73 F	2.25	125
2	1	10		61.26	20	66.2	5.3	SM	<.004	<.004	6.05	6.15	18	80-230	10900	850	8.50	0.30	ground	24 - 26 Hours in Limewater at 73 F	2.25	125
2	1	11		62.18	20	66.2	5.1	SM	<.004	<.004	6.05	6.25	18	90-260	9730	745	8.50	0.40	ground	24 - 26 Hours in Limewater at 73 F	2.25	125
2	1	12		61.68	20	67.1	4.3	SM	<.004	<.004	6.00	6.15	18	60-190	9780	770	9.00	0.80	ground	24 - 26 Hours in Limewater at 73 F	2.25	125
2	1	13		61.94	20	67.1	5.1	SM	<.004	<.004	6.00	6.25	18	80-220	10460	805	8.50	0.60	ground	24 - 26 Hours in Limewater at 73 F	2.25	125
2	1	14		61.10	20	67.1	5.5	SM	<.004	<.004	6.00	6.20	18	80-210	10550	830	8.00	0.50	ground	24 - 26 Hours in Limewater at 73 F	2.25	125
2	1	15		62.12	20	68.0	5.6	SM	<.004	<.004	6.05	6.20	18	60-200	10530	820	8.50	0.50	ground	24 - 26 Hours in Limewater at 73 F	2.25	125
2	1	16		61.90	20	68.0	4.5	SM	<.004	<.004	6.05	6.20	18	90-190	10300	795	8.25	0.40	ground	24 - 26 Hours in Limewater at 73 F	2.25	125
2	2	9		61.00	20	69.3	10.0	SM	0.004	0.002	6.05	6.05	18	125	11880	965	9.150	5.90	Ground/ Shims	at least 20 hours in tank at Office	0.25	3.7
2	2	10		61.40	20	68.9	8.0	SM	0.004	0.002	6.10	6.10	18	125	11650	925	9.150	5.70	Ground/ Shims	at least 20 hours in tank at Office	0.25	3.7
2	2	11		60.70	20	69.1	8.0	SM	0.004	0.003	6.15	6.05	18	125	11890	950	9.375	5.10	Ground/ Shims	at least 20 hours in tank at Office	0.25	3.7
2	2	12		61.30	20	68.8	8.0	SM	0.003	0.002	6.10	6.10	18	125	11690	930	9.625	5.40	Ground/ Shims	at least 20 hours in tank at Office	0.25	3.7
2	2	13		61.50	20	67.3	10.0	SM	0.004	0.003	6.10	6.10	18	125	11980	950	9.375	4.70	Ground/ Shims	at least 20 hours in tank at Office	0.25	3.7
2	2	14		61.90	20	67.6	10.0	SM	0.003	0.003	6.15	6.15	18	125	12070	935	8.750	4.20	Ground/ Shims	at least 20 hours in tank at Office	0.25	3.7
2	2	15		61.10	20	67.9	10.0	SM	0.004	0.003	6.20	6.10	18	125	11810	920	9.500	3.60	Ground/ Shims	at least 20 hours in tank at Office	0.25	3.7
2	2	16		61.50	20	67.9	10.0	SM	0.004	0.002	6.15	6.20	18	125	11150	850	9.625	3.80	Ground/ Shims	at least 20 hours in tank at Office	0.25	3.7
2	4	9		64.90	24	71.0	10.0	SW	0.004	0.004	6.10	6.10	18	600	13000	1015	9.00	0.35	NA	24 - 26 Hours in Limewater at 73 F	2.17	117
2	4	10		65.60	24	71.0	10.0	SW	0.004	0.004	6.05	6.15	18	600	13850	1085	8.00	0.43	NA	24 - 26 Hours in Limewater at 73 F	2.17	117
2	4	11		64.80	24	71.0	10.0	SW	0.004	0.004	6.10	6.15	18	600	13050	1030	8.50	0.39	NA	24 - 26 Hours in Limewater at 73 F	2.17	117
2	4	12		65.30	24	71.0	10.0	SM	0.004	0.004	6.10	6.10	18	600	11550	905	10.00	0.31	NA	24 - 26 Hours in Limewater at 73 F	2.17	117
2	4	13		66.60	24	71.0	10.0	SW	0.004	0.004	6.00	6.00	18	600	11450	935	9.75	0.33	NA	24 - 26 Hours in Limewater at 73 F	2.17	117
2	4	14		67.10	24	71.0	10.0	SW	0.004	0.004	6.00	6.05	18	600	10800	885	9.00	0.37	NA	24 - 26 Hours in Limewater at 73 F	2.17	117
2	4	15		66.60	24	71.0	10.0	SW	0.004	0.004	6.00	6.00	18	600	10500	865	8.50	0.77	NA	24 - 26 Hours in Limewater at 73 F	2.17	117
2	4	16		68.00	24	71.0	10.0	SM	0.004	0.004	6.00	6.15	18	600	11550	825	8.50	0.37	NA	24 - 26 Hours in Limewater at 73 F	2.17	117
2	5	9		61.30	20	72.0	12.0	SM	<.015	<.015	6.10	6.10	18	125-170	9810	780	8.60	0.16	Shims	24 Hours in Limewater at 73 F	2.00	110
