MANUAL FOR

QUALITY CONTROL

For Plants and Production of

STRUCTURAL PRECAST CONCRETE PRODUCTS

MNL–116–99

FOURTH EDITION

PCI Precast/Prestressed Concrete Institute
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Every effort has been made to ensure the accuracy of the information presented in this Manual. However, PCI cannot accept responsibility for errors, oversights, or the misuse of the information contained herein. The user must recognize that no manual or regulation can substitute for experience and sound judgment. This publication is intended for use by personnel competent to evaluate the significance and limitations of the information it contains, and accept responsibility for its proper interpretation and application.

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FOREWORD

This is the fourth printing of this manual, which was first completed in 1966. The format remains in two parts – the standards and commentary. However, with this edition, these two have been brought together and aligned. The standards are on one side of the page and the commentary on the other providing for convenient reference. This revision was undertaken to update the manual to current standards.

The late William E. Dean of Howard Needles Tammen Bergendoff and previously retired as Florida State Bridge Engineer, wrote the first manual. It was then reviewed by the PCI Technical Activities Committee and edited by PCI staff. After three years of experience with the PCI Plant Certification Program, the manual was revised and printed in the familiar blue hardback cover in 1970. The second edition in 1977 was developed by the PCI Plant Certification Committee to update references and standards as well as incorporate certain revisions. The third edition in 1985 was developed and written by the consulting firm of Ross Bryan Associates, Inc., under contract to the Institute. The PCI Plant Certification Committee developed this fourth edition. Committee members working on the 4th edition were as follows:

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Lee Lawrence of Wiss, Janney, Elstner Associates, Inc., for accomplishing final editing.

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INTRODUCTION
MNL-116, Fourth Edition

The information in this manual is intended to serve as standards for quality control for the manufacture of precast and prestressed concrete products and as a complete guide for the development of an internal manufacturing quality control program. The Standard portion serves as a specification reference document, while the Commentary provides additional information and discussions of the Standards. The manual was developed for plant-produced, precast concrete members, or precast, prestressed concrete members manufactured by the process of pretensioning, post-tensioning, or a combination of the two methods. The principles established herein are, however, applicable to site-cast precast concrete or prestressed concrete.

The manual was written by or under the direction of the PCI Plant Certification Committee. Pertinent information and requirements have been obtained from publications and standards of the Precast/Prestressed Concrete Institute (PCI), American Concrete Institute (ACI), Portland Cement Association (PCA), U.S. Bureau of Reclamation, and other agencies. This, combined with experience gained through more than 30 years of operation of the PCI Plant Certification Program, has contributed to the development of the manual.

The fundamental intent of this manual is to provide a basis for establishing a satisfactory quality control program for general precast operations. It should be augmented, as required by the specifier or producer, for addressing specialized products and operations. The value of the manual, in regard to establishing a standard of quality that will be recognized and respected by the general public, is dependent on the appropriate application by the owner, designer, specifier, and producer.

Routine conformance to the requirements of the Standards should result in products of consistent and optimum quality when used with proven procedures. Optimum quality is considered the level of quality that appropriately satisfies the project requirements for intended use and economics of the product.

Satisfactory conformance with the Standards in this manual is required for certification in the PCI Plant Certification Program for the Bridge and Commercial (Structural) Product Groups. For an explanation of the Program requirements and procedures, see Appendix F, *Certification Programs*.

The Standards and Commentary portions of this manual are presented in a side-by-side column format; with the Standards placed in the left column and the corresponding Commentary aligned in the right column. The Standards have been printed in the same typeface as shown in this paragraph.

The Commentary is printed in the same typeface as shown in this paragraph. Additionally, a "C" precedes Commentary article numbers to help further distinguish the Commentary from the Standards.

The dimensional tolerances contained in Appendix B were developed by the PCI Tolerances Committee and approved by the PCI Technical Activities Committee and PCI Board of Directors.

SPECIAL FINISHES

Standards for structural precast concrete products that are produced with architectural finishes and in accordance with the structural tolerances in this manual, are included at the end of each Division. Examples of such products are exposed columns and spandrel beams used on the exterior of parking structures.

At the end of each Division, only those Articles that pertain to the application of special finishes are listed. The special provisions are identified with an "A" preceding the Article number. **The criteria established in this manual govern except as specifically modified by these special provisions for architectural finishes.** The Article numbers are the same as the corresponding Articles in the main portion of the Standards. Where a special provision for architectural finishes does not have a matching Article for basic structural products, the provision is placed at the end of an Article or the Division with numbering continued sequentially.

