QUALITY CONTROL MANUAL

for Precast Concrete Products

NPCA

Precast ... The Concrete Solution

"Dedicated to expanding the use of quality precast concrete"

NPCA QUALITY CONTROL MANUAL
For Precast Concrete Plants

FIFTH EDITION
May 2005

NPCA
The association of the manufactured concrete products industry.
10333 North Meridian Street
Suite 272
Indianapolis, Indiana 46290
800-366-7731
317-571-0041 (fax)
www.precast.org

(5.0)

NOTES

1. This manual does not claim or imply that it addresses all safety-related issues, if any, associated with its use. Manufacture of concrete products may involve the use of hazardous materials, operations and equipment. It is the user's responsibility to determine appropriate safety, health and environmental practices and applicable regulatory requirements associated with the use of this manual and the manufacture of concrete products.

2. Use of this manual does not guarantee the proper function or performance of any product manufactured in accordance with the requirements contained in the manual. Routine conformance to the requirements of this manual should result in products of an acceptable quality according to current industry standards.

FORWARD

Since its introduction in 1987 the NPCA Quality Control Manual for Precast Concrete Plants (also known as the NPCA QC Manual) has been a reliable quality management tool for the precast concrete industry. Its use in day-to-day plant operations allows management and production personnel to understand the requirements for producing quality precast concrete. The NPCA QC Manual's practical information and adherence to accepted industry standards helps provide consistency to plant operations.

One of the NPCA QC Manual's purposes is to define the fundamental requirements for a quality control program for precast concrete plants. The manual furnishes a framework for management decisions regarding equipment, procedures, or personnel, which may be necessary to create a quality manufacturing environment.

Specifiers and users of precast concrete products are constantly seeking ways to identify high quality products. The NPCA Plant Certification Program is based on the premium quality control program outlined in this manual and is intended to assure that precast concrete plants are capable of manufacturing quality products.

The NPCA QC Manual was originally written by Armand Gustaferro, P.E. of the Consulting Engineers Group, Mt. Prospect, Illinois, in consultation with members of the National Precast Concrete Association. Since its creation, the manual has been periodically revised and updated. The June 2000 edition of the manual was revised by Paul Krauss, P.E. of Wiss, Janney, Elstner Associates, Inc., Northbrook, Illinois. The May 2004 and May 2005 editions were revised by Dean Frank, P.E., NPCA Director of Technical Services, based on the direction of and in consultation with the NPCA Quality Assurance Committee and the NPCA Board of Directors.

NPCA Quality Assurance Committee Members (2004 - 2005):

- Todd Ebbert, San Diego Precast Concrete, Inc. (Chairman)
- Randy Lindsay-Brisbin, Firebraugh Precast Inc. (Board of Directors Liaison)
- Jim Bolich, Atlantic Precast Concrete, Inc.
- Tom Jacobs, Atlantic Precast Concrete, Inc.
- Tim Queior, Jefferson Concrete Corp. (2004)
- Mark Wieser, Wieser Concrete Products, Inc.
- Barry Stevens, Superior Concrete Products (2004)
- Russell Regen, Sherman-Dixie Concrete Industries, Inc.
- Scott Hayward, Colorado Precast Concrete Inc.
- Mike Vaughn, Vaughn Concrete Products Inc.
- Paul Heidt, Garden State Precast Inc.(2005)

TABLE OF CONTENTS

Page

INTRODUCTION

This manual outlines the basic requirements of precast concrete plants to assure the production of quality precast concrete products. Sizes of precast plants vary widely, hence the quality control facilities will vary. For example, a large precast plant is more likely to find that a well equipped quality control laboratory is justified while a small plant is likely to have little, if any, quality control facilities, and instead utilizes a commercial laboratory for its testing. Both plants can produce quality products.

Information in the Commentary should be considered as explanatory. The purpose of the Commentary is to provide additional information and comments, not to add requirements.

Reference is made to many standards of the American Concrete Institute (ACI), ASTM International (ASTM), the Prestressed Concrete Institute (PCI), the Concrete Reinforcing Steel Institute (CRSI), and the American Welding Society (AWS). Where titles of standards are cited, the word "standard" has been omitted. The most recent edition of these standards should be used unless otherwise noted.

Technical terms used in this manual are defined in ACI 116, "Cement and Concrete Terminology." The technical terms used in this manual are those generally used in the concrete industry in North America. There are many terms used only in certain regions and the authors have tried to avoid such terms. Readers are encouraged to write to NPCA if they feel that certain terms used in the manual should be defined.

OBJECTIVES

The main purpose of this manual is to outline the quality requirements for precast concrete plants. Requirements specified in the design of products will apply. If certain requirements are not specified in the design, the requirements outlined in this manual shall apply.

The quality guidelines presented in this manual are based on industry consensus.

In cases where specific project criteria are defined or specified, those requirements should prevail.

This manual defines a minimum satisfactory level of quality that the purchaser of precast concrete products can reasonably expect and that the precast concrete products manufacturer should provide.

Quality control requires the attention and cooperation of all management and production personnel. An effective quality control program typically requires management to make necessary changes in equipment, procedures, or personnel to produce quality products.

MAJOR FACTORS IN QUALITY CONTROL

The single most important factor in quality control is management commitment to produce quality products. Management must implement a quality control program that monitors quality and reports on conformance with requirements.

Qualified personnel are also required. Qualifications include a thorough knowledge of precast concrete, or successful completion of an accredited course in concrete technology or in precast concrete production. Plants should maintain training records of all employees and key individuals should be accredited.

Items that must be monitored and compared with standards include:

a. Completeness of work orders and product drawings
b. Quality of raw materials
c. Quality of forms
d. Concrete quality
e. Placement and consolidation of concrete
f. Product dimensions
g. Positioning of embedded items
h. Curing of concrete
i. Handling, storing, and transporting products
j. Recordkeeping

Quality of products is generally defined to be the consistent conformance with requirements. Quality control of precast concrete products requires much more than achieving the required concrete strength. Procedures for implementing the monitoring of the quality of products should be established by management and management should assure that the procedures are implemented. Accredited courses in concrete technology and precast concrete production are offered by NPCA.

Another aspect of a successful QC program is the concept of continuous improvement. There is substantial benefit derived from documenting materials, procedures and/or products that do not conform to the applicable standards and using those documents to develop corrective action so that the nonconforming issues are reduced or eliminated in the future.

STANDARD COMMENTARY

CHAPTER 1 - GENERAL

1.1 PLANT QUALITY CONTROL PROCEDURES AND MANAGEMENT POLICIES

1.1.1 Plant Management and Personnel

Plant management and personnel must be committed to the production of a consistently high-quality product. Understanding the company policies and a commitment to quality is essential. Frequent training reinforces this commitment. Also, personnel must be given the authority to enforce minimum QC policy over production requirements. The organizational structure of a precast concrete plant shall include the implementation of a Quality Control Program, which is the responsibility of the general manager or chief executive officer.

Management must support and be dedicated to the production of quality products; otherwise, a Quality Control Program is unlikely to be successful. The plant QC Policy Statement should clearly state the management's commitment to producing high-quality products. This policy should be frequently discussed with employees and customers.

A person not directly involved in production and who is responsible to the general manager or chief executive officer administers quality control functions most effectively.

1.1.2 Plant-Specific Quality Control Manual

The plant shall have a plant-specific QC manual that details the production and QC policies and procedures used by the plant. The manual shall be compiled in one notebook or binder for easy review by plant personnel or by an inspector. At a minimum, the manual shall include the requirements of this manual and the following sections:

1. Management QC policy statement
2. Company QC personnel organizational chart
3. Description of responsibilities for QC personnel
4. Description of training requirements for QC personnel, production staff, forklift operators and drivers.

A plant-specific quality control procedural manual should specifically define any attributes or practices unique to the plant. This manual should be reviewed annually and updated as necessary.

STANDARD	COMMENTARY
5. Housekeeping plan	
6. Product pre, post and final inspection procedures	
7. Plant curing procedures for all seasons	*Standard Operating Procedures (SOP) are a good way to define QC expectations.*
8. Minimum strength requirements for stripping and shipping product	
9. Product repair policy and procedures	
10. Product tolerances	*A formal review process of all QC records should be incorporated into the plant's QC operations with the intent of continually improving operations and quality. This can include a periodic review of documentation indicating nonconforming materials, production procedures and/or products and establishing appropriate corrective action.*
11. Form tolerances and maintenance policy	
12. Mix design qualification and testing procedures (including requirements of 3.1.1 for use of SCC and 4.6.1 for defining minimum stripping strengths)	
13. Raw material testing policy and procedures	
14. Equipment calibration policy and procedures	
15. Product performance test policy and procedures applicable to Chapter 6	
16. Examples of all documentation and forms used by plant to record QC and production processes	
17. Documentation of products manufactured under franchise agreements, including all design specifications and drawings.	
1.1.3 Plant Requirements:	
1. Maintain a current copy of this NPCA Manual in ready access to inspectors and plant personnel.	
2. Develop and periodically update a written plant-specific QC manual.	
3. Maintain current copies of applicable ASTM International test methods and specifications on file.	
4. Maintain files of project specifications and requirements.	
5. Maintain employee training records in company files.	
6. Designate and train a plant QC Inspector for each work shift, with an assigned individual designated as backup. The QC Inspector shall report to plant management and not directly to production personnel. In small plants, the designated QC Inspector can be included in daily production duties but should not be the same person responsible for meeting	

production demands. A designated QC Inspector shall be present any time the plant is in production.

7. Plant QC Inspectors and assigned backup inspectors shall complete the following minimum training requirements:

   a. NPCA Production and Quality School (PQS), OR other local agency required certification (such as DOT, or other), OR equivalent in-house training (see minimum requirements in commentary).

   AND

   b. American Concrete Institute (ACI) Concrete Field Testing Technician - Grade I.

   Training records, including course outline, syllabus, test results and instructor qualifications shall be maintained on file at the plant for five years.

8. Management or a designated representative shall hold QC meetings with QC and plant personnel a minimum of once every 6 months. A record of the minutes of these meetings and a list of attendees shall be kept in the plant files.

Because of the importance of properly trained personnel, training must remain current. Retraining every five years in the NPCA Production and Quality School (PQS) is recommended.

Equivalent in-house training should cover the following topics, at a minimum:
- Reinforcement
- Pre-Pour Operations
- Production Practices
- Post-Pour Operations

1.2 PLANT SAFETY

1.2.1 Safety Program

Each plant shall have an active plant safety program. The program shall include requirements of local, state, and federal laws, and in particular the requirements of the Occupational Safety and Health Administration (OSHA).

This manual does not outline a plant safety program, but states that one should be in effect.

1.2.2 Plant Requirements:

1. Maintain a plant safety manual and documented safety program. A plant-specific manual developed in accordance with the NPCA Guide to Plant Safety, or similar manual shall be in ready access to inspectors and plant personnel.
2. Management or designated representative shall hold safety meetings with plant personnel a minimum of once every month. A record of the minutes of these meetings and a list of attendees shall be kept in the plant files.

CHAPTER 2 – MATERIALS

2.1 CONCRETE

2.1.1 Cement

Cement shall conform to ASTM C150, "Standard Specification for Portland Cement" or shall be Type IS – portland blast-furnace slag cement or Type IP – portland-pozzolan cement conforming to the requirements of ASTM C595, "Standard Specification for Blended Hydraulic Cement." Evidence of conformance shall be a certified mill test report for each shipment or lot of cement.

Five types of Portland cement are specified in ASTM C150 but only three types are commonly used:

Type I - This cement is most commonly used in most of North America.

Type II - Moderate heat of hydration and moderate sulfate resistance cement is used extensively where soils are high in sulfates and in massive construction.

Type III - High early strength cement is used where rapid strength gain is needed.

The remaining other two types are not readily available in most parts of the country. Type IV, low heat of hydration cement, is manufactured only for large dam construction. Type V, sulfate-resisting cement is specified by some agencies where high sulfate resistance is needed.

When using blended cements, trial batches should be tested to ensure adequate strength is reached prior to stripping the product.

2.1.2 Fine Aggregate

Fine aggregate shall conform to the requirements of ASTM C33, "Standard Specification for Concrete Aggregates." In addition, fine aggregate shall be evaluated and documentation maintained on file at the plant for potential deleterious expansion due to alkali reactivity, unless the aggregate is received from a state department of transportation approved source. Fine aggregate shall be tested for gradation for each 1,500 tons (1,350 metric tons) of aggregate used, or once a month, whichever occurs first. In addition, fine aggregate from all suppliers shall be tested for deleterious substances initially, then annually thereafter and whenever the aggregate is suspected of contamination. At a minimum, deleterious substance tests shall include:

ASTM C40, "Standard Test Method for Organic Impurities in Fine Aggregates for Concrete"

ASTM C117, "Standard Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing"

ASTM C123, "Standard Test Method for Lightweight Particles in Aggregate"

ASTM C142, "Standard Test Method for Clay Lumps and Friable Particles in Aggregates"

Uniformity of aggregate gradation is needed to maintain uniformity of concrete quality. A reduction in the amount of material passing the No. 30 (0.600 mm) and No. 50 (0.300 mm) sieves may tend to cause excessive bleeding so it may be advisable to blend in a fine masonry sand, increase the sand content in the mix (and reduce the coarse aggregate content), or increase the amount of cement in the mix. An increase in fines may permit a reduction in the sand content in the mix.

Aggregate suppliers may offer to perform testing at no charge. If the aggregate supplier will not perform the required testing, the plant may perform the testing in-house (for gradation and organic impurities) or may employ a local testing laboratory.

Sands with organic impurities may result in erratic setting times of the concrete. In addition, some organic impurities such as roots and vegetable or wood fibers may affect the appearance and durability of exposed concrete products. Sands that fail to meet the organic impurity

tests should not be used in precast concrete products.

Most specifications indicate that sand must be free of organic impurities. The test is relatively simple to perform in the plant. If there are no organic impurities, the results are positive and no additional tests are needed, but if the results indicate possible contamination of the aggregates, strength tests of mortar cubes made with the sand in question should be made and tested in compression.

Companion cubes made of sand containing no organic impurities should be made and tested in compression at the same age as those made with the sand in question. If the strength of the questionable cubes is at least 90% of the strength of the companion cubes, the sand may be used for making concrete. It should be noted that some organic impurities will affect setting time of concrete, but the organic impurities test does not give an indication of setting time.

Additional aggregate test methods not listed in this manual may be necessary if contamination is suspected.

2.1.3 Coarse Aggregate

Coarse aggregate shall conform to the requirements of ASTM C33, “Standard Specification for Concrete Aggregates.” In addition, course aggregate shall be evaluated and

If possible, coarse and fine aggregates should be obtained from sources

documentation maintained on file at the plant for potential deleterious expansion due to alkali reactivity, unless the aggregate is received from a state department of transportation approved source. The maximum size of coarse aggregate shall be as large as practical, but shall not exceed one-fifth of the minimum thickness of the precast concrete product, or three-fourths of the clear cover between reinforcement and the surface of the product. Larger maximum sizes of aggregate may be used if evidence shows that satisfactory concrete products can be produced.

approved for use in highway pavements by state departments of transportation. Otherwise it will be necessary to obtain test reports that show that the aggregates not only conform to ASTM C33 but also are non-reactive and are stable.

Coarse aggregates shall be tested for gradation for each 2,000 tons (1,800 metric tons) of coarse aggregate used, or once a month, whichever occurs first. In addition, coarse aggregate from all suppliers shall be tested for deleterious substances initially, then annually thereafter and whenever the aggregate is suspected of contamination. At a minimum, deleterious substance tests include:

Aggregate suppliers may offer to perform testing at no charge. If the aggregate supplier will not perform the required testing, the plant may perform the testing in-house (for gradation) or may employ a local testing laboratory.

ASTM C117, "Standard Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing"

ASTM C123, "Standard Test Method for Lightweight Particles in Aggregate"

ASTM C142, "Standard Test Method for Clay Lumps and Friable Particles in Aggregates"

Additional aggregate test methods not listed in this manual may be necessary if contamination is suspected.

2.1.4 Lightweight Aggregate

Lightweight aggregates shall conform to the requirements of ASTM C330, "Standard Specification for Lightweight Aggregates for Structural Concrete." Tests for lightweight aggregate gradation and unit weight and shall be preformed initially and for each 200 cubic yards (150 cubic meters) of lightweight aggregate supplied, or once a month, whichever occurs first. Test records shall be maintained at the plant.

To assure a uniform quality of lightweight concrete, the gradation and dry-loose unit weight of the lightweight aggregates should be consistent. Variation in either the gradation or the unit weight generally requires adjustments to the mix proportions in order that uniform concrete will be produced. Control of aggregate moisture can be even more important with lightweight aggregates. It is usually best to wet

stockpiles in lightweight aggregate and adjust the mix water for excess water on the aggregate.

2.1.5 Mixing Water

Water used in mixing concrete shall conform to the requirements of ASTM C1602, "Standard Specification for Mixing Water used in the Production of Hydraulic Cement Concrete" and shall be free from deleterious amounts of oils, acids, alkalis, salts, organic material or other substances that may adversely affect the properties of fresh or hardened concrete.

Water from municipal water supply systems or from other sources approved for drinking can be used for making concrete. Seawater, brackish water, or other water with high chloride contents should not be used in reinforced concrete. Impure water can affect setting time and algae in water can entrain additional air.

ASTM C1602 covers the compositional and performance requirements for mixing water used in hydraulic cement concrete.

2.1.6 Chemical Admixtures

Admixtures shall conform to the applicable specification as follows:

Admixture Type	Specification Title	Specification Designation
Air entrainment	"Standard Specification for Air-Entraining Admixtures for Concrete"	ASTM C260
Water reducers, retarders, accelerators, high-range water reducers	"Standard Specification for Chemical Admixtures for Concrete"	ASTM C494

Chemical admixtures may be helpful or may be needed to improve the properties of fresh or hardened concrete. Such admixtures include those used to entrain air, retard or accelerate set, reduce water content, reduce permeability, make the concrete more workable, reduce steel corrosion or to add color to the concrete.

	STANDARD		COMMENTARY
Coloring	"Standard Specification for Pigments for Integrally Colored Concrete"	ASTM C979	
Corrosion Inhibitors	"Standard Test Method for Determining the Effects of Chemical Admixtures on the Corrosion of Embedded Steel Reinforcement in Concrete Exposed to Chloride Environments"	ASTM G109	*Corrosion Inhibitors are evaluated through test method outlined in ASTM G109. Calcium chloride or admixtures containing high chloride concentrations are not recommended for use in precast concrete products that contain reinforcement or other metals.*

Admixtures shall be products from manufacturers from whom test data are available to establish their effects on concrete and compatibility with other materials in the mix.

2.1.7 Supplementary Cementitious Materials

Supplementary cementitious materials (SCMs) shall conform to the applicable specifications shown below. Evidence of conformance shall be a certified mill test report for each shipment or lot of SCMs.

When using SCMs and depending on the cement replacement levels, certain SCMs may delay the initial strength gain of the concrete. Proper measures should be taken to ensure product has achieved adequate strength prior to stripping and shipping.