2	5	10		62.80	20	72.0	11.0	SM	<.015	<.015	6.10	6.20	18	125-170	9660	740	7.40	0.16	Shims	24 Hours in Limewater at 73 F	2.00	110
2	5	11		62.30	20	72.0	12.0	SM	<.015	<.015	6.15	6.20	18	125-170	10280	785	9.80	0.14	Shims	24 Hours in Limewater at 73 F	2.00	110

Round	Lab ID Number	Beam ID Number	Suspected Hole or poor consolidation	Beam Weight (lb)	Overall Beam Length (in)	Ambient Temperature at Time of Test (°F)	Time Between Removal From Cure and Start of Test (min)	Moisture Condition	Gap Measurement Application	Gap Measurement Support	Average Width (in)	Average Depth (in)	Span Length (in)	Rate of Loading (psi/min)	Max Applied Load (lb)	Modulus Of Rupture (psi)	Location of Fracture (in)	1 Hour Moisture Loss (%)	Notes:	Curing History	Transport Time (hrs)	Transport Miles (mile)
2	5	12		61.20	20	72.0	12.0	SM	<.015	<.015	6.10	6.15	18	125-170	10560	825	7.10	0.19	Shims	24 Hours in Limewater at 73 F	2.00	110
2	5	13		61.40	20	72.0	11.0	SM	<.015	<.015	6.10	6.10	18	125-170	10970	870	9.00	0.22	Shims	24 Hours in Limewater at 73 F	2.00	110
2	5	14		62.10	20	72.0	11.0	SM	<.015	<.015	6.10	6.20	18	125-170	10610	815	7.70	0.19	Shims	24 Hours in Limewater at 73 F	2.00	110
2	5	15		61.40	20	72.0	12.0	SM	<.015	<.015	6.10	6.10	18	125-170	11640	925	9.30	0.16	Shims	24 Hours in Limewater at 73 F	2.00	110
2	5	16		61.70	20	72.0	12.0	SM	<.015	<.015	6.00	6.15	18	125-170	10280	815	7.20	0.17	Shims	24 Hours in Limewater at 73 F	2.00	110
2	6	9		62.30	20	74.0	5.0	SM	0.004	0.002	6.05	6.20	18	165	12990	1035	9.50	0.24	Shims	at least 20 hours in Laboratory	2.00	103
2	6	10		62.40	20	74.0	5.0	SM	0.008	0.002	6.05	6.15	18	180	12910	1030	9.30	0.26	Shims	at least 20 hours in Laboratory	2.00	103
2	6	11		63.10	20	74.0	4.0	SM	0.006	0.000	6.10	6.20	18	170	13500	1055	9.75	0.21	Shims	at least 20 hours in Laboratory	2.00	103
2	6	12		63.00	20	74.0	8.0	SM	0.004	0.000	6.10	6.15	18	170	13020	1030	9.75	0.21	Shims	at least 20 hours in Laboratory	2.00	103
2	6	13		62.40	20	74.0	8.0	SM	0.004	0.001	6.10	6.15	18	130	13420	1060	8.50	0.29	Shims	at least 20 hours in Laboratory	2.00	103
2	6	14		62.50	20	74.0	8.0	SM	0.010	0.000	6.10	6.10	18	125	14070	1115	8.75	0.23	Shims	at least 20 hours in Laboratory	2.00	103
2	6	15		62.50	20	74.0	8.0	SM	0.008	0.002	6.10	6.10	18	120	15240	1205	8.75	0.23	Shims	at least 20 hours in Laboratory	2.00	103
2	6	16		62.60	20	74.0	11.0	SM	0.006	0.000	6.00	6.15	18	160	13110	1060	8.60	0.27	Shims	at least 20 hours in Laboratory	2.00	103
2	7	9		64.90	21	62.7	6.0	SM	.015-.004	<.004	6.15	6.00	18	150	9570	780	10.30	1.90	Shims	23-25 hours cure	2.00	107
2	7	10		64.90	21	63.4	5.0	SM	.015-.004	<.004	6.15	6.05	18	150	10060	805	9.50	2.70	Shims	23-25 hours cure	2.00	107
2	7	11		64.90	21	63.4	5.0	SM	.015-.004	.015-.004	6.15	6.00	18	150	10490	755	6.80	3.20	Shims/M OR Formula R=3Pa/bd^2	23-25 hours cure	2.00	107
2	7	12		64.30	21	63.6	5.0	SM	.015-.004	<.004	6.05	6.00	18	150	8805	730	10.10	2.30	Shims	23-25 hours cure	2.00	107
2	7	13		63.60	21	63.6	7.0	SM	<.004	.015-.004	6.00	6.05	18	150	8675	710	9.70	3.70	Shims	23-25 hours cure	2.00	107
2	7	14		64.70	21	63.2	6.0	SM	.015-.004	.015-.004	6.05	6.05	18	150	10225	830	8.30	3.00	Shims	23-25 hours cure	2.00	107
2	7	15		63.40	21	63.4	4.0	SM	.015-.004	.015-.004	6.00	6.00	18	150	8955	745	8.60	2.30	Shims	23-25 hours cure	2.00	107
