Certified PCCP Field Supervisor Manual

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Appendix A

ITM 402	Strength of Portland Cement Concrete Pavement (PCCP) using the Maturity Method utilizing the Time Temperature Factor Methodology
ITM 403	Water-Cementitious Ratio
ITM 404	PCCP Core Length Determination
ITM 803	Contractor Quality Control Plans

Appendix B

2014 Indiana Standard Specifications

Title-Time Subjects Reference Instructors **Tuesday Morning** Moderator: Ron Walker Introduction 9:00 **Opening Comments** Ron Walker Chp 1 Agenda/Manual Update to Supervisor Requirements 9:15 **Concrete Materials** 9:15 Aggregates (FHWA Video) Ron Walker Chp 2 Portland Cement Tony Zander to 10:00 Admixtures Dowel Bars Tie bars Material Certifications 10:00 to 10:15 **BREAK** Mix Design and Trial Batch Tony Zander Preparation Chp 3 10:15 Procedures to 12:00 12:00 to 1:00 **LUNCH**

CERTIFIED PCCP FIELD SUPERVISOR TRAINING COURSE AGENDA

Tuesday Afternoon Moderator: Ron Walker

Quality Assurance Procedures

1:00 to 1:45	Sublots and Lots Random Sampling Acceptance Testing Pavement Smoothness Protection of Pavement Opening to Traffic Pavement Thickness Deficient Pavement Thickness Pay Factors Quality Assurance Adjustment Failed Materials Appeals	Ron Walker Tony Zander	Chp 4
1:45 to 2:00	**BREAK**		
Quality Control P	lan Requirements		
2:00 to 2:45	QCP Requirements INDOT QCP Checklist	Ron Walker	Chp 5
Contractor Quality	y Control Plans		
2:45 to 4:00	Contractor Personnel Materials Process Control of Aggregates Trial Batch Demonstration Concrete Batching Process Control of Concrete Process Control of Pavement Control Charts Response to Test Results Concrete Hauling Concrete Paving Joints Finishing, Texturing and Curing Documentation	John Berscheit	Chp 5

Wednesday Morning Moderator: Ron Walker

Traffic Control

8:00 to 8:45	Basic Setup Continual Inspection	Pat McCarty	Chp 6
Preparation of the	Grade		
8:45 to 9:30	Subgrade Subbase	Steve Thieroff	Chp 7
9:30 to 9:45	**BREAK**		
Process Control			
9:45 to 10:15	Aggregates – Stockpiling Admixtures Testing Monitoring Concrete Behind Paver	Dick Newell	Chp 5
Paving Operation	<u>Requirements</u>		
10:15 to 12:00	Dowel Bars Assemblies and Alignment Tie Bars Placing Concrete Strike Off, Consolidation, and Finishing Curing Form Removal Sawing Smoothness Thickness Pavement Joints	Chad Nierman Jason Deering	Chp 8 & 9
12:00 to 1:00	**LUNCH**		

Wednesday Afternoon Moderator: Ron Walker

Paving Operation Best Practices

1:00 to 2:45	Paving Equipment	Neil Douglass Gary McLeland Steve Fox Tony Korba Ernie Howard Rick Wampler	Chp 9
2:45 to 3:00	**BREAK**		

Paving Troubleshooting

3:00	Problems Observed Before Concrete Has Set	Mike Byers	Chp 10
to	Problems Observed in First Days after Placement		
4:15	Preventing Problems Observed after Construction		

Thursday Morning Moderator: Ron Walker

Course Exam

8:00 to 11:00

CERTIFIED PCCP FIELD SUPERVISOR



PROCEDURES and POLICIES

MANUAL

INDOT CERTIFIED PCCP FIELD SUPERVISOR

Objectives

The Indiana Department of Transportation (INDOT) has established a Quality Control/Quality Assurance Program for the purpose of properly assigning INDOT and Producer responsibilities for all aspects of the production of quality Portland Cement Concrete Pavement (PCCP). The QC/QA PCCP Pavement specifications require that the Quality Control Plan Field Manager be a Certified PCCP Field Supervisor.

The principal objective of the Certified PCCP Field Supervisor Program is to provide the necessary training to field personnel so that they may administer quality control of the PCCP. Knowledge of materials, equipment, paving operations, testing, specifications and other field concrete related topics are provided to enhance the Supervisor's ability to meet the program requirements.

Administration

The training program is administered by INDOT, the Indiana Chapter of the American Concrete Pavement Association (IN-ACPA), and Purdue University. Specific duties of each agency include:

INDOT

- 1. Course Announcement
- 2. Writing and Maintenance of the Training Manual
- 3. Notification to Students of Examination Results
- 4. Mailing Certificates
- 5. Maintenance of Certified PCCP Field Supervisor List
- 6. Retesting
- 7. Recertification

IN-ACPA

- 1. Training Facility Arrangements
- 2. Meal and Refreshment Arrangements
- 3. Training Course Materials
- 4. Miscellaneous Administrative Tasks

Purdue University

- 1. Registration of Students
- 2. Manual Printing
- 3. Distribution of Funds
- 4. Grading the Examination
- 5. Certificate Preparation
- 6. Continuing Education Units
- 7. Miscellaneous Administrative Tasks

Program Committee

The Program Committee acts as the steering committee which establishes the needs for the certification program and provides technical assistance for course materials and examinations. The committee is composed of representatives from INDOT, FHWA, IN-ACPA, and Purdue University.

Certification Committee

The Certification Committee is responsible for revocation or suspension of certifications. Their tasks include reviewing the violations of standard policies, rendering judgement of the seriousness of the violation, and hearing any subsequent appeal. The committee is composed of the following members:

Manager, Office of Materials Management 1 Representative of Purdue University 1 Representative of IN-ACPA

Certification Requirements

An individual is required to pass a written examination to become certified. Participation in the certification training course is required to take the examination. Also, verification of attendance of the OSHA 10 or OSHA 30 training course on construction safety is required for certification.

Training Course Announcement

The announcement for the training course will be made on December 1 for a course offered the next year.

Certification Examination

The certification examination is given upon completion of the training course. The examination time is limited to a maximum duration of two hours and the examination is open book/open note. A minimum score of 70 percent is required to pass the examination. Notification of the examination results will be made within 10 days of the examination date.

One retake of the examination will be allowed. The retake examination will be open book/open note and consist of a format similar to the original examination. The retake examination will be given at the INDOT Office of Materials Management within 30 days of notification of the results of the original examination. A minimum score of 70 percent is required to pass the retake examination. A failure of the retake examination will require participation in the training course and passing the examination to become certified.

The examinations will be retained by Purdue University for a period of one year after such time the examinations will be destroyed. Examinations may be reviewed in the presence of an INDOT representative within one year of the examination date. Arrangements for review of the examination shall be made with INDOT.

Recertification Requirements

The certification is valid for three years as determined from the date of initial issuance. Recertification will require obtaining 12 credits and attending a recertification refresher course or by passing a written examination. The 12 credits may be obtained as follows:

QCP Field Manager of one or more INDOT	
contracts in one construction season	4 credits
Consultant Project Manager of one or more INDOT	
contracts in one construction season	4 credits

The recertification refresher course will include a condensed version of the certification training course. There will be no fee for the recertification refresher course.

If the certification is not renewed, the certification will expire. Renewal of the certification may be made within the subsequent year after expiration by passing the recertification examination or retake examination, if required. Renewal of the certification after one year from the expiration of the certification will require review by the Certification Committee to determine the certification requirements.

Notification of the recertification procedures will be made prior to the expiration of the certification. Applying for certification renewal and verification of the required recertification credits using the form in Appendix A are the responsibility of each individual. A current address will be on file with INDOT. Any address revision or the recertification credit form is required to be sent to:

Concrete Engineer Indiana Department of Transportation Office of Materials Management 120 S. Shortridge Rd. Indianapolis, IN 46219 Fax: 317-356-9351

Recertification Examination

The recertification examination may be taken in an INDOT District or at the site of the refresher course upon completion of the training. The examination is limited to two hours and is open book/open note. A minimum score of 70 percent is required to pass the examination. Notification of the examination results will be made within 10 days of the examination date.

One retake of the examination will be allowed if the recertification exam is failed. Two hours will be allowed for the retake examination. The examination will be open book/open note and consist of a format similar to the original recertification examination. The retake examination will be given at the INDOT Office of Materials Management within 30 days of notification of the results of the original recertification examination. A minimum score of 70 percent is required to pass the retake examination. A failure of the retake examination will require participation in the certification training course and passing the certification examination to become certified.

The recertification examinations will be retained by Purdue University for a period of one year. After that period the examinations will be destroyed. Examinations may be reviewed in the presence of an INDOT representative within one year of the examination date. Arrangements for review of the examination are required to be made with INDOT.

Fees

The fee for attending the certification training course will be established by the Program Committee. The fee will cover a training manual, course materials, refreshments, and several meals.

The refund policy for the certification course fee is as follows:

- 1. An administration fee of \$100 will be charged for cancellation within 7 days of the course.
- 2. Lack of attendance of the course will result in no refund of the fee.
- 3. Unforeseen emergencies that result in absences during the course will result in a refund of the course fee.

Failure to pay the training course or examination fees will result in suspension of the certification.

Cancellation Policy

If a scheduled certification or recertification refresher course is cancelled because of insufficient class size, notification will be sent one week prior to the start of the course and the course fee will be reimbursed.

Continuing Education Units

Two continuing education units will be awarded for completion of the certification training course and passing the examination. Purdue University will maintain the necessary files for those individuals requesting that the continuing education units be recorded.

Revocation or Suspension of Certification

Certifications awarded may be revoked or suspended at any time by the Certification Committee for just cause. The procedure that will be taken to revoke or suspend a certification is as follows:

1. The individual will be sent written notification of the revocation or suspension of certification by a registered letter. A copy of the written notification will be sent to the individual's employer. The letter will state the grounds for the revocation or suspension, request a written response, and establish a hearing date.

- 2. Sixty days from the date of the notification will be allowed to respond and the response is required to be by letter. The response shall include an explanation of why the individual disagrees with the decision to revoke or suspend the certification.
- 3. After the 60 day time period has elapsed or upon receipt of the response, the case will be reviewed by the Certification Committee on the hearing date. The individual's response letter will be considered and the individual may appear before the Certification Committee.
- 4. The Certification Committee will issue a decision within one week of the hearing.
- 5. If the individual does not send a response letter or fails to appear before the Certification Committee, a default judgement will be issued by the Certification Committee based on the evidence available. The revocation or suspension may be affirmed, modified, or vacated following the hearing.

The reasons that a certification may be revoked or suspended include:

- 1. Cheating on recertification examinations
- 2. Falsification of quality control records

The Certification Committee may decide to revoke or suspend the certification depending upon the seriousness of the violation. Violations deemed as unintentional will result in a penalty of a letter of reprimand to the individual and the employer. Subsequent violations will result in suspension of certification for a designated period as determined by the Certification Committee. The certification will return to good standing after the period of suspension expires.

Intentional violations will result in a one year suspension of the certification. Subsequent violations will result in permanent revocation of the certification. If the individual wishes to become recertified after the period of suspension, participation in the certification training course and passing the certification examination will be required.

Appendix A

PCCP Field Supervisor Recertification Credit Form

Name: _____

Year: _____

I verify that the above-noted person was identified as the Quality Control Plan Field Manager on PCCP INDOT contract No.: ______.

Project Engineer/Supervisor

Send To: Concrete Engineer Indiana Department of Transportation Office of Materials Management 120 S. Shortridge Rd. Indianapolis, IN 46219 Fax: 317-356-9351

1 Portland Cement Concrete Pavement Supervision

Prerequisites

Duties

Chain of Command *INDOT Project/District Level Central Office Contractor*

Safety

Hazards Possible Injuries Safety Precautions

Terms Related to Portland Cement Concrete Pavement

Pavement Description

Types of Concrete Pavement

Plain Concrete Pavement Plain Concrete Pavement with Joints Reinforced Concrete Pavement with Joints Continuously Reinforced Concrete Pavement

CHAPTER ONE: PORTLAND CEMENT CONCRETE PAVEMENT SUPERVISION

The purpose of this course is to provide information on how to properly construct Portland Cement Concrete Pavement (PCCP). Emphasis will be on acquiring the skills and knowledge that a PCCP Field Supervisor will need to supervise and ensure construction of quality pavements in conformance with the plans and specifications. The construction of smooth, durable, and safe highways requires careful planning and continuous monitoring.

This manual is intended to provide the best practices for the Certified PCCP Field Supervisor. Many of the techniques, procedures, and methods provided are not applicable to all pavement circumstances, and other methods may be used to meet the requirements of the specifications. The manual is not to be considered part of the specifications or override the specifications or contract documents.

PREREQUISITES

A PCCP Field Supervisor should have knowledge of the following items prior to taking this course.

- 1) INDOT Standard Specifications
- 2) Indiana Test Method 803 (Appendix A)
- 3) PCCP paving processes and methods
- 4) Paving equipment operations
- 5) Pavement deficiencies and how to correct these problems
- 6) Plans and contract Special Provisions
- 7) Profilographs
- 8) OSHA 10 or OSHA 30 training course on traffic and safety
- 9) Certified Worksite Traffic Supervisor (CWTS) requirements

DUTIES

The general duties of a PCCP Field Supervisor are contained within **Sections 105, 305,** and **500.** These duties may be designated to other personnel on the project. The duties are summarized as follows:

- 1) Provide all work and materials in reasonably close conformance with the plans and specifications (Section **105.03**)
- For work conducted in accordance with Sections 305, and 500, serve as the Contractors "competent superintendent" (Section 105.05)
- 3) Be responsible to recognize and furnish acceptable materials and perform all work in accordance with the requirements of plans and specifications (Section **105.09**)
- 4) Keep the Project Engineer or Project Supervisor (PE/PS) informed as to the schedule of the work, the progress of the work and the manner in which the work is being performed (Sections **108.04**, **108.05**, **108.06** and **108.07**)
- 5) Be knowledgeable of the Construction Requirement Sections of **501**, **502**, **503**, **504**, **505**, **506**, **507**, and **508**
- 6) Complete the Paving Quality Control Plan (QCP) in accordance with ITM 803 (See Appendix A) and perform the work in accordance with the QCP
- 7) Be knowledgeable of and implement the maintenance of traffic plan in accordance with Section **801.03** for the PCCP operations
- 8) Be responsible for constructing PCCP meeting the plans and specifications for the contract.

CHAIN OF COMMAND

Every organization has a number of management levels, each with their own assigned authority and responsibility. The chain of command within INDOT and the Contractor should be known and followed. Working through the chain usually minimizes problems and maintains cooperation.

INDOT PROJECT/DISTRICT LEVEL

The levels of management in the field include:

- 1) PCCP Technician/Inspector
- 2) Project Engineer/Project Supervisor
- 3) District Area Engineer
- 4) District Construction Engineer
- 5) District Deputy Commissioner

When there are major problems on the contract, such as equipment breakdown or non-routine questions or requests, the PE/PS is contacted. If the problem is urgent and the PE/PS is not available, the Area Engineer is contacted.

CENTRAL OFFICE

Each District Construction Director has a Central Office Construction Field Engineer to provide guidance concerning PCCP operations. The Field Engineers are each assigned a construction specialty and work in the Construction Management Division of INDOT.

CONTRACTOR

A typical Contractor organization may include:

- 1) The crafts -- operators, carpenters, laborers
- 2) Field Quality Control Technicians
- 3) Job Foremen/Paving Foremen

- 4) PCCP Field Supervisor. This position is responsible for communication occurring between the PCCP field operations and the PCCP plant in accordance with the QCP.
- 5) Job Superintendent
- 6) General Superintendent/Project Manager
- 7) Executive

SAFETY

The PCCP Field Supervisor is required to be concerned with the safety of the traveling public, INDOT employees, and the Contractor's work force, as well as their own safety. Although many safety devices and procedures have been established to provide a safe construction work zone, various hazards still exist. These hazards are required to be identified and the necessary safety precautions taken to prevent injuries and accidents.

HAZARDS

Safety hazards that are present every day for inspecting PCCP include:

Equipment

Type of Equipment	Potential Hazard
Trucks	Dump bed operation
	Climbing on side of bed to check concrete
	Overhead power lines
Pavers	Clothing catches causing injuries
Air hammers	Flying debris and dust
Hand tools	Long handles
Vehicle and Equipment fires	Burns

Materials

Type of Material	Potential Hazard
Fresh concrete	skin irritation and burns
Traffic	
Type of Traffic	Potential Hazard
Traveling public through or adjacent to the work zone	Being hit

Construction traffic Being hit

POSSIBLE INJURIES

Safety hazards may result in accidents which cause injuries or death. The possible injuries that may occur are:

Part of Body	Possible Injury
Eyes	Concrete splatter
Hands and arms	Cuts and lacerations
	Bruises and abrasions
Body	Falls
	Bruises
	Electrocution
	Serious, extensive and possibly fatal injuries if run over
Feet	Blisters
	Burns
	Bruises

SAFETY PRECAUTIONS

Dress

<u>Clothing</u>

Full-length trousers and shirts should be worn. Loose jackets, shirts, or pants are never worn because of the danger of getting caught in moving parts.

<u>Shoes</u>

Work type leather boots with non-skid soles and steel toes are required to be worn. Tennis shoes do not provide adequate foot protection and are not worn. When working with concrete, rubber boots should be worn.

Safety Vests

Type III Fluorescent vests, t shirts, and hardhats, are required to be worn at all times while engaged in operations upon or adjacent to a highway construction and public traffic.

Safety vests and caps are bright colored so that equipment operators and motorists are more likely to see them.

The vest may get caught on equipment and/or other projections, and should be properly adjusted to minimize snagging.

Safety Equipment

Hard Hats

Hardhats should be worn in accordance with OSHA and Contractor safety policies.

Specifically, hard hats are required to be worn when an employee is on any worksite where overhead equipment, such as cranes, backhoes, loaders, or other large equipment (as deemed necessary by the Supervisor), is considered a part of the worksite.

When bending over, the hard hat may fall off or get blown off. Care is taken in making any sudden movement to recover the hat as a safety hazard may exist. A hat strap may be attached to hold the hat on.

Seat Belts

All operators and occupants of Contractor and INDOT vehicles are required to wear the complete seat belt assembly of the vehicle.

<u>Safety Glasses</u>

Safety glasses are available and worn when there is any possibility of damaging the eyes.

<u>Gloves</u>

When climbing on the truck and conducting other similar tasks, gloves are worn.

Ear Plugs

Ear protection may be needed if jackhammers or other loud noises are prevalent.

Minimizing Exposure

The risk of having an accident that results in injury may be minimized by following these precautions:

- 1) When climbing onto a truck or equipment, use the steps and hand holds when they are available with the 3 contact mounting and dismounting method
- 2) Do not climb onto truck/equipment, unless absolutely necessary to do so
- 3) Inform the driver/operator before climbing on the truck/equipment
- 4) Be alert to changes in the conditions on the contract that affect safety hazards. One example is one-way traffic versus two-way traffic.
- 5) Park vehicles out of the way of the traffic

Pertinent Information

<u>Fires</u>

Fires on the contract or in the field office are not common, but may occur. Basic fire suppression, the locations of fire extinguishers, and how to operate the fire extinguishers is required to be known.

First Aid

The proper treatment of minor cuts and burns not only reduces the irritation but also reduces the chance of infection and more serious complications. Basic methods of treatment and the location of the first aid kit are required to be known.

Emergencies

Emergency situations may arise that require contacting aid. At the start of the contract, the location and phone number or best method to contact a medical facility, an ambulance, the fire department, and the State Police are required to be identified.

TERMS RELATED TO PCCP

AASHTO - American Association of State Highway and Transportation Officials

Absorption - The amount of water absorbed under specific conditions, usually expressed as a percentage of the dry weight of the material; the process by which the water is absorbed.

Accelerator - An admixture which, when added to concrete, mortar, or grout, increases the rate of hydration of hydraulic cement, shortens the time of set, or increases the rate of hardening or strength development.

ACI - American Concrete Institute

ACPA - American Concrete Pavement Association

Admixture - A material other than water, aggregates, and portland cement (including air-entraining portland cement, and portland blast furnace slag cement) that is used as an ingredient of concrete and is added to the batch before and during the mixing operation

Agitating Truck - A vehicle in which freshly mixed concrete can be conveyed from the point of mixing to that of placing; while being agitated, the truck body may either be stationary and contain an agitator or may be a drum rotated continuously so as to agitate the contents

Air Content - The amount of air in mortar or concrete, exclusive of pore space in the aggregate particles, usually expressed as a percentage of total volume of mortar or concrete

Air-Entraining Admixture - An addition for concrete which causes air, usually in small quantity, to be incorporated in the form of minute bubbles in the concrete during mixing, usually to increase its workability and frost resistance. An entrapped air void is characteristically 1 mm or more in width and irregular in shape whereas an entrained air void is typically between 10 and 1000 μ m in diameter and spherical or nearly so

Air-Entrainment - The inclusion of air in the form of minute bubbles during the mixing of concrete or mortar

Alkali-Silica Reaction - The reaction between the alkalies (sodium and potassium) in portland cement binder and certain siliceous rocks or minerals, such as opaline chert, strained quartz, and acisic volcanic glass, present in some aggregates; the products of the reaction may cause abnormal expansion and cracking of concrete in service

ASTM - American Society for Testing and Materials

Backer Rod - Foam cord that inserts into a joint sealant reservoir and is used to shape a liquid joint sealant and prevent sealant from adhering to or flowing out of the bottom of the reservoir

Bag (of cement) - A quantity of cement; 42.6 kg in the United States; portland or air-entraining portland cement, or as indicated on the bag for other kinds of cement

Base Course - A layer of specified select material of planned thickness constructed on the subgrade or subbase below a pavement to serve one or more functions such as distributing loads, providing drainage, minimizing frost action, or facilitating pavement construction

Bleeding - The self-generated flow of mixing water within, or its emergence from, freshly placed concrete or mortar

Blistering - The irregular rising of a thin layer of placed mortar or concrete at the surface during or soon after completion of the finished operation

Bulk Specific Gravity - The ratio of the weight in air of a given volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the weight in air of an equal volume of distilled water at the same temperature

Bulk Specific Gravity (Saturated Surface Dry (SSD)) – The ratio of the weight of a volume of a material including the weight of water within the pores in the material (but excluding the voids between particles) at a stated temperature, to the weight of an equal volume of distilled water at a stated temperature

Bull Float - A tool comprising a large, flat, rectangular piece of wood, aluminum, or magnesium usually 8 in. wide and 39 to 60 in. long, and a handle 1.1 to 5.5 yd in length used to smooth unformed surfaces of freshly placed concrete

Burlap - A coarse fabric of jute, hemp, or less commonly flax, for use as a water-retaining cover for curing concrete surfaces; also called Hessian

Burlap Drag - Surface texture achieved by trailing moistened coarse burlap from a device that allows control of the time and rate of texturing

California Profilograph - Rolling straight edge tool used for evaluating pavement profile (smoothness) consisting of a 25-ft frame with a sensing wheel located at the center of the frame that senses and records bumps and dips on graph paper or in a computer

Cement, Blended - A hydraulic cement consisting essentially of an intimate and uniform blend of granulated blast-furnace slag and hydrated lime; or an intimate and uniform blend of portland cement and granulated blast-furnace slag cement and pozzolan, produced by intergrinding Portland cement clinker with the other materials or by blending Portland cement with the other materials, or a combination of intergrinding and blending

Cement, High Early-Strength - Cement characterized by producing earlier strength in mortar or concrete than regular cement, referred to in as Type III.

Cementitious Materials - Substances that have hydraulic cementing properties (set and harden in the presence of water); includes ground, granulated blast-furnace slag, natural cement, hydraulic hydrated lime, and combinations of these and other materials

Central Mixer - A stationary concrete mixer from which the fresh concrete is transported to the work

Certified Material - An aggregate product produced in accordance with the Certified Aggregate Producer Program (CAPP) for INDOT use

Certified Aggregate Producer - A Plant/Redistribution Terminal that meets the requirements of ITM 211, continues to be under the same ownership, and is approved by INDOT

Coarse Aggregate - Aggregate that has a minimum of 20 percent retained on the No. 4 (4.75 mm) sieve

Cohesiveness - The property of a concrete mix which enables the aggregate particles and cement paste matrix therein to remain in contact with each other during mixing, handling, and placing operations; the "stick-togetherness" of the concrete at a given slump

Compressive Strength - The measured resistance of a concrete or mortar specimen to axial loading; expressed as pounds per square inch (psi) of cross-sectional area

Consistency - The relative mobility or ability of fresh concrete or mortar to flow. The usual measures of consistency are slump or ball penetration for concrete and flow for mortar

Construction Joint - The junction of two successive placements of concrete, typically with a keyway or reinforcement across the joint

Continuously Reinforced Pavement - A pavement with continuous longitudinal steel reinforcement and no intermediate transverse expansion or contraction joints

Contraction Joint - A plane, usually vertical, separating concrete in a pavement, at a designated location such as to prevent formation of objectionable shrinkage cracks elsewhere in the concrete. Reinforcing steel is discontinuous.

Crack Saw - Small three-wheeled specialty saw useful for tracing the wandering nature of a transverse or longitudinal crack; usually contains a pivot wheel and requires a small diameter crack sawing blade.

CRC Pavement (CRCP) - Continuously reinforced concrete pavement

Curing - The maintenance of a satisfactory moisture content and temperature in concrete during its early stages so that desired properties may develop

Curing Blanket - A built-up covering of sacks, matting, Hessian, straw, waterproof paper, or other suitable material placed over freshly finished concrete

Curing Compound - A liquid that can be applied as a coating to the surface of newly placed concrete to retard the loss of water

D-Cracking – a series of cracks near to and roughly parallel to features such as joints, edges, and structural cracks

DTE – District Testing Engineer

Deformed Bar - A reinforcing bar with a manufactured pattern of surface ridges that provide a locking anchorage with surrounding concrete

Diamond Grinding - The process used to remove the upper surface of a concrete pavement to remove bumps and restore pavement rideability

Dispersing Agent - admixtures capable of increasing the fluidity of pastes, mortar or concretes by reduction of inter-particle attraction

Dowel:

1) A load transfer device, commonly a plain round steel bar, which extends into two adjoining portions of a concrete construction, as at a joint in a pavement slab, so as to transfer shear loads

2) A deformed reinforcing bar intended to transmit tension, compression, or shear through a construction joint.

