MICHIGAN
DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION
FOR
QUALITY CONTROL AND ACCEPTANCE OF PORTLAND CEMENT CONCRETE

a. Description. The Contractor must administer quality control (QC) and the Department will administer quality assurance (QA) procedures that will be used for acceptance of and payment for all Portland cement concrete (PCC) for the project. Except as explicitly modified by this special provision, all materials, test methods, and PCC mixture requirements of the standard specifications and the contract apply.

Do not place concrete until the Engineer's daily startup testing verifies that the fresh concrete properties have been met, in accordance with subsection d.2 of this special provision.

Percent-within-limits (PWL) analysis for payment applies only to pavements for mainline, shoulder, miscellaneous concrete pavement (including ramps), and concrete pavement overlay applications. Non-PWL analysis will apply for all other applications including temporary concrete pavements.

Provide the Engineer a minimum of 24 hours notification prior to each concrete placement.

1. Terminology.

Acceptable Quality Level (AQL). The threshold limit that would warrant 100 percent payment for the production lot of concrete. AQL only applies for PWL quality index analysis.

Air Content of Fresh Concrete. The recorded air content of fresh concrete sampled and tested according to this special provision.

Air Content Test Results. The recorded air content of fresh concrete corresponding to the strength test specimens that were molded for acceptance.

Alkali-Silica Reactivity (ASR). A chemical reaction which occurs over time within concrete between highly alkaline cement paste and reactive forms of silica found in some aggregates. In the presence of moisture, an expansive ASR gel is formed which can exert pressure within the concrete, causing random cracking and premature deterioration of the concrete. See subsection c.5.A of this special provision.

Concrete Mix Design. The process, by which the concrete mixture performance characteristics are defined, based on selected materials, performance requirements, environmental exposure considerations, placement methods, and other factors that control the plastic and hardened properties of the concrete in efforts to produce an economical and durable product.

Dispute Resolution. The process used to referee discrepancies between the Contractor's QC test results and the Department's QA test results. Dispute resolution applies for PWL quality index analysis of 28-day compressive strength only.

Job Mix Formula (JMF). The actual batch quantities (mixture proportions) of each constituent included in the concrete mixture, based on adjustments to the target weights attained from the mix design process necessary to optimize the concrete mixture properties.

Non-PWL Applications. All concrete applications which are not subject to percent within limits (PWL) analysis for payment. Quality index analysis using PWL will not apply. Pay factor determination and price adjustment will be according to subsection d.5 of this special provision.

Optimized Aggregate Gradation. The method described in Appendix 1 to produce a well-graded blend of aggregates used for high performance concrete pavement (Grade P1M) and bridge deck (Grade DM) applications, when specified.

Pay Factor (PF). The factor that is determined according to subsections d.4 and d.5 of this special provision, used to calculate the price adjustment for a discrete quantity of concrete relative to its respective level of quality. Pay factor determination for PWL applications will be according to subsection d.4 of this special provision using the MDOT Concrete PWL Worksheet. Pay factor determination for non-PWL applications will be according to subsection d.5 of this special provision.

Percent Within Limits (PWL). The method used to determine acceptance and payment for mainline, shoulder, miscellaneous concrete pavement (including ramps), and concrete pavement overlays. PWL will not apply for temporary concrete pavement applications. The PWL is the cumulative area under a standard curve which represents the estimated percentage of a production lot that falls above the Lower Specification Limit (LSL), beneath the Upper Specification Limit (USL), or between the LSL and USL.

Price Adjustment (ADJ). The price adjustment applied to the quantity of concrete represented by the respective quality index analysis described in subsections d.3 through d.5 of this special provision. The maximum potential positive price adjustment (quality initiative) for concrete acceptance items subject to PWL quality index analysis is five percent of the original contract unit price for the pay item. Non-PWL applications and small incidental quantities, regardless of the pay item, are not eligible for positive price adjustment (quality initiative) consideration.

Production Lot. A discrete cubic yard quantity of concrete containing the same JMF and used for the same application, typically made up of five sublots, as described in subsection d.2.A.(1) of this special provision.

Quality Assurance (QA). Activities administered by the Department dealing with acceptance of the product, including, but not limited to, materials selection, sampling, testing, construction inspection, and review of Contractor QC documentation. All concrete QA sampling and testing will be administered by the Engineer. Department administered QA is described in section d of this special provision.

Quality Control (QC). All activities administered by the Contractor to monitor, assess, and adjust production and placement processes to ensure the final product will meet the specified levels of quality, including, but not limited to, training, materials selection,

sampling, testing, project oversight and documentation. Contractor administered QC is described in section c of this special provision.

QC Action Limits. A range of values established by the Contractor in the QC plan that, if exceeded, requires that corrective action be taken by the Contractor to restore the continuity and uniformity of the mixture and methods in conformance with specification requirements. The QC action limits must not exceed the QC suspension limits.

QC Plan. The project-specific plan developed by the Contractor describing, in detail, all aspects of production and construction for the project to ensure consistent control of quality to meet specification requirements.

QC Plan Administrator. An employee of, or consultant engaged by the Contractor, responsible for developing and overseeing all aspects of QC for the project. This includes, but is not limited to preparing the QC plan, managing the Contractor QC personnel, communicating routinely with the production personnel to ensure quality, initiating corrective action and suspending operations when the process is found to be producing non-conforming materials, and preparing and submitting all necessary QC documentation to the Engineer within the specified time period.

QC Suspension Limits. A range of values defined in Table 2 that, if exceeded on a single QC test, requires that the Contractor suspend operations and determine, correct, and document the deficiencies before resuming production. The QC suspension limit must not exceed specification requirement thresholds.

Quality Index. The calculated percent of material that meets specification.

Quality Index Parameter. The quality characteristics that are evaluated under the Department's QA program and on which payment for material is based. The quality index parameters used for price adjustment are 28-day compressive strength and air content of fresh concrete.

Quality Initiative. A budgeted amount established to cover the potential positive price adjustment for concrete acceptance items subject to PWL quality index analysis only. Non-PWL applications and small incidental quantities, regardless of the pay item, are not eligible for positive price adjustment (quality initiative) consideration.

Rejectable Quality Level (RQL). The threshold limit (defined in Table 3) for the quality index parameters that if not met, would require rejection of the concrete production lot. RQL only applies for PWL quality index analysis.

Sample. A representative quantity of concrete taken during production which is used to measure the quality characteristics for the concrete.

Sampling Rate. The number of times the fresh concrete is sampled for acceptance, as described in subsection d.2 of this special provision.

Small Incidental Quantity. A single day’s placement of less than 20 cubic yards of concrete used for non-structural or non-pavement related applications, including, but not limited to: curb and gutter, sidewalks and sidewalk ramps (excluding driveways and driveway ramps), installing sign or fence posts, guard rail or cable rail foundations (excluding end anchorage foundations), or other contract items where the small quantity of

concrete is not paid for separately, as approved by the Engineer. Requirements for small incidental quantity consideration are described in subsections c.5.G, d.2.A, d.2.B, and d.3.C of this special provision. The corresponding weekly QA test results must meet specification limits defined in Table 4.

Specification Limits. The threshold values placed on a quality characteristic used to evaluate the quality of the material.

Strength Sample Test Result. The average of the two companion 28-day compressive strength test specimens taken from the same sample of concrete is considered a strength sample test result. For PWL quality index analysis, described in subsection d.3 of this special provision, each individual strength test specimen from the sample of concrete is considered a strength sample test result.

Strength Test Specimen. A strength test specimen is an individual 6-inch by 12-inch strength test cylinder or 4-inch by 8-inch strength test cylinder molded and cured according to *AASHTO T 23/ASTM C 31* and tested according to *AASHTO T 22/ASTM C 39*. All respective QC or QA strength test specimens must be the same nominal size. Strength test specimen cylinder size of 4-inch by 8-inch is permitted only if the nominal maximum coarse aggregate particle size, as specified for the coarse aggregate in the concrete mixture, is 1-inch or less (not permitted for Grade P1M concrete).

Sublot. A portion of a production lot, from PWL applications only, represented by a complete set of QA tests, as described in subsection d.2.A of this special provision. The Engineer and the Contractor may agree to reduce the typical sublot size based on project staging or other project conditions.

b. Materials. Mixture requirements must be in accordance with the contract.

c. Contractor Administered Quality Control (QC).

1. Contractor Quality Control Plan (QC Plan). Prepare, implement, and maintain a QC plan specific to the project for concrete that will provide quality oversight for production, testing, and control of construction processes. The QC plan must identify all procedures used to control production and placement including when to initiate corrective action necessary to maintain the quality and uniformity of the work.

Develop concrete mix designs and JMFs, as specified, and conduct QC sampling, testing, and inspection during all phases of the concrete work at the minimum frequency, or at an increased frequency sufficient to ensure that the work conforms to specification requirements.

Project-specific items required in the QC plan include (where applicable), but are not limited to the following:

A. Organization chart.

B. QC Plan Administrator and contact information.

C. The name(s) and credentials of the QC staff.

D. Methods for interaction between production and QC personnel to engage timely corrective action, including suspension of work.

E. Coordination of activities.

F. Documentation, procedures, and submittals.

G. Project and plant specifics.

H. Concrete production facilities inspections and certifications.

I. Current testing equipment calibration documentation including calibration factor.

J. Testing and initial field curing facilities for QC and QA strength test specimens (*AASHTO T 23/ASTM C 31*).

K. Stockpile management plan.

L. Corrective action plan.

M. Mixing time and transportation, including time from batching to completion of delivery and batch placement rate (batches per hour), along with the manufacturer's documentation relative to the batching equipment's capabilities in terms of maximum mixing capacity and minimum mixing time (*ASTM C 94*).

N. Placement and consolidation methods including monitoring of vibration, depth checks, and verification of pavement dowel bar alignment.