Conformance with these additional Standards is recognized in the PCI Plant Certification Program by certification in two product categories. The Product Categories are designated as "Bridge Architectural" (BA), or "Commercial Architectural" (CA) within the Bridge Products and Commercial (Structural) Products Groups. For a description of these Groups, see Appendix F, *Certification Programs – Product Groups and Categories*.

This manual incorporates proven standards of practice. It contains requirements necessary to achieve an acceptable level of quality, but not the means or methods for doing so. The requirements of the manual are not intended to be applied in a manner that is restrictive to the development of individual plant techniques or innovation. As new materials and processes are developed, their application should be considered within the scope and intent of these Standards. The information contained in the Commentary is not part of the Standards and shall not be used in judging quality control or production procedures.

Note: The production of precast concrete may involve hazardous materials, operations, and equipment. This manual does not address the safety issues associated with production. It is the responsibility of the producer to establish appropriate safety and health practices and determine the applicability of regulatory requirements.

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DIVISION 4 – CONCRETE

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DEFINITIONS

Accelerated curing – The intentional addition of heat to the concrete environment to expedite curing. For the systems described in this Manual, all curing is at atmospheric pressure.

Admixture – A material other than water, aggregates and cement used as an ingredient in concrete, mortar, or grout to impart special characteristics.

Aggregate – Granular material, such as sand, gravel, and crushed stone, used with a cementing medium to form a hydraulic-cement concrete or mortar.

Aggregate, structural lightweight – Aggregate with a dry, loose weight of 70 lbs/ft^3 (1121 kg/m^3) or less.

Air entraining admixture – A chemical added to the concrete for the purpose of providing minute bubbles of air (generally smaller than 1 mm) in the concrete during mixing to improve the durability of concrete exposed to cyclical freezing and thawing in the presence of moisture.

Ambient temperature – The temperature of the air surrounding the forms and molds into which concrete is to be cast, or of the air surrounding an element during curing.

Anchorage – The means by which the prestressing force is permanently transmitted from the prestressing steel to the concrete. In post-tensioning applications, a mechanical device comprising all components required to anchor the prestressing steel and transmit the prestressing force to the concrete.

Architectural precast concrete – A product with a specified standard of uniform appearance, surface details, color, and texture.

Architectural precast concrete Trim Units – Wet cast products with a high standard of finish quality and of relatively small size that can be installed with equipment of limited capacity, such as sills, lintels, coping, cornices, quoins, medallions, bollards, benches, planters, and pavers.

Backup mix – The concrete mix cast into the mold after the face mix has been placed and consolidated.

Bleeding – A form of segregation in which some of the water in a mix rises to the surface of freshly placed concrete; also known as water gain.

Blocking – Materials used for keeping concrete elements from touching each other or other materials during storage and transportation.

Bondbreaker – A substance placed on a material to prevent it from bonding to the concrete, or between a face material such as natural stone and the concrete backup.

Bonding agent – A substance used to increase the bond between an existing piece of concrete and a subsequent application of concrete such as a patch.

Bull float – A tool comprising of a large, flat, rectangular piece of wood, aluminum, or magnesium usually 8 in. (200 mm) wide and 42 to 60 in. (1.0 to 1.5 m) long, and a handle 4 to 16 ft. (1 to 5 m) in length used to smooth the unformed surfaces of freshly placed concrete.

Bugholes – Small holes on formed concrete surfaces formed by air or water bubbles, sometimes called blowholes.

Bundled strand – Strands that are grouped together in a bundle to concentrate the prestressing force. Bundled strand are in contact with each other and must be splayed out to the end of the member to allow bond to develop each strand from the end to the bundle point.

Camber – (1) The deflection that occurs in prestressed concrete elements due to the net bending resulting from application of a prestressing force (It does not include dimensional inaccuracies); (2) A built-in curvature to improve appearance.

Certification – Assurance by a competent third party organization, operating on objective criteria and which is not subject to undue influences from the manufacturer or purchaser or to financial considerations, that elements are consistently produced in conformity with a specification. It not only proclaims compliance of a product with a specification, but also that the manufacturer's quality control arrangements have been approved and that a continuing audit is carried out.

Clearance – Interface space (distance) between two items.

Coarse aggregate – Aggregate predominately retained on the U.S. Standard No. 4 (4.75 mm) sieve; or that portion of an aggregate retained on the No. 4 (4.75 mm) sieve.

Compaction – The process whereby the volume of the concrete is reduced to the minimum practical space by the reduction of voids usually obtained through vibration, tamping, or a combination of both.

