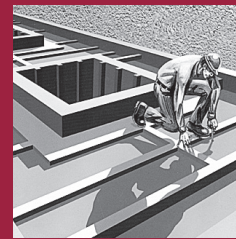


click buy full version



Precast/Prestressed Concrete Institute

# Quality Control Technician/Inspector Level III Training Manual



TM-103

Click buy full version

**PCI**  
**Quality Control Personnel**  
**Level III**  
**Training Manual**

**TM-103**

**January 1996**

TM-103

Copyright © 2000 by  
PRECAST/PRESTRESSED CONCRETE INSTITUTE

All rights reserved. No part of this book may  
be reproduced in any form without permission  
in writing from the publisher.

First Edition, 1996  
First Edition, Second Printing, 2000

ISBN 0-937040-64-9

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.

# PCI TECHNICAL/INSPECTOR LEVEL III TRAINING MANUAL

## TABLE OF CONTENTS

Notation	i
Foreword	iii
Introduction	v
Chapter 1 - Properties of Concrete Components	1.1
1.1 Cement	1.2
1.1.1 Water-Cement Ratio	1.2
1.2 Aggregates	1.3
1.2.1 Fine Aggregates	1.3
1.2.2 Coarse Aggregates	1.4
1.2.3 Lightweight Aggregates	1.5
1.3 Admixtures	1.6
1.3.1 Air-Entraining Admixtures	1.6
1.3.2 Water Reducers	1.8
1.3.3 Retarders	1.9
1.3.4 Accelerators	1.9
1.3.5 High Range Water Reducers (Superplasticizers)	1.9
1.3.6 Pozzolans	1.11
1.3.7 Silica Fume (Microsilica)	1.12
1.3.8 Corrosion Inhibitors	1.14
Chapter 2 - Essentials of Quality Concrete	2.1
2.1 Suitable Materials	2.1
2.1.1 Cement	2.1
2.1.1.1 Understanding Mill Certificates	2.1
2.1.2 Aggregates	2.9
2.1.2.1 Control of Uniformity	2.9
2.1.2.2 Comprehensive Acceptance Testing	2.10
2.1.3 Admixtures	2.12
2.1.3.1 Compatibility	2.12
2.1.3.2 Batching	2.12
2.1.3.3 Chloride Content	2.13
2.1.4 Water	2.13
2.2 Proportioning, Mixing, Transporting	2.14
2.2.1 Proportioning	2.14
2.2.2 Mixing	2.15
2.2.3 Transporting	2.17

Currently in preview

2.3	Placing and Consolidation	2.18
2.3.1	Placing	2.18
2.3.2	Consolidation	2.18
2.3.2.1	Use of Internal Vibrators	2.19
2.3.2.2	Form Vibrators	2.21
2.3.2.3	Vibrating Screeds	2.21
2.3.2.4	Circular Plate Vibrators	2.22
2.4	Finishing	2.22
2.4.1	Surfaces to Receive Composite Concrete	2.23
2.4.2	Flat Finish	2.23
2.4.3	Broom Finish	2.24
2.4.4	Trowel Finish	2.24
2.4.5	Formed Surfaces	2.24
2.5	Curing	2.25
2.5.1	Methods	2.25
2.5.2	Curing with Applied Heat	2.25
2.5.3	Accelerated Curing Cycle	2.26
2.6	Economy	2.27
2.6.1	Minimizing Cement Content	2.27
2.6.2	Balancing Concrete Costs and Cost of Placing, Consolidation, and Finishing	2.27
Chapter 3 - Properties of Fresh Concrete		3.1
3.1	Consistency	3.1
3.1.1	Items Affecting Consistency	3.1
3.1.2	Slump Test	3.2
3.1.3	Control of Consistency	3.3
3.1.4	Adjusting Consistency	3.4
3.2	Uniformity	3.5
3.2.1	Batch Variation	3.5
3.3	Workability	3.6
3.3.1	Definition	3.6
3.3.2	Controlling Workability	3.6
3.4	Bleeding	3.7
3.5	Avoiding Plastic Shrinkage Cracking	3.7
3.6	Finishability	3.10

