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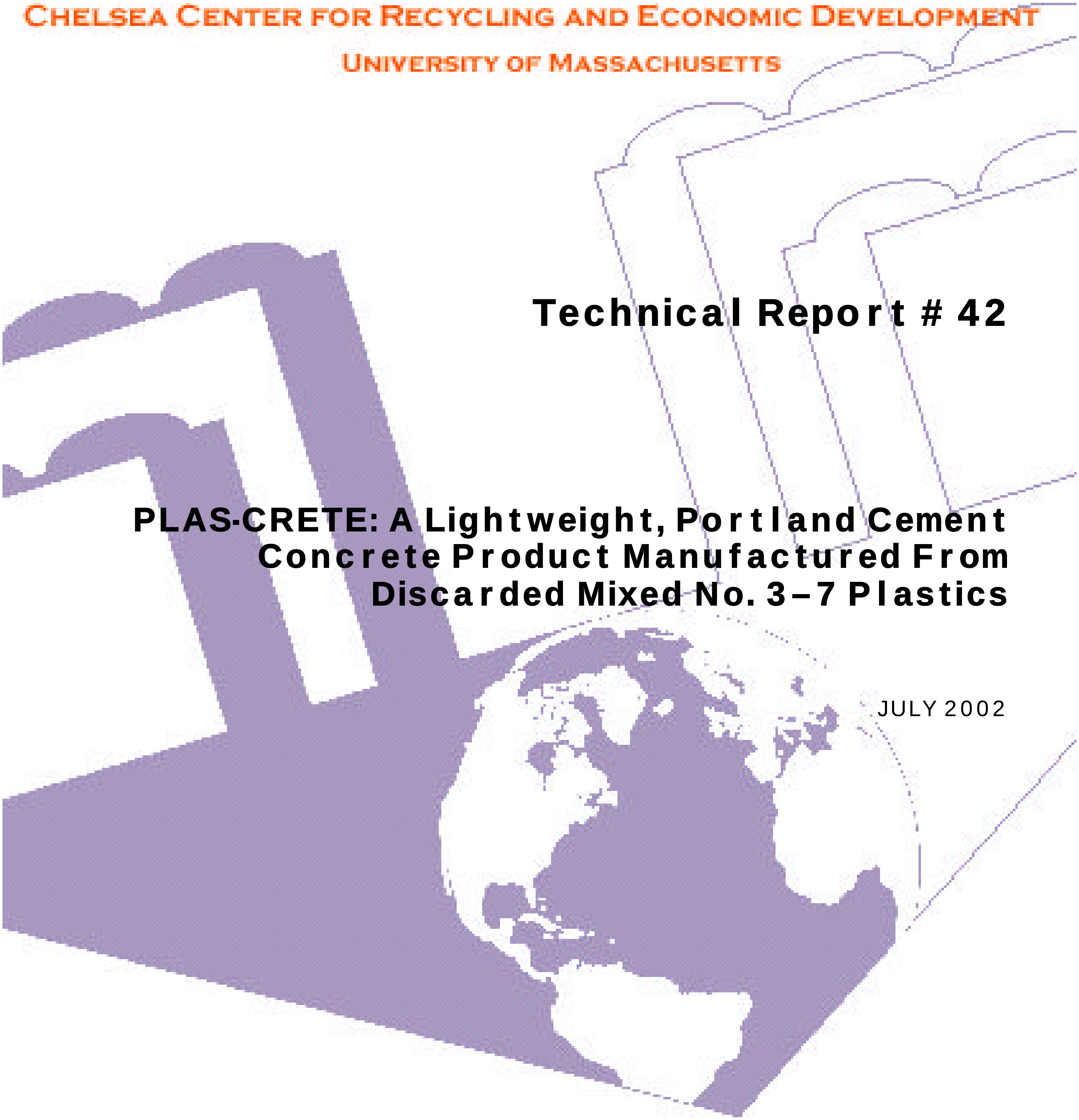

# Technical Report # 42

# PLAS-CRETE: A Lightweight, Portland Cement Concrete Product Manufactured From Discarded Mixed No. 3–7 Plastics

JULY 2002

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# PLAS-CRETE: A Lightweight, Portland Cement Concrete Product Manufactured From Discarded Mixed No. 3 – 7 Plastics

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## Chelsea Center for Recycling and Economic Development
## Technical Research Program

JULY 2002

 This project is funded by the University of Massachusetts' Chelsea Center for Recycling and Economic Development, through the Executive Office of Environmental Affairs and the Clean Environment Fund, which is comprised of unredeemed bottle deposits.

The Chelsea Center for Recycling and Economic Development, a part of the University of Massachusetts' Center for Environmentally Appropriate Materials, was created by the Commonwealth of Massachusetts in 1995 to create jobs, support recycling efforts, and help the economy and the environment by increasing the use of recyclables by manufacturers. The mission of the Chelsea Center is to develop an infrastructure for a sustainable materials economy in Massachusetts, where businesses will thrive that rely on locally discarded goods as their feedstock and that minimize pressure on the environment by reducing waste, pollution, dependence on virgin materials, and dependence on disposal facilities. Further information can be obtained by writing the Chelsea Center for Recycling and Economic Development, 80 Everett Avenue, Suite 221, Chelsea, MA 02150.

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**July 2002**

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# PLAS-CRETE: A LIGHTWEIGHT, PORTLAND CEMENT CONCRETE PRODUCT MANUFACTURED FROM MIXED NO. 3–7 PLASTIC

## 1. ABSTRACT

This is a report on the development, testing and evaluation of a Portland cement concrete (PCC) product containing mixed No. 3–7 waste plastic. This product falls under the category of a lightweight PCC, and is produced under the name 'Plas-Crete' by Conigliaro Industries in Framingham, Massachusetts.

Studies have estimated up to 100,000 tons of mixed No. 3–7 plastic are generated annually in the Commonwealth (MADEP; CCFRED). This equates to approximately 2-million cubic yards of ground plastic that, if not beneficially used, will be subject to costly disposal in a landfill every year. Conigliaro Industries has addressed the Commonwealth's need for beneficial use of this material by developing a series of products that incorporate No. 3-7 plastics. High-value, marketable products such as Boston's Best Patch, an asphalt cold patch previously developed with funding from the Chelsea Center for Recycling and Economic Development (CCFRED), have resulted in the recycling of tons of plastic annually. 'Plas-Crete', Conigliaro's most recent recycled plastic product development effort, has been pursued to beneficially use even more amounts of waste plastic.

Prior to initiation of this study, Conigliaro Industries had begun producing Plas-Crete mixes for proof-of-concept. Work presented in this report and funded by CCFRED, was subsequently needed to provide quantitative data to better define the most appropriate mix parameters. GeoTesting Express' Materials Technology Center (GTX-MTC) was retained to conduct third-party testing, evaluation, and related engineering services.

Plas-Crete batches containing a range of sizes and types of waste plastic exhibited compressive strengths ranging from 300 to 1,700 psi. These values indicate Plas-Crete can be used for "low-density" (i.e., insulating) and "moderate-strength" lightweight concrete. We are confident that with alteration of mix ratios and use of specific plastic sizes and particle shapes, higher compressive strengths (e.g., >2,500 psi) may be obtained allowing use of Plas-Crete as "structural" lightweight concrete. Plas-Crete has been an immediate success in the marketplace. Specifically, Plas-Crete wall blocks are currently being sold at a rate of 250 per week consuming about 31 tons per week of plastic that would otherwise go to a landfill.

## 2. STATEMENT OF PROBLEM

The approximately 100,000 tons of mixed waste (Nos. 3–7) plastic generated annually in Massachusetts poses a significant problem to the Commonwealth's objective of a 70-percent recycling rate by year 2010 (MADEP; CCFRED). Unless beneficially used, this material, which amounts to approximately 2-million cubic yards of ground plastic each year, will be subject to costly disposal in a landfill. Subsequently, mixed No. 3–7 has been designated by CCFRED as a priority material for recycling market development in the Commonwealth.

Standard Portland cement concrete (PCC) products such as wall blocks and parking stops, are heavy and must be handled with heavy equipment during construction activities. This presents added costs, effort, safety concerns, and inefficiencies during construction operations. Conigliaro Industries recognized this problem, and began investigating the production of the same PCC products, only using waste plastic as a substitute for the comparatively heavy virgin stone. They envisioned PCC products serving the same uses, only much lighter, easier to handle. The No. 3–7 mixed plastics used to substitute for the virgin stone comes primarily from town and city plastic collection and drop-off programs, as well as demanufacturers of computers and electronics.

In the summer of 2000, Conigliaro began production of a series of Plas-Crete trials to verify proof of concept. Plas-Crete consisted of a blend of virgin sand, ground No. 3–7 mixed plastic, water, and Portland cement. Results were positive, and it became necessary to determine the specific sizes and particle shapes of plastic, as well as amounts of cement that would produce PCC with the required properties for intended uses. This study, funded by CCFRED, was needed to establish these specific mix parameters for full-scale production, and/or further study. This work was also important to provide critical design criteria to engineers and other potential users.

## 3. SCOPE OF WORK

Work funded by CCFRED was conducted according to the "Product Development, Testing and Evaluation Plan" (Conigliaro Industries, Inc. and GTX-MTC) dated September 11, 2000 and the Scope of Work (CCFRED). The specific Plas-Crete product to be investigated was standard sized wall blocks with dimensions of two (2)-foot high by two (2)-foot wide by four (4)-foot long. Although any size may be produced, this size was selected so that the block would weigh 1-ton or less, enabling handling by small equipment (e.g., fork lifts). Plas-Crete consists of four main ingredients: Portland cement, water, sand, and ground No. 3–7 mixed plastic. Four (4) sizes of ground plastic (as defined by the maximum particle size) and three (3) amounts of Portland cement (Type I/II) were evaluated (Table 1). On October 24$^{th}$ and 25$^{th}$, 2000, Conigliaro Industries produced twelve (12) Plas-Crete batches in their Zimmerman 400N Ready-Mix Concrete Plant. Batches were produced according to the formulations given in Table 1.

The sand and ground plastic were evaluated for gradation and moisture content according to the methods and schedule given in Table 2. During Plas-crete production, batch samples were analyzed for consistency (slump), temperature, and unit weight (Table 3). At 7- and 28-day cure times, cylinders of hardened concrete were evaluated for compressive strength (Table 4). The densities of 28-day cured Plas-crete batches were also determined. Test results and analysis are presented and discussed in Section 5.

## Table 1: Trial Mix Designs

| Batch No. | Portland Cement (%) | Plastic/Sand Ratio | Max Plastic Particle Size |
|---|---|---|---|
| 1 | 15 | 3:2 | 1/8" |
| 2 | 15 | 3:2 | 5/16" |
| 3 | 15 | 3:2 | 1/2" |
| 4 | 15 | 3:2 | 1.25" |
| 5 | 20 | 3:2 | 1/8" |
| 6 | 20 | 3:2 | 5/16" |
| 7 | 20 | 3:2 | 1/2" |
| 8 | 20 | 3:2 | 1.25" |
| 9 | 25 | 3:2 | 1/8" |
| 10 | 25 | 3:2 | 5/16" |
| 11 | 25 | 3:2 | 1/2" |
| 12 | 25 | 3:2 | 1.25" |

## Table 2: Materials Properties Testing

| Parameter | ASTM Method | No.of Tests | No.of Materials | Total No. of Tests |
|---|---|---|---|---|
| Sampling | D75 | — | — | — |
| Grading of Sand | C117/C136 | 1 | 1 | 1 |
| Grading of Plastic | C117/C136 | 1 | 4 | 4 |
| Moisture of Sand | C566 | 1 | 1 | 1 |
| Moisture of Plastic | C566 | 1 | 4 | 4 |

## Table 3: Fresh Mix Testing

| Parameter | ASTM Method | No.of Tests per Batch |
|---|---|---|
| Sampling | C172 | — |
| Consistency (Slump) | C143 | 3 |
| Temperature | C1064 | 3 |
| Unit Weight/Yield | C138 | 3 |
| Strength Specimens | C31 | 6 |

**Table 4: Hardened Concrete Testing**

| Parameter | ASTM Method | Curing Time 7-day | Curing Time 28-day |
|---|---|---|---|
| Compressive Strength | C39 (C617) | 2 specimens | 3 specimens |
| Density | C642 | – | 2 specimens |

## 4. DESCRIPTION AND APPLICATION OF TECHNOLOGY

### 4.1 Process Description

Plas-Crete is a blend of virgin sand, ground No. 3–7 mixed plastic, water and Portland cement. Plas-Crete is produced in a Zimmerman 400N "Ready-Mix" Concrete Plant (See photos in Appendix I). Each ingredient material is placed in a separate feed unit on the plant. The plant is equipped with controls so that each material can be metered producing batches according to specified mix designs. The materials are blended together by an auger which leads to a mold where the uncured Plas-Crete is vibrated into place. Standard Plas-Crete wall blocks are two (2)-foot high by two (2)-foot wide by four (4)-foot long, and are fully nestable (See photos in Appendix 1). Half-size blocks are 2-foot by 2-foot by 2-foot. Other size blocks can be produced, and may find use in future applications. After molding, the Plas-Crete is allowed to cure for 12-to-24 hours prior to removal of the mold. The Plas-Crete product is then ready to be sold in the marketplace.

### 4.2 Site Description

The site for Plas-Crete production is Conigliaro Industries Framingham, Massachusetts facility. It is a fully permitted 88,000 square foot Material Recovery Facility which includes two outdoor tipping pads, 9 loading docks, a ShredPax AZ-80 shredder, a Marathon Two Ram TR-10 Baler with conveyor pit and sorting station, a Komatsu Excavator with Grapple Assembly, as well as a Clean Wood, Newspaper, and Commingled Container Sorting and Bulk Handling Area.