Connection – A device for the attachment of precast concrete units to each other or to the building or structure.

Covermeter – See R-meter.

Crazing – A network of visible, fine hairline cracks in random directions breaking the exposed face of a panel into areas from 1/4 in. to 3 in. (6 to 75 mm) across.

Creep – The time dependent deformation (shortening) of prestressing steel or concrete under sustained loading.

Curing – The maintenance of moisture and temperature within freshly placed concrete during some defined period following placing, casting, or finishing to assure satisfactory hydration of the cementitious materials and proper hardening of the concrete.

Deflected Strand – Strand that is deflected from a straight-line position in a member to enhance the moment-resisting capacity of the member. Deflected strand may be spaced apart or bundled together. If bundled at a point, the strand must be splayed-out from the bundle to the end of the member to develop bond on each strand.

Detensioning of strand or wire – The transfer of strand or wire tension from the bed anchorage to the concrete.

Draft – The slope of concrete surface in relation to the direction in which the precast concrete element is withdrawn from the mold; it is provided to facilitate stripping with a minimum of mold breakdown.

Dunnage – See Blocking.

Elastic shortening – The shortening of a member that occurs immediately after the application of the prestressing force.

Elongation – Increase in length of the prestressing steel (strand) under the applied prestressing force.

Exposed aggregate concrete – Concrete manufactured so that the aggregate on the face is left protruding.

Face mix – The concrete at the exposed face of a concrete unit used for specific appearance purposes.

Fine aggregate – Aggregate passing the 3/8 in. (9.5 mm) sieve and almost entirely passing the No. 4 (4.75 mm) sieve and predominately retained on the No. 200 (75μm) sieve; or that portion of an aggregate passing the No. 4 (4.75 mm) sieve and predominately retained on the No. 200 (75μm) sieve.

Form – The container or surface against which fresh concrete is cast to give it a desired shape; sometimes used interchangeably with mold. (The term “mold” is used in this Manual for custom-made forms for specific jobs while “form” is used for standard forms or forms of standard cross section.)

Formed surface – A concrete surface that has been cast against formwork.

Form release agent – A substance applied to the mold for the purpose of preventing bond between the mold and the concrete cast in it.

Friction loss – In post-tensioning applications, the stress (force) loss in a prestressing tendon resulting from friction created along the tendon profile during stressing.

Gap-graded concrete – A mix with one or a range of normal aggregate sizes eliminated, and/or with a heavier concentration of certain aggregate sizes over and above standard gradation limits. It is used to obtain a specific exposed aggregate finish.

Grout – A mixture of cementitious materials and water, with or without sand or admixtures.

Hardware – Items used in connecting precast concrete units or attaching or accommodating adjacent materials or equipment. Hardware is normally divided into three categories:

> **Contractor’s hardware –** Items to be placed on or in the structure in order to receive the precast concrete units, e.g., anchor bolts, angles, or plates with suitable anchors.
>
> **Plant hardware –** Items to be embedded in the concrete units themselves, either for connections and precast concrete erector’s work, or for other trades, such as mechanical, plumbing, glazing, miscellaneous iron, masonry, or roofing trades.
>
> **Erection hardware –** All hardware necessary for the installation of the precast concrete units.

Harped strand – Strand partially tensioned in the lowest position along the length of the member and subsequently lifted or harped at the ends of a member to enhance the moment capacity at the center of the member. This can reduce the applied stresses at the end of the member by reducing the total amount of prestress.

Homogeneous mix – A uniform concrete mix used throughout a precast concrete element.

Initial prestress – The stress (force) in the tendon immediately after transferring the prestressing force to the concrete.

Jacking force – The maximum temporary force exerted by the jack while introducing the prestressing force into the concrete through the prestressing strand.

Jig – A template or device to align parts of an assembly, usually for pre-assembling reinforcing steel and hardware cages, with a minimum of measurement to attain consistent accuracy from one cage to the next.

Laitance – Residue of weak and nondurable material consisting of cement, aggregate fines, or impurities brought to the surface of plastic concrete by bleed water.

Lifting frame (or beam) – A rigging device designed to provide two or more lifting points of a precast concrete element with a predictable load distribution and pre-arranged direction of pulling force during lifting.

Mark number – The individual identifying mark assigned to each precast concrete unit designating its position in the building.

Master mold – A mold which allows a maximum number of casts per project; units cast in such molds need not be identical, providing the changes in the units can be simply accomplished as pre-engineered mold modifications.