Currently in preview

Chapter 4 - Properties of Hardened Concrete	4.1
4.1 Strength	4.1
4.1.1 Testing Methods	4.1
4.1.2 Water-Cement Ratio	4.3
4.1.3 Aggregate Properties	4.3
4.1.4 Testing for Strength per ACI 318	4.3
4.1.5 Control of Strength per ACI 318	4.4
4.1.6 Modulus of Elasticity	4.5
4.2 Durability	4.6
4.2.1 General	4.6
4.2.2 Freeze-Thaw Resistance	4.6
4.2.3 Sulfate Resistance	4.8
4.2.4 Alkali-Aggregate Reaction Resistance	4.9
4.3 Creep and Shrinkage	4.9
4.4 Watertightness and Absorption	4.10
4.4.1 General	4.10
4.4.2 Silica Fume (Microsilica)	4.12
4.5 Abrasion Resistance	4.12
4.6 Chloride Content	4.12
4.6.1 General	4.12
4.6.2 Sources of Chloride Ions	4.13
4.6.3 Testing for Chloride Content	4.14
Chapter 5 - Concrete Mix Design	5.1
5.1 Design of Normal Weight Concrete Mixes	5.1
5.1.1 Determining Water Content	5.2
5.1.2 Determining Cement Content	5.3
5.1.3 Water-Cement Ratio	5.3
5.1.4 Selecting Slump Range	5.3
5.1.5 Determining Coarse Aggregate Volume	5.4
5.1.6 Determining Amount of Fine Aggregate	5.4
5.1.7 Trial Mixes	5.5
5.1.8 Mix Adjustments	5.5
5.1.9 Minimizing Cement Content	5.5
Example Problem	5.5
5.1.10 Adjusting Mixes for Silica Fume (Microsilica)	5.10
5.2 Design of Lightweight Concrete Mixes	5.11
5.2.1 Basic Principles	5.12
5.2.2 Water Absorption of Lightweight Aggregates	5.12
5.2.3 Concrete Unit Weight	5.12
5.2.4 Trial Mixes	5.13

Currently in preview

5.2.5	Mix Adjustment	5.14
5.2.6	Control of Lightweight Mixes	5.14
	Example Problem	5.15
5.3	Design of Architectural Concrete Mixes	5.17
5.3.1	Establishing Design Criteria	5.17
5.3.2	Sample	5.18
5.3.3	Strength Versus Appearance	5.18
5.3.4	Aggregate Size	5.18
5.3.5	Test Batches	5.19
5.4	ACI Reference Tables	5.19
<b>Chapter 6 - Alternate Testing for Concrete Compressive Strength</b>		<b>6.1</b>
6.1	Concrete Test Cylinders	6.1
6.1.1	Cylinders Smaller than 6 x 12-in.	6.1
6.1.2	Neoprene Caps for Test Cylinders	6.2
6.2	Pulse Velocity Method (ASTM C597)	6.3
6.3	Rebound Number of Hardened Concrete (ASTM C805)	6.4
6.4	Penetration Resistance of Hardened Concrete (Windsor Probe, ASTM C803)	6.6
6.5	Pullout Strength of Hardened Concrete (ASTM C900)	6.7
6.6	Cores and Sawed Beams (ASTM C42)	6.7
6.7	Correlation Curves (linear regression analysis)	6.8
6.7.1	Hand-Drawn Correlation Curves	6.9
6.7.2	Statistically Based Correlation Model	6.10
<b>Chapter 7 - Deflected Prestressing Strands</b>		<b>7.1</b>
7.1	General	7.1
7.2	Methods	7.4
7.2.1	Tensioning with Strands in Deflected Position	7.4
7.2.2	Depressing Strands to Hold-downs	7.6
7.2.3	Raising Strands at Supports Between Ends of Members	7.9
7.3	Tolerances	7.9
7.4	Control of Tensioning of Deflected Strands	7.9
7.4.1	Tension Values	7.10
7.4.2	Reducing Friction	7.12
7.5	Control of Detensioning of Deflected Strands	7.12



7.6	Basic Calculations	7.12
7.6.1	Fundamental Relationships	7.12
7.6.2	Vertical Forces--Two-Point Hold-Downs	7.13
7.6.3	Vertical Forces--One-Point Hold Downs	7.14
7.6.4	Net Jacking Force	7.14
7.6.5	Other Factors Affecting Strand Force	7.15
7.7	Example Problems	7.15
7.7.1	Beam with Parallel Depressed Strands--(Tensioning Strands in Draped Position)	7.15
7.7.2	Simplified One-Point Hold-Down	7.16
7.7.3	Double Tee with Strands Bundled at Hold-Down	7.18
Chapter 8 - Product Control		8.1
8.1	Dimensional Tolerances	8.1
8.1.1	Published Tolerances	8.1
8.1.2	Adjusting Tolerances to Specific Project Requirements	8.3
8.1.3	Measurement Techniques	8.4
8.2	Appearance	8.4
8.2.1	Establishing Acceptance Criteria	8.4
8.2.2	Factors Affecting Appearance	8.5
8.2.3	White and Colored Concrete	8.6
8.2.4	Efflorescence	8.7
8.2.4.1	What is Efflorescence	8.7
8.2.4.2	Causes of Efflorescence	8.8
8.2.4.3	Minimizing Efflorescence	8.9
8.2.5	Minimizing Discoloration	8.12
8.3	Cracking	8.13
8.3.1	Measurement of Crack Widths	8.14
8.3.2	Cracks in Hollow-Core Slabs	8.15
8.3.2.1	Longitudinal Crack at Void	8.15
8.3.2.2	Longitudinal Crack at Web	8.16
8.3.2.3	Transverse Crack	8.16
8.3.2.4	Web Crack Above the Strands	8.17
8.3.2.5	Web Crack at or Near the Strands	8.17
8.3.2.6	Corner Cracks	8.18
8.3.2.7	Miscellaneous Cracks	8.18
8.3.3	Cracks in Double Tees	8.19
8.3.3.1	Horizontal End Crack in Stem	8.19
8.3.3.2	Horizontal Crack in Stem	8.19
8.3.3.3	Vertical Crack at Top of Member	8.20
8.3.3.4	Vertical Crack at Bottom of Stem	8.20
8.3.3.5	Diagonal Cracks in Stem	8.21
8.3.3.6	Flange Cracks Outside of Stems	8.21