O. Process for monitoring stability of air content of fresh concrete during concrete production and placement.

P. Hot and cold weather protection considerations and methods.

Q. Control charts with action and suspension limits.

R. Verification for non-deleterious alkali-silica reactivity (see subsection c.5.A of this special provision).

S. Mix design and JMFs.

T. Proposed production lot size and location for use of each JMF on the project.

U. Frequency of sampling and testing.

V. Handling, protection, initial curing, and transporting of strength test specimens (*AASHTO T 23/ASTM C 31*).

W. Methods to monitor construction equipment loading and open-to-traffic strengths.

X. Finishing and curing procedure.

Y. Ride quality control.

Z. List of QC records to be submitted to the Engineer in accordance with subsection c.2 of this special provision.

Submit the QC plan, for the appropriate items of work, to the Engineer for review a minimum of 10 working days before the start of related work. The Engineer will notify the Contractor of any objections relative to the content of the QC plan within 5 working days of receipt of the QC plan. Do not begin concrete placement before acceptance of the QC plan by the Engineer.

2. QC Records. Maintain complete records of all QC tests and inspections. Document what action was taken to correct deficiencies. Include sufficient information to allow the test results to be correlated with the items of work represented.

Furnish one copy of all QC records, including test reports for the fresh concrete placement and optimized aggregate (where applicable), to the Engineer within 24 hours after the date covered by the record in a format acceptable to the Engineer. The Engineer will withhold acceptance of the concrete, and the Contractor will forfeit eligibility for dispute resolution consideration described in subsections d.6 through d.8 of this special provision, for failure to provide properly documented and timely QC records and reports.

If the Engineer is performing QA sampling and testing at the same time the Contractor is performing QC sampling and testing, all associated QC records must include the appropriate production lot identification number that correlates with the Department's QA production lot identification number.

3. Personnel Requirements. The QC Plan Administrator must have full authority and responsibility to take all actions necessary for the successful implementation of the QC plan, including but not limited to, the following:

A. Monitoring and utilizing QC tests, control charts, and other QC practices to ensure that delivered materials and proportioning meets specification requirements.

B. Monitoring materials shipped to the project, prior to their use, to ensure their continued compatibility toward producing consistent quality.

C. Periodically inspecting all equipment utilized in transporting, proportioning, mixing, placing, consolidating, finishing, and curing to ensure proper operation.

D. Monitoring materials stockpile management, concrete batching, mixing, transporting, placement, consolidation, finishing, and curing to ensure conformance with specification requirements.

E. Maintaining and submitting all QC records and reports.

F. Directing the necessary corrective action to ensure continual conformance within the QC action limits.

G. Suspending production for the project when suspension limits are exceeded.

H. Conducting or monitoring adjustments to the JMF.

Individuals performing QC tests must demonstrate that they are proficient and capable of sampling and testing concrete or aggregate, where applicable, in accordance with the associated test procedures and Department requirements prior to commencement of related work. Any adjustments to the JMF must be made by a certified concrete technician (Michigan Concrete Association (MCA) Michigan Level II).

QC tests may be considered eligible to initiate consideration for dispute resolution only if the respective QC sampling and testing was conducted by a certified concrete technician (MCA Michigan Level I or II), or (MCAT) certified aggregate technician, where applicable. QC sampling and testing must have been conducted in the same manner, but not concurrently, as the QA sampling and testing for the associated production lot of materials. Dispute resolution applies for PWL quality index analysis only.

4. QC Laboratory Requirements. Laboratories, including field laboratories and all associated testing equipment that prepare concrete mixes or perform QC testing, must demonstrate to the Engineer that they are equipped, staffed, calibrated, and managed so as to be capable of batching and testing PCC in accordance with the applicable test methods and procedures. Mix designs and their accompanying JMFs must include a statement, signed by a certified concrete technician (MCA Michigan Level II), that all applicable standard test methods have been followed in verifying the mix design and JMF.

5. Mix Design and Documentation. Design concrete mixtures meeting the requirements specified in Table 1. Provide the grade of concrete for the section number reference application specified in Table 1 or as specified in the contract. Request variance in writing when proposing a mix design that exhibits temperature, slump or air content other than those specified. Include the proposed mix design, JMF, and associated trial batch verification test data. Do not use a grade of concrete with a lower specification limit (LSL) 28-day compressive strength greater than what is designated for the application. Unless specified otherwise, concrete mixtures using optimized aggregate gradation may be used in lieu of standard concrete mixtures for other applications, as approved by the Engineer.

Blended cement meeting the requirements of *ASTM C 595* Type IL is permitted.

Secure prior approval from the Engineer to use concrete intended for early opening to traffic to facilitate driveway gaps or other features necessary for required local access.

Unless otherwise specified in the contract, set accelerating admixtures are prohibited.

Provide concrete mixture (Grade P1M) for high performance mainline pavement, shoulder, miscellaneous pavement (including ramps), and concrete pavement overlay applications. Provide concrete mixture (Grade DM) for high performance bridge deck applications. Provide either concrete Grade P1M or Grade DM for bridge approach slab applications. The Engineer may approve Grades P1M or DM for other applications. Use Appendix 1 for Optimized Aggregate Gradation, included in this special provision, to develop and monitor the optimized gradation.

Concrete Grades P1M and DM require 25 to 40 percent replacement of the Portland cement in the concrete mixture with slag cement (Grade 100 minimum) or fly ash.

If replacing Portland cement for concrete Grades other than P1M and DM, do not exceed 40 percent replacement of the Portland cement in the concrete mixture with slag cement (Grade 100 minimum) or fly ash.

Do not exceed 40 percent total replacement of the Portland cement if both slag cement and fly ash are used in the concrete mixture.

Use the combined weight of all cementitious materials to determine compliance with the maximum water-cementitious ratio and cementitious material content requirements specified in Table 1.

Table 1: Minimum Mix Design Requirements for Concrete

Mix Design Parameter	Grade of Concrete						
	P1M (a,b,e)	P1 (a,b)	D,DM (a,b,e)	T	S1 (a)	S2 (a,b)	S3/P2 (a)
PWL Applications							
Lower Specification Limit (LSL) (28-day compressive, psi)	3500	3500	—	—	—	—	—
Rejection Limit for an Individual Strength Sample Test Result - Lower	2500	2500					
Non-PWL Applications							
Lower Specification Limit (LSL) (28-day compressive, psi)	3500	3500	4500	3500	4000	3500	3000
Rejection Limit for an Individual Strength Sample Test Result - Lower	3000	3000	4000	3000	3500	3000	2500
All Concrete Applications							
Maximum Water/Cementitious Ratio (lb/lb) (c)	0.45						
Cementitious Material Content (lb/yd^3) (d)	470-564	517-611	517-658	517-611	517-611	517-611	489-517
Air Content (percent) (f)	5.5 – 8.0						
Slump (inch) (max.)	(g)						
Section Number Reference (h)	602,603	602, 603, 801,802, 803,810	706,711, 712	706, 718	705	401, 706, 712, 713, 718, 801, 802, 803, 810, 819	402, 403, 602, 803, 804, 806, 808, 810, 813, 814

a. If the local average minimum temperature for the next 10 consecutive days is forecast to be below 40 degrees F, submit a revised QC plan, for the Engineer's approval, addressing, in detail, changes in materials, concrete batching and mixing processes, construction methods, curing, and protection of the in situ concrete to ensure that the necessary quality characteristics of the hardened concrete product will not be compromised as a result of the cold weather. The revised QC plan must be approved by the Engineer prior to cold weather concrete placement.

b. Use aggregates from only geologically natural sources for pavement, shoulder, miscellaneous pavement (including ramps), concrete pavement overlay, structural concrete, drilled shaft, bridge railing, and bridge sidewalk applications.

c. Use admixtures as listed in the Qualified Products Lists to reduce mixing water. Ensure concrete in concrete diaphragms contains a water-reducing admixture, or a water-reducing retarding admixture.

d. Type III cement is not permitted.

e. Aggregates must meet the physical requirements specified in subsection 902.03.C.

f. For action, suspension, and specification limits, see Tables 2, 3 and 4, where applicable. Air content of fresh concrete less than 5.5 percent for concrete that lies in the finished work at least 3 feet below the surface of the ground or entirely under water will not be cause for rejection.

g. The maximum slump for Grades P1, P1M, and P2 concrete is 3 inches or as documented on the approved JMF. All other grades of concrete will be according to Table 701-1 of the Standard Specifications for Construction.

h. Section Number Reference:

401 Culverts
402 Storm Sewers
403 Drainage Structures
602 Concrete Pavement
603 Concrete Pavement Restoration
705 Foundation Piling
706 Structural Concrete Construction
711 Bridge Railings
712 Bridge Rehabilitation-Concrete
713 Bridge Rehabilitation-Steel
718 Drilled Shafts
801 Concrete Driveways
802 Concrete Curb, Gutter and Dividers
803 Concrete Sidewalk, Sidewalk Ramps, and Steps
804 Concrete Barriers and Glare Screens
806 Shared Use Paths
808 Fencing
810 Permanent Traffic Signs and Supports
813 Slope Protection
814 Paved Ditches
819 Electrical and Lighting

For night casting, where applicable, a water-reducing admixture may be used in lieu of a water-reducing and retarding admixture, provided the concrete can be placed and finished in the sequence specified on the plans prior to initial set, is not subjected to residual vibration, or is not within the areas influenced by dead load deflections as a result of adjacent concrete placement operations. When the maximum air temperature is not forecast to exceed 60 degrees F for the day, the Contractor may use a water-reducing admixture or a water-reducing retarding admixture.

A. Alkali-Silica Reactivity. Provide documentation to the Engineer that the concrete mixture does not present the potential for excessive expansion caused by alkali-silica reactivity (ASR). Provide a Test Data Certification, for ASR testing of the fine aggregate that is proposed to be used in the concrete, from an independent testing laboratory with the latest test results (valid for 2 years from completion of testing). Test results must conform to the specified criterion for one of the following standard test methods. ASR requirements specified in subsection c.5.A of this special provision are not required for concrete pavement repairs and temporary concrete pavements. Use the Rounding Method described in *ASTM E 29* when determining significant digits for reporting expansion test results.

(1) Method 1. *ASTM C 1260*. Mortar Bar Test. If the expansion of the mortar bars is less than 0.10 percent (rounded to the nearest 0.01 percent) at 14 days of immersion, the fine aggregate is considered non-deleterious to ASR and may be used in the concrete without the need for ASR mitigation.

(2) Method 2. *ASTM C 1293*. Concrete Prism Test.

