LIGHTWEIGHT SELF CONSOLIDATING FIBER REINFORCED CONCRETE

By

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A thesis submitted to the

Graduate School-New Brunswick

Rutgers, The State University of New Jersey

in partial fulfillment of the requirements

for the degree of

Master of Science

Graduate Program in Civil and Environmental Engineering

Written under the direction of

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New Brunswick, New Jersey

October 2013

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ABSTRACT OF THE THESIS

LIGHTWEIGHT SELF CONSOLIDATING FIBER REINFORED CONCRETE

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The object of this research was to determine the effects steel and polypropylene fibers have on the fresh and mechanical properties of a lightweight self consolidating concrete (LWSCC). Secondary objectives were to determine which of the two chosen fibers yield superior results, and to determine approximate optimal fiber content by volume. A LWSCC mix was developed for the control mix using a design procedure based on the volumetric method. Two fibers, steel and polypropylene, were chosen for this research. Each fiber type had two different densities by volume creating a total of five mixes including the control. All mixes were tested for workability, passing ability, density, compressive strength, elastic modulus, splitting tension, and flexural strength. All tests were performed in accordance with the appropriate ASTM specification. Overall, fiber specimens performed better than the control in splitting tension, compression, and flexural strength testing since they could hold a residual load. Effect on modulus of elasticity and workability was minimal. Fibers did increase the density of the samples; however the equilibrium density of all mixes fell into acceptable ranges. Passing ability was greatly affected by the addition of fibers; however simple adjustments in mix proportion could easily resolve this issue. The steel samples outperformed the polypropylene samples. More specifically the Steel30 samples produced the best results.

Acknowledgements

First I would like to thank Rutgers Civil and Environmental Engineering Department for providing me with funding throughout my graduate studies and enabling me to focus on a topic that was most important to me. Thank you to Dr. Najm, Dr. Balguru, and Dr. Prendergast for all of your advice and unwavering support throughout this process. A very special thank you to Alicia Plinio and Anthony Casale for taking the time to be my labor force and for always making sure that I measure twice and cut once! Thank you to all the companies who donated materials in order for me to complete my project, especially William Wolfe from Norlite Corp who answered many of my questions and was always willing to help. Lastly a huge thank you to my family and friends, Mom, Dad, Anthony and Ed. Your support and prayers never went unnoticed and I couldn’t have done any of this without you.

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Chapter 1 Introduction

Concrete had been successfully used to construct many of the world's historic icons such as the coliseum, and the basic combination of aggregates, cement, and water are still suitable for many of today's projects (ACI 213R-03). However due to the introduction of new technologies and increasingly complex structural designs the old standard formulation is not always a valid option. Some new concrete innovations include the use of lightweight aggregates, free flowing or self consolidating concrete, and fiber reinforcement. This research focused on creating a lightweight self consolidating concrete (LWSCC) and studying the effects that fibers had on the fresh and mechanical properties. Lightweight concrete has become popular due to its reduced unit weight and ability to have strengths comparable to normal weight concrete. The reduction in unit weight is favorable since it can decrease the total dead load of a structure thus, reducing the size of the structural members which in turn will usually reduce the total cost of the project (Kosmatka et al. 2002). Self consolidating, or self compacting concrete (SCC) is a preferred substitution for conventional concrete where highly congested reinforcement is present or forms with complex shapes need to be filled. It is able to flow and consolidate under its own weight without the need for mechanical vibration (ACI 237R-07). Fiber reinforced concrete is beneficial because of its flexibility in methods of fabrication. Fibers are discontinuous and are generally distributed randomly throughout the concrete matrix. Fiber manufactures claim that fiber can replace the requirement for welded wire reinforcement to control shrinkage cracking and reduce labor costs by reducing the need for tied rebar cages. The most popular fibers found in the construction industry are steel and synthetic (ACI 544.1R-96).

Industry is constantly looking for new innovations in concrete mix design and has been using the aforementioned components independently for some time. It is believed that by incorporating the three items; self consolidating concrete, fibers, and lightweight aggregate, the benefits of each will translate to create a concrete that is better than using only one of its parts. However very little research has been done on using lightweight aggregates in self consolidating concrete and nearly no research has been performed on the effects of fibers on the mix. The object of this research was to:

- Determine the effects steel and polypropylene fibers have on the fresh and mechanical properties of a lightweight self consolidating concrete,
- Determine which of the two chosen fibers yield superior results, and to
- Determine approximate optimal fiber content by volume.

In order to satisfy the objective, data was obtained on the fresh and mechanical properties of: 1) a control mix without fibers: 2) two mixes with steel fibers: and 3) two mixes with polypropylene fibers. The fresh property testing included workability, passing ability, and air content (for control only). The mechanical properties tested were compression, splitting tension, elastic modulus, flexural properties, and density.

Chapter 2 Literature Review

2.1 Structural Lightweight Concrete

2.1.1 Background

Structural lightweight concrete has a unit weight that ranges from 70pcf to 120pcf as compared to normal weight concrete that ranges from 140pcf to 155pcf (ACI 213R-03). It has a minimum 28-day compressive strength of 2500psi, but can achieve strengths as high as 8000psi in some cases (Kosmatka et al. 2002). Structural lightweight concrete is made of aggregates that are either all lightweight, or a combination of lightweight and normal weight. Lightweight aggregates can be combined in one of these three configurations:

- Lightweight coarse and lightweight fine aggregate
- Normal weight coarse and lightweight fine aggregate
- Lightweight coarse and normal weight fine aggregate.

The last combination is most commonly chosen in industry and was used in this research.

The defining component of lightweight concrete is its unique aggregates. Aggregates can be classified in two categories: natural lightweight aggregate and manufactured lightweight aggregate. Natural aggregates are produced by processing naturally occurring materials such as pumice, scoria or tuff. These materials are not readily used in the United States due to their irregularities and inconsistencies (Andrews 2009). Manufactured aggregates should meet the requirements of ASTM C330 and include rotary kiln expanded clays, shales, slates, sintering grate expanded shales and slates, pelletized or extruded fly ash and expanded slags (Kosmatka et al. 2002).

All lightweight aggregates, whether natural or manufactured, greatly affect how mixtures are proportioned. Since these aggregates are very porous, they will absorb a great deal of moisture, hence altering the original mix proportions. Most normal weight concrete mixture proportions are calculated based on a moisture condition easily obtained in the laboratory and in the field. “In structural lightweight concrete, the main problem is accounting properly for the moisture in (absorbed), and on (adsorbed), the lightweight aggregate particles as well as for the effects of absorption for a specific application” (ACI 211.2-98). Most structural lightweight concrete mix proportions are reported in the oven dried condition, however this condition rarely, if ever occurs in the field. Usually field aggregates are in a damp or wet condition which is achieved by sprinkling, soaking, thermal quenching, or vacuum saturation and are referred to as the “as-is” condition. The main problem for researchers is creating an easy way to convert the mix proportions using oven dried conditions to proportions using the “as-is” moisture conditions.

In addition to variability in mix design, the cost of using lightweight concrete also varies. The use of lightweight concrete is usually based on the reduction of total project cost as a byproduct of lighter overall structural mass, improved functionality, or a combination of both. According to ACI 213, lightweight concrete is generally about 1% more costly than normal weight concrete. This cost however, is usually offset by one of the many benefits to functionality. Most of the benefits stem from a decrease in unit weight and therefore, lead to a decreased dead load. Reduction in dead loads may result in reductions in size of foundations and smaller supporting members such as beams and girders. In locations where the cost of transportation is significant, a reduced unit weight can be beneficial. With respect to mechanical properties, lightweight concrete has a lower elastic modulus than normal weight concrete. This means that it is more flexible and can be beneficial in cases where differential foundation settlement may occur, improved dynamic response is needed, or in certain types of structures, such as shell roofs, where a decease in stiffness is desirable (ACI 213R-03).

2.1.2 Testing

Generally structural lightweight concrete can be tested using the same standards for normal weight concrete. Two tests, however, are important in determining specific qualities of lightweight concrete. The first is the air content of a mix in its plastic state. There are three different types of tests that are approved for sampling air content in concrete (gravimetric, pressure, volumetric) however, only the volumetric method will suffice for the testing of lightweight concrete. The reason is due to the porous nature of the lightweight aggregates. The “Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method” (ASTM C173/C173M-12) works by measuring the air contained in the mortar fraction of the concrete, but by nature of the test, is not affected by air that may be present inside porous aggregate particles. It is therefore the recommended and most appropriate test to determine the air content of concretes containing lightweight aggregates, air-cooled slag, and highly porous or vesicular natural aggregates. The test is conducted by first filling a bowl with a sample of the fresh mix.

Figure 2.1: Volumetric Air Content Apparatus (NDT James Instruments, Inc.)

The lid is clamped on and is filled with a mixture of water and isopropyl alcohol. Next the apparatus is agitated in order to mix all of the material inside. When mixing is complete the air content that was displaced by the water and alcohol is can be read from the neck of the apparatus.

The second test of great importance to structural lightweight concrete is density. Since lightweight concrete must have a smaller unit weight than normal weight to be effective, this number must be determined. For this research, density testing was performed according to ASTM C567/C567M-11 “Standard Test Method for Determining Density of Structural Lightweight Concrete”. Since the test for equilibrium density can take up to 3 months, many researchers choose to only find the oven dried density, and subsequently use an equation supplied by ASTM to find the approximate equilibrium density. Since density of lightweight concrete is of great significance to this research, both oven dried and equilibrium procedures were performed, as opposed to using the approximate equilibrium density equation. Both procedures used three cylinders for testing. In this regard, cylinders are individually weighted while immersed in water, then weighted once saturated. To determine the oven dried density, samples are then placed in an oven and continually weighted until there is minimal change in the weight (oven dried weight). Conversely, for the equilibrium density test, the remaining three cylinders are placed in a temperature and humidity controlled chamber and continually weighted until there is minimal change in weight (equilibrium weight).

2.2 Self Consolidating Concrete

2.2.1 Background

Self consolidating concrete (SCC), also referred to as self compacting concrete, is able to flow and consolidate under its own weight without the need for mechanical vibration. It is also cohesive enough to fill spaces of almost any size and shape without segregation or bleeding. These properties make SCC a useful substitute to conventional concrete wherever placement is difficult, such as in heavily reinforced members where spacing between bars in small or in complex formwork (ACI 237R-07). In order to create SCC a few proportions need to be modified. The first is to increase the amount of fine material, without changing the water content. This changes the rheological behavior of the concrete. To increase the plasticity of the mixture a high range water reducer based on polycarboxylate ethers can be added in addition to the increased fines in the mix (Kosmatka et al. 2002). What differentiates SCC from conventional concrete are its fresh, or plastic properties. Due to this, many new tests have been developed to measure the workability, filling ability, passing ability, and stability of SCC. Workability describes the ease with which concrete can be mixed, placed, and finished. The workability of SCC is defined by its filling and passing ability, as well as its stability. The filling ability describes the capability of SCC to flow into and completely fill formwork fully under its own weight. The passing ability refers to the ease in which concrete can pass through various obstructions and tight spacing of reinforcement without blockage. The stability of concrete describes the ability of the material to maintain homogeneous distribution of its various parts during placing and setting (ACI 237R-07). This stability is affected by the density of the aggregates. For instance, a denser aggregate is more prone to segregate to the bottom of the concrete mix as the paste floats to the top. In contrast, a lightweight aggregate will have the tendency to segregate to the top and float (Andrews 2009). In order to reduce the chances of segregation, a viscosity modifying admixture (VMA) is added. “A VMA is an admixture used to enhance the rheological properties of cement based materials in the plastic state to reduce the risk of segregation and washout” (ACI 237R-07).

The strength and durability of SCC are comparable to that of conventional concrete, however its production is more expensive and its desired consistency is difficult to maintain over a long period of time. These disadvantages are often overlooked due to SCCs ability to reduce construction time and its ability to produce a quality product without the need for mechanical vibration (Kosmatka et al. 2002).

