
Contents

Preface.....	xi
The Author.....	xiii
Chapter 1 How Good Is Your Quality?.....	1
Costs Due to Poor Quality	1
Why Is It So Important to Lower Standard Deviation?	2
Is It Worthwhile Not to Invest in Improved Quality under Certain Circumstances?	5
2010 NRMCA Quality Measurement and Bench Marking Survey	5
How Can a Concrete Producer Improve Quality?.....	6
Chapter 2 Variation in Concrete Strength Due to Cement	7
Cement from a Given Source Varies between Shipments.....	7
ASTM C917.....	11
How Should a Ready Mixed Concrete Producer Use ASTM C917?....	12
Cement Choice	12
Better Understand Concrete Variability and Lower It	12
Reduce Low-Strength Problems and Optimize Mixture Proportions	13
Troubleshoot Low-Strength Problems.....	14
How Should a Cement Producer Use ASTM C917?	14
Summary	15
Chapter 3 Variation in Concrete Strength Due to Water and Air Content Variation.....	17
Mixing-Water Content Variation and Its Effect on Compressive Strength Variation	17
Air Content Variation and Its Effect on Strength Variation.....	18
Combined Effect of Water and Air Content Variation on Strength Variation	19
Discussion.....	20
Summary	22
Chapter 4 Mixing-Water Control	23
Sources of Water	23
Washwater in Truck Mixer Drum from Previous Load	23
Batchwater	24
Free Water from Aggregates	24

	Water Added at Slump Rack	25
	Water Added at Job Site	26
	Variations in Mixing-Water Demand	26
	Effect of Mixing-Water Content, Mixing-Water Demand on Measured Slump.....	29
	Plant Tests for Quality Assurance	30
	Summary	32
Chapter 5	Variation in Concrete Strength and Air Content Due to Fly Ash	35
	Variability of Fly Ash Shipments from Given Source	35
	Air Entrainment	36
	Strength Activity	42
	Fly Ash Testing Required by ASTM C311 and C618	46
	Suggested Producer Actions.....	47
	Air Entrainment.....	47
	Strength Activity Index	48
	Other Tests	48
	Summary of Suggested Producer Actions	49
Chapter 6	Variation in Concrete Performance Due to Aggregates.....	51
	Variability of Aggregate from Single Source.....	51
	Aggregate Properties and Their Effect on Concrete Mixture	
	Proportioning and Performance	52
	Relative Density and Absorption of Aggregate	52
	Aggregate Moisture Content	52
	Void Content in Coarse Aggregates	52
	Void Content of Fine Aggregates	53
	Aggregate Grading	53
	Material Finer than 75 μm (No. 200)	56
	Sand Equivalency	57
	Using Aggregate Test Results.....	57
	Table 6.1 Test Results	57
	Table 6.2 Test Results—Tests Conducted by the Aggregate Producer.....	57
	Table 6.2 Test Results—Tests Conducted by the Concrete Producer.....	58
Chapter 7	Basic Statistics.....	61
	Basic Statistical Parameters	61
	Variability.....	61
	Frequency Distributions	62
	Normal Distribution	63
	Predictions Using a Normal Distribution	65

Types of Variation	67
Common Causes and Special Causes	67
Step Changes	67
Control Charts	67
Individual Chart.....	68
Average and Range Charts	68
Moving Average and Moving Range Charts	72
CUSUM Charts	73
Example	73
Chapter 8 Variation in Concrete Performance Due to Batching	81
ASTM C94 Scale Accuracy and Accuracy of Plant Batching.....	81
Two Issues with Batching.....	83
Over-Batching.....	83
Variation of Batch Weights and Its Effects	85
Cementitious Weight Variation and Its Effect on Strength Variation	86
How Can a Company Improve Batching Accuracy?.....	88
Yield Measurements—A Tool to Improve Batching Accuracy	90
Summary	90
Chapter 9 Variation in Concrete Performance Due to Manufacturing.....	91
ASTM C94 Requirements for Uniformity of Concrete	91
Improving Uniformity of Concrete Produced in Truck Mixer	92
Batching Sequence	92
Mixing Revolutions	93
Mixing Speed	93
What Can a Company Do to Improve Uniformity of Concrete Produced in a Truck Mixer?	94
Variation in Concrete Performance Due to Temperature.....	95
Effect of Temperature on Setting Time.....	96
Effect of Temperature on Early-Age Strength.....	97
Effect of Temperature on Mixing-Water Demand.....	98
Variation in Concrete Performance Due to Delivery Time	98
Summary	100
Chapter 10 Variation in Concrete Performance Due to Testing	101
A Measure of Testing Variability.....	101
Other Methods of Evaluating Testing	104
Other Property Measurements	104
Producer Testing.....	104
7- to 28-Day Strength Gain	104