(a) If the expansion of concrete prisms is not greater than 0.040 percent (rounded to the nearest 0.001 percent) after 1 year, the fine aggregate is considered non-deleterious to ASR and may be used in the concrete without the need for ASR mitigation.

(b) If the expansion of concrete prisms is greater than 0.040 percent, but not exceeding 0.120 percent (rounded to the nearest 0.001 percent) after 1 year, the fine aggregate is considered moderately deleterious to ASR and mitigation is required, as follows: A Low-Alkali cement with Na_2O equivalent alkalies (Na_2O + 0.658 × percent K_2O) not exceeding 0.60 percent must be used in the concrete mixture to mitigate the potential for ASR. Slag cement or fly ash may be used in conjunction with the low-alkali cement. The total alkali content for the cementitious materials combination must not exceed 3.0 pounds per cubic yard of Na_2O equivalent.

(3) Method 3. *ASTM C 1567*. Mortar Bar Test. If no previous test data are available for the fine aggregate that shows it is resistant to ASR using either Method 1 or 2, above, replace 25 to 40 percent of the Portland cement in the concrete mixture with slag cement (Grade 100 minimum) or fly ash. A blended cement meeting the requirements of *ASTM C 595* containing Portland cement and slag cement or fly ash may also be used.

Demonstrate the ability of the fly ash or slag cement to control the deleterious expansion caused by ASR by molding and testing mortar bars according to the standard test method described in *ASTM C 1567* using the mix proportions and

constituent sources for both the aggregates and the cementitious materials that will be used for the project. Make at least three test specimens for each cementitious materials-aggregate combination. If the average of three mortar bars for a given cementitious materials-aggregate combination produces an expansion less than 0.10 percent (rounded to the nearest 0.01 percent) at 14 days of immersion, the JMF associated with that combination will be considered non-deleterious to ASR. If the average expansion is 0.10 percent (rounded to the nearest 0.01 percent) or greater, the JMF associated with that combination will be considered not sufficient to control the deleterious expansion caused by ASR and the JMF will be rejected.

The Engineer will not approve the use of the JMF if the expansion exceeds the respective threshold limits for the respective ASTM test method used.

B. Contractor Provided Mixes. Provide mix design and accompanying JMFs using the methods of verification included in this special provision. Include sufficient information on constituent materials and admixtures along with optimized aggregate gradation analysis (where applicable), trial batch verified physical properties of the fresh concrete, mix proportions per cubic yard for all constituents and compressive strength test results necessary to allow the Engineer to fully evaluate the expected performance of the concrete mixture.

(1) Mix Documentation. Prepare mix designs for each grade of concrete required on the project. Submit JMF for each mix design, including all required documentation, to the Engineer for review 10 working days before the anticipated date of placement. The Engineer will notify the Contractor of any objections within 5 working days of receipt of the mix documentation. Number or otherwise identify each JMF and reference all accompanying documentation to this identification. Reference each JMF to the appropriate method of verification. Mix design and JMF submittals that do not include all required documentation will be considered incomplete and the Engineer will return them without review.

Mix documentation is valid for 2 years.

All mix designs and accompanying JMFs must be traceable to a laboratory meeting the requirements of this special provision.

Submit mix design and JMF on the MDOT Job Mix Formula (JMF) Concrete Field Communication form (MDOT Form Number 1976); include accompanying documentation. List the source of materials, bulk density (unit weight) of coarse aggregate (rodding procedure or shoveling procedure), absorption of aggregates, relative density (specific gravity) of aggregates, aggregate correction factors, batch weights, and project specific or historical laboratory test data. Include the recorded air content of fresh concrete using the same admixture and cementitious material sources to be used in the production of the concrete for the project. A JMF will be approved only if all of the minimum mix design requirements specified in the contract have been met.

(2) Job Mix Formula (JMF). Select proportions for concrete mixtures according to *ACI Standard 211.1*. The bulk volume (dry, loose) of coarse aggregate per unit volume of concrete must be 65 to 75 percent, inclusive. For concrete mixtures using optimized aggregate gradation, the above specified volume of coarse aggregate per unit volume of concrete includes the intermediate aggregate.

Four methods of verification of proposed JMF are acceptable.

(a) Method 1. Trial Batches. Verification of JMF is based on trial batches with the same materials and proportions proposed for use on the project. Prepare at least one trial batch for each mix design in sufficient time before starting concrete placement to allow for review according to subsection c.5.B.(1) of this special provision. Provide the results of temperature, slump, density (unit weight), air content of fresh concrete, 28-day compressive strength, and age of concrete at the time of strength testing, for a minimum of three independent samples. All samples may be taken from a single trial batch for a mix design provided the trial batch is at least four cubic yards in volume. For JMF trial batch verification purposes only, 7-day compressive strength test results which report at least 70 percent of the specified 28-day lower specification limit (LSL) will be sufficient documentation in lieu of 28-day compressive strengths. The average of at least two strength test specimens represents one compressive strength sample test result for each independent sample. Provide the necessary ASR documentation as described in subsection c.5.A of this special provision.

(b) Method 2. Same Mix. Verification of JMF is based on experience with the same mix design, JMF, and the same materials. Provide the results of temperature, slump, density (unit weight) air content of fresh concrete, 28-day compressive strength, and age of concrete at the time of strength testing, for a minimum of three independent samples. The average of at least two strength test specimens represents one compressive strength sample test result for each independent sample. Do not substitute material types or sources, including admixtures or cementitious materials, nor change mix proportions in the JMF. Provide the necessary ASR documentation as described in subsection c.5.A of this special provision.

(c) Method 3. Similar Mix. Verification of the JMF is based on requirements described in method 2, above. Substitution of coarse and intermediate aggregate sources is permitted if the new source is of the same geologic type as the original aggregate, and conforms to the specification requirements for the application. Substitution of fine aggregate is permitted only if the new source has been tested for ASR. Provide the necessary ASR documentation as described in subsection c.5.A of this special provision.

Provide the supporting laboratory trial batch documentation and accompanying calculations showing how the mix proportions in the JMF were adjusted, based on the documented differences in relative density (specific gravity), bulk density (unit weight) and absorption of the substituted aggregate sources, to produce a theoretical yield of 100 percent and the required fresh concrete properties.

(d) Method 4. Annual Verification. At the Engineer's option, verification may be accepted annually for a concrete plant rather than on a project basis provided the sources and proportions of the constituent materials, including cementitious materials and source and types admixtures, do not change. If the project is the continuation of work in progress during the previous construction season and written certification is submitted to the Engineer that materials from the same source and with the same mixture properties are to be used, the Engineer may waive the requirement for annual renewal verification of the JMF for the project.

Provide the necessary ASR documentation as described in subsection c.5.A of this special provision.

C. Department Provided Mixes. Unless otherwise specified in the contract or approved by the Engineer, the Engineer will provide the concrete JMF for the following types of concrete regardless of the total quantity for the project.

(1) Structural concrete patching mixtures, mortar and grout.

(2) Bridge deck overlay concrete mixtures.

(3) Project-specific concrete grades not defined in Table 1.

Provide all other mix designs and accompanying JMF's according to subsection c.5.B of this special provision.

The ASR documentation for the fine aggregate described in subsection c.5.A of this special provision must accompany the Contractor's request for the concrete JMF.

D. Changes in Materials and Proportions. Any change from one approved JMF to another for the same grade of concrete must have prior approval by the Engineer.

Prior to batching, verify that the proposed JMF changes will not affect the properties of the fresh concrete (slump, temperature, air content, density (unit weight), workability), nor result in excessive mortar bar expansion as a result of deleterious reactivity between the aggregates and cementitious materials as described in subsection c.5.A of this special provision.

Resubmittal of a mix design and its accompanying JMF, as described in subsection c.5.B of this special provision, is not required when making adjustments to the aggregate mix proportions included in the approved JMF in order to maintain optimization of the aggregate gradation in accordance with Appendix 1.

Record all changes to JMF in the QC records along with the rationale for the change.

E. QC Sampling and Testing. Conduct startup sampling and testing for temperature, slump, density (unit weight), and air content on the first load. Do not place concrete until testing verifies that the fresh concrete properties have not exceeded the QC action and suspension limit thresholds specified in Table 2. Continue testing subsequent loads as described in the QC plan, for each grade of concrete delivered to the work site each day. Startup or initial sampling and testing will not be eligible for consideration to initiate PWL dispute resolution process. The QC sampling and testing must be independent from the Department's QA sampling and testing.

Provide the curing facilities in accordance with subsection d.2.C of this special provision prior to start of concrete production.

Perform QC sampling and testing of the fresh concrete that is either slipformed or pumped for air content loss, as follows:

(1) At least once during each week of production.

(2) Whenever QC tests have shown that QC action limits have been exceeded.

(3) Whenever the concrete pump is relocated, where applicable.

(4) Whenever there is a significant change in the boom angle of the concrete pump during concrete placement, where applicable.

Sample and test a representative haul unit of concrete immediately after its discharge but before the paver or pump hopper, where applicable. Sample and test the concrete representing the same haul unit, again, after the paver or after discharge from the pump (after vibration), where applicable. If the difference in measured air content between the two test locations for the same concrete is greater than 2.0 percent air by volume of concrete, suspend operations and administer corrective action. Resume concrete placement only after taking the necessary corrective action to reduce the loss in air content of fresh concrete between the two test locations, as approved by the Engineer. Document the corrective action to be taken in the QC records and make the necessary changes to the QC plan, where applicable.

The Contractor's QC and the Department's QA strength test specimens for 28-day compressive strength must be the same size (either 6-inch by 12-inch or 4-inch by 8-inch) for lot dispute resolution consideration. Dispute resolution only applies for PWL quality index analysis.

Independent QC sampling and testing must be conducted on each sublot within a respective production lot in order for the production lot to be considered for dispute resolution.

Concrete exceeding the maximum specification limits for slump or temperature must be rejected regardless of the total mixing time at the time of arrival to the project.

The Engineer may require the Contractor to administer additional QC sampling and testing if the Engineer determines the Contractor's current QC sampling and testing methodology is shown to be insufficient to ensure continual control of the quality of the concrete.