### 4.3 Potential Impacts

When this project began in Fall 2000, the through-put of mixed plastics (No. 3–7) processing line at Conigliaro Industries was 4,000,000 lbs. per year. We foresaw Plas-Crete having the potential for almost doubling this amount. We had anticipated our range of mix designs to require approximately 5,000 lbs. of mixed waste plastics per day initially (20 blocks/day x ~250 lbs. of plastic/block), and then grow to over 20,000 lbs. per day, producing 80 blocks per day (~2,300 tons of plastic per year = 80 blocks/day x ~250 lbs./block x 19 working days per month x 12 months). As of December 2001, Conigliaro Industries is selling blocks at a rate of about 250 per week consuming about 31 tons per week of plastic. Thus within a year of initiating this project, Conigliaro Industries' through-put of mixed plastics (No. 3–7) has increased by over 3,000,000 lbs. per year.

### 4.4 Applicability to Industry

As presented in the above section, Plas-Crete is able to consume large amounts of waste plastic. By substituting such a high amount of comparatively heavy stone aggregate with ground plastic, the PCC product is significantly lighter resulting in much more cost effective, safe and efficient construction. The Plas-Crete product presents a high-end use of waste plastic.

### 4.5 Innovation of Technology

Lightweight concrete is not new. It has been employed for a variety of applications where standard weight concrete is unsuitable. Examples include use as floors in high-rise buildings to reduce support load requirements, and as thermal and sound insulation in walls and roof panels (Kosmatka/PCA). Strength requirements vary depending upon the particular use. Structural lightweight concrete has strengths comparable to normal weight concrete (e.g., >2,500 psi), while low-density and moderate-strength concrete can have compressive strengths of 100-1,000 psi and 1,000-2,500 psi, respectively (Kosmatka/PCA). Aggregates currently used in lightweight concrete include pelletized fly ash, slags, and vermiculite. Until now the use of mixed No. 3-7 plastic as a substitute aggregate in lightweight concrete has not been capitalized on in the marketplace.

### 4.6 Development History

Conigliaro Industries began developing Plas-Crete in the summer of 2000. After a series of trials, this study was developed to further refine initial field results. The results of this study were used to identify specific mixes that could go into full-production or be modified as needed to produce the desired Plas-Crete grade of lightweight concrete. Currently, Plas-Crete blocks are being sold across Massachusetts for use in retaining walls, bin structures, loading docks and salt buildings. These structures are considered semi-permanent. The blocks nestle together by the male-female connections (see photos in Appendix 1), and if necessary, may be further secured by placing a 'structural mastic' at the contact surfaces. The block structure may be dismantled easily. If a mastic has been used, the mastic bond needs to be broken prior to dismantling.

## 5. TECHNOLOGY PERFORMANCE

### 5.1 Performance Goals

As discussed in Section 3.5, desired performance properties depend upon the intended use of the lightweight concrete. Plas-Crete products were initially envisioned for moderate-to-structural lightweight concrete items such as wall blocks and parking stops. The main goal of this study was to determine benchmark properties for a range of Plas-Crete mixes so that potential uses for Plas-Crete could be verified, and so that we'd have a reference point from which to modify mix designs, if needed.

## 5.2 Discussion of Test Results and Comparison with Standard PCC

### 5.2.1 Material Properties

The Portland cement used in the study met ASTM C150 specifications for Type I/II cement. Grain-size distribution and moisture contents of the sand and four different sizes of plastic are summarized in Table 5 (See Appendix 2 for details). The types of aggregates used in current lightweight concrete products include perlite, vermiculite, shale, and slag (Kosmatka/PCA). The grain-size distributions of these materials vary. The unit weights of these currently used materials range from 6 to 70 pounds per cubic foot (Kosmatka/PCA). Previous work with ground plastic (i.e., use in asphalt products) have shown unit weights of approximately 30-40 pcf.

**Table 5: Grain-Size Distributions and Moistures of Aggregates**

| | Grain-Size Distributions | | | | |
|---|---|---|---|---|---|
| | Plastic Designation | | | | |
| **Sieve Size** | 1/8" | 5/16" | 1/2" | 1.25" | Sand |
| **1.25"** | | | | | |
| **1"** | | | | 100 | |
| **3/4"** | | | | 99.9 | |
| **1/2"** | | | 100 | 90 | |
| **3/8"** | | 100 | 99.7 | 66 | 100 |
| **#4** | 100 | 69 | 60 | 14 | 96 |
| **#8** | 85 | 20 | 17 | 2 | 78 |
| **#16** | 26 | 8 | 4 | 0.4 | 57 |
| **#30** | 7 | 3 | 1.2 | 0.1 | 36 |
| **#50** | 3 | 1 | 0.4 | 0.1 | 18 |
| **#100** | 1 | 0.6 | 0.2 | 0.1 | 8 |
| **#200** | 0.3 | 0.6 | 0.1 | 0.1 | 5.3 |
| **Moist.** | 0.5 | 0.6 | 1.7 | 0.1 | 4.8 |

*Plastic designation is defined by the grinding apparatus.

As shown in the photos (Appendix 1), the 1/8" plastic, primarily from wire strippings, is curly in shape and compressible. As will be discussed in Section 4.2.3, this had the effect of entrapping high volumes of air in the PCC, possibly contributing to low strength. The 5/16" plastic consisted of solid chunks of plastic with some flat, angled pieces and some rubbery chunks (see photos). The 1/2" plastic were primarily from razor-blade housings and subsequently had significant amounts of metal and particles that tended to entrap air in the PCC (Section 4.2.3). The 11/4" plastic consisted of flat and elongated, pliable pieces, as well as film and chunks of hard plastic.

During full-scale production operations, size and shape of the plastic pieces will be controlled by both the type of waste plastic accepted for recycling (influx control), as well as the shredder and grinder screen sizes.

### 5.2.2 Fresh Mix Testing

As shown in Figure 1, temperatures of fresh mixes ranged from 60° to 80°F, falling within those desirable for adequate strength gain. Temperatures greater than 85°F can result in lower long-term strengths (Kosmatka/PCA). Differences in temperatures measured may have been affected by ambient temperatures during mixing operations. Fresh mix made in the cool late-October mornings (~60°F) were cooler than those in afternoon (~75°F). Regardless, the mix temperatures do not appear to have effected strength gain, as indicated as indicated by comparison with Figure 4 (28-day cure plot). See Appendix 1 for photos, and Appendix 3 for data.

Slump is a measure of the consistency or flowability of the fresh mix. The objective of a slump requirement is to ensure the fresh mix is able to be placed. Lightweight concrete will typically show lower slumps than the same mix with normal-weight aggregate, while the workability remains the same (Kosmatka/PCA). Slump requirements for normal-weight aggregate depend upon the particular application, but for the majority, requirements range from a minimum of 1-inch to maximum values of 3-to-6 inches (Kosmatka/PCA; MassHighway). As shown in Figure 2, the majority of batches evaluated showed slumps of 1-3 inches with some less than 1-inch. Based on Kosmatka/PCA's description and observations during field work, all slumps measured were adequate for placement, except for the 1/2" plastic mixes which tended to be difficult to place. We did observe differences in water contents for the 12-batches, which likely effected slump. Differences may have been due to variability in water added during production. See Appendix 1 for photos, and Appendix 3 for data.

As shown in Figure 3, the unit weights for all mixes were generally lower than standard PCC made with normal-weight aggregates (e.g., 110-125 pcf vs. 135-160 pcf, respectively). We do see some variation among the four plastic mixes, and suspect this has to do with the different specific gravities and particle shapes of the plastics. The 1/8" and 1/2" plastic mixes showed the lowest unit weights. This is likely to be due to air entrapment. Although we did not specifically measure air content in the fresh mix, evolution of bubbles were observed for the 1/8" and 1/2" mixes. This was most evident for the 1/8" mix where once placed in a mold, the fresh mix began to expand vertically out of the mold within a few minutes. We suspect this was due to the curly particle shape of the wire strippings, as discussed in Section 4.2.1. See Appendix 1 for photos, and Appendix 3 for data.

Figure 1: Fresh Mix Temperature vs. Plastic Size

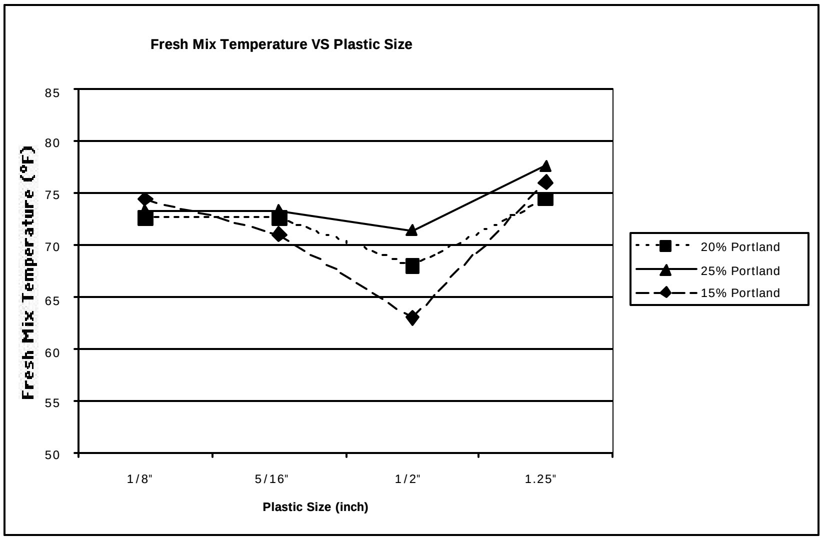



Figure 2: Slump vs. Plastic Size

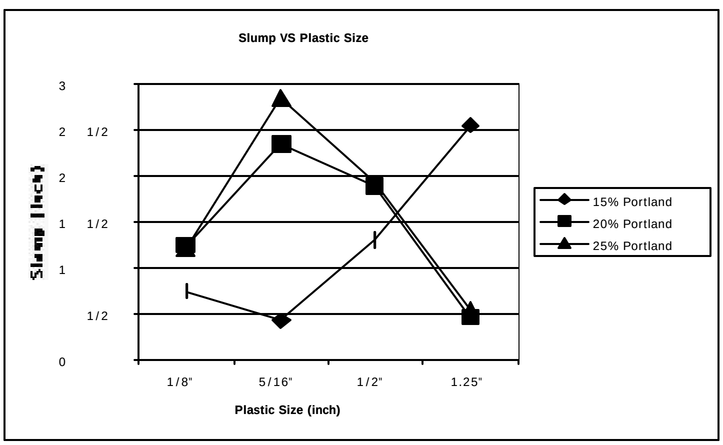
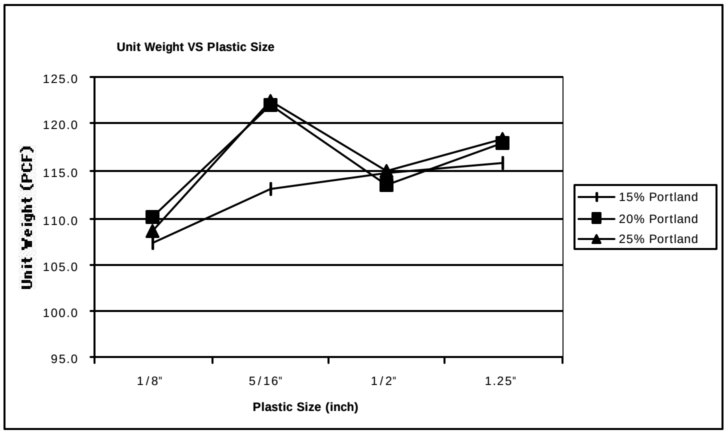


Figure 3: Unit Weight vs. Plastic Size



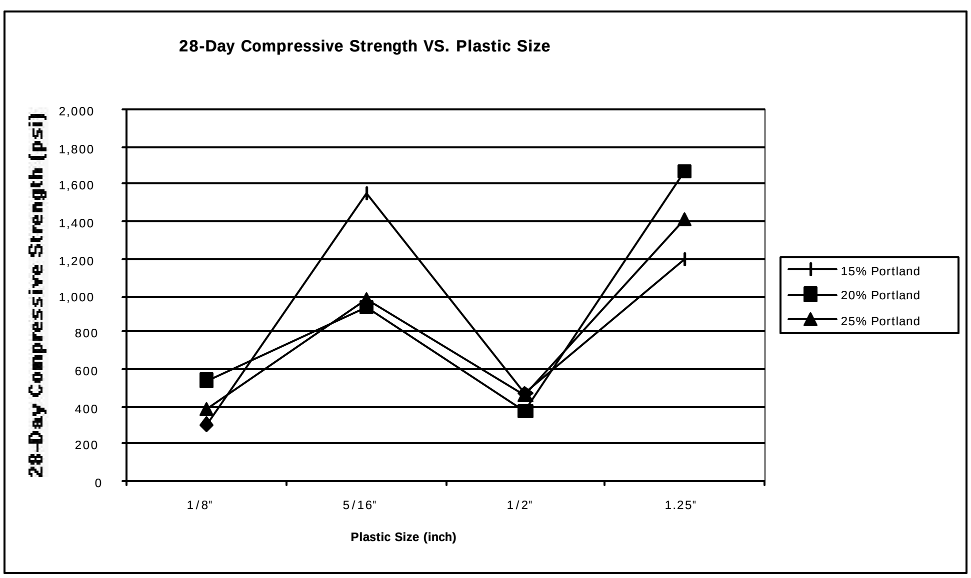

### 5.2.3 Hardened Concrete Testing

Average 7- and 28-day compressive strengths for all mixes are presented in Table 6 with complete data presented in Appendix 4. The highest strengths were for batches containing 5/16" and 1 1/4" plastic (Figure 4). 28-Day strengths for these batches ranged from about 900 to 1,700 psi. These strength values fall into the "moderate-strength" lightweight concrete category (Kosmatka/PCA). Batches containing 1/8" and 1/2" plastic achieved considerably lower strengths. 28-Day strengths ranged from about 300 to 600 psi. These strength values fall into the "low-density" or "insulating" lightweight concrete category (Kosmatka/PCA). For all plastics evaluated, there were no observed relationship between break type, plastic size/shape, or cement content. Break types included shear, cone & split, columnar, and cone. See Appendix 4 for details.