Matrix – The portion of the concrete mix containing only the cement and fine aggregates (sand).

Miter – An edge that has been beveled to an angle other than 90 deg.

Mold – See “Form”

Pattern or positive – A replica of all or part of the precast element sometimes used for forming the molds in concrete or plastic.

Plastic cracking – Short cracks often varying in width along their length that occur in the surface of fresh concrete soon after it is placed and while it is still plastic.

Post-tensioning – A method of prestressing concrete whereby the tendon is kept from bonding to the plastic (wet) concrete, then elongated and anchored directly against the hardened concrete, imparting stresses through end bearing.

Precast engineer – The person or firm that designs precast concrete members for specified loads and may direct the preparation of the shop drawings.

Pretensioning – A method of prestressing concrete whereby the tendons are elongated, anchored while the concrete in the member is cast, and released when the concrete has gained sufficient strength to receive the forces transferred from the tendon through bond of the hardened concrete.

Production drawings – A set of instructions in the form of diagrams and text that contain all the information necessary for the manufacturer to produce the unit.

Quality – (1) The appearance, strength, and durability which is appropriate for the specific product, particular application, and expected performance requirements. (2) The totality of features and characteristics of a product that bear on its ability to satisfy stated or implied needs.

Quality assurance (QA) – All those planned or systematic actions necessary to ensure that the final product or service will satisfy given requirements for quality and perform intended function.

Quality control (QC) – Those actions related to the physical characteristics of the materials, processes, and services, which provide a means to measure and control the characteristics to predetermined quantitative criteria.

Quirk miter – A corner formed by two chamfered members to eliminate sharp corners and ease alignment.

R-meter – An electronic device used to locate and size reinforcement in hardened concrete.

Retarder – An admixture which delays the setting of cement paste and therefore of concrete.

Retarder, surface – See “Surface Retarder”

Retempering – The addition of water or admixture and remixing of concrete which has started to stiffen in order to make it more workable.

Return – A projection that angles away from the main face or plane of view.

Reveal – (1) Groove in a panel face generally used to create a desired architectural effect; and (2) The depth of exposure of the coarse aggregate in the matrix after production of an exposed aggregate finish.

Rustication – A groove in a panel face for architectural appearance; also reveal.

Sandwich wall panel – A prefabricated panel, which is a layered composite, formed by attaching two wythes or skins of concrete separated by an insulating core.

Scabbing – A finish defect in which parts of the form face, including release agent, adhere to the concrete. Some probable causes are an excessively rough form face, inadequate application of release agent, or delayed stripping.

Scouring – Irregular eroded areas or channels with exposed stone or sand particles. Some probable causes of this finish defect are excessively wet concrete mix, insufficient fines, water in the form when placing the concrete, poor vibration practices, and low temperature when placing concrete.

Sealer – A clear chemical compound applied to the surface of precast concrete units for the purpose of improving weathering qualities or reducing water absorption.

Segregation – The tendency for the coarse particles to separate from the finer particles during handling. In concrete, the coarse aggregate and drier material remaining behind and the mortar and wetter material flowing ahead. This also occurs in a vertical direction when wet concrete is overvibrated or dropped vertically into the forms, the mortar and wetter material rise to the top. In aggregate, the coarse particles roll to the outside edges of the stockpile.

Self-stressing form – A structural form provided with suitable end bulkheads and sufficient strength to resist the total prestressing force.

Set-up – The process of preparing molds or forms for casting, including installation of materials (reinforcement and hardware) prior to the actual placing of concrete.

Sheathing – A covering that forms an enclosure around the prestressing steel to avoid temporary or permanent bond between the prestressing steel and the surrounding concrete.

Shrinkage – The volume change in precast concrete units caused by drying normally occurring during the hardening process of concrete.

Shop drawings – (1) Collective term used for erection drawings, production drawings, and hardware details; and (2) Diagrams of precast concrete members and the connecting hardware, developed from information needed for both field assembly (erection) and manufacture (production) of the precast concrete units.

Specially finished structural precast concrete – A product fabricated using forms and techniques common to the production of structural elements as defined in MNL-116 and having specified surface finishes that require uniformity and detailing more demanding than typically required for structural elements. These surface finish requirements should be clearly specified and verified with appropriate samples and mockups.

Spreader beam – A frame of steel channels or beams attached to the back of a panel, prior to stripping, for the purpose of evenly distributing loads to inserts and for lifting the panel about its center of gravity.

Strand – A group of wires laid helically over a central-core wire. A seven-wire strand would thus consist of six outer wires laid over a single wire core.