Take the appropriate corrective action, as described in the QC plan, when QC testing shows the QC action limits for any quality characteristic are exceeded. Suspend production if any of the QC suspension limits are exceeded or if the corrective action is not sufficient to restore the quality to acceptable levels.

Resume production only after making all necessary adjustments to bring the mixture into conformance with all applicable specifications and receiving approval to resume work from the Engineer. Document these adjustments in the QC records.

Table 2: QC Action and Suspension Limits

Quality Characteristic	Action Limits	Suspension Limits
Air Content (percent)	See Note Below (a)	< 5.0 or > 8.5
Air Content Loss (percent)	As Defined in the Contractor QC Plan	Greater than 2.0
Conc. Temp. (deg. F)		< 45 or > 90 at time of placement
Slump (max.) (inch)		See Table 1, footnote (g)
Density (unit weight)		N/A
Aggregate Gradation	Appendix 1 for Optimized Aggregate Gradation (for optimized aggregate gradation only)	
a. Action limits to be defined in the Contractor QC Plan and cannot exceed 5.5 to 8.0 inclusive.		

F. Work Progress Test Specimens. Determine the strength of concrete for opening to construction traffic or regular traffic, for removing shoring and forms, or for other similar purposes in accordance with subsections 104.11, 601.03.H, and 701.03.D of the Standard Specifications for Construction, and as approved by the Engineer. Cure work progress test specimens in the same manner as the in-situ concrete. Allow the Engineer to witness testing of work progress test specimens.

For pavement repairs described in section 603 of the Standard Specifications for Construction, the maturity method may be used to determine the in-place, opening-to-traffic flexural strength, provided the necessary preliminary flexural strength versus opening-to-traffic time correlations, using the same materials and JMF, are established and approved by the Engineer before placing the concrete.

G. Reduced QC for Small Incidental Quantities. If approved by the Engineer, reduced levels of on-site QC testing for concrete may be considered for small incidental quantities as defined in subsection a.1 of this special provision.

Unless approved by the Engineer, multiple small incidental quantities, including ones that are consecutively placed throughout the project on the same day, are not eligible for reduced QC consideration if the total plan quantity of concrete for the item exceeds 100 cubic yards in volume. Include details for reduced QC testing and oversight in the approved QC plan, and in accordance with following:

(1) The small incidental quantity of concrete will be limited to a single day's concrete placement of 20 cubic yards in volume.

(2) The small incidental quantity of concrete is not an integral part of a structural load bearing element.

(3) The Engineer received written certification from the Contractor that the concrete supplier has a current QC plan in place and available for review upon request by the Engineer.

(4) The concrete supplier employs a certified concrete technician (MCA Michigan Level II) available at the plant or on call during concrete placement to validate and authorize modifications to the concrete JMF, as necessary.

(5) Prior to the first concreting operation, concrete representing the JMF for the small incidental quantity has been sampled and tested by a certified concrete

technician (MCA Michigan Level I or II) to verify that, historically, the JMF produced a concrete mixture meeting the minimum requirements for density (unit weight), slump, air content, and strength. Annual verification may be acceptable provided there are no changes to the material types or sources, including the cementitious materials and admixtures.

(6) The Engineer verified that the temperature, slump, and air content conform to specification requirements at the start of the day's concreting operation associated with the small incidental quantity.

(7) The Engineer is notified and provided sufficient opportunity to witness concrete placement.

d. Department Administered Quality Assurance (Acceptance).

1. Department Quality Assurance Plan (QA plan). The Engineer will be responsible for administering the quality-based acceptance and will institute any actions necessary toward its successful implementation.

Acceptance of concrete pavement repair mixtures and concrete mixtures not included in Table 1 will be in accordance with the contract.

The Engineer will develop and follow a QA plan. The Engineer will provide the QA plan to the QC Plan Administrator a minimum of 5 working days prior to the pre-production meeting. The QA plan will be reviewed at the pre-production meeting and any proposed changes will be documented.

The nominal QA strength test specimen size, defined in subsection a.1 of this special provision will be noted in the QA plan.

A. Personnel Requirements. The personnel responsible for field inspection and for obtaining QA samples will possess the required qualifications to collect QA samples. Sampling will be performed by a certified concrete technician (MCA Michigan Level I or II) or (MCAT) certified aggregate technician, where applicable.

B. QA Testing Correlation. The testing equipment and associated testing personnel for both the Engineer's QA and Contractor's QC will conduct side by side testing of the same concrete representing the first production lot (or at a greater frequency as directed by the Engineer) for the project to verify correlation of both the Department's and the Contractor's test results for temperature and air content of fresh concrete. Side by side testing correlation must be conducted whenever there is a change in QC or QA equipment and/or personnel for the project. The temperature measuring devices used for QC and QA must correlate relative to each other within 2 degrees F. The Engineer will request an Independent Assurance Test in the event the air content results of two tests conducted between the Department's and the Contractor's testers differ by more than 1.0 percent air by volume of concrete.

C. Laboratory Facilities. The testing laboratory with responsibility for acceptance testing on this project is the Region testing laboratory, or a qualified facility under the authority of the Engineer. Dispute resolution testing for 28-day compressive strength, where applicable, will be conducted at the Department's Central CFS laboratory or an independent *AASHTO* Accredited laboratory facility designated by the Department.

2. QA Sampling and Testing. The Engineer will conduct: daily QA startup sampling and testing of temperature, slump, and air content of fresh concrete; QA sampling and testing; monitoring Contractor adherence to the QC plan; and an inspection of field placed materials in such a manner as to ensure that all concrete for the project is represented. Initial approval of daily QA startup sampling and testing is required prior to concrete placement.

The following *ASTM* test methods will apply. The Department's established procedures for sampling and testing are acceptable alternatives.

C 31 Practice for Making and Curing Concrete Test Specimens in the Field

C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

C 138 Test Method for Density (Unit Weight), Yield and Air Content (Gravimetric) of Concrete

C 143 Test Method for Slump of Hydraulic-Cement Concrete

C 172 Practice for Sampling Freshly Mixed Concrete

C 173 Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 293 Test Method for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading)

A. Lot Size and Make Up. A production lot will not include more than one grade of concrete, concrete of the same grade having different specified slump or air content, or concrete of the same grade having different mix designs, or JMFs. Non-PWL application and small incidental quantities will not be included in PWL production lots.

Consecutively placed concrete mixes where the aggregate proportions were adjusted to maintain an optimized gradation may be included in the same production lot provided they are the same grade and same JMF.

(1) PWL Applications. PWL applies only to pavements for mainline, shoulder, miscellaneous concrete pavement (including ramps), and concrete pavement overlay applications. PWL will not apply for temporary concrete pavement applications. Where applicable, a production lot may consist of a single day’s production. Each production lot will be divided into five approximately equal sublots. At the option of the Engineer, occasional small individual quantities of concrete may be combined with a larger production lot provided they are of the same grade, contain the same JMF, and are used for the same PWL application.

(2) Non-PWL Applications. Non-PWL applies to all concrete placements other than PWL and small incidental quantity applications. Lot size and makeup will be determined by the Engineer, based on site conditions.

(3) Small Incidental Quantities. At the option of the Engineer, daily 28-day compressive strength QA test cylinders for small incidental quantities of concrete, as defined in subsection a.1 of this special provision, may not be required provided QA test cylinders representing the same JMF as the small incidental quantity of concrete were sampled and molded at least once during the same week (see subsection d.2.B of this special provision). Unless approved by the Engineer, multiple small incidental quantities, including ones that are consecutively placed throughout the project on the same day are not eligible for reduced QC consideration if the total plan quantity of concrete for the pay item exceeds 100 cubic yards in volume.

B. Sampling. Except as modified herein, QA sample locations will be determined as described in the "Random Sampling for Quality Control/Quality Assurance Projects" section of the *Materials Quality Assurance Procedures Manual*.

The QA sampling rate and sample location will be based on cubic yard quantities.

Samples will be taken from the concrete at the location as close to its final placement into the forms or on the grade as practical. If sampling from the discharge of the haul unit, the representative sample will be taken from approximately the middle one-third of the load.

Samples for acceptance will not be taken at the concrete production facility (batch plant), nor prior to discharge from a concrete pump (excluding tremie seal placement applications). Mix adjustments to the concrete contained within the haul unit selected for QA sampling and testing (beyond normal QC) will not be permitted prior to QA sampling and testing. QA sampling will be without prior notification.

(1) PWL Applications. The random number method for PWL sampling will be used to determine the sampling locations. A random number will be generated for each respective sublot. The sampling frequency for a production lot is one QA sample per sublot.

(a) Prior to the pre-production meeting, the Engineer will generate a list of random numbers using a computer spreadsheet program or a calculator. The random numbers will be used to designate when QA samples are to be taken, based on cubic yard quantities.

(b) At the pre-production meeting, each page that lists random numbers will be signed by the QC Plan Administrator and the Engineer. Each sheet containing the random numbers will be covered by a separate sheet of paper so as to prevent disclosure of the random numbers.

(c) The original signed list will be placed in the project file and a copy will be provided to the Engineer's field inspector for the project.

(d) When the project is completed, a copy of the list of random numbers will be provided to the Contractor upon request.

If a sublot is not completed in sufficient quantity to permit it to be randomly sampled during its respective production day, as planned, the quantity of concrete for the sublot that was not placed as part of the day's production will be sampled during the following production day according to the original random number sampling protocol. The random sample will then represent the total quantity of concrete for the sublot placed over the respective multiple days of production.

If the quantity of a grade of concrete to be sampled on the last day of production for the project is not sufficient to make up three or more equivalent sublots, combine the test results for these one or two remaining sublots, or fraction thereof, with the previous day's production lot for quality index analysis.

(2) Non-PWL Applications. QA sampling and testing will be conducted by the Engineer during concrete placement. The sampling rate will be approximately one sample per 50 cubic yards, as determined by the Engineer, based on the anticipated total quantity of concrete to be placed and site conditions, with a minimum of one sampling for each day of production.