2	7	16		63.70	21	62.7	4.0	SM	<.004	.015-.004	6.05	6.00	18	150	10430	860	9.70	3.20	Shims	23-25 hours cure	2.00	107
2	8	9		62.10	21	68.0	15.0	SW	.004-.015	.004-.015	6.10	6.05	18	170	9350	755	9.25	1.90	Shims	24 - 26 Hours in Limewater at 73 F	2.00	108
2	8	10		62.34	21	68.0	5.0	SW	.004-.015	<.004	6.10	6.05	18	170	9940	800	9.00	3.00	Shims	24 - 26 Hours in Limewater at 73 F	2.00	108
2	8	11		61.80	21	68.0	7.0	SW	<.004	.004-.015	6.10	6.00	18	170	10500	860	9.50	2.40	Shims	24 - 26 Hours in Limewater at 73 F	2.00	108
2	8	12		62.60	21	68.0	6.0	SW	<.004	<.004	6.20	6.10	18	170	10460	815	9.25	3.30		24 - 26 Hours in Limewater at 73 F	2.00	108
2	8	13		60.20	21	68.0	5.0	SW	.004-.015	.004-.015	6.15	5.90	18	170	8560	720	8.75	2.60	Shims	24 - 26 Hours in Limewater at 73 F	2.00	108
2	8	14		62.30	21	68.0	5.0	SW	<.004	<.004	6.15	6.05	18	170	10000	800	8.00	2.20		24 - 26 Hours in Limewater at 73 F	2.00	108

Round	Lab ID Number	Beam ID Number	Suspected Hole or poor consolidation	Beam Weight (lb)	Overall Beam Length (in)	Ambient Temperature at Time of Test (°F)	Time Between Removal From Cure and Start of Test (min)	Moisture Condition	Gap Measurement Application	Gap Measurement Support	Average Width (in)	Average Depth (in)	Span Length (in)	Rate of Loading (psi/min)	Max Applied Load (lb)	Modulus Of Rupture (psi)	Location of Fracture (in)	1 Hour Moisture Loss (%)	Notes:	Curing History	Transport Time (hrs)	Transport Miles (mile)
2	8	15		62.50	21	68.0	7.0	SW	<.004	<.004	6.20	6.05	18	170	10800	855	9.00	2.40		24 - 26 Hours in Limewater at 73 F	2.00	108
2	8	16		61.80	21	68.0	5.0	SW	<.004	.004-.015	6.10	6.00	18	170	9600	785	7.25	2.90	Shims	24 - 26 Hours in Limewater at 73 F	2.00	108
2	9	9		61.70	20	64.0	10.0	SM	0.004	0.003	6.19	5.96	20	115-165	10420	945	8.375	4.00	Ground	24 - 26 Hours in Limewater at 73 F	2.00	108
2	9	10		61.95	20	64.0	14.0	SW	0.004	0.004	6.27	5.99	20	115-165	10510	935	8.000	2.60	Ground	24 - 26 Hours in Limewater at 73 F	2.00	108
2	9	11		61.80	20	64.0	8.0	SM	0.004	0.002	6.21	5.91	20	115-165	10030	925	8.000	2.60	Ground	24 - 26 Hours in Limewater at 73 F	2.00	108
2	9	12		61.70	20	64.0	8.0	SW	0.002	0.002	6.26	5.90	20	115-165	8500	780	9.875	2.60	Ground	24 - 26 Hours in Limewater at 73 F	2.00	108
2	9	13		61.20	20	64.0	6.0	SW	0.004	0.004	6.16	5.94	20	115-165	9010	830	9.375	2.60	Ground	24 - 26 Hours in Limewater at 73 F	2.00	108
2	9	14		61.50	20	64.0	4.0	SW	0.002	0.003	6.17	5.93	20	115-165	8730	805	9.375	3.90	Ground	24 - 26 Hours in Limewater at 73 F	2.00	108
2	9	15		61.60	20	64.0	13.0	SW	0.002	0.003	6.21	5.91	20	115-165	10140	935	8.500	3.30	Ground	24 - 26 Hours in Limewater at 73 F	2.00	108
2	9	16		62.30	20	64.0	6.0	SW	0.002	0.001	6.23	6.02	20	115-165	9320	825	8.375	2.30	Ground	24 - 26 Hours in Limewater at 73 F	2.00	108
2	10	9		62.17	20	62.0	6.8	SM			6.00	6.10	18	100-145	11015	888	7.625	0.97	Filed/Shims	at least 20 hours curing in Laboratory	2.33	114
2	10	10		61.92	20	62.0	8.4	SM			6.00	6.10	18	100-145	9680	780	8.500	1.07	Filed/Shims	at least 20 hours curing in Laboratory	2.33	114
2	10	11		61.67	20	62.0	4.1	SM			6.05	6.15	18	100-145	9290	735	9.125	1.03	Filed/Shims	at least 20 hours curing in Laboratory	2.33	114