2.2.2 Testing

Self consolidating concrete is dramatically different than typical concrete while in its plastic state. This led to the utilization of different tests in order to determine workability and passing ability. Since SCC flows much like water in its fresh state, a typical slump test would be invalid. Therefore, workability of SCC is measured by ASTM

C1611/C1611M-09b "Standard Test Method for Slump Flow of Self-Consolidating Concrete". In this test fresh concrete is poured into an inverted mold in one layer without tamping or vibration. The mold is then raised, and the concrete sample is allowed to spread. After spreading ceases, two diameters of the concrete mass are measured in approximately orthogonal directions. The slump flow is calculated as the average of the two diameters. The greater the diameter, the more workable the concrete is. Other, non-mandatory information, can also be determined from the slump flow test. The stability of self-consolidating concrete can be observed visually by examining the concrete mass, and therefore can be used for quality control of self-consolidating concrete mixtures.

Visual Stability Index Values

VSI Value	Criteria
0 = Highly Stable	No evidence of segregation or bleeding.
1 = Stable	No evidence of segregation and slight bleeding observed as a sheen on the concrete mass.
2 = Unstable	A slight mortar halo ≤ 10 mm [≤ 0.5 in.] and/or aggregate pile in the of the concrete mass.
3 = Highly Unstable	Clearly segregating by evidence of a large mortar halo > 10 mm [> 0.5 in.] and/or a large aggregate pile in the center of the concrete mass.

Figure 2.2: Visual Stability Index Values (ASTMC1611)

The values given to the mix come from the Visual Stability Index (VSI), seen in figure 2.2, which have corresponding criteria to give a qualitative assessment of the concrete sample.

There are a few generally accepted tests for passing ability; however there is only one test that has been accepted by ASTM. The "Standard Test Method for Passing Ability of Self-Consolidating Concrete by J-Ring", ASTM C1621/C1621M-09b, is used in conjunction with the data recorded from the slump flow to find passing ability. The test is performed much like the slump flow test. It is important to keep the orientation of the mold (inverted in this research) the same for both the J-Ring test and for the slump flow test. After filling, the mold is raised, and the concrete is allowed to spread through the J-Ring.

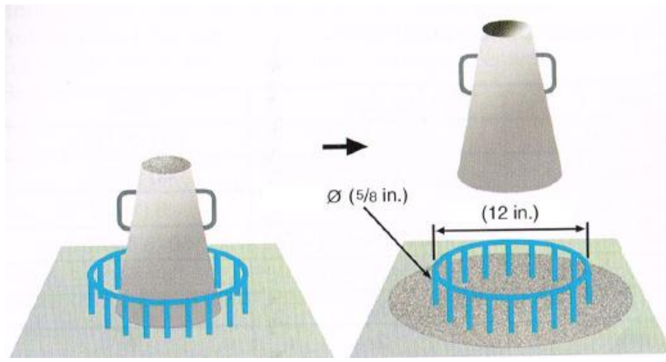

Figure 2.3: J-Ring Test (Kosmatka et al. 2002)

After spreading ceases, two diameters of the concrete mass are measured in approximately orthogonal directions; the average of these diameters is the J-ring flow. The difference between the slump flow and J-Ring flow is an indicator of the passing ability of the concrete. A diameter difference less than 1 in. indicates good passing ability and a difference greater than 2 in. indicates poor passing ability.

2.3 Fiber Reinforced Concrete

2.3.1 Background

Fibers can be used to enhance certain concrete properties such as tensile strength, compressive strength, shrinkage, and fatigue life as well as many others (ACI 544.1R-96). Fibers can be made from steel, plastic, glass, synthetics, and natural materials such as wood cellulose. They are available in a variety of shapes, sizes and thicknesses; they may be flat, round, or deformed, and have typical lengths from .25in to 6in and thicknesses ranging from .0002in to .03in. In most cases they are added to the concrete during mixing. In this research both steel and synthetic (polypropylene) fibers were used.

Steel fibers intended for reinforcement are “short, discrete lengths of steel with an aspect ratio (ratio of length to diameter) from about 20 to 100, and with any of several cross sections” (Kosmatka et al. 2002). Some steel fibers have hooked ends in order to improve resistance to pullout. Fibers must also be small enough to be randomly dispersed in a fresh concrete mixture by using normal mixing procedures. ASTM A820 classifies four different types steel fibers based on how they are manufactured. Type-I Cold drawn wire fibers are manufactured from drawn steel wire and are most commercially available. These are the types of fibers used in this research. Type-II are called cut sheet fibers and are created by laterally shearing off steel sheets. Type-III are melt extracted fibers and are manufactured by using a rotating wheel to lift liquid metal then to rapidly freeze it into fibers which are then thrown off by centrifugal force (ACI 544.1R-96).

The fiber strength, stiffness, and ability of the fibers to bond with the concrete are important fiber reinforcement properties. In the terms of steel fibers, bond is dependent on the aspect ratio of the fiber. The steel fibers themselves have an elevated high strength and high modulus of elasticity and are protected from corrosion by the alkaline environment of the cementitious matrix. Steel fiber volumes typically range from 0 .25 to 2 percent, with volumes more than 2% greatly reducing workability. Based on research by Altoubat and Lange, the addition of 1.5% steel fiber by volume can increase the direct tensile strength by up to 40% and the flexural strength by up to 150%.

Synthetic fibers are man-made fibers resulting from research and development in the petrochemical and textile industries. The most common types used in concrete are acrylic, aramid, carbon, nylon, polyester, polyethylene, and polypropylene. Polypropylene fibers are the most popular of the synthetics. They are produced in an extrusion process and can be chopped to specific lengths. Some benefits include chemical inertness, hydrophobic properties, and lighter weight. Many tests have been conducted on composites containing polypropylene fibers at volumes ranging from 0.1 to 10 percent; however the properties of these composites vary greatly depending on fiber volume, geometry, and composition of the concrete matrix. One study by Suprenant and Malisch showed that using 0.1% by volume of polypropylene fibers reduced plastic shrinkage cracking, and subsidence cracking over steel reinforcement. On the contrary, by adding 0.1% fibers by volume showed that there was no increase in compressive strength, and by adding more fibers would actually decrease compressive strength (ACI 544.1R-96).

2.3.2 Testing

Fiber reinforced concrete is beneficial in its increased flexural performance and its ability to hold more stress in tension. Due to this fact, flexural performance testing was used to compare the samples. The four (4) samples with fibers were tested in accordance with ASTM C1609/1609M-12 "Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam with Third-Point Loading)". This test method evaluated the flexural performance of fiber reinforced concrete using data from the load-deflection curve obtained by testing a simply supported beam under third-point loading. This test is used to determine the first peak load strength, peak load strength, residual strengths, toughness, and flexural strength ratio. The specimens used were molded with dimensions of 4"x4"x14", and were tested on a 12" span. For testing, specimens were placed on their sides and loaded at a rate of 0.002in/min for the entirety of the test. Testing was stopped when the deflections reached 0.08in (L/150), or the sample was split entirely it two pieces. The load deflection graph was created from the data and subsequent strengths were determined by the equations provided in the specification.

Chapter 3 Methodology

The main purpose of this research is to study the effects that fibers have on lightweight self consolidating (LWSC) concrete. In doing so, a LWSC mix had to be chosen as a control mix. This process became more of a challenge than originally anticipated due to minimal published research on the topic. This led to the creation and testing of preliminary LWSC mixes in order to determine the best design to act as a control. After a control mix was created, it was decided to test the effects of different concentrations of steel and polypropylene fibers. Each mix would be tested in the same manner in accordance with the appropriate ASTM testing procedures for both fresh and mechanical properties. Part of this research also included deciding which tests would be appropriate for a mix that combines three very different types of concrete. For instance, a typical slump test for lightweight concrete utilizes a cone and is measured in inches by height, however this mix is also self consolidating so it will create a spread that cannot be measured using a cone, hence the decision to ultimately measure slump flow and passing ability. The mechanical properties tested were compression, indirect tension, oven dried density, equilibrium density, elastic modulus, and flexural capacity. Properties of each mix would be compared directly to the other designs as well as the control. For example, the 28 day compressive strengths of each mix were compared to determine the strongest sample in compression. After analyzing and ranking each mix based on individual properties, the mix that performed best globally was chosen as a potential candidate for future research.

Chapter 4 Experimental Procedure

4.1 Material Properties

Type I Portland cement, supplied by Lafarge, and Type F fly ash, supplied by Pro Ash, were used in all of the concrete mixes. Fly ash is a by-product from the combustion of pulverized coal. Benefits in its plastic state include reductions in the heat of hydration and increased workability (ACI 232.2R-03). Lightweight coarse aggregates (3/8- No. 8 size) were supplied by Norlite, LLC and were tested on site to meet the specifications set forth by ASTM C330/C330M-09. Natural siliceous sand came from a local quarry operated by Weldon Materials. A polycarboxylate-based high range water reducer with added viscosity modifying agent (ADVA Cast 575) was supplied by W.R. Grace & Co.

4.2 Lightweight Self Consolidating Control Mix

In order to test the effect of fibers on the mix, a control was designed. Since there is no standard specified by ACI to design a LWSC mix, an experimental procedure was developed. Here the mix was designed by volume following the flowchart shown in figure 4.1 based on the research performed by Kristopher Pierce.

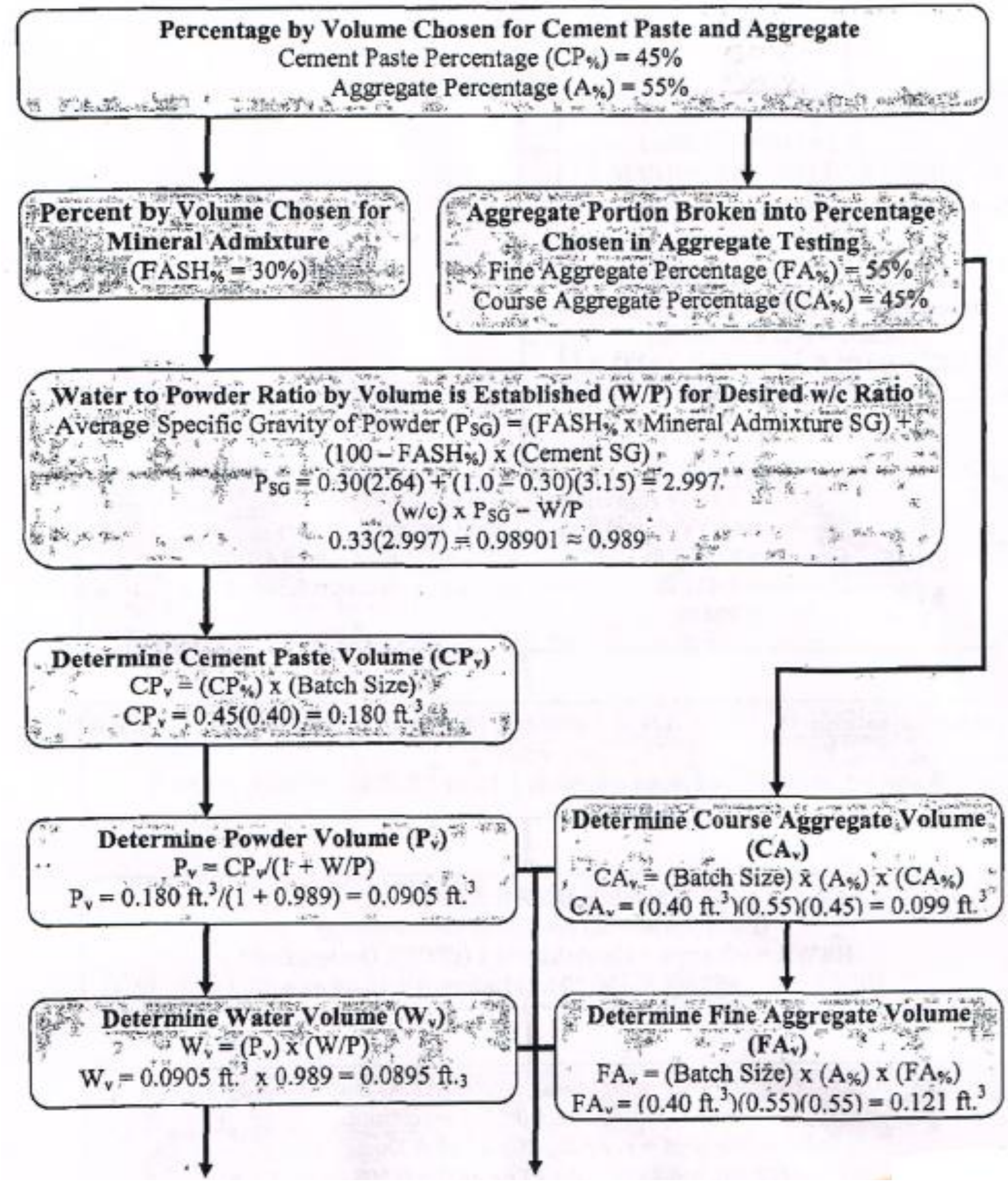

Figure 4.1: Procedure for Proportioning Control Mix (Pierce 2007).