(3) Small Incidental Quantities. At the option of the Engineer, small incidental quantities as defined in subsection a.1 of this special provision may be accepted (visually inspected and noted on the Inspector's Daily Report) without daily 28-day compressive strength QA test specimens provided there is a current acceptable strength test history of the JMF for the project prior to placement of the small incidental quantity. One set of compressive strength QA test specimens will then be molded for each small incidental quantity JMF at least once per week during production thereafter, as determined by the Engineer (note the test results or identification number for the corresponding weekly QA compressive strength test result on the Inspector's Daily Report for each small incidental quantity). Quality control testing and daily QA testing for temperature, slump, and air content are still required as described in subsection c.5.G of this special provision.

C. Testing. The location(s) within the project limits for QA testing of the fresh concrete and placement of curing facilities for initial curing of the 28-day compressive strength QA test cylinders will be determined by the Engineer in conformance with the following criteria:

(1) The elapsed time between obtaining the first and the final portion of the composite sample must not exceed 15 minutes.

(2) Testing for slump, temperature, and air content of fresh concrete must begin within 5 minutes after obtaining the final portion of the composite sample.

(3) Molding of the 28-day compressive strength QA test cylinders must begin within 15 minutes after obtaining the final portion of the composite sample.

(4) The concrete sample must be protected from the sun, wind, and other sources of rapid evaporation, and from contamination.

Two QA concrete strength test specimens per sample will be molded for 28-day compressive strength QA testing. For PWL applications only, two additional concrete strength test specimens will be molded and cured in the same manner as the QA specimens, to be retained by the Department in the event of dispute resolution. The

dispute resolution QA concrete strength test specimens will be tested by the Engineer only in the event of dispute resolution according to subsection d.6 of this special provision.

The Contractor will provide curing facilities equipped to ensure the proper environment for the Department's QA concrete strength test specimens during initial cure. Each initial cure facility must provide ventilation or insulation, where applicable, to ensure the ambient temperature surrounding the specimens is maintained according to *AASHTO T 23/ASTM C 31*. Failure by the Contractor to maintain the proper curing environment during initial cure will not be basis for rejection of samples, dispute resolution, or claims against the Department. Each initial curing facility must be capable of being locked, using a Department provided padlock. The Contractor will ensure that all initial curing facilities are accounted for at all time, and protected against theft and damage. The Contractor will place and secure each initial cure facility throughout the project limits in such a manner so as to minimize excessive transport of the test specimens prior to initial cure, as follows:

(5) Immediately after finishing molded specimens, the Engineer will move the QA concrete strength test specimens to the closest initial cure facility provided by the Contractor.

(6) Immediately after all QA concrete strength test specimens are placed into the cure facility and the proper initial curing conditions have been established, the Engineer will secure the facility using the Department provided padlock. Access to the QA concrete strength test specimens, thereafter, must be coordinated with the Engineer and will only be permitted in the presence of the Engineer.

(7) The Engineer will transport the QA concrete strength test specimens within 48 hours after molding, but not prior to 8 hours after final set of the concrete, from the initial curing facility to the Department's designated testing laboratory for final curing and strength testing. The specimens will be protected with a suitable cushioning material to prevent damage from jarring during transport. The total transportation time must not exceed 4 hours prior to commencement of final curing.

D. QA Stop Production Criteria. The Engineer will issue a Notice of Non-Compliance with Contract Requirements (Form 1165) and concrete production must stop when one or more of the following are observed.

(1) The QA testing shows that one or more of the suspension limits for quality characteristics defined in Table 2 are in non-compliance.

(2) The QC plan is not being followed.

(3) Segregation, excessive slumping of unsupported slipformed edges, or other notable changes in the fresh concrete properties is observed that may prevent proper placement, consolidation and finishing, or compromise the performance or long-term durability of the finished product.

(4) The required curing system is not being applied in a timely manner, as specified by the contract.

(5) If the measured air content loss between the two testing locations for the same concrete is greater than 2.0 percent air by volume of concrete as described in subsection c.5.E of this special provision.

The Engineer will issue a Notice to Resume Work (Form 1165) only after all necessary adjustments are made to restore conformance with all applicable specifications, and the appropriate documentation is made in the QC records.

E. QA Records. The Engineer will maintain a complete record of all QA tests and inspections. The records will contain, as a minimum, signed originals of all QA test results and raw data, random numbers used (where applicable) and resulting calculations. The QA test results will not be provided to the Contractor until the corresponding QC test results are received by the Engineer.

3. Quality Index Analysis. The Engineer's QA test results will be used to determine the pay factor (PF) and price adjustment (ADJ). The Contractor's QC test results will not be used for pay factor and price adjustment analysis. The Engineer will complete pay factor and price adjustment analysis within 7 working days after completion of all 28-day compressive strength testing for the represented production lot or quantity of concrete.

A. PWL Applications. The PWL, PF and associated ADJ will be determined according to subsection d.4 of this special provision using the MDOT Concrete PWL Worksheet. The AQL, RQL, LSL and USL used in the quality index analysis are shown in Table 3. The Engineer will perform the quality index analysis for all concrete represented by sufficient lot size and makeup necessary for random sampling according to subsections d.2.A and d.2.B of this special provision. All values of PWL, PF, and OLPF in these formulae are percent, not decimal. All values of PWL are rounded to whole numbers. All values of PF and OLPF are rounded to two decimal places.

B. Non-PWL Applications. The PF and associated ADJ will be determined according to subsection d.5 of this special provision. All values of PF and OLPF in these formulae are decimal, not percent. All values of PF and OLPF are rounded to two decimal places.

C. Small Incidental Quantities. Price adjustment will not be applied to small incidental quantities provided the concrete is of acceptable quality and all other provisions are met for the contract item.

Table 3: Quality Index Parameter Specification Limits for PWL Applications

Quality Index Parameters	Grade of Concrete
	P1/P1M
28-Day Compressive Strength	
Specification Limit – Lower (LSL) (psi)	3500
Specification Limit – Upper (USL)	N/A
Acceptable Quality Level (AQL)	95 PWL
Rejectable Quality Level (RQL)	50 PWL
Air Content of Fresh Concrete	
Specification Limit – Lower (LSL) (percent)	5.5
Specification Limit – Upper (USL) (percent)	8.0
Acceptable Quality Level (AQL)	90 PWL
Rejectable Quality Level (RQL)	50 PWL
Suspension Limits (percent)	< 5.0 or > 8.5

4. Pay Factor (PF) Determination and Price Adjustment for Percent Within Limits (PWL) Applications. The MDOT Concrete PWL Worksheet uses the following formulae to calculate the PF and associated ADJ for each production lot. The maximum calculated numerical values for PF and OLPF will not exceed 105.00.

A. Pay Factor for 28-Day Compressive Strength (PF_s). If PWL for 28-day compressive strength (PWL_s) is 95 to 100 inclusive, use the following formula to determine PF_s.

$$PF_s = 5 + PWL_s$$

If PWL_s is 50 to less than 95, use the following formula to determine PF_s.

$$PF_s = 47.22 + (0.5556 \times PWL_s)$$

If PWL_s is less than 50, the production lot is rejectable and the Engineer will require additional evaluation to decide what further action may be warranted as described in subsection d.9 of this special provision.

B. Pay Factor for Air Content of Fresh Concrete (PF_{ac}). If PWL for air content of fresh concrete ($PWL_{\mathbf{ac}}$) is 70 to 100 inclusive, use the following formula to determine $PF_{\mathbf{ac}}$.

$$PF_{ac} = 55 + (0.5 \times PWL_{ac})$$

If $PWL_{\mathbf{ac}}$ is 50 to less than 70, use the following formula to determine $PF_{\mathbf{ac}}$.

$$PF_{ac} = 37.5 + (0.75 \times PWL_{ac})$$

If $PWL_{\mathbf{ac}}$ is less than 50, the Engineer will elect to do one of the following.

(1) Require removal and replacement of the entire production lot with new testing conducted on the replacement concrete and repeat the evaluation procedure.

(2) Provided no individual test results for the production lot are outside the suspension limits for air content specified in Table 2, allow the production lot to remain in place and apply an OLPF of 50.00.

(3) Allow submittal of a corrective action plan for the Engineer's approval. If the Engineer does not approve the plan for corrective action, subsection d.4.B.(1) or d.4.B.(2) of this special provision will be applied. All costs associated with plan submittal and corrective action under this subsection will be borne by the Contractor. Positive ADJ (quality initiative) will not apply for production lots subject to corrective action.

C. Overall Lot Pay Factor (OLPF). The following formulae are used to calculate the OLPF and ADJ. Both pay factors (PF_s and PF_{ac}) must be 100.00, or greater for the production lot to be eligible for positive ADJ (quality initiative) consideration. If either individually calculated pay factor (PF_s or PF_{ac}) is less than 100.00, the maximum value for its companion pay factor (PF_s or PF_{ac}) to be used in the OLPF calculation for the respective production lot will not exceed 100.00.

$$OLPF = (0.60 \times PF_s) + (0.40 \times PF_{ac})$$

$$ADJ = (OLPF-100)(Price)/100$$

ADJ = Price adjustment per pay unit to be applied to the production lot quantity
Price = Original contract unit price bid for the pay item

5. Pay Factor (PF) Determination and Price Adjustment for Non-PWL Applications. Use the following formulae to calculate the PF and associated ADJ for each concrete item. Positive ADJ (quality initiative) does not apply for non-PWL applications. Each individual QA strength sample test result will be used to determine the PF and ADJ for the respective quantity of concrete that it represents, based on the sampling rate described in subsection d.2.B.(2) of this special provision.

The specification limits for non-PWL applications are defined in Table 4. Unless otherwise specified in the contract, concrete not conforming to the requirements specified in Table 4 is rejectable and subject to further evaluation.

Table 4: Quality Index Parameter Specification Limits for Non-PWL Applications

Quality Characteristic	Specification Limits
Air Content of Fresh Concrete (percent)	5.5 – 8.0
Rejection Limit (percent)	<5.0 or >8.5
Conc. Temp. (deg. F)	45 - 90 at time of placement
Slump (max.) (inch)	See Table 1, footnote (g)
28-day Compressive Strength (psi)	For LSL see Table 1
Rejection Limit - Lower 28-day Compressive Strength	See Table 1

A. Pay Factor for 28-Day Compressive Strength (PF_s).

$$PF_s = \frac{\text{Tested Strength}}{\text{LSL}}$$

Where:

PF_s = Pay Factor for 28-day compressive strength (not to exceed 1.00)

Tested Strength = QA 28-day compressive strength sample test result

LSL = Lower specification limit (see Table 1)

If the tested strength does not meet the lower rejection limit specified in Table 1, the Engineer will require additional evaluation as described in subsection d.9 of this special provision.