2	10	12		62.02	20	62.0	5.1	SM			6.00	6.15	18	100-145	9885	785	9.000	1.25	Filed/Shims	at least 20 hours curing in Laboratory	2.33	114
2	10	13		61.88	20	62.0	3.1	SW			6.00	6.10	18	100-145	9155	740	8.375	1.33	Filed/Shims	at least 20 hours curing in Laboratory	2.33	114
2	10	14		61.93	20	62.0	2.3	SW			6.00	6.10	18	100-145	10480	845	9.250	2.56	Filed/Shims	at least 20 hours curing in Laboratory	2.33	114
2	10	15		60.64	20	62.0	3.2	SW			6.00	6.05	18	100-145	9150	750	8.250	1.46	Filed/Shims	at least 20 hours curing in Laboratory	2.33	114
2	10	16		61.33	20	62.0	2.0	SW			6.00	6.10	18	100-145	8745	705	8.875	1.28	Filed/Shims	at least 20 hours curing in Laboratory	2.33	114
2	11	9		61.60	20	62.0	15.0	SM	0	0	6.10	6.10	18	175	10800	855	10.2500	0.32	Leather Shims	20 Hours in Limewater at 73+-3 F	3.00	135
2	11	10		62.40	20	62.0	10.0	SM	0	0	6.10	6.10	18	175	10300	815	8.6250	0.32	Leather Shims	20 Hours in Limewater at 73+-3 F	3.00	135
2	11	11		62.10	20	62.0	15.0	SM	0	0	6.10	6.00	18	175	10100	830	9.3125	0.32	Leather Shims	20 Hours in Limewater at 73+-3 F	3.00	135
2	11	12		61.50	20	62.0	10.0	SM	0	0	6.10	6.00	18	175	10600	870	9.6250	0.32	Leather Shims	20 Hours in Limewater at 73+-3 F	3.00	135
2	11	13		60.80	20	62.0	10.0	SM	0	0	6.10	6.00	18	175	9000	740	9.2500	0.16	Leather Shims	20 Hours in Limewater at 73+-3 F	3.00	135
2	11	14		62.00	20	62.0	10.0	SM	0	0	6.10	6.00	18	175	10100	830	9.8125	0.32	Leather Shims	20 Hours in Limewater at 73+-3 F	3.00	135
2	11	15		61.30	20	62.0	15.0	SM	0	0	6.10	6.10	18	175	9100	720	9.0000	0.32	Leather Shims	20 Hours in Limewater at 73+-3 F	3.00	135
2	11	16		61.80	20	62.0	15.0	SM	0	0	6.10	6.10	18	175	10200	835	9.8125	0.32	Leather Shims	20 Hours in Limewater at 73+-3 F	3.00	135
2	12	9		63.55	20	66.0	4.0	SM	0.004	0	6.10	6.20	18	120-180	12080	925	8.4	0.60	Filed Edge	21 hours curing in office	1.13	47
2	12	10		63.70	20	66.0	3.0	SM	0.004	0.004	6.10	6.30	18	120-180	13200	980	8.5	1.50	Filed Edge	21 hours curing in office	1.13	47

Round	Lab ID Number	Beam ID Number	Suspected Hole or poor consolidation	Beam Weight (lb)	Overall Beam Length (in)	Ambient Temperature at Time of Test (°F)	Time Between Removal From Cure and Start of Test (min)	Moisture Condition	Gap Measurement Application	Gap Measurement Support	Average Width (in)	Average Depth (in)	Span Length (in)	Rate of Loading (psi/min)	Max Applied Load (lb)	Modulus Of Rupture (psi)	Location of Fracture (in)	1 Hour Moisture Loss (%)	Notes:	Curing History	Transport Time (hrs)	Transport Miles (mile)
2	12	11		63.65	20	66.0	7.0	SM	0.012	0.012	6.10	6.30	18	120-180	11890	880	7.2	0.70	Filed Edge	21 hours curing in office	1.13	47
2	12	12		63.40	20	66.0	6.0	SM	0	0	6.00	6.20	18	120-180	10700	835	7.4	1.00	Filed Edge	21 hours curing in office	1.13	47
2	12	13		63.40	20	66.0	5.0	SM	0.003	0.008	6.10	6.30	18	120-180	13440	1000	7.9	0.90	Filed Edge	21 hours curing in office	1.13	47
2	12	14		64.05	20	66.0	6.0	SM	0.0015	0.012	6.10	6.10	18	120-180	11830	940	7.6	1.30	Filed Edge	21 hours curing in office	1.13	47
2	12	15		63.70	20	66.0	3.0	SM	0.004	0.002	6.10	6.30	18	120-180	11750	875	8.9	1.10	Filed Edge	21 hours curing in office	1.13	47
2	12	16		59.85	20	66.0	4.0	SM	0	0	6.00	6.30	18	120-180	11570	875	9.3	1.10	Filed Edge	21 hours curing in office	1.13	47

APPENDIX D – ROUND THREE DATA SHEETS.