**Table 6. Compressive Strengths**

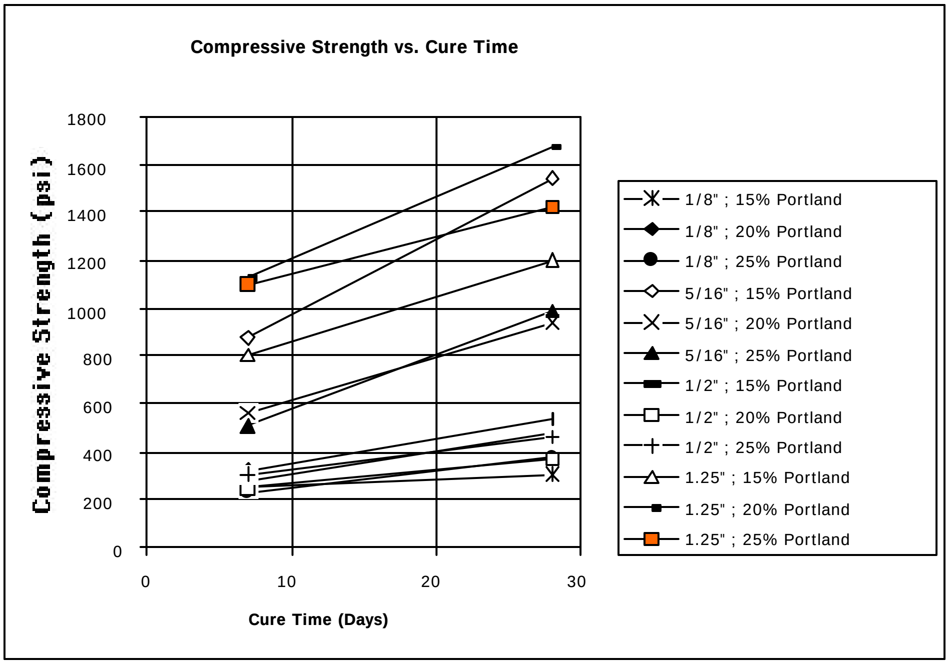
| Batch | Portland Cement (%) | Plastic Size (inch) | 7-Day Cure Compressive Strength, Avg. (psi) | 28-Day Cure Compressive Strength, Avg. (psi) |
|---|---|---|---|---|
| 1 | 15 | 1/8" | 250 | 305 |
| 2 | 15 | 5/16" | 878 | 1,546 |
| 3 | 15 | 1/2" | 274 | 478 |
| 4 | 15 | 1.25" | 800 | 1,198 |
| 5 | 20 | 1/8" | 326 | 539 |
| 6 | 20 | 5/16" | 560 | 941 |
| 7 | 20 | 1/2" | 253 | 372 |
| 8 | 20 | 1.25" | 1,129 | 1,668 |
| 9 | 25 | 1/8" | 229 | 381 |
| 10 | 25 | 5/16" | 508 | 984 |
| 11 | 25 | 1/2" | 308 | 460 |
| 12 | 25 | 1.25" | 1,096 | 1,417 |

Figure 4: 28-day Compressive Strength vs. Plastic Size



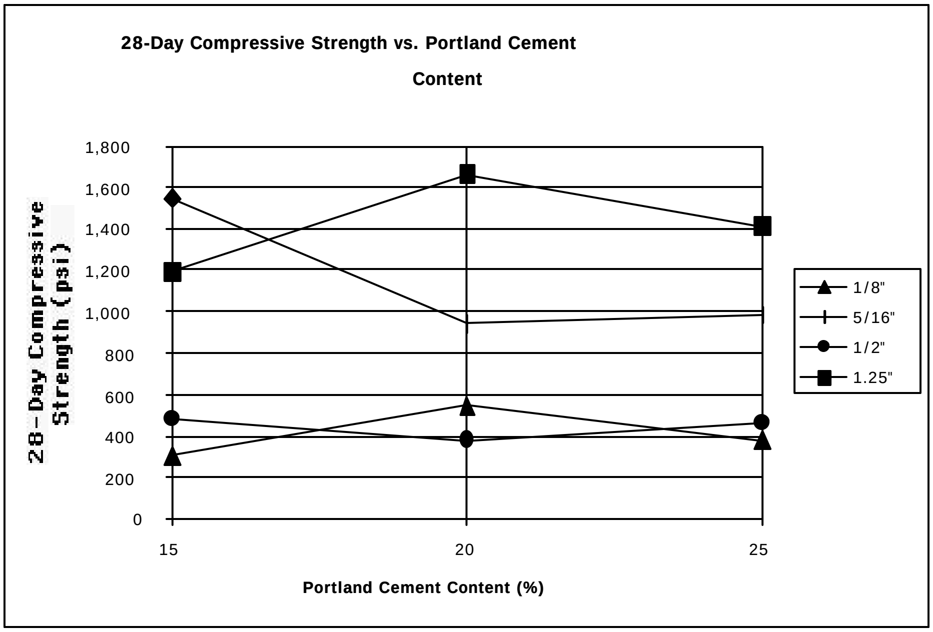
Comparing 7-day with 28-day cure strengths, we see the 7-day strengths for all batches to be approximately 65% of 28-day values (Figure 5). Generally, standard concrete mixes attain about 70% of their final strength at 7-days curing, although this figure varies anywhere from 60 to 80% depending upon the mix (Kosmatska/PCA).

Figure 5: Compressive Strength vs. Time



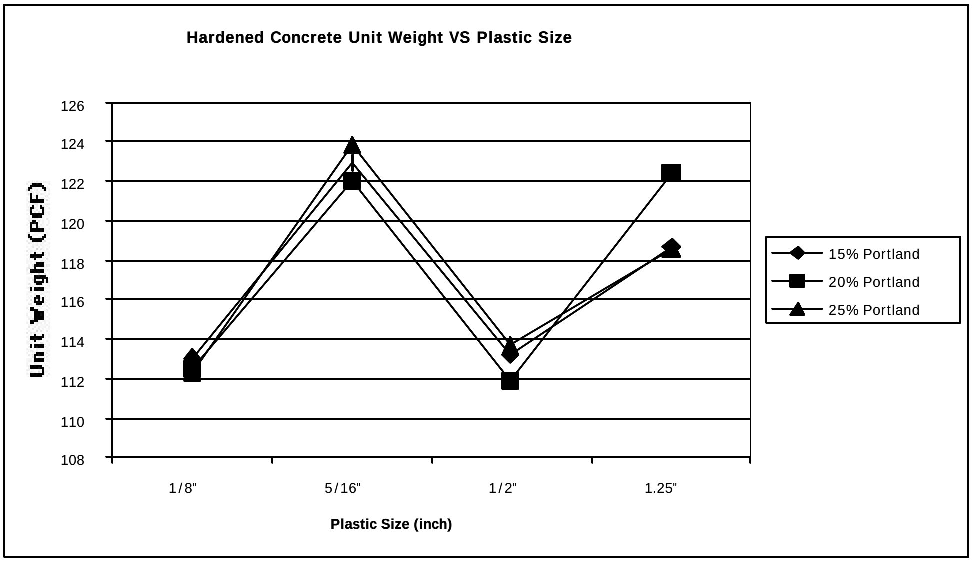

The data do not show observable relationships between Portland cement content and compressive strength (Figure 6). Typically, if the water content was kept constant we would expect the strength to increase with cement content. However, high water content mixes will tend to show lower long-term (28-day) strengths than lower water content mixes. As described in Section 4.2.1, water contents in the 15%, 20%, and 25% Portland cement mixes were variable, and may have contributed to the observed data.

Figure 6: 28-day Compressive Strength vs. Cement Content



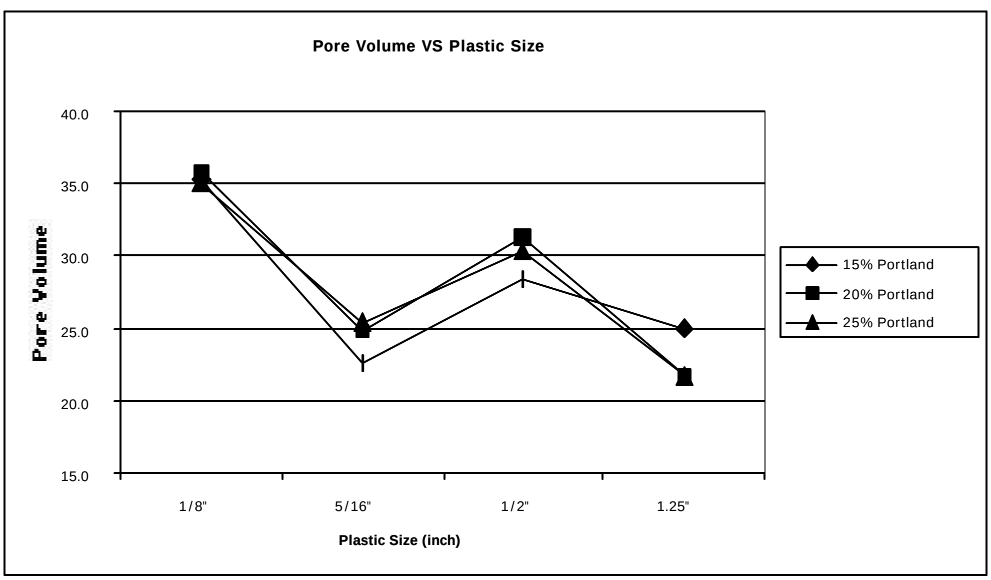

Plas-Crete mixes containing 1/8" and 1/2" plastic showed hardened concrete unit weights of 112-to-114 pcf. Mixes with 5/16" and 11/4" plastic had higher unit weights of 118-to-124 pcf. These values fall into the "moderate" and "structural" lightweight concrete range of 50-to-120 and 85-to-120 pcf, respectively (Kosmatska/PCA). These values are similar to fresh mix unit weights for each mix (See Figure 3 in Section 4.2.2.).

Figure 7: Hardened Concrete Unit Weight vs. Plastic Size




Pore volume has an inverse relationship to unit weight, as we would expect (Compare Figures 7 and 8). Assuming the unit weights of each plastic grading to be the approximately similar, we suspect the difference in pore volumes to be due to the ability of 1/8" and 1/2" to entrap air. Figure 8 shows the 1/8" plastic pore volume to be 5-percent higher than the 1/2" which is about 5-percent higher than both the 5/16" and 11/4" plastic mixes. These results compare well with observations during batching operations where the 1/8" mix in particular showed significant vertical expansion in the cylinder mold and visible air bubbles evolving from the fresh mix.

Figure 8: Hardened Concrete Pore Volume vs. Plastic Size



We suspect differences in strengths of the plastic mixes are a result of both particle shape and size. We suspect that since particles which are not solid spheres can be compressed more than the surrounding PCC, they may tend to become foci for fracture points during measurement of compressive strength. We also suspect that such particle shapes tend to entrap (not entrain) large amounts of air such that during initial curing, the mix expands rapidly, possibly preventing solid and continuous bonding from forming. Mixes with 1/8" plastic fit this scenario (See Section 4.2.1 and above). We did not measure the specific amount of air in the fresh mix. However, as discussed above, we observed these mixtures expanding out of the molds within a few minutes of pouring and consolidating. In addition, because of the smaller size, the same volume of 1/8" plastic provides many more (non-solid) particles that provide foci for fracture initiation (See photos in Appendix 1). Mixes with 5/16" and 1 1/4" plastic consisted primarily of solid pieces, and the strengths are higher (See Section 4.2.1.).

## 6. COST INFORMATION

### 6.1 Capital Costs

Capital costs for Plas-Crete production equipment is approximately $96,500,. This is the cost to acquire the equipment needed to produce blocks from virgin materials at a rate similar to what has been proposed for Plas-Crete. Equipment includes a Zimmerman mixer, cement silo, conveyors, and molds.

### 6.2 Operating Costs

Operating costs are predicted to be about $80,000 per month. This covers equipment amortization, materials, labor and utilities for producing up to 1,700 blocks per month.

### 6.3 Cost Benchmarks

Conigliaro Industries is seeking to sell the blocks for $65 per 2'x 2'x 4' block, FOB Conigliaro.

## 7. REGULATORY / SAFETY ISSUES AND REQUIREMENTS

### 7.1 Applicable Regulations and Permit Requirements

Conigliaro Industries is subject to several regulations and regulatory agencies. First, the firm is located in a Heavy Manufacturing Zone as shown on the Town of Framingham Zoning Map. Second, Conigliaro Industries was granted a Determination of Need Permit by the Department of Environmental Protection to operate its recycling business. Third, Conigliaro Industries has received three separate $50,000 DEP sponsored Recycling Investment Reimbursement Credit Grants for the development of a) Boston's Best Patch Pot Hole Filler, b) Plas-Crete Blocks, and c) A Mattress Recycling Plant. Conigliaro Industries operates according to these regulations and requirements.

### 7.2 Health and Safety Issues

Conigliaro Industries' operations are subject to known Standard Safety Regulations promulgated by such agencies as the Massachusetts Division of Labor and Industries.

## 8. TRANSFERABILITY OF THE RESEARCH

Results of this study are applicable to anyone interested in producing and using lightweight Portland cement concrete made from ground, mixed No. 3-7 plastic. Interested parties include design engineers, owners of constructed facilities (state and local highway officials), contractors, concrete product manufacturers, and others researchers.