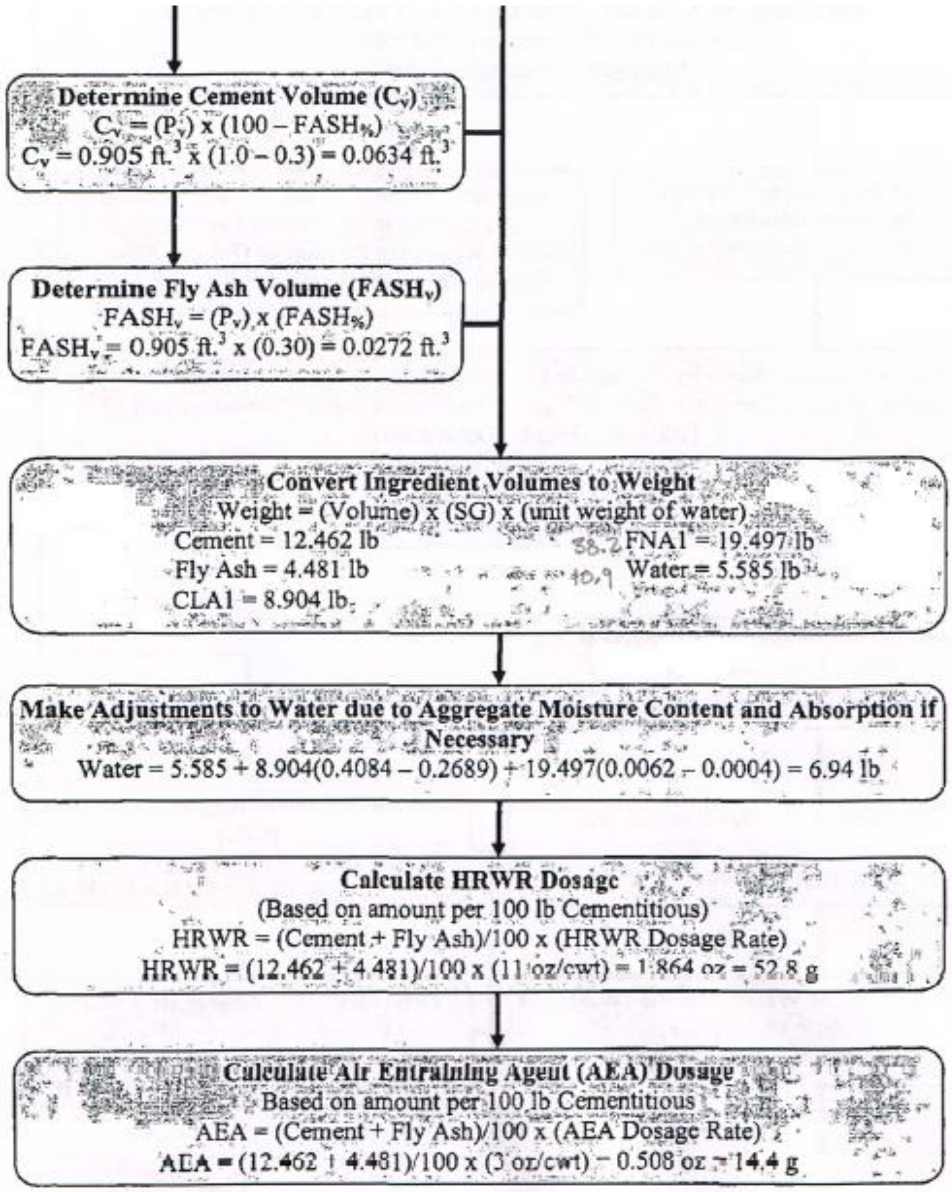

Figure 4.1: Procedure for Proportioning Control Mix (continued) (Pierce 2007).

Since the design was preliminary, physical mixes needed to be created and tested in order to find the best control mix for the remainder of the research. In each test mix the ratio of cement paste and aggregate remained the same at 45% cement paste and 55% aggregate. Different ratios of coarse to fine aggregate were tested as well as varying the water to cement ratio and amount of superplasticizer. A sample of a LWSC control mix design can be seen in Appendix A.

To determine which design should be used as the control mix for the experiment, a series of tests were performed on the fresh and hardened properties of the concrete. As explained in a previous section, the slump flow and J-ring tests were performed according to ASTM C1611/C1611M-09be1 and ASTM C1621/C1621M-09b respectively. A successful mix had a slump flow between 20 and 25 inches. The mix should also show no signs of segregation or excessive water bleed. The mix also had to pass the J-ring test with a diameter of no less than 2 inches less than that of the slump flow diameter. The only mechanical property tested was compressive strength in accordance with ASTM C39/C39M-12a. A 7 day and 28 day compression test was performed on 3 cylinders for each day of testing. The data collected from the compression tests was used as a secondary factor in deciding which LWSC mix to choose as the control. The compressive strength of the mix is required by ACI to reach 2500psi to be considered structural lightweight concrete (ACI 213R-03).

4.3 Lightweight Self Consolidating Fibers Mix

4.3.1 Fiber Selection

The first step in researching fibers begins with the selection of which fibers to use. As discussed in section 2.3.1 there are many fibers of varying lengths and materials to choose from. For this investigation steel fibers that measure 750μm in diameter and 50mm in length supplied by Maccaferri, Inc. were used. In contrast to the steel fibers, polypropylene fibers that measure 690μm in diameter and 2inches in length supplied by Euclid Chemical were also tested. It was decided to test two different fiber concentrations for each type of fiber. The steel fibers were added at a concentration of 30lb/yd^3 and

60lb/yd^3. Since the polypropylene fibers are less dense, the concentrations used were 2lb/yd^3 and 4lb/yd^3.

4.3.2 Mixing

Each mix was batched according to the design of the control mix. Since the mix design was based on volume, the specific gravity of each material was utilized to convert volume to weight. Materials were then measured by weight and placed in 5 gallon buckets prior to being added to the mixer. As explained in section 2.1.1 pertaining to lightweight aggregates, the aggregates had to be soaked and then dried to SSD conditions. This was achieved by first soaking the aggregate in buckets for approximately 48 hours. The aggregates were then strained and placed in a thin layer on a plastic sheet for approximately 18 hours in order to evaporate off excess water. These times were chosen based on the previous research done for the control mix and yielded the best results. On the day of mixing a moisture test of the sand was performed in order to determine if any moisture adjustments were needed. The water and superplasticizer were also measured the day of mixing. The mix began with adding all superplasticizer to the water bucket and mixing to ensure full dissolution. Next the coarse aggregate and 2/3 of the water were added to the mixer and mixed for a few revolutions. The mixer was then stopped where at this point sand, cement, fly ash, and the remaining water were added respectively. The mixer spun covered for 3 minutes, rested covered for 3 minutes, and then spun covered for 2 more minutes. If fibers were required for the mix they were then added while the mixer was in motion to ensure proper dispersion throughout the mix and spun uncovered for 3 minutes. After incorporation of the fibers was complete, fresh property testing could begin.

4.3.3 Fresh Property Testing

The tests performed included air content (control mix only), slump flow, and passing ability. The air content testing was done in accordance with ASTM C173/C173M-12 for volumetric method. The volumetric method had to be used since the mix incorporated lightweight aggregates. The air content could not be tested on the fiber mixes since the apparatus warned against testing any mix with steel or “steel like” particles in it as it may damage the apparatus. Slump flow was conducted by following ASTM C1611/C1611M-09be1 and using the inverted cone method. An image of the test set up can be seen in the figure below.

Figure 4.2: Slump flow test set up

After the test was complete, the concrete used was placed back in the mixer and mixed for 1 minute while the passing ability test was being set up. The batch was mixed again in order to better incorporate the previously tested material. The passing ability test was done according to ASTM C1621/C1621M-11 which utilizes a J-Ring apparatus which can be seen below.

Figure 4.3: Passing ability test with J-Ring

Upon completion of all fresh property testing (excluding air content) the concrete was returned to the mixer.

4.3.4 Making and Curing Specimens

Specimens were made in 15 plastic cylinder molds that measured 4” in diameter and 8” in height in compliance with ASTM C1758/C1758M-11 which explains the process of making self consolidating samples. There were also 6 beam molds that were filled according to the aforementioned standard. All specimens were then cured in accordance with ASTM C192/C192M-07 with the exception of the 6 density cylinders (3 for equilibrium density and 3 for oven dried density) which followed ASTM C567/C567M-11.

4.3.5 Mechanical Property Testing

Compressive strength is one of the most important properties specified for concrete. Testing was performed following ASTM C39/C39m-12a specification. Cylindrical specimens measured 4” x 8” and three cylinders were tested at 7 and 28 days. Prior to testing, the specimens were capped according to ASTM C617/C617m-12 using sulfur capping material. At 28 days the elastic modulus and splitting tensile strength were tested according to ASTM C469/C469-10 and ASTM C496/C496M-11 respectively. Three cylinders were capped and first used for the elastic modulus test. The caps where then removed and the unbroken cylinders were used to test splitting tensile strength. This was done in order to conserve material, since while testing for elastic modulus the samples were not damaged. The final test at 28 days was the flexural testing of the beams. The test for the control mix followed ASTM C78/C78M-10e1, since the mix lacked fibers. For the samples with fibers, testing was performed in accordance with ASTM C1609/C1609M-12. Three beams were tested for each mix and the remaining three beams were kept as spares in case of damage during testing of the original three. There were two density tests performed as well. The first was oven dried density which utilized three cylinders. The second was equilibrium density, also done with three cylinders. Both tests were done following ASTM C567/C567M-11. In all 15 cylinders and 6 beams were made per batch.

Chapter 5 Results and Analysis

5.1 Fresh Properties

Fresh properties were measured prior to placement into molds when the concrete was still plastic. All samples were tested for its workability and passing ability. Only the control mix was tested for air content.

5.1.1 Slump Flow

Slump flow is the measure of workability. This test was performed in order to determine the effects fibers have on the workability of a SCC mix.

Table 5.1: Slump flow ranked by performance

Rank	***Mix***	***Slump Flow (in)***
1	Control	20
2	Steel 30	19.75
3	PP2	18.375
4	PP4	17.5
5	Steel 60	16.5

As seen in Table 5.1, fibers negatively affected the workability of the concrete. The control mix had no fibers and therefore had the largest spread followed by Steel 30, PP2, PP4, and finally Steel 60. These results were as anticipated since an increase in fiber density decreases the concretes ability to flow freely. This effect can be remedied by increasing the workability of the mix prior to the addition of fibers in order to obtain a targeted slump flow.

A non-mandatory part of ASTM C1611/C1611M-09b is the determination of the stability of the concrete mix by visual examination. Each mix is given a Visual Stability Index (VSI) number in accordance with the criteria set forth by Table 5.2.

Table 5.2: Visual Stability Index Values (ASTM C1611)

Visual Stability Index Values

VSI Value	Criteria
0 = Highly Stable	No evidence of segregation or bleeding.
1 = Stable	No evidence of segregation and slight bleeding observed as a sheen on the concrete mass.
2 = Unstable	A slight mortar halo ≤ 10 mm [≤ 0.5 in.] and/or aggregate pile in the of the concrete mass.
3 = Highly Unstable	Clearly segregating by evidence of a large mortar halo > 10 mm [> 0.5 in.] and/or a large aggregate pile in the center of the concrete mass.