Round	Lab ID Number	Beam ID Number	Suspected Hole or poor consolidation	Beam Weight (lb)	Overall Beam Length (in)	Ambient Temperature at Time of Test (°F)	Time Between Removal From Cure and Start of Test (min)	Moisture Condition	Gap Measurement Application	Gap Measurement Support	Average Width (in)	Average Depth (in)	Span Length (in)	Rate of Loading (psi/min)	Max Applied Load (lb)	Modulus Of Rupture (psi)	Location of Fracture (in)	1 Hour Moisture Loss (%)	Notes:	Curing History	Transport Time (hrs)	Transport Miles (mile)
3	1	17		62.02	20	66.2	7.4	SM	<.004	<.004	6.05	6.20	18	60-200	8580	665	9.50	0.90	ground	24 - 26 Hours in Limewater at 73 F	2.25	125
3	1	18		61.90	20	66.2	5.1	SM	<.004	<.004	6.05	6.20	18	90-250	9240	720	8.60	1.20	ground	24 - 26 Hours in Limewater at 73 F	2.25	125
3	1	19		62.12	20	66.2	4.3	SM	<.004	<.004	6.00	6.20	18	90-210	8650	670	9.25	0.80	ground	24 - 26 Hours in Limewater at 73 F	2.25	125
3	1	20		61.90	20	66.2	4.4	SM	<.004	<.004	6.00	6.20	18	110-210	8460	665	9.50	0.60	ground	24 - 26 Hours in Limewater at 73 F	2.25	125
3	1	21		61.42	20	67.1	4.4	SM	<.004	<.004	6.05	6.15	18	100-230	9050	710	10.00	1.70	ground	24 - 26 Hours in Limewater at 73 F	2.25	125
3	1	22		62.54	20	67.1	5.1	SM	<.004	<.004	6.00	6.25	18	80-190	8630	660	9.50	0.80	ground	24 - 26 Hours in Limewater at 73 F	2.25	125
3	1	23		60.90	20	67.1	4.6	SM	<.004	<.004	6.00	6.20	18	60-230	9030	705	8.50	1.50	ground	24 - 26 Hours in Limewater at 73 F	2.25	125
3	1	24		61.76	20	67.1	4.3	SM	<.004	<.004	6.05	6.15	18	80-200	9320	730	8.20	0.90	ground	24 - 26 Hours in Limewater at 73 F	2.25	125
3	2	17		62.20	20	69.8	10.0	SM	0.003	0.002	6.05	6.10	18	125	9710	780	9.25	5.10	Ground/ Shims	at least 20 hours in tank at Office	0.25	3.7
3	2	18		61.70	20	69.2	10.0	SM	0.004	0.002	6.10	6.10	18	125	10970	870	8.00	5.90	Ground/ Shims	at least 20 hours in tank at Office	0.25	3.7
3	2	19		62.90	20	68.9	10.0	SM	0.004	0.003	6.10	6.10	18	125	9140	725	7.75	5.70	Ground/ Shims	at least 20 hours in tank at Office	0.25	3.7
3	2	20		62.60	20	68.6	10.0	SM	0.003	0.002	6.15	6.05	18	125	10990	880	9.25	4.30	Ground/ Shims	at least 20 hours in tank at Office	0.25	3.7
3	2	21		61.60	20	68.9	10.0	SM	0.004	0.002	6.05	6.15	18	125	10610	835	8.25	5.70	Ground/ Shims	at least 20 hours in tank at Office	0.25	3.7
3	2	22		61.80	20	69.0	10.0	SM	0.004	0.004	6.10	6.10	18	125	10070	800	9.50	5.50	Ground/ Shims	at least 20 hours in tank at Office	0.25	3.7
3	2	23		60.80	20	68.9	10.0	SM	0.004	0.003	6.15	6.15	18	125	10620	820	9.75	4.70	Ground/ Shims	at least 20 hours in tank at Office	0.25	3.7
3	2	24		62.00	20	69.0	10.0	SM	0.003	0.002	6.10	6.10	18	125	9660	770	9.25	5.50	Ground/ Shims	at least 20 hours in tank at Office	0.25	3.7
3	4	17		65.50	24	70.0	10.0	SD	0.004	0.004	6.10	6.15	18	600	13500	1050	9.00	0.69	NA	24 - 26 Hours in Limewater at 73 F	2.17	117
3	4	18		65.60	24	70.0	10.0	SW	0.004	0.004	6.05	6.15	18	600	12450	975	8.50	0.36	NA	24 - 26 Hours in Limewater at 73 F	2.17	117
3	4	19		65.50	24	70.0	10.0	SW	0.004	0.004	6.10	6.15	18	600	11050	865	8.50	0.72	NA	24 - 26 Hours in Limewater at 73 F	2.17	117
3	4	20		65.50	24	70.0	10.0	SW	0.004	0.004	6.10	6.10	18	600	10550	830	9.75	0.33	NA	24 - 26 Hours in Limewater at 73 F	2.17	117
3	4	21		66.60	24	70.0	10.0	SW	0.004	0.004	6.00	6.00	18	600	11250	930	10.25	0.32	NA	24 - 26 Hours in Limewater at 73 F	2.17	117