## 9. CONCLUSIONS

Mixed No. 3–7 plastic is a viable aggregate for production of lightweight concrete. Plas-Crete products have the potential for recycling significant amounts of plastic, and addresses the Commonwealth's need for beneficial use of this material. Plas-Crete also addresses the need for making specific concrete products, such as wall blocks, lighter.

### 9.1 Lessons Learned

Both particle size and shape of plastic appear to be factors strength gain. Plastic particles solid in shape (5/16" and 11/4" plastic) provide the highest strength, and can be used for "moderate" lightweight concrete products. However, we are confident that with adjustments in mix design (e.g., water/cement ratio), structural lightweight concrete can be produced. Increase in cement content alone cannot be directly correlated to strength increase. The water/cement ratios should be looked at more carefully in achieving desired strengths. Non-solid plastic (1/8" and 1/2" plastic) shows potential use as "low-density" lightweight concrete.

### 9.2 Implementation Issues

Plas-Crete has been an immediate success in the marketplace. Plas-Crete wall blocks are currently being sold at a rate of 250 per week, consuming about 31 tons per week of plastic that would otherwise go to a landfill. These 2-foot by 2-foot by 4-foot blocks weigh just under 1-ton (1,850 lbs.), have a unit weight of about 115 pounds per cubic foot, and contain about 250 lbs. of plastic per block. However, in addition to current successes, results of this study indicate the market for Plas-Crete products is even larger. Plas-Crete has the potential uses as low-density and moderate strength products such as floors in high-rise buildings, and thermal and sound insulation in walls and roof panels. These markets and the specific product requirements will need to be researched.

### 9.3 Benefits and Limitations of Application

Plas-Crete products require significant amounts of mixed No. 3-7 plastic and provide the marketplace with lightweight alternatives to standard (i.e., heavy) weight concrete products. This addresses the goals of the Commonwealth for recycling of this waste material into high-value, marketable products.

Plas-Crete shows promise for use as "low-density" (i.e., insulating) and "moderate-strength" lightweight concrete. We are confident that with alteration of mix ratios and use of specific plastic sizes and particle shapes, higher compressive strengths (e.g., >2,500 psi) may be obtained allowing use of Plas-Crete as "structural" lightweight concrete.

### 9.4 Recommendations for Future Work

Based on benchmark properties determined in this study, mix designs should be altered to achieve increased compressive strength. Water-cement ratios and use of admixtures, among other alterations, should be evaluated for increasing strength. A Quality Assurance, Quality Control (QA/QC) Plan for production of Plas-Crete should be implemented. Markets for low-density and moderate strength lightweight concrete need to be investigated also. Specific performance requirements need to be determined, and Plas-Crete should be more carefully evaluated for those uses.

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# APPENDICES

# APPENDIX A: Photographs

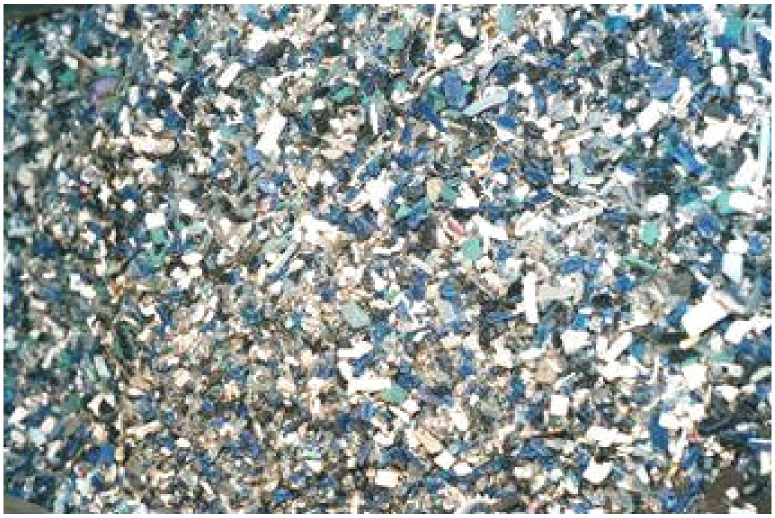
Zimmerman Plant

Salt shed made from Plas-Crete blocks

**Slump Test**

**1/8" Plastic**

**5/16" Plastic**



**½ Plastic**

**1.25" Plastic**

**5/16" Plas-Crete**

**½” Plas-Crete**

**1.25” Plas-Crete**

**Placing Plas-Crete block**

# APPENDIX 2

## Grain-size Distribution and Moisture Contents of the Sand and Plastics

# GEOTECHNICAL LABORATORY TEST DATA

Project : Plas-Crete
Project No. : GTMT10010
Boring No. : ---
Sample No. : 1/8 plastic
Location : ---
Soil Description : Wire stripping which are curly and compressible
Remarks : ---

Depth : ---
Test Date : 10/27/00
Test Method : ASTM C117/136

Filename : PLSCRT18
Elevation : ---
Tested by : DL
Checked by : FPH

FINE SIEVE SET

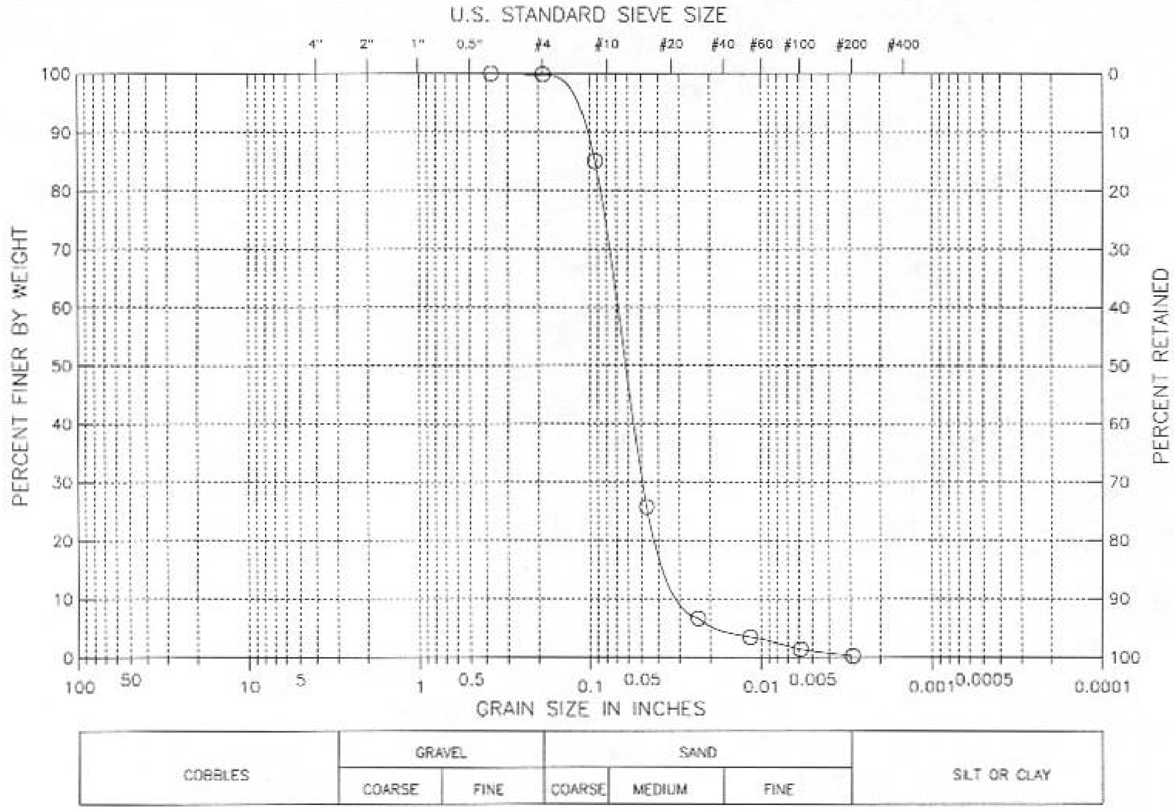
| Sieve Mesh | Sieve Openings Inches | Millimeters | Weight Retained (gm) | Cumulative Weight Retained (gm) | Percent Finer (%) |
|---|---|---|---|---|---|
| 0.375" | 0.374 | 9.51 | 0.00 | 0.00 | 100 |
| #4 | 0.187 | 4.75 | 0.50 | 0.50 | 100 |
| #8 | 0.093 | 2.36 | 64.50 | 65.00 | 85 |
| #16 | 0.047 | 1.19 | 259.00 | 324.00 | 26 |
| #30 | 0.023 | 0.60 | 83.00 | 407.00 | 7 |
| #50 | 0.012 | 0.30 | 14.00 | 421.00 | 3 |
| #100 | 0.006 | 0.15 | 9.00 | 430.00 | 1 |
| #200 | 0.003 | 0.07 | 4.90 | 434.90 | 0 |
| Pan | | | 1.30 | 436.20 | 0 |

Total Dry Weight of Sample = 436.2

D85 : 2.3573 mm
D60 : 1.7669 mm
D50 : 1.5745 mm
D30 : 1.2502 mm
D15 : 0.8052 mm
D10 : 0.6711 mm

Soil Classification
ASTM Group Symbol : SP
ASTM Group Name : Poorly graded sand
AASHTO Group Symbol : A-1-a(0)
AASHTO Group Name : Stone Fragments, Gravel and Sand

| | | |
|---|---|---|
| | Boring No.: --- <br> Sample No: 1/8 plastic <br> Test Method ASTM C117/136 <br> Filename : PLSCRT18 | Project : Plas-Crete <br> Project No.: GTMT10010 <br> Location: --- <br> Date : Wed Oct 10 2001 |




Classification :
(SP) Poorly graded sand

Visual Description :
Wire stripping which are curly and compressible

Remarks :
---

Figure 1

GEOTECHNICAL LABORATORY TEST DATA

Project : Plas-Crete
Project No. : GTMT10010
Boring No. : ---
Sample No. : 5/16 plastic
Location : ---
Depth : ---
Test Date : 10/27/00
Test Method : ASTM C117/136
Filename : PLSCT516
Elevation : ---
Tested by : DL
Checked by : FPH
Soil Description : angular chnks plastic some flat w/ rubbery chnks
Remarks : ---

FINE SIEVE SET

| Sieve Mesh | Sieve Openings Inches | Millimeters | Weight Retained (gm) | Cumulative Weight Retained (gm) | Percent Finer (%) |
|---|---|---|---|---|---|
| 0.375" | 0.374 | 9.51 | 0.50 | 0.50 | 100 |
| #4 | 0.187 | 4.75 | 285.50 | 286.00 | 69 |
| #8 | 0.093 | 2.36 | 451.00 | 737.00 | 20 |
| #16 | 0.047 | 1.19 | 117.00 | 854.00 | 8 |
| #30 | 0.023 | 0.60 | 48.00 | 902.00 | 3 |
| #50 | 0.012 | 0.30 | 15.00 | 917.00 | 1 |
| #100 | 0.006 | 0.15 | 4.00 | 921.00 | 1 |
| #200 | 0.003 | 0.07 | 0.40 | 921.40 | 1 |
| Pan | | | 5.10 | 926.50 | 0 |

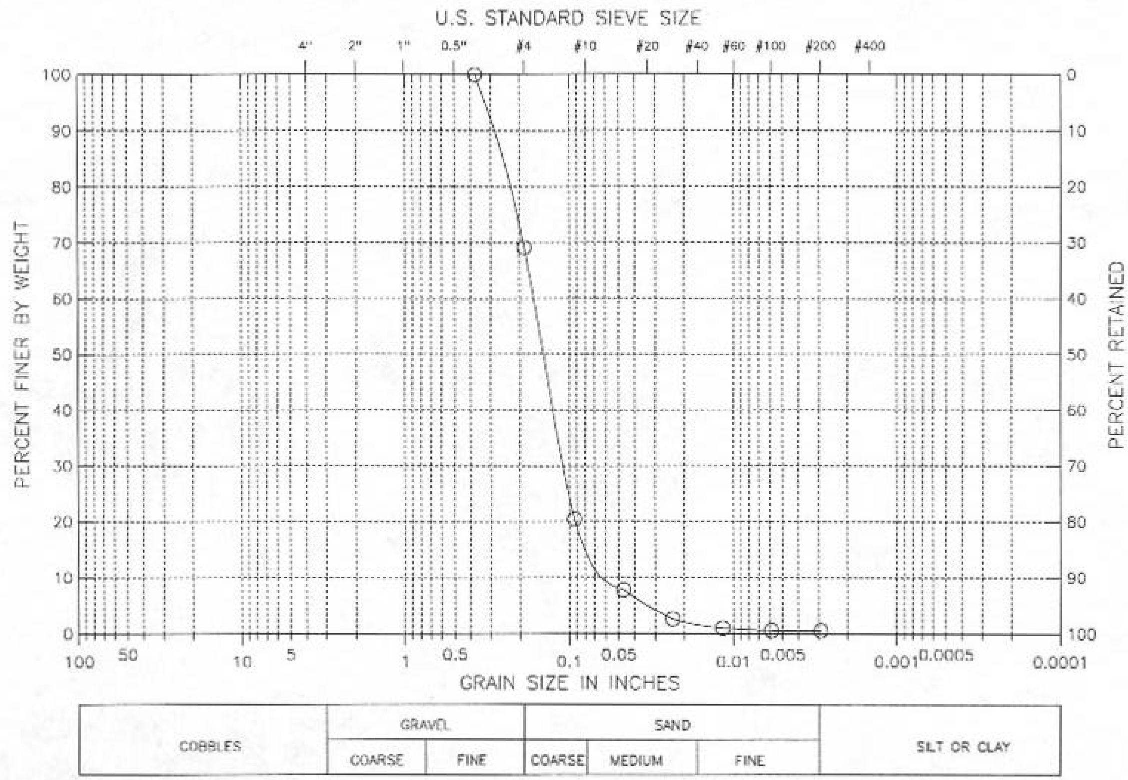
Total Dry Weight of Sample = 926.5

D85 : 6.7913 mm
D60 : 4.1659 mm
D50 : 3.6083 mm
D30 : 2.7070 mm
D15 : 1.7559 mm
D10 : 1.3389 mm