Pozzolans	"Standard Specification for Coal Fly Ash and Raw or Calcinated Natural Pozzolan for Use in Concrete"	ASTM C618
Silica Fume	"Standard Specification for Silica Fume Used in Cementitious Mixtures"	ASTM C1240
Slag	"Standard Specification for Ground Granulated Blast-Furnace Slag for use in Concrete and Mortars"	ASTM C989

STANDARD	COMMENTARY
2.1.8 Plant Requirements:	
1. The following documentation shall be maintained current in the plant records: - Cement and supplementary cementitious material mill certificates, - Aggregate supplier and test reports, - Mix water potability test reports or other test records indicating the acceptability of the mix water (annually) unless using municipal water supply, - Chemical admixture and other additive certifications (annually).	*Unless records of aggregate and concrete tests are identified in such a manner that make it possible to determine which products were made with the materials tested, they are not very useful. A simple orderly method of relating such records to specific products can make the test reports valuable. Placing the date cast on the product is usually sufficient to track the product to the daily quality control records and raw materials.*
2. Documentation of conformance to ASTM C33 (excluding gradation testing) and test reports indicating that the aggregates are non-reactive and stable shall be maintained for each aggregate source used. Such documentation shall be obtained from the supplier, an appropriate state agency, or a testing laboratory engaged by the plant, a minimum of once per year for each material used. The maximum aggregate size shall be proper for the products being cast. Tests for aggregate gradation and deleterious substances shall be performed at the minimum frequency. Lightweight aggregate shall be tested for gradation and unit weight at the minimum frequency.	*Documentation showing that the aggregate source is department of transportation approved is an acceptable means of documenting aggregates are non-reactive and stable.*
3. Records of incoming raw materials and plant materials tests shall be kept current and on file for a minimum of three (3) years.	
4. The cement type, supplementary cementitious materials, and chemical admixtures shall be appropriate for the intended use.	
2.2 REINFORCEMENT	
2.2.1 Reinforcing Bars	
Steel reinforcing bars shall conform to the specification required in the design:	
“Standard Specification for Deformed and Plain Billet – Steel Bars for Concrete Reinforcement” ..... ASTM A615	
“Standard Specification for Low-Alloy Steel Deformed and Plain	

Bars for Concrete Reinforcement" ..... ASTM A706

Other bars may be used for specific purposes if permitted by the design.

Reinforcing bar suppliers shall furnish mill certificates for each shipment. Records of incoming reinforcing steel mill certificates shall be kept current and on file for a minimum of three (3) years.

Bars conforming to ASTM A706 have a low carbon equivalency and can be readily welded. However, they are not commonly stocked by suppliers and generally rather sizeable minimum quantities must be ordered.

2.2.2 Reinforcing Wire

Except for wire used for prestressing, steel wire shall conform to one of the applicable specifications:

"Standard Specification for Steel Wire, Plain, for Concrete Reinforcement" ..... ASTM A82

"Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement" ..... ASTM A496

Other wire may be used for specific purposes if permitted by the design. Reinforcing wire suppliers shall furnish mill certificates for each shipment. Records of incoming reinforcing wire mill certificates shall be kept current and on file for a minimum of three (3) years.

Section 2.2.2 permits the use of wire other than the types listed, but it is recommended that other types of wire not be used unless specifically specified.

2.2.3 Bar Mats and Welded-Wire Reinforcement

Steel bar mats and welded wire reinforcement shall conform to the specification required in the design:

"Standard Specification for Welded Deformed Steel Bar Mats for Concrete Reinforcement" ..... ASTM A184

"Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete"..... ASTM A185

"Standard Specification for Steel Welded Wire Reinforcement, Deformed for Concrete Reinforcement"..... ASTM A497

Suppliers of bar mats and welded wire reinforcement shall furnish mill certificates with each shipment. Records of incoming reinforcing steel mill certificates shall be kept current and on file for a minimum of three (3) years.

Welded wire reinforcement delivered in rolls should be used in circular or curved products, unless the reinforcement is first straightened. Otherwise it is quite difficult to position and support the reinforcement within straight-walled product.

2.2.4 Zinc or Epoxy-Coated Reinforcement

Where required by the design, reinforcement shall be galvanized in accordance with ASTM A767, "Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement," or epoxy coated in accordance with ASTM A775, "Specification for Epoxy-Coated Reinforcing Steel Bars," ASTM A884, "Standard Specification for Epoxy-Coated Steel Wire and Welded Wired Fabric for Reinforcement," or ASTM A934, "Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars." Epoxy-coated reinforcing steel supplied by a CRSI-certified applicator shall be evidence of conformance. Epoxy-coated reinforcement shall be stored and handled in such a manner as to minimize damage to the epoxy coating.

Currently there are no ASTM Standards for zinc-coated welded wire fabric. However, the product is available and may be used in precast concrete products when specified.

2.2.5 Plant Requirements:

1. Mill certificates and certificates of conformance shall be maintained current for all reinforcement including reinforcing bars, reinforcing wire, bar mats, welded wire reinforcement and coated reinforcing.
2. The plant QC Inspector shall crosscheck that certificates are on file for all reinforcing heat numbers being used or stored.
3. Certificates shall be maintained in the plant records for a minimum of three (3) years.

2.3 MISCELLANEOUS MATERIALS

2.3.1 Lifting Devices and Lifting Apparatus

Lifting devices used in precast concrete products shall be verified for capacity and shall have an adequate factor of safety for lifting and handling products taking into account the various forces acting on the device including form release suction, impact, and various positions of the product during handling. The capacity of commercial lifting devices shall be marked on the devices or posted in production areas.

Lifting apparatus such as slings, lift bars, chains, hooks, etc., shall be verified for capacity and shall have an adequate factor of safety for lifting and handling products.

All lifting devices and apparatus should meet OSHA requirements documented in "Code of Federal Regulations" Title 29 Part 1926. Other applicable codes and standards are ANSI A10.9 and ASTM C857, C890 and C913.

A factor of safety of at least

4 is recommended for lifting devices. Manufacturers of standard lifting devices should provide test data to allow selection of appropriate loading.

Because of their brittle nature, reinforcing bars should not be used as lifting devices. Instead, smooth bars made of steel conforming to ASTM A36 can be used.

A factor of safety of at least 5 is recommended for lifting apparatus, such as chains, slings, spreader beams, hooks, shackles, etc.

2.3.2 Embedded Steel Shapes and Plates

Steel shapes and plates that are to be embedded in precast concrete shall conform to the requirements of ASTM A36, "Standard Specification for Carbon Structural Steel." Other types of steel shapes and plates may be used if the requirements are specified in the design. Applicable mill test reports shall be maintained at the plant for each shipment received.

If embedded steel shapes or plates will be exposed to moisture or other corrosive environments, they should be galvanized, stainless steel, or coated with suitable rust-inhibiting materials.

2.3.3 Headed Studs and Deformed Anchor Studs

Studs to be welded to steel shapes or plates for concrete anchors shall conform to the requirements of ASTM A108, "Standard Specification for Steel Bars, Carbon, Cold-finished, Standard Quality," unless higher strengths are required by design.

Proper use of stud welding equipment is necessary to assure adequately strong welds. Studs should be able to withstand 30 degree bend test without failure. Test bending of studs should be made on the first two studs at the start of each welding production period. If welds fail the 30 degree bend test, adjustments should be made to the settings on the

generator, timer and stud gun. If adjustments fail to produce suitable welds, the equipment should not be used until acceptable welds can be produced consistently.

2.3.4 Manufacturing Accessories

Spacers for reinforcement, inserts, form ties, and similar accessories incidental to the manufacture of precast concrete products shall be adequate for their intended purposes and shall result in minimum marring of the concrete surfaces. Use of accessories of dissimilar metals shall be avoided, unless surfaces of the manufacturing accessories are permanently protected against corrosion.

Coated tie wires shall be used with epoxy-coated reinforcement.

Corrosion caused by metal bar chairs is unsightly and for certain products might be objectionable. More serious, however, is galvanic corrosion caused by dissimilar metals. For example, aluminum conduit embedded in reinforced concrete is likely to corrode, particularly if it is in contact with reinforcing steel or if there are chlorides in the concrete.

2.3.5 Fiber Reinforcement

Data shall be provided to show conclusively that the type, brand, quality and quantity of fibers to be included in the concrete mix are not detrimental to the concrete or to the precast concrete product.

Fiber reinforced concrete shall conform to ASTM C1116, “Standard Specification for Fiber-Reinforced Concrete and Shotcrete,” (Type I or Type III).

Only two types of fibers are typically used: synthetic and steel fibers. Fibers should not be used to replace primary structural reinforcing steel.

Synthetic fibers are typically used in concrete to reduce plastic shrinkage cracks and to improve impact resistance. They can help to reduce chipping of products that are stripped. Synthetic fibers do not increase the compressive strength of concrete.

Steel and some synthetic fibers increase the flexural strength of concrete, but the concrete mix should be

STANDARD	COMMENTARY
	designed so that the mix is workable. It is important to follow manufacturer's instructions on introducing the fibers into the mix and on safety precautions.
2.3.6 Joint Sealants, Gaskets and Connectors Certifications shall be obtained from all suppliers and maintained on file for each type of joint sealant, gasket, and connector used by the plant, a minimum of once per year, or as required in Sections 6.2.6 and/or 6.3.5.	
2.3.7 Plant Requirements:	
1. Commercial lifting devices shall be certified and posted for maximum capacity. As a minimum, annually inspect all lifting apparatus and maintain inspection records in the plant files.	*OSHA requirements for lifting devices and apparatus are documented in "Code of Federal Regulations" Title 29 Part 1926.*
2. Non-commercial lifting devices shall be load tested to determine ultimate load and a safety factor of 4 shall be used. Maintain test records for a minimum of three years.	
3. Embedded steel shall be protected from corrosion when necessary and dissimilar metals shall not be in contact.	*More frequent inspection of lifting devices may be required to meet local safety requirements or for devices under severe working conditions. Personnel using lifting devices and apparatus are expected to visually inspect each device prior to use.*
4. Accessories and fiber reinforcement shall be appropriate for their intended use.	

CHAPTER 3 - CONCRETE

3.1 CONCRETE MIXES

3.1.1 Mix Proportions

Concrete mixes shall be proportioned in accordance with ACI 211.1, “Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete,” ACI 211.2, “Practice for Selecting Proportions for Structural Lightweight Concrete,” or ACI 211.3, “Practice for Selecting Proportions for No-Slump Concrete.” Mix proportions shall be determined by a commercial laboratory, project specifications, or by qualified precast plant personnel for each combination of aggregates, cement, water, and admixtures. Mix proportions shall be appropriately modified for changes in source of materials, gradation of aggregates, moisture content of aggregates, cement content, or admixtures.

Concrete should be proportioned so that it will (1) be adequately workable, (2) have the required properties after it hardens (durability, strength, impermeability, acceptable volume change characteristics, etc.), and (3) be economical. To achieve the required properties after hardening requires an adequately low water-cementitious ratio and proper air entrainment. Economy of raw materials is best achieved by using the maximum practical size of coarse aggregate, the optimum fine-to-coarse aggregate ratio, and the stiffest mix that is practical while maintaining the correct water-cementitious ratio and air content.

Plants using self-consolidating concrete (SCC) shall include SCC-specific quality control procedures in their plant-specific QC manual, as discussed in 1.1.2. At a minimum, written procedures shall address the steps necessary for:

1. Initial mix qualification, including trial batching and in-depth concrete testing. Mix qualification procedures shall include developing the range for acceptable test results of daily quality control testing used for mixture acceptance (e.g., target slump flow of 22 to 27 in.) and a daily quality control regimen.
2. Subsequent daily quality control operations. Daily test method regimen must be the same regimen that

Because of the current lack of accepted standardized quality control procedures, the plant should consult with the SCC admixture manufacturer in developing appropriate quality control operations. The plant may also consider consulting the PCI Interim Guidelines for the use of Self-Consolidating Concrete.

was developed during mix qualification (see Section 5.2 and 5.3).

3.1.2 Water-Cementitious Ratio

Water-cementitious ratios for each mix design shall be calculated and documented. Concrete that will be exposed to freezing and thawing shall contain entrained air and shall have water-cementitious ratios of 0.45 or less. Concrete which will not be exposed to freezing, but which is required to be watertight, shall have a water-cementitious ratio of 0.48 or less if the concrete is exposed to fresh water. For corrosion protection, reinforced concrete exposed to deicer salts, brackish water or seawater shall have a water-cementitious ratio of 0.40 or less.

Careful control of all water going into the concrete is important to achieving consistent, high quality concrete. Reducing the water-cementitious ratio increases concrete strength, reduces concrete permeability, and results in a more durable concrete.

The values of water-cementitious ratio cited in section 3.1.2 are needed for adequate durability.

It is recommended that the workability be achieved by using water-reducing admixtures instead of increasing cement contents. Without water-reducing admixtures in the concrete, it is likely that 600 to 700 pounds (270 kg to 320 kg) of cement will be needed per cubic yard of concrete. Even higher cement contents may be needed if aggregate gradations are poor or if high slump concrete is used.

3.1.3 Air Content

The air content of concrete that will be exposed to freezing and thawing shall be within the limits given in Table 3.1.3.

Very wet mixes from which the water is removed by pressure or vacuum de-watering contain little or no entrained air. However,

such concrete can be durable if the water-cementitious ratio is low enough.

TABLE 3.1.3
TOTAL AIR CONTENT FOR FROST - RESISTANT CONCRETE

Nominal Maximum Aggregate

Size (inches)	Air Content, %	
	Severe Exposure	Moderate Exposure
3/8	6.0 to 9.0	4.5 to 7.5
1/2	5.5 to 8.5	4.0 to 7.0
3/4	4.5 - 7.5	3.5 to 6.5
1	4.5 to 7.5	3.0 to 6.0
1 1/2	4.5 to 7.0	3.0 to 6.0

* For specified compressive strengths greater than 5,000 psi (34 MPa), air content may be reduced 1%.

3.1.4 Compressive Strength

A compressive strength test is defined as the average of the strengths of two specimens made from the same concrete batch, cured in the same manner, and tested at the same age. The compressive strength of the concrete as determined from test specimens shall be equal to or greater than that specified by design. If no strength is specified, the strength shall be sufficient to minimize damage caused by product handling, and in no case shall the concrete strength be less than 2,500 psi (17 MPa) at the time the product is shipped.

Compressive strength is commonly specified using cylinders made, cured, and tested in a standard manner, usually tested 28 days after the cylinders are cast. However, some specifications require minimum strengths at ages different than 28 days, and some require cylinders to be cured in the same manner as the concrete they represent.

If strengths are consistently low, several cylinders should be made from one batch; some should be cured in a standard manner (laboratory conditions

defined in ASTM C31), while the rest are cured in the same manner as the product represented. If the strengths of those cured in the standard manner are lower than expected, the mix proportions must be adjusted to give higher strengths. If specimens cured in the standard manner have satisfactory strengths, while those cured with the products are low, curing must be improved or the mix adjusted, or both.

Most precast concrete producers furnish their products with strengths in excess of 4,000 psi (28 MPa). Lower strength concrete is damaged more readily while it is being handled. A minimum strength of 2,500 psi (17 MPa) at the time of shipment might be too low to minimize damage for some types of products, so higher strengths are recommended. A minimum of 80 percent of the 28-day design strength is sometimes specified prior to shipping products.

3.1.5 Admixtures

Admixtures shall be used in accordance with the manufacturers' instructions. If more than one admixture is used in a concrete mix, data shall be obtained to assure that each admixture performs as required without adversely affecting the performance of the others. Admixtures shall be introduced into the concrete mix in a controlled manner to assure uniform distribution into the mix.

Some admixtures conforming to ASTM C494 are affected by composition of the cement, particularly the tricalcium aluminate and the sulphur trioxide contents. Thus it is

Admixture supplier shall supply certification of admixture dosing equipment annually.

recommended that the effectiveness of admixtures be evaluated in concrete mixes at the plant so that the reaction between the cement being used and the admixture can be noted. Some admixtures are not compatible with other admixtures, particularly if they are introduced into the mix in a sequence other than that recommended by the manufacturer.

3.1.6 Plant Requirements:

1. Mix proportions for each mix shall be clearly listed and maintained in the plant files and at the mixer. The water - cementitious ratio of the mixes shall not exceed the limits stated in Section 3.1.2 and shall be documented in the mix proportion. The concrete shall be air-entrained if it will be exposed to freezing and thawing per Table 3.1.3.
2. Compressive strength must be adequate for the intended use of the product and never less than 2,500 psi (17 MPa) at time of shipping. If product is shipped prior to obtaining strength data, additional compressive cylinders shall be tested prior to shipping to ensure minimum strength requirements are met. Rebound hammer tests can also be used for strength determination if the rebound hammer has been properly calibrated on cylinders at several ages for each mix design. Compressive strength (7- or 28-day age) of the concrete shall be tested a minimum of once per week and preferably on a daily basis. Strength data shall be routinely reviewed and tracked by management. Strength data shall be retained in the files for a minimum of three (3) years.

3.2 BATCHING AND MIXING

3.2.1 Requirements for Batching and Mixing Plants

Plants shall be equipped so that batching and mixing will result in adequately mixed concrete of the correct proportions with the desired workability of the fresh concrete and required properties of hardened concrete in adequate quantities to maintain the casting schedule. Plants for batching and mixing concrete and their operations shall conform to ASTM C94, “Standard

A wide variety of batch plants from manual to fully-automated can provide concrete of consistent quality and can conform to these requirements.

Specification for Ready-Mixed Concrete." Alternatively, plants may conform to the requirements for batching and mixing given in ASTM C685, "Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing."

3.2.2 Storage of Cement and Supplementary Cementitious Materials

Separate bins or silos shall be provided for each type of bulk cement and supplementary cementitious materials. Bins and silos shall be watertight to prevent intrusion of moisture. Cement and supplementary cementitious materials in bags shall be stored under cover to prevent contact with moisture.

Cement will begin to hydrate when it comes in contact with water. Partly hydrated cement forms lumps, which are difficult to pulverize, and thus should not be used. If lumps of cement are discharged from the bin, the bin should be emptied and repaired if necessary. Bagged cement, which is lumpy, should be discarded.

3.2.3 Handling and Storage of Aggregates

Aggregates shall be handled and stored in such a manner that segregation of particle sizes is minimized, gradations are kept within specified limits, contamination from underlying soil does not occur and cross-contamination between adjacent aggregate stock does not occur.

In addition, organic matter (such as leaves and twigs) shall not be allowed to accumulate and plants shall not be allowed to grow in aggregate stockpiles.

Minimal handling of aggregates is recommended to curb segregation. Storing aggregates in conical piles should be avoided. Preferably aggregates should be stored on slabs or on planking in horizontal layers. Methods for minimizing segregation of aggregates are described in ACI 304, "Guide for Measuring, Mixing, Transporting, and Placing Concrete."

3.2.4 Batching Equipment

Weigh batching equipment shall be maintained and operated in accordance with ASTM C94 or ASTM C685.

For plants that utilize mass batching or a combination of mass and volumetric (for liquid) batching, the equipment must be capable of measuring and batching the concrete raw materials within the following tolerances:

Cement	±1%; for batches less than 1 cubic yard, 0 to +4%
Water	±1%
Fine Aggregates	±2%
Coarse Aggregates	±2%
Cumulative Weigh Batch Aggregate	±1%
Admixtures	±3% or ± dosage per bag of cement, whichever is greater

Scales shall be calibrated annually or any time there is a reason to question their accuracy. Calibration stickers shall be displayed prominently at the batch control location. Records for calibration of batch plant scales shall be readily accessible to the equipment operator.

Scale calibrations shall include the entire anticipated range of use and the percent error at each test weight shall be documented. Scales shall be calibrated to within 0.2% of the certified test weight at each quarter of the anticipated load range.

Liquid admixtures shall be measured by weight or volume. Powdered admixtures shall be measured by weight. Calibration of the admixture dispensers shall be performed at least annually.

Plants that utilize volumetric or continuous batching shall be capable of proportioning the component materials in concrete within the following tolerances:

Cement	0 to + 4% (weight)
Water	±1% (weight or volume)
Fine Aggregates	±2% (weight)
Coarse Aggregates	±2% (weight)
Admixtures	±3% (weight or volume)

The tolerances given in this section are those specified in ASTM C94 and ASTM C685. Methods for calibrating the measuring equipment are outlined in those standards. There are two reasons for displaying calibration records prominently. Records that show deviations should be used by plant personnel to obtain correct readings. Also, inspectors from outside agencies can be assured that the equipment has been calibrated recently.

Note that when using self-consolidating concrete, very small discrepancies in batch water content can be detrimental to the desired properties of the mix.