3	4	22		66.70	24	70.0	10.0	SW	0.004	0.004	6.00	6.05	18	600	11100	910	10.50	0.32	NA	24 - 26 Hours in Limewater at 73 F	2.17	117
3	4	23		66.10	24	70.0	10.0	SW	0.004	0.004	6.00	6.00	18	600	10900	915	10.75	0.31	NA	24 - 26 Hours in Limewater at 73 F	2.17	117
3	4	24		67.50	24	70.0	10.0	SW	0.004	0.004	6.00	6.15	18	600	10200	820	10.00	0.32	NA	24 - 26 Hours in Limewater at 73 F	2.17	117
3	5	17		62.70	20	72.0	10.0	SM	<.015	<.015	6.00	6.15	18	125-170	9700	770	8.60	0.31	Shims	24 Hours in Limewater at 73 F	2.00	110
3	5	18		62.50	20	72.0	11.0	SM	<.015	<.015	6.00	6.20	18	125-170	8260	645	7.40	0.20	Shims	24 Hours in Limewater at 73 F	2.00	110
3	5	19		62.90	20	72.0	10.0	SM	<.015	<.015	6.15	6.20	18	125-170	9980	760	9.80	0.24	Shims	24 Hours in Limewater at 73 F	2.00	110
3	5	20		61.30	20	72.0	10.0	SM	<.015	<.015	6.10	6.15	18	125-170	9220	720	7.10	0.26	Shims	24 Hours in Limewater at 73 F	2.00	110

Round	Lab ID Number	Beam ID Number	Suspected Hole or poor consolidation	Beam Weight (lb)	Overall Beam Length (in)	Ambient Temperature at Time of Test (°F)	Time Between Removal From Cure and Start of Test (min)	Moisture Condition	Gap Measurement Application	Gap Measurement Support	Average Width (in)	Average Depth (in)	Span Length (in)	Rate of Loading (psi/min)	Max Applied Load (lb)	Modulus Of Rupture (psi)	Location of Fracture (in)	1 Hour Moisture Loss (%)	Notes:	Curing History	Transport Time (hrs)	Transport Miles (mile)
3	5	21		62.20	20	72.0	10.0	SM	<.015	<.015	6.10	6.20	18	125-170	9200	705	9.00	0.24	Shims	24 Hours in Limewater at 73 F	2.00	110
3	5	22		62.00	20	72.0	11.0	SM	<.015	<.015	6.10	6.20	18	125-170	9150	700	7.70	0.17	Shims	24 Hours in Limewater at 73 F	2.00	110
3	5	23		63.60	20	72.0	11.0	SM	<.015	<.015	6.15	6.15	18	125-170	9300	720	9.30	0.20	Shims	24 Hours in Limewater at 73 F	2.00	110
3	5	24		62.90	20	72.0	10.0	SM	<.015	<.015	6.10	6.20	18	125-170	9020	690	7.20	0.21	Shims	24 Hours in Limewater at 73 F	2.00	110
3	6	17		61.50	20	72.0	7.0	SM	0.003	0.003	6.10	6.00	18	130	9370	750	9.00	0.49	Shims	22 hours in tank after arrival in office	6.50	117
3	6	18		61.60	20	72.0	7.0	SM	0.004	0.01	6.05	6.15	18	160	8810	705	8.50	0.40	Shims	22 hours in tank after arrival in office	6.50	117
3	6	19		60.70	20	72.0	9.0	SM	0.004	0.021	6.10	6.00	18	140	9080	735	8.50	0.34	Shims	22 hours in tank after arrival in office	6.50	117
3	6	20		62.20	20	72.0	11.0	SM	0.011	0.005	6.10	6.10	18	130	8830	705	9.25	0.32	Shims	22 hours in tank after arrival in office	6.50	117
3	6	21		61.80	20	72.0	5.0	SM	0.003	0.005	6.10	6.05	18	150	9310	750	9.33	0.48	Shims	22 hours in tank after arrival in office	6.50	117
3	6	22		62.20	20	72.0	10.0	SM	0.011	0.012	6.10	6.15	18	180	9130	720	8.75	0.40	Shims	22 hours in tank after arrival in office	6.50	117
3	6	23		63.60	20	72.0	5.0	SM	0.011	0.005	6.25	5.95	18	130	9480	730	9.25	0.34	Shims	22 hours in tank after arrival in office	6.50	117
3	6	24		68.60	24	72.0	7.0	SM	0.003	0.015	6.10	6.05	18	130	8800	700	10.25	0.38	Shims	22 hours in tank after arrival in office	6.50	117
3	7	17		65.30	21	63.1	5.0	SM	.015-.004	.015-.004	6.15	6.05	18	150	8385	670	9.70	3.90	None	23-25 hours cure	2.00	107
3	7	18		65.50	21	63.8	6.0	SM	.015-.004	.015-.004	6.10	6.00	18	150	8010	655	9.50	4.40	None	23-25 hours cure	2.00	107
3	7	19		65.00	21	63.6	5.0	SM	<.004	<.004	6.10	6.00	18	150	8375	685	9.50	5.00	None	23-25 hours cure	2.00	107
3	7	20		64.40	21	61.6	5.0	SM	<.004	<.004	6.05	6.00	18	150	8350	690	9.70	3.70	Shims	23-25 hours cure	2.00	107