Durability - The ability of concrete to remain unchanged while in service; resistance to weathering action, chemical attack, and abrasion

Early Strength - Strength of concrete developed soon after placement, usually during the first 72 hours

Efflorescence - Deposit of calcium carbonate (or other salts), usually white in color, appearing upon the surface or found within the near-surface pores of concrete. The salts deposit on concrete upon evaporation of water that carries the dissolved salts through the concrete toward exposed surfaces.

Entrained Air - Round, uniformly distributed, microscopic, non-coalescing air bubbles entrained by the use of air-entraining agents; usually less than 1 mm (.04 in.) in size

Entrapped Air - air in concrete that is not purposely entrained. Entrapped air is generally considered to be large voids (larger than .04 in.)

Equivalent Single Axle Load (ESAL) – The effect on pavement performance of any combination of axle loads of varying magnitude equated to the number of 80-kN (18,000-lb.) single-axle loads that are required to produce an equivalent effect

Faulting - Differential vertical displacement of a slab or other member adjacent to a joint or crack

Fine Aggregate - Aggregate that is 100 percent passing the 3/8 in. (9.5 mm) sieve and a minimum of 80 percent passing the No. 4 (4.75 mm) sieve

Fineness Modulus – a factor obtained by adding the percentages of material in the sample that is coarser than each of the following sieves (cumulative percentages retained), and dividing the sum by 100: No. 100, No. 50, No. 30, No. 16, No. 8, No.4, 3/8 in., 3/4 in., $1\frac{1}{2}$ in., and 3 in.

Flexural Strength - A property of a material or structural member that indicates the ability to resist failure in bending

Float - A tool usually of wood, aluminum, or magnesium, used in finishing operations to impart a relatively even but still open texture to an unformed fresh concrete surface

Fly Ash - The finely divided residue resulting from the combustion of ground or powdered coal and which is transported from the fire box through the boiler by flu gasses; used as mineral admixture in concrete mixtures

Grooving - The process used to cut slots into a concrete pavement surface to provide channels for water to escape beneath tires and to promote skid resistance

Hairline Cracking - Barely visible cracks in random pattern in an exposed concrete surface which do not extend to the full depth or thickness of the concrete, and which are due primarily to drying shrinkage

Hardening - When portland cement is mixed with enough water to form a paste, the compounds of the cement react with water to form cementitious products that adhere to each other and to the intermixed sand and stone particles and become very hard. As long as moisture is present, the reaction may continue for years, adding continually to the strength of the mixture.

Harshness - Deficient workability and cohesiveness caused by insufficient sand or cement, or by improperly graded aggregate

Header - A transverse construction joint installed at the end of a paving operation or other placement interruptions. To a Contractor, a header is the location at which paving will resume on the next day.

Heat of Hydration - Heat evolved by chemical reactions of a substance with water, such as that evolved during the setting and hardening of portland cement

High Early-Strength Concrete - Concrete that, through the use of high-earlystrength cement or admixtures, is capable of attaining specified strength at an earlier age than normal concrete

Honeycomb - Concrete that, due to lace of the proper amount of fines or vibration, contains abundant interconnected large voids or cavities; concrete that contains honeycombs was improperly consolidated.

Hydration - The chemical reaction between cement and water which causes concrete to harden

Jointed Plain Concrete Pavement (JPCP) - Pavement containing enough joints to control all natural cracks expected in the concrete; steel tiebars are generally used at longitudinal joints to prevent joint opening, and dowel bars may be used to enhance load transfer at transverse contraction joints depending upon the expected traffic.

Jointed Reinforced Concrete Pavement (JRCP) - Pavement containing some joints and embedded steel mesh reinforcement to control expected cracks; steel mesh is discontinued at transverse joint locations.

Keyway - A recess or groove in one lift or placement of concrete, which is filled with concrete of the next lift, giving shear strength to the joint

Load-Transfer Assembly - Most commonly, the basket or carriage designed to support or link dowel bars during concreting operations so as to hold them in place, in the desired alignment

Longitudinal Joint - A joint parallel to the long dimension of a structure or pavement

Map Cracking:

1) Intersecting cracks that extend below the surface of hardened concrete; caused by shrinkage of the drying surface concrete which is restrained by concrete at greater depths where either little or no shrinkage occurs; vary in width from fine and barely visible to open and well-defined

2) The chief symptom of chemical reaction between alkalis in cement and mineral constituents in aggregate within hardened concrete; due to differential rate of volume change in different portions of the concrete; cracking is usually random and on a fairly large scale, and in severe instances the cracks may reach a width of ¹/₂-in.

Maturity – The extent of the development of a property of a cementitious mixture. Maturity is usually used to describe the extent of relative strength development of concrete. The term may also be applied to the evolution of other properties which are dependent on the chemical reactions which occur in cementitious materials. At any age, maturity is dependent on the curing history.

Maximum Particle Size - The sieve on which 100 percent of the material will pass

Membrane Curing - A process that involves either liquid sealing compound or non-liquid protective coating (e.g., sheet plastics or "waterproof" paper), both of which types function as films to restrict evaporation of mixing water from the fresh concrete surface

Mixing Time - The period during which the mixer is combining the ingredients for a batch of concrete. For stationary mixers, the time is measured from the completion of batching cement and aggregate until the beginning of discharge. For truck mixers, mixing is given in terms of the number of revolutions of the drum at mixing speed.

Modulus of Rupture - A measure of the ultimate load-carrying capacity of a beam, sometimes referred to as "rupture modulus" or "rupture strength." This value is calculated for apparent tensile stress in the extreme fiber of a transverse test specimen under the load that produces rupture.

Moist - Slightly damp but not quite dry to the touch; the term "wet" implies visible free water, "damp" implies less wetness than "wet," and "moist" implies not quite dry

Mortar - Concrete with essentially no aggregate larger than about 3/16 in.

NCHRP - National Cooperative Highway Research Program

NHI - National Highway Institute

NRMCA - National Ready Mixed Concrete Association

Nominal Maximum Particle Size - The smallest sieve opening through which the entire amount of the aggregate is permitted to pass

Open-Graded Subbase - Unstabilized layer consisting of crushed aggregates with a reduced amount of fines to promote drainage

PCA - Portland Cement Association

PCC - Portland Cement Concrete

Pitting - A localized disintegration taking the form of cavities at the surface of concrete.

Plastic Shrinkage Cracking - Cracks, usually parallel and only a few inches deep and several feet long, in the surface of concrete pavement that are the result of rapid moisture loss through evaporation

Popout - Pit or crater in the surface of concrete resulting from cracking of the mortar due to expansive forces associated with a particle of unsound aggregate or a contaminating material, such as wood or glass

Portland Cement - A commercial product which when mixed with water alone or in combination with sand, stone, or similar materials, has the property of combining with water, slowly, to form a hard solid mass. Physically, portland cement is a finely pulverized clinker produced by burning mixtures containing lime, iron, alumina, and silica at high temperature and in definite proportions, and then intergrinding gypsum to give the properties desired.

Pozzolan - A siliceous or siliceous and aluminous material, which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties

Process Control - Those quality assurance actions and considerations necessary to assess production and construction processes so as to control the level of quality being produced in the end product. This includes sampling and testing to monitor the process but usually does not include acceptance sampling and testing.

Pumping - The forceful displacement of a mixture of soil and water that occurs under slab joints, cracks and pavement edges which are depressed and released quickly by high-speed heavy vehicle loads; occurs when concrete pavements are placed directly on fine-grained, plastic soils or erodible subbase materials

Quality Assurance - Planned and systematic actions by an owner or his representative to provide confidence that a product or facility meet applicable standards of good practice. This involves continued evaluation of design, plan and specification development, contract advertisement and award, construction, and maintenance, and the interaction of these activities.

Quality Assurance/Quality Control Specification - Statistically based specification that is a combination of end result and material and method specifications. The Contractor is responsible for quality control (process control), and the highway agency is responsible for acceptance of the product.

Quality Control - Actions taken by a Producer or Contractor to provide control over what is being done and what is being provided so that the applicable standards of good practice for the work are followed

Quality Control Plan (QCP) - A document written by the Contractor that is contract-specific and includes the policies, and procedures used by the Contractor

Qualified Technician - An individual who has successfully completed the written and proficiency testing requirements of the Department Qualified Laboratory and Technician Program

Raveling - Displacement of aggregate or paste near the slab surface from sawing; normally indicates that concrete strength is too low for sawing

Release Agent - Material used to prevent bonding of concrete to a surface

Retardation - Reduction in the rate of hardening or strength development of fresh concrete, mortar, or grout; i.e., an increase in the time required to reach initial and final set

Saturated Surface-Dry - Condition of an aggregate particle or other porous solid when the permeable voids are filled with water but there is no water on the exposed surface

Sawed Joint - A joint cut in hardened concrete, generally not to the full depth of the member, by means of special equipment

Sawing - Cutting of joints in hardened concrete by means of special equipment utilizing diamond or silicon carbide blades or discs; cut goes only part way through the slab

Scaling - Flaking or peeling away of the near-surface portion of hydraulic cement concrete or mortar
Screed:

- 1) To strike off concrete lying above the desired plane or shape
- 2) A tool for striking off the concrete surface, sometimes referred to as a Strikeoff

Segregation - The tendency, as concrete is caused to flow laterally, for coarse aggregate and drier material to remain behind and for mortar and wetter material to flow ahead. This also occurs in a vertical direction when wet concrete is over-vibrated, the mortar and wetter material rising to the top. In the vertical direction, segregation may also be called Stratification.

Shrinkage Crack - Crack from restraint of volume reduction due to shrinkage or temperature contraction; usually occurring within the first few days after placement.

Slump - A measure of consistency of freshly mixed concrete, equal to the subsidence measured to the nearest 1/4-in. of the molded specimen immediately after removal of the slump cone

Soundness - In the case of cement, freedom from large expansion after setting. In the case of aggregate, the ability to withstand aggressive conditions to which concrete containing the aggregate might be exposed, particularly those due to weather.

Spalling, Surface - Cracking, breaking, chipping, or fraying of slab surface; usually within a confined area less than 0.5 square meters

Specific Gravity - The ratio of the weight in air of a given volume of material at a stated temperature to the weight in air of an equal volume of distilled water at the same temperature

Stratification - The separation of over-wet or over-vibrated concrete into horizontal layers with increasingly lighter material toward the top; water, laitance, mortar, and coarse aggregate will tend to occupy successively lower positions (in that order)

Subbase - A layer in a pavement system between the subgrade and base course or between the subgrade and a portland cement concrete pavement.

Subgrade – The soil prepared to support a pavement structure or a pavement system. The subgrade is the foundation of the pavement structure.

Structural Backfill - Suitable sand, gravel, crushed stone, air-cooled blast furnace slag, or granulated blast furnace slag used to fill designated areas excavated for structures that are not occupied by permanent work

Transit-Mixed Concrete - Concrete, the mixing of which is wholly or principally accomplished in a truck mixer

Water-Cementitious Materials Ratio - The ratio of the amount of water, exclusive only of that absorbed by the aggregates, to the amount of portland cement and other cementitious material (fly ash, pozzolan, etc.) in a concrete or mortar mixture; preferably stated as a decimal by weight

Water-Reducing Admixture - A material that either increases slump of freshly mixed mortar or concrete without increasing water content or maintains a workability with a reduced amount of water, the effect being due to factors other than air entrainment; also know as water reducer

Water-Reducing Admixture (High Range) - A water-reducing admixture capable of producing large water or great flowability without causing undue set retardation or entrainment of air in mortar or concrete

Workability - The property of freshly mixed concrete or mortar which determines the ease and homogeneity with which concrete may be mixed, placed, compacted, and finished

Yield - The volume of fresh concrete produced from a known quantity of ingredients; the total weight of ingredients divided by the unit weight of the freshly mixed concrete

PAVEMENT DESCRIPTION

A rigid pavement such as PCCP is designed to resist bending and not crack under the traffic load. The strength of the pavement structure or soil conditions under the rigid surface are usually of lesser concern because a surface rigid enough to prevent deflection will adequately distribute loads to the existing soil (Figure 1-1).



Figure 1-1. Load Distribution

PCCP is composed of Portland cement concrete and, when specified, reinforcing steel and various joint materials. The basic components of a concrete pavement are illustrated in Figure 1-2





Concrete pavement is placed at the thickness specified in the plans or proposal and is constructed on a prepared subgrade and subbase course. The pavement is placed in reasonably close conformance to the lines, grades, and typical cross-sections shown in the plans. Concrete basically consists of Portland cement, water, and fine and coarse aggregates. The curing of the concrete is a chemical reaction of the Portland cement and water, which causes the concrete to shrink and crack. To control the cracking, transverse joints and longitudinal joints are constructed in the pavement. All pavements require transverse joints to control transverse cracking. These are sometimes known as contraction joints. Pavements wider than 16 ft require longitudinal joints to control longitudinal cracking. Pavements with transverse joints are referred to as pavements with joints or jointed pavements. There are several types of concrete pavements and requirements for their corresponding contraction joints.

TYPES OF CONCRETE PAVEMENT

PLAIN CONCRETE PAVEMENT

Plain concrete pavement is constructed of only concrete with no reinforcement or joints and is used mainly for base widening of an existing pavement. This pavement is used in conjunction with a Hot Mix Asphalt (HMA) overlay. Uncontrolled random cracking as shown in Figure 1-3, occurs in this type of pavement.



Figure 1-3. Random Cracks in Plain Concrete Pavement

PLAIN CONCRETE PAVEMENT WITH JOINTS

Plain concrete pavement with joints has no reinforcing steel but is constructed with various transverse joint spacing (joints from edge of pavement to edge of pavement). The types of joints used in plain concrete are shown in Figure 1-4. Nearly all of the concrete pavements constructed by INDOT are of this type.





Figure 1-4. Plain Concrete Pavement with Joints

REINFORCED CONCRETE PAVEMENT WITH JOINTS

Reinforced concrete pavement with joints (Figure 1-5) is pavement reinforced with steel mesh and is built with transverse joint spacing of 40 ft.





Figure 1-5. Reinforced Concrete Pavement with Joints

CONTINUOUSLY REINFORCED CONCRETE PAVEMENT

Continuously reinforced concrete (CRC) pavement (Figure 1-6) is reinforced with a large amount of longitudinal steel (No. 5 bars, 6 inches on center) and only longitudinal joints as required. There are no transverse joints in this type of pavement.







2 Concrete Materials

Aggregates

Requirements Certified Aggregate Producer Program (CAPP) Fine Aggregate Gradation Fineness Modulus Coarse Aggregate Gradation Mixture Gradation Particle Shape and Surface Texture Specific Gravity Absorption and Surface Moisture

Portland Cement Requirements

Admixtures Mineral Admixtures Chemical Admixtures

Water

CHAPTER TWO: CONCRETE MATERIALS

PCCP is normally constructed with paving concrete described in Section **500**. The proportions of materials vary with different types of concrete. Admixtures that affect the air content, water requirements, and the time required for the concrete to set may be required.

Concrete Mix Design (CMD) proportions are important to know before starting the paving operation. Concrete mix designs are the responsibility of the Contractor, both for QC/QA and non-QC/QA concrete. The Specifications give broad parameters for the Contractor to design an acceptable CMD. The design is reviewed and approved by INDOT. Some specifications require the Contractor to conduct trial batch demonstrations prior to concrete pours on the contract. Mix designs for QC/QA contracts and concrete using fly ash or other pozzolans are examples of situations requiring trial batches. The Specifications should always be reviewed to determine if a trial batch is required. The PE/PS is required to have the CMD prior to placement of the concrete.

Paving concrete is composed of the following materials (Figure 2-1):

- 1) Fine aggregate, size No. 23 or gradation as identified in the QCP
- 2) Coarse aggregate, quality rating class AP, Size No. 8
- 3) Portland cement
- 4) Water

Additional materials that may be found in paving concrete are:

- 1) Fly Ash
- 2) Water-reducing admixture
- 3) Air-entraining admixture



Figure 2-1. Concrete Materials

AGGREGATES

Aggregates generally occupy approximately 75 percent of the concrete volume and strongly influence the concrete's hardened and freshly mixed properties. The properties of the aggregate have a major effect on the durability, strength, shrinkage, unit weight, and frictional properties of hardened concrete, as well as the mix proportions, slump, workability, bleeding, finishing characteristics and air content of freshly mixed concrete. The selection of the proper aggregates and control of the use of those aggregates is essential in producing quality concrete mixtures.

REQUIREMENTS

The QC/QA PCCP specifications have several restrictions on the use of aggregates in concrete. They include:

- 1) Fine aggregate is required to be natural sand.
- 2) Coarse aggregates are required to be crushed limestone or dolomite, crushed or uncrushed gravel, or air cooled blast furnace slag.
- 3) The gradation of the fine and coarse aggregates is required to be in accordance with size No. 23 and size No. 8, respectively, or a proposed alternate gradation for each.

If alternate gradations are proposed, the tolerances for each sieve are required to be as stated in the QCP

- 4) For coarse aggregates, 100 percent is required to pass the 1 in. sieve.
- 5) The combined amount of fine and coarse aggregate passing the No. 200 sieve is required to be from 0.0 to 2.0 percent for sand and gravel, and from 0.0 to 2.5 percent for sand and stone or slag.
- 6) The fine aggregate is required to be no less than 35 percent or more than 50 percent of the total volume of the aggregate in each cubic yard, based upon saturated surface dry aggregates.

Fine aggregates and coarse aggregates are defined as follows:

Fine Aggregate -- Material that is 100 percent passing the 3/8 in. sieve and a minimum of 80 percent passing the No. 4 sieve

Coarse Aggregate -- Material that has a minimum of 20 percent retained on the No. 4 sieve.

CERTIFIED AGGREGATE PRODUCER PROGRAM (CAPP)

The Certified Aggregate Producer Program is a program in which a qualified mineral aggregate Producer or Redistribution Terminal desiring to supply material to INDOT does so by assuming all of the Plant site controls and a portion of the testing responsibility that had been previously assumed by INDOT. The program focuses on production testing by the Producer and a site specific QCP that indicates how the Producer proposes to control the materials at the plant. Benefits of the program to the Producer include improved customer service, more plant control, and better documentation of test results and events at the plant.

The CAPP requires the source to conduct numerous tests as the aggregate is being produced and when the aggregate is shipped out. As a minimum, the gradation, decantation, crushed particle content, and deleterious tests are required, if applicable. Gradation, crushed particle content, and deleterious content are determined during production of the aggregate, and the gradation and decantation tests are conducted when material is shipped.

Gradation tests are required to be plotted on a control chart by the Certified Aggregate Producer. Figure 2-2 illustrates an example of a control chart for the "critical sieve" (1/2 in.) of a No. 8 aggregate. The CAPP defines what the critical sieve is for each Standard Specification coarse aggregate material and this is the only sieve required to be plotted for coarse aggregates; however, all sieves having a gradation limit designated in the specification are required to be tested. Coarse aggregates not meeting the established limits of the Standard



Figure 2-2. Control Chart

Specifications are classified as QA products and the Producer is required to designate the critical sieve and all the gradation limits in the QCP. Fine aggregate gradations are required to be plotted on control charts for all applicable sieves designated either in the Standard Specifications or in the QCP if the material is a QA sand.

FINE AGGREGATE GRADATION

Fine aggregate is required to be natural sand and meet the gradation requirements of No. 23 sand or a QA sand with a designated gradation from the Certified Aggregate Producer. No. 23 sand is the most common size of fine aggregate used. The gradation requirements for this material are included in the following chart:

Sieve Size	Min. % Passing	Max % Passing
3/8 in.	100	
No. 4	95	100
No. 8	80	100
No. 16	50	85
No. 30	25	60
No. 50	5	30
No. 100	0	10
No. 200	0	3

Concrete mixtures lacking the proper amount of fine sand are harsh and difficult to finish. In particular, the amounts passing the No. 50 and No. 100 sieves affect workability, surface texture and bleeding of concrete the most.

In general, if the water/cementitious ratio is kept constant and the ratio of fine-to-coarse ratio is chosen correctly, a wide range in fine aggregate gradations may be used without a measurable effect on flexural strength.

The fineness modulus is an indicator of the fineness of an aggregate and is most used for evaluating fine aggregates. The higher the number, the coarser the aggregate. The fineness modulus is computed by adding the cumulative percentages retained on the 6 in., 3 in., 1 $\frac{1}{2}$ in., 3/4 in., 3/8 in., No. 4, No. 8, No. 16, No. 30, No. 50, and No. 100 sieves, and then dividing by 100. The fineness modulus of a fine aggregate is useful in estimating the proportions of fine and coarse aggregates in concrete mixtures. An example of determining the fineness modulus of a fine aggregate is as follows:

Sieve Size	100	-	% Passing	=	% Retained
3/8 in.	100	-	100	=	0.0
No. 4	100	-	100	=	0.0
No. 8	100	-	89.2	=	10.8
No. 16	100	-	68.3	=	31.7
No. 30	100	-	45.1	=	54.9
No. 50	100	-	13.8	=	86.2
No. 100	100	-	2.6	=	97.4
					281.0
281.0) = 2.81 =	= Fine	ness Modulus		

100

COARSE AGGREGATE GRADATION

Coarse aggregate is required to be limestone, dolomite, gravel or air cooled blast furnace slag and meet the gradation requirements of a No. 8 coarse aggregate or a QA coarse aggregate with a designated gradation from the Certified Aggregate Producer. Also, the coarse aggregate is required to have 100 percent passing the 1 in. sieve. No. 8 coarse aggregate is the most common size used in pavement concrete. The specification requires that when the material is stone or slag, the decant may be 0 to 2.5 % and when the material is gravel the decant shall be 0 to 1.5 %. The gradation requirements for No. 8 aggregate is as follows:

Sieve Size	Min. % Passing	Max % Passing
1 in.	100	
3/4 in.	75	95
1/2 in.	40	70
3/8 in.	20	50
No. 4	0	15
No. 8	0	10
Decant *	0	1.5

* When the material is stone or slag, the decant may be 0 to 2.5

A coarse gradation is one having a percent passing each required sieve that is close to the bottom limit for that sieve (e.g., 75% passing the 3/4 in. sieve). Coarse aggregates with a coarse gradation, in general, require less water and cement than aggregates that are finer. The reason for this is that there is less surface area and therefore less cementitious paste required to adequately coat and bind the aggregate to other particles.

MIXTURE GRADATION

The combined mixture gradation affects relative aggregate proportions as well as cement and water requirements, workability, economy, porosity, shrinkage, and durability of concrete. In general, aggregates that do not have a large deficiency or excess of any size and give a smooth grading curve produce the most satisfactory results.

PARTICLE SHAPE AND SURFACE TEXTURE

Particle shape and surface texture of an aggregate predominately influence the properties of freshly mixed concrete. Rough-textured, angular, elongated particles require more water to produce workable concrete than do smooth, rounded, cubical-shaped particles. Concrete with an excess of angular particles may cause problems with workability and finishing. Irregular and angular particles that tend to interlock when consolidated will increase the strength of the mixture. Rough-textured particles give the cementing material something to grip, producing a stronger bond, and therefore also increase the strength of the mixture. Flat and elongated particles require an increase in mixing water and thus may affect the strength of concrete if the water/cementitious ratio is not maintained.

SPECIFIC GRAVITY

The specific gravity of an aggregate is the ratio of its weight to the weight of an equal volume of water. The value is used in computations for mixture proportioning and control, such as the absolute volume occupied by an aggregate. The specific gravity of an aggregate may be determined on an oven-dry basis or a saturated-surface-dry (SSD) basis. Oven-dry aggregates do not contain any absorbed or free water. Saturated-surfacedry aggregates are aggregates in which the pores in each aggregate particle are filled with water and no excess water is on the particle surface.

The bulk specific gravity is determined by first drying the test sample to a constant weight in accordance with **AASHTO T 84** and **AASHTO T 85**. Both test methods allow the elimination of this initial drying if the absorption and specific gravity values are to be used in proportioning concrete mixtures in which the aggregates are in their naturally moist condition. However, the absorption and bulk specific gravity (SSD) values may be significantly higher for aggregates that are not oven-dried

initially before soaking. This is especially true of particles with a high porosity since the water may not be able to penetrate the pores to the center of the particle in the prescribed soaking period.

Mixture design and proportioning of QC/QA PCCP are determined using bulk specific gravity (SSD) of each aggregate component. The bulk specific gravity determined on a dry basis is a common test conducted by the aggregate industry. However, using the absorption value of the aggregate, the bulk specific gravity (SSD) may be calculated in accordance with **AASHTO T 84** and **AASHTO T 85** as follows:

$$S_s = (1 + A/100) S_d$$

where:

 S_s = bulk specific gravity (SSD) S_d = bulk specific gravity (dry) A = absorption in percent

Example: $BSG_{(dry)} = 2.615$ Absorption = 3.21%

$$S_s = (1 + 3.21/100) 2.615$$

= 1.0321 x 2.615
= 2.699

The calculated bulk specific gravity (SSD) value is an estimate. QC/QA PCCP specifications require that the actual bulk specific gravity (SSD) test value be used for mixture design and proportioning of concrete.

ABSORPTION AND SURFACE MOISTURE

The absorption and surface moisture (free moisture) of aggregates are required to be determined so that the net water content of the concrete may be controlled and the correct batch weights determined. Internally, aggregate particles are made up of solid mater and voids that may or may not contain water. Definitions of absorption and surface moisture, derived from **AASHTO T 85** and **AASHTO T 255**, respectively, are as follows:

Absorption -- the increase in the weight of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles

Surface Moisture (Free Moisture) -- the water adhering to the outside surface of the particles

AASHTO T 255 designates the procedure for determining the total moisture content of the aggregate by drying. The surface or free moisture content of a fine or coarse aggregate may be determined by deducting the absorption from the total moisture content.