Figure 5.1: Slump flow test with Visual Stability Index Values

Figure 5.1 shows that all mixes have a VSI of 0, indicating that there is no evidence of segregation or bleeding. This could be due to the presence of the viscosity modifying agent in the superplasticizer as well as a low slump flow number.

5.1.2 Passing Ability

This test was done using a J-Ring apparatus which mimics the tightly spaced reinforcing bars seen in many SCC applications. The goal is to have a passing ability below 2 inches. The blocking assessment criteria can be found in Table 1 of ASTM 1621/C1621M-09b.

Table 5.3: Passing ability ranked by performance with blocking assessment

Rank	*Mix*	*Passing Ability (in)*	**Blocking Assessment**
1	Steel 30	1.5	minimal to noticible blocking
2	Control	2	minimal to noticible blocking
3	Steel 60	2.125	noticible to extreme blocking
4	PP2	2.375	noticible to extreme blocking
5	PP4	2.5	noticible to extreme blocking

Table 5.3 indicates that Steel 30 has the best passing ability followed by the Control, Steel 60, PP2 and PP4. One explanation of why the Control came in second can be attributed to the extended amount of time it took to mix the Control batch. This extra time was mainly due to inexperience with this particular mix on a larger scale and the extra testing (air content) that had to be performed. This may have caused the control mix to evaporate, and/or begin to set. The polypropylene mixes showed the greatest affect on passing ability. This may have been caused by moisture loss through absorption by the polypropylene fibers.

5.1.3 Air Content

Air content testing was only performed on the control mix, since the apparatus warned against adding any particles made from steel, or was "steel like".

Figure 5.2: Air content of control mix

Figure 5.2 shows the air content of the control mix to be 1.25%. According to ACI the recommended air content of a lightweight concrete for aggregate size 3/8" is 4.5%-7.5% for concrete that will be subjected to freeze thaw cycles or deicer salts. The air content in the control mix is much lower than recommended, however no air entraining admixture was added. It is believed that the self consolidating properties of the mix may have caused the decreased air content.

5.2 Mechanical Properties

All tests were done on a series of three 4"x8" cylinders that were moist cured according to ASTM C192/C192M-07. All tests were performed at 28 days with the exception of the 7 day compressive strength and density testing.

5.2.1 Density

The density of the concrete mixes was of great significance in this research. If the equilibrium density of the mixes was above 120 pcf, the concrete could no longer be classified as structural lightweight. There are two different tests for density, equilibrium density and oven dried density. The equilibrium density value is the most accurate, and hence the official number used to classify density.

Table 5.4: Rank of equilibrium density from low to high

Rank	***Mix***	***Average Density (pcf)***
1	Control	99.996
2	Steel 60	105.633
3	Steel 30	113.3
4	PP4	115.288
5	PP2	116.569

The equation used is as follows:

$$E_m = \frac{A \times 62.3}{(B - C)} \qquad \text{(Eqn 5.1)}$$

Where:

$$E_m = measured\ equilibrium\ density\ (lb/ft^3)$$

$$A = mass\ of\ cylinder\ as\ dried\ (lb)$$

$$B = mass\ of\ saturated\ surface - dry\ cylinder\ (lb)$$

$$C = apparent\ mass\ of\ suspended - immersed\ cylinder\ (lb)$$

In Table 5.4 the Control mix has the lowest equilibrium density followed by Steel 60, Steel 30, PP4, and PP2. It was surprising to see that the density of the Steel 60 was so low, however it was determined that this was due to an abundance of large honeycombs in the cylinders. The Steel 60 mix had the lowest slump flow and therefore did not consolidate fully, leaving behind large voids when finally hardened. These voids decreased the mass of the cylinders and gave a false result of density. Again, the PP2 and PP4 mixes were at the bottom most likely due to the moisture absorbed by the fibers.

Table 5.5: Rank of oven dried density from low to high

Rank	***Mix***	***Average Density (pcf)***
1	Steel 30	97.4345
2	PP4	105.313
3	Control	107.139
4	PP2	108.743
5	Steel 60	111.371

Table 5.5 indicates that the Steel 30 mix was the lightest followed by PP4, control, PP2, and Steel 60. This shows that the oven dried density might not be an accurate representation of equilibrium density. Further research on this topic is recommended.

5.2.2 Compressive Strength

Compressive strength is the main value used in concrete design and is the most widely compared value in research. Compression testing was performed at 7 days and 28 days. Three cylinders were tested at each age and the average strength for each mix can be viewed in the tables below.

Table 5.6: Rank of 7 day compressive strength from high to low

Rank	***Mix***	***Strength (psi)***
1	Steel 30	5467.09
2	Steel 60	5268.05
3	Control	5201.7
4	PP2	5188.43
5	PP4	5175.16

Table 5.7: Rank of 28 day compressive strength from high to low

Rank	***Mix***	***Strength (psi)***
1	Steel 30	6661.36
2	PP4	6502.12
3	Steel 60	6462.31
4	Control	6223.46
5	PP2	6050.96

Both Table 5.6 and 5.7 show Steel 30 having the strongest compressive strength out of all 5 mixes. A possible reason for such a large increase in compressive strength of the PP4 samples can be attributed to the samples being tested after the 28 day mark since it fell on a weekend. All mix designs do classify as structural lightweight concrete since their compressive strength resulted in values greater than 4000psi.

5.2.3 Elastic Modulus

The elastic modulus of the samples described the stiffness of each mix. Knowing the rigidity of each mix is beneficial in design as it informs the proper applications for the material. Elastic Modulus was found for three cylinders by determining the slope of the elastic region of the stress vs strain curve. The theoretical modulus was found using the equation below. The unit weights came from the equilibrium density of each mix as previously stated.

Table 5.8: Summary of elastic modulus

Sample	Modulus (psi)	Theoretical (psi)	% Error
Control	3,299,090	3,281,084	26.9
Steel 30	3,600,561	3,234,959	11.3
Steel 60	3,339,605	2,862,560	16.6
PP2	3,205,410	2,598,423	0.37
PP4	3,610,119	3,193,571	10.1

Note: Modulus if slope of trend line while theoretical is from Eqn 5.2

$$E_c = 33{,}000 w_c^{1.5} \sqrt{f_c'} \qquad \text{(Eqn. 5.2)}$$

Where:

$$w_c = unit\ weight\ of\ concrete\ (kcf)$$

$$f_c' = specified\ compressive\ strenght\ of\ concrete\ (ksi)$$

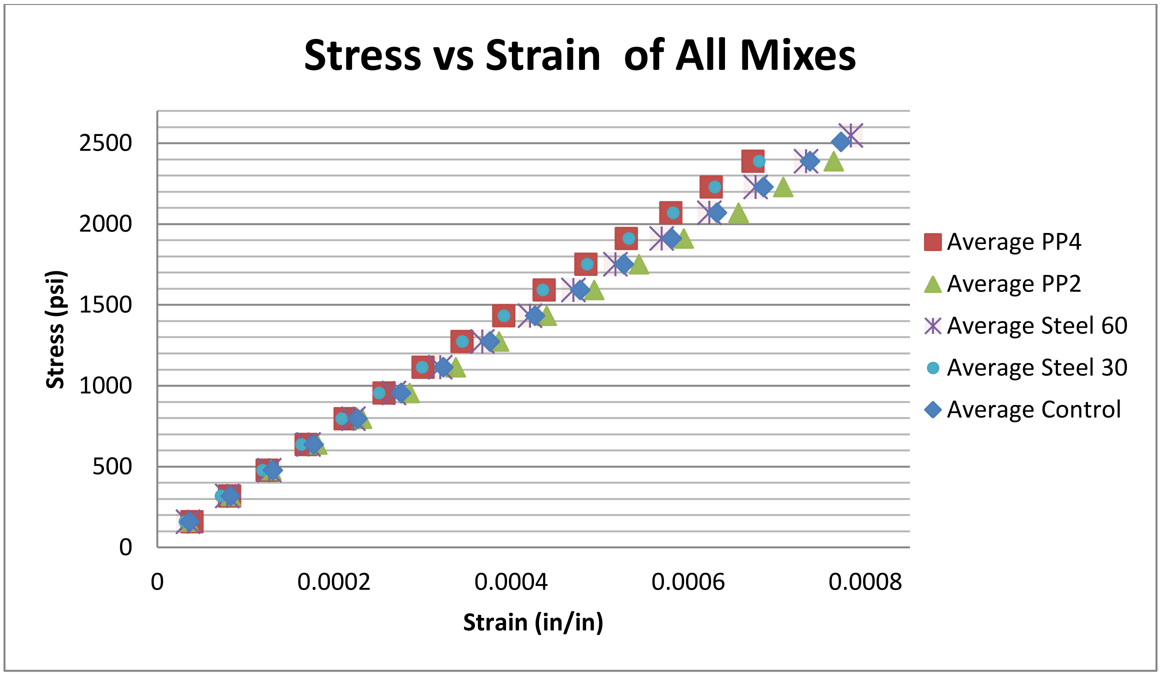

Figure 5.3: Graph of average stress vs. strain curves for all mixes

As can been seen from Table 5.8 and Figure 5.3 the addition of fibers did not significantly affect the modulus of elasticity. All moduli were within 400ksi of each other. The percent error did decrease with the addition of fibers for a reason not apparent at this time.

5.2.4 Splitting Tensile Strength

Three cylinders of each mix were tested for splitting tensile strength by placing them on their sides and loading in compression.

Table 5.9: Rank of splitting tensile strength from high to low

Rank	Mix	Strength (psi)	Residual Strength (psi)
1	PP4	348.15	NA
2	PP2	293.11	NA
3	Steel 60	282.5	535.2
4	Control	253.32	NA
5	Steel 30	242.05	424.7

The results in Table 5.9 show that Steel 30 exhibited the lowest strength in tension. However, when the Steel 30 and Steel 60 mixes were tested they had an initial failure load from which the data above was originally calculated. After this initial failure, the samples continued to hold a load until a second failure occurred as can be seen in the residual strength column above. The Steel 30 and Steel 60 samples were the only mixes that were capable of having a residual strength. After failure, the Control cylinders were fully broken in 2 sections while the fiber mixes were intact with a lateral crack separating the 2 halves as can been seen in the figure below.

Control Mix　　　　Fiber Mix

Figure 5.4: Cylinders after splitting tensile strength test.

5.2.5 Flexural Strength

The main way to measure the benefit of fibers in concrete is to conduct flexure testing. Fibers are known to affect the flexural capacity of concrete beams more than the tension or compressive properties (ACI 544.1R-96). Beams measuring 4”x4”x14” were tested in third point loading.