3	7	21		64.60	21	62.0	5.0	SM	<.004	<.004	6.00	6.05	18	150	7610	625	9.10	4.50	Shims	23-25 hours cure	2.00	107
3	7	22		63.60	21	62.2	6.0	SM	<.004	<.004	6.00	6.00	18	150	7835	650	10.40	3.60	Shims	23-25 hours cure	2.00	107
3	7	23		64.60	21	61.2	6.0	SM	<.004	<.004	6.10	6.00	18	150	8015	655	9.80	3.60	Shims	23-25 hours cure	2.00	107
3	7	24		64.70	21	60.5	8.0	SM	<.004	.015-.004	6.05	6.05	18	150	8310	675	9.70	3.70	Shims	23-25 hours cure	2.00	107
3	8	17		62.10	21	67.0	5.0	SW	<.004	<.004	6.15	6.05	18	170	8670	695	8.75	4.10		24 - 26 Hours in Limewater at 73 F	2.00	108
3	8	18		61.40	21	67.0	5.0	SW	.004-.015	<.004	6.10	6.10	18	170	8900	705	8.00	3.00	Shims	24 - 26 Hours in Limewater at 73 F	2.00	108
3	8	19		61.80	21	67.0	4.0	SW	<.004	<.004	6.20	6.05	18	170	8240	655	8.50	3.20		24 - 26 Hours in Limewater at 73 F	2.00	108
3	8	20		61.60	21	67.0	7.0	SW	<.004	<.004	6.15	6.05	18	170	8690	695	8.50	3.40		24 - 26 Hours in Limewater at 73 F	2.00	108
3	8	21		62.00	21	67.0	10.0	SW	<.004	<.004	6.20	6.00	18	170	5350	430	9.50	3.80		24 - 26 Hours in Limewater at 73 F	2.00	108
3	8	22		62.10	21	67.0	5.0	SW	<.004	<.004	6.10	6.05	18	170	9080	730	9.00	2.40		24 - 26 Hours in Limewater at 73 F	2.00	108
3	8	23		62.00	21	67.0	6.0	SW	<.004	<.004	6.20	6.05	18	170	8500	675	8.00	2.80		24 - 26 Hours in Limewater at 73 F	2.00	108
3	8	24		61.70	21	67.0	6.0	SW	.004-.015	<.004	6.15	6.00	18	170	8440	685	9.00	2.30	Shims	24 - 26 Hours in Limewater at 73 F	2.00	108

Round	Lab ID Number	Beam ID Number	Suspected Hole or poor consolidation	Beam Weight (lb)	Overall Beam Length (in)	Ambient Temperature at Time of Test (°F)	Time Between Removal From Cure and Start of Test (min)	Moisture Condition	Gap Measurement Application	Gap Measurement Support	Average Width (in)	Average Depth (in)	Span Length (in)	Rate of Loading (psi/min)	Max Applied Load (lb)	Modulus Of Rupture (psi)	Location of Fracture (in)	1 Hour Moisture Loss (%)	Notes:	Curing History	Transport Time (hrs)	Transport Miles (mile)
3	9	17		62.20	20	60.0	14.0	SM	0.002	0.003	6.24	6.00	20	120-160	8060	720	8.6000	3.40	Ground	24 - 26 Hours in Limewater at 73 F	2.00	120
3	9	18		62.10	20	60.0	10.0	SM	0.002	0.002	6.19	5.99	20	120-160	7690	695	8.7500	3.00	Ground	24 - 26 Hours in Limewater at 73 F	2.00	120
3	9	19		61.90	20	60.0	10.0	SM	0.002	0.002	6.20	5.95	20	120-160	7890	720	9.1250	4.50	Ground	24 - 26 Hours in Limewater at 73 F	2.00	120
3	9	20		61.80	20	60.0	6.0	SM	0.001	0.002	6.23	5.92	20	120-160	8500	780	7.5625	3.40	Ground	24 - 26 Hours in Limewater at 73 F	2.00	120
3	9	21		61.45	20	60.0	8.0	SM	0.002	0.002	6.27	5.95	20	120-160	9060	815	9.3125	3.80	Ground	24 - 26 Hours in Limewater at 73 F	2.00	120
3	9	22		61.65	20	60.0	6.0	SM	0.002	0.002	6.25	5.99	20	120-160	7860	700	8.0625	3.30	Ground	24 - 26 Hours in Limewater at 73 F	2.00	120
3	9	23		61.30	20	60.0	8.0	SM	0.002	0.002	6.14	6.00	20	120-160	8300	760	8.7500	3.00	Ground	24 - 26 Hours in Limewater at 73 F	2.00	120
3	9	24		62.00	20	60.0	7.0	SM	0.002	0.002	6.24	5.91	20	120-160	8410	770	8.0625	3.90	Ground	24 - 26 Hours in Limewater at 73 F	2.00	120
3	10	17		73.74	24	64.0	11.4	SM	0	0	6.00	6.05	20	120-175	6705	610	11.125	1.42	Filed/Shims	at least 20 hours curing in Laboratory	2.00	114
3	10	18		76.14	24	64.0	3.9	SW	0	0	6.05	6.10	20	120-175	7060	630	10.000	1.91	Filed/Shims	at least 20 hours curing in Laboratory	2.00	114