The moisture conditions of aggregates at the jobsite and their contribution to the water in the concrete include:

- 1) Oven-dry -- no contribution to the water content. Particles will absorb an amount of water equal to the water absorption of the aggregate.
- 2) Air Dry -- dry at the particle surface but containing some interior moisture. Particles have not reached full absorption and will absorb some water from the concrete mixture
- 3) Saturated Surface Dry (SSD) -- particles have obtained the full absorption that is available and will neither absorb water from nor contribute water to the concrete mixture
- 4) Damp or Wet -- particles have more moisture than the quantity needed for full absorption and will contribute water (free moisture) to the concrete mixture

The amount of water used for the concrete mixture is required to be adjusted for the moisture content of the aggregates to meet the designated water requirement. The strength, durability, workability, and other properties are affected if the water content of the concrete mixture is not kept constant.

Absorption test results for a particular size of aggregate that differ by more than 1.0 percentage points from the INDOT's source value shall be investigated. The Contractor is required to report any differences that exceed 1.0% to INDOT. The Contractor's results shall be used when calculating the water/cementitious ratio.

PORTLAND CEMENTS

Portland cements are finely ground powders that set and harden by reacting chemically with water. During this reaction, called hydration, cement combines with water to form a solid mass. When the paste (cement and water) is added to aggregates, the paste acts as an adhesive and binds the aggregates together to form concrete.

Hydration of the cement begins as soon as there is contact with water. Each cement particle forms a growth on the surface that spreads until connecting with the growth of other particles or adheres to adjacent substances. This reaction results in progressive stiffening, hardening, and strength development. As the concrete stiffens there is a loss of workability that usually occurs within three hours of mixing; however, the composition and fineness of the cement, the mixture proportions, and temperature conditions all may have an effect on the loss of workability.

Hydration will continue as long as there is available space for the hydration products and the moisture and temperature conditions are favorable. The concrete will become stronger as the hydration continues. Most of the hydration and strength development takes place within the first month after mixing, and will continue slowly for a long time.

REQUIREMENTS

The more common types of cements allowed for QC/QA PCCP are Portland Cement (Type I), Portland Blast-Furnace Slag Cement (Type IS), or Portland-Pozzolan Cement (Type IP); however, Type I is most often used. A general description of these types of cements is as follows:

Type I

Under normal conditions, Type I portland cement is used in paving concrete where special properties, such as sulfate resistance, high early strength, or low heat of hydration, are not required. This cement is used in concrete that is not subject to aggressive exposures, such as sulfate attack from soil or water, or to an objectionable temperature rise due to heat generated by hydration. Air-entrained Portland cement, Type I-A, is cement that has been entrained with air during the manufacturing process and requires less air-entraining agent to be added to obtain the required air content.

Type IS

Type IS portland blast-furnace slag cement is used for general concrete construction applications. This cement is a blend of portland cement and granulated blast-furnace slag. These cements are produced by intergrinding the slag with the portland cement, separately grinding the slag and blending with the cement, or combining the grinding and blending of the two products.

Type IP

Portland-pozzolan cement, Type IP is similar to Type I, except that the cement also contains a pozzolan, such as fly ash, to reduce the cost. Airentrained Portland-pozzolan cement, Type IP-A, is similar to Type I-A, except that this cement also contains a pozzolan. When Portland cement, Type IP-A is used, the fly ash specifications are also required. Type IP portland-pozzolon cement is used for general concrete construction applications. This cement is a blend of portland cement and a pozzolon with the pozzolan content of $20 \pm 5\%$ by weight. These cements are produced by intergrinding portland cement clinker with the pozzolon, by blending portland cement and a pozzolon, or by a combination of intergrinding and blending.

Further restrictions on the use of portland cement include:

- 1) Cements are accepted from qualified manufacturers or manufacturer/distributors that are included on the INDOT approved list of Cement Sources
- 2) A means for storing and protecting the cement against dampness is required to be provided. Cement which has become partially set, contains lumps or caked cement, or is salvaged from discarded or used sacks is not allowed to be used.
- 3) Different kinds or brands, or cement of the same brand from different mills, shall not be mixed during use unless permitted, and then only as directed. They shall not be used alternately in any one pour, unless otherwise permitted.
- 4) Blended cements may only be incorporated into concrete placed between April 1 and October 15 of the same calendar year. This time period restriction does not apply if traffic is not anticipated on the concrete.
- 5) If Type IP, type IP-A, type IS or type IS-A cements are used, the minimum portland cement content is increased to 500 lb/yd³.

ADMIXTURES

Admixtures are those ingredients added to concrete immediately before or during mixing other than portland cement, water, and aggregates. The major reasons for using admixtures include:

- 1) To reduce the cost of concrete construction
- 2) To achieve certain properties in concrete more effectively than by other means
- 3) To insure the quality of concrete during the stages of mixing, transporting, placing, and curing in adverse weather conditions

The effectiveness of any admixture is dependent on such factors as:

- 1) Type, brand, and amount of cement
- 2) Water content
- 3) Aggregate shape, gradation, and proportions
- 4) Mixing time
- 5) Slump
- 6) Temperatures of the concrete and air

Trial batches of the contract materials and the admixtures should be made to verify the compatibility of the materials as well as the effects on the properties of the concrete. The amount of admixture recommended by the manufacturer should be used.

MINERAL ADMIXTURES

Mineral admixtures are powdered or pulverized materials added to concrete before or during mixing to improve or change some of the plastic or hardened concrete properties. The mineral admixtures allowed in QC/QA PCCP are classified as pozzolons (ground granulated blast-furnace slag and fly ash).

Ground Granulated Blast Furnace Slag

Ground granulated blast-furnace slag is a nonmetallic material that is developed in a molten condition simultaneously with iron in a blast furnace. A glassy granular material is formed when molten blast-furnace slag is rapidly chilled by immersion in water. This glassy granular material is then ground to cement fineness resulting in ground granulated blastfurnace slag. The rough and angular-shaped ground slag hydrates and sets in a manner similar to portland cement when exposed to water and portland cement.

Fly Ash

Fly ash is a finely divided residue that results from the combustion of pulverized coal in electric power generating plants. In general, class F fly ash is produced from burning anthracite or bituminous coal and class C fly ash is produced from burning lignite or subbituminous coal. During combustion, the coal's mineral impurities (such as clay, feldspar, and shale) fuse in suspension and are carried away from the combustion chamber by the exhaust gas. In the process, the fused material cools and

solidifies into spherical particles called fly ash, which is collected by electrostatic precipitators or bag filters.

The use of fly ash reduces the cost of concrete, but may extend the time needed to achieve the proper strength for opening the pavement to traffic. Class C fly ash has better structural qualities than Class F and is therefore more commonly used. The ratio of Portland cement to fly ash for use in QC/QA PCCP is required to be a minimum of 3.2 by weight.

Mineral Admixture Effect on Concrete

The effects of the ground granulated blast-furnace slag, and fly ash on the concrete are as follows:

Ground Granulated Blast Furnace Slag

- 1) Increases long-term strength
- 2) Lowers permeability
- 3) Improves sulfate resistance
- 4) Lowers heat of hydration
- 5) Reduces potential alkali-silica reaction
- 6) Improves workability
- Fly Ash
 - Enhances workability
 Lowers permeability
 Lowers water demand
 Slightly enhances long term strength
 Reduces the heat of hydration
 Retards setting time
 - 7) Delays strength gain

Requirements

QC/QA PCCP has the following restrictions on the use of mineral admixtures:

- 1) Fly ash and ground granulated blast-furnace slag may only be incorporated into the concrete between April 1 and October 15 of the same calendar year.
- 2) Fly ash or ground granulated blast-furnace slag are not permitted when blended Portland cements are used

CHEMICAL ADMIXTURES

Chemical admixtures are materials added to concrete before or during mixing and are required to be included in the list of approved Admixtures for PCC. The admixtures affect the concrete as follows:

- Air-Entraining Admixtures -- used to entrain microscopic air bubbles in concrete.
- Water-Reducing Admixtures -- used to reduce the quantity of mixing water required to produce concrete of a certain slump, reduce water/cementitious ratio, or increase slump.

Retarding Admixtures -- used to retard the rate of setting of concrete.

- Accelerating Admixtures -- used to accelerate strength development at an early age.
- High-Range Water Reducers (Superplasticizers) -- added to concrete with low-to-normal slump and water-cement ratio to make high-slump flowing concrete.

Water reducing admixture Type A is not allowed to be used in conjunction with water reducing and retarding admixture Type D. in QC/QA PCCP.

WATER

When water is added to the cement, the setting process begins. In a central-mix plant this process occurs in the mixing drum, and in a transit mix this process occurs in the truck mixer. Only clean, potable water may be used. Contaminated water may contain materials which are detrimental to the concrete after placement.

After the water is added to the mix, the concrete is required to be placed within 90 minutes, if hauled in truck mixers or truck agitators. If the hauling vehicles have no agitators, this time is reduced to 30 minutes. The time the water is added to the concrete is stamped on the ticket at the concrete plant.

The amount of water added at the plant varies from day to day depending upon the moisture contents of the fine and coarse aggregates used. If an overnight rain has caused the stockpiled materials to become wetter than the day before, less water is required to be added at the plant. Materials exposed to hot, dry conditions for several days require more water to be added. The mixture is required to contain no more water than is necessary to produce a concrete that is workable, plastic, and meets the slump requirements; however, the water-cementitious ratio is required to meet the Specification limits at all times.

3 Trial Batch Demonstration

Preparation

Procedure

Aggregate Properties for QC/QA PCCP Concrete Batching and Mixing for QC/QA PCCP Concrete Testing for QC/QA PCCP Trial Batch Requirements for PCCP High Early Strength and PCCP Patching

CHAPTER THREE: TRIAL BATCH DEMONSTRATION

A trial batch is required for a qualifying CMDS, as detailed in Section **501.06**, **502.04(b)** and **506.05** of the Standard Specifications. Regardless of the type of pavement concrete, the purpose of a trial batch is much more than validating the required concrete properties to be within the specification requirements of the concrete mixture. For example, the trial batch of a CMDS for QC/QA PCCP also provides an opportunity for the Contractor's Certified Technician and the Department's Qualified Technician to verify proper equipment calibration and testing procedures prior to any placement of concrete pavement. The Contractor and the PE/S should both be assured that QC testing will accurately represent the concrete for any process control decision and that acceptance testing will assess the proper adjustment points, if any. Failure to obtain this at the trial batch for QC/QA PCCP, may result in an inaccurate assessment of adjustment points or erroneous failed material investigations when pavement concrete is placed.

The results from a successful trial batch provide the Contractor with baseline properties from which to plan process control of the concrete mixture. In addition, should there be any future material changes to the concrete mix, the original trial batch results provide a means of performance comparison.

For QC/QA PCCP, the trial batch may be conducted at a concrete plant or in the laboratory, as detailed in the Standard Specifications. For High-Early Strength PCCP and PCCP Patching, a trial batch is required to be conducted through a plant. A trial batch completed through a plant provides an opportunity for the Contractor and Engineer to witness the process upstream from the plant (i.e. material receipt, storage, and handling), through batching and actual concrete production. The complete process should be inspected to provide insight as to any potential process control problems prior to production and placement. A properly conducted trial batch works to resolve many problems which would otherwise become evident on the day of concrete placement.

PREPARATION

Scheduling a trial batch is dependent of several key items, which are as follows:

- 1) Both the Contractor's Certified Technician and the Department's Qualified Technician are to be present
- 2) The trial batch is used to evaluate a CMDS that has been reviewed and approved by the DTE.
- 3) Adequate time is required to be allocated to complete the trial batch demonstration. Experience has shown that a properly conducted trial batch will typically require 4-6 hours to complete. A poorly planned trial batch will substantially increase the length of the trial batch by several hours or even days.

A trial batch is not to be used for mix design experimentation or development. The Contractor and his concrete supplier are required to have sufficient experience in preparing a CMDS for workable concrete that will perform as expected during the trial batch. Problems should be few, if any, and only of a minor nature.

PROCEDURE

A two-page worksheet has been developed for each pavement concrete type, which outlines a systematic approach to conducting a proper trial batch in accordance with the appropriate section of the Standard Specifications (i.e. 501.06, 502.04(b) & 506.05). These worksheets are part of the Microsoft Excel workbook that was created at the time the CMDS was originally approved by the DTE. The trail batch worksheet has a title and tab identification within the Excel workbook to help the Proper use of the worksheets by both the Contractor and users. Department has proven to be critical in progressing through the trial batch successfully in the shortest amount of time. The following is a breakdown of the various parts of the trial batch worksheets for QC/QA PCCP. The worksheet is to be prepared and submitted by the Contractor to the DTE; however, the Department's representative at the trial batch is required to be involved in accurately recording and reporting results and other pertinent information.

AGGREGATE PROPERTIES FOR QC/QA PCCP

Once the preliminary information is entered at the top of the worksheet, the first major task is to evaluate the properties of the fine and coarse aggregate which are to be incorporated into the concrete. Certain aggregate properties (i.e. bulk specific gravity at saturated surface dry condition and absorption) were predetermined by the Contractor and submitted as part of the CMDS that was reviewed and approved by the DTE. These aggregate properties appear on the trial batch worksheet when the CMDS is processed by the DTE as part of the Excel workbook. If working with a blank hard copy of the worksheet forms, the properties are required to be entered on the form manually. The certified and qualified technicians are required to obtain samples of sufficient quantity of the fine and coarse aggregate to test for moisture content and aggregate correction factor. The moisture contents and aggregate absorptions are used in determining Water/Cementitious Ratio. Aggregate Correction Factor is used to determine air content. Additional samples of the fine and coarse aggregate may also be necessary for gradation analysis and possibly rechecking/troubleshooting bulk specific gravity and/or absorption measurements. For trial batches conducted in the laboratory, the gradation and moisture determinations shall be in accordance with the method and procedures defined by ASTM C 192.

Should a trail batch be conducted at a concrete plant, the aggregate samples are to be representative of the material batched in the concrete, as defined by the CMDS. If the plant is equipped with a moisture probe(s), the samples should be obtained from material passing over the probe so that a check may be made on the accuracy of the moisture meter. Subsequent changes in the moisture meter reading, prior to batching, would then serve as a basis for adjusting the moistures entered in the worksheet at time of batching. If there are no probes to monitor moisture in the aggregate(s), batching is required to contain the aggregates that were accurately represented by the samples. In such a situation, the trial batch should occur on a day when production for commercial and/or other INDOT work is minimal. The moisture content results between the certified and qualified technicians are required to be fairly close, otherwise there may be too much discrepancy in results for Water/Cementitious Ratio and questions arise as to material uniformity, proper sampling and/or testing. The trial batch should not progress until aggregate moisture discrepancies are resolved.

An example of how the aggregate properties may look on the worksheet is presented in the table below (boldface numbers). In this example, the aggregates have a moisture content in excess of the saturated surface dry, ssd, condition; however, this may not always be the case.

AGGREGATE TEST RESULTS						
Properties	Contractor Result	ACI Certified Tech	INDOT Result	INDOT Qualified Tech		
FA Bulk Sp. Gr.(SSD)	2.658		NA	NA		
FA Absorption, %	1.36		NA	NA		
FA Moisture	5.23		5.25			
CA Bulk Sp. Gr. (SSD)	2.652		NA	NA		
CA Absorption, %	1,82		NA	NA		
CA Moisture, %	3.23		3.26			
Agg. Correction Factor						

The aggregate correction factor may be determined at this stage of the trial batch; however, a more effective use of time may be to conduct the test during the agitation period, which is intended to simulate the delivery time after batching and mixing of the concrete. Testing is required to be done by both the certified and qualified technicians to establish an accurate value to be used in measuring the air content. Aggregates in Indiana have been found to range from a value of 0.1 to 1.0 percentage points for the correction factor. Aggregates having a high absorption do not necessarily correlate to a high aggregate correction factor. The property is only determined by testing.

CONCRETE BATCHING & MIXING FOR QC/QA PCCP

The next step in the worksheet addresses concrete batching. The mix design batch weights from the CMDS are simply transferred to the second column of the table entitled "Concrete Batching". This is done automatically if working in the Excel workbook processed by the DTE. The third column in the table for concrete batching identifies what the target batch weights should be for one cubic yard of concrete, based on the aggregate moisture contents measured by the Contractor's qualified technician. The Excel worksheet calculates the moist aggregate target weight by multiplying the ssd aggregate weight (defined by the CMDS) by 1 plus the difference between total moisture content and absorption, as a decimal. An example of this calculation for the moist fine and coarse aggregate targets are as follows for a CMDS that has a cement content of 480 lb, fly ash content of 106 lb, ssd fine aggregate content of 217 lb:

Example: $1330 \times [1 + (0.0523 - 0.0136)] = 1381$ lb moist fine aggregate weight

 $1763 \times [1+(0.0323 - 0.0182)] = 1788$ lb moist coarse aggregate weight

The target batch weight for mix water is required to be reduced by the amount of free water provided by the aggregates. The difference between the aggregate batch weights in a moist condition and the saturated surface dry condition gives the needed result. An example of these calculations is as follows:

Example: 1381 - 1330 = 51 lb free water from fine aggregate

1788 - 1763 = 25 lb free water from coarse aggregate

51 + 25 = 76 lb free water contributed by aggregates

The Excel worksheet automatically determines the amount of free water contributed by the aggregates and subtracts the free water from the water content identified in the CMDS that was approved by the DTE. An example of this calculation is as follows:

Example: 217 - 76 = 141 lb of target batch water

The following table shows how the first three columns of the Concrete Batching table would appear based on the aggregate moistures for the example CMDS and calculations above. The summation of the batch weights are the same for the second and third columns (i.e. whether dealing with the CMDS, with aggregates at ssd condition, or batch weights adjusted for moisture content).

Materials	Design Batch Weights (SSD Aggregate) lb	Target Batch Weights (Moist Aggregates) lb
Cement	480	480
Fly Ash	106	106
GGBFS	0	0
FA	1330	1381
CA	1763	1788
Water	217	141
Σ	3896	3896

The moist aggregate weight may not always be above the weight representing a saturated surface dry condition. This is more likely to happen with a crushed stone coarse aggregate, particularly if that material is produced by a dry crushing operation. If the moisture content of an aggregate is below the absorption value, then the aggregate free water becomes a negative amount and additional water will be required to batch concrete at the target water/cementitious ratio. Many computerized batching systems for concrete plants make water adjustments by the same method as described above, using the free moisture content of the aggregates. The concrete producer and technicians present at the trial batch are required to understand the difference between total moisture content and free moisture content of an aggregate.

The next step in a trial batch is for the Contractor's representative to establish a target batch size of concrete to make. At a plant, the batch is required to be sufficiently large to account for the limited accuracy of the scales at low weights and preset gate openings for charging materials into the weigh hoppers. A minimum size of 3 to 4 yd³ is recommended. A lesser batch size may be out of tolerance creating a yield problem or a mix that does not represent the CMDS that was approved by the DTE. Once the target batch size is established and entered in the Excel worksheet, the total batch weight targeted for each ingredient is automatically calculated. This calculation is done by multiplying the value in the target batch weight column by the target batch size. If the target batch size is set at 5.0 cubic yards for the example that has been presented, the total target batch weights would be as shown in the table below:

Materials	Design Batch Weights (SSD Agg) lb	Target Batch Weights (Moist Agg) lb	Target Batch Size yd ³	Total Target Batch Weights lb
Cement	480	480	5.0000	2400.00
Fly Ash	106	106	5.0000	530.00
GGBFS	0	0	5.0000	0.00
FA	1330	1381	5.0000	6907.36
CA	1763	1788	5.0000	8939.29
Water	217	141	5.0000	703.35
Σ	3896	3896	NA	19480.00

The total batch weight calculated by the worksheet for each component is required to be checked against the values that the batch plant operator intends to use. This should be done even with plants that have a computerized batching system. Miscommunication or errors in control panel settings or aggregate moisture inputs may quickly create significant delays in time and effort. The amount of water to be batched by the plant may intentionally be reduced by the amount of water to be introduced in washing down the funnel and fins of a transit mixing truck. This amount of water, which is typically 25 to 42 lb, may have a significant effect on water/cementitious ratio in a reduced size batch of 3 to 4 cubic yards. The Excel worksheet has been set up to calculate total target batch weights to the nearest 0.01 lb, in order to provide a worksheet that may be used for trial batches conducted in the laboratory in accordance with **ASTM C 192**.

Once the total trial batch weights are confirmed as being correct, the ingredients may be weighed and recorded in the column entitled "Actual Batch Weights". The percentage error between the total target batch weight and the actual batch weight is calculated by the Excel worksheet and recorded in the last column of the form. This calculation is done by subtracting the total target batch weight from the actual batch weight and dividing by the total target batch weight. This number is then multiplied by 100 to determine percentage. For example, if 6960 lbs of moist fine aggregate was batched into the mixer, the calculation for batching error would be as follows:

Example: [(6960.00 - 6907.36)/6907.36] x 100 = 0.76 % batching error, fine aggregate

Materials	Design Batch Weights (SSD Agg) lb	Target Batch Weights (Moist Agg) lb	Target Batch Size yd ³	Total Target Batch Weights Ib	Actual Batch weights lb	Batching Error ± %	Allowable Error ± %
Cement	480	480	5.0000	2400.00	2400.00	0.00	± 1.49
Fly Ash	106	106	5.0000	530.00	530.00	0.00	± 1.49
GGBFS	0	0	5.0000	0.00			± 1.49
FA	1330	1381	5.0000	6907.36	6960.00	0.76	± 2.49
CA	1763	1788	5.0000	8939.29	8980.00	0.46	± 2.49
Water	217	141	5.0000	703.35	708.00	0.66	± 1.49
Σ	3896	3896	NA	19480.00	19578.00	NA	NA

The table below illustrates an example data entry and calculations on the worksheet for all ingredients.

At this stage of a trial batch, a determination is made whether the batched concrete represents the intended proportioning of the CMDS. Batching tolerance is required to be within the requirements of Section **508.02(b)**, as follows:

	Required
<u>Material</u>	<u>Accuracy</u>
Cement	±1%
Aggregates	±2%
Water	±1%
Admixtures	±3%

These tolerances are also defined in the last column labeled "Allowable Error" in the Concrete Batching tabulation on the worksheet. For the example problem, all of the ingredients were batched well within the allowable tolerance and considered representative of the CMDS. The same procedure is followed for air entraining and chemical admixtures. After batching, the concrete is to be mixed for the appropriate number of revolutions of the drum at mixing speed. Once mixing is complete, the

concrete should be discharged. Prior to sampling and testing, the concrete agitation and/or transit time to the point of placement on the job should be simulated.

Space is provided at the bottom of the first page of the worksheet for entering pertinent information concerning the aggregate sampling and moisture measurements, as well as the batching operations. This information is valuable in explaining the details of events that occurred during the trial batch.

CONCRETE TESTING FOR QC/QA PCCP

The Contractor should conduct a series of initial tests for slump, air content and unit weight on the plastic concrete after completion of the mixing cycle. This initial testing may serve as an early indicator of compliance and results may be compared to the true testing conducted after the simulated transit time. If the air content is less than the 5.0% minimum requirement, the Contractor may add additional air entraining agent (AEA) to the mixed load of concrete in an effort to increase the air content, prior to discharge from the mixer. However, this procedure is difficult to obtain since a very large dosage of AEA will increase the air content only a few tenths of a percentage point. Additional water may be used to assist in the dispersal of the AEA within the mixed concrete if the water is measured accurately and recorded as part of the batch water. If more than one adjustment is needed to obtain the desired air content, the truckload should be rejected and another batch prepared.

At the end of the mixing and delivery simulation, the concrete is tested by the qualified and certified technicians. Both technicians are required to test the concrete for the specified plastic properties and cast at least two beams for flexural strength determination at 7 days. The plastic concrete properties and technician name are reported on the second page of the worksheet within the table entitled "Plastic Concrete Test Results, 501.06". An example of such testing is presented as follows:

PLASTIC CONCRETE TEST RESULTS, 501.06						
Plastic Property 093501007S	Contractor Certified Technician Results	ACI Certified Technician	INDOT Qualified Technician Results	INDOT Qualified Technician		
Water/Cementitious	0.371		0.372			
Unit Weight. (pcf)	143.8		143.1			
Air Content (%)	7.3		7.4			
Slump (in.)	1.50					
Relative Yield	1.008		1.013			

The technicians are required to check the plastic concrete properties against the requirements stated in Section **501.06**. Failure to meet these requirements will be cause for rejecting the trial batch as not being representative of the CMDS and another attempt should be made if the Contractor wishes to pursue the use of the mix. The Excel worksheet automatically calculates the water/cementitious ratio and relative yield and enters the result in the appropriate cell. Without the Excel worksheet, water/cementitious ratio is required to be calculated in accordance with **ITM 403**. Since air content influences unit weight, the air content also has an effect on the relative yield. The following table indicates what should be the expected range of relative yield based on the measured air content:

Air Content	Relative Yield
5.0 %	0.980 - 0.990
6.5 %	0.995 - 1.005
8.0~%	1.010 - 1.020
10.0 %	1.030 - 1.040

The DTE should be contacted if there are any concerns or questions about relative yield results for the measured air content. The DTE may request that the certified and qualified technicians obtain fine and coarse aggregate samples for the possibility of testing bulk specific gravity (ssd) and absorption.

The beam specimens are required to be cured and transported properly to the testing laboratory. The specimens should be clearly identified as to which CMDS they represent. The age at which the specimens are to broken is clearly identified on the worksheet. Beam specimens that are tested at an age other than 7 days, are to be considered for information only. The test results and technician name are reported on the second page of the worksheet within the table entitled "Flexural Strength Test Results, 501.06". An example of this testing is as follows:

	FLEXURAL STRENGTH TEST RESULTS, 501.06								
1 99	Contractor's		Contractor	INDOT Qua	alified	INDOT			
Lab Resu		sults		Technician Result		Qualified			
Dovo	psi		Tech	psi		Tech			
Days	Specimen	Avg.		Specimen	Avg				
7	625	625		635	625				
7	625	023		635	033				

Based on the two individual beam results entered, the Excel worksheet automatically calculates the average flexural strength and reports the flexural strength in the appropriate cell.