B. Pay Factor for Air Content of Fresh Concrete (PF_{ac}). The pay factor for air content of fresh concrete (PF_{ac}) will be according to Table 5.

Table 5: Air Content of Fresh Concrete Pay Factor (PF_{ac}) for Non-PWL Applications

Air Content of Fresh Concrete (percent)	Pay Factor (PF_{ac})
5.5 – 8.0	1.00
5.0 – 5.4	0.50
Below 5.0	Rejection
8.1 – 8.5	0.50
Above 8.5	Rejection

If the air content of fresh concrete is below 5.0 or above 8.5 percent, the Engineer will elect to do one of the following.

(1) Require removal and replacement of the entire quantity of concrete represented by the test with new testing conducted on the replacement concrete and repeat the evaluation procedure.

(2) Allow submittal of a corrective action plan for the Engineer's approval. If the Engineer does not approve the plan for corrective action, subsection d.5.B.(1) of this special provision will be applied. All costs associated with plan submittal and corrective action under this subsection will be borne by the Contractor.

C. Overall Lot Pay Factor (OLPF). The following formulae are used to calculate the OLPF and ADJ. The OLPF will not exceed 1.00.

$$OLPF = (0.60 \times PF_s) + (0.40 \times PF_{ac})$$

$$ADJ = (OLPF - 1)(Price)$$

ADJ = Price adjustment per pay unit to be applied to the quantity represented by the QA test

Price = Original contract unit price bid for the pay item

6. Lot Dispute Resolution. Dispute resolution pertains to production lots subject to quality index analysis for PWL applications only. The air content of fresh concrete is not eligible for dispute resolution. The Contractor's 28-day compressive strength QC test results must be submitted to the Engineer, accompanied by a signed statement certifying that the QC test results are true and accurate, prior to the Engineer's release of any QA test results for the respective production lot. The 28-day compressive strength QA test results for a production lot of concrete may be eligible for dispute resolution only if the following criteria are met:

A. The request for dispute resolution testing was submitted by the Contractor in writing within 2 working days of receipt of the results of the quality index analysis for the production lot.

B. Complete records and reports for all QC tests and inspections as described in subsection c.2 of this special provision, including documentation of what action was taken to correct deficient concrete, along with sufficient information and production lot identification to allow the test results to be correlated with the items of work represented, were submitted to the Engineer within 24 hours after the date covered by the records and reports.

C. QC sampling and testing procedures were conducted in the same manner as the Department's QA sampling and testing procedures.

D. The Contractor's QC and Department's QA 28-day compressive strength test specimen for the production lot in dispute are the same nominal size (either 6-inch by 12-inch or 4-inch by 8-inch).

E. The pay factor for 28-day compressive strength (PF_s), as re-calculated by the Engineer using the Contractor's QC test results, is greater than that determined by the Engineer using the QA test results.

F. Each sublot within the respective production lot under dispute is represented by complete QC test results.

G. The QC sampling and testing for the production lot in dispute was conducted by a certified concrete technician (MCA Michigan Level I or II).

H. A current and complete QC plan, for the appropriate items of work, was submitted and approved by the Engineer prior to start of related work.

I. The QC sampling and testing was performed on the same production lot of concrete as the Department's QA sampling and testing, and all associated QC records include the appropriate production lot identification number that coincides with the Engineer's QA production lot identification number.

J. The corresponding Contractor QC and Department QA 28-day compressive strength test specimens for the production lot in dispute were properly secured during initial curing in the curing facility provided and maintained by the Contractor.

K. The QC test results and documentation for aggregate gradation (where applicable), slump, air content of fresh concrete, temperature, and density (unit weight) of the fresh concrete were complete and within specification requirements.

L. The appropriate corrective action was taken in the event QC action limits were exceeded, as described in the QC plan.

M. QC suspension limits for the associated production lot of concrete were not exceeded.

Dispute resolution will not be considered if it is shown that the Contractor QC has not been completed in accordance with the approved QC plan.

If the Engineer determines, based on the above criteria, that further evaluation is not warranted, the ADJ for the production lot will be based on the Engineer's original 28-day compressive strength QA test results.

7. Dispute Resolution Schedule. If the Engineer determines, based on the above criteria, that lot dispute resolution is warranted, the following schedule and testing process will be initiated.

A. The Engineer will document receipt of the request for dispute resolution and will deliver the dispute resolution samples along with the appropriate sample identification submittal forms to the MDOT CFS Central Laboratory for testing within 3 working day of the receipt of the request.

B. The Department's CFS Central laboratory will test all dispute resolution test specimens within 2 working days of their receipt.

C. The 28-day compressive strength (psi) LSL specified in Table 3 will be increased 10 psi for each additional day beyond 28 days after molding of the test specimens associated with the production lot under dispute, up to and including 60 days after molding (32 additional days after 28 days; 320 psi to account for additional strength gain after the 28-day standard curing period).

D. The MDOT CFS Central laboratory will return the dispute resolution test results to the Engineer within 10 working days from receipt of the dispute resolution samples.

8. Dispute Resolution Testing Process.

A. All lot dispute resolution samples will be tested for the production lot under dispute resolution.

B. All dispute resolution test results will replace respective original QA test results.

C. The adjusted LSL described in subsection d.7.C of this special provision will then be used to determine the PWL for the production lot under dispute.

D. The PF_s for the production lot under dispute will be recalculated using the compressive strength test results from the dispute resolution test specimens.

E. If the recalculated lot PF_s is less than or equal to the original corresponding PF_s, the costs for dispute resolution sample testing will be borne by the Contractor.

F. If the recalculated lot PF_s is greater than the original corresponding PF_s, the costs for dispute resolution sample testing will be borne by the Department.

G. The OLPF will then be recalculated using the PF_s from the compressive strength dispute resolution test results and the original corresponding PF_{ac}.

9. Evaluation of Rejectable Concrete. The Engineer will require additional evaluation to decide what further action may be warranted, as described below. Acceptance for air content of fresh concrete will be based on QA test results reported at the time of concrete placement.

If the Engineer determines that non-destructive testing (NDT) is appropriate, this work will be done by the Contractor in the presence of the Engineer within 45 calendar days from concrete placement. All costs associated with this work will be borne by the Contractor. A complete set of non-destructive tests must be conducted (in accordance with the respective standard test method) at a minimum three randomly selected locations. If NDT is used to estimate the in-situ strength, a calibrated relationship between the project JMF under evaluation and the NDT apparatus must have been established prior to NDT testing according to its respective standard test method.

A. PWL Applications. If the quality index analysis for 28-day compressive strength shows that the RQL has not been met (50 PWL, min.) for a production lot (as specified in Table 3) or the lower rejection limit for the individual strength sample test result represented by the rejected sublot within a production lot has not been achieved (as specified in Table 1), the associated concrete will be rejected.

(1) If the results from evaluation of the rejected concrete report that the RQL has been met (50 PWL, min.) for the rejected production lot, or the lower rejection limit for the individual strength sample test result represented by the rejected sublot within a production lot has been achieved, the represented quantity of concrete under evaluation will remain in place and a pay factor for 28-day compressive strength (PF_s) of 50.00 will be applied for overall lot pay factor (OLPF) and price adjustment (ADJ) determinations according to subsection d.4 of this special provision.

(2) If the results from evaluation of the rejected concrete confirm that the RQL has not been met (50 PWL, min.) for the rejected production lot, or the lower rejection limit for the individual strength sample test result represented by the rejected sublot within a production lot has not been achieved, the Engineer will elect to do one of the following:

(a) Require removal and replacement of the entire rejected production lot, or the individual rejected sublot within a production lot, including new initial tests for quality index analysis conducted according to subsection d.3 of this special provision.

(b) Allow the Contractor to submit a plan for corrective action, for the Engineer's approval, to address the disposition of the rejected concrete. If the Engineer does not approve the plan for corrective action, subsection d.9.A.(2).(a) of this special provision will be applied. All costs associated with plan submittal and corrective action under this subsection will be borne by the Contractor.

B. Non-PWL Applications. If the 28-day compressive strength QA test results show that the lower rejection limit (as specified in Table 1) has not been achieved, the quantity of concrete under evaluation will be rejected and the Engineer will require additional evaluation to decide what further action may be warranted.

Propose an evaluation plan and submit it to the Engineer for approval before proceeding. The results from NDT will be used only to decide what further action is required. This determination will be made by the Engineer, as follows:

(1) For non-structural concrete only. If no test result from non-destructive testing falls below the lower specification limit (LSL), the represented quantity of concrete under evaluation will remain in place and a pay factor for 28-day compressive strength (PF_s) of 1.00 will be applied for overall lot pay factor (OLPF) and price adjustment (ADJ) determinations according to subsection d.5 of this special provision.

(2) For structural concrete only. If no test result from non-destructive testing falls below the lower specification limit (LSL), the represented quantity of concrete under evaluation will remain in place and a pay factor for 28-day compressive strength (PF_s) of 0.85 will be applied for overall lot pay factor (OLPF) and price adjustment (ADJ) determinations according to subsection d.5 of this special provison.

(3) If one or more of the non-destructive test results fall below the lower specification limit (LSL), the Engineer may elect to do one of the following:

(a) Require removal and replacement of the entire rejected quantity of concrete, including new initial tests for quality index analysis conducted according to subsection d.3 of this special provision.

(b) Allow the Contractor to submit a plan for corrective action, for the Engineer's approval, to address the disposition of the rejected concrete. If the Engineer does not approve the plan for corrective action, subsection d.9.B.(3).(a) of this special provision will be applied. All costs associated with plan submittal and corrective action under this subsection will be borne by the Contractor.