STANDARD	COMMENTARY
3.2.5 Discharge of Materials into Mixers	
Mixer drum or blades shall be rotating while materials are discharged into the mixer. Materials shall be discharged into the mixer in a sequence that ensures a homogenous mix. Admixtures shall be fed into the mixer in a sequence that is recommended by the admixture supplier and to ensure uniform distribution in the mix. The sequence of discharge and mixing shall be documented and maintained at the concrete batching station.	*Materials should be discharged into the mixer in a sequence that approaches the ideal condition. Each facility should develop and document a sequence that results in a uniform mix.* *For lightweight aggregates, pre-wetting is recommended to prevent mix-water absorption. It is also advisable to develop a specific batching sequence starting with the lightweight aggregates and part of the water before adding the other materials.*
3.2.6 Mixers	
The batch size shall not exceed the capacity recommended by the manufacturer. Mixers shall be capable of producing concrete of uniform consistency and uniform coarse aggregate distribution as required by ASTM C94 for batch mixing, or ASTM C685 for continuous mixing. Mixers shall be checked periodically for cleanliness, clearances on blades and shoes, proper gate seals, lockout controls, etc.	*The condition of the mixer should be checked daily for mortar or concrete build-up and worn blades. The manufacturer's drawing of the mixer showing all dimensions should be available so that the amount of wear can be determined. Blades worn more than 10% should be adjusted or replaced. Concrete and mortar build-up should be removed and discarded.*
3.2.7 Mixing	
Concrete may be mixed by (a) stationary central mixer, (b) mixing screw (volumetric type), or (c) truck mixing and delivery. For batch mixers, mixing time or number of drum rotations shall be established by uniformity tests in ASTM C94, either by the	*ASTM C94 gives the maximum permissible differences in results of tests of samples of concrete taken from two*

equipment manufacturer or by qualified plant personnel.

Daily reports of actual concrete mix proportions used in each batch and quantities of concrete produced shall be kept by the precast plant for at least three (3) years.

locations in a batch. Items to be tested include unit weight, air content, slump, coarse aggregate content, and compressive strength. If the differences in values are within the tolerances given in ASTM C94, the mixer should be approved. However, if the differences in test results are greater than the tolerances in ASTM C94, the mixer should not be used.

3.2.8 Ready-Mixed Concrete

Concrete supplied by a ready-mixed concrete producer (whether located at the same location as the precast plant or off-site) shall conform to the requirements given in Sec. 3.2.1 through 3.2.7. The facilities for batching concrete supplied by a ready-mixed concrete producer shall conform to the same requirements of batch plant facilities cited above. Certification of the supplier's facilities by the National Ready Mixed Concrete Association (NRMCA) or State DOT shall be evidence of conformance to Sec. 3.2.1 through 3.2.7. In addition, the plant shall maintain a file of current mixture designs, batch plant printouts, truck delivery receipts, and appropriate raw material certifications and gradations. Total quantities of raw materials used by the precast plant shall be used to determine the required frequency of raw materials testing.

The plant should verify that the ready-mixed concrete supplier is operating in accordance to ASTM C94.

Plastic concrete tests (slump, temperature, air content, unit weight) should be performed at the plant prior to casting products. Mark any added water on the delivery batch ticket for each truck and keep on file.

Truck delivery receipts shall be received with each load. Record all water added at the plant to the ready-mixed concrete deliveries.

"Bring-back" concrete or any other concrete originally intended for an entity other than the precast concrete manufacturer shall not be used for production of precast concrete products.

3.2.9 Plant Requirements:

1. Aggregate stockpiles shall be properly configured to minimize segregation and contamination.
2. Scales shall be calibrated at least annually and the calibration sticker displayed prominently at the concrete batch control station.

3. Batching tolerances for all concrete components shall conform to the tolerances listed in Section 3.2.4.
4. Mixers shall be checked periodically for cleanliness, clearances on blades and shoes, proper gate seals, lockout controls, etc.
5. Ready-mixed supplied concrete shall be from a NRMCA or State DOT certified plant or conform to all above requirements. Documentation of the ready mix supplier's conformance shall be maintained in the files at the precast plant. Truck delivery receipts and any water added at the precast plant shall be documented. Only fresh concrete intended for the precast concrete manufacturer is permitted to be used for production of precast concrete products.
6. Daily reports of actual concrete mix proportions used in each batch and concrete quantities produced shall be kept by the precast plant for at least three (3) years.

STANDARD COMMENTARY

CHAPTER 4 – PRODUCTION PRACTICES

4.1 GENERAL

4.1.1 Plant Layout

The physical layout of the plant shall be such that production, handling, storage and shipment of concrete products can be done in an efficient, safe manner and with minimal product damage.

The plant layout shall incorporate the following general guidelines:

1. Minimize transport distances of fresh concrete.
2. Adequate workspace to minimize safety and tripping hazards.
3. Avoid stripping or lifting products over personnel or equipment.
4. Prevent marking or splash on other products during casting operations.
5. Adequate storage space for materials.
6. Adequate space to strip products and perform post-pour inspections and repairs.

Because of the wide range in sizes of precast concrete manufacturing plants and in the diversity of products manufactured, there can be no standard or ideal organization structure or plant layout.

4.1.2 Housekeeping

Each plant shall have an active housekeeping program. The purpose of the program shall be to provide a clean and safe environment so that quality precast concrete products can be manufactured efficiently.

The plant QC Inspector shall spot-check housekeeping daily.

A clean plant provides a much better environment for producing quality products than does a cluttered plant. A clean plant is also good for morale of workers, minimizes safety hazards, and generally improves production efficiency and quality.

Some plants require each worker or crew to be responsible for the cleanliness of a particular area of the plant. In other plants a "clean-up" or housekeeping crew is

STANDARD	COMMENTARY
	responsible for the cleanliness of the entire plant. In general, management attitude will dictate the effort expended in keeping a plant clean.
4.1.3 Forms and Forming Equipment	
Forms and forming equipment for manufacturing precast products shall be of a quality that prevents product damage due to forces and vibrations subjected to the forms. All forms and forming equipment (including pallets, headers, truing rings, etc.) shall be measured prior to initial use and not less than annually for dimensional conformance with applicable tolerances. Forms shall be carefully cleaned of concrete build-up after each use. Coatings of form release agents shall not be allowed to build up.	*Forms that are well built and properly maintained can be used almost daily for 20 years or more. Quality forms are rugged yet produce surface defect -free products within dimensional tolerances. Typically, form dimension tolerances should be about half the product tolerances specified. A routine maintenance program to repair hinges, remove bulges, minimize seam leakage, etc.; can result in improved quality as well as reduced production costs.*
4.1.4 Handling Equipment	
Equipment such as hoists, overhead cranes, gantries, mobile cranes, fork lift trucks, shall be used to lift and handle products which weigh less than the rated capacity of the equipment. Inspection and maintenance records for all handling equipment must be maintained in accordance with applicable requirements.	*Routine inspections should be made of all handling equipment to assure that safety is not compromised. Worn cables and other parts should be replaced or repaired. The equipment operators should make daily inspections of all handling equipment.* *Ensure all crane and lift operators are properly trained and meet OSHA requirements. Forklift operators should be familiar with local and OSHA safety requirements and the NPCA Guide to*

Plant Safety.

4.1.5 Machine-Made and/or Dry-Cast Products

Precast concrete products that are manufactured by mechanized equipment and/or dry-cast process shall conform to the applicable provisions of this manual.

Many products such as patio stones, interlocking pavers, and manhole sections can be dry-cast or manufactured with mechanized equipment. In such operations, control of the concrete mixture is critical because the products are stripped immediately after they are cast, and the concrete units must retain their shape.

For products containing reinforcement fabricated in the plant with mechanized equipment, verification of the reinforcement for conformance with the design shall be performed and documented on a minimum of three (3) reinforcing cages or 3% of each production run daily, whichever is greater, chosen on a random basis by QC personnel. At least one cage shall be checked when a shift change occurs during the course of a production run and whenever a setting is changed. These reinforcement checks shall be documented and maintained in the plant records for a minimum of three (3) years.

See section 4.2.1 for inspection requirements for reinforcement that is not fabricated in the plant using mechanized equipment.

Dimensions of machine-made products shall be within acceptable tolerances regardless of any slumping of the concrete after stripping.

Dimensional checks of machine-made products shall be performed daily for each type of product cast. Dimensional checks shall be performed on a minimum of three (3) products or 3% of each production run daily, whichever is greater, chosen on a random basis by QC personnel. These dimensional checks shall be documented and maintained in the plant records for a minimum of three (3) years.

If non-conforming product is discovered, the plant shall immediately make attempts to correct the non-conforming issue until it has been resolved.

4.1.6 Architectural Precast Concrete

By its inherent nature, the level of quality, in terms of appearance, is of the utmost importance. Final product shall match previously approved samples and/or already established industry standards stated in individual job specifications.

Concrete products can be created through adjustments to shape, color, finish/texture or design to create an appearance that fits the needs of the public and/or project specific design requirements. Color can

Consistent quality shall be maintained through documented plant-specific procedures, as required in Section 1.1.2. Strength and durability shall not be compromised for architectural appearance, unless a specific application or specification allows

deviations.

Natural stone or clay products may be used as a veneer to create the desired finish. Procedures to accommodate differences in thermal and moisture movement between the veneer and the concrete shall be established.

be affected by the choice of cement, coarse and fine aggregates or pigment used and how they are proportioned. Finishes can be applied in a number of ways such as sandblasting, pressure wash or other mechanical means.

Various procedures for an architectural finish may vary from plant-to-plant. It is the precast concrete producer's responsibility to establish the proper methods to achieve a specific finish.

Depending on the type of product, a wide range of strength and durability requirements may be expected (i.e. a birdbath and a post-tensioned wall panel will not necessarily be expected to perform equally).

Careful attention shall be made when using veneers. Establishing standards to accommodate material incompatibility shall be well researched.

4.1.7 Plant Requirements:

1. Maintain an active housekeeping plan. Continual efforts shall be made by all production personnel to maintain a clean work area. Spot-check by QC Inspector at least once each work shift.
2. Maintain records of form and forming equipment dimensional checks on all new equipment and on an annual basis thereafter.
3. Maintain inspection records of all handling equipment in

accordance with applicable requirements.

4. For reinforcement fabricated with mechanized equipment and used in machine-cast, or dry-cast products, perform and document reinforcing checks on a minimum of three (3) reinforcing cages or 3% of each production run daily, whichever is greater. At least one cage shall be checked when a shift change occurs during the course of a production run and whenever a setting is changed.
5. For machine-cast and/or dry-cast products, dimensional checks shall be performed and documented on a minimum of three (3) products or 3% of each production run daily, whichever is greater.
6. Appearance of architectural precast concrete shall match approved samples and meet industry standards. Compatibility of veneers shall be established and documented. Production and quality control measures shall be developed and documented in the plant-specific QC manual.
7. Unless otherwise noted, maintain records for a minimum of three (3) years.

4.2 FABRICATION OF REINFORCEMENT AND BLOCKOUTS

4.2.1 Fabrication of Reinforcement

Reinforcing steel shall be fabricated in conformance with the precast concrete product tolerances. If no tolerances have been established, dimensional tolerances given in the Concrete Reinforcing Steel Institute publication, “Placing Reinforcing Bars,” shall govern.

Adequate concrete cover is required in order to protect the steel against corrosion and to provide adequate structural bond between the steel and concrete. Cages should be made so that concrete cover requirements are maintained.

Reinforcing steel cages shall be inspected for conformance to approved design requirements and documented with the pre-pour inspection.

When inspecting reinforcing steel cages, the approved design documentation they are compared to may consist of plant shop drawings.

All reinforcing bars shall be bent in accordance with standard CRSI fabrication practices and bend diameters shall not be less than those established by CRSI.

Cages of reinforcement shall be fabricated either by tying or clipping the bars, wires or welded wire reinforcement into rigid assemblies, or by welding where permissible in accordance with Section 4.2.2.

Damage to the coating on epoxy-coated reinforcing steel shall be repaired with patching material in a manner conforming to the patching material manufacturer's recommendations. When epoxy-coated reinforcing steel is cut or welded, the cut ends and the weld areas shall be repaired with patching material. Epoxy-coated reinforcing steel shall not be flame cut.

4.2.2 Welding of Reinforcing Steel

Cages of reinforcement may be welded if permitted by the applicable ASTM product standards. Welding of reinforcing steel may be also permitted in other situations as determined by the manufacturer where the steel is not used for structural purposes.

Reference the American Concrete Institute's Building Code (ACI 318) and The American Welding Society publication (AWS D1.4). Each references each other within their codes. Both contain complete and useful guidelines for welding of reinforcing steel.

In all cases care and discretion must be used to assure that the integrity of the precast product is maintained.

Reinforcing steel used for structural purposes may be welded as long as it is accomplished in compliance with standards set forth in the American Concrete Institute's "Building Code Requirements for Reinforced Concrete" (ACI 318) and The American Welding Society's "Structural Welding Code - Reinforcing Steel" (AWS D1.4).

Welding of ASTM A615 reinforcing steel is not generally an acceptable practice. According to the American Welding Society D1.4 Structural Welding Code for Reinforcing Steel, the carbon equivalent for bars to be welded should be less than 0.45 percent for bars larger than #7 and 0.55 percent for #6 bars and smaller. If ASTM A615 steel is to be welded, the carbon equivalent shall be calculated and the bars preheated if necessary.
Use of ASTM A706 weldable grade rebar for welding applications is acceptable.

The Carbon Equivalent (CE) for ASTM A615 reinforcing steel is calculated as follows:

$$CE = \%C + \%Mn/6$$

The Carbon Equivalent (CE) for ASTM A706 reinforcing steel is calculated as follows:

$$CE = \%C + \%Mn/6 + \%Cu/40 + \%Ni/20 + \%Cr/10 - \%Mo/50 - \%V/10$$

STANDARD	COMMENTARY
4.2.3 Welding of Steel Assemblies	
Welding of steel assemblies which are cast into or attached to precast concrete products shall be performed in accordance with American Welding Society D1.1, "Structural Welding Code - Structural Steel."	*Most structural steel assemblies in precast concrete consist of ASTM A36 steel, which is readily weldable with standard equipment. Welding of stainless steel and steels other than ASTM A36 steel should be performed in accordance with AWS D1.1.*
4.2.4 Fabrication and Positioning of Blockouts	
Blockouts may be made of any rigid, non-absorptive material that will not harm the concrete and that can be held in place during the casting and curing of concrete. Dimensional blockout tolerances shall be specified for each product and blockout type. Blockouts shall be held in place during casting with non-corrosive supports and not with reinforcing steel.	*Expendable blockouts are often made of non-absorptive expanded polystyrene. Reusable blockouts are made of a variety of materials such as wood, steel, sheet metal, rubber, neoprene, and a variety of plastics. Most blockouts tend to float during and immediately after casting concrete so they must be held rigidly in place. Blockouts should be designed to minimize damage to the concrete when they are removed. Coring holes in the hardened concrete is sometimes used instead of installing blockouts.*
4.2.5 Plant Requirements: 1. Reinforcement shall be fabricated within applicable tolerances and supported rigidly. 2. Welding of steel shall be performed properly with minimal undercutting. Welding of ASTM A615 reinforcing shall not be allowed unless carbon equivalent calculations are performed and preheat is used when necessary.	

3. Blockouts shall be non-absorptive and held rigidly in place with non-corrosive supports.

4.3 PRE-POUR OPERATIONS

4.3.1 Cleaning of Forms

Forms shall be cleaned after each use. Concrete, tape, polystyrene, and other materials adhering to the forms shall be removed.

It is generally easiest to clean forms immediately after products are stripped. Waiting too long allows the concrete to bond more tenaciously to the forms.

4.3.2 Application of Form Release Agent

Form release agent shall be applied after the forms are cleaned and, if necessary, the seams sealed. Reinforcement and other items to be embedded in concrete shall be free of form release agent. Care shall be taken to avoid over-application of form release agent, which may lead to puddling. If puddling does occur, the puddle shall be removed prior to casting.

Form release agents prevent concrete from bonding or adhering to forms. Reinforcement, inserts and other embedment items on which form release agents have been inadvertently applied may fail to bond to the concrete and may be ineffective in performing their intended functions. It is recommended that form release agents be applied in a thin coat and there should be no puddles.

4.3.3 Positioning of Reinforcement

Reinforcing steel shall be positioned as specified by the design and the concrete cover must conform to product requirements. Unless otherwise required, the tolerance on concrete cover shall be one-third of that specified but not more than ½ inch. Concrete cover shall not be less than ½ inch, however concrete cover greater than ½ inch is recommended. Positive means shall be taken to assure that the reinforcement does not move significantly during the casting operations. Cages shall be supported away from all form surfaces. Liberal use of chairs, spacers, positioning wheels, etc. is encouraged especially with small diameter bars or wire. Rolled welded-wire fabric shall be

For precast products made in accordance with standards like ASTM (e.g. manholes, barriers and utility structures) the reinforcement positions are cited in the standards. For products not made in accordance with standards, ACI 318 generally determines

mechanically straightened to use in straight-walled products.

reinforcement positioning.

(See Section 4.1.5 for reinforcement in machine-cast or dry-cast products)

4.3.4 Positioning of Miscellaneous Embedded Items

Embedded items shall be positioned at locations specified in the design. Inserts, plates, weldments, lifting devices and other items to be embedded in precast concrete products shall be held rigidly in place during casting operations.

Some embedded items are placed in the concrete after concrete has been cast but before it hardens. If embedded items such as lifting inserts are required to develop significant stresses, care should be taken to ensure adequate consolidation of the concrete around the item.

4.3.5 Plant Requirements:

1. Pre-pour inspections shall be performed prior to casting each form. Form dimensions, form tightness, form cleanliness, form release agent application, positioning and securing of reinforcing, embedded items and blockouts shall all be checked.
2. The plant shall have a procedure to identify when a form has received a pre-pour inspection and is ready for casting.
3. Documentation of the pre-pour inspections can be on a piece or production shift basis and must be documented at least daily.
4. Pre-pour inspections for machine-made products shall be a minimum of checking the form condition prior to each work shift and checking and documenting reinforcing cages as required in Section 4.1.5.

4.4 CASTING CONCRETE

4.4.1 Transporting Concrete

Concrete may be transported from the mixer to the casting location by any means that does not contaminate the concrete or cause excessive segregation. Concrete discharged directly from the mixer into the forms is permitted.

After concrete is discharged from a mixer all casting operations tend to cause segregation.

STANDARD	COMMENTARY
	Excessive segregation is undesirable. Thus all casting operations should be done in such a way that segregation is minimized. An effective method of minimizing segregation is to minimize handling of the concrete. If possible, concrete should be delivered directly to the forms after it is discharged from the mixer.
4.4.2 Depositing Concrete into Forms	
Concrete shall be deposited into forms as near to its final location as practical, unless the mix being used is self-consolidating. Keep the free fall of concrete to a minimum.	*Generally concrete can be deposited into forms with minimal free fall. Conventional concrete (not SCC) should first be deposited in one corner or edge of flat forms and additional concrete should be deposited into previously cast concrete until the form is filled. For vertical forms such as walls or pipe sections, concrete should be cast in horizontal layers instead of depositing the concrete to full height at one point and allowing the concrete to flow to other locations. There are exceptions to that rule. For example, when using SCC or when casting a wall section with a large rectangular blockout, concrete is generally cast high on one side of the blockout and the concrete is allowed to flow beneath the blockout until the level of concrete on the opposite side is*

higher than the bottom of the blockout.

Similarly, when casting an open-top, five-sided box, concrete is allowed to flow from one vertical side beneath the top form of the bottom slab until the concrete begins to rise on the opposite side. For such products, the use of high-range water reducers (superplastercizers) and continuous vibration are recommended.

4.4.3 Consolidating Concrete

Concrete shall be consolidated in such a manner that segregation of the concrete is minimized. Vibrators used to consolidate concrete shall have frequencies and amplitudes sufficient to produce well-consolidated concrete.

Proper use of vibrators to consolidate concrete requires trained operators. High slump concrete, such as concrete with slumps greater than about 5 inches can easily be over-vibrated thus causing excessive segregation. Low slump concrete, (i.e., slump less than about 3 inches) is seldom over-vibrated to the point that excessive segregation occurs. Trained operators follow the procedures given in Sec. 4.4.3 and can sense the effectiveness of vibration by watching the surface, and by the sound of the vibrator when the concrete is fully consolidated.