Space is provided at the bottom of the second page of the worksheet for entering pertinent information concerning the plastic concrete tests results and flexural strength results. Test result from a third party (e.g. Independent Assurance Technician) should be entered in the comments section of the worksheet. Such information is very valuable in explaining the details of events that occurred during a trial batch.

TRIAL BATCH REQUIREMENTS FOR PCCP HIGH EARLY STRENGTH & PCCP PATCHING

The trail batch worksheets for High-Early Strength PCCP and PCCP Patching concretes are similar to what has been previously explained for QC/QA PCCP. The specific requirements are detailed in Sections **502.04(b)** and **506.05**, respectively. Trial batch worksheets for these concretes follow the requirements of the Standard Specifications and should be self explanatory.

4 Quality Assurance Procedures

Sublots and Lots

Random Sampling

Random Numbers Sample Location -- Plastic Concrete Sample Location -- Cores Sampling Procedures

Testing Equipment Calibration

Referenced Documents

Safety

Acceptance Testing

Flexural Strength Air Content Unit Weight Water/Cementitious Ratio Thickness Smoothness

Pay Factors

Flexural Strength Air Content Air Content Range Thickness Smoothness

Quality Assurance Adjustment

Flexural Strength, Air Content, Air Content Range Thickness Smoothness Total Quality Assurance Adjustment

Failed Materials

Appeals

Flexural Strength Appeal for Sublot Air Content Appeal for Sublot
CHAPTER FOUR: *QUALITY ASSURANCE PROCEDURES*

Quality Assurance specifications require that the acceptance of material be the responsibility of INDOT. The specification addresses specifically:

- 1) The units of material quantity used for acceptance.
- 2) The process of obtaining random samples
- 3) What mixture characteristics are considered of critical importance
- 4) At what test values may the mixture be accepted at 100% payment
- 5) At what levels may the mixture serve at less than design intent and still be of value, and be paid at some adjusted price.
- 6) At what level should rejection of the material be considered
- 7) An appeal procedure for resolving disagreements in QC and QA test results

This chapter discusses the procedures and requirements for sampling, testing, and payment of QC/QA PCCP.

SUBLOTS AND LOTS

Quality Assurance Specifications consider a sublot as typically 2400 yd². A partial sublot of 480 yd² or less is considered as part of the previous sublot and a partial sublot greater than 480 yd² is considered an individual sublot.

A lot typically consists of three sublots or 7200 yd^2 of concrete for each mix design. If there is one or two sublots in an incomplete lot, then the quantity of material is considered a lot. Therefore, a lot may contain one, two, or three sublots. If the concrete is placed at several locations on one contract, then the sublots are determined in the order that the material was placed.

Lots and sublots are numbered and tested for a given pay item regardless of the number of CMD's used and are closed out at the end of the paving season or construction phase.

RANDOM SAMPLING

Sampling of material for acceptance testing is done by INDOT on a random basis using **ITM 802**. A random target area for plastic concrete within a sublot is determined and the location of the random quantity is established. Cores for thickness are determined by establishing random longitudinal and transverse locations. The random locations are not given to the Contractor so that there is no possible influence on the production operations.

RANDOM NUMBERS

A table of Random Numbers from **ITM 802** (Figure 4-1) is used to determine the random quantity to sample. The numbers occur in this table without aim or reason and are in no particular sequence. Therefore, samples obtained by the use of this table are truly random or chance and eliminate any bias in obtaining samples.

To use this table to determine the random square yard of concrete to sample, one block is selected in the table. After the block is selected the top left number in the block is used as the first random number. This number is the beginning number for the contract. Additional numbers are obtained by proceeding down the column. The top of the next column on the right is used when the bottom of the column is reached. When the bottom of the last column on the right is reached, the top of the column at the left is used. If all numbers in the table are used before the contract is completed, a new starting number is selected and the same procedure is repeated.

To use this table to determine the location of the pavement core, again a block in the table is selected and the top left number is used. This number is used to determine the test site station. The adjacent number within the block is used to determine the transverse distance to the random site. Additional numbers are obtained by proceeding down by pairs until the bottom numbers are reached and proceeding to the adjacent top block to the right, if available. When the bottom pair of numbers on the right are reached, the top block on the left in the table is used.

0.576	0.730	0.430	0.754	0.271	0.870	0.732	0.721	0.998	0.239
0.892	0.948	0.858	0.025	0.935	0.114	0.153	0.508	0.749	0.291
0.669	0.726	0.501	0.402	0.231	0.505	0.009	0.420	0.517	0.858
0.609	0.482	0.809	0.140	0.396	0.025	0.937	0.310	0.253	0.761
0.971	0.824	0.902	0.470	0.997	0.392	0.892	0.957	0.040	0.463
0.053	0.899	0.554	0.627	0.427	0.760	0.470	0.040	0.904	0.993
0.810	0.159	0.225	0.163	0.549	0.405	0.285	0.542	0.231	0.919
0.081	0.277	0.035	0.039	0.860	0.507	0.081	0.538	0.986	0.501
0.982	0.468	0.334	0.921	0.690	0.806	0.879	0.414	0.106	0.031
0.095	0.801	0.576	0.417	0.251	0.884	0.522	0.235	0.389	0.222
0.509	0.025	0.794	0.850	0.917	0.887	0.751	0.608	0.698	0.683
0.371	0.059	0.164	0.838	0.289	0.169	0.569	0.977	0.796	0.996
0.165	0.996	0.356	0.375	0.654	0.979	0.815	0.592	0.348	0.743
0.477	0.535	0.137	0.155	0.767	0.187	0.579	0.787	0.358	0.595
0.788	0.101	0.434	0.638	0.021	0.894	0.324	0.871	0.698	0.539
0.566	0.815	0.622	0.548	0.947	0.169	0.817	0.472	0.864	0.466
0.901	0.342	0.873	0.964	0.942	0.985	0.123	0.086	0.335	0.212
0.470	0.682	0.412	0.064	0.150	0.962	0.925	0.355	0.909	0.019
0.068	0.242	0.777	0.356	0.195	0.313	0.396	0.460	0.740	0.247
0.874	0.420	0.127	0.284	0.448	0.215	0.833	0.652	0.701	0.326
0.897	0.877	0.209	0.862	0.428	0.117	0.100	0.259	0.425	0.284
0.876	0.969	0.109	0.843	0.759	0.239	0.890	0.317	0.428	0.802
0.190	0.696	0.757	0.283	0.777	0.491	0.523	0.665	0.919	0.246
0.341	0.688	0.587	0.908	0.865	0.333	0.928	0.404	0.892	0.696
0.846	0.355	0.831	0.218	0.945	0.364	0.673	0.305	0.195	0.887
0.882	0.227	0.552	0.077	0.454	0.731	0.716	0.265	0.058	0.075
0.464	0.658	0.629	0.269	0.069	0.998	0.917	0.217	0.220	0.659
0.123	0.791	0.503	0.447	0.659	0.463	0.994	0.307	0.631	0.422
0.116	0.120	0.721	0.137	0.263	0.176	0.798	0.879	0.432	0.391
0.836	0.206	0.914	0.574	0.870	0.390	0.104	0.755	0.082	0.939
0.636	0.195	0.614	0.486	0.629	0.663	0.619	0.007	0.296	0.456
0.630	0.673	0.665	0.666	0.399	0.592	0.441	0.649	0.270	0.612
0.804	0.112	0.331	0.606	0.551	0.928	0.830	0.841	0.702	0.183
0.360	0.193	0.181	0.399	0.564	0.772	0.890	0.062	0.919	0.875
0.183	0.651	0.157	0.150	0.800	0.875	0.205	0.446	0.648	0.685

Figure 4-1. Random Numbers

SAMPLE LOCATION -- PLASTIC CONCRETE

The location where the random sample is obtained is calculated using the random target area procedure of **ITM 802** as follows:

- 1) Determine the sublot size from which a random location is required to the nearest 1 yd^2
- 2) Divide the area by 100 and round down to the nearest whole number. The resulting number is the number of segments within the area that are available for sampling.
- 3) Divide the area by the number of sample segments to determine the sample segment size to the nearest 1 yd^2 .
- 4) Select a random number
- 5) Multiply the number of sample segments by the random number and round down to the nearest whole number. The resulting number represents the random target area. The sample is taken from material placed within the random target area.
- 6) Divide the sample segment size by the width of the area and round to the nearest 0.1 foot length. The resulting number is the length of the random target area.
- 7) Multiply the random target area by the length of the random target area and round to the nearest whole foot. The resulting number is the distance to the beginning of the random target area as measured from the start of the area to be sampled.

The following examples explain the procedure for obtaining the random target area:

Example No. 1

A PCCP is being placed at a width of 12 ft and the starting station of the sublot is 102+50. The sublot size is 2400 yd^2 .

Number of Sample Segments	=	$\frac{2400}{100} =$	24
Sample Segment Size	=	$\frac{2400}{24}$ =	100 yds^2
Random Number	= 0.830)	

Random Target Area	$= 24 \times 0.830$			
		= 19.9 (Round down t	o 19)
Length of Random	Samp	le Segment Size (yd ²)	v	9 ft ²
Target Area	$= \frac{1}{\text{Width (nearest 0.1 ft)}}$		х	1 yd^2
		100		0
	=	12	Х	9
	=	75 ft		

Distance to the beginning of the Random Target Area $= 19 \times 75$ = 1425 ft

The sample is obtained at 1425 feet from the beginning station of the sublot (102 + 50).

Example No. 2

A PCCP is being placed at a width of 24 ft and the starting station of the sublot is 165+00. The sublot size is 550 yd^2 .

Number of Sample Segments = $\frac{550}{100}$ = 5.5(Round down to 5) Sample Segment Size = $\frac{550}{5}$ = 110 yd^2 Random Number = 0.361Random Target Area = $5 \times 0.361 = 1.8$ (Round down to 1) Length of Random Target Area = $\frac{\text{Sample Segment Size (yd^2)}}{\text{Width (nearest 0.1 ft)}} \times \frac{9 \text{ ft}^2}{1 \text{ yd}^2}$ $= \frac{110}{24} \times 9 = 41.2 \text{ ft}$

Distance to the beginning of the Random Target Area = $1 \times 41 = 41$ ft.

The sample is obtained at 41 feet from the beginning station of the sublot (165 + 00).

SAMPLE LOCATION -- CORES

The location where the random core for thickness is obtained using the random location per area procedure of **ITM 802** is as follows:

- 1) Identify the sublot from which a random location is required
- 2) Select a pair or random numbers from the random number table (Figure 4-1). Use the first number for the longitudinal location and the second number for the transverse location.
- 3) Determine the length of the sublot
- 4) Multiply the longitudinal length by the first random number
- 5) Multiply the transverse width by the second random number
- 6) The resulting numbers represent the random location

The station at which a core is taken is determined using the length of pavement required for the sublot of PCCP. The transverse distance is determined using the width of pavement being placed, and is measured from the right edge of the lane determined by looking in the direction of increasing station numbers. Computations for the longitudinal distance and the transverse distance are made to the nearest 1 foot. Cores are not taken at the following locations:

- 1) Less than 6 in. from the edge of pavement
- 2) Less than 2 ft from a D-1 contraction joint
- 3) Less than 3 in. from the longitudinal joint
- 4) Less than 5 ft from a transverse construction joint

If a core location is less than 6 in. from the edge of pavement, a new location is determined by subtracting or adding 6 in. from the random transverse distance. If a core location is over a dowel bar, a new location is determined by subtracting or adding 3 ft from the random station. If a core location is less than 5 ft from a transverse construction joint, a new location is determined by subtracting or adding 5 ft from the random station.

Example:

A PCCP is being placed at a width of 12 feet and the starting station of the sublot is 75+00. The sublot size is 2400 yd².

Length of Sublot $=$	Sublot Size(yd ²) x Width (nearest 1 ft)	$\frac{9 \text{ ft}^2}{1 \text{ ud}^2}$			
= -	$\frac{2400}{12}$ x 9 =	1 yu = 1800 ft			
Random Numbers	= 0.935, 0.114				
Longitudinal Distance	$= 1800 \ge 0.935 = 1683 $ ft				
Random Station	=(75+00) + (16+83) = 91+83	=(75+00) + (16+83) = 91+83			
Transverse Distance	$= 12 \times 0.114 = 1.4 \text{ ft (say 1 ft)}$				

SAMPLING PROCEDURES

AASHTO T 141 is the test method required for sampling freshly mixed concrete. An exception to this test method that INDOT allows is that the entire sample may be obtained from one portion of the load. Obtaining a representative sample of the concrete to be tested is important for assuring an accurate determination of the concrete properties. The test results are not acceptable if any sample is improperly taken. Representative material is important for samples taken by the Contractor for job control, samples taken by independent testing companies, and samples that are used to appeal INDOT test results. Although **AASHTO T 141** does not define the sampling container, other test methods are very specific on acceptable types of containers. A wheelbarrow meets the requirements of all the AASHTO test methods used for acceptance testing of concrete by INDOT and therefore is generally used as the sampling and mixing container.

INDOT test samples are obtained at the point of placement whenever possible. QC/QA PCCP samples are taken on the grade after the material has been placed by a material transfer machine, but before the concrete paver has distributed the mixture INDOT allows two types of freshly mixed plastic concrete samples:

- 1) A composite sample consisting of two or more increments taken from the batch and mixed together in the sampling receptacle
- 2) One large increment taken from one portion of the load

The type of sample required is determined by the sampling technique method.

Regardless of where the sample is obtained, no more than 15 minutes should elapse between obtaining the first and final portions of the sample. Also, no sample is obtained before approximately 10 % of the load has been discharged or after approximately 90 % of the load has been discharged.

Sampling from Trucks

When sampling from a revolving drum truck mixer (transit-mix truck) or an agitator truck, the sample may be obtained by directing the chute to a wheelbarrow (Figure 4-2) or to a receptacle on the ground near the testing site. The sample is not obtained from the chute of the truck or from the discharge stream of the concrete when filling the receptacle.



Figure 4-2. Sampling from Truck

Sampling from Grade

When sampled from the grade (Figure 4-3), the sample is taken before any machinery comes in contact with the concrete.

When the sample is obtained from a pile on the grade or the ground near the testing site, samples are taken from five different portions of the pile. The sample should not be contaminated with the base material.

After obtaining the concrete sample, all portions of the concrete are mixed together with a shovel the minimum amount necessary to obtain proper uniformity.



Figure 4-3. Sampling from Grade

Sampling from Central Mixed Plants

When a concrete sample is tested at a central mixed plant, such as would be required for a trial batch or for casting concrete beams, the procedure for sampling the concrete is to have the plant discharge a load directly into the bucket of a loader (Figure 4-4).



Figure 4-4. Loading a Bucket

The loader bucket is cleaned ahead of time to minimize any possible contamination of the sample. The loader then transports the material to the testing location where the concrete is sampled (Figure 4-5).



Figure 4-5. Sampling from a Loader

After sampling the concrete, all portions are thoroughly mixed together with a shovel the amount necessary to obtain proper uniformity (Figure 4-6).



Figure 4-6. Mixing Sample

TESTING EQUIPMENT CALIBRATION

All concrete job-control testing equipment is required to be calibrated at the proper frequency. The calibration process includes sieves, electronic scales, air test equipment, slump equipment, thermometers, and equipment for determination of the unit weight of concrete. Flexural strength testing machines and compressive strength testing machines are required to be calibrated annually and after being moved.

Flexural strength testing machines used by the Contractor on QC/QA contracts are required to also be calibrated. The calibrations of the equipment at these locations are the responsibility of the Contractor. Calibration documentation should be produced by the Contractor for each testing machine and reviewed by INDOT personnel prior to the use of the testing machine for testing concrete for INDOT work.

The following documents should be reviewed for calibration:

- 1) AASHTO T 152 Air Meter and Unit Weight Containers
- 2) **ITM 902** Sieves

- 3) **ITM 903** Ovens
- 4) **ITM 910** Electronic Balances
- 5) **ITM 911** Slump Cones

REFERENCED DOCUMENTS

ITM and AASHTO test methods are used for concrete job control. INDOT specifications contain several exceptions to the AASHTO test methods. If there are INDOT exceptions to AASHTO, then INDOT specifications take precedent over AASHTO test methods. The AASHTO test methods and Section **505** should be reviewed for any corresponding exceptions. The Supplemental Specifications and/or Special Provisions of a contract may have additional or different exceptions than those found in Section **505**. All three documents should be reviewed prior to placing concrete on the contract.

SAFETY

Prolonged exposure of skin and tissue to the cement in concrete may be harmful. Therefore, plastic or latex gloves are recommended during the sampling and testing of concrete. Protective eye wear is also recommended because concrete may splatter during testing.

ACCEPTANCE TESTING

The Contractor is required to submit a mix design and provide verification of the design by the Trial Batch Demonstration. The concrete properties are required to meet the concrete parameters of the Specifications prior to placement.

Acceptance testing results are shared with the Contractor. The flexural strength, air content, unit weight, water/cementitious ratio, and thickness are measured for acceptance. The frequency, test method, and precision of test results are as follows:

Test or Determination	Frequency	Test Method	Precision
7-Day Flexural	Two beams		10 kPa
Strength	per sublot	AASIITO 1 97	(1 psi)
		AASHTO T 152	
Air Content	One per sublot	or	0.1
		ASTM C 173	
Unit Weight	One per sublot AASHTO T 12		1
Water/Cementitious	One per two lots	ITM 402	0.001
Ratio	One per two lots	1111405	0.001
Thickness	Two per sublot	ITM 404	0.1

FLEXURAL STRENGTH

The average lot values for flexural strength are required to be a minimum of 570 psi. Price adjustments for values below 570 psi are required.



AASHTO T 97 is the test method used for determining the flexural strength of concrete beams. This test consists of breaking the test beams on a self-recording beam calculating breaker and the flexural strength results. Sections 502.18, 702.05, and 702.13(h) include the flexural strength requirements.

Figure 4-7. Flexural Strength Machine

AIR CONTENT

The average lot air content is required to not vary more than - 0.8 % or + 2.4 % from the 6.5 % target air content. Also, the range of values is required to not exceed 2.5 %. Range is defined as the difference between the highest sublot air content and the lowest air content sublot within a lot. Price adjustments are required for exceeding the tolerances for air content and the range of air content.

Pressure Method

AASHTO T 152 is the required test method for determining the air content of freshly mixed concrete by the Pressure method. An aggregate correction factor is required and is dependent on the source of the fine aggregate, the source of the coarse aggregates and ledges for stone, and the percentages of each used in the The aggregate correction mix. factor should therefore be checked each time one of these factors changes. An aggregate correction factor determination is required for each CMD.



Figure 4-8. Type B Air Meter

Volumetric Method

The volumetric method for air content (**AASHTO T 196**) is required by INDOT when porous aggregate such as air-cooled blast furnace slag is specified; however, this test method may be used on concrete containing any type of aggregate.



Figure 4-9.Volumetric Air Meter

UNIT WEIGHT

The sublot unit weight is required to not vary more than $\pm 3.0\%$ from the target unit weight. A stop paving order is issued if the plastic unit weight exceeds the $\pm 3.0\%$ tolerance. Paving operations are not allowed to resume until satisfactory changes are made or an alternate CMD is used.

AASHTO T 121 is the test method required for determining the unit weight of the freshly mixed concrete (Figure 4-10). **AASHTO T 121** requires the use of a 24-inch tamping rod and **AASHTO T 152** requires only a 16-inch tamping rod. Since the unit weight and the air content are generally determined at the same time, a 24-inch tamping rod is used to meet the requirements of both methods. Also an exception in **505.01(c)** requires that the weight be determined to the nearest 0.01 lb.



Figure 4-10. Unit Weight

WATER/CEMENTITIOUS RATIO

The water/cementitious ratio is required to not vary by more than ± 0.030 from the target value or exceed a value of 0.450. A stop paving order is issued if the test results exceed these values. Paving operations are not allowed to resume until satisfactory changes are made or an alternate CMD is used.

ITM 403 is used for determining the water/cementitious ratio of concrete. Representative sampling of the fine aggregate and the coarse aggregate for moisture content is critical to determine this value on the day of the concrete pour. If the moisture content of the aggregates changes (e.g. overnight rain), then the batch weights are required to be changed accordingly to maintain the proper proportions of materials to produce a cubic yard of concrete.

The W/C ratio calculation is determined from the amount of free water in the concrete batch. The free water is the total of all water added at the jobsite plus the water on the aggregates in excess of the amount of water required to satisfy the absorption of the fine and the coarse aggregates.

Free water is expressed in pounds of water per pound of cement and the ratio of the two is called the water to cementitious ratio. If pozzolans are included in the concrete mixture, then the weight of pozzolans is added to the cement weight for this calculation. A form in **ITM 403** is used to calculate the W/C ratio.

THICKNESS

The PCCP thickness is required to be determined after all corrective grinding of the pavement, if necessary, is completed. The Contractor is required to obtain two 4 in. diameter cores for each sublot (Figure 4-11). The cores are taken the full depth of the PCCP at the locations determined by the PE/PS in accordance with **ITM 802**; however, cores are not taken in the following locations:

- 1. Less than 2 ft from the edge of pavement
- 2. Less than 2 ft from a D-1 contraction joint
- 3. Less than 3 in. from the longitudinal joint
- 4. Less than 5 ft from a transverse construction joint



Figure 4-11. Concrete Coring

The cores are taken and measured with a core length apparatus (Figure 4-12) in accordance with **ITM 404** at 10 locations on the core. The average of these measurements is considered the length of the core.



Figure 4-12. Core Length Apparatus

The thickness of the PCCP for each sublot is the average lengths of both cores from the sublot. The sublot pay factor is determined by subtracting the design thickness from the average sublot thickness and comparing this value to the allowable tolerances. Values exceeding ± 0.2 inches are required to have a price adjustment.

SMOOTHNESS

As soon as the concrete has cured enough to permit testing, the profile of the pavement is required to be checked for smoothness. INDOT may require that the pavement be tested within 24 h following the placement of the concrete. This requirement is continued until the paving operation is consistently providing pavement meeting the smoothness requirements without corrective action. All remaining pavement is to be checked for smoothness before opening to traffic or before work is suspended for the winter.

Smoothness is checked by one of three methods:

1) A profilograph (Figure 4-13) is used on all mainline traveled ways and ramps, including adjacent acceleration or deceleration lanes where both the design speed is greater than 45 mph and the traveled way or ramp lane width is constant and is 0.1 mi. in length or longer.



Figure 4-13. Profilograph

If the posted speed limit is greater than 45 mph for a portion of a smoothness section and is less than or equal to 45 mph for the remainder, the section smoothness acceptance is as follows:

- a. By profilograph for the portion of the section with a posted speed limit greater than 45 mph
- b. By 16 ft straightedge for the portion of the section with a posted speed limit less than or equal to 45 mph

- 2) For contracts which include a requirement for profilograph testing, a 16 ft straightedge is used at the following locations:
 - a. All mainline traveled way lanes shorter than 0.1 mi.
 - b. All mainline traveled way lanes within smoothness sections with posted speed limits less than or equal to 45 mph throughout the entire section length
 - c. All mainline traveled way lanes at locations exempted from profilograph operation in accordance with **ITM 912**
 - d. All tapers
 - e. All turn lnes, including bi-directional left turn lanes
 - f. All ramps with design speeds of 45 mph or less
 - g. All acceleration and deceleration lanes associated with ramps with design speeds of 45 mph or less
 - h. All shoulders
- 3) A 10 ft straightedge is used on transverse slopes, approaches, and crossovers

Profile smoothness is checked 3 ft from, and parallel to, the outside edge of each lane up to 12 ft wide. Lanes wider than 12 feet are checked 3 ft from both edges. Any curing compound removed during straightedging should be replaced immediately.

When correction is needed, a groove type cutter is used to grind the pavement to the proper smoothness while maintaining the required skid resistance.

The required surface tolerances for QC/QA pavements are:

- 1) 16 ft straightedge 1/4 in. or less
- 2) 10 ft straightedge 1/8 in. or less

In addition to the requirements for the profile index for the profilogragh, any area having a high point deviation in excess of 0.3 in. is required to be removed.

PAY FACTORS

Pay factors are determined for flexural strength, air content, air content range, thickness, and smoothness. When the PCCP test results exceed the allowable tolerances, pay factors are determined.

FLEXURAL STRENGTH

Lot Average Flexural Strength			
psi	Pay Factors		
570 and above	1.00		
565 - 569	0.98		
560 - 564	0.96		
555 - 559	0.94		
550 - 554	0.92		
545 - 549	0.89		
540 - 544	0.86		
535 - 539	0.83		
525 - 534	0.78		
515 - 524	0.72		
514 or less	*		

Pay factors for flexural strength are assessed as follows:

*The PCCP is adjudicated as a failed material in accordance with normal INDOT practice as listed in Section **105.03**. The PCCP may be subject to removal and replacement or left in place with reduced or no payment.

AIR CONTENT

Pay factors for air content are assessed as follows:

Lot Average Air Content			
Percent %	Pay Factors		
> 9.8	*		
9.7 - 9.8	0.80		
9.5 - 9.6	0.90		
9.3 - 9.4	0.95		
9.0 - 9.2	0.99		
5.7 - 8.9	1.00		
5.6	0.93		
5.5	0.90		
5.4	0.85		
5.3	0.79		
< 5.3	*		

*The PCCP is adjudicated as a failed material in accordance with normal INDOT practice as listed in Section **105.03**. The PCCP may be subject to removal and replacement or left in place with reduced or no payment.

AIR CONTENT RANGE

The lot air content range is assigned pay factors in accordance with the following::

Lot Range for Air Content			
Percent %	Pay Factors		
0.0 - 2.5	1.00		
2.6 - 3.0	0.99		
3.1 - 3.5	0.97		
> 3.5	*		

*The PCCP is adjudicated as a failed material in accordance with normal INDOT practice as listed in Section **105.03**. The PCCP may be subject to removal and replacement or left in place with reduced or no payment.

