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Tech Brief

EFFECTIVE QUALITY ASSURANCE FOR CONCRETE PAVING OPERATIONS

Best Practices for Concrete Pavements

BACKGROUND AND INTRODUCTION

This tech brief looks at the elements needed to implement an effective quality assurance (QA) program for concrete paving operations. The benefit of a good QA program far outweighs the costs for both the agency and contractors.

The topic of QA can be intimidating, but all of us make quality-based judgments in our lives every day. This tech brief aims to outline the basics of an effective quality system for concrete pavements using new technologies.

Commitment

Quality at any organization is a top-down philosophy to build with high quality. The key is to understand that all parties can save money by aiming for high quality, because it saves them from needing to budget for replacing mistakes or premature failures.

If the corporate philosophy is that quality is not negotiable, it is a lot easier to implement an effective program that delivers a reliable transportation infrastructure to the tax-paying public, cost effectively.

It is tempting to not bother with quality and to save that inspector's salary, but mistakes happen and the low-bid system incentivizes cutting corners. Errors may only become apparent long after the final payments are made, potentially leaving the owner agency with a very expensive repair bill or a far shorter life than originally planned for the pavement.

Motivation

Work toward quality is only possible if every person understands what is in it for them. Does it save money? Will the pavement last longer? Will we need a lawyer or a party-planner at the end of the contract? Will I keep my job or be able to land future contracts with this agency?

FHWA Mobile Concrete Laboratory (MCL) 2011

Use of MIT-SCAN-T2 device to measure jointed plain concrete pavement thickness

U.S. Department of Transportation
Federal Highway Administration

THE AGENCY

Federal regulations require each state highway agency to have a QA system in place to assess the quality of items produced. The aim is to ensure that the public's dollar is spent wisely. The reason for having a systematic approach to quality is to consistently assess and pay for items provided on construction projects. The primary components are discussed below.

Owner/Agency Acceptance

It is the responsibility of the owner/agency to establish how it will accept and pay for work done under a construction contract. The acceptance process should focus only on factors that are directly related to the ultimate performance of the product.

Rigorous inspection is a key part of the acceptance process. A concrete mixture can perform well in the laboratory, yet be unacceptable if the workmanship at the site is poor. The agency should also insist that the contractor implement an effective quality control (QC) plan.

Quality Control

QC is the act of monitoring progress toward the final product to ensure it will meet acceptance criteria. The QA specification should mandate a minimum level of QC.

Experience has shown that better contractors often exceed minimum requirements because an effective QC program enhances productivity and reduces the risk of failure. A QC plan should detail the activities that will be performed by the contractor and monitored and enforced by the agency.

Personnel Qualifications

Individuals performing sampling, testing, and inspection, for all QA activities, must be suitably trained, qualified, and ethical. This is because their findings have direct implications on pay. The specification should establish which qualifications are required and which individuals should have these qualifications.

Laboratory Qualifications

Laboratory qualification is part of a QA system for the same reason as personnel qualification. Laboratories should be accredited through the American Association of State Highway and Transportation Officials (AASHTO) accreditation program or an equivalent.

Independent Assurance

Independent assurance (IA) refers to the periodic checking done on the individuals and equipment performing sampling and testing activities. The IA process assures that these professionals continue to provide accurate results. Two concepts are important:

- IA is conducted using split samples to remove material and construction-related variability.
- The IA evaluation addresses only the accuracy of the test result, not the actual result itself. For example, if a test sample fails to meet the specification's limit, yet the two results are within the allowable tolerance for that test, the tester "passes" their IA evaluation.

Dispute Resolution

Dispute resolution refers to the referee process used when the test results from the owner/agency laboratory do not agree with results from the contractor laboratory. Typically, an independent, qualified, laboratory not involved in the original testing is used as the referee.

THE CONTRACTOR

Like the agency, effective contractors must be committed from the top down to delivering products that are acceptable to their clients. Unlike the agency, the contractor must consider all aspects of the construction process.

Corporate Culture

Emphasis should be placed on using the quality system to teach and encourage good practices at all levels. Failures should become training opportunities rather than tools to punish individual employees.

Internal policies are needed to guide every aspect of a project. The guidelines should include the following:

- Plant calibration steps and responsibilities
- Tools used to evaluate the properties of aggregates
- Cementitious materials handling, testing, and monitoring
- Testing frequency and tolerances
- Degree of overdesign

Technical staff must be given the authority to initiate changes when corrective actions are required, even if the changes are costly. This authority to initiate a proactive response demonstrates management's commitment to quality and helps show project staff what the company perspective is on "good enough."

Trained and Experienced Managerial Technical Staff

A well-trained and experienced managerial technical staff is a key to reducing risk. The value added in having this level of expertise on projects greatly exceeds the cost to the company. These professionals are able to optimize the concrete design mixture and often reduce the cost of materials, as well as improve the constructability of the concrete. These personnel are able to monitor test results, analyze the test data, and then initiate changes during construction when needed.

QC managers are responsible for using process control to ensure that the product will be accepted by the agency. A skilled QC manager knows when to act and, equally important, when not to act.