Internal vibrators shall be lowered vertically into the concrete without being forced downward until the tip of the vibrator reaches the bottom of the form or until it penetrates into a previously consolidated lift. Vibrate the concrete until air bubbles within the vibrator's field of action essentially stop coming to the surface. Withdraw the vibrator slightly slower than it was lowered. Reinsert the vibrator making sure the fields of action overlap and repeat the vibration process until all of the concrete in the product has been consolidated. Do not use vibrators to move concrete laterally.

External vibrators (form vibrators) shall be mounted on the form structure in locations that best distribute their impact, but not directly on the form skins. External vibrators shall operate until air bubbles essentially stop coming to the surface.

Surface vibrators (vibrating screeds) shall be moved at a rate such that air bubbles essentially stop coming to the surface.

Similarly, vibrating tables shall operate only long enough that air bubbles essentially stop coming to the surface.

Refer to Section 3.1.1 for the use of self-consolidating concrete.

Consolidation of machine-made products shall be considered to

be adequate if the products are free of honeycombed areas.

4.4.4 Finishing Unformed Surfaces

Unformed surfaces of wet-cast precast concrete products, such as steps, platform slabs, etc., which will serve as wearing surfaces for foot traffic or light vehicular traffic, shall be finished as specified. If no finishing procedure is specified, such surfaces shall be finished using a strike-off to level the concrete with the top of the form.

After concrete has been consolidated and struck off, no finishing, except perhaps edging, should be done until the concrete is stiff enough to support the weight of a man without leaving footprints deeper than about 1/4 inch Excess bleed water on the surface should be removed using a squeegee or a rubber hose pulled across the surface before finishing the concrete. The surface should then be floated using a wood or magnesium float, followed by troweling, if required. For hard, dense surfaces, repeated trowelings may be needed.

Recommended procedures for finishing are given in ACI 302, "Guide for Concrete Floor and Slab Construction."

ACI 350, "Environmental Engineering Concrete Structures" cites the surface finish as a significant factor for water tightness.

4.4.5 Secondary Pours

For products that require secondary pours, procedures shall be established to assure that concrete cast during the secondary pour adequately bonds to the precast concrete product and becomes an integral part of that product.

The surfaces of the product against which the secondary pour is to be made should be free of laitance, dirt, dust, grease

or any other material that will tend to weaken the bond between the original and new concretes. If the surface is very smooth, it should be roughened to help promote good bond. The procedures given in Sec. 4.7.1 may be useful in assuring secondary pours of adequate quality and bond.

4.4.6 Hot Weather Precautions

In hot weather the temperature of concrete at the time of placing shall not exceed 90 degrees F (32 degrees C).

There are generally more problems in placing concrete in hot weather than there are in cold weather, therefore emphasizing the importance of quality practices. Refer to ACI 305R, "Hot Weather Concreting."

For the purposes of this manual and according to ACI 305R, "Hot Weather Concreting," hot weather is defined as any combination of the following conditions that tend to impair the quality of freshly-mixed or hardened concrete by accelerating the rate of moisture loss and the rate of cement hydration:

- High ambient temperature
- High concrete temperature
- Low relative humidity
- Wind
- Solar radiation

The following list presents some hot weather rules-of-thumb:

Special precaution shall be taken in hot weather for concrete that is cast out-of-doors in order to prevent plastic shrinkage cracking and low strengths. These precautions may include:

1. Using cold water or adding ice as part of the mixing water.
2. Sprinkling aggregate stockpiles.
3. Fog spraying forms immediately prior to casting.
4. Placing fog sprays upwind and above the products during concreting, particularly during finishing of unformed surfaces.
5. Covering the products with wet burlap or white plastic sheets as soon as concreting is completed.
6. Monitor concrete temperatures during curing.

1. Concrete sets and hardens faster. This means that concrete must be deposited, consolidated and finished quickly if the concrete temperature is high.

2. On warm windy days, plastic shrinkage cracks are likely to form unless precautions are taken.

3. Unless curing begins immediately, the surface of the concrete is likely to dry out, resulting in cracking or weakening of the concrete surface.

4.4.7 Cold Weather Precautions

In cold weather the temperature of concrete at the time of placing shall not be less than 45 degrees F (7 degrees C).

For the purposes of this manual and according to ACI 306R, "Cold Weather Concreting," cold weather is defined as a period when, for more than three (3) consecutive days, the following conditions exist:

- The average daily air temperature is less than 40 degrees F (5 degrees C), and
- The air temperature is not greater than 50 degrees F (10 degrees C) for more than one-half of any 24-hour period.

Concrete that freezes before its compressive strength reaches at least 500 psi (3.4 MPa) shall be discarded. Suitable precautions shall be taken in cold weather to prevent concrete from freezing. Such precautions may include:

a. Heating the mixing water, but not above 180 degrees F (82 degrees C).
b. Avoid using frozen aggregates.
c. Heat forms prior to and after casting.
d. If concrete does not freeze and no heat is applied, do not strip the product until adequate strength is attained.
e. Monitor concrete temperatures during curing.

In cold weather, if concrete does not freeze before its strength reaches at least 500 psi (3.4 MPa), it will eventually be stronger than similar concrete cast in warm weather. Setting time is delayed in cold weather and concrete gains strength slowly, but most properties of concrete are improved. Because of the slow strength gain, curing with heat is often used. Refer to ACI 306R," Cold Weather Concreting."

The average daily air temperature is the average of the lowest and the highest temperatures occurring during the period from midnight to midnight. As such, cold weather, as defined by ACI 306R, generally starts during the fall and continues until spring.

4.4.8 Plant Requirements:

1. Plant equipment used to transport concrete shall be inspected daily by the plant QC Inspector to ensure that concrete does not segregate or become contaminated. The QC Inspector shall perform and document a spot-check of the concrete transport, placement, consolidation, and finishing of each product line.

2. Workers shall be properly trained in the use of internal and external vibrators.

3. The plant shall maintain written procedures for concreting during hot and cold weather conditions, if applicable, as required in Section 1.1.2.

STANDARD COMMENTARY

4.5 CURING CONCRETE

4.5.1 General

Effective curing shall begin as soon as casting is completed. If concrete is cured with steam or radiant heat, curing procedures must be established and records kept of the temperature of the concrete and environment during the curing period.

Concrete hardens by the chemical reaction between cement and water, a process called hydration. Hydration continues for years provided moisture is present, but if concrete dries, hydration stops and concrete stops gaining strength. Like most chemical reactions, hydration proceeds faster at warm temperatures than at cooler temperatures. Curing of concrete means providing the proper environment for hydration to occur. Thus the necessary factors are moisture, time and temperature. Concrete can be cured by covering it with damp burlap, ponding the surface, steam, or by other means of preventing moisture within the concrete from evaporating. Alternate wetting and drying during the first few days after casting is almost as bad as no curing.

4.5.2 Curing by Moisture Retention

Preventing moisture from evaporating from the exposed surfaces of a precast concrete product shall be considered an effective method of curing, provided the concrete temperature is above 55 degrees F (13 degrees C). If the concrete temperature is lower than 55 degrees F (13 degrees C) but above 35 degrees F (2 degrees C), and moisture evaporation is prevented, the curing period must be extended. Forms shall be considered effective in preventing evaporation from the contact surfaces. The use of a membrane-curing compound applied

Covering the exposed surfaces of products while in forms immediately after casting is often adequate to assure that hydration will continue. Covers made of polyethylene sheets should be at least 6 mils (0.15 mm) thick. There should be no air

thick enough to prevent evaporation of moisture shall also be considered an effective curing method.

circulation beneath the cover. Curing compounds should be applied at a rate not to exceed about 200 square feet per gallon (5 square meters per liter).

4.5.3 Curing with Heat and Moisture

Concrete shall not be subjected to steam, hot air, or other means of accelerated curing until after the concrete has attained its initial set. Record the initial set of the concrete (ASTM C403) a minimum of once per month when heat-curing. Steam, if used, shall be applied within a suitable enclosure that permits free circulation of the steam. If hot air is used for curing, precautions shall be taken to prevent moisture loss from the concrete. These requirements do not apply to products cured with steam under pressure in an autoclave. The temperature of the concrete shall not be permitted to exceed 150 degrees F (65 degrees C) unless measures to prevent delayed ettringite formation (DEF) are employed. In addition, the rise in curing temperature shall be limited to a maximum of 40 degrees F (22 degrees C) per hour.

Gas-fired heaters shall not be used to directly heat exposed concrete surfaces due to the risk of severe carbonation of the concrete.

This section applies to curing with heat and moisture for the purposes of accelerating the strength gain of the concrete, not the maintenance of form and/or ambient temperatures at relatively low temperatures. Accelerated curing heat should not be applied to concrete until about 30 minutes after initial set of the concrete. Initial set can be determined in accordance with ASTM C403, "Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance." If heat is applied too soon, concrete can be damaged permanently. It is important that the heat does not dry out the surface of the concrete, otherwise the concrete near the surface will be weak and chalky. Concrete cured with heat will gain strength rapidly, but long-term strength gains are reduced. Curing temperatures greater than 150 degrees F (65 degrees C) have been found to accelerate deterioration in concretes containing certain cements susceptible to delayed ettringite formation (DEF).

4.5.4 Plant Requirements:

1. If products are heat-cured, the temperature of the concrete shall be monitored during the curing period. Temperature records shall be maintained in the plant records.

2. If heat curing is used, the necessary initial-set period shall be determined, per Section 4.5.3.

3. Products cast outdoors or in dry conditions shall be protected from moisture loss by application of a curing compound, moist curing or impervious sheeting.

4. The QC Inspector shall inspect curing of products and exposed surfaces of stripped products for evidence of plastic cracking. Damage shall be documented.

4.6 STRIPPING PRODUCTS FROM FORMS

4.6.1 Minimum Strength Requirement

Products shall not be removed from the forms until the concrete reaches the designed compressive stripping strength. If no such requirement exists, the plant shall define product-specific minimum stripping strengths that must be obtained prior to stripping. These requirements shall be defined in the plant-specific quality control manual discussed in Section 1.1.2. In addition, one-day, or stripping compressive strength tests shall be performed for each mix design at least quarterly in order to confirm that adequate stripping strengths are being attained. These requirements do not apply to dry-cast and/or machine-made products.

Some products, such as those that serve a structural function, are required to have a certain strength level at the time of stripping to assure adequate bond between the concrete and reinforcement, and to minimize stresses in the product.

4.6.2 Product Damage During Stripping

Products damaged during stripping shall be evaluated by qualified plant personnel to determine if repairs are necessary, and if so, what repair is required before shipping.

A record of any major damage and the repairs shall be kept on file with the final inspection report, as required in Section 4.8.5.

See 4.7.2 for definition of “major repairs.”

The “qualified plant personnel” should be completely knowledgeable about the end use of the product, including its environment, and should know which types of repairs are feasible. It is advisable to learn the cause of the damage so that management

STANDARD	COMMENTARY
	can take action to minimize similar damage in the future.
4.6.3 Formed Surfaces	
Formed surfaces shall be considered satisfactory if they are relatively free of air voids and honeycombed areas, unless the surfaces are required by the design to be finished.	*A minor number of voids in the surface are quite normal. Filling of those voids is done for cosmetic purposes and usually only when required by specifications. For special surface finishes, it is recommended that a mockup panel is made and accepted by the purchaser prior to production. The mockup should be keep until the project is complete.*
4.6.4 Post-Pour Inspection	
After products are stripped from the forms, they shall be inspected for conformance with the design. Items to be repaired shall be classified as “major” or “minor” defects, or as honeycombed areas. Post-pour inspection records shall be kept in the files for a minimum of three (3) years. See 4.7.1 and 4.7.2 for “minor” and “major” repairs.	*Post-pour inspections are useful for managing quality. Recurring major defects require decisive action by management. Major defects in small products usually means rejection of the products, while major defects of large products are generally costly and often disrupt the orderly operation of the plant. It is generally easiest to make repairs while the product is young, but repairs should not begin until appropriate techniques are developed for making the repair.*
4.6.5 Plant Requirements:	
A post-pour inspection shall be made of each product. The inspections shall document any damage, excessive bugholes or honeycombing, poor dimensional tolerances, or other problems such as exposed reinforcing. A mark shall be made on the product indicating whether it is acceptable, requires repair, or it has been rejected.	

4.7 REPAIRING CONCRETE

4.7.1 Repairing Minor Defects

Defects not impairing the functional use or expected life of a precast concrete product shall be considered minor defects. Minor defects may be repaired by any method that does not impair the product.

When honeycombed areas are to be repaired, all loose material shall be removed and the areas cut back into essentially horizontal or vertical planes to a depth at which coarse aggregate particles break under chipping rather than merely being dislodged. Proprietary repair materials shall be used in accordance with the manufacturer's instructions. If a proprietary repair material is not used, the area shall be saturated with water and, immediately prior to repair, the area shall be damp, but there shall be no excess water. A cement-sand grout or an approved bonding agent shall be applied to the chipped surfaces, followed immediately by consolidating an appropriate repair material into the cavity.

It is assumed that qualified personnel will judge which defects are minor and which are major. The person making the judgment must be thoroughly familiar with the functional use of the product, including the environment in which the product will function. Behavior of concrete in the product and in that environment must be known. Repairs of minor defects are essentially cosmetic, (e.g., the product would behave as intended without the repairs)

4.7.2 Repairing Major Defects

Defects in precast concrete products that impair the functional use or the expected life of products shall be considered major defects. Unless major defects are repaired the product shall be rejected. Major defects shall be evaluated by qualified personnel to determine if repairs are feasible and if so, to establish the repair procedure. Proper repairing procedures and curing shall be inspected.

Repairs should be made as soon as feasible after the defect is noted so that differential shrinkage between the original concrete and the repair concrete is minimized. Concrete used in repairs of major defects should be essentially the same as the original concrete except that the repair concrete should contain less water. Also, the maximum size of aggregate should be as large as possible but not greater than one-half the minimum dimension of the repair. The procedures outlined in Sec. 4.7.1 can be used to repair the product. The repair concrete should become an integral part of

the product with no delaminations or cracks.

4.7.3 Inspection of Repairs

Products that require repairs of honeycombed areas or major repairs shall be inspected while repairs are made. A record of any major repairs shall be documented and filed with the final inspection report for that product.

Even minor repairs should be inspected to assure that no damage has been done to products being repaired. The inspection records for repairs of major defects should indicate any deviations from the established repair procedure.

4.7.4 Plant Requirements:

1. The plant shall have documented procedures for repair of damaged products, including procedures for repair of honeycombing, excessive air voids, and minor and major defects. The procedures shall list acceptable repair products to be used.

2. After repairs are completed and inspected, a mark shall be made on the product indicating that it is acceptable, or that it is rejected.

3. QC Inspector shall perform spot checks of repairs.

4. Major repairs shall be documented.

4.8 MARKING, STORAGE, AND SHIPMENT OF PRODUCTS

4.8.1 Product Marking

Products shall be marked as required by project specifications. Unless otherwise prevented by product specifications or aesthetic reasons, products shall be prominently marked indicating conformance with this manual. For plants participating in the NPCA Plant Certification Program this mark shall be the “NPCA Certified Plant” symbol.

4.8.2 Storage Areas

Areas used for storage of products shall be firm enough and level enough to avoid causing damage to stored products.

It is good practice to place in storage only products that

are ready for shipment, thus minimizing product handling. Also, repairs are generally controlled better and done more effectively in a designated area than in a storage yard. Thus, storage areas should be arranged so that products will not be damaged and are readily accessible.

4.8.3 Storage of Products

Products shall be stored in a manner that will minimize damage caused by uneven bearing, improperly located dunnage blocks, stacking products too high or difficulty in handling.

Products should preferably be stored on level surfaces. Bearing surfaces should be large enough to prevent chipping or fracturing of the product.

Reject product that cannot be adequately repaired shall be uniquely marked such that plant personnel can easily identify it as reject. Reject product shall be stored separately from normal stock.

4.8.4 Shipment of Products

Trucks and other conveyances used to transport precast concrete products from the plant to the location designated by the customer shall be equipped and maintained to deliver those products without damaging them to the extent that they must be repaired or rejected.

Trucks and other delivery equipment should be inspected periodically to ensure products will be delivered without damage. Copies of delivery receipts are normally kept for billing and inventory purposes. They should also be reviewed by management to monitor the number of products damaged and how they were damaged, so that appropriate action can be taken to minimize future damage.

Records shall be kept for at least a year of all products and accessories shipped on each load. The record shall indicate which items, if any, were damaged when delivered.

Refer to the NPCA publication titled "Cargo Securement Regulations for the Precast Concrete Industry" for more information.

4.8.5 Final Inspection

Prior to shipment, products shall be inspected to assure design conformance and proper identification. The precast plant shall establish a procedure for sampling and inspecting products that are shipped in bulk. Products that are handled individually during out-loading shall be inspected individually. Inspections shall be documented.

Many precast products should be inspected individually, but some products such as modular pavers and transformer bases can be inspected in groups.

Products not conforming to requirements shall be clearly labeled and the defects noted on the inspection report. Only products conforming to the requirements shall be shipped unless the purchaser is notified of defects. Management shall be notified of defects prior to shipment so that action can be taken.

Management should review inspection reports prior to shipment in order to minimize sub-quality products leaving the yard.

4.8.6 Plant Requirements:

1. Storage areas shall be maintained firm and level such that products are not damaged during handling and do not sink into the ground.
2. Products shall be stored to minimize damage.
3. The QC Inspector shall inspect the storage area and the stored product daily.
4. A final inspection of products prior to shipment shall be made. This inspection shall be documented in the plant records. The inspection shall include verification that the product conforms to project requirements, contains the proper post-pour inspection markings, and that repairs have been made and inspected where needed.
5. The QC Inspector shall spot check the final inspection of the products, loading and tie-down procedures.

CHAPTER 5 - QUALITY CONTROL OPERATIONS

5.1 SUMMARY OF REQUIRED RECORDS

Unless otherwise specified in this manual, all required documentation and records shall be kept for a minimum of three (3) years. Plants initially entering the NPCA Plant Certification Program shall have a minimum of 30 calendar days of records prior to their initial audit. Thereafter, all required documentation and records shall be kept on file until the applicable minimum retention time has elapsed.

It is suggested that all of the required records be maintained in a central location at the plant. In addition, it is very helpful if the records are organized in a similar sequence as the sections of this manual.

5.1.1 Raw Material Test Records

Records of incoming raw materials shall be kept by the precast plant for a minimum of three (3) years. These records shall at a minimum include the following:

a. Cement mill certificates
b. Aggregate reports
c. Mix water potability or suitability tests
d. Chemical admixture and supplementary cementitious material certifications
e. Reinforcement supplier reports
f. Joint sealant, gasket and connector supplier reports
g. Accessories supplier reports
h. Batching records or ready-mixed concrete delivery tickets

Test records are useful in verifying that materials used in manufacturing precast concrete products conformed to the product specifications. They are useful in isolating problems that occur either soon after a product is cast or long after a product has been in service. Accessories are design items included in the products but do not include the wire, chairs, clips, etc.

5.1.2 Work Orders and Product Drawings

Work orders for each project shall be kept by the precast plant until the project is completed. Product drawings shall be kept by the precast plant for at least three (3) years.

Most work orders are internal documents and as such need not be kept for quality control purposes. However, product drawings are important documents that may be useful in product evaluation years after the product has been in service. Precast plants that make custom products should have a procedure for keeping drawings, electronic scans, microfilms of the drawings, or other methods of retaining

product drawings.

5.1.3 Equipment Calibration Records

Records for calibration of equipment shall be maintained so that the equipment operator has ready access to the records. Current calibration stickers shall be attached to and prominently displayed on all equipment requiring calibration. All of the following equipment shall be calibrated a minimum of once per year:

- Concrete batching scales
- Water meters
- Admixture batching equipment
- Concrete compression test machines
- Portable scales
- Air meter
- Unit weight bucket
- Rebound hammer (if used)
- Temperature recorders and clocks
- Three-edge bearing test machines
- Pipe and manhole measuring devices (i.e., go-no-go gages)
- Vacuum and hydrostatic testing equipment

Calibration of batching scales, compression testing machines and three-edge bearing testing machines shall be performed by an independent, third-party calibration company. All other calibrations shall be performed in-house, by the supplier, or by an independent, third-party calibration company.