THICKNESS

The sublot core thickness is assigned a pay factor in accordance with the following:

Sublot Pay Factors For Thickness			
Average Core Depth (ACD) Design Depth (DD)			
ACD Minus DD	Pay Factor		
> +0.5 in.	1.05		
(>+13 mm)	1.05		
+ 0.3 in. to +0.5 in.	1.02		
(+ 7 mm to +13 mm)			
0.2 in.(± 6 mm)	1.00		
- 0.3 in. to - 0.5 in.	0.06		
(- 7 mm to - 13 mm)	0.90		
- 0.6 in. to - 0.7 in.	0.90		
(- 14 mm to - 19 mm)	0.90		
- 0.8 in. to - 1.0 in.	0.80		
(- 20 mm to - 25 mm)	0.00		
< - 1.00 in.	*		
(< - 25 mm)			

SMOOTHNESS

When pavement smoothness is tested with a profilograph, pay factors are determined for each 0.1 mile long sections represented by the profile index. The pay factors are calculated in accordance with the following table:

Section Pay Factors for Smoothness Zero Blanking Band				
Design Speed Greater Than 45mph				
Profile Index in./0.1 mi. Pay Factor				
Over 0.00 to 1.40 in.	1.06			
Over 1.40 to 1.60 in.	1.05			
Over 1.60 to 1.80 in.	1.04			
Over 1.80 to 2.00 in.	1.03			
Over 2.00 to 2.40 in.	1.02			
Over 2.40 to 2.80 in.	1.01			
Over 2.80 to 3.60 in.	1.00			
Over 3.60 to 3.80 in.	0.96			
All pavements with a Profile Index $(PI_{0.0})$ greater than 3.80 in. shall be corrected to 3.80 in.				

QUALITY ASSURANCE ADJUSTMENT

The pay factors are used to calculate a quality assurance adjustment quantity for the lot. The adjustment for flexural strength, air content, air content range, thickness and smoothness are calculated as follows:

FLEXURAL STRENGTH, AIR CONTENT, AIR CONTENT RANGE

For flexural strength, air content, and air content range determination:

q = L x U x (P - 1.00)

where:

q = quality assurance adjustment quantity L = lot quantity U = unit price for QC/QA-PCCP, ($\frac{y}{yd^2}$) P = pay factor

THICKNESS

For sublot thickness determination:

 $q_{\rm T} = l_{\rm T} \ge 0 = 0$

where:

 q_T = quality assurance adjustment quantity l_T = sublot quantity for thickness U = unit price for QC/QA-PCCP, (\$/yd²) P = pay factor For section smoothness determination:

$$q_s = (PF_s - 1.00) x A x U$$

where:

 q_s =quality assurance adjustment for smoothness for one section

 $PF_s = pay factor for smoothness$

A = area of the section, (SYS)

U = unit price for the material, (\$/SYS)

The quality assurance adjustment for smoothness for the contract, Q_S , will be the total of the quality assurance adjustments for smoothness, q_s , on each section as follows:

 $Q_s = \Sigma q_s$

TOTAL QUALITY ASSURANCE ADJUSTMENT

The total quality assurance adjustments are calculated as follows:

$$Q_{\rm T} = \Sigma (q_{\rm T1} + q_{\rm T2} + q_{\rm T3})$$
, and

$$Q = \Sigma (q_F + q_A + q_R + Q_T) + Q_S$$

where:

Q = total quality assurance adjustment quantity $Q_S =$ quality assurance adjustment for smoothness $q_F =$ lot quality assurance adjustments for flexural strength $Q_T =$ lot quality assurance adjustments for thickness $q_A =$ lot quality assurance adjustments for air content $q_R =$ lot quality assurance adjustments for range

Example:

The PCCP has the following test results. Determine the Quality Assurance Adjustments for the lot.

Sublot 1 = 2400 yd² Sublot 2 = 2400 yd² Sublot 3 = 2400 yd² Design Depth (DD) = 14.0 in. Quality Assurance Adjustment for Smoothness (Qs) = - 1200

Unit Price = \$32.00 sys

Sublot 2 Sublot 3 Lot Avg. Pay Factor <u>Sublot 1</u> Flexural Strength 565 psi 560 psi 570 psi 565 psi 0.98 6.2% Air Content 7.4% 5.3% 6.3% 1.00 Air Content Range 7.4 - 5.3 = 2.1% 1.00 $q_F = 7200 \text{ x } 32.00 \text{ x } (0.98 \text{ - } 1.00)$ = - \$4608 $q_A = 7200 \text{ x } 32.00 \text{ x } (1.00 - 1.00)$ = \$0 $q_R = 7200 \text{ x } 32.00 \text{ x } (1.00 - 1.00)$ = \$0 Thickness

<u>Sublot 1</u>	<u>Sublot 2</u>	<u>Sublot 3</u>
14.1 in.	13.9 in.	14.4 in.
+0.1 in.	-0.1 in.	+0.4 in.
100	1.00	1.02
0	0	+1536
	<u>Sublot 1</u> 14.1 in. +0.1 in. 100 0	Sublot 1 Sublot 2 14.1 in. 13.9 in. +0.1 in. -0.1 in. 100 1.00 0 0

 $Q_{\rm T} = 0 + 0 + 1536 = \1536

Total Quality Assurance Adjustment

 $Q = \sum (q_F + q_A + q_R + Q_T) + Q_S$ = (-4608 + 0 + 0 + 1536) + (-1200) = - \$4272

FAILED MATERIALS

Sublot and lot values that are excessively out of tolerance are required to be submitted to INDOT for final payment. The test value criteria that requires such submittal include:

- 1. An individual sublot having an air content test value of less than 4.5 percent or more than 10.0 percent
- 2. An individual sublot having a flexural strength test value less than 500 psi
- 3. A lot having a flexural strength test value average of 514 psi or less

- 4. A lot having an air content test value average of less than 5.3 % or greater than 9.8 %
- 5. A range of air content of greater than 3.5%
- 6. A core thickness that is less than the design depth required pavement thickness by more than 1.00 in.

As a minimum, the Failed Materials Committee considers the above-noted items for no additional payment adjustment, an increased payment adjustment to offset potential maintenance costs, additional payment to cover the cost of the investigation, no payment, or removal and replacement

APPEALS

If the Contractor does not agree with the acceptance test results for a lot of QC/QA pavement concrete, an appeal may be submitted. The appeal is required to meet the following criteria:

- 1. Appeals are submitted in writing to the PE/PS within five calendar days of receipt of INDOT's written results for the lot.
- 2. The submission is required to contain quality control test data that equals or exceeds the number of tests required.
- 3. The difference between the acceptance test result and the nearest quality control test result is required to be at least 50 psi for flexural strength.
- 4. The difference between the acceptance test result and the nearest quality control test result is required to be at least 0.5 percent for air content.

Cores are obtained by the Contractor at locations determined by the PE/PS within the appealed sublot. The location of the cores is at the center of a lane at the acceptance sample location. Cores are not taken over dowels or within 5 ft of a header. Each core is required to be 4 in. in diameter for the full depth of the pavement. All core holes are filled by the Contractor with PCC within 24 hours of drilling.

The core value is considered as the flexural strength or air content for the sublot in question and is used to determine all subsequent actions involving the sublot and lot.

FLEXURAL STRENGTH APPEAL FOR SUBLOT

For a flexural strength appeal, two cores are taken within the appealed and adjacent sublots using the same CMD.

Each core is tested for split tensile strength in accordance with **ASTM C 496**. The cores are submerged in lime saturated water prior to testing for a minimum of 40 hours.

The average core split tensile strength is determined for the appealed and adjacent sublots. Flexural strength is calculated as follows.

$$F_{D} = S_{D} \times \left[\frac{F_{A1}}{2S_{A1}} + \frac{F_{A2}}{2S_{A2}} \right]$$

where:

 F_D = flexural strength of the appealed sublot F_{A1} = flexural strength of the previous adjacent sublot F_{A2} = flexural strength of the subsequent adjacent sublot S_D = split tensile strength of the appealed sublot S_{A1} = split tensile strength of the previous adjacent sublot S_{A2} = split tensile strength of the subsequent adjacent sublot

AIR CONTENT APPEAL FOR SUBLOT

For an air content appeal, one core is taken from each sublot. The hardened concrete air content is determined in accordance with **ITM 401** and converted to a value representing the air content in the plastic state.

5 Quality Control Procedures

Contractor Personnel

QCP Manager QCP Field Manager Quality Control Technician

Testing Facility *Testing Equipment*

Materials

Process Control of Aggregates

Trial Batch Demonstration

Concrete Batching

Process Control of Concrete Flexural Strength Air Content Unit Weight Water/Cementitious Ratio

Process Control of Pavement Pavement Depth Surface Profile Surface Smoothness

Control Charts

Response to Test Results Water Absorption Other Quality Control Tests

Concrete Hauling

Concrete Paving Paving Plan Cold Weather Paving Night Paving Paving Equipment Alignment and Profile Placement and Consolidation

Joints

D-1 Contraction Joint Longitudinal Transverse Construction Longitudinal Construction

Finishing, Texturing, and Curing

Documentation

CHAPTER FIVE: QUALITY CONTROL PROCEDURES

The foundation for a successful Quality Assurance program is the control maintained by the Contractor to assure that all materials submitted for acceptance conform to the contract requirements. To accomplish this, the Contractor is required to have a functional Quality Control Plan (QCP) to keep the process in control, quickly determine when the process goes out of control, and respond adequately to bring the process back into control.

This chapter includes the minimum requirements for maintaining quality control during production of QC/QA Portland Cement Concrete Pavement. Acceptance test results by INDOT are shared with the Contractor; however, results of these tests are not used for quality control purposes.

CONTRACTOR PERSONNEL

The Contractor personnel required to provide quality control on a QC/QA PCCP contract includes a QCP Manager, QCP Field Manager, and a Quality Control Technician. One quality control person may perform the duties of more than one position.

QCP MANAGER

The QCP Manager is responsible for the overall administration of the QCP on the contract.

QCP FIELD MANAGER

The QCP Field Manager is responsible for the execution of the QCP and is the liaison with the PE/PS. This person is often also the QCP Manager.

QUALITY CONTROL TECHNICIAN

The quality control technician is required to be an American Concrete Institute (ACI) certified field testing technician, grade 1.

TESTING FACILITY

The Contractor is required to designate the location of the testing facility and a list of test equipment. The testing facility shall be in accordance with the following:

- 1) The facility shall be capable of maintaining a controlled curing environment in accordance with **AASHTO T 23** and contain sufficient storage tanks with curing solution to cure both production control and acceptance test beams
- 2) Water shall be conveniently available for cleaning testing equipment and for serving other tasks at the facility.
- 3) Office space, having suitable heat and air conditioning, shall be provided to INDOT within the testing facility.
- 4) A telephone shall be provided in the testing facility
- 5) Floor space shall be provided for an INDOT furnished beam breaker.
- 6) A current set of AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing, Part II Tests, and ASTM C 173 shall be provided.

A statement of accessibility of the testing facility is required that will allow INDOT personnel to witness the quality control activities and review quality control tests.

TESTING EQUIPMENT

A list of the testing equipment proposed for quality control testing, and the test methods and frequency of calibration or verification of the equipment is required. The equipment shall be provided to perform production control testing and shall be maintained in suitable working order. The equipment is required to be in accordance with AASHTO requirements where applicable. The Contractor is also required to provide a spud vibrator with a power source in suitable working order.

The Contractor is required to maintain a record of all equipment calibration or verification results at the testing facility. The minimum frequency and procedures shall be as follows:

Equipment	Requirement	Minimum Frequency	Procedure	
Air Motor	Calibration	2 months	AASHTO T 152	
All Metel	Calibration	5 monuis	or ASTM C173	
Balances	Verification	12 months	ITM 910	
Siguas	Check Physical	6 months	ITM 002	
Sieves	Condition	0 monuis	11101 902	
Slump Cones	Verify Dimensions	12 months	ITM 911	
Thermometers	Verification	6 months	ITM 909	
Unit Weight	Calibration	12 months		
Measure	Canoration	12 monuis	ААЗПІО І 121	

MATERIALS The source, transportation, handling, and storage procedures, as applicable, are required for the following materials to be used in the PCCP.

- 1) Admixtures type
- 2) Aggregates size
- 3) Curing Materials
- 4) Dowel Bars size
- 5) Dowel Bar Assemblies size
- 6) Fly Ash class
- 7) Ground Granulated Blast Furnace Slag grade
- 8) Joint Fillers type
- 9) Joint Materials type
- 10) Portland Cement type
- 11) Reinforcing Steel size and type
- 12) Water Potable or non potable. If non-potable, the sampling and testing procedures shall be designated.

PROCESS CONTROL OF AGGREGATES

A plan for control of the gradation and moisture in the aggregate stockpiles, identification of stockpiles by signing or other acceptable methods, techniques for construction of proper stockpiles, and loading procedures is required.

The gradation control band tolerances on each sieve for aggregates not in accordance with the gradations of 904.02 and 904.03 shall be included.

Gradation tests for each aggregate size shall be conducted daily when concrete paving operations exceed 200 yd² (200 m²) per day. The procedure for determination of the combined aggregate gradation shall be included. Gradation tests shall verify the maximum size of the aggregates and the mathematically combined amount passing the No. 200 (75 μ m) sieve of fine and coarse aggregates which have been proportioned in accordance with the CMD. Gradation tests shall also verify compliance with intermediate sieves in accordance with 904.02 and 904.03 or with sieve band tolerances as stated.

The procedure for determination of the water absorption of the aggregate shall be included. The minimum frequency is required to be two tests for each aggregate used during the concrete paving operations.

TRIAL BATCH DEMONSTRATION

The procedures, location, and type of equipment to be utilized during the trial batch demonstration(s) are required. The identification and intended use of each mixture shall be included.

CONCRETE BATCHING

The techniques and controls of the concrete batching operations are required. A description of the plant, including the capacity and intended batch size, and the methods and sequence by which the plant produces a batch shall be included. The minimum mixing time shall be stated.

The initial and routine equipment checks, including those conducted on mixers, scales, water meters, and admixture dispensers, shall be included. All material checks, including frequencies of testing, shall be identified. The methods to monitor the ingredients used, and the record of each batch shall be included.

PROCESS CONTROL OF CONCRETE

The procedures for sampling and testing the concrete mix for flexural strength, air content, unit weight, and water/cementitious ratio shall be designated. The frequency of tests shall be included and as a minimum shall meet the following:

FLEXURAL STRENGTH

The minimum frequency of tests for determination of the flexural strength shall be one set of two beams for each sublot.

AIR CONTENT

The minimum frequency of tests shall be one air content determination for each sublot.

UNIT WEIGHT

The minimum frequency of tests shall be one unit weight determination for each sublot.

WATER/CEMENTITIOUS RATIO

The minimum frequency of determination of the water/cementitious ratio shall be one per week or one for every five lots, whichever is more restrictive by frequency.

PROCESS CONTROL OF PAVEMENT

The procedures for determining the pavement depth, surface profile, and surface smoothness shall be as follows:

PAVEMENT DEPTH

The procedure for monitoring the depth of the concrete pavement shall be included.

SURFACE PROFILE

The procedure for measuring the surface profile and correcting profile non-compliance of the concrete pavement shall be included.

SURFACE SMOOTHNESS

The procedure for measuring the smoothness and correcting smoothness non-compliance of the concrete pavement shall be designated. The certification of the profilograph in accordance with ITM 901 shall be included.

CONTROL CHARTS

The procedures for charting quality control results for tests for flexural strength, unit weight, and air content of the concrete shall be designated. The control charts shall indicate process control limits for each sublot and lot, 100 percent payment limits, and have a legend. The charts shall be maintained at a readily accessible location at the common testing facility. The control chart legend shall be as follows:

- 1) The target value, if applicable, shall be the center of the chart and shall be represented by a heavy long dash followed by a short dash line.
- 2) Control limits shall be represented by heavy solid lines.
- 3) One hundred percent payment limits shall be indicated by short dashed lines.
- 4) The horizontal lines on the chart indicating the 100 percent payment limits, control limits, and target value, if applicable, shall be numerically identified in the left margin.
- 5) The vertical distance between upper and lower control limits shall be no less than 2 in. (50 mm).
- 6) The plot point for the test results shall be surrounded by a small circle, and each consecutive point shall be connected by a solid straight line.
- 7) Test results shall be plotted left to right in chronological order, and dates corresponding to each test shall be shown along the horizontal axis.

Any proposed deviation from these procedures shall be identified in the QCP.

RESPONSE TO TEST RESULTS

The response to process control tests shall include as a minimum the following:

WATER ABSORPTION

The procedure for corrective action when the absorption test results for a particular size of aggregate differs from the design mix value by more than 0.5 percent. A statement that production shall be discontinued when this tolerance is exceeded shall be included.

OTHER QUALITY CONTROL TESTS

The procedure for corrective action for results outside of satisfactory limits for each type of test shall be designated.

CONCRETE HAULING

The equipment and methods for delivery to the paver shall be designated. The description or plan drawing of the traffic patterns in the vicinity of the plant and for delivery of the concrete mix to the site of work shall be stated. Information concerning temporary adjustments to traffic flow shall be included. When using transit mixers, the procedures for adding water to the PCC and the required mixing time to increase workability shall be included.

CONCRETE PAVING

The procedures for placement of the concrete shall include as a minimum the following.

PAVING PLAN

The general sequence of construction, the widths and methods of placement for all areas, and the planned date for paving to begin and to be completed on each phase of the contract shall be designated.

COLD WEATHER PAVING

The procedures to be utilized when ambient temperature is below $35^{\circ}F$ (2°C) shall be designated. The procedures shall address protection of the subgrade, treatment of the concrete components, and protection of the PCCP. ACI 306 may be used for additional guidance.

NIGHT PAVING

The procedures to be utilized for artificial lighting when natural light is insufficient shall be designated. The procedures shall include the number and type of units with respect to the paving operations.

PAVING

The techniques used to place concrete throughout the project with specific details pertaining to difficult locations, such as joining existing pavement, gaps, headers, crossovers, approaches, or tapers shall be designated.

EQUIPMENT

Identification of the equipment used in the paving operations on each phase of the contract shall be designated.

ALIGNMENT AND PROFILE

The methods of controlling the alignment and profile shall be designated.

PLACEMENT AND CONSOLIDATION

Methods of depositing plastic concrete from the hauling equipment to the grade shall be designated. The proposed methods of spreading and consolidating shall be included.

JOINTS

The type of sealant to be used and the manufacturer's recommended installation procedure for each type of joint construction shall be designated. The measures to be taken to prevent the flow of cementious material into previously placed and sawn joints, when placing adjacent concrete pavement shall be included.

D-1 CONTRACTION

The procedure for identifying the contract conditions so that the joints are continuous from edge of pavement to edge of pavement shall be designated. Methods of installation, alignment, timing of sawing, and protection shall be included.

LONGITUDINAL

The method of construction to include details of how the reinforcing steel is to be placed and when the joints are to be sawed at identified planned locations shall be designated.

TRANSVERSE CONSTRUCTION

The method of construction, which shall include details of the type of header and reinforcing used, when paving operations are suspended shall be designated.

LONGITUDINAL CONSTRUCTION

The method of construction and proposed spacing if other than shown on the plans shall be designated.

FINISHING, TEXTURING, AND CURING

The methods for finishing, texturing, and curing the PCCP shall be designated. The equipment to be used shall be identified.

DOCUMENTATION

A statement that the test results for control shall be maintained for a period of three years upon completion of the contract shall be included. The records, either electronic and/or hard copies, shall be maintained at a readily accessible location for review by the Department at any time. The documentation shall include results for the aggregate tests, mixture tests, and the profile, smoothness, and depth of pavement tests.

QUALITY CONTROL PLAN

The Contractor is required to submit a QCP that is contract specific and states how the process control of materials, equipment, and operations are maintained. As a minimum, the QCP is required to include the following information for each contract.

- 1) The name, telephone number, duties, and employer of all quality control personnel necessary to implement the QCP. The minimum number of quality control personnel is required to include a QCP Manager, QCP Field Manager, and Quality Control Technician.
- 2) The location of the test facility, list of test equipment, the test methods and frequency of test equipment calibration/verification, and a statement accessibility of the testing facility
- 3) The source, transportation, handling, and storage procedures of the materials used in the concrete
- 4) The procedures for the control of the gradation and moisture of the aggregates, and the procedures for stockpiling, identification of the stockpiles, and plant loading
- 5) The procedures, location, and type of equipment to be utilized during the trial batch demonstration, and the intended use of each mixture
- 6) The techniques and controls of the concrete batching operations, and the initial and routine checks of the equipment
- 7) The procedures for the process control of the concrete to include the sampling and testing procedures to determine the flexural strength, air content, unit weight, and water/cementitious ratio
- 8) The procedures for process control of the pavement for determining the pavement depth, surface profile, and surface smoothness
- 9) The procedures for charting quality control results for tests for flexural strength, unit weight, and air content of the concrete
- 10) The response to process control tests not within the established requirements for water absorption, flexural strength, unit weight, and air content
- 11) The procedures for delivery of the concrete to the paver and the equipment required
- 12) The procedures for the concrete paving to include a paving plan, cold weather paving, night paving, equipment, alignment and profile, and placement and consolidation
- 13) The procedures for installation for each type of joint and the type of sealant to be used
- 14) The procedures for finishing, texturing, and curing the concrete
- 15) The procedures for documentation of the quality control tests and the equipment used on the contract

QCP APPROVAL

The QCP is required to be submitted to the PE/PS for review at least 15 calendar days prior to commencing PCCP operations. The Contractor is required to sign and date the QCP at the time of submittal to the PE/PS. The PE/PS signs and dates the QCP if the contents of the QCP are in compliance with the above-noted requirements. PCCP operations are not allowed to begin before the QCP has been accepted.

The QCP is required to be maintained to reflect the current status of the operations, and revisions are required to be provided in writing prior to initiating the change. The change may not be implemented until the revision has been accepted.

6 Traffic Control

Basic Setup

Continual Inspection

Temporary Pavement Markings

CHAPTER SIX: TRAFFIC CONTROL

The need for standard traffic control is essential during roadway construction to guide traffic safely and efficiently through what would otherwise be hazardous areas.

Traffic control procedures are used at work sites to:

- 1) Warn motorists of the hazards involved and to advise them of the proper manner for traveling through the area
- 2) Inform the user of changes in regulations or additional regulations that apply to traffic traversing the area
- 3) Guide traffic through and around the work site
- 4) Delineate areas where traffic should not operate

BASIC SETUP

The required basic traffic control setup depends on several factors. Is the work being performed under traffic or is the road closed? Is the road closed to through traffic, but residences and businesses are located within the work area for which access is required to be maintained? Is the work zone at a fixed location or is the work zone moving down the road? Is the work being performed on a two lane road or a multi-lane facility? Is the work being performed on a travel lane or a shoulder? Is the work area on an interstate only affected by infrequent ramps or on a roadway with a number of driveways and at-grade intersections? The above factors, along with others, all affect the required traffic control setup.

On individual projects, the following contract documents apply:

- 1) Indiana Manual on Uniform Traffic Control Devices
- 1)2) Maintenance of Traffic Plan Sheets, if included in ← - Formatted: Bullets and Numbering the plans

2) 3)	_Standard Specifications Section 801	4 -	 Formatted: Bullets and Numbering
3)<u>4)</u>	Section 801 Standard Drawings	4 -	 Formatted: Bullets and Numbering
4 <u>)5)</u>	Special Provisions in the Contract Information Book	* -	 Formatted: Bullets and Numbering

Section **801.03** of the Standard Specifications outlines the requirements for the Certified Worksite Traffic Supervisor (CWTS). The CWTS is not required to be on the contract site on a daily basis; however, the CWTS is responsible for the layout and maintenance of all traffic control devices on a contract. The CWTS should be involved in the initial layout of traffic control devices as well as the layout associated with all construction phase shifts that occur during the life of the contract.

For the purposes of this discussion, the primary emphasis will be related to resurface work or other moving operations conducted on a travel lane under traffic. Many of the principles discussed apply to other work situations. The appropriate contract documents for the actual traffic control setups required for other types of work should be reviewed on each contract.

Two typical traffic control situations are illustrated in Figures 6-1 and 6-2. The sign layouts noted in each figure are associated with the moving operation only. Additional ground mounted signs are required at the contract limits as noted in the Maintenance of Traffic Plans or Section **801** Standard Drawings.

A basic setup for a two-lane roadway with two-way traffic is shown in Figure 6-1. This situation requires a flagger with advance warning signs at both ends of the work area. All of the signs for this situation are to be located in relation to the roadway in accordance with the Standard Drawing. As the moving operation progresses down the road, relocation of the signs to maintain proximity to the work area is necessary. If the operation is allowed to progress too far in advance of the warning signs, a motorist may conclude that there is no work being conducted. This may result in a dangerous situation when the driver ultimately encounters the work area.



Figure 6-1. Lane Closure on a Two-Lane Roadway Using Flaggers



Figure 6-2. Stationary Lane Closure on a Divided Highway

Flaggers shall wear high-visibility safety apparel that meets the Performance Class 2 or 3 requirements of the ANSI/ISEA 107-2004 publication entitled "American National Standard for High-Visibility Apparel and Headwear". Flaggers are required to be equipped with 24 in. diameter STOP/SLOW paddles. The use of these paddles should be limited to emergency situations. Flaggers should also be equipped with two way radios if they will not be able to see each other.

Basic flagging procedures are shown in Figure 6-3. All flaggers are required to remain alert while conducting flagging duties. Additional personnel available to provide breaks for the flaggers may be necessary. The following additional requirements for the flagger are necessary:

- 1. Stand either on the shoulder adjacent to the road user being controlled or in the closed lane prior to stopping road users
- 2. Stand only in the lane being used by moving road users after the road users have stopped
- 3. Be clearly visible to the first approaching road user at all times
- 4. Be visible to other road users
- 5. Be stationed sufficiently in advance of the workers to warn them of approaching danger by out-of-control vehicles with an audible warning device such as a horn or whistle
- 6. Stand alone, away from other workers, work vehicles, or equipment

Flagger and other crew members should be alert for trucks associated with the work as they enter and leave the work area. Material delivery trucks entering or exiting the work zone are often moving slower than the through traffic and may cause traffic slowdowns. Also, motorists may follow these vehicles into the work area.