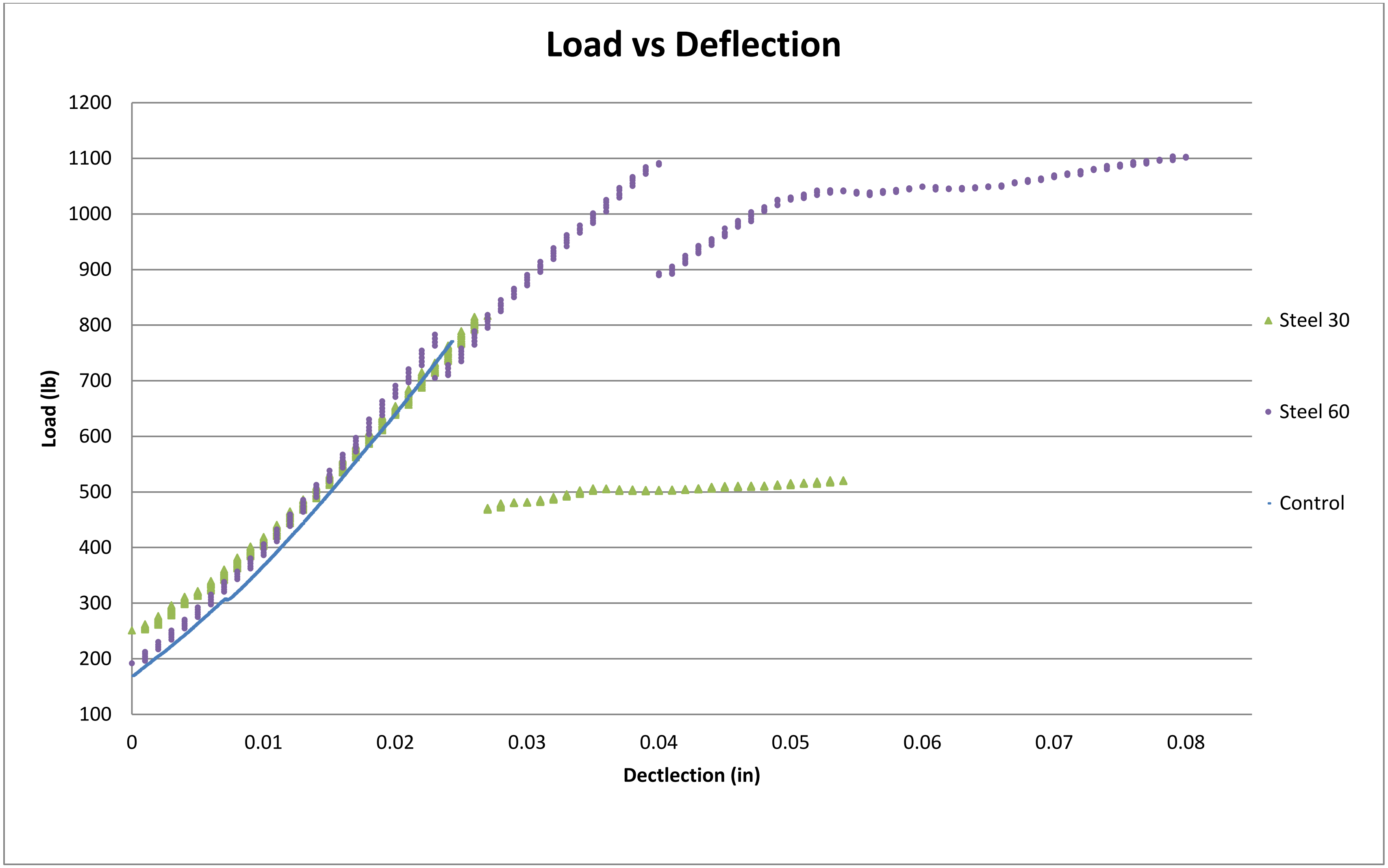

Figure 5.5: Load vs. Deflection of Steel30, Steel60, and Control

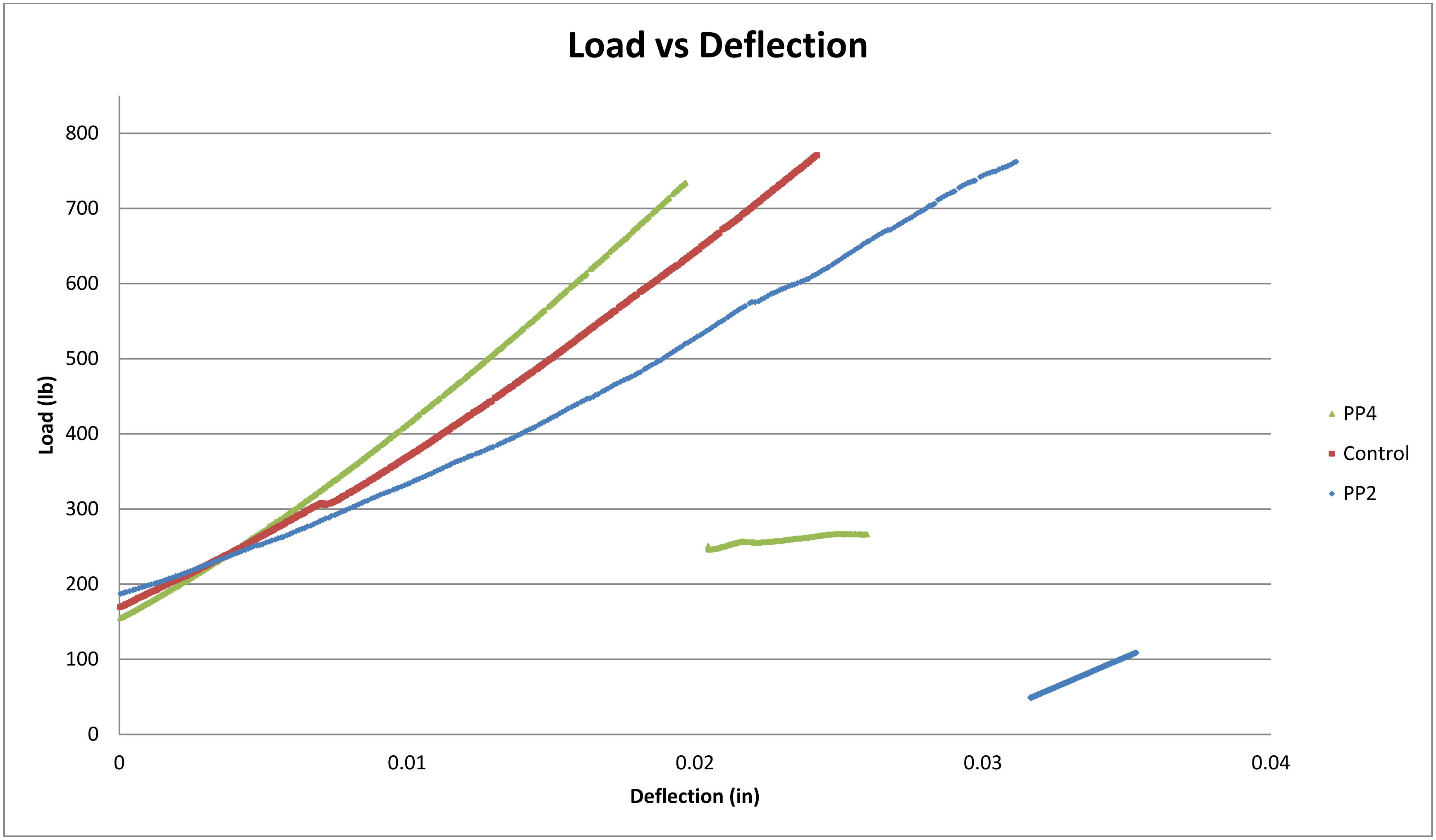

Figure 5.6: Load vs. Deflection of PP2, PP4, and Control

As can be seen in Figure 5.5 the Control mix failed at 771lbs and was split in two separate sections as can be seen in the figure below.

Figure 5.7: Failed beam of control after flexural testing

The Steel 60 sample first cracked at almost 800lb; however it quickly recovered and continued to gain strength until its second crack at approximately 1100lbs. It again regained strength until it reached a maximum load of 1128lbs. The Steel 30 sample cracked at 816lbs but never regained full strength and showed a residual load of only 521lbs. Both samples with steel fibers exhibited one large crack but were being held together by the fibers as can be seen in figure 5.8.

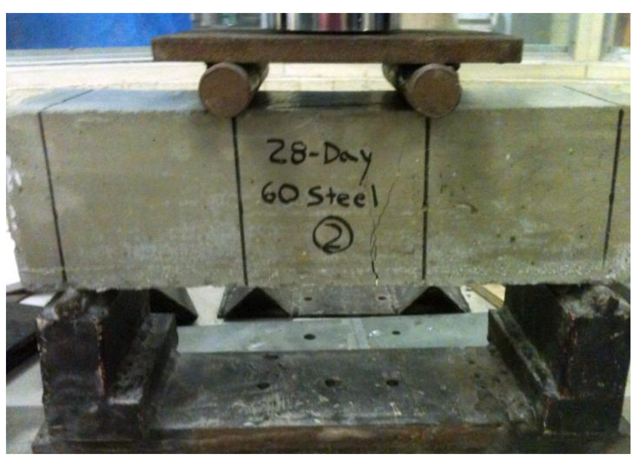

Figure 5.8: Failed beam of Steel60 after flexural testing

Due to an insufficient volume of steel fibers according to ACI guidelines, the expected flexural strength increase of 50 to 70 percent was not reached. The small percentage of fiber also affected the shape of the load vs. deflection graphs. The test specified in ASTM C1609/C1609M-10 assumes a beam that was more ductile that the samples actually tested. This resulted in a graph that demonstrates more brittle behavior as seen in typical unreinforced samples.

In Figure 5.6 the PP4 has the lowest failure point at 734lbs followed by the PP2 sample at 762lbs and the Control at 771lb. Both fiber specimens cracked and then exhibited a slight recovery in strength, but failed to reach any load close to the previous ultimate load. Like the steel specimens, the polypropylene beams showed one failure crack but were still being held together by the fibers. The lack of increased flexural strength demonstrated by the polypropylene beams was expected since ACI has determined that there is “no consensus in the published literature about the effect of adding polypropylene fibers on the first-crack strength” (ACI 544.1R-96).

Table 5.10: Rank of Modulus of Rupture from high to low

Rank	Mix	Ult Load (lb)	Modulus of Rupture (psi)
1	Steel60	1091.55	204.67
2	Steel30	816.59	153.11
3	Control	770.74	144.51
4	PP2	762.11	142.90
5	PP4	734.05	137.63

Table 5.10 above reinforces the data shown on the graphs above. Again the steel specimens showed an increase in flexural capacity; however it was not as significant as anticipated due to an ineffective percentage of fibers. The polypropylene specimens

showed very similar results to the control beam which was anticipated based on previously published literature.

Chapter 6 Conclusions and Future Research

A LWSCC mix was designed and tested according to the appropriate ASTM procedures in order to determine both its fresh and mechanical properties. Two types of fibers, varying in quantity, were then added to the LWSCC control mix. Each mix was then analyzed using the same appropriate ASTM procedures and compared to each other as well as the control mix. Based on the data collected, a LWSCC fiber reinforced mix is considered plausible for the following reasons:

- Overall, fiber specimens performed better than the control in splitting tension, compression, and flexural strength testing since they could hold a residual load.
- Effect on modulus of elasticity and workability was minimal.
- Fibers did increase the density of the samples; however the equilibrium density of all mixes fell into acceptable ranges.
- Passing ability was greatly affected by the addition of fibers; however simple adjustments in mix proportion could easily resolve this issue.

This research also indicates shows that the steel samples outperformed the polypropylene samples. More specifically the Steel30 samples produced the best results for the following reasons:

- After demolding, the Steel30 cylinders had a smooth appearance without the need for vibration as opposed to the Steel60 cylinders which presented large honeycombs and did not perform as a SCC mix when poured.
- Steel30 ranked highest in passing ability as well as compressive strength.

- It also ranked second in workability (behind Control), splitting tension (residual strength behind Steel60), and modulus of rupture (behind Steel60).
- It was third in equilibrium density however, the steel samples ranked higher than the polypropylene mixes.
- There was no great effect on elastic modulus.

Future research should consist of additional trial testing of lightweight self consolidating mix designs in order to obtain an optimal design. This could be accomplished by adjusting the water to cement ratio, high range water reducer dosing, as well as the ratio of coarse to fine aggregate. Different types of lightweight coarse aggregates could also be tested for comparison. The ultimate goal of this research would be to create an ACI approved mix design procedure for LWSCC based on a specified compressive strength. Other research could include studying how fibers affect workability quantitatively and how mix designs could be adjusted to compensate for the addition of fibers. Finally, additional research on this material is necessary to solve problems in the construction industry related to normal weight SCC and formwork pressures, for instance. Other research goals could seek to improve the characteristics of lightweight concrete with SCC.

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Appendix A

Appendix A shows raw data samples of the various mixes used in this research.