5.1.4 Aggregate and Concrete Test Records

Records of tests for aggregate gradation, organic impurities in aggregates, and aggregate moisture content shall be kept for a minimum of three (3) years. Records of tests of concrete temperature, slump, air content, density (unit weight), and compressive strength shall be kept by the precast plant for a minimum of three (3) years.

Unless records of aggregate and concrete tests are identified in such a manner that make it possible to determine which products were made with the materials tested, they are not very useful. A simple orderly method of relating such records to specific products can make the test reports valuable.

STANDARD	COMMENTARY
5.1.5 Concrete Batching Reports	
Daily reports of actual concrete mix proportions for each mix used and quantities of concrete produced shall be documented and maintained on file by the precast plant for a minimum of three (3) years.	*A method of identifying which products are made from each batch should be used in order to make the records useful.*
5.1.6 General Plant and Product Inspection Records	
QC Inspector inspection reports and product inspections records shall be maintained on file by the precast plant for a minimum of three (3) years.	*Records of final inspections of products are only useful from the standpoint that they show the products were judged to be of adequate quality when they left the plant. Thus, they are most useful as a plant management tool.*
5.1.7 Plant Requirements:	
Maintain the required records in an easily accessible and well-organized file. Documentation shall be easily retrievable and indexed to specific products by date or piece number. Records shall be maintained for the minimum duration.	
5.2 AGGREGATE TESTING	
5.2.1 Aggregate Gradation	
Gradation tests shall be made for each 1,500 tons (1,350 metric tons) of fine aggregate and each 2,000 tons (1,800 metric tons) of coarse aggregate by either the aggregate supplier or by the precast plant. Gradation tests shall be performed in accordance with ASTM C136, “Standard Test Method of Sieve Analysis of Fine and Coarse Aggregates.”	*Gradation tests are used to determine if aggregates conform to applicable specifications. Concrete mixes are generally designed based on aggregates having specific gradations (particle size distributions). One of the reasons for performing aggregate gradation tests is to note changes in gradation so that concrete mixes can be adjusted, or*

perhaps they should be redesigned. A rule of thumb is that a change in the fineness modulus of the fine aggregate of 0.20 or more indicates that an adjustment or redesign should be made. Large variations in coarse aggregate gradations may warrant adjustments to the concrete mix. Changes in the amount of material passing the No. 50 (0.300 mm) sieve often indicate changes in workability and in the bleeding characteristics of the concrete.

5.2.2 Moisture Content

5.2.2.1 For conventional and/or dry-cast concrete, aggregate surface moisture content (i.e., water in excess of that absorbed by the aggregates) shall be determined at least once per day in accordance with ASTM C70, "Standard Test Method for Surface Moisture in Fine Aggregate," by alternate methods such moisture meters or probes, or by ASTM C566, "Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying." Drying aggregate using a microwave or hot plate shall be permitted in addition to using an oven.

It is very important to know the moisture content of the aggregate in order to determine the water content in the concrete batch. This information is useful for determining and making adjustments to mix designs as well.

5.2.2.2 For SCC when moisture probes or meters are used with automatic mixing water adjustment systems, the aggregate surface moisture content shall be determined at least once a day prior to making the first SCC batch. Moisture tests shall be performed in accordance with ASTM C70, "Standard Test Method for Surface Moisture in Fine Aggregate," or by ASTM C566, "Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying." Drying aggregate using a microwave or hot plate shall be permitted in addition to using an oven. Samples for moisture tests shall be taken as close as possible to the area where the probe is located.

Since SCC concrete is very moisture sensitive, precise control of the water content is essential. Verifying aggregate surface moisture will allow for necessary adjustments in mix water as the moisture content of the aggregates changes throughout the day. Slump Flow and VSI testing will only confirm whether a SCC mixture is within spec and become necessary for

5.2.2.3 For SCC made without moisture probes or meters and automatic mixing water adjustment systems, the aggregate surface moisture content shall be determined at least once a day prior to making the first SCC batch and then once every four hours of elapsed time after the first batch, while SCC is being mixed. Moisture tests shall be performed in accordance with ASTM C70, "Standard Test Method for Surface Moisture in Fine Aggregate," or by ASTM C566, "Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying." Drying aggregate using a microwave or hot plate shall be permitted in addition to using an oven. In addition, Slump Flow and VSI tests shall be performed in accordance with section 5.3.1.2 for every three batches of SCC produced (This is to ensure that moisture fluctuations of aggregates are accounted for correctly). In lieu of this additional Slump Flow and VSI testing, moisture tests may be performed as specified in this section every three batches.

this confirmation if moisture tests are not performed on a regular basis (every 3 mixes).

In situations where the plant is producing SCC, the plant should consider performing unit weight of the mix in addition to slump flow and VSI as another verification of proper mix proportioning.

5.2.3 Plant Requirements:

Records of aggregate gradations, deleterious substance and aggregate moisture tests shall be maintained in the plant records.

5.3 CONCRETE TESTING *

** Critical Requirement – plants participating in the NPCA Plant Certification Program must receive a minimum passing grade, as shown on the grading schedule, for this entire section and others designated as Critical Requirements, when applicable.*

5.3.1 Slump, Slump Flow, and Visual Stability Index

5.3.1.1 Slump

A slump test shall be performed for each 150 cubic yard (115 cubic meters) of concrete, or once a day, whichever comes first. Slump tests shall be performed in accordance with ASTM C143, "Standard Test Method for Slump of Hydraulic-Cement Concrete." SCC, no-slump, or dry-cast concrete does not need to be tested for slump.

5.3.1.2 Slump Flow and Visual Stability Index

For SCC mixtures, slump flow and Visual Stability Index (VSI) tests shall be performed each day by testing the first batch of SCC, and then consecutive batches until two consecutively produced batches are within spec., as defined by the initial mix qualification process. Thereafter, slump flow and VSI testing

The slump test is used to determine the consistency of fresh concrete and the uniformity of concrete from batch-to-batch. If the batch

shall be performed as follows:

- Every 50 yards or 25 batches, whichever comes first
- When changing mix designs
- When changing raw materials
- When a mixture becomes suspect or a problem occurs, and
- As required in Section 5.2.2.3

Slump flow and VSI tests shall be performed in accordance with the test methods described in the PCI Interim Guidelines for Using Self-Consolidating Concrete, Appendix 1, until such time that ASTM International standards have been completed. At that time, the ASTM test methods shall become the standard. Variations in PCI test methods are acceptable until ASTM test methods become available and if such variations are documented in the plant-specific QC manual and also were used in the initial mix qualification process.

weights of cement, water, and aggregates are reasonably correct, changes in slump are probably due to changes in aggregate moisture or in dispensing of admixtures. However, slump variations can also occur because of changes in aggregate gradations, temperature and air content.

The air content of an SCC mix can affect the desired properties of the mixture and it is recommended that the air content be tested regularly with the Slump Flow and VSI.

5.3.2 Temperature

The temperature of fresh concrete shall be measured when slump or air content tests are made and when compressive test specimens are made. The measured concrete temperature shall be recorded together with other fresh concrete test data. Concrete temperature testing shall be performed in accordance with ASTM C1064, “Standard Test Method for Temperature of Freshly Mixed Portland Cement Concrete.”

Temperature of fresh concrete affects a number of properties of concrete. Warm concrete sets faster than cool concrete. Warm concrete gains strength faster than cool concrete, but the strength at later ages will be lower than that of cool concrete.

Knowledge of the temperature of fresh concrete permits the batch plant operator to adjust mixes and allows the concrete foreman to better allocate workmen. Also, warm concrete tends to dry faster so curing of warm concrete is even more important than curing of cool concrete.

STANDARD	COMMENTARY
5.3.3 Density (Unit Weight)	
Tests for density (unit weight) of fresh concrete shall be performed a minimum of once per week to verify the yield of batch mixes. Unit weight tests shall be performed for each 100 cubic yards (75 cubic meters) of lightweight concrete or once per month, whichever occurs first. Tests shall be performed in accordance with ASTM C138, "Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete."	*The density (unit weight) of concrete is often specified for products made of lightweight concrete. If the density is higher or lower than the specified limits, adjustments should be made to the mix to increase or decrease the density. After adjustments are made, the density should again be measured. The best method for checking the yield of concrete (the actual volume of concrete produced from quantities of materials, which theoretically are needed for one cubic yard or one cubic meter of concrete) is by dividing the total weight for a cubic yard or a cubic meter (theoretical) by the density of the concrete.*
5.3.4 Air Content	
Tests for air content shall be made on air-entrained, wet-cast concrete for each 150 cubic yards (115 cubic meters) of concrete, but not less often than once each day when air-entrained concrete is used. Air content shall be determined by either the pressure method, ASTM C231, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method," or the volumetric method, ASTM C173, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method." A unit weight test, performed in accordance with ASTM C138, may be substituted for ASTM C231 or ASTM C173 after a correlation between air content and unit weight has been established.	*Concrete is air-entrained not only for its improved resistance to freezing and thawing but also because air-entrainment reduces bleeding and segregation. For frost resistance, air contents given in Table 3.1.3 should be used. Air contents higher than the values given in that table will reduce concrete strength dramatically. Air contents lower than the tabulated values will not provide adequate frost resistance. However, if the air contents are slightly*

lower than the tabulated values, the concrete will benefit from reduced segregation and bleeding as compared to a non air-entrained concrete.

For normal-weight concrete, either the pressure method or the volumetric method can be used, but the pressure method is generally preferred because the test can be done more quickly and more easily. For lightweight concrete, the volumetric method is generally required and much more accurate than the pressure method.

An air indicator is a small hand-held device, which utilizes a thimbleful of material passing a No. 10 (2.0 mm) sieve. It can be done very quickly and gives a reasonable indication of air content, provided it has been calibrated by comparing a number of air indicator measurements with results of air- meter tests.

5.3.5 Compressive Strength

5.3.5.1 For wet-cast concrete, specimens shall be a 6-inch diameter by 12-inch high cylinders unless the maximum aggregate size is 3/4 inch or smaller, in which case 4-inch diameter by 8-inch high cylinders may be used. Compressive strength cylinders shall be made in accordance with ASTM C31, "Standard Practice for Making and Curing Concrete Test Specimens in the Field." Specimens shall be cured in a manner similar to the curing of the concrete products represented by the specimens, unless otherwise required by project

The main reason for making and testing compressive strength specimens is to determine if the concrete strength conforms to the requirements. Strength tests are also useful at early ages to evaluate curing methods and to

requirements.

determine uniformity of concrete. Making and testing 4 x 8-inch cylinders is easier and costs less than using 6 x 12-inch specimens so the use of 4 x 8-inch cylinders is encouraged unless specifications prohibit their use. Use of 4 x 8-inch cylinders has advantages that specimens are smaller, are easier to make, use less concrete, are easier to handle and require less storage space.

5.3.5.2 For machine-cast and/or dry-cast concrete products, test cylinders can be vibrated or cores cut from the product. Test cylinders shall be vibrated in the same method as the product they represent or fabricated according to the applicable section of ASTM C497.

Often times, dry-cast equipment is equipped with test cylinder holding devices that enable specimens to be vibrated the same as the product. Sometimes cores or cubes cut from products after the concrete has hardened are required as test specimens. For small products, the entire product might be used as a specimen and tested in compression. Whatever the specimen, a "standard" test procedure should be established so that results of tests conducted at different times can be correlated.

5.3.5.3 At least four compressive strength specimens shall be made for each 150 cubic yards (115 cubic meters) of concrete of each mix or once per week, whichever occurs first. Two specimens shall be tested at or before 7 days and the other two shall be tested at 28 days or at the age specified by the design. Specimens made in cylinder molds shall be tested in accordance with ASTM C39, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens." Cubes or cores cut

It is generally not necessary to perform the 28-day tests if the results of the 7-day tests exceed the 28-day strength requirement. Nevertheless, it is useful to perform the 28-day tests on some specimens to establish a relationship

from products shall be tested in accordance with ASTM C42, "Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete."

between the 28-day and earlier tests.

5.3.5.4 As an alternate to the use of test cylinders, or if cylinder tests fall below the specified value, three cores may be used to determine concrete strength. Cores shall be obtained and tested in accordance with ASTM C42. If the concrete products represented by the cores will be dry under service conditions, cores shall be air dried (at room temperature with the relative humidity less than 60%) for 7 days, and shall be tested dry. If the concrete in service will be more than superficially wet, cores shall be immersed in water for at least 40 hours and tested wet. Concrete represented by cores obtained because of low-strength cylinders shall be considered adequate if the average strength of the cores is at least 85% of the specified strength.

Care should be taken to avoid cutting reinforcing bars where cores are obtained. Reinforcement in cores can affect the strength, depending on the quality and orientation of the reinforcement. The average value for cores of 85% of the specified strength is realistic since cores will generally yield lower strength results than test cylinders because of differences in size of specimens, conditions for obtaining samples and curing.

5.3.5.5 If the concrete strength is lower than specified and the compressive strength test specimens have been depleted, a calibrated impact rebound hammer may be used to indicate strength of the concrete after additional curing of the concrete. Impact rebound hammer shall be used in accordance with ASTM C805, "Standard Test Method for Rebound Number of Hardened Concrete."

Impact rebound hammers are useful devices but they should be calibrated periodically. One way of calibrating the hammer is to compare the rebound number on products with the compressive strengths of specimens representing the concrete in the products. Rebound numbers on products should be obtained at the same age as the age at which the compressive strength specimens are tested.

5.3.6 Plant Requirements:

1. Persons conducting QC tests shall be properly trained to perform the tests (see Section 1.1.3).
2. Proper test techniques and procedures shall be demonstrated

See table 5.3.6 a, b, and c for required minimum frequency of Quality Control

for slump, temperature, unit weight, air content, and fabrication of compressive strength cylinders during the NCPA inspection.

3. Track the number of tests on each neoprene compression test pad, if used.
4. If testing is performed by an outside testing agency, maintain records that the personnel performing the tests have been properly trained.

operations.

Table 5.3.6 a
Frequency of Quality Control Operations
Materials Certifications and Equipment Calibrations

Section in NPCA QC manual	Item	Each Shipment	Each 1,500 Tons (b)	Each 2,000 Tons (c)	Each 200 CY (d)	Each Pour	Each 150 CY (e)	Each 100 CY (f)	Daily	Weekly	Monthly	Annually	Remarks
2.1.1	Cement mill test report	X[(a)]											
2.2.1	Reinforcing bars mill certificates	X[(a)]											
2.2.2	Reinforcing wire mill certificates	X[(a)]											
2.2.3	Bar mats and welded wire fabric mill certificates	X[(a)]											
3.1.4	Admixture dosing equipment certification											X[(a)]	
3.2.4	Weigh batch scales calibration											X	

Notes:

(a) Items may be furnished by the raw material supplier

(b) 1,350 cubic meters

(c) 1,800 cubic meters

(d) 150 cubic meters

(e) 115 cubic meters

(f) 75 cubic meters

Table 5.3.6 b
Frequency of Quality Control Operations
Production Practices

Section in NPCA QC manual	Item	Each Shipment	Each 1,500 Tons	Each 2,000 Tons	Each 200 CY	Each Pour	Each 150 CY	Each 100 CY	Daily	Weekly	Monthly	Annually
4.1.2	Housekeeping								X			
4.1.3	Forms cleaned of build-up					X						
4.1.5	Dimensional checks of machine-made products								X			
4.3.5	Pre-pour inspection					X						
4.6.4	Post-pour inspection					X						
4.8.3	Final inspection	X										

Table 5.3.6 c
Frequency of Quality Control Operations
Aggregates and Concrete

Section in NPCA QC manual	Item	Each Shipment	Each 1,500 Tons (a)	Each 2,000 Tons (b)	Each 200 CY (c)	Each Pour	Each 150 CY (d)	Each 100 CY (e)	Daily	Weekly	Monthly	Annually	Remarks
2.1.2	Fine aggregate gradation and deleterious substances		X								X		whichever occurs first
2.1.3	Coarse aggregate gradation and deleterious substances			X							X		whichever occurs first
2.1.4	Lightweight aggregate gradation and deleterious substances				X						X		whichever occurs first
5.2.2	Organic impurities in fine aggregate												When aggregate is suspect
5.3.1	Slump of concrete						X		X				whichever occurs first
5.3.2	Temperature of concrete						X		X				When air content or slump is tested
5.3.3	Density (unit weight) of concrete									X			Except for lightweight concrete
5.3.3	Density (unit weight) of *lightweight* concrete							X					
5.3.4	Air content of air-entrained concrete						X		X				whichever occurs first
5.3.5.3	Compressive strength of wet cast concrete						X			X			whichever occurs first
5.3.5.3	Compressive strength of dry cast concrete						X						

Notes:

(a) 1,350 metric tons

(b) 1,800 metric tons

(c) 150 cubic meters

(d) 115 cubic meters

(e) 75 cubic meters

STANDARD	COMMENTARY

CHAPTER 6 - SPECIAL REQUIREMENTS FOR SPECIFIC PRODUCTS

6.1 PRODUCTS MANUFACTURED ACCORDING TO ASTM INTERNATIONAL AND OTHER INDUSTRY STANDARDS

The requirements in this chapter are in addition and complementary to the requirements in chapters 1 through 5. The plant shall comply with all applicable requirements of this manual.

The requirements in sections 6.1 through 6.5 are intended for the producer to demonstrate that the final product is capable of performing in a manner consistent with ASTM International specifications and other industry standards that are used to verify acceptable product manufacture and performance.

6.1.1 Product Manufacture

Precast concrete products, which are covered by ASTM International standards, exclusive of those covered in Sections 6.2 through 6.5 of this manual, shall be manufactured in accordance with those standards, unless otherwise dictated by project specifications. Product specifications and drawings that supersede certain ASTM requirements are permitted. Additional product-specific requirements are outlined in Sections 6.2 through 6.5.

If the plant claims to manufacture certain products that meet ASTM specifications, then the plant should be able to prove such claims.

Whenever ASTM International standards are referenced in this manual, the latest edition of the standard shall apply, unless the specifier specifically requires conformance with an earlier edition.

Applicable precast concrete product-specific ASTM standards include are listed in Appendix A.

Each individual ASTM International standard specifically states the necessary documentation and proof of conformance required.

6.1.2 Proof of Conformance

Proof of conformance to specific ASTM International standards shall be maintained on file at the plant. Proof of conformance shall consist of one or more of the following: design calculations and drawings, documentation of performance testing, documentation of the design conditions and specific requirements stated in individual ASTM International standards.

Proof of conformance with ASTM standards should be a normal part of the quality control operations, unless other more stringent design requirements are specified for projects.

STANDARD	COMMENTARY
6.1.3 Plant Requirements:	
Proof of conformance to applicable ASTM International standards shall be documented and maintained on file at the plant for all products being produced according to ASTM International standards. Annual test data (or other test data) shall be maintained at the plant for a minimum of three years.	
6.2 STORMWATER CONCRETE PIPE REQUIREMENTS	
Plants producing concrete pipe shall specifically conform to the requirements in section 6.2 of this manual, in addition to the applicable requirements in chapters 1 through 5.	*NOTE: Section 6.2 is intended for pipe that will be used for <u>stormwater</u> drainage systems.* *Additional testing may be required for pipe intended to be used for sanitary wastewater drainage systems, however such testing is not outlined in this manual.*
6.2.1 Reinforcing Steel Inspection *	
As required in Section 4.1.5 and 4.2.1, maintain documentation of reinforcing cage inspections with information on the required cage design versus the actual cage used, including WWR style, steel area, wire diameter, cage diameter, cage length, and welded/tied wire laps.	** Critical Requirement – plants participating in the NPCA Plant Certification Program must receive a minimum passing grade, as shown on the grading schedule, for section 6.2.1 and others designated as Critical Requirements, when applicable.*
6.2.2 Three-Edge Bearing Testing *	
For reinforced concrete pipe, verification of conformance to applicable standards (ASTM C76 and C655) shall be documented by performance of three-edge bearing testing in accordance with ASTM C497. The plant shall load the pipe up to the specified design strength D-load to produce a 0.01-inch crack. Test frequency shall be a minimum of one test per year, for each size (and class) of pipe, or as described below, whichever is greater.	** Critical Requirement – plants participating in the NPCA Plant Certification Program must receive a minimum passing grade, as shown on the grading schedule, for section 6.2.2 and others designated as Critical Requirements, when applicable.*

Pipe Size/Diameter (inches)	Test Frequency
12 through 15	one for every 800
18 though 36	one for every 400
42 through 60	one for every 200
66 and larger	as specified by project requirements

Three-edge bearing testing is critical since it is an industry-accepted method of verifying the strength and design of the pipe.