(c) Allow the in-situ quantity of concrete under evaluation to remain in place and apply a pay factor (PF_s) of 0.50 will be applied for overall lot pay factor (OLPF) and price adjustment (ADJ) determinations according to subsection d.5 of this special provision.

e. Measurement and Payment. Any positive adjustment payment made in connection with this special provision will use the following pay item:

Pay Item	**Pay Unit**
Conc Quality Initiative	Dollar

Conc Quality Initiative is a budgeted amount established in the contract to cover the potential positive ADJ for the pay items associated with the PWL application.

If a price adjustment is made for reasons included in this special provision, that adjustment will be made using the original unit price bid for the specific item. If a contract unit price requires

adjustment for other reasons not described in this special provision, the adjustments will be made using the original unit price and the adjustments will be cumulative.

Separate payment will not be made for providing, implementing, and maintaining an effective QC program. All costs associated with this work will be included in the applicable unit prices for the concrete items. Failure by the Contractor to maintain the proper curing environment during initial cure will not be basis for claim against the Department.

All costs associated with providing, locating, relocating, maintaining, and securing the adequate number of portable initial curing facilities for both the QC and QA strength test specimens will be included in the applicable unit prices for the concrete items. No additional payment will be permitted. The Contractor is responsible for damage, theft, subsequent replacement, and removal after completion of the work for each curing facility used on the project.

APPENDIX 1
FOR
OPTIMIZED AGGREGATE GRADATION

1. Scope.

1.1 This method covers the procedures for determining optimized aggregate gradations for Portland Cement Concrete (PCC).

2. Applicable Documents.

2.1 Michigan Department of Transportation (MDOT) Standard Specifications for Construction.

2.2 *ASTM* and *AASHTO* Standards:

ASTM D 4791 Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

AASHTO T 11 Materials Finer than No. 75 µm (No. 200) Sieve in Mineral Aggregates by Washing

AASHTO T 27 Sieve Analysis of Fine and Coarse Aggregates

AASHTO T 248 Reducing Samples of Aggregate to Testing Size

2.3 *Michigan Test Methods* (MTM):

MTM 107 Sampling Aggregates

MTM 108 Materials Finer than No. 75 µm (No. 200) Sieve in Mineral Aggregates by Washing

MTM 109 Sieve Analysis of Fine, Dense Graded, Open Graded and Coarse Aggregates in the Field

MTM 110 Determining Deleterious and Objectionable Particles in Aggregates

3. Materials.

3.1 Refer to 902.03.C in the Standard Specifications for Construction for coarse, intermediate, and fine aggregate size definitions and physical requirements, except that the maximum Loss by Wash per *MTM 108* for intermediate aggregate is 3.0 percent.

No more than 15 percent of aggregates from a quarried carbonate source may pass the #4 sieve.

Aggregate with a freeze-thaw dilation greater than 0.040 percent retained on the 1/2 inch sieve cannot constitute more than five percent of the total combined aggregate.

3.2 General Aggregate Requirements.

3.2.1 **Aggregate Sources**. A listing of aggregate sources meeting the specified values for freeze-thaw dilation and absorption is available from the Engineer.

3.2.2 **Stockpiles**. The Contractor must provide a detailed stockpile management plan, describing process controls for shipping, handling, and storage of each aggregate (including the use of radial stackers with elevating conveyors) to minimize segregation and contamination, including proposed method(s) for aggregate quality control.

Production mixes can only be produced from stockpiles tested under the Contractor's Quality Control Plan for materials that represent that day's production gradation.

3.2.3 **Preconditioning**. All coarse and intermediate aggregates must be maintained at a minimum of saturated surface-dry condition prior to batching concrete.

3.2.4 **Verification of Physical Requirements**. The Contractor must provide the Engineer with written verification from the aggregate supplier(s) that the coarse, intermediate, and fine aggregates meet the specified physical requirements. Acceptable verification must include records of the supplier's quality control tests and supporting documentation, including most current MDOT freeze thaw test results.

3.3 Aggregate Particle Size Requirements. Maximum aggregate size for each optimized gradation will depend on the minimum concrete pavement thickness and application.

Pavements with a minimum thickness of concrete ≥ 6 inches = 2 inch maximum particle size aggregate

Pavements with a minimum thickness of concrete < 6 inches = 1½ inch maximum particle size aggregate

All other applications = 1½ inch maximum particle size aggregate

4. Procedure.

4.1 Sampling.

4.1.1 Obtain three samples of each individual coarse, intermediate, and fine aggregate using the mini-stockpile method in accordance with *MTM 107*. One mini-stockpile of each individual coarse, intermediate, and fine aggregate can be used to obtain all three samples of each individual coarse, intermediate, and fine aggregate.

Development of the initial Job Mix Formula may utilize historical pit gradations along with the aggregate samples described above.

4.1.2 All sampling must be performed by a Michigan Certified Aggregate Technician (MCAT).

4.2 Mechanical Analysis.

4.2.1 Combine the three samples from each individual coarse and intermediate aggregate and reduce using Method B from *AASHTO T 248*. Combine the three samples from each fine aggregate and reduce using Method C from *AASHTO T 248*. After combining and reducing samples, perform a mechanical analysis on each of the coarse, intermediate and fine aggregate samples in accordance with *AASHTO T 11* and *AASHTO T 27*. Use the following nest of sieves for the mechanical analysis:

2 inch, 1½ inch, 1 inch, 3/4 inch, 1/2 inch, 3/8 inch, No.4, No. 8, No. 16, No. 30, No. 50, and No. 100

4.2.2 All mechanical analyses must be performed by a Michigan Certified Aggregate Technician (MCAT).

4.3 Use the gradations for each of the coarse, intermediate, and fine aggregates as determined in sections 4.1 and 4.2 of this Appendix for all calculations described in section 4.4 of this Appendix.

4.4 Determination of Optimum Aggregate Proportions.

4.4.1 Combining Aggregate Gradations. Multiply the relative percentage for each classification of individual aggregate by the percent passing for each respective sieve. Add the resulting values based on each sieve size, for all aggregate classifications and divide by 100.

Note: "Relative Percentage" is the percent that each individual aggregate classification represents of the total combined aggregate blend. The sum of the relative percentages must equal 100 percent.

$$P = \frac{C(c) + I(i) + F(f)}{100}$$

P = Theoretical combined percent passing of a given sieve
C,I,F = Percent passing given sieve for Coarse, Intermediate, and Fine aggregate classification, respectively.
c,i,f = Relative percentage of total aggregate content.

Example from Appendix 1-Table 1:

Theoretical combined percent passing the ½ inch sieve ($P_{1/2\ inch}$)

$$P_{1/2\ inch} = \frac{35(51.0) + 100(8.0) + 100(41.0)}{100} = 66.9\%\ passing$$

Convert the theoretical combined gradation percent passing to the theoretical combined gradation percent retained by subtracting the theoretical combined percent passing on the top sieve from 100. The theoretical combined gradation percent retained for each subsequent sieve is then calculated by subtracting its respective theoretical combined gradation percent passing from the preceding larger sieve's theoretical combined gradation percent passing.

This procedure may require a number of iterations to determine the desired proportion for each course, intermediate, and fine aggregate in efforts to produce an optimized combined gradation that meets the requirements for the project. There are software programs available to assist in the process.

Appendix 1-Table 1: Example of Combining Aggregate Gradations

	Aggregate Classification				
Sieve	Coarse Aggregate	Intermediate Aggregate	Fine Aggregate	Theoretical Combined Gradation %Passing	Theoretical Combined Gradation %Retained
Relative Percent	51.0	8.0	41.0		
	Percent Passing				
2 inch	100	100	100	100.0	0.0
1½ inch	100	100	100	100.0	0.0
1 inch	83	100	100	91.3	8.7
¾ inch	65	100	100	82.2	9.2
½ inch	35	100	100	66.9	15.3
⅜ inch	14	100	100	56.1	10.7
No. 4	2.1	33	96	43.1	13.1
No. 8	0.9	2.8	82	34.3	8.8
No. 16	0.8	2.3	63	26.4	7.9
No. 30	0.7	1.8	37	15.7	10.8
No. 50	0.5	1.2	9.4	4.2	11.5
No. 100	0.4	0.7	1.0	0.7	3.5

4.4.1.1 Additional Requirements. The following conditions must also be met by the optimized aggregate blend.

4.4.1.1.1 The maximum theoretical combined gradation percent retained on a single sieve must be on a sieve larger than the ⅜ inch sieve.

4.4.1.1.2 The maximum theoretical combined gradation percent retained value must be equal to or greater than the theoretical combined gradation percent retained on any sieve smaller than the ½ inch sieve.

4.4.1.1.3 The sum of the theoretical combined gradation percent retained on any two adjacent sieves must be at least 13 percent, except for the maximum sieve size, nominal maximum sieve*, No. 100, and No. 200 sieves.

4.4.1.1.4 The theoretical combined gradation percent retained must be at least five percent for each sieve, except for the maximum sieve size, nominal maximum sieve*****, No. 100, and No. 200 sieves, and at least eight percent retained on the 1 inch sieve for optimized blends with 2 inch maximum size aggregate or at least five percent retained on the

¾ inch sieve for optimized blends with 1½ inch maximum size aggregate.

*****The nominal maximum sieve is the 1½ inch sieve for an aggregate with a 2 inch maximum size and the 1 inch sieve for an aggregate with a 1½ inch maximum size.

4.4.2 Coarseness Factor. Use the optimized aggregate blend and the following formula to calculate a Coarseness Factor (CF).

$$CF = \frac{[\text{combined \% retained on } {}^{3}/_{8} \text{ inch sieve and above}]}{[\text{combined \% retained on No.8 sieve and above}]} \times 100$$

Example (see Appendix 1-Table 1):

$$CF = \frac{10.7+15.3+9.2+8.7}{8.8+13.1+10.7+15.3+9.2+8.7} \times 100 = 66.7 \approx 67$$

4.4.3 Workability Factor. Use the optimized aggregate blend and the following formula to calculate a Workability Factor (WF).

WF***** = Combined % Passing No.8 Sieve

Example (see Appendix 1-Table 1):

WF = 34.3 ≈ 34

*****Increase the calculated WF by 2.5 percent for each increase of 94 pounds of cementitious material over 564 pounds per cubic yard.

4.4.4 CF vs. WF Chart. Plot the coarseness factor vs. workability factor (CF calculated in 4.4.2 and the WF calculated in 4.4.3) on the CF vs WF chart (see Figure 1).