The data below shows the materials and proportions used to create the control LWSCC mix:

Total Volume	2.100531	ft^3									
Cement Paste	45	%			Aggregate	55	%				
FASH	30	% by vol of powder		**Coarse**	50	%	**Fine**	50	%		
FASH SG	2.6										
Cement SG	3.15			**CA Vol**	0.577646025	ft^3	**FA Vol**	0.577646	ft^3		
Avg SG Powder	2.985										
				SG	1.3		**SG**	2.6			
W/C Ratio	0.38										
Water to Powder Ratio by vol	1.1343				**SF**	25"	D4				
					Control SF	20	Inches				
Cem. Paste Vol	0.94523895	ft^3									
(cem/h2o/FASH)					J-Ring	18					
					Air Content	1.25	%				
Powder Vol	0.442880078	ft^3			T50	3.53	sec				
Water Vol	0.502358872	ft^3									
Cement Vol	0.310016054	ft^3			*Note:	Added .5 lb of water and 5ml of SP (which equals 5.2 oz)					
Fly Ash Vol	0.132864023	ft^3				Used one bottle OH (946ml)					
		Convert Volumes to Weight									
		Weight= Vol*SG*unit weight of H2O									
Cement	60.93675566	**lb**			**CA**	46.85865	**lb**				
Flyash	21.55585915	**lb**			**FA**	93.71729	**lb**				
Water	31.34719363	**lb**									
		Moisture Adjustment									
	FA 95.47										
FA 1.88%											
	Water 29.585										

A sample of the control Moisture Content of aggregates, Oven-Dried Density, and Equilibrium Density data is shown below:

Moisture Content

Cup	Empty Weight (g)	Wet Weight (g)	Dry Weight (g)	Moisture Content, %
1 FA	53.53	111.4	110.5	1.579778831
2 FA	52.3	109.1	108.2	1.610017889
3 FA	54.1	104.4	103.2	2.443991853
			Avg	1.877929524

Oven Dried Density

Sample	W_I (g)	W_S (g)	W_D (g)	W_D (g)2	W_D (g)3	Density
ODD1	1542.8	3194.3	2852.7	2813	2802.3	106.4802503
ODD2	1519.3	3156	2852.2	2779	2770.4	106.6006151
ODD3	1580.4	3234.9	2927	2866	2838.3	108.3368571
	1/15/2013	1/15/2013	1/18/2013		2/4/2013 Average	107.1392

Equilibrium Density						
Sample	**W_I (g)**	**W_S (g)**	**W_E (g)**	**W_E(g) 2**	**Density**	
ED1	1238.8	3125.5	3048.7	3021	100.6699581	
ED2	1256.3	3218.2	3141.6	3112.6	99.76129262	
ED3	1254.1	3217.4	3137.4	3109.2	99.55687872	
	1/22/2012	1/22/2013	2/11/2013	3/11/2013 Average		99.9960432

Below is the Indirect Tension, 7 Day, and 28 Day Compression testing for the Steel 30 mix.

Compression 7 Day		2/8/2013		
Sample	**Defects**	**Area**	**Load**	**Stress (psi)**
1	Honeycomb	12.56	69500	5533.44
2	Honeycomb	12.56	71500	5692.68
3	Honeycomb	12.56	65000	5175.16
			Avg	5467.09

Compression 28 Day	3/1/2013			
Sample	**Defects**	**Area**	**Load**	**Stress (psi)**
1		12.56	83000	6608.28
2		12.56	86000	6847.13
3		12.56	82000	6528.66
			Average	6661.36

Indirect Tension	3/1/2013			
Sample	**Defects**	**Load**	**Load 2**	**Splitting Tensile Strength (psi)**
1	Honeycomb	15400	20250	306.37
2	Honeycomb	11600	23100	230.77
3	Honeycomb	9500	20700	189.00

The raw data for the PP2 Elastic Modulus testing can be seen below. This test was performed with three different samples and then averaged.

Elastic Modulus				
1	L=	5.0345	A=	12.56
Load (lb)	**Elongation**	**Adj Elongation**	**Stess**	**Strain**
2000	0.00035	0.000175	159.2356688	3.476E-05
4000	0.00085	0.000425	318.4713376	8.4418E-05
6000	0.00135	0.000675	477.7070064	0.00013407
8000	0.0019	0.00095	636.9426752	0.0001887
10000	0.0024	0.0012	796.1783439	0.00023836
12000	0.003	0.0015	955.4140127	0.00029794
14000	0.0035	0.00175	1114.649682	0.0003476
16000	0.004	0.002	1273.88535	0.00039726
18000	0.0046	0.0023	1433.121019	0.00045685
20000	0.0051	0.00255	1592.356688	0.00050651
22000	0.00565	0.002825	1751.592357	0.00056113
24000	0.00625	0.003125	1910.828025	0.00062072
26000	0.0069	0.00345	2070.063694	0.00068527
28000	0.0074	0.0037	2229.299363	0.00073493
30000	0.008	0.004	2388.535032	0.00079452

2	L=	5.26125	A=	12.56
Load (lb)	**Elongation**	**Adj Elongation**	**Stess**	**Strain**
2000	0.0004	0.0002	159.2356688	3.8014E-05
4000	0.0009	0.00045	318.4713376	8.5886E-05
6000	0.0013	0.00065	477.7070064	0.00012406
8000	0.0019	0.00095	636.9426752	0.00018132
10000	0.0024	0.0012	796.1783439	0.00022903
12000	0.00295	0.001475	955.4140127	0.00028152
14000	0.0035	0.00175	1114.649682	0.000334
16000	0.004	0.002	1273.88535	0.00038172
18000	0.0045	0.00225	1433.121019	0.00042943
20000	0.00515	0.002575	1592.356688	0.00049146
22000	0.0056	0.0028	1751.592357	0.0005344
24000	0.0061	0.00305	1910.828025	0.00058212
26000	0.00675	0.003375	2070.063694	0.00064415
28000	0.0073	0.00365	2229.299363	0.00069663
30000	0.00785	0.003925	2388.535032	0.00074912

3	L=	5.0735	A=	12.56
Load (lb)	**Elongation**	**Adj Elongation**	**Stess**	**Strain**
2000	0.00035	0.000175	159.2356688	3.4493E-05
4000	0.0008	0.0004	318.4713376	7.8841E-05
6000	0.0013	0.00065	477.7070064	0.00012812
8000	0.00175	0.000875	636.9426752	0.00017246
10000	0.0023	0.00115	796.1783439	0.00022667
12000	0.0028	0.0014	955.4140127	0.00027594
14000	0.00335	0.001675	1114.649682	0.00033015
16000	0.00385	0.001925	1273.88535	0.00037942
18000	0.0044	0.0022	1433.121019	0.00043363
20000	0.0049	0.00245	1592.356688	0.0004829
22000	0.00545	0.002725	1751.592357	0.0005371
24000	0.0059	0.00295	1910.828025	0.00058145
26000	0.0065	0.00325	2070.063694	0.00064058
28000	0.007	0.0035	2229.299363	0.00068986
30000	0.0076	0.0038	2388.535032	0.00074899

Average S	Average Strain
159.2357	3.57556E-05
318.4713	8.30482E-05
477.707	0.00012875
636.9427	0.000180826
796.1783	0.000231351
955.414	0.000285134
1114.65	0.00033725
1273.885	0.000386132
1433.121	0.000439968
1592.357	0.000493622
1751.592	0.000544212
1910.828	0.000594762
2070.064	0.000656667
2229.299	0.00070714
2388.535	0.000764208

The table below shows the raw data used for the steel 60 Flexural Strength test.

Load (lbf)	Extension (in)	Stress (psi)	Strain (in/in)
-0.068	-0.021	-0.019	-0.004
0.018	-0.021	0.005	-0.004
0.185	-0.021	0.052	-0.004
0.512	-0.021	0.144	-0.003
0.514	-0.021	0.144	-0.003
0.725	-0.021	0.204	-0.003
0.797	-0.02	0.224	-0.003

1.038	-0.02	0.292	-0.003	13.648	-0.015	3.839	-0.002
1.318	-0.02	0.371	-0.003	14.268	-0.015	4.013	-0.002
1.457	-0.02	0.41	-0.003	14.832	-0.014	4.172	-0.002
1.824	-0.02	0.513	-0.003	15.559	-0.014	4.376	-0.002
2.278	-0.019	0.641	-0.003	16.196	-0.014	4.555	-0.002
2.477	-0.019	0.697	-0.003	17.003	-0.014	4.782	-0.002
2.752	-0.019	0.774	-0.003	17.575	-0.014	4.943	-0.002
3.536	-0.019	0.994	-0.003	17.999	-0.013	5.062	-0.002
3.726	-0.019	1.048	-0.003	19.096	-0.013	5.371	-0.002
4.183	-0.018	1.177	-0.003	19.639	-0.013	5.524	-0.002
4.521	-0.018	1.272	-0.003	20.61	-0.013	5.797	-0.002
4.901	-0.018	1.378	-0.003	21.486	-0.012	6.043	-0.002
5.411	-0.018	1.522	-0.003	22.829	-0.012	6.421	-0.002
6.065	-0.018	1.706	-0.003	23.846	-0.012	6.707	-0.002
6.463	-0.017	1.818	-0.003	24.882	-0.012	6.998	-0.002
7.206	-0.017	2.027	-0.003	26.436	-0.012	7.435	-0.002
7.722	-0.017	2.172	-0.003	27.804	-0.011	7.82	-0.002
8.507	-0.017	2.393	-0.003	29.466	-0.011	8.287	-0.002
8.989	-0.016	2.528	-0.003	31.367	-0.011	8.822	-0.002
9.53	-0.016	2.68	-0.003	33.316	-0.011	9.37	-0.002
9.974	-0.016	2.805	-0.003	35.669	-0.011	10.032	-0.002
10.604	-0.016	2.982	-0.003	37.58	-0.01	10.569	-0.002
11.278	-0.016	3.172	-0.003	40.182	-0.01	11.301	-0.002
11.916	-0.015	3.351	-0.003	42.182	-0.01	11.864	-0.002
12.516	-0.015	3.52	-0.003	44.389	-0.01	12.484	-0.002
13.293	-0.015	3.739	-0.002	46.953	-0.009	13.206	-0.002

49.134	-0.009	13.819	-0.002
51.651	-0.009	14.527	-0.002
53.844	-0.009	15.143	-0.001
56.415	-0.009	15.867	-0.001
58.586	-0.008	16.477	-0.001
60.947	-0.008	17.141	-0.001
63.201	-0.008	17.775	-0.001
65.757	-0.008	18.494	-0.001
68.021	-0.008	19.131	-0.001
70.288	-0.007	19.768	-0.001
73.127	-0.007	20.567	-0.001
75.275	-0.007	21.171	-0.001
78.14	-0.007	21.977	-0.001
80.82	-0.007	22.731	-0.001
84.025	-0.006	23.632	-0.001
86.979	-0.006	24.463	-0.001
89.628	-0.006	25.208	-0.001
93.032	-0.006	26.165	-0.001
95.348	-0.006	26.817	-0.001
98.883	-0.005	27.811	-0.001
101.76	-0.005	28.62	-0.001
105.11	-0.005	29.562	-0.001
108.038	-0.005	30.386	-0.001
110.352	-0.005	31.036	-0.001
111.083	-0.004	31.242	-0.001
114.172	-0.004	32.111	-0.001

117.845	-0.004	33.144	-0.001
121.148	-0.004	34.073	-0.001
124.454	-0.004	35.002	-0.001
127.62	-0.003	35.893	-0.001
130.23	-0.003	36.627	-0.001
133.539	-0.003	37.558	-0.001
136.41	-0.003	38.365	0
140.504	-0.003	39.517	0
143.47	-0.002	40.351	0
146.891	-0.002	41.313	0
149.93	-0.002	42.168	0
152.892	-0.002	43.001	0
157.017	-0.002	44.161	0
160.039	-0.001	45.011	0
164.152	-0.001	46.167	0
167.795	-0.001	47.192	0
171.792	-0.001	48.316	0
174.708	-0.001	49.137	0
177.684	0	49.973	0
181.397	0	51.018	0
184.303	0	51.835	0
188.089	0	52.9	0
191.886	0	53.968	0
196.348	0.001	55.223	0
200.596	0.001	56.417	0
204.276	0.001	57.452	0
208.807	0.001	58.727	0
212.426	0.001	59.745	0
216.998	0.002	61.031	0
221.204	0.002	62.214	0
225.295	0.002	63.364	0
230.368	0.002	64.791	0
234.383	0.003	65.92	0
238.818	0.003	67.167	0
243.079	0.003	68.366	0
246.483	0.003	69.323	0.001
250.855	0.003	70.553	0.001
254.569	0.004	71.597	0.001
259.117	0.004	72.876	0.001