Strand anchor – A device for holding a strand under tension, sometimes called a strand chuck or vise.

Stripping – The process of removing a precast concrete element from the form in which it was cast.

Strongback/stiffback – A steel or wooden member that is attached to a panel for the purpose of adding stiffness during handling, shipping, and/or erection.

Structural lightweight concrete – Structural concrete made with lightweight aggregate with an air-dry unit weight of the concrete in the range of 90 to 115 lb/ft^3 (1440 to 1850 kg/m^3) and a 28-day compressive strength of more than 2500 psi (17.24 MPa).

Superplasticizer – A high-range water-reducing (HRWR) admixture that produces concrete of significantly higher slump without addition of water.

Surface retarder – A material used to retard or prevent the hardening of the cement paste on a concrete surface to facilitate removal of this paste after curing. This is primarily used to produce an exposed aggregate finish.

Tendon – A high strength steel element consisting of one or more wires, strands, or bars, or a bundle of such elements, used to impart prestressing forces to the concrete. In post-tensioned applications, a complete assembly consisting of anchorages, prestressing steel (strand), corrosion-inhibiting coating, and sheathing. It imparts the prestressing force to the concrete.

Tolerance – Specified permissible variations from stated requirements such as dimensions, location, alignment, strength, and air entrainment, etc.

> **Product tolerances –** Those variations in dimensions relating to individual precast concrete members.
>
> **Erection tolerances –** Those variations in dimensions required for acceptable matching of precast members after erection.
>
> **Interfacing tolerances –** Those variations in dimensions associated with other materials in contact with or in close proximity to precast concrete.

Transfer strength – The minimum concrete strength specified for the individual concrete elements before transfer of the prestressing force. This is sometimes called detensioning strength or release strength.

Unbonded tendon – A tendon in which the prestressing steel (strand) is prevented from bonding to the concrete. When unbonded tendons are used, prestressing force is permanently transferred to the concrete only by the anchorage.

Veneered construction – The attachment of other materials, such as natural stone or clay products, to a concrete panel.

Wedges – Pieces of tapered metal with teeth that bite into the prestressing steel (strand) during transfer of the prestressing force. The teeth are beveled to assure gradual development of the tendon force over the length of the wedge. These are standard internal portions of a strand chuck assembly.

Wedge set – The relative movement of the wedges into the anchorage cavity during the transfer of the prestressing force to the anchorage.

Workability – The ease with which a given set of materials can be mixed into the concrete and subsequently handled, transported, placed, and finished with a minimum loss of homogeneity.

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DIVISION 1 - QUALITY SYSTEM

Standard

1.1 Objective

Quality control shall be an accepted and functioning part of the plant operation. Overall product quality results from individual as well as corporate efforts. Plant management must make a commitment to quality before quality programs can be effectively adopted or implemented at the operational level. Management shall establish a corporate standard of quality based on uniform practices in all stages of production, and shall require strict observance of such practices by all levels of personnel.

1.2 Plant Quality Assurance Program

1.2.1 General

The plant shall implement and maintain a documented quality assurance program in addition to this manual. Each plant shall have a unique Plant Quality System Manual based on operations at that facility.

Commentary

C1.1 Objective

The general objective of this manual is to define the required minimum practices for the production of precast concrete units and for a program of quality control.

Construction project specifications and manuals can prescribe and explain proper quality control criteria for all phases of production consistent with producing products of the highest quality. However, to ensure that such criteria are followed, inspection personnel and a regular program of auditing all aspects of production should be provided.

The individuals in control of operations should have the commitment to produce products of proper quality, and should delegate authority for assignment of the responsibilities necessary to achieve the desired results. Consistent quality can only be achieved if proper procedures are established and then carried out.

While the guidelines in this division address the quality control function, it is recognized that the primary responsibility for quality rests with production personnel. Accordingly, the production personnel should understand the role of quality control and work to ensure effective monitoring, timely responses, corrective actions, and improvement.

Although production personnel are responsible for the quality of products, it is necessary to have a system of checks and balances. Quality control inspections provide this check and balance system and consequently are a vital tool for management. The number of persons required to effectively perform the quality control functions will vary with the size and extent of plant operations.

Supervisory personnel are an integral part of the process and should be committed to the quality standards. The production of quality products requires uniformity of management's expectations for all areas of operations and types of products.

C1.2 Plant Quality Assurance Program

C1.2.1 General

The use of a written Plant Quality System Manual requires an initial effort by plant management for development of the document. It further requires periodic updating to establish new practice guidelines for addressing the