The result is improved control of the mixture and a lower standard deviation in the test results. This adds value by helping the contractor to bid and produce mixtures, with less overdesign, that are more economical but still meet the requirements of the contract.

New Technologies

Utilizing new technologies to gather better data, sooner, can reduce risk and improve the finished product. Many new and often nondestructive tests can provide information instantly and aid a contractor in monitoring the process to assure that it is under control.

Materials Selection

Materials selection is critical to the development of a concrete mixture so it will not only meet the project requirements but also positively affect the construction process. Running mixture trials and evaluating products prior to bid letting is very important to ensuring that the cost of the project is known and surprises don't pop up. This work should be the responsibility of the individuals with quality management responsibilities.

It is important for QC management personnel to understand that the process of materials selection is much greater than just the contract testing requirements. Some examples include the following:

- Cost/benefit considerations
- Performance of alternative materials sources
- Haul distances
- Delivery method
- Placement equipment

Qualified personnel recognize during the mixture design process and evaluation that a mixture made in the laboratory acts differently in the field. First, the small laboratory mixer is different from the large drum mixer used in mainline paving. Also, the weather is not normally 72°F in the field as it was in the laboratory. Humidity, sunshine, and night conditions all affect the properties and behavior of the concrete.

TEST METHODS

Construction of concrete pavements is complex and the service life of the pavement is dependent on many factors. The process of building a concrete pavement is as critical as the materials that go into it. Therefore, we need to measure the right properties at the right time, and often watch the process as well, to be assured that the quality is indeed "good enough."

Traditionally, the only tests available were strength, slump, air content, and thickness. These tests have been the backbone for specifications for decades, despite their poor correlation with long-term performance in modern systems. The lack of more effective tests has been a significant barrier to implementation of performance specifications.

However, recent years have seen some major advances in the concrete testing arena. Several new tests are now available that are more practical, faster, more economical, easier to implement in the field, and measure properties that are related to actual concrete and pavement quality. Many of these tests could be incorporated in QA programs while others are more suitable for QC activities.

The following sections briefly describe new technologies and tests that are available and when they should be used. Detailed information on these tests is available in the references provided.

Box Test – Workability (Mixture Design Phase)

The box test is a simple and economical test method to evaluate if a concrete mixture is suitable for slip-formed concrete paving (Cook et al. 2014). This test measures the response of the concrete to vibration and the ability of the concrete to hold an edge.

The box test is a (contractor) QC test.

VKelly Test – Workability (Mixture Design Phase)

The vibrating Kelly ball test (VKelly test) is a tool that also assesses the response of a mixture to vibration (Taylor et al. 2015). Like the box test, the VKelly test can be used to guide the design of slip-formed concrete mixtures and to assess any changes during construction due to changes in source materials or the environment.

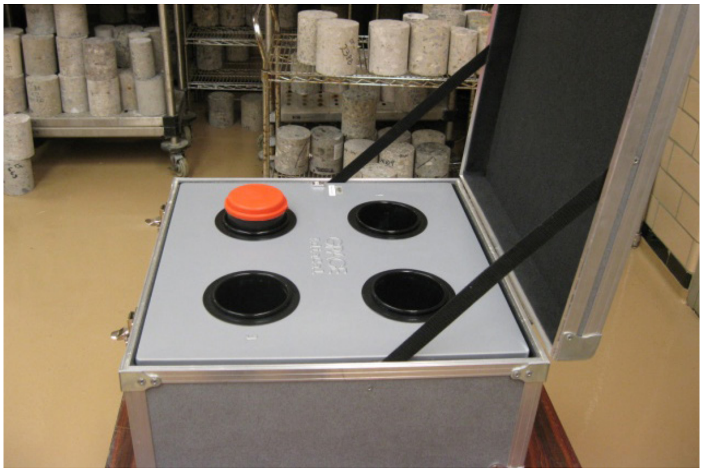
The VKelly test is a (contractor) QC test.

Jagan Gudimettla/FHWA Mobile Concrete Laboratory (MCL) 2015

Box test result for a stiff mixture

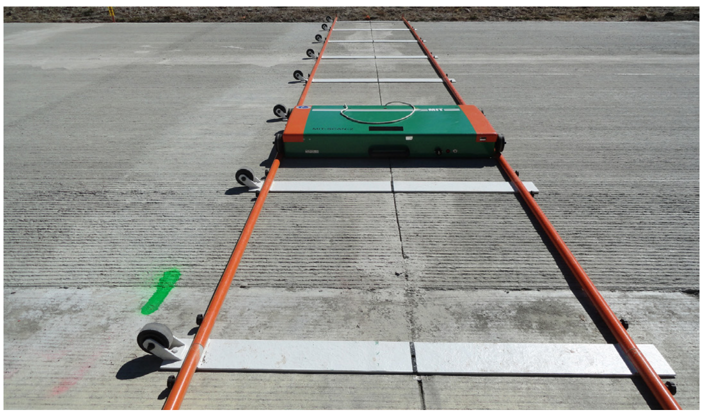
National Concrete Pavement Technology (CP Tech) Center