262.747	0.004	73.897	0.001	469.847	0.013	132.144	0.002
267.199	0.004	75.149	0.001	474.053	0.013	133.327	0.002
270.373	0.004	76.042	0.001	480.003	0.013	135	0.002
274.974	0.005	77.336	0.001	485.778	0.013	136.625	0.002
279.621	0.005	78.643	0.001	490.908	0.014	138.067	0.002
283.748	0.005	79.804	0.001	497.116	0.014	139.814	0.002
288.317	0.005	81.089	0.001	502.132	0.014	141.224	0.002
292.54	0.005	82.277	0.001	508.278	0.014	142.953	0.002
297.719	0.006	83.733	0.001	512.78	0.014	144.219	0.002
300.951	0.006	84.642	0.001	519.663	0.015	146.155	0.002
306.117	0.006	86.095	0.001	524.162	0.015	147.42	0.002
310.932	0.006	87.449	0.001	530.804	0.015	149.288	0.003
315.426	0.006	88.713	0.001	538.397	0.015	151.424	0.003
320.515	0.007	90.145	0.001	543.788	0.016	152.94	0.003
324.515	0.007	91.27	0.001	549.979	0.016	154.681	0.003
329.1	0.007	92.559	0.001	556.291	0.016	156.456	0.003
333.419	0.007	93.774	0.001	561.594	0.016	157.948	0.003
338.252	0.007	95.133	0.001	567.257	0.016	159.541	0.003
343.07	0.008	96.488	0.001	572.641	0.017	161.055	0.003
347.504	0.008	97.735	0.001	579.975	0.017	163.117	0.003
352.384	0.008	99.108	0.001	585.123	0.017	164.565	0.003
356.903	0.008	100.379	0.001	591.762	0.017	166.432	0.003
362.29	0.009	101.894	0.001	597.383	0.017	168.013	0.003
366.149	0.009	102.979	0.001	603.785	0.018	169.814	0.003
371.433	0.009	104.465	0.001	610.471	0.018	171.694	0.003
376.103	0.009	105.779	0.002	616.218	0.018	173.311	0.003
380.71	0.009	107.074	0.002	624.04	0.018	175.511	0.003
386.266	0.01	108.637	0.002	630.548	0.018	177.341	0.003
390.595	0.01	109.855	0.002	638	0.019	179.437	0.003
395.328	0.01	111.186	0.002	644.483	0.019	181.26	0.003
399.64	0.01	112.398	0.002	650.368	0.019	182.915	0.003
406.033	0.01	114.196	0.002	657.221	0.019	184.843	0.003
411.23	0.011	115.658	0.002	663.237	0.019	186.535	0.003
416.151	0.011	117.042	0.002	670.851	0.02	188.676	0.003
422.059	0.011	118.704	0.002	677.057	0.02	190.422	0.003
426.902	0.011	120.066	0.002	684.071	0.02	192.394	0.003
432.723	0.011	121.703	0.002	691.086	0.02	194.367	0.003
438.688	0.012	123.381	0.002	697.166	0.021	196.077	0.003
443.646	0.012	124.775	0.002	701.925	0.021	197.416	0.003
448.637	0.012	126.179	0.002	707.09	0.021	198.869	0.003
453.87	0.012	127.65	0.002	714.592	0.021	200.978	0.004
459.528	0.012	129.242	0.002	720.801	0.021	202.725	0.004
464.266	0.013	130.574	0.002	727.872	0.022	204.713	0.004

734.562	0.022	206.595	0.004
741.528	0.022	208.554	0.004
748.594	0.022	210.541	0.004
754.364	0.022	212.164	0.004
762.967	0.023	214.584	0.004
769.389	0.023	216.39	0.004
775.903	0.023	218.222	0.004
783.052	0.023	220.233	0.004
705.039	0.023	198.292	0.004
710.076	0.024	199.708	0.004
714.805	0.024	201.038	0.004
722.43	0.024	203.183	0.004
728.348	0.024	204.847	0.004
734.922	0.025	206.696	0.004
741.137	0.025	208.444	0.004
747.224	0.025	210.156	0.004
752.922	0.025	211.759	0.004
758.165	0.025	213.233	0.004
764.715	0.026	215.076	0.004
771.076	0.026	216.864	0.004
777.522	0.026	218.677	0.004
783.237	0.026	220.285	0.004
789.032	0.026	221.915	0.004
795.171	0.027	223.641	0.004
800.158	0.027	225.044	0.004
806.969	0.027	226.959	0.005
812.621	0.027	228.549	0.005
818.452	0.027	230.189	0.005
824.935	0.028	232.012	0.005
829.159	0.028	233.2	0.005
835.043	0.028	234.855	0.005
838.701	0.028	235.884	0.005
845.253	0.028	237.727	0.005
850.155	0.029	239.105	0.005
855.544	0.029	240.621	0.005
861.484	0.029	242.292	0.005
865.683	0.029	243.473	0.005
871.426	0.03	245.088	0.005
875.329	0.03	246.186	0.005
881.252	0.03	247.851	0.005
885.789	0.03	249.127	0.005
890.483	0.03	250.447	0.005
895.658	0.031	251.903	0.005

899.812	0.031	253.071	0.005
904.893	0.031	254.5	0.005
908.052	0.031	255.389	0.005
913.994	0.031	257.06	0.005
918.8	0.032	258.412	0.005
924.082	0.032	259.897	0.005
929.103	0.032	261.309	0.005
933.273	0.032	262.482	0.005
938.646	0.032	263.993	0.005
941.79	0.033	264.878	0.005
948.247	0.033	266.694	0.005
952.542	0.033	267.901	0.006
957.378	0.033	269.262	0.006
962.061	0.033	270.579	0.006
966.178	0.034	271.737	0.006
971.119	0.034	273.126	0.006
973.701	0.034	273.853	0.006
979.358	0.034	275.444	0.006
983.578	0.035	276.63	0.006
987.563	0.035	277.751	0.006
992.571	0.035	279.16	0.006
997.279	0.035	280.484	0.006
1001.242	0.035	281.599	0.006
1004.364	0.036	282.477	0.006
1011.469	0.036	284.475	0.006
1015.721	0.036	285.671	0.006
1021.212	0.036	287.215	0.006
1025.367	0.036	288.384	0.006
1029.285	0.037	289.485	0.006
1033.95	0.037	290.797	0.006
1036.194	0.037	291.429	0.006
1042.661	0.037	293.247	0.006
1046.929	0.037	294.448	0.006
1050.277	0.038	295.389	0.006
1055.075	0.038	296.739	0.006
1060.512	0.038	298.268	0.006
1064.219	0.038	299.311	0.006
1066.57	0.038	299.972	0.006
1072.101	0.039	301.528	0.006
1077.028	0.039	302.913	0.006
1080.01	0.039	303.752	0.007
1084.306	0.039	304.96	0.007
1088.608	0.04	306.17	0.007

1091.547	0.04	306.997	0.007	1023.504	0.049	287.86	0.008
893.309	0.04	251.242	0.007	1024.99	0.049	288.278	0.008
889.727	0.04	250.235	0.007	1025.664	0.049	288.467	0.008
892.296	0.041	250.957	0.007	1026.952	0.05	288.829	0.008
893.639	0.041	251.335	0.007	1029.774	0.05	289.623	0.008
898.687	0.041	252.755	0.007	1026.985	0.05	288.839	0.008
902.259	0.041	253.759	0.007	1025.538	0.05	288.432	0.008
905.478	0.041	254.665	0.007	1029.334	0.05	289.499	0.008
910.946	0.042	256.203	0.007	1028.461	0.051	289.254	0.008
913.77	0.042	256.997	0.007	1028.808	0.051	289.351	0.008
918.314	0.042	258.275	0.007	1030.868	0.051	289.931	0.009
920.636	0.042	258.928	0.007	1033.403	0.051	290.644	0.009
924.907	0.042	260.129	0.007	1035.09	0.051	291.118	0.009
929.298	0.043	261.364	0.007	1033.952	0.052	290.798	0.009
932.085	0.043	262.148	0.007	1039.123	0.052	292.252	0.009
936.427	0.043	263.369	0.007	1039.199	0.052	292.274	0.009
940.519	0.043	264.52	0.007	1042.332	0.052	293.155	0.009
942.675	0.043	265.127	0.007	1042.651	0.053	293.245	0.009
944.105	0.044	265.529	0.007	1042.674	0.053	293.251	0.009
948.486	0.044	266.761	0.007	1040.055	0.053	292.515	0.009
951.782	0.044	267.688	0.007	1038.028	0.053	291.944	0.009
954.827	0.044	268.544	0.007	1039.551	0.053	292.373	0.009
959.671	0.045	269.907	0.007	1040.907	0.054	292.754	0.009
962.795	0.045	270.785	0.007	1040.51	0.054	292.643	0.009
965.907	0.045	271.661	0.007	1042.4	0.054	293.174	0.009
966.524	0.045	271.834	0.008	1041.296	0.054	292.864	0.009
974.02	0.045	273.942	0.008	1042.075	0.054	293.083	0.009
976.778	0.046	274.718	0.008	1039.045	0.055	292.23	0.009
978.63	0.046	275.239	0.008	1039.978	0.055	292.493	0.009
982.317	0.046	276.276	0.008	1037.232	0.055	291.72	0.009
985.749	0.046	277.241	0.008	1036.442	0.055	291.498	0.009
987.704	0.046	277.791	0.008	1037.018	0.056	291.66	0.009
986.756	0.047	277.524	0.008	1033.724	0.056	290.734	0.009
991.045	0.047	278.731	0.008	1036.532	0.056	291.524	0.009
996.213	0.047	280.184	0.008	1035.472	0.056	291.226	0.009
997.392	0.047	280.516	0.008	1038.943	0.056	292.202	0.009
1003.373	0.047	282.198	0.008	1040.101	0.057	292.527	0.009
1004.917	0.048	282.632	0.008	1037.628	0.057	291.832	0.009
1008.295	0.048	283.582	0.008	1041.033	0.057	292.789	0.01
1007.054	0.048	283.233	0.008	1040.315	0.057	292.588	0.01
1012.358	0.048	284.725	0.008	1041.396	0.057	292.892	0.01
1015.539	0.049	285.619	0.008	1039.338	0.058	292.313	0.01
1016.372	0.049	285.854	0.008	1042.98	0.058	293.337	0.01