Other considerations when setting up flagging operations include intersections, driveways, and other site specific features within the work area. Flaggers should not stand in the center of an intersection. Additional flaggers may be necessary to prevent motorists from entering the available travel lane from an intersecting road or driveway.



Properly Trained Flaggers

- give clear messages to drivers as shown
- allow time and distance for drivers to react
- coordinate with other flaggers

Properly Equipped Flaggers

- approved sign paddles
- paddles are not to be used in a signalized intersection
- approved Personal Protective Garments (PPE)
- brightly colored hat for better visibility
- retroreflective night equipment

Proper Flagging Stations

- good approach sight distance
- highly visible to traffic
- never stand in moving traffic lane
- always have an escape route

Proper Advance Warning Signs

- always use warning signs
- allow reaction distance from signs
- remove signs if not flagging

Flags should only be used in emergency situations or when a paddle would present a conflicting message to the motorist. Flags shall be a minimum of 24in. x 24in., red in color, and mounted on a staff about 3ft long.

Figure 6-3. Flagging Procedures

The basic setup for a multi-lane roadway is shown in Figure 6-2. A flagger is not normally required in this situation since advance warning signs are sufficient to warn motorists. A set of signs is required to be located on both the outside and inside shoulders and installed in relation to the roadway in accordance with the Standard Drawing. The flashing arrow sign is placed on the pavement shoulder a calculated distance from the beginning of the work area. Channelizing devices are required to direct motorists from the lane to be closed to the adjacent open lane. For daylight operations, the use of cones or tubular markers for the channelizing devices is acceptable. For protection of nighttime work areas, drums or cones with a minimum height of 2 ft-4 in. are typically required.

CONTINUAL INSPECTION

All traffic control devices used at roadway work sites are required to be inspected daily to ensure the safety of the work force, the traveling public, pedestrians, as well as to protect the freshly placed mat. While the performance of these duties may be delegated to anyone, the CTWS is ultimately responsible for the inspection and maintenance of all traffic control devices on the contract. If an inspection determines that individual traffic control devices require reinstallation or replacement, the individual making that inspection is required to know how to contact the CTWS or designee to facilitate the repair or replacement of the defective devices.

TEMPORARY PAVEMENT MARKINGS

As the paving operation progresses down the road, any pavement markings that are covered by the newly placed mat are required to be replaced by temporary markings. The temporary pavement markings are required to be placed prior to reopening the work area to traffic. Section **801.12** of the Standard Specifications includes the requirements associated with temporary pavement markings. This information includes which markings are required and which marking materials are appropriate. There are also requirements associated with the length of time that the temporary markings will be in place and for situations where the traffic markings are used to indicate no passing zones.

7 **Preparation of the Grade**

Grade Preparation

Subgrade

Subbase

CHAPTER SEVEN: PREPARATION OF THE GRADE

A concrete pavement is only as good as the grade on which the pavement is placed. In this chapter, the importance of grade preparation, the various types of subbase that may be used under the pavement, maintaining the constructed grade until paving begins, and the final trimming of the subgrade and subbase are discussed.

GRADE PREPARATION

The preparation of the subgrade, subbase for full depth sections, and base course for overlays are very important steps since these materials have a considerable impact on the riding quality of the finished concrete pavement. Full depth concrete pavement or bases are placed on subbase constructed on a treated subgrade. A concrete overlay is usually placed on a thin asphalt bond breaking layer placed directly on an existing pavement.

SUBGRADE

Subgrades are treated in accordance with Section **207.04** by one of the following methods to achieve the desired support for a concrete pavement or base:

- a) Soil
- b) Chemical Modification
- c) Compacted Aggregate
- d) Compacted Aggregate with Geogrid

The subgrade treatment is required to be compacted in accordance with Section **203** for soils, in accordance with Section **215** for chemical modified soil, and in accordance with Section **301** for aggregates. Figure 7-1 is a typical section for soil subgrade treatment of fill and cut sections.



Figure 7-1. Soil Subgrade Treatment Fill and Cut Sections

The subgrade is to be constructed so that the material has a uniform density or stiffness throughout. Any soft, yielding, or other unsuitable material is required to be removed and replaced if corrective measures are not effective. Proof rolling is done just prior to placing the subbase in accordance with Section **203.26**.

The uniform compaction, correction of unstable areas, and proof rolling of the subgrade should receive special attention at the form lines when forms are used for paving and at the track lines when the slip-form method is used. Settlement of the forms or tracks of the slip form paver due to poor subgrade stability results in a poor riding pavement.

The subgrade is required to be well drained at all times. No pavement or subbase may be placed if the subgrade is frozen or muddy.

The subgrade is required to be finished to within 1/2 in. of the true grade. There is a pay deduction for construction of thin pavement and this deduction may be made for deficiencies greater than one tenth of an inch. In form paving, these tolerances are usually accomplished with a machine called a sub-grader which rides on the forms (Figure 7-2). The subgrade may be trimmed with a conventional grader. In slip form paving, an auto-grade machine with an automatic grade control sets the grade from a string line.



Figure 7-2. Form Paving Spreader

No equipment or traffic is allowed on the finished subgrade because distortion of the subgrade may occur if a weak soil condition exists or the subgrade is overly wet after a rain.

SUBBASE

Subbase is a foundation course that is placed and compacted on a prepared subgrade. Section **302** lists the materials and construction requirements for subbase.

Subbase for PCCP consists of 3 in. of an aggregate drainage layer placed over an aggregate separation layer. For all alignments, the thickness of the separation layer is required to be 6 in. The drainage layer consists of coarse aggregate size No. 8 in accordance with Section **904.03** and may be crushed stone or air-cooled blast furnace slag. The separation layer consists of coarse aggregate size No. 53 in accordance with Section **904.03**.

Dense graded subbase consists of a 6 in layer of compacted coarse aggregate size No. 53 in accordance with Section **904.03**.

The preparation and placement of subbase is required to be in accordance with the applicable requirements of Section **302**. Compaction of the drainage layer requires two passes with a vibratory roller before trimming and one pass with a tandem roller after trimming.

After the final trimming and compacting of the subbase, depth determinations are made for each layer. These measurements are taken at a minimum frequency of one depth determination per each traffic lane for each 500 linear ft of each layer of subbase. A permanent record is required to be made of all depth checks that includes the date, location, and thickness of all checks. This record accompanies the final construction record and is required to verify the quantity of material actually placed. If deficiencies are found in the thickness, appropriate measures are required to be taken. If more material is required, the additional material is mixed with the layer and the layer is re-compacted. Additional depth determinations are then obtained.

The width of the subbase is also checked and recorded. These checks are required to verify the quantity of material in cubic yards that were actually placed.

8 Equipment

Concrete Plants

Central Mix Plant Ready-Mix Plant

Delivery Equipment

Paving Equipment

Finishing Machine Spreader Slip-Form Pavers Hand Placement Equipment Tining Machine Vibrators

Hand Equipment

10 ft Staightedge Hand-Held Vibrators

Saws

Forms

CHAPTER:EIGHT EQUIPMENT

The importance of having the proper equipment to do the job correctly and efficiently can not be overstated, especially for construction of concrete pavements. This chapter discusses concrete equipment that has a profound effect on the quality of the final pavement.

CONCRETE PLANTS

INDOT categorizes concrete plants as captive plants or commercial plants. Captive plants, sometimes known as portable plants, are usually temporary and are used primarily to produce concrete for a specific INDOT contract. When the contract is completed, the plant is disassembled and moved. Commercial plants are permanent installations and may serve many customers.

Concrete plants are inspected and certified by the District Testing. Commercial plants are inspected once a year. Captive plants are inspected at the beginning of each construction season and whenever they are moved to a new location.

A concrete plant is made up of several components. These include bins for the cement (and fly ash, if used), weighing hoppers, scales for the fine and coarse aggregates, admixture dispensers, and material conveyors.

Before the concrete is produced, the plant Technician is required to verify that all scales are balanced and that all conveyors and hoppers are generally clean and free of foreign materials.

Most concrete plants today are operated by the use of computers. The plant operator has a computer card for each mix. When the card is placed into the computer, each material is dropped or conveyed to the scales automatically, one at time. The plant Technician is required to observe the scales for accuracy as each material is weighed.

Central mix plants and ready-mix plants are the two types of plants used to supply pavement concrete.

Central mix plants (Figure 8-1) are normally mobile units that are located at large quantity work sites; however, more and more of these types of plants are being placed at permanent locations. A central mix plant proportions and mixes the concrete in the plant. Mixing is required to be no less than 60 seconds for each batch. When using a transit mixer for additional mixing, the mixing time in the central mix plant may be reduced to approximately 30 seconds. The freshly mixed concrete is deposited into trucks for delivery. The delivery truck from a central mix plant does not need to provide any further mixing of the concrete, unless a transit mixer is used.



Figure 8-1. Central Mix Plant

READY-MIX PLANT

The second type of plant used is the ready-mix plant (Figure 8-2). Readymix concrete plants are the types of plants used most commonly on INDOT contracts and are referred to as "commercial plants". Ready-mix plants batch the ingredients into a truck-mixer and the revolving drum on the truck mixes the ingredients.



Figure 8-2. Ready-Mix Plant

DELIVERY EQUIPMENT

Concrete is typically delivered to the job-site in transit mixer trucks, agitator trucks, or non-agitator trucks. All delivery trucks are required to comply with Sections **501**, **502**, **508**, and **702**.

Transit mixer trucks are designed for mixing concrete at or on the way to the job site. For this reason, transit mixer trucks always have a water tank on board and a measuring device that is capable of controlling the amount of water that is added to the mix.

When transit mixer trucks (Figure 8-3) are used, the following items are required to be checked:

- 1) Manufacturer's rating plates are in place and legible
- 2) Revolution counters are operating properly
- 3) Mixing speed is as shown on plate and number of revolutions are in compliance with the specifications. (The number of revolutions of the drum at mixing speed is required to be between 70 and 100)
- 4) Trucks are operated at or below their rated capacity
- 5) Old concrete has been removed from the drum
- 6) Wash water has been properly drained from the drum
- 7) Discharge of the concrete is completed within 90 minutes of mixing water, cement, and aggregates



Figure 8-3. Transit Mixers

Agitator trucks (Figure 8-4) deliver concrete that has already been mixed. These trucks are not capable of mixing additional water and none may be added. Any water on board is for cleaning purposes only, not for mixing.



Figure 8-4. Agitator Truck

When non-agitator trucks (Figure 8-5) are used, the truck beds are required to be smooth, mortar tight metal containers capable of discharging the concrete at a satisfactorily controlled rate without segregation. A watertight cover is required for a truck agitator or non-agitating equipment. The concrete is discharged from the bottom of the container. When the discharge is done by tilting, the container is required to be baffled to retard the flow of the mix. When the concrete temperature is 90°F or above, discharge of the concrete is required to be completed within 30 minutes of mixing the water, cement, and aggregates. For concrete temperatures below 90°F, discharge of the concrete is required to be completed within 45 minutes of mixing the water, cement, and aggregates. The concrete temperature is measured in accordance with AASHTO T 309 at the point of delivery.



Figure 8-5. Non-Agitator Truck

The concrete is required to be incorporated into the paving equipment within 15 minutes of discharge by a truck mixer, truck agitator, or non-agitating equipment. Regardless of the type of equipment used to deliver the concrete to the job site, the concrete is required to be uniformly mixed. Slump tests may be taken to verify uniformity of the mixture at approximately the 1/4 and 3/4 points of discharge of the load. If the slump differs by more than 1 in. when the average slump is 3 in. or less or by more than 2 in. when the average slump is greater than 3 in., the delivery equipment is required to have smaller loads, shorter haul distances, longer mixing times, or a combination thereof.

PAVING EQUIPMENT

FINISHING MACHINE

When forms are used, the finishing machine (Figure 8-6) is the device that rides on top of the forms and strikes off the concrete to the proper grade. Finishing machines are required to have two or more oscillating type transverse screeds and a transverse smoothing float. The transverse screed and float are suspended and guided by a rigid frame with a maximum effective wheel base of 14 ft. The float is approximately 2 in. less than the nominal width of the pavement, has an adjustable crown section, and has an adjustable forward speed. The oscillating motion of the screeds consolidates the concrete. The finishing machine may also be fitted with concrete vibrators.





Figure 8-6. Finishing Machine

SPREADER

A concrete spreader (Figure 8-7) is a device which rides on the forms in front of the paver and spreads the concrete evenly after the concrete has been discharged onto the grade by the delivery truck. In slip-form paving, the spreader rides on tracks similar to the paver. The use of a spreader is not required, but allows paving to proceed faster by reducing the work of the finishing machine.



Figure 8-7. Concrete Spreaders

SLIP-FORM PAVERS

The slip-form paver (Figure 8-8) differs from the finishing machine in that the forms are mounted to the machine instead of being stationary. As the slip-form paver passes over the concrete, the concrete is spread, consolidated, and finished. Only a small amount of handwork is required after the concrete is placed.



Figure 8-8. Slip-Form Paver

The slip-form paver rides on tracks and is controlled by a preset stringline (Figure 8-9). Sensors ride on the stringline and transmit line and grade information to the paver. Grade information is taken from the base course or from a ski. The paver is required to be of sufficient weight and power to place the concrete at an adequate variable forward speed without transverse, longitudinal, or vertical instability. The paver is equipped with an automated steering and elevation control system.



Figure 8-9. Stringline

The slip-form paver is required to be equipped with vibrators capable of vibrating the entire depth and width of the pavement. The paver also is required to be equipped with forms long enough to prevent an edge slump of greater than 3/8 inch from a typical section. If the edge is joined by another pavement, the edge slump may not exceed 1/4 inch. If these requirements cannot be met, additional trailing forms are required to support the plastic concrete for a longer period of time.

Mechanical tie bar inserters are required to be rigidly attached to the slipform paver and may be controlled manually or automatically. The mechanical belt, if used, has a deflector plate mounted on the end of the discharge belt to recombine the concrete.

Because the slip-form paver does all the forming of the pavement, the paver should be stopped only when absolutely necessary. When stopped, the paver may leave a slight imperfection in the pavement. All vibrators and tampers should be turned off immediately, if the paver is stopped.

HAND PLACEMENT EQUIPMENT

Hand placement equipment is required to produce a uniform surface that is free of voids and meets the specified smoothness. The mechanical tube finisher and vibratory screed finisher are two types of hand placement equipment that are used.

Mechanical Tube Finisher

A mechanical tube finisher (Figure 8-10) consists of single or multiple rotating strike-off/finish tubes setting approximately transverse to the longitudinal movement of the machine. The length of the finish tubes is required to be a minimum of 2 ft longer than the planned PCCP width. The forward speed of the machine and the rate of the finish tube rotation are required to be variable and reversible to allow for multiple finish passes.



Figure 8-10. Mechanical Tube Finisher

Vibratory Screed Finisher

A vibratory screed finisher (Figure 8-11) consists of a truss frame with a minimum base width of 1 ft, which extends across the transverse width of the PCCP. The frame is required to extend 2 ft beyond the width of the PCCP and hold the shape of the frame when moved forward. The screed moves forward with either hydraulic or manual wenches, which are capable of maintaining the screed at a right angle to the direction of travel. The screed vibrates when moving forward, and the vibration is required to stop when the forward motion ceases. Vibration is accomplished with mechanical driven eccentric weights or with auxiliary driven pneumatic vibrators.



Figure 8-11. Vibratory Screed Finisher

TEXTURING EQUIPMENT

Final finishing is normally done with a power driven tining device, which automatically places uniform transverse grooves in the plastic concrete. The tining device (Figure 8-12) uses a texturing comb with steel tines spaced as specified. The grooves are placed in the pavement to provide additional skid resistance and eliminate hydroplaning. A uniform depth and alignment of the grooves in the PCCP without tearing the surface is required.





Figure 8-12. Tining Machine

A hand tool with steel tines (Figure 8-13) may be used and is required to produce grooves which conform to the same requirements as those specified for the grooves formed by the mechanical tining device. The hand device is used on ramps, connections, and other miscellaneous areas where the mechanical tining device is not practical.



Figure 8-13. Hand Tining Device

VIBRATORS

Vibrators are required to consolidate and fill in the large air voids in the concrete.

There are two basic types of vibrators:

- 1) Surface pan vibrators (Figure 8-14) that ride over the top of the pavement
- 2) Internal type vibrators, sometimes called spuds, that are immersed into the concrete. Instead of individual spuds, internal type vibrators may be single tubes.



Figure 8-14. Surface Pan Vibrators

Vibrators may be attached to the finishing machine, the spreader, or mounted on a separate carriage. The maximum spacing of spud vibrators is 24 in. Vibrators are required to be capable of the following frequencies:

- 1) Surface pan vibrators: no less than 3500 impulses per minute
- 2) Spud vibrators: from 10,000 to 12,000 impulses per minute in air for pavers using forms
- 3) Tube vibrators: no less than 5000 impulses per minute
- 4) Internal vibrators used in slip-form paving: from 7000 to 12000 impulses per minute and a amplitude of vibration from 0.025 to 0.060 in.

The Contractor is required to provide the PE/PS with a device, such as a hand reed tachometer, to determine if the specified frequencies are being obtained. This device remains the property of the Contractor and no additional payment is made for the use of the tachometer.

All vibrators attached to paving equipment or the paving carriage are required to be equipped with a control to automatically shut down the vibrators when forward motion stops. Also, each vibrator is required to have an on/off warning light to indicate when the vibrator is in operation. These indicator lights are required to be visible from the ground for pavers using forms.

HAND EQUIPMENT

There are many hand tools available for concrete work and each has a specific use. The most common hand tools used are floats and trowels. A wide float of at least 5 ft in length and 6 in. in width is used to remove smooth and fill in open texture areas in the pavement (Figure 8-15). Equipment made of or coated with aluminum or aluminum alloys shall not be used.



Figure 8-15. Long Handle Float

Smaller floats (Figure 8-16) may be used for finishing around manholes, inlets and other types of irregularities. Trowels are used to obtain very smooth surfaces as may be required along the edge of the pavement (Figure 8-17) and at expansion and butt joints.



Figure 8-16. Small Float



Figure 8-17. Pavement Edger

10 ft STRAIGHTEDGE

A 10 foot straightedge (Figure 8-18) with a handle 3 ft longer than onehalf of the width of the pavement is used last to remove any longitudinal imperfections or surplus water from the surface.



Figure 8-18. 10 ft. Straightedge

HAND HELD VIBRATORS

Hand held vibrators (Figure 8-19) are required to have a head diameter of $1 \frac{1}{4}$ to $2 \frac{1}{2}$ in. and be capable of 7000 to 10,800 impulses per minute in air. The vibrators may be used in areas where the machine mounted vibrators cannot reach such as at joints, in areas with large amounts of reinforcing steel, or around manholes and inlets.



Figure 8-19. Hand Held Vibrator

When jointed pavement is being constructed, self-propelled single or gang-mounted concrete saws (Figure 8-20) are used to saw the joints to the proper width and depth. These saws usually have small lights attached to them since much of the time they are used during night-time hours after the concrete has been poured. The required depth and alignment of the cuts is required to be done without damaging the concrete.



Figure 8-20. Self Propelled Concrete Saw

FORMS

When a standard finishing machine is used, forms (Figure 8-21) are required to be set to the proper line and grade. Forms are a minimum of 10 ft in length and are required to have a depth of at least the pavement edge thickness. The base of the form is as wide as the depth of the form. The forms are fastened end to end and to the subgrade with at least three form pins and wedges and are required to be locked tightly to each other. The top face of the form is required to not vary from a true plane by more than 1/8 in. in 10 ft.



Figure 8-21. Forms

9 Paving Operations

Condition of Grade

Pavement Joints D-1 Contraction Longitudinal Joints Transverse Construction Joints Terminal Joints Expansion Joints Retro-Fitted Tie Bars

Mixing Concrete

Weather Restrictions

Placing Concrete

Placing Reinforcing Steel

Strike Off, Consolidation, and Finishing Floating Checking Finish and Surface Corrections Tining Edging

Edge Slump

Pavement Dates and Stations

Curing

Wet Burlap Wet Straw Waterproof Blankets Ponding Curing Compound

Sawing Joints

Sealing Joints

Protection of Pavement

Opening Pavement to Traffic *Construction Vehicles Non-Construction Vehicles*

Removal of Forms

CHAPTER NINE: PAVING OPERATIONS

Once the subgrade or base course has been checked for true line and grade, the paving operation may begin. The procedures for paving are in general specified by the Contractor for QC/QA PCCP in the Quality Control Plan for the contract. This chapter covers each step in the paving operation and explains why each is necessary for a quality concrete product. The following topics are discussed:

- 1) Checking the condition of the grade
- 2) Checking placement of the steel and joint assemblies
- 3) Mixing and placing concrete
- 4) Finishing and curing concrete
- 5) Cutting pavement joints
- 6) Observing weather restrictions

CONDITION OF GRADE

The prepared subgrade or base course is required to be maintained in a smooth and compacted condition up to the time paving begins. A dry grade will absorb moisture from the concrete. Therefore, the grade is required to be uniformly moist when the concrete is placed. Spraying water on the grade ahead of the paving operation may be necessary (Figure 9-1). Care is taken to avoid creating mud or pools of water.



Figure 9-1. Subgrade Preparation

PAVEMENT JOINTS

Pavement joints are vital to control pavement cracking and pavement movement. Without joints, most concrete pavements would be riddled with cracks within one or two years after placement. Water, ice, salt and loads would eventually cause differential settlement and premature pavement failures. These same effects may be caused by incorrectly placed or poorly designed pavement joints

Forethought should be given to the design and placement of the pavement joints so that the end result is a properly functioning pavement system. Special care is given at intersecting approaches, turn lanes and crossovers so that the joints required at these locations will complement the joints placed in the mainline pavement. Since the mainline pavement is typically placed prior to any auxiliary pavement, the location of all joints is required to be known in advance of the initial pours. If the initial joint placement is correct, the extension of the same joint lines throughout any adjacent pavements is done. "Dead ending" of joints in the middle of adjacent slabs is avoided whenever possible to prevent the risk of reflective cracking.

An example of a well planned joint design is shown in Figure 9-2. The joints in this diagram are continuous from edge of pavement to edge of pavement. Also, the joints in the mainline pavement are aligned to serve the joints in the adjoining pavements.



Figure 9-2. Pavement Joint Design
There are many types of joints used in the construction of concrete pavements but they all control the movement of the pavement and the associated cracking and/or differential settlement.

Unless otherwise indicated, all joints are placed perpendicular to the grade. Longitudinal joints are placed parallel to the center line, and transverse joints are placed at right angles to the center line for the full width of the pavement. Understanding the use and function of the different types of joints is required in determining their placement.

D-1 CONTRACTION JOINTS

Typically, a contraction joint is a sawed transverse joint normally placed every 18 ft to control cracking due to pavement contraction caused by shrinkage and temperature fluctuations. The plans for the particular contract are required to be checked to verify the proper joint placement. The minimum/maximum joint spacing is established so that joints in the initial pours will complement adjacent pavements.

Dowel bars are smooth, epoxy coated, steel bars which are placed at all transverse joints to provide load transfer across the joints. Dowel bars allow the pavement to slide freely at the joint during expansion and contraction of the pavement. When the dowel bars are used for expansion joints, the free end of each bar has an expansion tube attached to the bar.

Generally, dowel bars are mounted in a welded wire assembly referred to as a basket (Figure 9-3). This basket holds the dowel bars evenly and securely in place so they do not shift during the paving operation. If paving over a granular grade, sand plates under the baskets may be necessary to keep the baskets from being pushed into the grade.



Figure 9-3. Dowel Bar Assembly

The entire dowel bar assembly, or basket, is secured to the grade with basket pins (Figure 9-4). There is required to be at least 8 basket pins in a 10, 11, or 12 ft assembly.

Suitable tie wires (Figure 9-4) are required to be provided to hold the assembly in the correct position during installation. The tie wires are required to be size W 7.5 or smaller and there shall be a maximum of 5 tie wires for each dowel bar assembly. Dowel bars are coated with an approved material to break the bond with the concrete and should be free of dirt, loose rust, or scale at the time of placement. If there is suspect of damage to the dowel bars by exposure to ultraviolet light, a sample may be obtained and tested for coating thickness.



Figure 9-4. Dowel Bar Basket Detail

Dowel bar assemblies are required to be inspected at least every 2000 ft for vertical and horizontal alignment before paving. If there is a question about the stability of the basket during the paving operation, a dowel bar check may be necessary after the concrete has been placed. If this is required, the concrete is removed from the ends of each dowel bar on the assembly and each bar is checked. This procedure is done quickly because any correction is required to be made while the concrete is still plastic.

Vertical alignment may be checked with a dowel bar checker (Figure 9-5). This device is first placed on the form or grade next to the basket being checked, and the bubble is leveled to conform to the grade. Each dowel is then checked. If the bubble is not in the center, one leg of the checker is lifted until the bubble is in the center. If this correction is more than 1/4 inch, the dowel bars are required to be corrected.



Figure 9-5. Dowel Bar Checker

Horizontal alignment is checked by measuring the distance from each end of the dowel to the form or string line and comparing the two measurements. If the measurements differ by more than 3/8 in., the horizontal alignment is required to be corrected.

The deviation of any bar after the pavement has been finished is required to be no greater than an angle the tangent of which is 1/48. This means that the bar cannot deviate by more than 1/4 in. per foot. This is generally a simple requirement to meet and, if baskets are stored and handled properly, there are very few problems.

The location of the center of the dowel bar assembly is marked outside of the form/slab line so that the dowel bar assembly may be established once the pavement is in place. These locations are maintained during the pouring operations because the markings may easily become disturbed during construction.