Use of the vibrating Kelly ball test (left) to assess response to vibration for mixture workability and super air meter (right) for indication of air distribution in concrete for freeze-thaw durability



Jagan Gudimettla/FHWA Mobile Concrete Laboratory (MCL) 2014

Semiadiabatic calorimeter used to indicate relative performance and uniformity of materials



FHWA Mobile Concrete Laboratory (MCL) 2011

Nondestructive MIT Scan-2 device used to measure dowel bar positions embedded in jointed plain concrete pavements

Semiadiabatic Calorimetry – Chemistry Consistency (Mixture Design – Production Phase)

Hydration of cementitious materials is exothermic, meaning that the progress of the chemical reactions can be monitored by measuring the total heat liberated over time using a semiadiabatic calorimeter (ASTM C1753). The shape of the power curve obtained through calorimetry is an indicator of relative performance and uniformity of cementitious materials.

This is a (contractor) QC test.

Surface Resistivity – Permeability/Durability (Mixture Design Phase – Production Phase)

Permeability is an indicator of concrete durability because most damage mechanisms involve the presence of water. Mixtures that limit the transportation of fluids through the pore system tend to be longer lasting. A good test to measure permeability directly doesn't exist, but resistivity provides an indirect measure (Rupnow and Icenogle 2012) because electricity is more readily conducted through fluids than through solids.

This test could be used as both a QC and an acceptance test.

Super Air Meter – Freeze-Thaw Durability (Mixture Design Stage – Production Stage)

The presence of closely spaced air voids in concrete is recognized as the primary factor in improving the freeze-thaw durability of concrete. Normal tests performed on fresh concrete provide information on the total air content of the sample, but do not give any indication of the quality of the air void system. Petrographic methods (ASTM C457) and freeze-thaw tests (ASTM C666) take many days and therefore are of little value in monitoring concrete during construction.

The super air meter (SAM) is a field test that gives an indication of the distribution of air in concrete (Ley and Tabb 2014). The test takes just over 10 minutes to run and provides immediate information about the air void quality in the fresh concrete.

This test could be used both as a QC and as an acceptance test.

MIT-SCAN-T2 – Pavement Thickness (Construction Stage)

The service life of a concrete pavement is significantly influenced by the pavement thickness. However, coring to measure thickness is destructive, expensive, and time consuming. The MIT-SCAN-T2 uses pulse induction technology to measure pavement thickness nondestructively using a metal target pre-placed on the top of the base prior to paving.

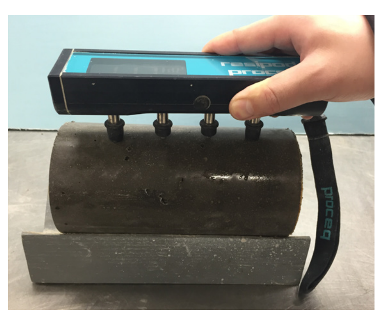
This test could be used as both a QC and an acceptance test for jointed plain concrete pavement.

MIT Scan-2 – Dowel Alignment (Construction Stage)

Properly aligned dowel bars help provide load transfer between panels in jointed plain concrete pavements. Misaligned dowels may lead to joint locking that can cause slabs to crack. Insufficient embedment leads to a decrease in load transfer efficiency, which can result in faulting and other pavement distresses.

The MIT Scan-2 is a nondestructive testing device for measuring the position of dowel bars embedded in concrete. The device helps in determining the horizontal alignment, vertical alignment, side shift, and depth of the dowel bar from the top of the pavement (Rao et al. 2009).

This test could be used as both a QC and an acceptance test for jointed plain concrete pavement.



Surface resistivity provides an indirect measure of permeability, which is an indicator of concrete's potential durability

National Concrete Pavement Technology (CP Tech) Center

HIPERPAV III

HIPERPAV III is a software program, sponsored by the Federal Highway Administration (FHWA), that can be used to predict early-age cracking risk related to moisture and temperature changes within the pavement (Rasmussen et al. 2002). The software is useful in assessing conditions for both jointed plain concrete pavement and continuously reinforced concrete pavement.

The current version of the software includes the ability to compare different construction scenarios and to compare cracking risk at different times during the day. Weather data can be automatically downloaded from the National Oceanic and Atmospheric Administration's website.

LIMITS

The challenge is defining how good is good enough. How do we know we've achieved adequate quality? If we have not, how bad is the problem and what is the sub-standard pavement worth or should it be replaced? Are we measuring the right things?

Utilizing the test results effectively is at the heart of a quality effort. Control charts plot consecutive test results to provide a visual track of the trends of the production. Setting limits that trigger actions is the companion step.

Contractors will set action limits to mark the point when something must be changed if a limit is crossed. Specification limits are set by the agency to define acceptable work. Engineering limits are the final step, beyond which the product is unacceptable. Between the specification limits and the engineering limits, agencies normally set degrees of penalty to account for the deficiency of the work.

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