3	10	19		74.28	24	64.0	3.2	SW	0	0	6.05	6.05	20	120-175	6860	620	10.000	1.77	Filed/Shims	at least 20 hours curing in Laboratory	2.00	114
3	10	20		74.01	24	64.0	3.1	SW	0	0	5.95	6.05	20	120-175	8605	790	11.250	1.35	Filed/Shims	at least 20 hours curing in Laboratory	2.00	114
3	10	21		61.67	20	64.0	4.1	SM	0	0	6.00	6.10	18	120-170	8690	700	9.250	2.35	Filed/Shims	at least 20 hours curing in Laboratory	2.00	114
3	10	22		61.82	20	64.0	2.6	SW	0	0	6.00	6.10	18	120-170	9415	760	8.375	2.67	Filed/Shims	at least 20 hours curing in Laboratory	2.00	114
3	10	23		62.04	20	64.0	2.7	SW	0	0	6.00	6.15	18	120-170	8050	640	7.875	1.02	Filed/Shims	at least 20 hours curing in Laboratory	2.00	114
3	10	24		61.74	20	64.0	2.8	SW	0	0	6.00	6.15	18	120-170	8585	680	8.000	2.27	Filed/Shims	at least 20 hours curing in Laboratory	2.00	114
3	11	17		62.40	20	61.0	15.0	SM	0	0	6.10	6.00	18	175	10000	820	8.3125	0.16	Leather Shims	20 Hours in Limewater at 73+-3 F	3.00	135
3	11	18		62.60	20	61.0	10.0	SM	0	0	6.20	6.05	18	175	9900	785	7.7500	0.27	Leather Shims	20 Hours in Limewater at 73+-3 F	3.00	135
3	11	19		62.50	20	61.0	10.0	SM	0	0	6.10	6.05	18	175	10100	805	8.0000	0.80	Leather Shims	20 Hours in Limewater at 73+-3 F	3.00	135
3	11	20		61.70	20	61.0	15.0	SM	0	0	6.15	6.05	18	175	10300	825	7.7500	0.16	Leather Shims	20 Hours in Limewater at 73+-3 F	3.00	135
3	11	21		61.40	20	61.0	10.0	SM	0	0	6.20	6.05	18	175	10000	795	8.6875	0.73	Leather Shims	20 Hours in Limewater at 73+-3 F	3.00	135
3	11	22		62.30	20	61.0	10.0	SM	0	0	6.10	6.05	18	175	10000	805	8.3125	0.29	Leather Shims	20 Hours in Limewater at 73+-3 F	3.00	135
3	11	23		60.70	20	61.0	10.0	SM	0	0	6.05	6.00	18	175	10000	825	8.0625	0.28	Leather Shims	20 Hours in Limewater at 73+-3 F	3.00	135
3	11	24		61.60	20	61.0	10.0	SM	0	0	6.05	6.10	18	175	10000	800	8.9375	0.20	Leather Shims	20 Hours in Limewater at 73+-3 F	3.00	135
3	12	17		62.25	20	67.0	3.0	SM	0	0	6.10	6.10	18	140-180	10610	840	9.5	0.90	Filed Edge	21 hours curing in office	1.13	47
3	12	18		62.85	20	67.0	2.0	SM	0	0	6.00	6.20	18	140-180	9010	700	9.4	1.80	Filed Edge	21 hours curing in office	1.13	47
3	12	19		62.20	20	67.0	5.0	SM	0	0	6.00	6.20	18	140-180	10350	810	8.0	1.10	Filed Edge	21 hours curing in office	1.13	47
3	12	20		62.00	20	67.0	4.0	SM	0	0	6.10	6.10	18	140-180	9640	765	8.5	1.10	Filed Edge	21 hours curing in office	1.13	47

Round	Lab ID Number	Beam ID Number	Suspected Hole or poor consolidation	Beam Weight (lb)	Overall Beam Length (in)	Ambient Temperature at Time of Test (°F)	Time Between Removal From Cure and Start of Test (min)	Moisture Condition	Gap Measurement Application	Gap Measurement Support	Average Width (in)	Average Depth (in)	Span Length (in)	Rate of Loading (psi/min)	Max Applied Load (lb)	Modulus Of Rupture (psi)	Location of Fracture (in)	1 Hour Moisture Loss (%)	Notes:	Curing History	Transport Time (hrs)	Transport Miles (mile)
3	12	21		62.45	20	67.0	4.0	SM	0.004	0	6.00	6.10	18	140-180	9320	750	7.8	1.40	Filed Edge	21 hours curing in office	1.13	47
3	12	22		62.90	20	67.0	3.0	SM	0.003	0.0015	6.00	6.20	18	140-180	9020	705	9.5	1.60	Filed Edge	21 hours curing in office	1.13	47
3	12	23		62.65	20	67.0	4.0	SM	0.006	0.0015	6.00	6.20	18	140-180	10050	785	9.6	0.90	Filed Edge	21 hours curing in office	1.13	47
3	12	24		62.60	20	67.0	4.0	SM	0.002	0	6.00	6.20	18	140-180	10110	790	8.5	1.20	Filed Edge	21 hours curing in office	1.13	47