Soil Classification
ASTM Group Symbol : SP
ASTM Group Name : Poorly graded sand with gravel
AASHTO Group Symbol : A-1-a(0)
AASHTO Group Name : Stone Fragments, Gravel and Sand

Boring No. : ---
Sample No: 5/16 plastic
Test Method ASTM C117/136
Filename : PLSCT516

Project : Plas-Crete
Project No.: GTMT10010
Location: ---
Date : Wed Oct 10 2001




Classification :
(SP) Poorly graded sand with gravel
Visual Description :
angular chnks plastic some flat w/ rubbery chnks

Remarks :
---

Figure 1

# GEOTECHNICAL LABORATORY TEST DATA

Project : Plas-Crete
Project No. : GTMT10010
Boring No. : ---
Sample No. : 1/2 plastic
Location : ---
Depth : ---
Test Date : 10/30/00
Test Method : ASTM C117/136
Filename : PLSCRT12
Elevation : ---
Tested by : DL
Checked by : PPH
Soil Description : plastic frm razor housing w/ sgnfcnt amnts of metl
Remarks : ---

FINE SIEVE SET

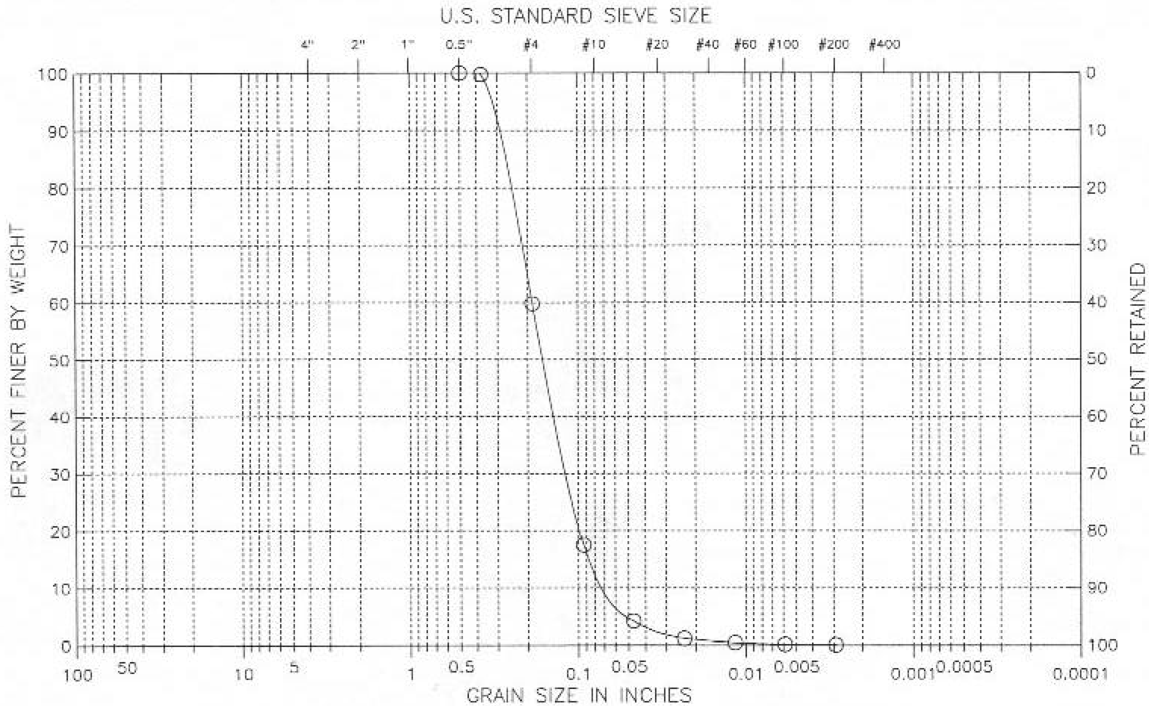
| Sieve Mesh | Sieve Openings Inches | Millimeters | Weight Retained (gm) | Cumulative Weight Retained (gm) | Percent Finer (%) |
|---|---|---|---|---|---|
| 0.5" | 0.500 | 12.70 | 0.00 | 0.00 | 100 |
| 0.375" | 0.374 | 9.51 | 1.60 | 1.60 | 100 |
| #4 | 0.187 | 4.75 | 252.10 | 253.70 | 60 |
| #8 | 0.093 | 2.36 | 267.60 | 521.30 | 17 |
| #16 | 0.047 | 1.19 | 83.80 | 605.10 | 4 |
| #30 | 0.023 | 0.60 | 19.20 | 624.30 | 1 |
| #50 | 0.012 | 0.30 | 4.70 | 629.00 | 0 |
| #100 | 0.006 | 0.15 | 1.80 | 630.80 | 0 |
| #200 | 0.003 | 0.07 | 0.60 | 631.40 | 0 |
| Pan | | | 0.40 | 631.80 | 0 |

Total Dry Weight of Sample = 631.8

D85 : 7.3580 mm
D60 : 4.7628 mm
D50 : 4.0372 mm
D30 : 2.9016 mm
D15 : 2.0754 mm
D10 : 1.6032 mm

Soil Classification
ASTM Group Symbol : SP
ASTM Group Name : Poorly graded sand with gravel
AASHTO Group Symbol : A-1-a(0)
AASHTO Group Name : Stone Fragments, Gravel and Sand

| | | |
|---|---|---|
| | Boring No. : ---<br>Sample No.: 1/2 plastic<br>Test Method ASTM C117/136<br>Filename : PLSCRT12 | Project : Plas-Crete<br>Project No.: GTMT10010<br>Location: ---<br>Date : Wed Oct 10 2001 |




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY |
|---|---|---|---|---|---|---|
| | COARSE | FINE | COARSE | MEDIUM | FINE | |

Classification :
(SP) Poorly graded sand with gravel
Visual Description :
plastic frm razor housing w/ sgnfcnt amnts of metl

Remarks :
---

Figure 1

GEOTECHNICAL LABORATORY TEST DATA

Project : Plas-Crete
Project No. : GTMT10010
Boring No. : ---
Sample No. : 1 1/4 plastic
Location : ---
Soil Description : elongated pliable pieces w/ film & hard chunks
Remarks : ---

Depth : ---
Test Date : 10/30/00
Test Method : ASTM C117/136

Filename : PLSCT114
Elevation : ---
Tested by : DL
Checked by : FPH

FINE SIEVE SET

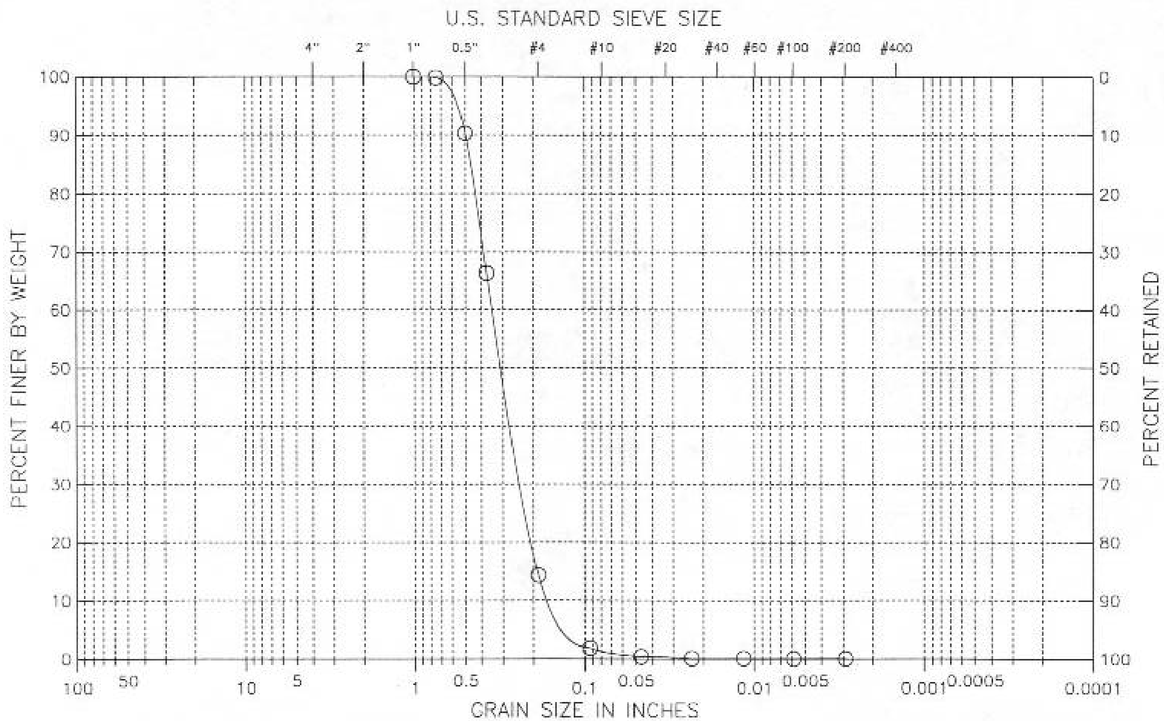
| Sieve Mesh | Sieve Openings Inches | Millimeters | Weight Retained (gm) | Cumulative Weight Retained (gm) | Percent Finer (%) |
|---|---|---|---|---|---|
| 1" | 1.012 | 25.70 | 0.00 | 0.00 | 100 |
| 0.75" | 0.748 | 19.00 | 1.00 | 1.00 | 100 |
| 0.5" | 0.500 | 12.70 | 66.00 | 67.00 | 90 |
| 0.375" | 0.374 | 9.51 | 167.00 | 234.00 | 66 |
| #4 | 0.187 | 4.75 | 361.00 | 595.00 | 14 |
| #8 | 0.093 | 2.36 | 87.00 | 682.00 | 2 |
| #16 | 0.047 | 1.19 | 10.00 | 692.00 | 0 |
| #30 | 0.023 | 0.60 | 2.00 | 694.00 | 0 |
| #50 | 0.012 | 0.30 | 0.00 | 694.00 | 0 |
| #100 | 0.006 | 0.15 | 0.40 | 694.40 | 0 |
| #200 | 0.003 | 0.07 | 0.10 | 694.50 | 0 |
| Pan | | | 0.40 | 694.90 | 0 |

Total Dry Weight of Sample = 694.9

D85 : 11.9068 mm
D60 : 8.7391 mm
D50 : 7.6460 mm
D30 : 5.8528 mm
D15 : 4.7898 mm
D10 : 3.7197 mm

Soil Classification
ASTM Group Symbol : GP
ASTM Group Name : Poorly graded gravel
AASHTO Group Symbol : A-1-a(0)
AASHTO Group Name : Stone Fragments, Gravel and Sand

| | | |
|---|---|---|
| | Boring No. : ---<br>Sample No.: 1 1/4 plastic<br>Test Method ASTM C117/136<br>Filename : PLSCT114 | Project : Plas-Crete<br>Project No.: CTMT10010<br>Location: ---<br>Date : Wed Oct 10 2001 |




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY |
|---|---|---|---|---|---|---|
| | COARSE | FINE | COARSE | MEDIUM | FINE | |

Classification :
(GP) Poorly graded gravel

Visual Description :
elongated pliable pieces w/ film & hard chunks

Remarks :
---

Figure 1

# GEOTECHNICAL LABORATORY TEST DATA

Project : Plas-Crete
Project No. : GTMT10010
Boring No. : ---
Sample No. : SND.102700
Location : ---
Soil Description : biege tan sand
Remarks : sand taken from mixer@conigliaro used for cnct mix