8.3.3.7	Flange Crack Between Stems on Opposite Sides	8.22
8.3.3.8	Flange Cracks Each Side of Stem	8.22
8.3.4	Cracks in Beams	8.23
8.3.4.1	Transverse Crack at Top of Beam	8.23
8.3.4.2	Horizontal End Crack in Web or Flange	8.24
8.3.4.3	Vertical and Diagonal Cracks at Bottom of Member	8.25
8.3.4.4	Ledge Corner Crack	8.26
8.3.4.5	Ledge Crack	8.27
8.3.4.6	Miscellaneous Cracks	8.27
8.3.5	Cracks in Columns	8.28
8.3.5.1	Interior Corner Crack in Corbel	8.28
8.3.5.2	Exterior Corner Crack or Spall in Corbel	8.28
8.3.5.3	Horizontal Crack	8.29
8.3.5.4	Vertical Crack at Ends	8.30
8.3.5.5	Diagonal Crack at Ends	8.30
8.3.5.6	Miscellaneous Cracks	8.31
Chapter 9	Welding	9.1
9.1	Carbon Equivalent of Reinforcing Bars	9.1
9.1.1	Calculation of Carbon Equivalent	9.2
9.1.2	Application	9.3
9.1.3	Electrodes	9.5
9.2	Visual Inspection of Welds	9.6
9.3	Welding ASTM A36 Steel	9.8
9.4	Welding Stainless Steels	9.8
9.5	Welding Galvanized Steel	9.9
9.6	Stud Welding	9.10
9.6.1	Description	9.10
9.6.2	Design and Stud Selection Considerations	9.15
9.6.3	Quality Control and Inspection for Stud Welding	9.16
9.6.3.1	Production Testing	9.17
9.6.3.2	Visual Inspection	9.20
9.6.3.3	Quality Assurance and Recordkeeping	9.21
Appendix A	Glossary of Terms	A.1
Appendix B	References	B.1
Appendix C	Aggregate Tests Related to Mix Design Methods	C.1



<b>Appendix D - Correlation Analysis Using Statistics</b>	<b>D.1</b>
<b>Appendix E - Answers to Sample Questions</b>	<b>E.1</b>
<b>Metric Conversion</b>	<b>F.1</b>



## NOTATION

Symbols used in this manual are listed below. The meanings given apply to the symbols as used in this manual. Symbols used in Sec. 6.7 and in Appendix D are defined in Appendix D.

$A$  = cross sectional area of strand

$B$  = weight of saturated surface dry sample of coarse aggregate in air (App. C)

$B$  = weight of pycnometer filled with water to the calibration mark (App. C)

$C$  = weight of saturated surface dry coarse aggregate in water (App. C)

$C$  = weight of pycnometer filled with sample of fine aggregate and water to calibration mark (App. C)

$E$  = modulus of elasticity of prestressing steel

$E_c$  = modulus of elasticity of concrete

$f_{avg}$  = average of  $n$  strength tests

$f'_c$  = compressive strength of concrete

$f_{c,t}$  = splitting tensile strength of concrete

$f_i$  = individual strength test

$G, G_n$  = specific gravity of a material

$a$  = length of strand between hold-up and hold-down

$H_d$  = hold-down force

$H_u, H_{um}$  = hold-up force

$L$  = length of strand under consideration

$m$  = aggregate absorption in percent divided by 100

$n$  = number of tests

$P$  = horizontal component of force in deflected strand

$S$  = weight of fine aggregate sample

$V_1, V_n$  = absolute volume of a given weight of a specific material

$W_1, W_n$  = weight of a given quantity of a specific material

$\Delta$  = increase in length of strand

$\sigma$  = standard deviation

## FOREWORD

This manual is part of a series of training and study guides published by the Precast/Prestressed Concrete Institute designed primarily for manufacturing plant quality control personnel. However, many companies use these books as references and for training of a much larger group of personnel. Further, the manuals are used outside the manufacturing plants by consulting testing agencies and various owner-agencies such as state and county highway departments.