In addition to the above requirements, a minimum of one test per year to ultimate load shall be performed on each size and class of pipe manufactured to verify that the applicable specified ultimate load can be achieved.

Although testing up to ultimate load destroys the product, it is the only way to ensure that the design requirements are being met.

For unreinforced concrete pipe, verification of conformance to applicable standards (ASTM C14 and C985) shall be demonstrated by performance of three-edge bearing testing in accordance with ASTM C497. The plant shall test up to the specified design strength ultimate load. Test frequency shall be a minimum of one test per year, for each size (and class) of pipe, or as described below, whichever is greater.

Pipe Size/Diameter (inches)	Test Frequency
12 through 15	one for every 800
18 through 36	one for every 400
42 through 60	one for every 200
66 and larger	as specified by project requirements

For pipe designed for installed conditions with soil interaction, three-edge bearing shall not be required.

Unless otherwise required by project specifications, three-edge bearing testing of elliptical and arch pipe shall not be required.

6.2.3 Absorption Testing *

Verification of conformance to the concrete absorption requirements of applicable standards shall be documented by performance of absorption testing in accordance with ASTM C497 (Test Method A or B). Testing shall be performed a minimum of once per year, on the mix design with the lowest amount of cementitious material used at each operation or manufacturing station. Both in-plant and laboratory testing shall be permitted.

** Critical Requirement – plants participating in the NPCA Plant Certification Program must receive a minimum passing grade, as shown on the grading schedule, for section 6.2.1 and others designated as Critical Requirements, when*

applicable.

6.2.4 Dimensional Checks

Verification of conformance to applicable dimensional requirements shall be performed and documented on a minimum of three concrete pipe or 3% of each day's production, whichever is greater, chosen randomly by plant quality control personnel.

Procedures for checking pipe dimensions and the associated acceptable tolerances should be documented in the plant-specific QC manual, as outlined in Section 1.1.2 of this manual.

Normal Post-pour inspection requirements apply to both wet-cast and dry-cast / machine-cast pipe, as required in Sections 4.6.4 and 4.6.5.

At a minimum, dimensional checks shall include internal diameter, wall thickness, and length of two opposite sides (measured directly across from each other). Joints must be checked for dimensional conformance with either manufacturer's specifications, applicable standards and/or specifying authorities.

6.2.5 Joint Design and Testing

Joints shall be designed according to the applicable requirements in ASTM C443, ASTM C990, or as required by project requirements. Critical dimensions and allowable tolerances shall be clearly indicated on the resulting joint design drawings. Joint designs drawings must be kept on file and readily available for routine and audit inspection personnel.

Proper joint designs are crucial to the performance of installed pipe when infiltration or exfiltration are a factor in the project.

The plant shall perform and document joint proof-of-design leakage testing on each size of gasketed pipe produced at the plant. Testing shall be repeated whenever joint or gasket designs are modified. Joint proof-of-design testing, unless otherwise required by the authority or authorities having jurisdiction, shall consist of either vacuum or hydrostatic testing conducted in two configurations:

Joint proof-of-design testing is required only in cases where the plant uses gasketed joints.

1) Assembled in-line (rectilinearly) and
2) Assembled with one side of the joint open 1/2-in. more than the opposite side.

6.2.5.1 Joint Proof-of-Design Hydrostatic Testing

Testing shall be performed according to the hydrostatic test method set forth in ASTM C497. Any water leaking from the joint being tested must be collected for measurement at the end of the

Pipe temperature should be as close to ambient as possible at the time of testing in order to ensure

test. Pipe shall be tested up to 3.5 psi for 12 minutes and the leakage shall not exceed:

accuracy and consistency of test results.

0.041 ozs / (inch internal pipe diam.)(ft. of pipe length)

Pipe that does not pass this test may be repaired and retested.

6.2.5.2 Joint Proof-of-Design Vacuum Testing

Testing shall be performed with a negative test pressure (vacuum) equivalent to 7 inches of mercury. The pipe being tested shall maintain a minimum of 6.9 inches of mercury throughout the test time period (T_{test}), which is calculated as follows:

T_{test} (seconds) = 1.5 x internal diam. of the pipe (inches)

If the pipe being tested does not hold the required vacuum, it may be repaired and retested.

6.2.6 Gasket Quality Control

Certificates of conformance shall be received for each shipment of gaskets. In addition to physical property test results, the certificates shall include information listed below for each gasket type (length, durometer, dimensions, etc.). In lieu of supplier certification documentation, in-house gasket testing shall be performed and documentation maintained on file at the plant. One gasket of each type shall be tested for every 300 received, according to the following:

Gasket quality control documentation is required only in cases where the plant actually uses gasketed joints.

Prelubricated gaskets shall be tested for durometer (ASTM D2240), length (ASTM C497), height, width and splice strength.

O-ring gaskets shall be tested for durometer (ASTM D2240), length (ASTM C497), volume (ASTM C497), diameter and splice strength.

Profile gaskets shall be tested for durometer (ASTM D2240), length (ASTM C497), height, width and splice strength.

For height, width and diameter measurements, several measurements should be made along the length of the gasket, away from the splice, and the average value should be recorded.

For splice strength testing, the gasket should be stretched approximately 100% and the splice visually inspected for defects and separation.

If any quality control measurements indicate that the gasket is not within acceptable tolerances, additional gasket testing shall

be performed to determine if the remainder of the lot should be used. Non-conforming gaskets shall not be used or supplied by the plant for installation on products.

6.2.7 Plant Requirements:

1. As required in Section 4.1.5, 4.2.1 and 6.2.1, maintain documentation of reinforcing cage inspections with information on the required cage design versus the actual cage used.

2. Three-edge bearing testing techniques of concrete pipe, when required by the applicable ASTM standard, shall be witnessed by the inspector during an NPCA Plant Certification inspection.

3. Test records and dimensional check documentation shall be maintained at the plant for a minimum of three (3) years.

4. Detailed reinforcing cage design drawings shall be readily available in the steel fabrication/production area.

5. Gasket certification records and/or quality control records shall be maintained at the plat for a minimum of three (3) years.

6. Joint design and proof-of-design testing documentation shall be maintained on file at the plant indefinitely.

7. As required in Section 4.1.3, maintain documentation of pallet, header and truing rings as long as each respective piece of forming equipment is in use at the plant.

6.3 ROUND MANHOLE COMPONENT REQUIREMENTS

Plants producing round manholes and associated components according to ASTM C478 “Standard Specification for Precast Reinforced Concrete Manhole Sections” shall specifically conform to the requirements in section 6.3 of this manual, in addition to the applicable requirements in chapters 1 through 5.

Section 6.3 pertains to manhole structures that are intended for utility, storm water drainage or sanitary wastewater drainage structures.

STANDARD	COMMENTARY
6.3.1 Reinforcing Steel Inspection *	
As required in Section 4.1.5 and 4.2.1, maintain documentation of reinforcing cage inspections with information on the required cage design versus the actual cage used, including WWR style, steel area, wire diameter, cage diameter, cage length, and welded/tied wire laps. Reinforcing steel inspection is not required if reinforcing steel is not used in certain manhole products or when fiber reinforcement is used in lieu of conventional reinforcing steel.	** Critical Requirement – plants participating in the NPCA Plant Certification Program must receive a minimum passing grade, as shown on the grading schedule, for section 6.3.1 and others designated as Critical Requirements, when applicable.*
6.3.2 Flat Slab Tops	
Verify the design for each size flat slab top produced or stocked by the plant, either by maintaining rational design calculations or by proof testing, as outlined in the applicable section(s) of ASTM C497. The design shall meet the minimum requirements of ASTM C478.	*Design calculations should be performed and stamped by a qualified, licensed engineer. Proof testing (when performed) should also be reviewed by a qualified, licensed engineer.* *Note: The minimum reinforcing steel requirements for flat slab tops outlined in ASTM C478 represent the absolute minimum steel that should be used in flat tops. Additional reinforcement and/or slab thickness may be required to adequately support the design loads.*
6.3.3 Base, Riser and Cone Sections	
6.3.3.1 Absorption Testing	
Verification of conformance to the concrete absorption requirements of ASTM C478 shall be documented by performance of absorption testing in accordance with ASTM C497 (Test Method A or B). Testing shall be performed a minimum of once per year, on the mix design with the lowest amount of cementitious material used at each operation or	*In order to obtain a true representative test for dry-cast products, it is suggested that a test from each manufacturing operation or station be*

manufacturing station. Both in-plant and laboratory testing shall be permitted.

conducted.

6.3.3.2 Step Testing

Step vertical and horizontal load testing must be performed according to the applicable section(s) of ASTM C497 once per year, per step design used and whenever a new step supplier is used. The loads achieved must meet the requirements of ASTM C478.

Spot checks of proper installation of steps should be included in post-pour inspections.

6.3.3.3 Dimensional Checks

For dry-cast / machine-cast manholes, verification of conformance to ASTM C478 dimensional requirements shall be performed and documented on a minimum of three manhole sections or 3% of each day's production, whichever is greater, chosen randomly by plant quality control personnel.

Normal Post-pour inspection requirements apply to both wet-cast and dry-cast / machine-cast manholes, as required in Sections 4.6.4 and 4.6.5.

At a minimum, dimensional checks shall include: manhole internal diameter; wall thickness; height of two opposite sides; verification of hole locations and size (when applicable); and verification of the invert dimensions and elevations (when applicable).

Procedures for checking manhole dimensions and the associated acceptable tolerances should be documented in the plant-specific QC manual, as outlined in section 1.1.2 of this manual.

6.3.3.4 Sanitary Manhole Vacuum Testing

If in-plant vacuum testing of sanitary manhole sections is required by the authority or authorities having jurisdiction, the plant shall maintain documentation of such testing on file at the plant for a minimum of three (3) years.

Vacuum testing after installation and prior to backfilling operations is the preferred method of watertightness testing of sanitary manholes. Testing should be performed according to ASTM C1244.

6.3.4 Joint Design

Joints shall be designed to perform as required in ASTM C443, ASTM C990, or as required by project requirements. Critical dimensions and allowable tolerances shall be clearly indicated on the joint design drawings.

Proper joint designs are crucial to the performance of installed manhole structures when infiltration or exfiltration are a factor in

STANDARD	COMMENTARY
	the project.
6.3.5 Gasket Quality Control	
Certificates of conformance shall be received for each shipment of gaskets. In addition to physical property test results, the certificates shall include information listed below for each gasket type (length, durometer, dimensions, etc.). In lieu of supplier certification documentation, in-house gasket testing shall be performed and documentation maintained on file at the plant. One gasket of each type shall be tested for every 300 received, according to the following:	Gasket quality control documentation is required only in cases where the plant actually uses gasketed joints.
Prelubricated gaskets shall be tested for durometer (ASTM D2240), length (ASTM C497), height, width and splice strength.	For height, width and diameter measurements, several measurements should be made along the length of the gasket, away from the splice, and the average value should be recorded.
O-ring gaskets shall be tested for durometer (ASTM D2240), length (ASTM C497), volume (ASTM C497), diameter and splice strength.	
Profile gaskets shall be tested for durometer (ASTM D2240), length (ASTM C497), height, width and splice strength.	For splice strength testing, the gasket should be stretched approximately 100% and the splice visually inspected for defects and separation.
If any quality control measurements indicate that the gasket is not within acceptable tolerances, additional gasket testing shall be performed to determine if the remainder of the lot should be used. Non-conforming gaskets shall not be used or supplied by the plant for installation on products.	
6.3.6 Plant Requirements:	
1. As required in Section 4.1.5, 4.2.1 and 6.3.1, maintain documentation of reinforcing cage inspections with information on the required cage design versus the actual cage used. Reinforcing steel inspection documentation shall be maintained on file at the plant for a minimum of three (3) years.	
2. Documentation of rational design calculations and/or proof-of-design testing of flat slab tops shall be maintained at the plant indefinitely.	
3. Documentation of riser and cone section dimensional checks and/or performance testing shall be maintained at the plant for a minimum of three (3) years.	

4. Joint design documentation shall be maintained at the plant indefinitely.

5. Gasket certification records and/or quality control records shall be maintained at the plat for a minimum of three (3) years.

6. Detailed reinforcing cage design drawings shall be readily available in the steel fabrication/production area.

7. As required in Section 4.1.3, maintain documentation of pallet, header and truing rings as long as each respective piece of forming equipment is in use at the plant.

6.4 BOX CULVERT REQUIREMENTS

Plants producing box culverts shall specifically conform to the requirements of Section 6.4 of this manual, in addition to the applicable requirements in chapters 1 through 5.

6.4.1 Absorption Testing

Absorption testing shall be performed and documented in accordance with ASTM C497 (Test Method A or B). Testing shall be performed a minimum of once per year, on the mix design with the lowest amount of cementitious material at each operation or manufacturing station. Both in-plant and laboratory testing shall be permitted.

6.4.2 Joint Design

Joints design drawings shall be maintained on file at the plant for each joint design used. Critical dimensions and allowable tolerances shall be clearly indicated on the joint design drawings. As a proof of design, the plant shall maintain documentation on file indefinitely showing that when assembled, the joint gap between any two box culvert sections is not greater than 3/4 inch (19 mm) in any one location.

Proper joint designs are crucial to the performance of installed box culvert structures when infiltration or exfiltration are a factor in the project. In addition, the joint must be capable of transferring loads across the joint from one section to another.

STANDARD	COMMENTARY
6.4.3 Pre-Pour Inspections *	
In addition to standard pre-pour inspections required in Section 4.3 of this manual, the plant shall also specifically check critical form dimensions including top, bottom and wall thicknesses. The plant shall verify and document compliance with the design drawings by performing a detailed reinforcement check. As required in Section 4.1.5 and 4.2.1, maintain documentation of reinforcing cage inspections for each box culvert reinforcing steel cage with information on the required cage design versus the actual cage used, steel areas, WWR style, cage length, and welded/tied wire laps.	** Critical Requirement – plants participating in the NPCA Plant Certification Program must receive a minimum passing grade, as shown on the grading schedule, for section 6.3.1 and others designated as Critical Requirements, when applicable.* *A sample box culvert inspection form can be found in Appendix B of this manual.*
6.4.4 Dimensional Checks *	
In addition to standard post-pour inspections required in Section 4.6.4 of this manual, the plant shall also specifically check critical product dimensions including top slab, bottom slab and wall thicknesses, and inside length, width and height. These dimensional checks shall be performed on at least one box culvert produced in each form per day.	** Critical Requirement – plants participating in the NPCA Plant Certification Program must receive a minimum passing grade, as shown on the grading schedule, for section 6.3.1 and others designated as Critical Requirements, when applicable.* *Procedures for checking box culvert dimensions and the associated acceptable tolerances should be documented in the plant-specific QC manual, as outlined in section 1.1.2 of this manual.*
6.4.5 Plant Requirements:	
1. Pre-pour inspection and dimensional check documentation shall be maintained at the plant for a minimum of three years. 2. Joint design documentation shall be maintained on file at the plant indefinitely. During an NPCA Plant Certification	

inspection, the inspector may require the plant to demonstrate that when assembled, the joint gap between any two box culvert sections is not greater than 3/4 inch (19 mm) in any one location. The inspector may choose box culverts sections at his/her discretion from reasonably-sized stock in the plant.

3. Detailed reinforcing cage design drawings shall be readily available in the steel fabrication/production area.

6.5 SEPTIC TANK REQUIREMENTS

Plants producing septic tanks shall document proof of conformance with ASTM C1227 "Standard Specification for Precast Concrete Septic Tanks", or other manufacturing requirements mandated by the authority or authorities having jurisdiction. The plant shall specifically conform to the requirements in section 6.5 of this manual, in addition to the applicable requirements in chapters 1 through 5.

It is recommended that plants producing septic tanks follow the practices outlined in the "NPCA Septic Tank Manufacturing Best Practices Manual."

6.5.1 Structural Proof-of-Design

Structural proof-of-design shall be demonstrated either by calculation or by proof testing.

Proof-of-design should be demonstrated for the maximum design burial depth, accounting for the local surface, soil and hydrostatic loading conditions.

Design calculations should be performed and stamped by a qualified, licensed engineer. Proof testing (when performed) should also be reviewed and signed-off by a qualified, licensed engineer.

6.5.2 Watertightness Testing *

Tank watertightness shall be demonstrated according to the applicable section(s) of ASTM C1227 or the requirements set forth by the authority or authorities having jurisdiction, whichever is more stringent. A minimum of one test per year on a septic tank produced in each septic tank form used at the plant shall be

** Critical Requirement – plants participating in the NPCA Plant Certification Program must receive a minimum passing grade, as*

performed and documented. If the authorities having jurisdiction require a greater frequency of testing, the plant shall maintain records of all additional tests at the plant.

shown on the grading schedule, for section 6.5.2 and others designated as Critical Requirements, when applicable.

Watertightness testing of a tank produced in each form is necessary to ensure that all forming equipment remains within appropriate tolerances.

6.5.3 Plant Requirements:

1. Documentation of rational design calculations and/or proof-of-design testing of septic tanks shall be maintained at the plant indefinitely.