Depth : ---
Test Date : 10/27/00
Test Method : ASTM C117/136

Filename : SND10270
Elevation : ---
Tested by : DL
Checked by : FPH

FINE SIEVE SET

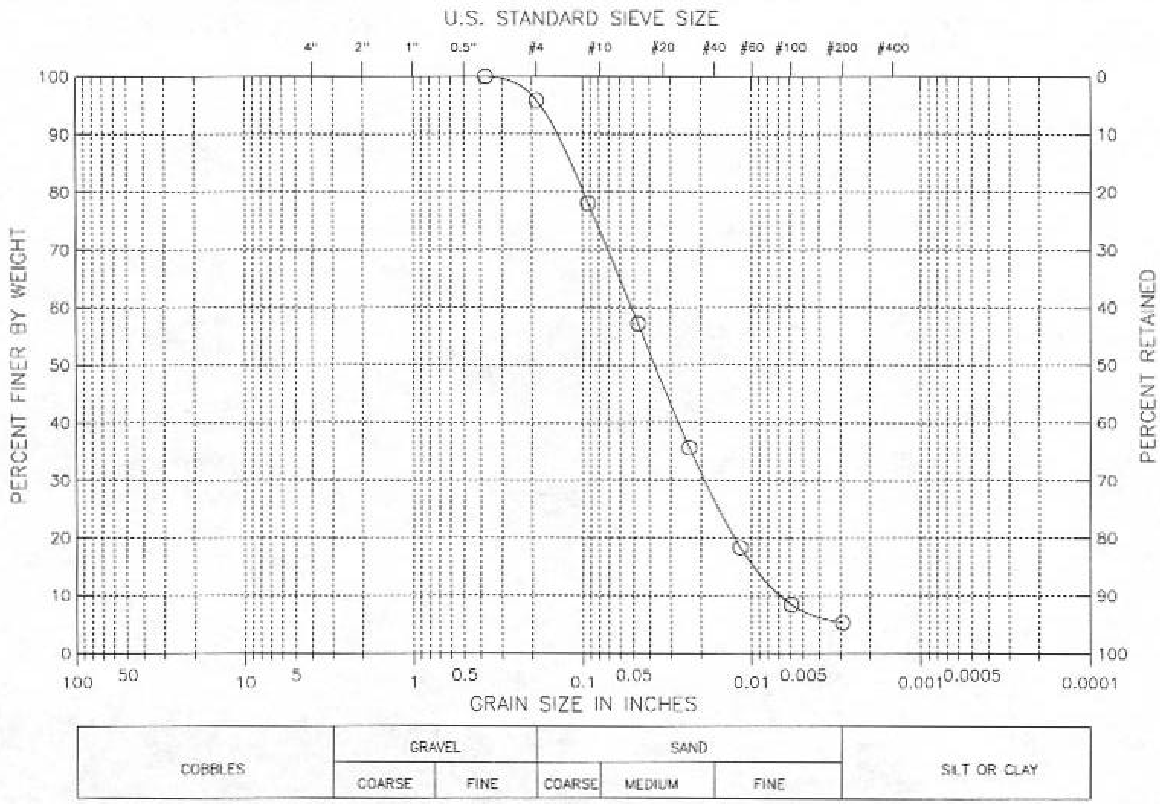
| Sieve Mesh | Sieve Openings Inches | Sieve Openings Millimeters | Weight Retained (gm) | Cumulative Weight Retained (gm) | Percent Finer (%) |
|---|---|---|---|---|---|
| 0.375" | 0.374 | 9.51 | 0.00 | 0.00 | 100 |
| #4 | 0.187 | 4.75 | 93.00 | 93.00 | 96 |
| #8 | 0.093 | 2.36 | 401.00 | 494.00 | 78 |
| #16 | 0.047 | 1.19 | 473.00 | 967.00 | 57 |
| #30 | 0.023 | 0.60 | 487.00 | 1454.00 | 36 |
| #50 | 0.012 | 0.30 | 392.00 | 1846.00 | 18 |
| #100 | 0.006 | 0.15 | 223.00 | 2069.00 | 8 |
| #200 | 0.003 | 0.07 | 70.80 | 2139.80 | 5 |
| Pan | | | 120.00 | 2259.80 | 0 |

Total Dry Weight of Sample = 2259.8

D85 : 3.0928 mm
D60 : 1.3038 mm
D50 : 0.9437 mm
D30 : 0.4733 mm
D15 : 0.2346 mm
D10 : 0.1660 mm

Soil Classification
ASTM Group Symbol : N/A
ASTM Group Name : N/A
AASHTO Group Symbol : A-1-a(0)
AASHTO Group Name : Stone Fragments, Gravel and Sand

| | | |
|---|---|---|
| | Boring No. : --- | Project : Plas-Crete |
| | Sample No.: SND.102700 | Project No.: GTMT10010 |
| | Test Method ASTM C117/136 | Location: --- |
| | Filename : SND10270 | Date : Wed Oct 10 2001 |




Classification :

Visual Description :
biege tan sand

Remarks :
sand taken from mixer@conigliaro used for cnct mix

Figure 1

GEOTECHNICAL LABORATORY TEST DATA

Project : Plas-Crete
Project No. : GTMT10010
Boring No. : ---
Sample No. : 1/8 plastic
Location : ---
Soil Description : Wire stripping which are curly and compressible
Remarks : ---

Depth : ---
Test Date : 10/27/00
Test Method : ASTM C117/136

Filename : PLSCRT18
Elevation : ---
Tested by : DL
Checked by : FPH

Natural Moisture Content

| Moisture Content ID | Mass of Container (gm) | Mass of Container and Moist Soil (gm) | Mass of Container and Dried Soil (gm) | Moisture Content (%) |
|---|---|---|---|---|
| 1) EE | 420.40 | 969.00 | 966.50 | 0.46 |

Average Moisture Content = 0.46

---



GEOTECHNICAL LABORATORY TEST DATA

Project : Plas-Crete
Project No. : GTMT10010
Boring No. : ---
Sample No. : 5/16 plastic
Location : ---
Soil Description : angular chnks plastic some flat w/ rubbery chnks
Remarks : ---

Depth : ---
Test Date : 10/27/00
Test Method : ASTM C117/136

Filename : PLSCT516
Elevation : ---
Tested by : DL
Checked by : FPH

Natural Moisture Content

| Moisture Content ID | Mass of Container (gm) | Mass of Container and Moist Soil (gm) | Mass of Container and Dried Soil (gm) | Moisture Content (%) |
|---|---|---|---|---|
| 1) HH | 0.00 | 1379.00 | 1370.50 | 0.62 |

Average Moisture Content = 0.62

GEOTECHNICAL LABORATORY TEST DATA

Project : Plas-Crete
Project No. : GTMT10010
Boring No. : ---
Sample No. : 1/2 plastic
Location : ---
Depth : ---
Test Date : 10/30/00
Test Method : ASTM C117/136
Filename : PLSCRT12
Elevation : ---
Tested by : DL
Checked by : FPH
Soil Description : plastic frm razor housing w/ sgnfcnt amnts of metl
Remarks : ---

Natural Moisture Content

| Moisture Content ID | Mass of Container (gm) | Mass of Container and Moist Soil (gm) | Mass of Container and Dried Soil (gm) | Moisture Content (%) |
|---|---|---|---|---|
| 1) GG8 | 0.00 | 1327.40 | 1325.70 | 0.13 |

Average Moisture Content = 0.13

---



GEOTECHNICAL LABORATORY TEST DATA

Project : Plas-Crete
Project No. : GTMT10010
Boring No. : ---
Sample No. : 1 1/4 plastic
Location : ---
Depth : ---
Test Date : 10/30/00
Test Method : ASTM C117/136
Filename : PLSCT114
Elevation : ---
Tested by : DL
Checked by : FPH
Soil Description : elongated pliable pieces w/ film & hard chunks
Remarks : ---

Natural Moisture Content

| Moisture Content ID | Mass of Container (gm) | Mass of Container and Moist Soil (gm) | Mass of Container and Dried Soil (gm) | Moisture Content (%) |
|---|---|---|---|---|
| 1) GG8 | 0.00 | 1327.40 | 1325.70 | 0.13 |

Average Moisture Content = 0.13

# GEOTECHNICAL LABORATORY TEST DATA

Project : Plas-Crete
Project No. : GTMT10010
Boring No. : ---
Sample No. : SND.102700
Location : ---
Soil Description : biege tan sand
Remarks : sand taken from mixer@conigliaro used for cnct mix

Depth : ---
Test Date : 10/27/00
Test Method : ASTM C117/136

Filename : SND10270
Elevation : ---
Tested by : DL
Checked by : FPH

Natural Moisture Content

| Moisture Content ID | Mass of Container (gm) | Mass of Container and Moist Soil (gm) | Mass of Container and Dried Soil (gm) | Moisture Content (%) |
|---|---|---|---|---|
| 1) JJ | 0.00 | 4558.90 | 4348.80 | 4.83 |

Average Moisture Content = 4.83

# APPENDIX 3

# Data on Fresh PlasCrete Mix

## Slump of Hydraulic Concrete

| | | | |
|---|---|---|---|
| **Project:** | Plas-Crete | **Method:** | ASTM C143 |
| **Client:** | Conigliaro Industries / Chelsea Center | **Tested By:** | DL |
| **Contact:** | Tony C. | **Checked By:** | FPH |
| **Site:** | Framingham, MA Plant | **Date:** | October 24-25, 2000 |

| Batch | Slump Test 1 (inches) | Slump Test 2 (inches) | Slump Test 3 (inches) | AVERAGE SLUMP (inches) | Plastic Size (inch) | Portland Cement (%) |
|---|---|---|---|---|---|---|
| 1 | 3/4 | 3/4 | 3/4 | 3/4 | 1/8" | 15 |
| 2 | 1/2 | 3/8 | 3/8 | 3/7 | 5/16" | 15 |
| 3 | 1 | 1 3/8 | 1 1/2 | 1 2/7 | 1/2" | 15 |
| 4 | 1 1/2 | 3 | 3 1/8 | 2 1/2 | 1.25" | 15 |
| 5 | 1 1/4 | 1 1/4 | 1 1/4 | 1 1/4 | 1/8" | 20 |
| 6 | 2 | 2 1/2 | 2 1/2 | 2 1/3 | 5/16" | 20 |
| 7 | 1 1/2 | 1 7/8 | 2 1/4 | 1 7/8 | 1/2" | 20 |
| 8 | 5/8 | 1/4 | 1/2 | 1/2 | 1.25" | 20 |
| 9 | 1 1/8 | 1 1/4 | 1 1/4 | 1 1/5 | 1/8" | 25 |
| 10 | 2 3/4 | 3 | 2 3/4 | 2 5/6 | 5/16" | 25 |
| 11 | 1 7/8 | 1 7/8 | 2 | 2 | 1/2" | 25 |
| 12 | 1/2 | 5/8 | 1/2 | 1/2 | 1.25" | 25 |

# Unit Weight of Concrete

| | | | |
|---|---|---|---|
| **Project:** | Plas-Crete | **Method:** | ASTM C 138 |
| **Client:** | Conigliaro Industries / Chelsea Center | **Tested By:** | DL |
| **Contact:** | Tony C. | **Checked By:** | FPH |
| **Site:** | Framingham, MA Plant | **Date:** | October 24-25, 2000 |

| Batch | Unit Weight Test | | | AVERAGE | Plastic | Portland |
|---|---|---|---|---|---|---|
| | 1 (PCF) | 2 (PCF) | 3 (PCF) | UNIT WEIGHT (PCF) | Size (inch) | Cement (%) |
| 1 | 105.8 | 108.7 | 107.3 | 107.3 | 1/8" | 15 |
| 2 | 113.4 | 111.7 | 113.8 | 113.0 | 5/16" | 15 |
| 3 | 115.7 | 113.9 | 114.7 | 114.8 | 1/2" | 15 |
| 4 | 115.7 | 115.5 | 116.6 | 115.9 | 1.25" | 15 |
| 5 | 109.3 | 110.6 | 110.4 | 110.1 | 1/8" | 20 |
| 6 | 121.7 | 121.5 | 122.7 | 122.0 | 5/16" | 20 |
| 7 | 112.9 | 113 | 114.4 | 113.4 | 1/2" | 20 |
| 8 | 119.7 | 117.8 | 116.4 | 118.0 | 1.25" | 20 |
| 9 | 109.3 | 110.8 | 105.7 | 108.6 | 1/8" | 25 |
| 10 | 123 | 122.4 | 122 | 122.5 | 5/16" | 25 |
| 11 | 114.9 | 114 | 115.9 | 114.9 | 1/2" | 25 |
| 12 | 117.1 | 119.5 | 118.6 | 118.4 | 1.25" | 25 |

# Temperature of Freshly Mixed Concrete

| | | | |
|---|---|---|---|
| **Project:** | Plas-Crete | **Method:** | ASTM C 1064 |
| **Client:** | Conigliaro Industries / Chelsea Center | **Tested By:** | DL |
| **Contact:** | Tony C. | **Checked By:** | FPH |
| **Site:** | Framingham, MA Plant | **Date:** | October 24-25, 2000 |

| Batch | Temperature Test 1 (°F) | Temperature Test 2 (°F) | Temperature Test 3 (°F) | AVERAGE TEMPERATURE (°F) | Plastic Size (inch) | Portland Cement (%) |
|---|---|---|---|---|---|---|
| 1 | 74 | 75 | 74 | 74 | 1/8" | 15 |
| 2 | 71 | 71 | 71 | 71 | 5/16" | 15 |
| 3 | 63 | 63 | 63 | 63 | 1/2" | 15 |
| 4 | 76 | 76 | 76 | 76 | 1.25" | 15 |
| 5 | 73 | 72 | 73 | 73 | 1/8" | 20 |
| 6 | 72 | 73 | 73 | 73 | 5/16" | 20 |
| 7 | 68 | 68 | 68 | 68 | 1/2" | 20 |
| 8 | 75 | 74 | 74 | 74 | 1.25" | 20 |
| 9 | 74 | 72 | 74 | 73 | 1/8" | 25 |
| 10 | 74 | 73 | 73 | 73 | 5/16" | 25 |
| 11 | 71 | 71 | 72 | 71 | 1/2" | 25 |
| 12 | 77 | 79 | 77 | 78 | 1.25" | 25 |