The first training manual for quality control personnel was published by the PCI Plant Certification Committee in 1987. That publication (PCI TM-101) was a study manual and text for the Levels I and II Technician/Inspector Certification Program (now called the Quality Control Personnel Certification Program). The manual proved to be very useful not only for quality control personnel but for production and engineering personnel as well.

In 1989, the PCI Plant Certification Committee, Technician/Inspector Certification Subcommittee, developed an outline of topics it wanted included in a Level III training manual. The subjects were more advanced than those in TM-101 and added additional topics as well.

PCI selected a consultant to work with its committees in the preparation of the manual. Armand H. Gustaferrero, Principal, The Consulting Engineers Group, Inc., Mount Prospect, Illinois managed the process and wrote much of the material in the manual.

Upon printing of this manual in 1996, the following PCI committees were providing oversight of the process:

Quality Assurance Council  
Larry G. Fischer, Chairman

Edwin A. McDougale  
Gary E. Oakes

Stanley J. Ruden  
Dino J. Scalia

**Personnel Training and Certification Committee  
(Formerly the Technician/Inspector Certification Committee)  
Edwin A. McDougle, Chairman**

**T. Henry Clark  
Gary E. Oakes**

**Joe Roche  
Dino J. Scalia**

Early in the project, the PCI Plant Certification Committee was responsible for development and coordination. The committee members who participated at that time were:

**PCI Plant Certification Committee  
Gary E. Oakes\*, Chairman**

**Ray Andrews  
T. Henry Clark\*  
Theodore W. Coons  
Peter D. Courtois†  
John S. Dick\*  
David Eddy  
Larry G. Fischer  
Ted J. Gutt**

**Ray L. Kennedy  
Ronald E. Knaack  
Michael W. Lanier  
Robert McCrossen  
Stanley J. Ruden  
Dino J. Scalia\*\*  
Wes Westermann**

**\*Formerly Members of the Technician/Inspector Certification Subcommittee**

**\*\*Formerly Chairman of the Technician/Inspector Certification Subcommittee**

**†Deceased**

**John S. Dick, Editor  
Precast/Prestressed Concrete Institute**

## **INTRODUCTION**

### **TM-103, First Edition**

This manual has been developed for use as a classroom text in the Precast/Prestressed Concrete Institute's Level III Quality Control School. It will also be valuable as a self-study guide for those interested in learning the requirements for producing quality prestressed concrete and as a reference and training manual for plant personnel.

Beginning in 1973 the PCI Plant Certification Committee has conducted Quality Control Schools to instruct producer member employees in the technical details of manufacturing prestressed concrete and to familiarize them with the industry's quality standards. These standards include the *Manual for Quality Control for Plants and Production of Precast and Prestressed Concrete*, (MNL-116) and *Manual for Quality Control for Plants and Production of Architectural Precast Concrete*, (MNL-117). In 1984 the Committee launched the Technician/Inspector\* Certification Program to formalize the training process and to recognize those that completed a specific course of instruction. Since 1985, PCI has awarded certificates as certified Technician/Inspector\* for Levels I and II. In 1987, the Committee published the *Quality Control Technician/Inspector Level I & II Training Manual*, (TM-101), to aid in preparation for taking the certification examinations. TM-103 is an expansion of the material contained in TM-101 and contains new material on advanced topics not previously presented. The material in TM-101 should be reviewed and understood before proceeding with the subjects in this text.

#### **Outline of Contents**

Quality concrete is fundamental to manufacturing quality precast concrete. Chapter 1, "Properties of Concrete Components" reviews the basic ingredients in concrete. Chapter 2, "Essentials of Quality Concrete" presents the processes required to obtain the desired finished concrete product. Chapters 3 and 4 describe the properties of fresh and hardened concrete that must be considered when selecting the appropriate concrete mix for a specific application. These chapters also describe the testing procedures for evaluation of concrete properties. Once a concrete mix has been selected for a project, the uniformity of the concrete throughout the project is a primary quality goal. Careful attention to the uniform application of concrete tests is critical to the successful control of concrete quality.

Detailed steps for the design of concrete mixtures are presented in Chapter 5. Some requirements of architectural concrete are the same as for structural concrete. Where special requirements occur for

\*The program is now the Quality Control Personnel Certification Program