1042.287	0.058	293.142	0.01	1054.914	0.067	296.694	0.011
1043.398	0.058	293.455	0.01	1057.482	0.068	297.416	0.011
1044.07	0.059	293.644	0.01	1058.345	0.068	297.659	0.011
1044.143	0.059	293.664	0.01	1058.068	0.068	297.581	0.011
1046.055	0.059	294.202	0.01	1059.767	0.068	298.059	0.011
1045.829	0.059	294.138	0.01	1061.17	0.068	298.453	0.011
1046.21	0.059	294.246	0.01	1060.983	0.069	298.4	0.011
1048.959	0.06	295.019	0.01	1060.858	0.069	298.365	0.011
1049.447	0.06	295.156	0.01	1063.318	0.069	299.057	0.012
1048.781	0.06	294.969	0.01	1063.994	0.069	299.247	0.012
1048.633	0.06	294.927	0.01	1061.094	0.069	298.432	0.012
1048.935	0.06	295.012	0.01	1065.992	0.07	299.809	0.012
1048.218	0.061	294.81	0.01	1068.204	0.07	300.431	0.012
1048.464	0.061	294.88	0.01	1066.775	0.07	300.03	0.012
1047.024	0.061	294.475	0.01	1066.121	0.07	299.846	0.012
1043.794	0.061	293.566	0.01	1069.534	0.07	300.806	0.012
1044.958	0.062	293.894	0.01	1071.736	0.071	301.425	0.012
1045.848	0.062	294.144	0.01	1070.009	0.071	300.939	0.012
1044.686	0.062	293.817	0.01	1072.65	0.071	301.682	0.012
1044.707	0.062	293.823	0.01	1073.071	0.071	301.8	0.012
1045.553	0.062	294.061	0.01	1071.085	0.072	301.242	0.012
1045.175	0.063	293.955	0.01	1075.902	0.072	302.596	0.012
1043.981	0.063	293.619	0.01	1077.172	0.072	302.954	0.012
1045.756	0.063	294.118	0.011	1077.056	0.072	302.921	0.012
1046.823	0.063	294.418	0.011	1074.843	0.072	302.299	0.012
1046.856	0.063	294.427	0.011	1079.913	0.073	303.725	0.012
1048.128	0.064	294.785	0.011	1080.534	0.073	303.899	0.012
1047.622	0.064	294.643	0.011	1078.839	0.073	303.422	0.012
1047.978	0.064	294.743	0.011	1081.084	0.073	304.054	0.012
1045.844	0.064	294.143	0.011	1080.797	0.073	303.973	0.012
1048.26	0.065	294.822	0.011	1080.425	0.074	303.868	0.012
1048.883	0.065	294.997	0.011	1080.322	0.074	303.84	0.012
1049.483	0.065	295.166	0.011	1085.475	0.074	305.289	0.012
1049.618	0.065	295.204	0.011	1083.963	0.074	304.864	0.012
1048.499	0.065	294.89	0.011	1086.573	0.074	305.598	0.012
1049.367	0.066	295.134	0.011	1085.832	0.075	305.389	0.012
1048.659	0.066	294.935	0.011	1085.006	0.075	305.157	0.012
1051.405	0.066	295.707	0.011	1088.937	0.075	306.263	0.013
1050.452	0.066	295.439	0.011	1088.214	0.075	306.059	0.013
1051.358	0.066	295.694	0.011	1088.774	0.076	306.217	0.013
1055.672	0.067	296.907	0.011	1088.035	0.076	306.009	0.013
1055.732	0.067	296.924	0.011	1089.48	0.076	306.415	0.013
1057.174	0.067	297.329	0.011	1093.426	0.076	307.525	0.013

1092.21	0.076	307.183	0.013	1115.422	0.086	313.711	0.014
1093.885	0.077	307.654	0.013	1119.705	0.086	314.916	0.014
1090.5	0.077	306.702	0.013	1116.922	0.086	314.133	0.014
1095.204	0.077	308.025	0.013	1118.797	0.086	314.661	0.014
1093.598	0.077	307.573	0.013	1117.764	0.086	314.37	0.014
1094.538	0.077	307.838	0.013	1121.494	0.087	315.419	0.014
1096.687	0.078	308.442	0.013	1122.216	0.087	315.622	0.014
1097.572	0.078	308.691	0.013	1120.483	0.087	315.135	0.015
1096.327	0.078	308.341	0.013	1123.109	0.087	315.873	0.015
1095.532	0.078	308.117	0.013	1119.856	0.087	314.959	0.015
1096.642	0.079	308.43	0.013	1119.613	0.088	314.89	0.015
1099.84	0.079	309.329	0.013	1117.209	0.088	314.214	0.015
1099.564	0.079	309.251	0.013	1123.452	0.088	315.97	0.015
1103.276	0.079	310.295	0.013	1120.69	0.088	315.193	0.015
1103.58	0.079	310.381	0.013	1122.3	0.089	315.646	0.015
1101.081	0.08	309.678	0.013	1123.52	0.089	315.989	0.015
1102.53	0.08	310.086	0.013	1124.495	0.089	316.263	0.015
1102.989	0.08	310.215	0.013	1124.448	0.089	316.25	0.015
1101.509	0.08	309.798	0.013	1119.419	0.089	314.835	0.015
1100.706	0.08	309.573	0.013	1125.143	0.09	316.446	0.015
1104.772	0.081	310.716	0.013	1125.665	0.09	316.592	0.015
1104.755	0.081	310.711	0.013	1124.733	0.09	316.33	0.015
1104.19	0.081	310.552	0.014	1124.411	0.09	316.24	0.015
1103.172	0.081	310.266	0.014	1124.148	0.09	316.166	0.015
1106.85	0.082	311.301	0.014	1123.936	0.091	316.106	0.015
1105.269	0.082	310.856	0.014	1123.514	0.091	315.987	0.015
1105.196	0.082	310.835	0.014	1126.822	0.091	316.918	0.015
1108.085	0.082	311.648	0.014	1127.792	0.091	317.19	0.015
1108.509	0.082	311.767	0.014	1125.984	0.092	316.682	0.015
1107.58	0.083	311.506	0.014	1123.765	0.092	316.058	0.015
1105.811	0.083	311.008	0.014	1125.774	0.092	316.623	0.015
1108.316	0.083	311.713	0.014	1124.435	0.092	316.246	0.015
1111.33	0.083	312.561	0.014	1122.196	0.092	315.617	0.015
1110.215	0.083	312.247	0.014	1125.118	0.093	316.438	0.015
1110.947	0.084	312.453	0.014	1122.858	0.093	315.803	0.015
1110.945	0.084	312.452	0.014	1121.488	0.093	315.417	0.016
1110.939	0.084	312.451	0.014	1121.487	0.093	315.417	0.016
1112.074	0.084	312.77	0.014	1123.221	0.093	315.905	0.016
1114.435	0.085	313.434	0.014	1120.961	0.094	315.269	0.016
1114.666	0.085	313.499	0.014	1123.649	0.094	316.025	0.016
1113.88	0.085	313.278	0.014	1122.118	0.094	315.595	0.016
1115.025	0.085	313.6	0.014	1120.707	0.094	315.198	0.016
1115.863	0.085	313.836	0.014	1120.557	0.095	315.156	0.016

1121.304	0.095	315.366	0.016
1119.971	0.095	314.991	0.016
1116.167	0.095	313.921	0.016
1120.536	0.095	315.15	0.016
1120.913	0.096	315.256	0.016
1120.172	0.096	315.047	0.016
1114.663	0.096	313.498	0.016
1119.735	0.096	314.924	0.016
1119.023	0.096	314.724	0.016
1116.336	0.097	313.969	0.016
1119.039	0.097	314.729	0.016
1117.873	0.097	314.401	0.016
1114.434	0.097	313.434	0.016
1111.93	0.097	312.729	0.016
1115.919	0.098	313.851	0.016
1115.71	0.098	313.792	0.016
1110.574	0.098	312.348	0.016
1115.927	0.098	313.854	0.016
1114.366	0.099	313.415	0.016
1114.309	0.099	313.399	0.016
1112.232	0.099	312.814	0.017
1112.932	0.099	313.011	0.017
1115.146	0.099	313.634	0.017
1112.99	0.1	313.027	0.017
1113.472	0.1	313.163	0.017
1113.594	0.1	313.197	0.017
1112.615	0.1	312.922	0.017
1112.863	0.101	312.992	0.017
1111.919	0.101	312.726	0.017
1112.003	0.101	312.75	0.017
1111.243	0.101	312.536	0.017
1114.261	0.101	313.385	0.017
1112.262	0.102	312.823	0.017
1112.096	0.102	312.776	0.017
1113.997	0.102	313.311	0.017
1114.064	0.102	313.329	0.017
1114.974	0.102	313.585	0.017
1113.294	0.103	313.113	0.017
1117.518	0.103	314.301	0.017
1112.018	0.103	312.754	0.017
1114.445	0.103	313.437	0.017
1115.511	0.104	313.736	0.017
1113.604	0.104	313.2	0.017
1112.444	0.104	312.874	0.017
1112.085	0.104	312.773	0.017
1112.431	0.104	312.87	0.017
1111.781	0.105	312.687	0.017
1111.727	0.105	312.672	0.017
1114.687	0.105	313.505	0.017
1110.625	0.105	312.362	0.018
1111.307	0.105	312.554	0.018
1110.344	0.106	312.283	0.018
1112.362	0.106	312.851	0.018
1112.973	0.106	313.023	0.018
1110.642	0.106	312.367	0.018
1113.581	0.106	313.194	0.018
1109.683	0.107	312.097	0.018
1109.446	0.107	312.031	0.018
1111.089	0.107	312.493	0.018
1111.525	0.107	312.616	0.018
1116.249	0.108	313.944	0.018
1111.352	0.108	312.567	0.018
1114.971	0.108	313.585	0.018
1113.725	0.108	313.234	0.018
1113.58	0.108	313.193	0.018
1111.354	0.109	312.567	0.018
1112.878	0.109	312.996	0.018
1111.521	0.109	312.614	0.018
1113.195	0.109	313.085	0.018
1112.616	0.109	312.922	0.018
1111.964	0.11	312.739	0.018
1112.975	0.11	313.023	0.018
1112.709	0.11	312.949	0.018
1112.147	0.11	312.79	0.018
1110.828	0.111	312.419	0.018
1111.538	0.111	312.619	0.018
1111.081	0.111	312.491	0.018
1111.043	0.111	312.48	0.019
1109.402	0.111	312.018	0.019
1108.973	0.112	311.898	0.019
1109.798	0.112	312.13	0.019
1104.775	0.112	310.717	0.019
1107.225	0.112	311.406	0.019
1106.416	0.112	311.179	0.019
1102.68	0.113	310.128	0.019
1100.938	0.113	309.638	0.019

1105.014	0.113	310.784	0.019	1098.87	0.119	309.056	0.02
1103.375	0.113	310.323	0.019	1098.211	0.119	308.871	0.02
1103.563	0.114	310.376	0.019	1095.295	0.12	308.051	0.02
1100.321	0.114	309.464	0.019	1093.339	0.12	307.501	0.02
1104.739	0.114	310.707	0.019	1099.661	0.12	309.279	0.02
1103.728	0.114	310.423	0.019	1096.891	0.12	308.5	0.02
1099.162	0.114	309.138	0.019	1093.662	0.121	307.592	0.02
1103.202	0.115	310.275	0.019	1094.551	0.121	307.841	0.02
1096.241	0.115	308.317	0.019	1092.703	0.121	307.322	0.02
1101.636	0.115	309.834	0.019	1092.537	0.121	307.275	0.02
1098.54	0.115	308.963	0.019	1094.795	0.121	307.91	0.02
1097.609	0.115	308.702	0.019	1093.845	0.122	307.643	0.02
1096.175	0.116	308.298	0.019	1090.712	0.122	306.762	0.02
1094.642	0.116	307.867	0.019	1096.897	0.122	308.501	0.02
1096.187	0.116	308.302	0.019	1095.581	0.122	308.131	0.02
1102.371	0.116	310.041	0.019	1094.182	0.122	307.738	0.02
1101.019	0.116	309.661	0.019	1096.787	0.123	308.47	0.02
1096.435	0.117	308.372	0.019	1095.547	0.123	308.122	0.02
1095.077	0.117	307.989	0.019	1095.489	0.123	308.105	0.021
1094.104	0.117	307.716	0.02	1093.522	0.123	307.552	0.021
1093.204	0.117	307.463	0.02	1097.639	0.123	308.71	0.021
1098.529	0.118	308.96	0.02	1098.851	0.124	309.051	0.021
1099.81	0.118	309.32	0.02	1097.03	0.124	308.539	0.021
1097.806	0.118	308.757	0.02	1093.711	0.124	307.605	0.021
1096.184	0.118	308.301	0.02	1094.364	0.124	307.789	0.021
1098.707	0.118	309.01	0.02	1094.428	0.125	307.807	0.021
1097.85	0.119	308.769	0.02	1098.442	0.125	308.936	0.021
1095.239	0.119	308.035	0.02	1097.344	0.125	308.627	0.021
1098.444	0.119	308.936	0.02	1100.741	0.125	309.582	0.021