2. Watertightness test records shall be maintained on file at the plant for a minimum of three years.

APPENDIX A

STANDARDS CITED IN THE MANUAL
AND REFERENCES

ACI STANDARDS

American Concrete Institute standards and other publications can be obtained from:

American Concrete Institute
PO Box 9094
Farmington Hills MI 48333-9094
Phone: 248-848-3700
Web: www.concrete.org

ACI Standards cited in this manual:

ACI 211.1 "Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete"

ACI 211.2 "Practice for Selecting Proportions for Structural Lightweight Concrete"

ACI 211.3 "Practice for Selecting Proportions for No-Slump Concrete"

ACI 302 "Guide for Concrete Floor and Slab Construction"

ACI 304 "Guide for Measuring, Mixing, Transporting, and Placing Concrete"

ACI 305R "Hot Weather Concreting"

ACI 306R "Cold Weather Concreting"

ACI 318 "Building Code Requirements for Structural Concrete"

ACI 350 "Code Requirements for Environmental Engineering Concrete Structures"

ASTM INTERNATIONAL STANDARDS

ASTM International standards and other publications can be obtained from:

ASTM International
100 Barr Harbor Drive
West Conshohocken PA 19428-2959
Phone: 610-832-9500
Web: www.astm.org

ASTM Standards cited in this manual (metric equivalents may also be applicable):

ASTM A36 "Standard Specification for Carbon Structural Steel"

ASTM A82 "Standard Specification for Steel Wire, Plain, for Concrete Reinforcement"

ASTM A108 "Standard Specification for Steel Bars, Carbon, Cold-Finished, Standard Quality"

ASTM A184 "Standard Specification for Welded Deformed Steel Bar Mats for Concrete Reinforcement"

ASTM A185 "Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete"

ASTM A496 "Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement"

ASTM A497 "Standard Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete"

ASTM A615 "Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement"

ASTM A706 "Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement"

ASTM A767 "Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement"

ASTM A775 "Standard Specification for Epoxy-Coated Steel Reinforcing Bars"

ASTM A884 "Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Fabric for Reinforcement"

ASTM A934 "Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars"

ASTM C14	“Standard Specification for Concrete Sewer, Storm Drain, and Culvert Pipe”
ASTM C31	“Standard Practice for Making and Curing Concrete Test Specimens in the Field”
ASTM C33	“Standard Specification for Concrete Aggregates”
ASTM C39	“Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens”
ASTM C40	“Standard Test Method for Organic Impurities in Fine Aggregates for Concrete”
ASTM C42	“Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete”
ASTM C70	“Standard Test Method for Surface Moisture in Fine Aggregate”
ASTM C76	“Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe”
ASTM C94	“Standard Specification for Ready-Mixed Concrete”
ASTM C117	“Standard Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing”
ASTM C123	“Standard Test Method for Lightweight Particles in Aggregate”
ASTM C136	“Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates”
ASTM C138	“Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete”
ASTM C142	“Standard Test Method for Clay Lumps and Friable Particles in Aggregates”
ASTM C143	“Standard Test Method for Slump of Hydraulic Cement Concrete”
ASTM C150	“Standard Specification for Portland Cement”
ASTM C173	“Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method”
ASTM C231	“Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method”

ASTM C260 “Standard Specification for Air-Entraining Admixtures for Concrete”

ASTM C330 “Standard Specification for Lightweight Aggregates for Structural Concrete”

ASTM C403 “Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance”

ASTM C443 “Standard Specification for Joints for Concrete Pipe and Manholes, Using Rubber Gaskets”

ASTM C478 “Standard Specification for Precast Reinforced Concrete Manhole Sections”

ASTM C494 “Standard Specification for Chemical Admixtures for Concrete”

ASTM C497 “Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile”

ASTM C566 “Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying”

ASTM C595 “Standard Specification for Blended Hydraulic Cement”

ASTM C618 “Standard Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete”

ASTM C655 “Standard Specification for Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe”

ASTM C685 “Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing”

ASTM C805 “Standard Test Method for Rebound Number of Hardened Concrete”

ASTM C857 “Standard Practice for Minimum Structural Design Loading for Underground Precast Concrete Utility Structures”

ASTM C890 “Standard Practice for Minimum Structural Design Loading for Monolithic or Sectional Precast Concrete Water and Wastewater Structures”

ASTM C913 “Standard Specification for Precast Concrete Water and Wastewater Structures”

ASTM C985 “Standard Specification for Nonreinforced Concrete Specified Strength Culvert, Storm Drain, and Sewer Pipe”

ASTM C979 “Standard Specification for Pigments for Integrally Colored Concrete”

ASTM C989 “Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars”

ASTM C990 “Standard Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants”

ASTM C1064 “Standard Test Method for Temperature of Freshly Mixed Portland Cement Concrete”

ASTM C1116 “Standard Specification for Fiber-Reinforced Concrete and Shotcrete”

ASTM C1227 “Standard Specification for Precast Concrete Septic Tanks”

ASTM C1240 “Standard Specification for Silica Fume Used in Cementitious Mixtures”

ASTM C1602 “Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete”

ASTM D2240 “Standard Test Method for Rubber Property—Durometer Hardness”

ASTM G109 “Standard Test Method for Determining the Effects of Chemical Admixtures on the Corrosion of Embedded Steel Reinforcement in Concrete Exposed to Chloride Environments”

Additional Relevant Precast Concrete Product-Specific ASTM International standards (metric equivalents may also be applicable):

ASTM C118 “Standard Specification for Concrete Pipe for Irrigation or Drainage”

ASTM C192 “Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory”

ASTM C361 “Standard Specification for Reinforced Concrete Low-Head Pressure Pipe”

ASTM C412 “Standard Specification for Concrete Drain Tile”

ASTM C444 “Standard Specification for Perforated Concrete Pipe”

ASTM C505 “Standard Specification for Nonreinforced Concrete Irrigation Pipe With Rubber Gasket Joints”

ASTM C506 “Standard Specification for Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe”

ASTM C507 “Standard Specification for Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe”

ASTM C654 “Standard Specification for Porous Concrete Pipe”

ASTM C822 “Standard Terminology Relating to Concrete Pipe and Related Products”

ASTM C825 “Standard Specification for Precast Concrete Barriers”

ASTM C858 “Standard Specification for Underground Precast Concrete Utility Structures”

ASTM C877 “Standard Specification for External Sealing Bands for Concrete Pipe, Manholes, and Precast Box Sections”

ASTM C915 “Standard Specification for Precast Reinforced Concrete Crib Wall Members”

ASTM C923 “Standard Specification for Resilient Connectors Between Reinforced Concrete Manhole Structures, Pipes and Laterals”

ASTM C936 “Standard Specification for Solid Concrete Interlocking Paving Units”

ASTM C1417 “Standard Specification for Manufacture of Reinforced Concrete Sewer, Storm Drain, and Culvert Pipe for Direct Design”

ASTM C1433 “Standard Specification for Precast Reinforced Concrete Box Sections for Culverts, Storm Drains, and Sewers”

ASTM C1478 ”Standard Specification for Storm Drain Resilient Connectors Between Reinforced Concrete Storm Sewer Structures, Pipes and Laterals”

ASTM C1479 “Standard Practice for Installation of Precast Concrete Sewer, Storm Drain, and Culvert Pipe Using Standard Installations”

ASTM C1504 “Standard Specification for Manufacture of Precast Reinforced Concrete Three-Sided Structures for Culverts, and Storm Drains”

ASTM C1603 “Standard Test Method for Measurement of Solids in Water”

ANSI STANDARDS

American National Standards Institute standards and other publications can be obtained from:

American National Standards Institute
1819 L Street, NW
6th floor
Washington, DC 20036
Phone: .202-293-8020
Web: www.ansi.org

ANSI Standards cited in this manual:

ANSI A10.9 “Concrete and Masonry Work Safety Requirements”

AWS STANDARDS

American Welding Society standards and other publications can be obtained from:

American Welding Society
550 NW LeJeune Rd
Miami FL 33126
Phone: 800-443-9353
Web: www.aws.org

AWS Standards cited in this manual:

AWS D1.1 “Structural Welding Code -- Structural Steel”

AWS D1.4 “Structural Welding Code -- Reinforcing Steel”

CFR STANDARDS

Copies of the Code of Federal Regulations can be obtained from:

U.S. Government
Printing Office
732 North Capitol St. NW
Washington, DC 20401
Phone: 202-512-0000
Web: www.gpo.org

CFR Standards cited in this manual:

CFR Title 29 Part 1926 “Safety and Health Regulations for Construction” (www.gpoaccess.gov/cfr/index.html)

CRSI STANDARDS

Concrete Reinforcing Steel Institute standards and other publications can be obtained from:

Concrete Reinforcing Steel Institute
933 N. Plum Grove Road
Schaumburg, IL 60173
Phone: 847-517-1200
Web: www.crsi.org

CRSI Standard cited in this manual:

"Placing Reinforcing Bars"

PCI STANDARDS:

Precast/Prestressed Concrete Institute standards and other publications can be obtained from:

Prestressed Concrete Institute
175 W. Jackson Blvd.
Chicago IL 60604
Phone: 312-786-0300
Web: www.pci.org

PCI Standards Cited in this Manual:

PCI TR-6-03 "Interim Guidelines for the Use of Self-Consolidating Concrete in Precast/Prestressed Concrete Institute Member Plants"

REFERENCES

"Techfiles: A Collection of NPCA Technotes and Techbriefs"

National Precast Concrete Association
10333 North Meridian Street, Suite 272
Indianapolis, IN 46290
Phone: 800-366-7731
Web: www.precast.org

ACI 116 "Cement and Concrete Terminology"

ACI 212.2 "Guide for the Use of Admixtures in Concrete"

ACI 301 "Specifications for Structural Concrete for Buildings"

ACI 308 “Practice for Curing Concrete”

ACI 309 “Guide for Consolidation of Concreting”

ACI 311.1 “ACI Manual of Concrete Inspection”

PCI MNL-116 “Manual for Quality Control for Plants and Production of Precast Prestressed Concrete Products

PCA EB1 “Design and Control of Concrete Mixtures”

PCA PA 015 “Tips on Control Tests for Quality Concrete”

Portland Cement Association
5420 Old Orchard Road
Skokie IL 60077
Phone: 847-966-6200
Web: www.cement.org

“Quality is Free -- The Art of Making Quality Certain” by Phillip B. Crosby
Mentor Book, New American Library
PO Box 999
Bergenfield, NJ 07621

“Concrete Manual” Part 2, 9th ed
NTIS (National Technical Information Services)
US Dept Commerce
Springfield VA 22161
800-553-6847

APPENDIX B

SAMPLE FORMS

Standardized forms are useful for recording and keeping information. Industry-wide forms are too often cumbersome for most plants, so it is recommended that each plant develop forms applicable to its operations and products. The basic principle in developing forms is to make each form complete but as simple as possible. The forms included in this appendix are examples of those being used in the precast concrete products industry.

RAW MATERIAL REPORT

QUALITY CONTROL DEPARTMENT

Job No _____ Job Name _____

CEMENT	mfr.		mill cert. #	
TYPE	Type I ☐	Type II ☐	Type III ☐	

FINE AGGREGATE

Sieve Size	Weight Retained	% Retained	% Passing	ASTM C 33 % Passing
3/8"				100
No. 4				95-100
No. 8				80-100
No. 16				50-85
No. 30				25-60
No. 50				10-30
No. 100				2-10
Pan				0
Fineness Modulus				

COARSE AGGREGATE

Sieve Size	Weight Retained	% Retained	% Passing	ASTM C 33 size 67 % Pass	ASTM C33 size 8 % Pass
1"				100	0
3/4"				90-100	0
1/2"				0	100
3/8"				20-55	85-100
No. 4				0-10	10-30
No. 8				0-5	0-10
No. 16				0	0-5

ADMIXTURE

☐corrosion inhibitor

☐air entraining agent

☐superplasticizer

☐fly ash

☐accelerator

☐other _____

Date _____

Inspector _____

Supervisor _____

PRE-POUR INSPECTION REPORT

QUALITY CONTROL DEPARTMENT

PRODUCT:							
Job # / Casting Date	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
Form Condition							
Form Cleanliness							
Form Joints							
Release Agent/Retarder							
Design Length (ft/in)							
Set-Up Length (ft/in)							
Design Width (ft/in)							
Set-Up Width (ft/in)							
Design Detph (ft/in)							
Set-Up Depth (ft/in)							
Blockouts							
Squareness							
End and Edge Details							
Reinforcing Steel							
Size of Reinforcing							
Spacing							
Rustification							
Plates and Inserts							
Lifting Devices							
Top Finish (wet)							

REMARKS: _____

_____

_____

_____

_____

QC Supervisor _____ **Date** _____ **Inspector** _____

CONCRETE TESTING REPORT

QUALITY CONTROL DEPARTMENT

JOB NUMBER _____ JOB NAME _____

PRODUCT:				**DATE:**			
Mark Number							
Slump							
Air %							
Ambient Temperature							
Concrete Temperature							
Mix Design No.							
Cylinder No.							
Break Date							
Time Made							
Time Break							
Curing Age							
Load (lbs)							
Strength (psi)							
Required Strength (psi)							

REMARKS: _____

QC Supervisor _____ **Date** _____ **Inspector** _____

POST-POUR INSPECTION REPORT

QUALITY CONTROL DEPARTMENT

PRODUCT:							
Job #	**Sun**	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**
Casting Date							
Inspection Date							
Mark Number							
Stripping Strength							
Top Finish							
Bottom Finish							
Surface Texture							
As Cast Length (ft/in)							
As Cast Width (ft/in)							
As Cast Depth (ft/in)							
Cracks or Spalls							
Squareness							
Chamfers							
Honeycomb / Grout Leak							
Bowing							
Exposed Reinforcement							
Exposed Chairs							
Plates and Inserts							
Chamfer & Radius Quality							
Openings / Blockouts							
Lifting Devices							

REMARKS: _____

_____

_____

_____

_____

QC Supervisor _____ **Date** _____ **Inspector** _____

CASTING INSPECTION FORM

Pour Date

*SCALE
1 - UNACCEPTABLE
2 - VERY POOR
3 - NEEDS ATTENTION
4 - ACCEPTABLE
5 - EXCELLENT

			REBAR			PRE-POUR							POST-POUR																	
Description	Casting #	Inspector	Rebar Condition	Rebar Spacing		Form Cleanliness*	Form Oil*	Terminators	Knockouts	Lid Position	Guide Pins	Inserts	Casting Strength	Top/Btm Finish*	Surface Texture*	Cast Length	Cast Width	Cast Height	Cracks or Spalls	Squareness	Honeycombing*	Grout Seal Leaks*	Inserts	Openings	Paint / Finish	Parting Line Gap	Mix Number	**Total # of Defects**	**# Defects Repaired**	**REJECTED**

Batch Report Form

Mix Designation: _____ *Date:* _____

Quantity: _____ *Time:* _____

Batch Operator: _____

Project/Job: _____

Material	**Quantity**			
Cement:	_____	*lbs.*	*Type:*	_____
Water:	_____	*gal./lbs.*		
Fine Aggregate:	_____	*lbs.*	*Type:*	_____
Coarse Aggregate:	_____	*lbs.*	*Type:*	_____
Air Entrainment:	_____	*ozs.*	*Type:*	_____
Water Reducer:	_____	*ozs.*	*Type:*	_____
Other:	_____		*Type:*	_____
Fine Agg. Moisture:	_____	*%*		
w/cm Ratio:	_____			

Optional QC Information

Slump: _____ *in.*

Spread (SCC): _____ *in.*

Air Content: _____ *%*

Comp. Strength: _____ *psi*

Batch Report Form

Mix Designation: _____ *Date:* _____

Quantity: _____ *Time:* _____

Batch Operator: _____

Project/Job: _____

Material	**Quantity**			
Cement:	_____	*lbs.*	*Type:*	_____
Water:	_____	*gal./lbs.*		
Fine Aggregate:	_____	*lbs.*	*Type:*	_____
Coarse Aggregate:	_____	*lbs.*	*Type:*	_____
Air Entrainment:	_____	*ozs.*	*Type:*	_____
Water Reducer:	_____	*ozs.*	*Type:*	_____
Other:	_____		*Type:*	_____
Fine Agg. Moisture:	_____	*%*		
w/cm Ratio:	_____			

Optional QC Information

Slump: _____ *in.*

Spread (SCC): _____ *in.*

Air Content: _____ *%*

Comp. Strength: _____ *psi*

GASKET QUALITY CONTROL REPORT

Test Number _____

Product Gaskets will be used on _____

Vendor _____ *Qty. Ordered* _____

Vendor Order # _____ *Plant P.O.#* _____

Date Received _____

Gasket #	*Durometer*	*Length*	*Dia./Width*	*Height*	*Volume*	*Splice Strength*
Required						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Printed Marking on Gasket _____

Gaskets Meet Specifications _____

Signed _____

Date _____

Remarks: _____

_____

_____

_____

CONCRETE PIPE DIMENSIONAL INSPECTION FORM

Pipe Size _____ *Pipe #* _____

Pipe Class _____

Pipe Wall _____

Mfg. Process _____ *Date* _____

Internal Diameter

Position	*Spigot End*	*Bell End*	*Required*
0º			
180º			

Wall Thickness

Position	*Spigot End*	*Bell End*	*Required*
0º			
90º			
180º			
270º			

Length Measurements

Position			*Measurements*	*Required*
0º		*Maximum Length*		
90º		*Minimum Length*		
180º		*Range*		
270º				

Signed _____

Date _____

REINFORCED CONCRETE PIPE THREE-EDGE-BEARING TEST REPORT (ASTM C497)

Test # _____

Test Date _____

Manufacture Date _____

Product Age (days) _____

Manufacturing Process _____

PRODUCT INFORMATION

Type	*Size*	*Class*	*Wall*	*Joint*

Length		
	Measured	*Allowable*
Min.		
Max.		

Wall Thickness		
	Measured	*Allowable*
Min.		
Max.		***N/A***

Inside Diameter		
	Measured	*Allowable*
Min.		
Max.		

REINFORCING INFORMATION

Cage	*Description*	*Area of Steel*	*Required Area of Steel*
Inside:			
Outside:			
Elliptical:			

Comments: _____

_____

THREE-EDGE-BEARING TEST RESULTS

	Actual Load	*Required Load*	*Actual D-Load*	*Required D-Load*
1st Crack				
.01" Crack				
Ultimate				

If Product was not tested to Ultimate Load:

*Load when test was stopped:*_____*lbs.*

*D-Load when test was stopped:*_____*lbs/ft*

Pipe condition when test was stopped:

_____

_____

_____

_____

I herby certify that the pipe was tested in accordance with ASTM C497.

Signature: _____

Date: _____

SINGLE CELL BOX CULVERT REINFORCEMENT INSPECTION

Date: _____

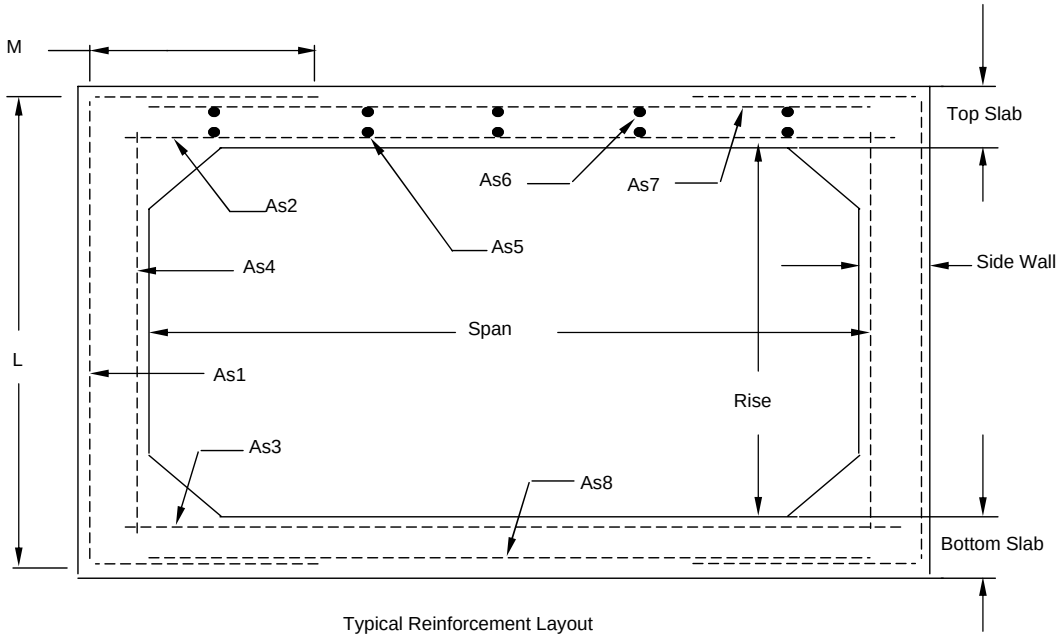
Inspector: _____

Comments: _____

_____

_____

Identification
Fabrication Date
Span
Rise
Design Table #
Earth Cover, Min.
Earth Cover, Max.



Typical Reinforcement Layout

	Area of Steel Used	Area of Steel Required	Mesh Type	Length	M
A_s1					
A_s2					
A_s3					
A_s4					
A_s5					
A_s6					
A_s7					
A_s8					
Inserts					
Spacers					
*Lap					

DOUBLE CELL BOX CULVERT REINFORCEMENT INSPECTION

Date: _____

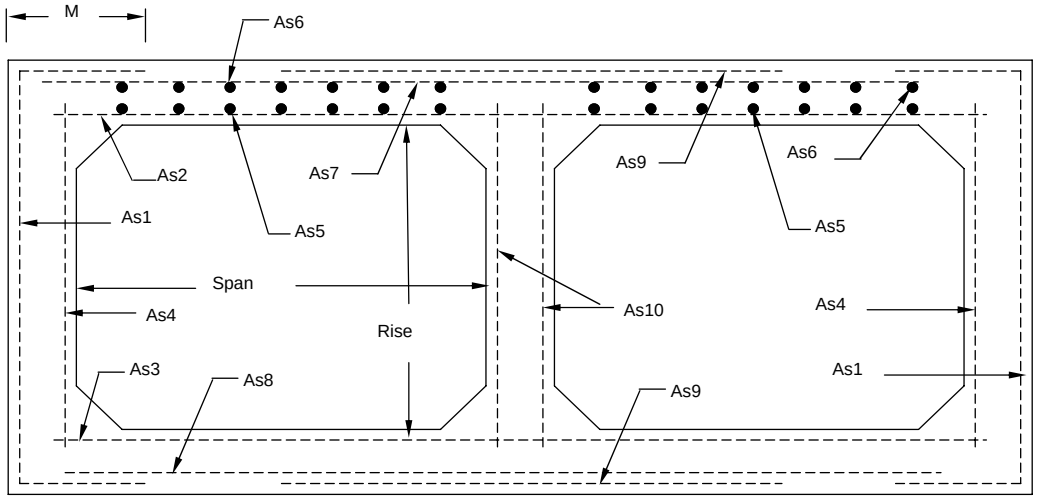
Inspector: _____

Comments: _____

_____

_____

Identification
Fabrication Date
Span
Rise
Design Table #
Earth Cover, Min.
Earth Cover, Max.