# APPENDIX 4

# Data on Hardened Concrete

## Specific Gravity, Absorption, and Voids

| | | | |
|---|---|---|---|
| **Project:** | Plas-Crete | **Method:** | ASTM C 642 |
| **Client:** | Conigliaro Industries / Chelsea Center | **Tested By:** | DL |
| **Contact:** | Tony C. | **Checked By:** | FPH |
| **Site:** | Framingham, MA Plant | **Date:** | 11-Dec-00 |

| Batch | Sample I.D. | Oven-Dried Sample In Air (g) | Surface-Dry Sample In Air After Immersion (g) | Surface-Dry Sample In Air After Immersion and Boiling (g) | Surface-Dry Sample In Water After Immersion and Boiling (g) |
|---|---|---|---|---|---|
| **1** | B1 S3 | 1109.3 | 1303.4 | 1369.3 | 620.8 |
| | B1 S5 | 993.9 | 1177.9 | 1242.7 | 550.4 |
| **2** | B2 S4 | 1164.3 | 1271.3 | 1303.7 | 651.1 |
| | B2 S5 | 764.7 | 844.6 | 871.2 | 422.4 |
| **3** | B3 S4 | 827.8 | 940.8 | 979.9 | 441.1 |
| | B3 S5 | 930.7 | 1060.1 | 1106.3 | 495.8 |
| **4** | B4 S4 | 782.2 | 882 | 903.8 | 422 |
| | B4 S5 | 1045.9 | 1170.2 | 1200.8 | 578.3 |
| **5** | B5 S4 | 911.4 | 1086.3 | 1132.9 | 509.3 |
| | B5 S5 | 815.30 | 993 | 1021.8 | 450.4 |
| **6** | B6 S3 | 969.50 | 1076.5 | 1101.7 | 546.7 |
| | B6 S5 | 785.30 | 884.7 | 907.8 | 436.1 |
| **7** | B7 S3 | 932.70 | 1080.8 | 1139 | 499.6 |
| | B7 S4 | 695.2 | 793.5 | 834.5 | 372.7 |
| **8** | B8 S3 | 1401.4 | 1525.5 | 1575.9 | 768 |
| | B8 S4 | 893.4 | 980.4 | 1004.9 | 495.6 |
| **9** | B9 S3 | 655.1 | 766.7 | 816.4 | 361.3 |
| | B9 S5 | 978.2 | 1151.1 | 1209.7 | 539.4 |
| **10** | B10 S4 | 1477.5 | 1645.6 | 1696.4 | 831.1 |
| | B10 S5 | 1135.2 | 1271.6 | 1299.5 | 653.1 |
| **11** | B11 S5 | 1147.5 | 1301 | 1372.8 | 619.3 |
| | B11 S6 | 794 | 910.9 | 955.7 | 430.4 |
| **12** | B12 S4 | 1470.9 | 1621.8 | 1653.2 | 793 |
| | B12 S5 | 1438.3 | 1599.4 | 1631.7 | 762.9 |

## Specific Gravity, Absorption, and Voids

| | | | |
|---|---|---|---|
| **Project:** | Plas-Crete | **Method:** | ASTM C 642 |
| **Client:** | Conigliaro Industries / Chelsea Center | **Tested By:** | DL |
| **Contact:** | Tony C. | **Checked By:** | FPH |
| **Site:** | Framingham, MA Plant | **Date:** | 11-Dec-00 |

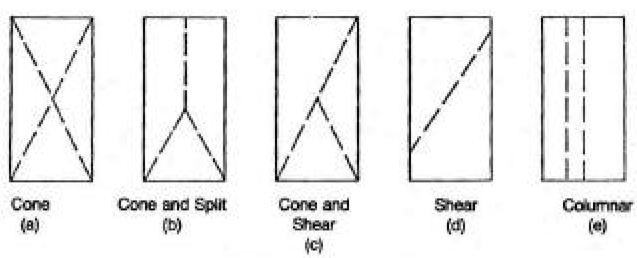
| Batch | Sample I.D. | Absorption After Immersion | Absorption After Immersion And Boiling | Bulk Specific Gravity Dry | Bulk Specific Gravity After Immersion | Bulk Specific Gravity After Immersion And Boiling | Apparent Specific Gravity | Volume of permeable pore space (voids) |
|---|---|---|---|---|---|---|---|---|
| **1** | B1 S3 | 17.5 | 23.4 | 1.48 | 1.74 | 1.83 | 2.27 | 34.7 |
| | B1 S5 | 18.5 | 25.0 | 1.44 | 1.70 | 1.80 | 2.24 | 35.9 |
| **2** | B2 S4 | 9.2 | 12.0 | 1.78 | 1.95 | 2.00 | 2.27 | 21.4 |
| | B2 S5 | 10.4 | 13.9 | 1.70 | 1.88 | 1.94 | 2.23 | 23.7 |
| **3** | B3 S4 | 13.7 | 18.4 | 1.54 | 1.75 | 1.82 | 2.14 | 28.2 |
| | B3 S5 | 13.9 | 18.9 | 1.52 | 1.74 | 1.81 | 2.14 | 28.8 |
| **4** | B4 S4 | 12.8 | 15.5 | 1.62 | 1.83 | 1.88 | 2.17 | 25.2 |
| | B4 S5 | 11.9 | 14.8 | 1.68 | 1.88 | 1.93 | 2.24 | 24.9 |
| **5** | B5 S4 | 19.2 | 24.3 | 1.46 | 1.74 | 1.82 | 2.27 | 35.5 |
| | B5 S5 | 21.8 | 25.3 | 1.43 | 1.74 | 1.79 | 2.23 | 36.1 |
| **6** | B6 S3 | 11.0 | 13.6 | 1.75 | 1.94 | 1.99 | 2.29 | 23.8 |
| | B6 S5 | 12.7 | 15.6 | 1.66 | 1.88 | 1.92 | 2.25 | 26.0 |
| **7** | B7 S3 | 15.9 | 22.1 | 1.46 | 1.69 | 1.78 | 2.15 | 32.3 |
| | B7 S4 | 14.1 | 20.0 | 1.51 | 1.72 | 1.81 | 2.16 | 30.2 |
| **8** | B8 S3 | 8.9 | 12.5 | 1.73 | 1.89 | 1.95 | 2.21 | 21.6 |
| | B8 S4 | 9.7 | 12.5 | 1.75 | 1.92 | 1.97 | 2.25 | 21.9 |
| **9** | B9 S3 | 17.0 | 24.6 | 1.44 | 1.68 | 1.79 | 2.23 | 35.4 |
| | B9 S5 | 17.7 | 23.7 | 1.46 | 1.72 | 1.80 | 2.23 | 34.5 |
| **10** | B10 S4 | 11.4 | 14.8 | 1.71 | 1.90 | 1.96 | 2.29 | 25.3 |
| | B10 S5 | 12.0 | 14.5 | 1.76 | 1.97 | 2.01 | 2.35 | 25.4 |
| **11** | B11 S5 | 13.4 | 19.6 | 1.52 | 1.73 | 1.82 | 2.17 | 29.9 |
| | B11 S6 | 14.7 | 20.4 | 1.51 | 1.73 | 1.82 | 2.18 | 30.8 |
| **12** | B12 S4 | 10.3 | 12.4 | 1.71 | 1.89 | 1.92 | 2.17 | 21.2 |
| | B12 S5 | 11.2 | 13.4 | 1.66 | 1.84 | 1.88 | 2.13 | 22.3 |

| | | | |
|---|---|---|---|
| **Client:** | Conigliaro Industries | **GTX #:** | 3167 |
| **Project Name:** | Plas Crete | **Test Date 1:** | 10/31/00 |
| **Project Location:** | 701 Waverly Street, Framingham, MA 01701 | **Test Date 2:** | 11/21/00 |

| Sample ID | Curing Age, days | Average Height, in | Average Diameter, in | Area, $in^2$ | Mass, g | Density, $lb/ft^3$ | Strength, lbs | Compressive Strength, $lb/in^2$ | Break Type |
|---|---|---|---|---|---|---|---|---|---|
| B1 S1 | 7 | 12.55 | 6.03 | 28.56 | 9560 | 101 | 7120 | 249 | |
| B1 S2 | 7 | 12.15 | 6.05 | 28.75 | 9220 | 100 | 7185 | 250 | d |
| B1 S3 | 28 | 12.38 | 6.04 | 28.62 | 9480 | 102 | 8307 | 290 | b |
| B1 S4 | 28 | 12.38 | 6.03 | 28.56 | 9480 | 102 | 10823 | 379 | e |
| B1 S5 | 28 | 12.38 | 6.03 | 28.59 | 9440 | 101 | 7016 | 245 | b |
| | | | | | | | | | |

**Comments:**

**Break Types:**




**Sketches of Types of Fracture**

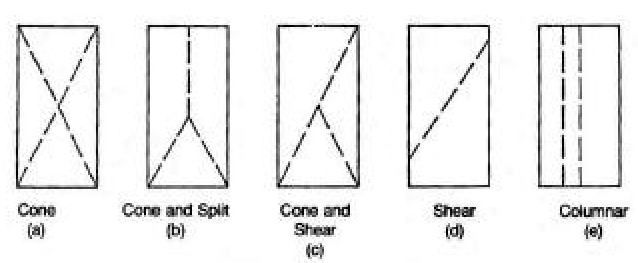
**Client:** Conigliaro Industries
**Project Name:** Plas Crete
**Project Location:** 701 Waverly Street, Framingham, MA 01701

**GTX #:** 3167
**Test Date 1:** 10/31/00
**Test Date 2:** 11/21/00

| Sample ID | Curing Age, days | Average Height, in | Average Diameter, in | Area, $in^2$ | Mass, g | Density, $lb/ft^3$ | Strength, lbs | Compressive Strength, $lb/in^2$ | Break Type |
|---|---|---|---|---|---|---|---|---|---|
| B2 S1 | 7 | 12.00 | 6.03 | 28.56 | 11000 | 122 | 25805 | 904 | a |
| B2 S2 | 7 | 12.00 | 6.03 | 28.56 | 10780 | 120 | 24345 | 852 | e |
| B2 S3 | 28 | 12.00 | 6.03 | 28.56 | 10900 | 121 | 44258 | 1550 | b |
| B2 S4 | 28 | 12.00 | 6.04 | 28.62 | 10760 | 119 | 39668 | 1386 | b |
| B2 S5 | 28 | 12.00 | 6.03 | 28.59 | 70860 | 785 | 48652 | 1702 | a |
| | | | | | | | | | |

**Comments:**

**Break Types:**




**Sketches of Types of Fracture**

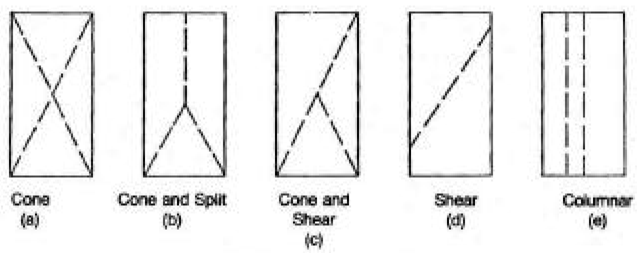
**Client:** Conigliaro Industries
**Project Name:** Plas-Crete
**Project Location:** Framingham, MA

**GTX #:** 3167
**Test Date 1:** 11/1/00
**Test Date 2:** 11/22/00

| Sample ID | Curing Age, days | Average Height, in | Average Diameter, in | Area, $in^2$ | Mass, g | Density, $lb/ft^3$ | Strength, lbs | Compressive Strength, $lb/in^2$ | Break Type |
|---|---|---|---|---|---|---|---|---|---|
| B3 S1 | 7 | 12.75 | 6.03 | 28.56 | 10140 | 106 | 7705 | 270 | b |
| B3 S2 | 7 | 12.58 | 6.05 | 28.72 | 10020 | 105 | 7995 | 278 | b |
| B3 S3 | 28 | 12.50 | 6.03 | 28.53 | 10000 | 107 | 14044 | 492 | a |
| B3 S4 | 28 | 12.63 | 6.03 | 28.59 | 10340 | 109 | 13457 | 471 | a |
| B3 S5 | 28 | 12.63 | 6.03 | 28.59 | 10060 | 106 | 13509 | 473 | c |

**Comments:**

**Break Types:**




**Sketches of Types of Fracture**

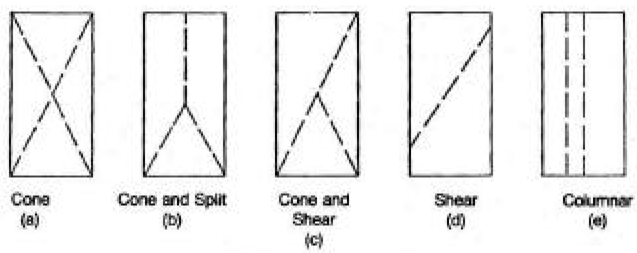
**Client:** Conigliaro Industries
**Project Name:** Plas-Crete
**Project Location:** Framingham, MA

**GTX #:** 3167
**Test Date 1:** 11/1/00
**Test Date 2:** 11/22/00

| Sample ID | Curing Age, days | Average Height, in | Average Diameter, in | Area, $in^2$ | Mass, g | Density, $lb/ft^3$ | Strength, lbs | Compressive Strength, $lb/in^2$ | Break Type |
|---|---|---|---|---|---|---|---|---|---|
| B4 S1 | 7 | 11.80 | 6.03 | 28.56 | 10280 | 116 | 23670 | 829 | |
| B4 S2 | 7 | 11.82 | 6.04 | 28.65 | 10260 | 115 | 22075 | 770 | b |
| B4 S3 | 28 | 11.75 | 6.03 | 28.59 | 10100 | 114 | 34712 | 1214 | d |
| B4 S4 | 28 | 11.75 | 6.03 | 28.56 | 10220 | 116 | 32569 | 1140 | d |
| B4 S5 | 28 | 11.75 | 6.03 | 28.56 | 10260 | 116 | 35430 | 1241 | a |

**Comments:**

**Break Types:**




**Sketches of Types of Fracture**

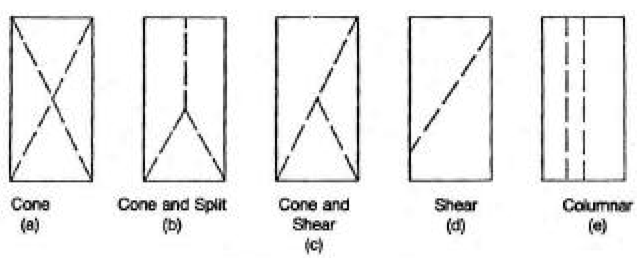
**Client:** Conigliaro Industries
**Project Name:** Plas-Crete
**Project Location:** Framingham, MA