The reinforcing steel placed as tie bars in the edges and at the center line of the pavement is placed to insure that the tie bars do not interfere with the operation of the D-1 joint. Tie bars placed over a basket assembly are adjusted longitudinally so that they do not hamper the movement designed into the joint. The longitudinal adjustment required is seldom more that 1 ft (Figure 9-6).



Figure 9-6. Basket Adjustment

LONGITUDINAL JOINTS

A longitudinal joint (Figure 9-7) is required in all pavements wider than 16 feet. If two adjacent lanes are poured at the same time, a longitudinal joint is sawed.



Figure 9-7. Longitudinal Joint

Tie bars (Figure 9-8), when required, are placed perpendicular to the longitudinal joint and parallel to the grade. Tie bars may be machine placed during paving or secured with chairs prior to paving. When tie bars are required along the form line or the edge of a slip-formed lane, bent bars are used. Bent bars are tie bars bent at a 60° angle. These bars are straightened after the concrete sets so that they extend into an adjacent lane. Special care is required to be taken when the tie bars are inserted in the side of a slip-formed pavement to assure no detrimental edge slump is caused by this operation.



Figure 9-8. Tie-Bar for Longitudinal Joint

Some longitudinal joints require the use of a keyway with no tie bars. Keyways (Figure 9-9) may be trapezoidal or semi-circular in shape. They are used when an adjacent pavement is expected to move independently and the two pavements cannot be tied together. The keyway, prevents any differential settlement of either pavement.



Figure 9-9. Keyway Joints

TRANSVERSE CONSTRUCTION JOINTS

A transverse construction joint is used when the paving operation is interrupted for longer than 30 minutes. These joints are commonly used at the end of the paving operation each day and may be retro-fitted to tie an existing slab into a new pavement. Transverse construction joints are required to be located at least 6 ft from an adjacent D-1 contraction joint.

Spacing of the tie bars in the construction joint is required to be 6 in. from any longitudinal joint and 1 ft, center to center, thereafter. The tie bars are required to be epoxy coated and inserted through a header board set to the proper line and grade. Care is taken to assure that the bars are placed parallel to the grade and the centerline.

TERMINAL JOINTS

A terminal joint (Figure 9-10) is placed where a pavement ends at a bridge or similar structure. A 2 ft gap is left between the end of the pavement and the beginning of the approach slab. The ends of the pavement and the approach slab are placed on a sleeper slab that has been previously poured. The sleeper slab is finished smooth and allowed to cure. A polyethylene sheet is placed over the slab prior to placing the pavement or approach slab. This sheet is a bond breaker, allowing the pavement and approach slab to move freely over the sleeper slab as they expand and contract.

The gap between the pavement and the approach slab is filled with HMA intermediate and surface mixtures to complete the joint.



Figure 9-10. Terminal Joint

EXPANSION JOINTS

Expansion joints consist of a preformed joint filler, generally 1 in. thick, that compresses and allows the pavement to expand. The joints are placed at the locations noted on the plans. The joint filler is required to be shaped to the subgrade, parallel to the surface, and the full width of the pavement. The edges of the expansion joint are to be finished.

RETRO-FITTED TIE BARS

When new pavement is to be tied to an existing pavement or a transverse joint is required, tie bars are used to tie the pavements together. Holes are drilled into the existing pavement for the epoxy coated tie bars. An approved chemical anchoring system, generally epoxy, is used to secure the tie bar in the hole. The size of the drilled hole is required to be in accordance with the recommendations of the anchoring system manufacturer for the size bar being inserted. Once the adjacent pavement has been poured, the joint is sawed and sealed the same procedure as required for a construction joint.

MIXING CONCRETE

Concrete may be mixed in any of the following ways:

- 1) On site mixers (these mixers are rarely used and are not discussed)
- 2) Central mix plants
- 3) Ready-mix plants using transit mixers

If transit mixer trucks are used, the concrete is required to be mixed for 70 to 100 revolutions. When central mix concrete is used, the mixing time is required to be no less than 60 seconds.

Water may need to be added to transit mix concrete at the paving site. This may only be done within 45 minutes from the time the water was added at the plant. If adding water to the concrete trucks becomes routine, a correction is required to be made in the amount of water being added at the plant. The amount of water added is noted on the concrete tickets (Figure 9-11) for the concrete record.

Concrete is required to be placed in a timely manner. Once the water is added at the concrete plant, the concrete is required to be placed within 90 minutes if hauled in transit mixers or truck agitators, or within 30 minutes if hauled in non-agitator trucks. The actual time the water was added is stamped on the ticket.

Chemical admixtures, Type B, Type C, and Type E, are allowed only with prior written approval. All other chemical admixtures may be used without written approval. Different brands of cement are not allowed to be used alternately, nor mixed. A Contractor may elect to use class "C" concrete which requires the use of a water reducer or retarder admixture. The water required for a workable mix allows for a lower water-cementitious ratio and faster strength. A retarder is generally used in warm weather to slow the set of the concrete, therefore keeping the concrete workable longer.

GRIFFITH READY MIXED CONCRETE, INC. DIV. OF OZINGA BROS., INC. 1108 E. MAIN ST., GRIFFITH, IN 46319 GRIFFITH, PH. 924-2607 HAMMOND GARY PORTAGE, PH. 762-5596 CUSTOMER C-17587 ORDER NO. C-17587 DATE 5-19-89 SOLD TO RIETH - RILEY									
FLOOR	SLOOP DRIVE STEPS WALLS FOOTINGS CURB						RB		
QUANTITY	MIX	DES	RIPTION		PRICE II	AMOUN	т		
10cts	Arole	REDI MI	X CONCRE	TE					
	FT. EXPANSION JOINT								
	Lbs. CALCIUM CHLORIDE								
	CEMBIT 564								
	#22 840 1260								
	#5 SLAG IS60								
	THE CHARGE 23/2 ON HO								
SUB TOTAL									
TIME - 5:50 A-					TAX				
LEFT PL	LEFT PLANT 6103 YARDS			TOTAL					
ARRIVED 6:16 YARDS HIPPED 10			10	DEMURRAGE					
STARTED 6:28 WATER ED					TAL PLUS				
FINISH	FINISHED 6:3 ADDED DEMURRAGE								
DRIVER Big Bab - 7 711.0600									
No. 76420 Received By/, Matham									
Not Responsible For Damage Done When Delivery Is Requested Off Public Road. ORIGINAL Unloading Time - 5 Mins. Per Yd. Demurrage Chg Current Rate This Serves as Notice To File Mechanics Lien on Unpaid Materials									

Figure 9-11. Concrete Ticket

WEATHER RESTRICTIONS

Sufficient lighting is required for the concrete paving operations. If paving continues after dark, lighting is used so that all operations are visible.

Unless authorized in writing, concrete paving may only start if the ambient temperature is above 35° F and rising. If temperatures are falling, the operation is required to stop when the ambient temperature reaches 40° F.

If cold weather paving has been authorized, the water and/or the aggregate may have to be heated before the concrete is mixed. The temperature of the mix when placed is required to be between 50 to 80° F.

At no time is the concrete placed on a frozen grade. Artificial means may sometimes be used to keep the grade from freezing at night. Any concrete placed that may be subject to freezing is required to be sufficiently insulated. Insulation is usually done by a combination of plastic sheeting, blankets, or straw.

PLACING CONCRETE

Enough equipment and material supplies are required to be kept on hand to allow for a continuous operation. The timing of the delivery of concrete is critical to the quality of the pavement, especially for slip-form paving.

Precautions may be necessary to prevent segregation of the concrete materials while being placed. After placing, concrete is re-handled as little as possible. Any re-handling is done by a machine or with a shovel (not with rakes). Equipment made of, or coated with, aluminum or aluminum alloys is not allowed to be used to place or transport concrete. All workers walking on the fresh concrete during placement are required to keep their footwear free of foreign material that may contaminate the fresh concrete.

Caution is taken by all workers to not disturb joints, dowel bars, and assemblies. Machine mounted vibrators may have to be lifted to avoid certain joints, manholes, and other possible hazards. Hand held vibrators are required to be used to consolidate the concrete in these areas as well as any other area that may not be accessible to the machine mounted vibrators. Consolidating the concrete against the faces of all forms and joints is important.

Vibrators are not to be used in any one spot for more than 15 seconds and may never come into direct contact with the side forms, joint assemblies, or the grade.



Figure 9-12. Form Paving

All manholes and similar structures are required to be adjusted to the proper grade and surrounded with preformed joint material before paving begins.

Any damage to adjoining pavements during the paving or any other related operation is required to be repaired by the Contractor

PLACING REINFORCING STEEL

The concrete is deposited on the grade and spread by a mechanical spreader which also strikes the concrete off to the proper elevation for placing wire fabric. Concrete is kept in front of the strike off at all times to prevent depressions in the pavement. Any depressions are required to be corrected before placing the wire fabric.

Reinforcing tie bars for longitudinal joints may be inserted into the concrete automatically by the paver. When paving two lanes at once, a straight tie bar is inserted every 3 ft along the longitudinal joint by the paver. If an adjacent lane is to be connected later to the lane currently being paved, tie bars are inserted into the edge of the pavement at 30 degrees to the perpendicular and bent straight after the concrete has set (Figure 9-13). If more than one of the deformed bars break in a panel during straightening, all broken bars are replaced with retrofitted tie bars.



Figure 9-13. Tie Bar Placement

All reinforcing steel is required to be free from dirt, harmful rust, scale, paint, grease, oil, or anything else that may prevent the concrete from bonding to the steel. Mesh is stored flat before placement so that the proper shape of the mesh wire is maintained during paving.

STRIKE-OFF, CONSOLIDATION, AND FINISHING

The paving equipment is designed to properly strike off, consolidate, and finish the concrete accurately to the required elevation and cross section. For this to occur, a sufficient amount of concrete is required to be carried in front of the screed (Figure 9-14) so that the paver is cutting the concrete at all times. All voids and depressions are filled if this procedure is used. The operation is controlled to ensure that an excess of mortar is not carried to the surface. If segregated particles come to the surface in front of the screed, they are required to be mixed back into the unfinished concrete by hand and not allowed to be pushed to the grade ahead of the concrete.



Figure 9-14. Paver Screed

Previously placed mesh is required to be observed for shifting as the final strike off proceeds. If the wire mesh is allowed to drift into a joint, a joint failure may occur.

When approaching a transverse expansion joint, concrete is poured over the joint ahead of the paver to provide stability to the joint assembly. The concrete around the joint is required to be properly consolidated to maintain the integrity of the joint. If the machine mounted vibrators or screeds are lifted to clear the joint assembly, consolidation may be done with hand held vibrators.

Hand methods of placing, compacting, and finishing (Figure 9-15) may only be used in the following situations:

- 1) For breakdowns of the finishing machine, and then only the concrete already mixed or being mixed
- 2) For widened portions at bridges, intersections, etc.
- 3) For certain widened portions of curves
- 4) For sections of pavement less than 600 ft long
- 5) For other places as allowed by the Specifications

When hand methods are required, the concrete is placed above the required grade and properly vibrated and struck off to obtain the desired results. If the width of the pavement is less than 4 ft, a simple board may be used to strike off the concrete after hand vibration. Wider pavements require a vibratory strike-off board. Bridge deck type finishers may also be used.



Figure 9-15. Hand Finishing

FLOATING

After proper strike-off and consolidation, the pavement is finished further by floating. This procedure may be done with a mechanical float which consists of large rollers which spin as they are moved across the surface. If specifically allowed, a hand float (Figure 9-16) of no less than 14 feet in length may be used. Hand floats are checked for distortions that may cause a rough riding surface.

Floating is required to be continuous from edge to edge. When hand floating, a work bridge may be required for the finisher to walk upon.

Smaller floats of no less than 5 feet in length may be used to correct surface blemishes or irregularities.



Figure 9-16. Floating

CHECKING FINISH AND SURFACE CORRECTIONS

When the final floating is complete, a long handled 10 ft straightedge is pulled across the concrete to remove any surface irregularities, surplus water, or inert material that may be present from the previous operations. This is the last opportunity to make corrections to the pavement and is an important process to assure pavement smoothness.

Once the straight-edging is complete, an initial surface texture is created by dragging a double thickness of burlap over the pavement. Now the pavement is ready for tining.

TINING

The final finish for the pavement is achieved by tining which is a process of placing grooves in the pavement to aid in skid resistance. This is done by a machine (Figure 9-17) using a comb with steel tines. Tining may be done manually on ramps, connections, and other miscellaneous areas where machines cannot be utilized.





Figure 9-17. Machine Tining

The grooves for tining are required to be between 3/16 and 1/8 in. in width and between 1/8 and 3/16 in. deep.

Spacing of the tines is random and may be any of the following spaces:

1)	5/8 in.	10)	1 in.	19)	1½ in.
2)	1 in.	11)	3/4 in.	20)	7/8 in.
3)	7/8 in.	12)	7/8 in.	21)	3/4 in.
4)	5/8 in.	13)	1¾ in.	22)	7/8 in.
5)	1¼ in.	14)	7/8 in.	23)	1 in.
6)	3/4 in.	15)	3/8 in.	24)	7/8 in.
7)	1 in.	16)	1 in.	25)	1 in.
8)	1 in.	17)	1 in.		
9)	1 in.	18)	1¼ in.		

The required spacing of the tines was previously 3/4 in. for all tines. This spacing created an irritating humming sound when vehicles drove on the pavement. The spacings described above break the rhythm and make the humming sound disappear.

Timing is very important for the tining process (Figure 9-18). If done too soon, the grooves may be too deep or close up. If done too late, the grooves may not be deep enough. When the latter occurs, grooves are required to be cut into the concrete by machine after the pavement hardens completely.



Figure 9-18. Tining Depth

EDGING

All edges of slabs and formed joints are required to be rounded to the radius indicated in the plans. This procedure is accomplished using a finishing tool called an edger (Figure 9-19).

Any tool marks left behind by the edger are removed before the burlap drag is used. All joints are checked with a straightedge to verify that no side of the joint is higher than the other. Corrections are required to be made immediately.



Figure 9-19. Hand Finishing Pavement Edge

EDGE SLUMP

When the slip-form method is used, special attention is placed on the edge slump (Figure 9-20). The edge slump is defined as how far the edge of the wet concrete pavement slumps down after the slip-form paver has passed.

For 6 in. from the edge of the pavement, a maximum 3/8 in. edge slump from a typical cross section is required; however, if the edge is joined by another pavement slab, the edge slump may not exceed 1/4 in. If edge slump requirements cannot be met additional trailing forms to support the edges longer may be needed to prevent the excessive edge slumping.



Figure 9-20. Edge Slump

PAVEMENT DATES AND STATIONS

Date and station numbers on the pavement are required and this operation is done immediately after tining, while the concrete is still plastic. Cast iron dies are used to place the date and the plus station at the beginning of each days run. Full stations are also stamped every 100 ft (Figure 9-21).



Figure 9-21. Pavement Stamping

Station numbers are to be stamped on the right side of the pavement with the nearest digit approximately 8 in. from the edge of the pavement (Figure 9-22).

In the case of multiple lanes, the station numbers are placed along the outside edge of the pavement, readable from the same direction as the flow of traffic.



Figure 9-22. Pavement Stamp Location

CURING

Curing is as important to the integrity of the pavement as anything previously discussed. For proper curing, the pavement is required to retain moisture and be kept from freezing. The entire required curing period of 96 hours is carefully monitored.

The methods used to retain moisture in the concrete include:

- 1) Wet burlap
- 2) Wet straw
- 3) Waterproof blankets
- 4) Ponding
- 5) Curing compound

WET BURLAP

When wet burlap is used, two layers are placed over the concrete pavement. The first layer is placed as soon as marring of the fresh surface may be avoided. The second layer of wet burlap is applied over the first before 9:00 a.m. of the next day. The burlap is required to be kept wet for the entire curing period (Figure 9-23).

WET STRAW

When straw is used, a layer of wet burlap is initially placed as mentioned above. Before 9:00 a.m. of the next day, the burlap is removed and replaced with 3 in. of straw. The straw is then thoroughly saturated and kept wet for the remainder of the curing period.

WATERPROOF BLANKETS

When waterproof blankets are used, the pavement is covered throughout the entire curing period. The blankets are securely held down. All overlaps and edges are sufficiently sealed to keep the moisture from escaping. When using this method, the pavement is fogged or covered with wet burlap until the blankets are in place, which is required before 9:00 a.m. of the following day.

PONDING

When ponding is used for curing, the initial burlap is removed by 9:00 a.m. of the following day and the surface is immediately covered with two inches of water for the remainder of the curing period.

Curing compound is a white membrane that is sprayed onto the pavement immediately after final finishing and after the surface water has disappeared (Figure 9-24). After sufficient agitation, the compound is uniformly distributed over the surface to form a waterproof membrane. If the membrane is marred from foot traffic or equipment during the curing period, additional curing compound is required to be applied to the affected areas. Curing compound is applied at a rate of not less than one gallon per 150 ft².





Figure 9-24. Curing Compound

When forms are removed, the edges of the pavement are required to be banked with earth 12 in. wide or covered by one of the curing methods listed above.

If there is a danger of freezing during the curing period, the concrete pavement is further protected by a suitable covering of straw or blankets. During this period, temperature checks are made under the covering at the pavement surface and recorded for the contract record.

SAWING JOINTS

After paving, the locations of the dowel bar assemblies are marked on the pavement and the initial saw cut is made for the joint (Figure 9-25).



Figure 9-25. Sawing Joints

Timing is critical when making this saw cut on contraction joints (Figure 9-26). If sawed too soon, the joint spalls and ravels. If sawed too late, the pavement may have already cracked randomly. For this reason, the sawing of joints often starts within 2 to 12 hours of the time of placement, depending upon the ambient/material temperature, humidity, and wind conditions. The initial sawing of a pavement continues, night and day, regardless of weather conditions until complete. If random cracking is observed ahead of current sawing operations, the sawing operation is advanced until the random cracking is controlled. The joint is required to be sawed straight for the full depth, width, and length of the joint.



Figure 9-26. Sawing Window of Time

Longitudinal sawed joints are cut with a power concrete saw concurrently with the contraction joints. The plans and/or Standards Drawings are required to be checked for the proper depth, width, line, and type of seal.

Transverse construction joints are sawed and sealed in accordance with the Standard Drawings and/or Specifications after the paving.

If a slurry is created by the sawing operation, this material is required to be flushed with high pressure water to remove the slurry to the entire depth of the joint. Care is taken not to damage the pavement while flushing because the concrete is still "green" and vulnerable to damage from excessive force. If the slurry is not removed from the joint, this material hardens and the joint is required to be re-sawed.

SEALING JOINTS

Just prior to sealing, the joint is blown with a jet of compressed air, or otherwise cleaned, to remove all foreign material and prepare the joint faces for the sealer. After cleaning, a backer rod is installed and the joint sealer is applied. The depth of the backer rod and thickness of joint sealer is critical for a properly functioning joint. The depth at which the backer rod is set establishes the bottom of the joint sealer. The surface of the sealer is required to be below the surface of the pavement so that traffic does not damage the sealer. Also, the thickness is critical so that the elasticity of the sealer is maintained. This is an instance where more is not better. Specifications and/or Standards are required to be checked to determine the proper placement (Figure 9-27).



Figure 9-27. D-1 Contraction Joint

All joints are required to be sealed prior to opening a section of pavement to any traffic, other than construction traffic, or before the end of the current construction season. The steps in constructing a D-1 contraction joint include the following:

- 1) A 1/8 in. cut is made in the pavement for the full width and proper depth of the joint.
- 2) The final cut is made to prepare the joint for the backer rod and sealant and the joint is cleaned (Figure 9-28).





3) The backer rod is installed at the proper depth (Figure 9-29).



Figure 9-28. Installing Backer Rod

4) The sealant is installed to the proper depth and thickness (Figure 9-29).



Figure 9-29. Installing Sealant

PROTECTION OF PAVEMENT

Rain may be very detrimental to unhardened concrete pavement and measures are required to be taken to protect the pavement from this occurrence. Pavement operations are ceased if rain appears likely to occur. The Contractor is required to have materials available at all times to protect the pavement in the event of an unexpected rain. If rain begins to fall, all available manpower is utilized to place a protective covering, usually plastic sheeting, on the pavement (Figure 9-30). Planks or forms are also required to be available to protect the edges of the pavement when slip-form paving.



Figure 9-27. Protective Covering

Until final acceptance of the new pavement, the Contractor is responsible for protecting the pavement against damage caused by any type of traffic, equipment, etc. This protection may require barricades, watchmen, lights, crossovers, or a number of other measures. All damage to pavement prior to final acceptance is required to be repaired or the pavement is replaced.

OPENING PAVEMENT TO TRAFFIC

CONSTRUCTION VEHICLES

Construction vehicles or equipment, having a gross weight exceeding 3t, are not permitted on the new pavement for 10 days after the pavement is placed or until the test beams indicate a modulus of rupture of at least 550 psi. Joint cutting saws are permitted on the new pavement.

NON-CONSTRUCTION VEHICLES

The pavement may be opened to traffic after 14 days or when test beams indicate a modulus of rupture of at least 550 psi. One set of beams are required to be made per one mile stretch of two lane pavement, with a minimum of one set per day.

If fly ash is used as an additive, or if type IP or IP-A cement is used, only the strength requirement applies to when the pavement may be opened to traffic. The 14-day rule for opening to traffic does not apply. For this reason at least two sets of beams are required to be made when fly ash is used.

The concrete pavement may also be opened to traffic based on results obtained from the Maturity Method (**ITM 402**). The Maturity Method is used to determine the in-place flexural strength of the concrete. The hydration of cement and gain in strength of concrete are dependent on both the curing time and temperature. Thus, the strength of concrete may be expressed as a function of time and temperature. This information is used to determine the strength of concrete without conducting destructive tests. In general the method is a three step process consisting of:

- 1) Laboratory procedure (**ITM 402 (7.0**))
- 2) Field procedure (**ITM 402 (8.0**))
- 3) Validation procedure (**ITM 402 (9.0**))

REMOVAL OF FORMS

Generally, paving forms may not be removed from fresh pavement until the concrete has been allowed to set for at least 8 hours. Forms may be removed at the ends of contraction joints as soon as joints may be sawed without raveling. Mechanical form pullers may not be used from the pavement side of the forms.

10 Paving Troubleshooting

Problems Observed Before The Concrete Has Set Mixture and Placement Issues Edge and Surface Issues

Problems Observed In The First Days After Placement Strength Cracking

Joint Issues

Preventing Problems That Are Observed Some Time After Construction

Edge and Surface Issues Cracking

CHAPTER TEN: PAVING TROUBLESHOOTING

Long-term pavement performance is the result of the smoothness and mat quality of the PCCP mixture. Smoothness affects the transportation costs of the road user to include vehicle maintenance coasts, fuel consumption, speed, passenger comfort, safety, and vehicle noise. Poor mat quality also affects the pavement performance and may be caused by cracks, poor joints, and other defects.

This chapter will discuss the problems that affect the smoothness and quality of the pavement mat and the possible solutions for correcting these deficiencies. Problems may be observed before the concrete has set, observed in the first days after placement, or sometime after placement.

PROBLEMS OBSERVED BEFORE THE CONCRETE HAS SET

MIXTURE AND PLACEMENT ISSUES

Slump is out of Specification

Potential Cause – Possible Solution

- 1. Change in water content or aggregate grading
 - a. Check aggregate moisture contents and absorptions
 - b. Check for segregation in the stockpile
 - c. Make sure the batch water is adjusted for aggregate moisture content
 - d. Conduct batch plant uniformity tests Check whether water was added at the site
- 2. Mix Proportions
 - a. Check batch equipment for calibration
- 3. Admixture dosage
 - a. Check delivery ticket for correct admixture dosage
- 4. Concrete temperature too high or too low
- 5. Haul time
 - a. Check the batch time on the concrete delivery ticket. Haul times should not be excessive.

Loss of Workability/Slump Loss/Early Stiffening

- 1. Dry coarse aggregates
 - a. Make sure the aggregate stockpile is kept consistently at saturated surface-dry (SSD) (use soaker hoses if necessary)

- 2. Ambient temperature increases
 - a. Do not add water
 - b. Chill the mix water or add ice
 - c. Sprinkle the aggregate stockpiles
 - d. Use a water reducer or retarder
 - e. Do not increase the water/cement ratio to a value greater than the maximum approved mix design
 - f. Use a mix design that includes slag or fly ash
- 3. Transport time too long
 - a. Reject the load if greater than specified
 - b. Use retarder in the mixture
 - c. Use an agitator rather than dump trucks
- 4. Mix proportions have changes
 - a. Check/monitor the moisture contents of the aggregate stockpiles
 - b. Check the batch weigh scales
 - c. Verify that aggregate gradations are correct
- 5. False setting (temporary)
 - a. Check for changes in cementitious materials
 - b. Reduce Class C fly ash replacement
 - c. Change the type of water reducer
 - d. Try restoring plasticity with additional mixing
 - e. Contact the cement supplier
- 6. Incompatibility
 - a. Check for changes in the cementitious materials
 - b. Reduce Class C fly ash replacement
 - c. Change chemical admixtures
 - d. Change the batching sequence
 - e. Cool the mixture.
- 7. Variation in air content
 - a. Check the air content/air entrainer dosage.

Mixture is Sticky

- 1. Sand too fine
 - a. Change the sand grading
- 2. Mix too sandy
 - a. Check the sand and combined aggregate grading
- 3. Cementitious materials
 - a. Check the cementitious materials contents (Mixtures containing GGBF slag and fly ash appear sticky but finish well and respond well to vibration energy)
 - b. Lower the vibration energy to avoid segregation
 - c. Adjust the mix proportioning
- 4. Using wood float on air-entrained concrete
 - a. Use magnesium or aluminum floats

Mixture Segregates

Potential Cause – Possible Solution

- 1. Inconsistent concrete material batching, mixing, placing
 - a. Check aggregate gradation; poorly graded mixtures may tend to segregate
 - b. Verify batching/mixing procedures so that the mixture is adequately mixed
 - c. Check aggregate stockpile, storage, and loading procedures to prevent aggregate segregation
 - d. Place concrete as close to final position as possible to minimize secondary handling
 - e. Perform uniformity testing on batch plant, if necessary, use agitator trucks for transport
 - f. Reduce the vibration energy if consolidation efforts cause segregation. (Vibration at 5,000-8,000 vpm is sufficient for most well-graded mixtures.)