Typical Reinforcement Layout

	Area of Steel Used	Area of Steel Required	Mesh Type	Length	M
A_s1					
A_s2					
A_s3					
A_s4					
A_s5					
A_s6					
A_s7					
A_s8					
A_s9					
A_s10					
Inserts					
Spacers					
*Lap					

NPCA PLANT CERTIFICATION PROGRAM

PART 1

PURPOSE, SCOPE AND INSPECTIONS

1.1 Purpose

1.1.1 To assure a uniformly high degree of excellence in plant facilities, production, procedures, and quality control operations.

1.1.2 To assist management in achieving excellence in plants and operations.

1.1.3 To provide recognition for plants which achieve a high degree of excellence.

1.1.4 To help users and specifiers of precast identify and select high quality precast concrete manufacturers.

1.2 Scope

The program outlined herein is directed at certifying that plants are qualified to produce precast concrete products with a high degree of excellence. This program certifies precast plants, not precast concrete products.

1.3 Plant Inspection

A plant qualifies as an NPCA Certified Plant if it exceeds the required level of excellence during the initial announced NCPA inspection and subsequent annual unannounced inspections. Plants shall remain certified if all necessary fees are paid and the plant attains the minimum score on each inspection.

PART 2

ADMINISTRATION OF NPCA PLANT CERTIFICATION PROGRAM

2.1 Administrator

The administrator of the program will be a member of the NPCA staff. The duties of the administrator include but are not limited to:

2.1.1 Implement the policies and directives issued by the NPCA Quality Assurance Committee, which oversees the NPCA Plant Certification Program.

2.1.2 Maintain the files generated by the plant certification program.

2.1.3 Maintain and distribute current lists of NPCA Certified Plants.

2.1.4 Coordinate scheduling of inspections with plants and inspecting agency.

2.1.5 Serve as treasurer for the NPCA plant certification program by initiating invoices to plants, approving bills for expenses attributable to the NPCA Plant Certification program, maintaining a system for collection of receivables, and reporting periodically on the financial status of the program to the NPCA Quality Assurance Committee.

2.1.6 Issue certificates or plaques to each plant that qualifies as an NPCA Certified Plant.

2.2 NPCA Quality Assurance Committee

Duties of NPCA Quality Assurance Committee include but are not limited to:

2.2.1 Establish policies relating to plant certification.

2.2.2 Give direction to the administrator of the NPCA Plant Certification Program.

2.2.3 Select plant inspection agency or agencies.

2.2.4 Oversee the plant certification program including plant inspections and program administration.

2.2.5 Promote the program to the NPCA members.

2.2.6 Publicize the program to buyers of precast concrete products.

2.2.7 Oversee revisions of the NPCA Quality Control Manual.

2.2.8 Oversee revisions of the NPCA Plant Certification Program, including the grading schedule.

2.2.9 Serve as an Appeals Board (see Part 5).

2.3 Inspection Agency

The NPCA Quality Assurance Committee will select an inspection agency that has personnel who are knowledgeable about the operations of precast concrete manufacturing plants and production of quality precast concrete products. They also must have experience in quality control operations, and be able to inspect plants with minimal advance notice.

Before making any inspections, the inspection agency must become familiar with both the NPCA Quality Control Manual and the Plant Certification Program. The agency must also develop a quality assurance program, which will ensure that all inspections are made in a uniform manner and that a uniform grading system is used.

The inspection agency will perform the inspections as detailed in Part 3.

The NPCA Quality Assurance Committee may select more than one inspection agency, in which case all of the above items are applicable to each agency, including uniformity of inspections and grading.

2.4 Recordingkeeping

The Administrator will maintain all pertinent records of the plant certification program. These records include but are not limited to:

2.4.1 Pertinent correspondence.

2.4.2 Meeting minutes of the NPCA Quality Assurance Committee.

2.4.3 Applications for plant certification.

2.4.4 Plant certificates.

2.4.5 Completed grading schedules.

2.4.6 Grading schedules.

2.4.7 Correspondence dealing with appeals.

2.4.8 Current list of certified plants.

PART 3

INSPECTIONS

3.1 Scheduling

The Administrator of the NPCA Plant Certification Program will help coordinate initial certification inspections between the plant and the inspection agency, so that the inspection is made at a mutually convenient time. Subsequent unannounced inspections shall be scheduled by the inspection agency and be between 0 and 12 months from the anniversary date of initial certification, each subsequent year. Annual plant fees shall be due on each anniversary date to the Administrator.

3.2 Plant Liaison Representative

Plant management will assign one person to serve as a liaison representative during the inspection. The plant liaison representative will be available to assist in the inspection by making quality control records, calibration records, drawings, etc., available for review by the inspector. He or she will also be available to accompany the inspector throughout most of the operations in order to utilize the inspector's time most efficiently.

3.3 Duties of the Inspector

3.3.1 The inspector will arrive at the plant prepared to begin the inspection.

3.3.2 The inspection will not depend upon the plant for transportation to or from the plant nor for meals or lodging during the inspection.

3.3.3 The inspector will abide by all safety regulations of the plant.

3.3.4 The inspector will neither impede nor delay any of the plant's operations.

3.3.5 The inspector may videotape parts of the inspection or take photographs, but only if permitted to do so by plant management.

3.3.6 The inspector will observe and grade those items for which points are assigned on the grading schedule. Items that are not applicable or not observed will be so marked.

3.3.7 The inspector will remain at the plant until he or she has observed and graded at least 90% of the items that can be observed.

3.3.8 The inspector will be available for consultation about the inspection with plant management immediately following the inspection.

3.3.9 The inspector will prepare a written report together with the completed grading schedule and send the original to company management with a copy to the Administrator of the plant certification program. The report will be sent no later than 30 days after the inspection. At a minimum, the report will explain the reasons for grades on items of 60% or lower.

PART 4

GRADING SCHEDULE

4.1 The NPCA grading schedule is shown in the section titled “Grading Schedule” in the NPCA Quality Control Manual for Precast Concrete Plants. It can be seen that the items listed specifically refer to sections of the NPCA Quality Control Manual.

4.2 Items to be graded are assigned “points” (A) shown in the first column on the right. The total number of points possible is 185. The inspector grades items which have been assigned points based on the percentage of compliance with the Quality Control Manual shown in the second column (B). Certain items may not be applicable (NA) or may not be observed (NO) by the inspector. Those items are not graded. For each graded item the number of points (A) is multiplied by the grade percentage (B). The sum of those values is obtained for each chapter. Because some items are not applicable or not observed, an adjustment is made.

4.3 The grade adjustment consists of multiplying the sum of A x B for each chapter by 100 and dividing by the total possible points that are applicable and/or observable. For example, if all of the items in Section 6.4 (which is assigned 3 points) are marked NA or NO, the sum of A x B for each chapter is multiplied by 100/(185-3) or 100/182. The final plant score represents the percentage of total points earned by the plant versus the total applicable and/or observable points.

4.4 It should be noted that a significant number of points are assigned to Chapter 4, Production Practices, followed by Chapter 5, Quality Control Operations. These two chapters account for a large percentage of the points. Thus it becomes clear that a plant can be readily certified if it follows good production practices and quality control operations. Conversely, a plant with poor production practices or a lack of adequate quality control will not likely qualify as an NPCA Certified Plant.

4.5 Completed grade sheets are sent to the plant representative, and a copy is kept on file by the Administrator of the NPCA Plant Certification Program. No other copies are distributed. Explanations of grades of 60% or less on any items will accompany the grade sheets.

4.6 A plant qualifies as a certified plant if it achieves a plant score of 75% or higher in each applicable Critical Requirement section and achieves an overall score of 80%. If a plant fails to achieve the required score for a Critical Requirement or receives a score above 75% and less than 80%, the plant shall receive probationary certification and must take corrective action to remedy the specific deficiency or deficiencies noted in the report and supply documentation of the corrective action to both NPCA and the inspection agency within 30 days of receiving the report. If, in the opinion of the inspection agency, the plant has not adequately addressed the specific deficiency or deficiencies, the plant must undergo an additional unannounced inspection, at the plant’s expense in the amount of the standard certification fee, within 60 days of the inspection agency’s decision. The plant may appeal the inspection agencies decision. The plant must score above 80% overall and receive a score of 75% or higher in each applicable Critical Requirement section to retain normal certification status, otherwise the plant will fail the inspection. See Part 5 for information regarding appeals.

PART 5

APPEAL PROCEDURE

5.1 If plant management disagrees with the grade resulting from an NPCA plant inspection, management may file an appeal for review by the NPCA Quality Assurance committee. Appeals must also meet the requirements set forth in the Contract for NPCA Plant Certification signed by the plant. Appeals should be reserved for situations when a plant has failed an inspection and/or when a plant wishes to appeal the decision of the inspection agency after making corrective action during probationary certification.

5.2 The appeal should be in the form of a letter addressed and sent to the Administrator of the NPCA Plant Certification Program. A copy of the completed grading schedule should accompany the letter. Individual grades on specific items with which management disagrees should be circled and the letter should explain why management believes each circled grade should be changed.

5.3 The Administrator will send copies of the letter and enclosures to all members of the Plant Certification Subcommittee and to the plant inspection agency within seven calendar days of receipt of the appeal.

5.4 The plant inspection agency will respond by letter to the Administrator with copies to members of the Plant Certification Subcommittee within 21 calendar days of receipt of the copy of the appeal.

5.4.1 If the inspection agency agrees with the appeal and that the grade should be changed as requested in the appeal, the agency will prepare a revised grading schedule.

5.4.2 If the inspection agency disagrees with the appeal and believes that the grades originally assigned are appropriate, reasons for the grades (perhaps including photographs or additional data) should be detailed in the response.

5.5 If the response from the inspection agency is in accordance with Sec. 5.4.2 and the plant wishes to have the appeal heard by the Quality Assurance committee (which acts as the appeals board), the chairperson of the NPCA Quality Assurance committee will poll the subcommittee members to determine if they (a) agree with the appeal and disagree with the inspection agency's response, (b) agree with the appeal and agree with the inspection agency's response, or (c) disagree with the appeal and agree with the inspection agency's response. The chairperson should also poll the members to determine if a hearing of the appeal is needed and if so, to establish a date for the hearing.

5.6 Hearings for appeals will usually be scheduled to coincide with the regularly scheduled meetings of the NPCA Quality Assurance committee, but hearings may be held at other times which are mutually convenient for the committee, management of the plant which filed the appeal, and the inspection agency and may consist of a conference call.

5.7 Hearings for appeals will be closed meetings with only the Quality Assurance committee, NPCA Plant Certification administrator, management of the appealing plant, and the inspection agency present. The management of the plant which filed the appeal will first present its case orally and the subcommittee may ask questions of the speaker. The inspection agency representative will then orally present its case followed by answering questions raised by the subcommittee. Management of the appealing plant then will make its closing statement and that will be followed by the closing statement of the inspection

agency representative. Representatives of the appealing plant and the inspection agency will then be excused so that the subcommittee can deliberate in executive session.

5.8 If a member of the Quality Assurance committee is a representative of the appealing plant, that committee member shall excuse themselves from the deliberations in executive session.

5.8 Decisions of the Quality Assurance committee will be sent to both the plant management and the inspection agency within ten days of the hearing. The Quality Assurance committee's decision(s) will be final.

NPCA PLANT CERTIFICATION
GRADING SCHEDULE

Plant:	Location:
Date:	Inspector:

CHAPTER 1	GENERAL	Points (A)	Grade % (B)	(A x B)	(A x B) Adjusted
1.1	Plant Quality Control Procedures and Management Policies				
	1.1.1 Plant Management & Personnel	3			
	1.1.2 Plant-Specific QC Manual				
1.2	Plant Safety				
	1.2.1 Safety Program	1			
	Total Chapter 1	4			
CHAPTER 2	MATERIALS				
2.1	Concrete				
	2.1.1 Cement	3			
	2.1.2 Fine Aggregate				
	2.1.3 Coarse Aggregate				
	2.1.4 Lightweight Aggregate				
	2.1.5 Mixing Water				
	2.1.6 Chemical Admixtures				
	2.1.7 Supplementary Cementitious Materials				
2.2	Reinforcement				
	2.2.1 Reinforcing Bars	3			
	2.2.2 Reinforcing Wire				
	2.2.3 Bar Mats and Welded-Wire Reinforcement				
	2.2.4 Zinc or Epoxy-Coated Reinforcement				
2.3	Miscellaneous Materials				
	2.3.1 Lifting Devices and Lifting Apparatus	2			
	2.3.2 Embedded Steel Shapes and Plates				
	2.3.3 Headed Studs and Deformed Anchor Studs				
	2.3.4 Manufacturing Accessories				
	2.3.5 Fiber Reinforcement				
	2.3.6 Joint Sealants, Gaskets and Connectors				
	Total Chapter 2	8			

CHAPTER 3	CONCRETE	Points (A)	Grade % (B)	(A x B)	(A x B) Adjusted
3.1	Concrete Mixes				
	3.1.1 Mix Proportions	5			
	3.1.2 Water-Cementitious Ratio				
	3.1.3 Air Content				
	3.1.4 Compressive Strength				
	3.1.5 Admixtures				
3.2	Batching and Mixing				
	3.2.1 Requirements for Batching and Mixing Plants	10			
	3.2.2 Storage of Cement and Supplementary Cementitious Materials				
	3.2.3 Handling and Storage of Aggregates				
	3.2.4 Batching Equipment				
	3.2.5 Discharge of Materials into Mixers				
	3.2.6 Mixers				
	3.2.7 Mixing				
	3.2.8 Ready-Mixed Concrete				
	Total Chapter 3	15			
CHAPTER 4	PRODUCTION PRACTICES				
4.1	General				
	4.1.1 Plant Layout	10			
	4.1.2 Housekeeping				
	4.1.3 Forms and Forming Equipment				
	4.1.4 Handling Equipment				
	4.1.5 Machine-Made and/or Dry-Cast Products				
	4.1.6 Architectural Precast Concrete				
4.2	Fabrication of Reinforcement and Blockouts				
	4.2.1 Fabrication of Reinforcement	8			
	4.2.2 Welding of Reinforcing Steel				
	4.2.3 Welding of Steel Assemblies				
	4.2.4 Fabrication and Positioning of Blockouts				

		Points (A)	Grade % (B)	(A x B)	(A x B) Adjusted
4.3	Pre-Pour Operations				
	4.3.1 Cleaning of Forms	8			
	4.3.2 Application of Form Release Agent				
	4.3.3 Positioning of Reinforcement				
	4.3.4 Positioning of Misc. Embedded Items				
4.4	Casting Concrete				
	4.4.1 Transporting Concrete	8			
	4.4.2 Depositing Concrete into Forms				
	4.4.3 Consolidating Concrete				
	4.4.4 Finishing Unformed Surfaces				
	4.4.5 Secondary Pours				
	4.4.6 Hot Weather Precautions				
	4.4.7 Cold Weather Precautions				
4.5	Curing Concrete				
	4.5.1 General	4			
	4.5.2 Curing by Moisture Retention				
	4.5.3 Curing with Heat and Moisture				
4.6	Stripping Products from Forms				
	4.6.1 Minimum Strength Requirement	5			
	4.6.2 Product Damage During Stripping				
	4.6.3 Formed Surfaces				
	4.6.4 Post-Pour Inspection				
4.7	Repairing Concrete				
	4.7.1 Repairing Minor Defects	4			
	4.7.2 Repairing Major Defects				
	4.7.3 Inspection of Repairs				

		Points (A)	Grade % (B)	(A x B)	(A x B) Adjusted
4.8	Marking, Storage, and Shipment of Products				
	4.8.1 Product Marking	5			
	4.8.2 Storage Areas				
	4.8.3 Storage of Products				
	4.8.4 Shipment of Products				
	4.8.5 Final Inspection				
	Total Chapter 4	52			

CHAPTER 5	QUALITY CONTROL OPERATIONS				
5.1	Summary of Required Records				
	5.1.1 Raw Material Test Records	9			
	5.1.2 Work Orders and Product Drawings				
	5.1.3 Equipment Calibration Records				
	5.1.4 Aggregate and Concrete Test Records				
	5.1.5 Concrete Batching Reports				
	5.1.6 General Plant and Product Inspection Records				
5.2	Aggregate Testing				
	5.2.1 Aggregate Gradation	3			
	5.2.2 Moisture Content				
5.3	Concrete Testing				
	5.3.1 Slump, Slump Flow, and VSI	9	(a)		
	5.3.2 Temperature				
	5.3.3 Density (Unit Weight)				
	5.3.4 Air Content				
	5.3.5 Compressive Strength				
	Total Chapter 5	21			

CHAPTER 6	SPECIAL REQUIREMENTS FOR SPECIFIC PRODUCTS	Points (A)	Grade % (B)	(A x B)	(A x B) Adjusted
6.1	Products Manufactured According to ASTM International and Other Industry Standards				
	6.1.1 Product Manufacture	3			
	6.1.2 Proof of Conformance				
6.2	Stormwater Concrete Pipe Requirements				
	6.2.1 Reinforcing Steel Inspection	10	(a)		
	6.2.2 Three-Edge Bearing Testing	10	(a)		
	6.2.3 Absorption Testing	1	(a)		
	6.2.4 Dimensional Checks	6			
	6.2.5 Joint Design and Testing				
	6.2.6 Gasket Quality Control				
6.3	Round Manhole Component Requirements				
	6.3.1 Reinforcing Steel Inspection	10	(a)		
	6.3.2 Flat Slab Tops	6			
	6.3.3 Base, Riser and Cone Sections				
	6.3.4 Joint Design				
	6.3.5 Gasket Quality Control				
6.4	Box Culvert Requirements				
	6.4.1 Absorption Testing	6			
	6.4.2 Joint Design				
	6.4.3 Pre-Pour Inspections	10	(a)		
	6.4.4 Dimensional Checks	10	(a)		

		Points (A)	Grade % (B)	(A x B)	(A x B) Adjusted
6.5	Septic Tank Requirements				
	6.5.1 Structural Proof-of-Design	3			
	6.5.2 Watertightness Testing	10	(a)		
	Total Chapter 6	85			
	Total Possible Points	185			
	Total Applicable and/or Observed Points				
	Sum of A x B for Each Chapter				
	PLANT SCORE [b]				

[a] Critical Requirement Section – This and all other applicable Critical Requirement Sections require a minimum passing grade of 75% in order to achieve normal certification status. Plants scoring less than 75% in one or more Critical Requirement Section shall receive probationary certification, must document and take corrective action within 30 days to improve plant operations, and may be required to complete an additional inspection within 90 days (at the plant's expense) and must receive a score equal to or greater than 75%.

[b] The Plant Score is equal to the percentage of total points earned by the plant divided by the total applicable and/or observable points. Plants must score 80% or higher in order to achieve normal certification status. Plants receiving a score above 75% and less than 80% shall receive probationary certification, must document and take corrective action within 30 days to improve plant operations, and may be required to complete an additional inspection within 90 days (at the plant's expense) and must receive a score equal to or greater than 80%.