**GTX #:** 3167
**Test Date 1:** 10/31/00
**Test Date 2:** 11/21/00

| Sample ID | Curing Age, days | Average Height, in | Average Diameter, in | Area, $in^2$ | Mass, g | Density, $lb/ft^3$ | Strength, lbs | Compressive Strength, $lb/in^2$ | Break Type |
|---|---|---|---|---|---|---|---|---|---|
| B5 S1 | 7 | 12.14 | 6.03 | 28.56 | 9460 | 104 | 9350 | 327 | |
| B5 S2 | 7 | 12.15 | 6.03 | 28.53 | 9500 | 104 | 9245 | 324 | |
| B5 S3 | 28 | 12.00 | 6.03 | 28.59 | 9460 | 105 | 15179 | 531 | a |
| B5 S4 | 28 | 12.00 | 6.04 | 28.62 | 9460 | 105 | 15935 | 557 | c |
| B5 S5 | 28 | 12.15 | 6.04 | 28.68 | 9420 | 103 | 15192 | 530 | b |
| | | | | | | | | | |

**Comments:**

**Break Types:**



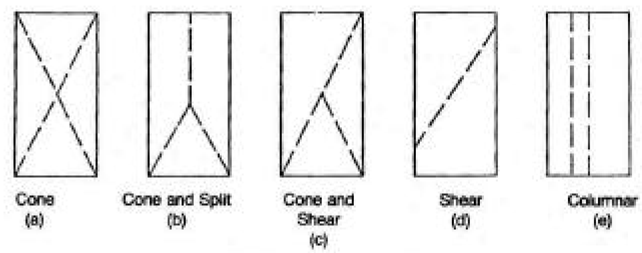
**Sketches of Types of Fracture**

| | | | |
|---|---|---|---|
| **Client:** | Conigliaro Industries | **GTX #:** | 3167 |
| **Project Name:** | Plas-Crete | **Test Date 1:** | 10/31/00 |
| **Project Location:** | Framingham, MA | **Test Date 2:** | 11/21/00 |

| Sample ID | Curing Age, days | Average Height, in | Average Diameter, in | Area, $in^2$ | Mass, g | Density, $lb/ft^3$ | Strength, lbs | Compressive Strength, $lb/in^2$ | Break Type |
|---|---|---|---|---|---|---|---|---|---|
| B6 S1 | 7 | 11.80 | 6.04 | 28.62 | 10660 | 120 | 15765 | 551 | |
| B6 S2 | 7 | 11.80 | 6.04 | 28.62 | 10660 | 120 | 16255 | 568 | |
| B6 S3 | 28 | 11.88 | 6.03 | 28.53 | 10680 | 120 | 24463 | 858 | b |
| B6 S4 | 28 | 11.88 | 6.04 | 28.65 | 10660 | 119 | 27958 | 976 | b |
| B6 S5 | 28 | 11.80 | 6.02 | 28.43 | 10640 | 121 | 28140 | 990 | d |
| | | | | | | | | | |

**Comments:**

**Break Types:**



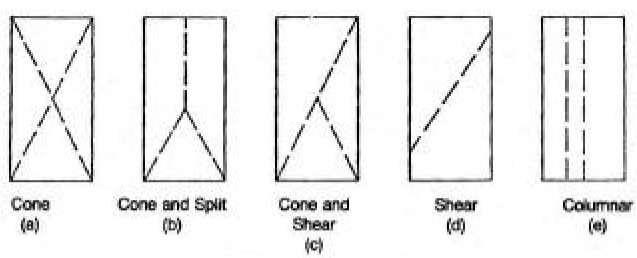

**Sketches of Types of Fracture**

| | | | |
|---|---|---|---|
| **Client:** | Conigliaro Industries | **GTX #:** | 3167 |
| **Project Name:** | Plas-Crete | **Test Date 1:** | 11/1/00 |
| **Project Location:** | Framingham, MA | **Test Date 2:** | 11/22/00 |

| Sample ID | Curing Age, days | Average Height, in | Average Diameter, in | Area, $in^2$ | Mass, g | Density, $lb/ft^3$ | Strength, lbs | Compressive Strength, $lb/in^2$ | Break Type |
|---|---|---|---|---|---|---|---|---|---|
| B7 S1 | 7 | 12.85 | 6.05 | 28.78 | 10100 | 104 | 7095 | 247 | |
| B7 S2 | 7 | 12.85 | 6.05 | 28.72 | 10100 | 104 | 7420 | 258 | |
| B7 S3 | 28 | 12.88 | 6.02 | 28.49 | 9960 | 103 | 9702 | 340 | d |
| B7 S4 | 28 | 12.88 | 6.03 | 28.53 | 10080 | 104 | 10784 | 378 | a |
| B7 S5 | 28 | 12.88 | 6.03 | 28.56 | 10240 | 106 | 11332 | 397 | e |
| | | | | | | | | | |

**Comments:**

**Break Types:**




**Sketches of Types of Fracture**

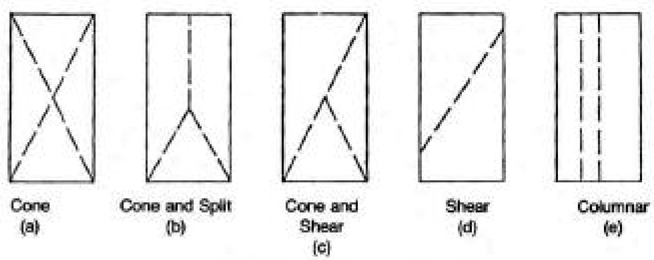
**Client:** Conigliaro Industries
**Project Name:** Plas-Crete
**Project Location:** Framingham, MA

**GTX #:** 3167
**Test Date 1:** 11/1/00
**Test Date 2:** 11/22/00

| Sample ID | Curing Age, days | Average Height, in | Average Diameter, in | Area, $in^2$ | Mass, g | Density, $lb/ft^3$ | Strength, lbs | Compressive Strength, $lb/in^2$ | Break Type |
|---|---|---|---|---|---|---|---|---|---|
| B8 S1 | 7 | 11.88 | 6.04 | 28.62 | 10460 | 117 | 32105 | 1122 | |
| B8 S2 | 7 | 11.62 | 6.03 | 28.59 | 10060 | 115 | 32455 | 1135 | |
| B8 S3 | 28 | 12.00 | 6.03 | 28.56 | 10560 | 117 | 47453 | 1662 | a |
| B8 S4 | 28 | 12.00 | 6.03 | 28.56 | 10640 | 118 | 46761 | 1637 | a |
| B8 S5 | 28 | 12.00 | 6.03 | 28.56 | 10500 | 116 | 48665 | 1704 | a |
| | | | | | | | | | |

**Comments:**

**Break Types:**




Sketches of Types of Fracture

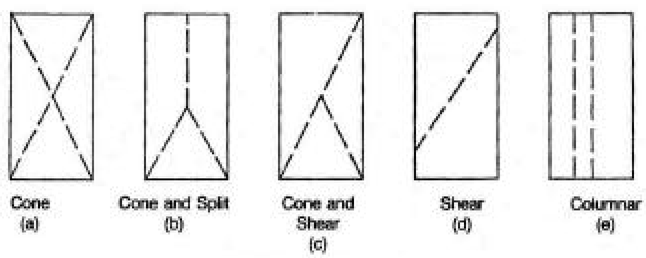
**Client:** Conigliaro Industries
**Project Name:** Plas-Crete
**Project Location:** Framingham, MA

**GTX #:** 3167
**Test Date 1:** 10/31/00
**Test Date 2:** 11/21/00

| Sample ID | Curing Age, days | Average Height, in | Average Diameter, in | Area, $in^2$ | Mass, g | Density, $lb/ft^3$ | Strength, lbs | Compressive Strength, $lb/in^2$ | Break Type |
|---|---|---|---|---|---|---|---|---|---|
| B9 S1 | 7 | 12.50 | 6.08 | 29.00 | 9320 | 98 | 5985 | 206 | |
| B9 S2 | 7 | 12.50 | 6.04 | 28.68 | 9280 | 98 | 7120 | 248 | |
| B9 S3 | 7 | 12.40 | 6.03 | 28.56 | 9260 | 99 | 6690 | 234 | |
| B9 S4 | 28 | 12.13 | 6.04 | 28.68 | 9240 | 101 | 9363 | 326 | a |
| B9 S5 | 28 | 12.21 | 6.04 | 28.65 | 9200 | 100 | 12675 | 442 | c |
| B9 S6 | 28 | 12.38 | 6.03 | 28.59 | 9300 | 100 | 10745 | 376 | c |

**Comments:**

**Break Types:**




**Sketches of Types of Fracture**

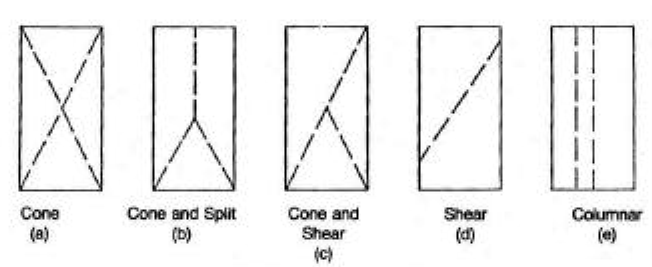
**Client:** Conigliaro Industries
**Project Name:** Plas-Crete
**Project Location:** Framingham, MA

**GTX #:** 3167
**Test Date 1:** 10/31/00
**Test Date 2:** 11/21/00

| Sample ID | Curing Age, days | Average Height, in | Average Diameter, in | Area, $in^2$ | Mass, g | Density, $lb/ft^3$ | Strength, lbs | Compressive Strength, $lb/in^2$ | Break Type |
|---|---|---|---|---|---|---|---|---|---|
| B10 S1 | 7 | 11.80 | 6.02 | 28.46 | 10640 | 120 | 14655 | 515 | d |
| B10 S2 | 7 | 11.80 | 6.02 | 28.46 | 10740 | 122 | 14225 | 500 | b |
| B10 S3 | 28 | 11.89 | 6.02 | 28.46 | 10560 | 119 | 28766 | 1011 | a |
| B10 S4 | 28 | 11.90 | 6.01 | 28.34 | 10600 | 120 | 27045 | 954 | a |
| B10 S5 | 28 | 11.89 | 6.02 | 28.46 | 10620 | 119 | 28062 | 986 | a |

**Comments:**

**Break Types:**

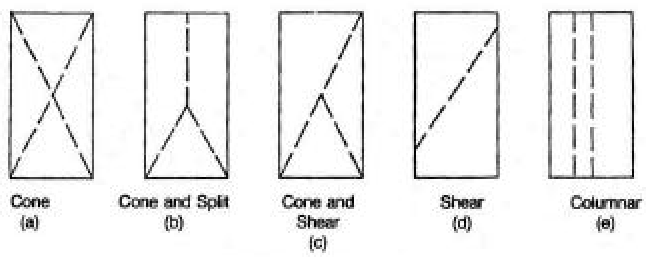



**Sketches of Types of Fracture**

| | | | |
|---|---|---|---|
| **Client:** | Conigliaro Industries | **GTX #:** | 3167 |
| **Project Name:** | Plas-Crete | **Test Date 1:** | 11/1/00 |
| **Project Location:** | Framingham, MA | **Test Date 2:** | 11/22/00 |

| Sample ID | Curing Age, days | Average Height, in | Average Diameter, in | Area, $in^2$ | Mass, g | Density, $lb/ft^3$ | Strength, lbs | Compressive Strength, $lb/in^2$ | Break Type |
|---|---|---|---|---|---|---|---|---|---|
| B11 S1 | 7 | 12.60 | 6.04 | 28.65 | 10160 | 107 | 9595 | 335 | e |
| B11 S2 | 7 | 12.65 | 6.05 | 28.78 | 10120 | 106 | 8255 | 287 | e |
| B11 S3 | 7 | 12.60 | 6.05 | 28.75 | 10120 | 106 | 8660 | 301 | a |
| B11 S4 | 28 | 12.80 | 6.04 | 28.62 | 10000 | 104 | 12753 | 446 | a |
| B11 S5 | 28 | 12.50 | 6.03 | 28.56 | 10180 | 108 | 13796 | 483 | a |
| B11 S6 | 28 | 12.50 | 6.04 | 28.65 | 10160 | 108 | 12884 | 450 | a |

**Break Types:**



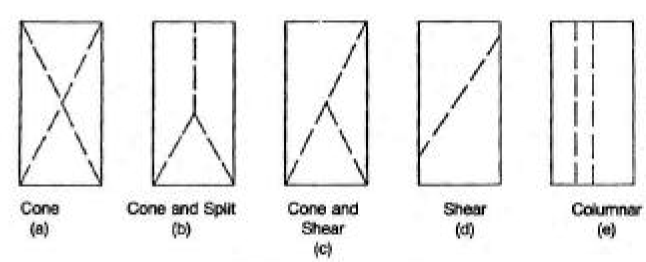

**Sketches of Types of Fracture**

**Client:** Conigliaro Industries
**Project Name:** Plas-Crete
**Project Location:** Framingham, MA

**GTX #:** 3167
**Test Date 1:** 11/1/00
**Test Date 2:** 11/22/00

| Sample ID | Curing Age, days | Average Height, in | Average Diameter, in | Area, $in^2$ | Mass, g | Density, $lb/ft^3$ | Strength, lbs | Compressive Strength, $lb/in^2$ | Break Type |
|---|---|---|---|---|---|---|---|---|---|
| B12 S1 | 7 | 11.50 | 6.03 | 28.59 | 10300 | 119 | 30760 | 1076 | a |
| B12 S2 | 7 | 11.50 | 6.05 | 28.75 | 10320 | 119 | 32080 | 1116 | a |
| B12 S3 | 28 | 11.50 | 6.02 | 28.49 | 10240 | 119 | 41154 | 1444 | a |
| B12 S4 | 28 | 11.38 | 6.03 | 28.56 | 10240 | 120 | 41624 | 1458 | a |
| B12 S5 | 28 | 11.50 | 6.04 | 28.62 | 10380 | 120 | 38598 | 1349 | a |

**Break Types:**




**Sketches of Types of Fracture**