Excessive Fresh Concrete Temperature

Potential Cause – Possible Solution

- 1. Hot ingredients
 - a. Do not add water
 - b. Follow hot-weather concreting practice as appropriate
 - c. Chill the mix water or use ice
 - d. Shade and sprinkle the aggregate stockpiles
- 2. Long haul times
 - a. Adjust the hauling operation to minimize haul times
 - b. Adjust paving time to off-peak traffic time if hauling through public traffic
- 3. Hot weather
 - a. Follow hot-weather concreting practice as appropriate
 - b. Chill the mix water; sprinkle the aggregate stockpiles
 - c. Pave at night or start paving in afternoon

Air Content is Too Low or Too High

- 1. Temperature changes
 - a. The air-entraining admixture dosage may need to be adjusted during hot/cold weather
- 2. Materials have changed
 - a. Check for uniformity of materials

- 3. Mix proportions have changed
 - a. Altering other admixture dosages may impact the effectiveness of the air-entraining admixture.
 - b. Check slump; it is easier to entrain air with increasing concrete workability
 - c. Check/monitor the moisture contents of the aggregate stockpiles
 - d. Check the batch weigh scales
 - e. Verify that aggregate gradations are correctf. Verify sand quantity
- 4. Short or inadequate mixing
 - a. Check the charging sequence
 - b. Increase mixing time
 - c. Check if the blades of the mixer are missing or dirty

Variable Air Content/Spacing Factor

- 1. Incorrect or incompatible admixture types
 - a. Change types or brands of admixtures
 - b. Try to work within one manufacturer's family of admixtures if airentraining agent is being combined with other admixtures
- 2. Admixture dosage
 - a. Check the batching equipment for calibration and settings
 - b. Change the sequence of batching
- 3. Mix proportions have varied or changed
 - a. Check/monitor the moisture contents of the aggregate stockpiles
 - b. Check the batch weigh scales
 - c. Verify that aggregate gradations are correct
- 4. Cementitious materials
 - a. Check for changes in cementitious materials, particularly the loss-onignition (LOI) content of fly ash.
- 5. Poor plant configuration
 - a. Introduce aggregates together on the plant's belt feed (requires a multiple weigh hopper)
- 6. Poor aggregate grading
 - a. Use a more well-graded coarse and fine aggregate mixture
 - b. Check variation in the amount of materials retained on the #30 through #100 sieves
- 7. Temperature changes
 - a. Air-entraining admixture dosage may need to be adjusted during hot/cold weather
 - b. Altering other admixture dosages may impact the effectiveness of the air-entraining admixture; air-entraining admixtures work more efficiently with increasing workability
- 8. Variable mixing
 - a. Ensure that each batch is handled consistently in the plant.

Potential Cause – Possible Solution

- 1. Cementitious materials
 - a. Check for changes in the cementitious materials; differing sources or changes in properties of a given material may result in incompatibility; changes in proportions may also affect setting times
- 2. Admixture dosage
 - a. Check the dosage of chemical admixtures, particularly accelerators
 - b. Check the batching equipment
- 3. Hot weather
 - a. Adjust the mix proportions
 - b. Use mix designs that include GGBF slag or fly ash
 - c. Use a retarder
 - d. Reduce haul time if possible
 - e. Reduce the placement temperature of the concrete
 - f. In hot weather, use a hot weather mix design
 - g. Cool the concrete ingredients

Delayed Set

- 1. Excessive retarder dosage
 - a. Verify the proper batch proportions
 - b. Check the batching equipment
 - c. Reduce the dosage of the retarder
- 2. Excessive water reducer dosage
 - a. Verify the proper batch proportions
 - b. Reduce the dosage of water reducer
- 3. Retarder not dispersed well
 - a. Improve mixing to disperse the retarder
- 4. Supplementary cementitious materials interference
 - a. Reduce GGBF slag content; GGBF slag in excess of 25 percent can cause a dramatic increase in set time
 - b. Eliminate/reduce fly ash content in the mix
- 5. Cold placement temperature
 - a. Follow cold-weather concreting practices if appropriate
- 6. Organic contamination
 - a. Verify the proper batch proportions
 - b. Check for contamination of water and aggregates

Potential Cause – Possible Solution

- 1. Cement
 - a. Refer to backup lab mixes if conditions were anticipated
 - b. Switch sources, batch new mix designs, and develop new laboratory strength gain and maturity information. (This action may require a project delay. To avoid unacceptable delays, a contractual agreement should be arranged prior to paving, which allows for unforeseen material supply changes, burden of delay costs, and risk of paving during batch revision testing. If paving activity is continued during testing, compare early-age strengths (1- and 3-day) and maturity data to confirm that the new mix will perform adequately.)
- 2. Supplementary cementitious materials
 - a. See cement supply change
 - b. Switch sources and compare early-age strengths (1- and 3-day) and maturity data to confirm that the mix will perform adequately
- 3. Aggregates
 - a. See cement supply change
 - b. Switch sources and compare early-age strengths (1- and 3-day) and maturity data to confirm that the mix will perform adequately
- 4. Chemical admixtures
 - a. See cement supply change
 - b. Switch admixture sources and compare early-age strengths (1- and 3- day) and maturity data to confirm that the mix will perform adequately

EDGE AND SURFACE ISSUES

Concrete Surface Does Not Close Behind Paving Machine

- 1. Insufficient volume contained in the grout box
 - a. Place more material in front of the paver; consider using a spreader
- 2. The concrete is stiffening in the grout box
 - a. Check for premature concrete stiffening (admixture compatibility) (See no. 2: Loss of workability/slump loss/early stiffening)
- 3. The fine/coarse aggregate volume or paste volume is too low
 - a. Check mixture proportions, particularly aggregate gradations
 - b. Check the uniformity of aggregate materials/supplies
- 4. The finishing pan angle needs adjustment
 - a. Adjust the pan angle
- 5. The paver speed is too high or vibrators need to be adjusted
 - a. Slow the paver
 - b. Lower the vibrator frequencies or use vibrators with greater force
 - c. Adjust the location of the vibrators; rise them closer to the surface
 - d. Place more material in front of the paver; consider using a spreader
 - e. Change the vibrator angle

Concrete Tears Through Paving Machine

Potential Cause – Possible Solution

- 1. Excessive concrete slump loss
 - a. Check for slump loss and mixture or weather changes
 - b. See no. 2: Loss of workability/slump loss/early stiffening
- 2. Insufficient concrete slump
 - a. Check the mixture proportions
- 3. Angular fine aggregate (manufactured sand)
 - a. Replace a portion of the manufactured sand with natural sand
- 4. Paver speed too high
 - a. Slow the paver
- 5. Coarse aggregate is segregated
 - a. Check the stockpile
- 6. Coarse aggregate is gap-graded
 - a. Check the combined aggregate grading
 - b. Blend the aggregate with intermediate aggregates to achieve a uniform combined grading

Paving Leaves Vibrator Trails

Potential Cause – Possible Solution

- 1. Vibratory frequency too low
 - a. Check if the seals on the vibrators are leaking
- 2. Vibrator frequency too high
 - a. Lower the vibrator frequency
- 3. Paver speed too slow
 - a. Increase the paver speed
- 4. Non-workable concrete mix
 - a. Review concrete workability field test data
 - b. See no. 2: Loss of workability/slump loss/early stiffening
- 5. Over-sanded mixes
 - a. Increase the coarse aggregate
- 6. Poor combined aggregate grading
 - a. check the combined aggregate grading

Slab Edge Slump

- 1. Poor and/or nonuniform concrete gap-graded aggregate, high water/cement ratio, etc.
 - a. Verify the mix design and batching procedures
 - b. Check the aggregate grading use a well-graded combined aggregate gradation

- 2. Inadequate operation of equipment
 - a. Check the construction procedures
 - b. Adjust the outside vibrator frequency
 - c. Adjust the side form batter
- 3. Improper equipment setup
 - a. Adjust the overbuild
 - b. Check the track speed (same on both sides)
 - c. Check the pan profile

Honeycombed Slab Surface or Edges



Potential Cause – Possible Solution

- 1. Hot weather may induce premature stiffening
 - a. Follow hot-weather concreting practices if appropriate
 - b. See no. 2: Loss of workability/slump loss/early stiffening
- 2. Inadequate vibration
 - a. Check that all vibrators are working properly at the right frequency and amplitude; the paver speed should not be too high
 - b. Add an additional vibrator near the slipformed edge
- 3. Poor workability
 - a. Check for changes in the aggregate grading

Plastic Shrinkage Cracks



Potential Cause – Possible Solution

- 1. High evaporation rate (excessive loss of moisture from surface of fresh concrete; i.e., evaporation rate > bleed rate)
 - a. Apply the curing compound as soon as possible to protect the concrete from loss of moisture
 - b. Use additional curing measures: fogging, evaporation retarder, windbreaks, shading, plastic sheets, or wet coverings
 - c. Make sure the absorptive aggregates are kept moist; a dry concrete mixture from concrete aggregates that are not saturated tends to surface dry at mixing. This is a problematic if not accounted for
 - d. Use a well-graded combined aggregate (gap gradation requires more paste and causes more shrinkage)
 - e. Refer to hot-weather concreting practices if appropriate
 - f. Pave at night
 - g. Chill the mixing water
 - h. Dampen the subgrade
 - i. Avoid paving on hot, windy days
 - j. Consider adding fibers to the mix
- 2. Delayed setting time
 - a. Check the time of set

PROBLEMS OBSERVED IN THE FIRST DAYS AFTER PLACING

STRENGTH

Strength Gain is Slow

- 1. Cold temperature during/after placement
 - a. Heat the mix water
 - b. Use burlap/insulating blankets for protection from freezing
 - c. Use an accelerating admixture
 - d. Eliminate/reduce GGBF slag and fly ash content in the mix
 - e. Increase the cement content
 - f. Use a Type III cement
 - g. Utilize early-entry sawing to reduce the potential for random cracking
 - h. Monitor the slab temperature with maturity sensors
- 2. Mix proportions or materials have changed
 - a. Check/monitor the moisture contents of the aggregate stockpiles
 - b. Check for uniformity of the cementitious materials
 - c. Check the batch weigh scales
 - d. Verify that aggregate gradations are correct
 - e. Verify that batch weights are consistent with the mix design

- 1. Cementitious materials
 - a. Check for changes in the cementitious materials
 - b. Check that the correct materials have been loaded into the cement/fly ash/slag silos
- 2. Water
 - a. Check the water content
 - b. Verify the aggregate moisture contents and batch weights
- 3. Change in sand grading
 - a. Check the sand stockpile to see whether the grading has changed.
- 4. Contamination with organics
 - a. Contamination of one of the ingredients with organics can also effect a sudden change in the required dosage of air-entraining admixture; try to isolate the source
- 5. Inadequate or variable mixing
 - a. Examine the mixer and mixing procedures
 - b. Check for worn mixer blades
 - c. Check for mixer overloading
 - d. Batch smaller loads
 - e. Check the sequencing of batching
 - f. Check for mixing time consistency
 - g. Conduct batch plant uniformity testing
- 6. Plant operations
 - a. Verify the acceptability of the batching and mixing process
 - b. Check for adequate mixing times
 - c. Check if water was added to the truck
- 7. Testing procedures
 - a. Verify proper making, curing, handling, and testing of strength specimens. (Flexural strength specimens are particularly vulnerable to poor handling and testing procedures.)
 - b. Verify the machine acceptability testing
 - c. Test the cores sampled from the pavement to verify acceptance
- 8. Air-void clustering
 - a. Use a vinsol resin-based air-entraining admixture
 - b. Avoid retempering
 - c. Increase the mixing time
CRACKING

Early Age Cracking



- 1. Concrete mixture
 - a. Check the combined aggregate grading
 - b. Examine the fine aggregates; fine aggregates may be too fine and angularity may cause harsh finishing (i.e., manufactured sands)
 - c. Reduce the paste content (minimize shrinkage potential)
 - d. Materials incompatibility may lead to delayed set and/or higher concrete shrinkage; consider mixture component adjustments.
 - e. Eliminate or reduce the content of fly ash or GGBF slag in coolweather conditions
 - f. Consider using an accelerator in cold weather.
- 2. Sawing



- a. Saw as early as possible but avoid excessive raveling
- b. Saw in the direction of the wind
- c. Check that the diamond saw blade is appropriate for concrete aggregate hardness, fines, etc.
- d. Use early-entry dry sawing
- e. Use HIPERPAV to model stress versus strength gain for conditions to determine the optimum sawing time

- 3. Curing
 - a. Improve/extend curing
 - b. Apply the curing compound at a higher rate
 - c. Apply the curing compound sooner
 - d. Use blankets between placing and saw-cutting
- 4. Insufficient joint depth
 - a. Check the saws for depth setting
 - b. Check the saw blade for wear (carbide blades)
 - c. Check that saw operators are not pushing saws too fast, causing them to ride up
 - d. Look for base bonding or mortar penetration into the open-graded base-altered effective section; increase the saw depth to create an effective weakened plane
 - e. Check the slab thickness
- 5. Excessive joint spacing
 - a. Reduce spacing between the joints
 - b. Slabs are too wide in relation to thickness and length; add intermediate joints
 - c. Maintain a reasonable length-width ratio
- 6. Warping (slab curvature due to moisture gradient; the term "curling," however, is commonly used in the industry to cover both moisture- and temperature-related slab distortion)



- a. Check the moisture state of base
- b. Improve or extend curing
- c. Minimize the shrinkage potential of the concrete mixture
- d. Cover the slab, particularly when night/day temperatures vary widely
- 7. High temperature
 - a. Cool the raw materials before mixing the concrete: shade, spray, ice, liquid nitrogen
 - b. Cool the equipment
 - c. Work at night
 - d. Watch for shaded areas where drying and strength gain may vary within a single day's work
 - e. Delay paving if conditions are too hot (>38° [100°F])
 - f. Apply an evaporative retardant prior to texturing
 - g. Apply the curing compound at an additional dosage rate and consider a non-water-based compound with better membrane-forming solids
- 8. Too many lanes tied together (generally only a consideration for longitudinal direction)
 - a. Do not exceed 15 m (50 ft) of pavement tied together
 - b. Add an untied construction or isolation joint
 - c. To prevent additional cracking, consider sawing through a longitudinal joint to sever bars
- 9. Edge restraint (paving against an existing or previously placed lane)
 - a. Cracks occur due to restraint to movement (sometimes referred to as sympathy cracks)
 - b. Tool the joint or use an early-entry dry saw to form the joints as early as possible
 - c. Match the joint location and type
 - d. Eliminate tiebars in a longitudinal construction joint that is within 24 inches on either side of transverse joint locations. Match all locations of the joints in the existing pavement (cracks, too)
- 10. Slab/base bonding or high frictional restraint
 - a. Moisten the base course prior to paving (reduce the base temperature by evaporative cooling
 - b. Use a bond-breaking medium (see reflective cracks)
 - c. If the base is open graded, use a choker stone to prevent the penetration of concrete into the base's surface voids
- 11. Misaligned dowel bars
 - a. Investigate whether the joints surrounding the crack have activated and are functioning; misaligned or bonded dowels may prevent joint functioning, causing cracks
- 12. Cold front with or without rain shower
 - a. Use early-entry sawing to create a weakened plane prior to temperature contraction
 - b. Skip-saw (saw every other joint or every third joint) until normal sawing can be resumed
 - c. Use HIPERPAV to model stress versus strength-gain conditions that may warrant a suspension or change of paving activities.

JOINT ISSUES

Raveling Along Joints

Potential Cause – Possible Solution

- 1. Sawing too soon
 - a. Wait longer to saw
 - b. Use formed joints
 - c. Blank out transverse tining at transverse contraction joints
- 2. Saw equipment problem
 - a. Blade selection for the concrete (coarse aggregate type) may be inadequate
 - b. A bent arbor on the saw causes the blade to wobble
 - c. The second saw cut can go back and forth; consider a single-cut design
- 3. Sawing too fast
 - a. Slow down

Spalling Along Joints



- 1. Excessive had finishing
 - a. Check for mixture problems that would necessitate overfinishing
 - b. Improve construction practice
- 2. Trying to fix edge slump of low spots by hand manipulating concrete
 - a. Check for mixture problems that would cause edge slump
 - b. Improve construction practice
- 3. Mortar penetration into transverse joints (after hardening mortar prevents joint closure)
 - a. Mortar penetration occurs when paving against an existing previously placed lane; apply duct tape or other means to block the penetration of mortar into the transverse joints of the existing lane
- 4. Collateral damage from equipment, slipform paver tracks, screeds, etc
 - a. Protect the edges of the slab from damage using gravel or dirt ramps
 - b. Delay placement of the next phase of construction until the concrete gains sufficient strength.

Dowels Are Out of Alignment

Potential Cause – Possible Solution

- 1. Movement in dowel basket assemblies
 - a. Cover the dowel baskets with concrete ahead of the paver
 - b. Use stakes to secure the baskets to the granular base
 - c. Increase the length and number of stakes
 - d. Use nailing clips on both sides of basket to secure the basket to the stabilized base
- 2. Dumping directly on dowel baskets
 - a. Deposit the concrete a few feet from the dowel basket to allow the concrete to flow around the dowel bars
- 3. Poor aggregate gradation
 - a. Dowel insertion into mixtures with gap-graded aggregates does not work well; improve the aggregate grading

PREVENTING PROBLEMS THAT ARE OBSERVED SOME TIME AFTER CONSTRUCTION

EDGE AND SURFACE ISSUES

Clay Balls Appear at Pavement Surface

Potential Cause – Possible Solution

- 1. Aggregate stockpile contamination generally caused by the following: haul trucks tracking clay and mud to stockpiles; loader operator digging into dirt; dirt coming from the quarry
 - a. Educate the loader operator on proper stockpile management techniques
 - b. Keep end-loader buckets a minimum of 2 ft off the ground
 - c. Do not stockpile aggregates on soft foundations
 - d. Stabilize the haul road at the plant site to avoid tracking contaminants
 - e. Use belt placers at stockpiles rather than end loaders
 - f. Check the aggregate producer's stockpiles
 - g. Check for contamination in the hauling equipment
 - h. Doe not drive over a bridge to unload the aggregate
- 2. Mud being thrown into concrete trucks from muddy haul roads
 - a. Cover the trucks

Popouts

- 1. Unsound aggregates
 - a. Use only aggregates that have been tested for chert, shale, and/or other undesirable fine particles
 - b. Reduce vibration to minimize the flotation of particles
- 2. Alkali-silica reactions
 - a. Use non-alkali silica reactive aggregates
 - b. Use blended cements or SCMs proven to control ASR

Scaled Surface



Potential Cause – Possible Solution

- 1. Premature finishing
 - a. Improve the finishing technique
- 2. Improper finishing
 - a. Do not add water to the surface during finishing
- 3. Over-finishing
 - a. Improve the finishing technique
- 4. Frost related
 - a. Protect the concrete from freezing until a sufficient strength is achieved
 - b. Concrete damaged by freezing must be removed and replaced
 - c. Check the air content and spacing factor in the hardened concrete
 - d. Premature salting; salts should not be applied to immature concrete
 - e. Check the de-icing salts being used

Dusting Along Surface

Potential Cause – Possible Solution

- 1. Adding water during finishing or finishing in bleed water
 - a. Prevent the addition of water during finishing
 - b. Delay finishing until after the dissipation of the bleed water

Surface Bumps and Rough Riding Pavement

- 1. Placement operations
 - a. Construct and maintain a smooth and stable paver track line
 - b. Check the string line tension and profile
 - c. Maintain a consistent quantity of concrete in front of the paver
 - d. Maintain a consistent forward motion; avoid a stop-and-go operation
 - e. Check the paver tracks
 - f. Check that the machine is level
 - g. Check the sensors on the paver
 - h. Verify that the paver electronics/hydraulics are functioning properly

- 2. Nonuniform concrete
 - a. Check the batching, mixing, and transport procedures for consistency
 - b. Check the aggregate grading and moisture contents for variations that might lead to set and dry batches
- 3. Damming or rebound from dowel baskets
 - a. Lack of consolidation to achieve a uniform concrete density within the dowel basket area may create a rough surface because the concrete may settle or slough over the dowels
 - b. Check that the dowel baskets are secured
 - c. The basket assembly deflects and rebounds after the slipform paver profile pan passes overhead and the extrusion pressure is released. The result is a slight hump in the concrete surface just ahead of the basket. Spring-back is more apt to occur on steeper grades and when there is too much draft in the pan; do not cut the basket spacer wires to prevent the basket from springing under the paver's extrusion pressure
 - d. Do not over vibrate the concrete at the baskets in an effort to prevent basket movement
- 4. Reinforcement ripple
 - a. Address reinforcement ripple issues with well-graded aggregates and uniform concrete; consolidation is achieved at lower vibration energy and extrusion pressure
 - b. Reinforcement ripple occurs when plastic concrete is restrained by the reinforcing bars, resulting in a ripple in the surface, with the surface slightly lower near each bar than in the area between the bars
 - c. Longitudinal depressions are caused when longitudinal bars limit the restitution of the surface level behind the profile pan by restraining the rebound of the concrete beneath the bars
 - d. Transverse ripple is caused by the transverse bars in the same way as longitudinal depressions, except that transverse ripple is found to be less noticeable than the prominent ridge caused by the damming effect of the transverse bars upon the upsurge flow of concrete behind the profile pan
 - e. The prominence of surface rippling depends on the finishing techniques and depth of cover to the reinforcement, with less cover producing more prominent rippling
- 5. Vertical grades (exceeding 3 percent)
 - a. Lower the slump of the concrete; the need to make an adjustment depends upon whether it is difficult to maintain a uniform head of concrete in front of the paver
 - b. Adjust the profile pan attitude, draft, or angle of attack. (When paving up a steeper grade, the pan elevation may be adjusted to abut 1.0 in. below the surface grade. When paving down a steeper slope, the pan may be adjusted to about 25 mm [1.0 in.] above the surface grade. This adjustment must be made carefully to avoid reinforcement ripple, particularly a spring-back of the embedded dowel baskets.)
 - c. Adjust the staking interval; closely follow the grade and staking calculations for these circumstances to reduce the semi-chord effect enough to produce a smooth surface.

Surface is Marred or mortar is Worn Away

Potential Cause – Possible Solution

- 1. Rained-on surface
 - a. Cover the slab to protect from rain
 - b. Remove the damaged surface by grinding
 - c. Restore the surface texture (if required) by grinding
- 2. Improper curing type or application
 - a. Place a curing blanket or plastic sheets after the bleed water sheen disappears
 - b. Consider using a membrane-forming curing compound instead of sheets/blankets
- 3. Use of higher dosages (>25%) of GGBF slag
 - a. Do not add water to the mixture
 - b. Reduce the vibration energy to avoid bringing too much moisture to the surface; vibration at 5,000-8,000 vpm is sufficient for most well-graded mixtures
- 4. Over-sanded mixes
 - a. Increase the coarse aggregate
- 5. Abrasion
 - a. Use a hard, wear-resistant aggregate
 - b. Use a concrete mix with sufficient strength

CRACKING

Cracking

- 1. Applied loads
 - a. Keep construction traffic away from the slab edges; early loading by traffic or equipment causes higher edge stresses
 - b. Keep public traffic away from the slab edges
- 2. Loss of support



- a. Ensure that the subgrade and base have been properly prepared
- b. Ensure that the joints are properly filled and sealed where appropriate

- 3. Reflective cracks from stabilized bases
 - a. Isolate the slab from cracks in the base course by using bond breakers. (Acceptable bond breakers include two coats of wax-based curing compound, dusting of sand, bladed fines, asphalt emulsion, polyethylene sheets, and tar paper. Sheet goods are difficult to handle in windy or other harsh conditions.)
 - b. Joint the base course to match the joints in the pavement
- 4. Slab/base bonding or high frictional restraint
 - a. Moisten the base course prior to paving (reduce the base temperature by evaporative cooling)
 - b. Use a bond-breaking medium (see "Reflective cracks from stabilized bases," immediately above)
 - c. If the base is open-graded, use a choker stone to prevent the penetration of concrete into the base's surface voids.
- 5. Mortar penetration into transverse joints (after hardening mortar prevents joint closure)
 - a. Mortar penetration occurs when paving against an existing previously placed lane; apply duct tape or other means to block the penetration of mortar into the transverse joints of the existing lane
- 6. Differential support condition created by frost heaving, soil settling, or expansive soils
 - a. Check the compaction, particularly above utility, culvert, and other trenches.
 - b. Proof roll the base
 - c. Stabilize the subgrade soil
 - d. Use selective grading techniques; cross-haul the soils to create smooth transitions between cut and fill sections and soil transitions
- 7. Misaligned dowel bars
 - a. Investigate whether the joints surrounding the crack have cracked and are functioning; misaligned or bonded dowels may prevent joint functioning, causing cracks
 - b. Designate personnel to ensure dowel alignment
- 8. Alkali-silica reactions



- a. Avoid using reactive aggregates if possible
- b. Use appropriate amounts of SCMs
- c. Use blended cements or SCMs proven to control ASR
- d. Use a low w/cm ratio
- 9. Chemical attack
 - a. Use a low w/cm ratio, maximum 0.45
 - b. Use an appropriate cementitious system for the environment
- 10. Frost related
 - a. Ensure that the air-void system of the in-place concrete is adequate
 - b. Use a low w/cm ratio
 - c. Use frost-resistant aggregates
 - d. Reduce the maximum particle size

Appendices A-B

Appendix A - Indiana Test Methods

1.	ITM No. 402	3. <u>ITM</u>	No.	404
2.	ITM No. 403	4. ITM	No.	803

<u>Appendix B</u>

1. 2012 Standard Specifications