Cylinder Density.....	105
Laboratory Reports.....	105
ACI Code and Specification Requirements Related to Concrete	
Testing	105
Steps to Improve the Quality of Acceptance Testing.....	107
Education.....	107
Round-Robin Testing Programs	108
Incentives to Testing Technicians.....	110
Preconstruction Conferences.....	110
Other Strategies	110
Summary	111
Chapter 11 Internal Concrete Testing	113
Why Test at the Plant When We Can Get Job-Site Test Data?	113
Criteria for Plant Testing	113
Selection of Mixture Classes	113
Sampling and Types of Testing	114
Frequency of Testing	116
Data Analysis	116
Control Charts	116
Slump.....	117
Air Content	117
Density	118
Air-Free Density	119
Temperature	119
Compressive Strength	119
CUSUM Charts	121
Summary	123
Chapter 12 Using Job-Site Test Results for Improving Concrete Quality	125
Acceptance Test Results.....	125
Data Analysis	125
Rejecting Outliers.....	126
Control Charts	127
Control Chart Limits	127
Monitoring S of Compressive Strength	128
CUSUM Charts	129
Use of Control and CUSUM Charts to Analyze Project	
Test Data	129
Project 1	129
Project 2	132
Project 3	134
Summary	138

Chapter 13 Impact of Specifications on Concrete Quality 139

 Allow Use of Standard Deviations Not Just over Designs 139

 Move from Prescriptive to Performance-Based Specifications..... 140

 Minimum Cementitious Content 140

 Maximum w/cm..... 141

 Changes to Mixture Proportions after Submittal..... 142

 Qualifications 142

 Producer Qualifications 142

 Installer and Testing Agency Qualifications 143

 Bonus–Penalty Provisions..... 143

 Job-Site Concrete Acceptance Testing 145

 Current information on Material Properties 145

 Summary 145

Chapter 14 Impact of Concrete Quality on Sustainability..... 147

 Target a Low Standard Deviation..... 147

 Better Job-Site Curing and Overall Testing Quality 147

 Mixture Optimization 148

 Fewer Returned Concrete and Hardened Concrete Issues 149

 Plant and Truck Mixer Maintenance..... 150

 Temperature Measurements 150

 Batching Accuracy and Yield Measurements 150

 Mixture Adjustments..... 151

 Summary 151

Chapter 15 Elements of a Quality Management System for a Concrete

 Producer 153

 Why Should a Company Have a QMS? 153

 What Are Elements of a QMS and How Does It Improve Quality?.... 154

 Quality Objectives and Measurement 154

 Management Commitment..... 155

 Customer Focus 155

 Personnel Qualifications..... 156

 Quality Manager..... 156

 Plant Operators 156

 Field Testing Technicians 156

 Laboratory Technicians 156

 Truck Mixer Operators 157

 Laboratory Testing Capabilities 157

 Aggregate Tests..... 157

 Concrete Tests..... 157

 Materials Management and Conformance 158

 Production Control 159

Specification Review, Mixture Development, Optimization.....	160
Receiving Orders and Record Keeping.....	160
Testing	161
Internal Testing at the Plant.....	161
Internal Testing at the Job Site	161
Quality Assurance Test Records.....	161
Nonconforming Acceptance Test Results.....	161
Identification/Traceability	162
Quality Audit.....	162
Returned Concrete and Washwater	162
Summary	163
References	165
Further Reading.....	169
Glossary	173
Appendix A—Submittal Requirements and Acceptance According to the ACI 318 Building Code.....	175
Appendix B—Calculation of Strength Variation from Water Content Variation	181
Appendix C—FLYASH Tests (NRMCA Draft Standard Practice 1988)	183
Appendix D—Initial Curing of Acceptance Test Cylinders and Transportation (NRMCA ASCC Checklist)	185
Appendix E—Outline of Training Requirements	187
Appendix F—Checklist for Laboratories Used for Mixture Development	189
Appendix G—Preventive Equipment Maintenance	191
Index.....	193