4.4.4.1 Job Mix Formula (JMF) Zone. The Contractor's initial proposed optimized aggregate gradation to be used in production, as submitted to the Engineer in the Initial Mix Design, must plot within the Job Mix Formula Zone Boundary of the CF vs WF chart (see Figure 1).

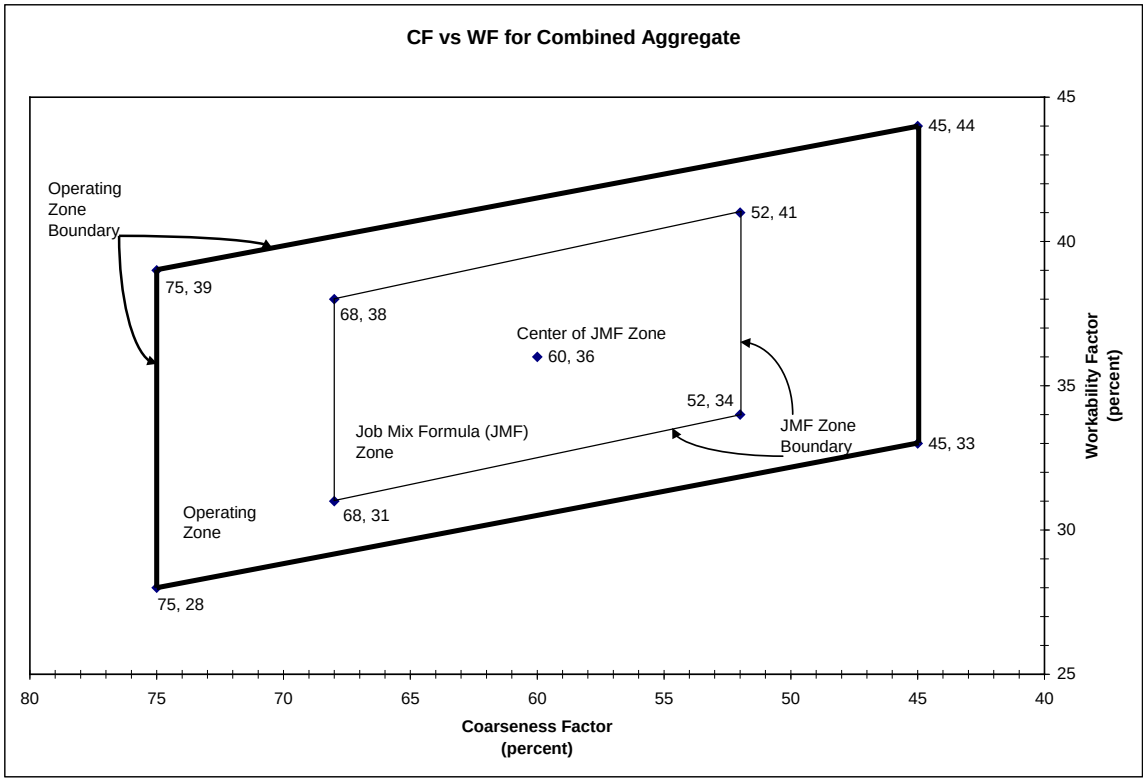
4.4.4.2 Operating Zone. The Contractor must not use an optimized aggregate gradation for production that plots outside of the Operating Zone Boundary of the CF vs WF chart (see Figure 1).

4.4.5 Loss by Wash (LBW). The combined aggregate gradation must not have a loss by wash (*MTM 108*; percent passing No. 200) of greater than 2.0 percent based on dry weight.

4.4.6 Finalized Combined Gradation Report. The Contractor must submit to the Engineer a report containing the individual gradation analysis report for each

course, intermediate, and fine aggregate, and the Combined Aggregate Gradation documentation (see Appendix 1-Table 1) and corresponding Coarseness Factor and Workability Factor charts (see Figure 1) with each Job Mix Formula for the Engineers approval prior to concrete production.

Figure 1: CF vs WF Chart



5. Process Control During Concrete Production.

5.1 Production Gradation. A Production Gradation is a combined aggregate gradation (described in section 4 of this appendix) that is used during concrete production.

Produce aggregate batch weights to reflect most current Production Gradation results.

5.1.1 The Contractor must produce one Production Gradation prior to initial startup and one randomly during each subsequent day of production thereafter that represents materials to be used during the next day's production. When approved by the Engineer, projects using 20 cubic yards or less of concrete per day for elements other than bridge decks may reduce the Production Gradation frequency to one per week of production. Each of these Production Gradations must be performed and completed, including aggregate proportion adjustments, to ensure that the CF vs WF will plot within the Action Limits Boundary (see subsection 5.2 of this appendix) prior to concrete production.

5.1.2 The Contractor must provide a Production Gradation Report verifying the completion, and results, of a Production Gradation to the Engineer prior to any production for that day. The Contractor must also provide a Production Gradation Report to the Engineer for any additional Production Gradation performed under the Contractor's Quality Control (see subsection 6.1.1.2 of this appendix).

5.1.2.1 The Production Gradation Report must include, but is not limited to, the following:

5.1.2.1.1 Contract Number (Control Section/Job Number).

5.1.2.1.2 Name of Contractor.

5.1.2.1.3 Date of Sampling and Testing and date test represents.

5.1.2.1.4 Individual aggregate gradations.

5.1.2.1.5 Combined aggregate gradations including the Theoretical Combined Gradation Percent Retained for each sieve (see Appendix 1-Table 1).

5.1.2.1.6 Optimized aggregate proportions – report in relative percentages and resulting batch weights.

5.1.2.1.7 CF and WF calculations.

5.1.2.1.8 Signed by a responsible representative of the Contractor.

5.2 Corrective Action Limits. Action Limits will be determined and documented by the Contractor in the Quality Control Plan. Action Limits must not extend beyond the Operating Zone Boundary described in 4.4.4.2 of this appendix (see Figure 2). Any Production Gradation (5.1 of this appendix) that plots outside of the Action Limits will require the Contractor to perform all necessary corrective actions detailed in the Quality Control Plan (see subsection 6.1.1.3 of this appendix) to return to within the documented Action Limits Boundary. The Contractor must notify the Engineer whenever the process approaches an action limit.

5.3 Suspension of Work Limits.

5.3.1 The Contractor must stop production and perform all necessary corrective actions detailed in the Quality Control Plan (see subsection 6.1.1.3 of this appendix) to return to within the documented Action Limits Boundary if any Production Gradation (5.1 of this appendix) has a plotted CF vs WF value that is outside the Operating Zone Boundary described in 4.4.4.2 of this appendix.

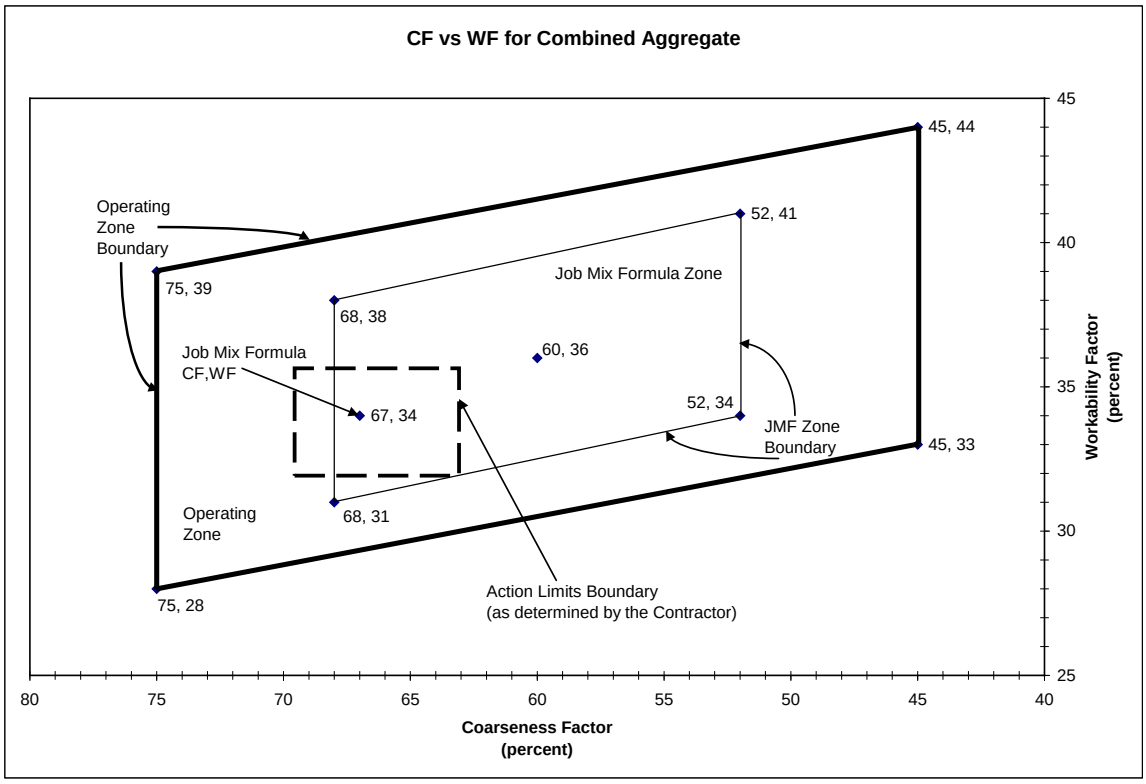
The Contractor must notify the Engineer whenever the process approaches a Suspension Limit.

After corrective action has been performed, a new Production Gradation (5.1 of this appendix) must be established to verify that the corrective actions were successful. Production will not be allowed to continue until a new Production

Gradation (5.1 of this appendix) results in a CF vs WF that plots within the Action Limits Boundary. This new Production Gradation (5.1 of this appendix) must then be used for process control and a new Production Gradation Report must be given to the Engineer.

5.3.2 The Contractor must stop production, perform all necessary corrective actions detailed in the Quality Control Plan (see subsection 6.1.1.3 of this appendix), and notify the Engineer and Region Materials Supervisor if any combined individual gradation (see 4.1 and 4.2 of this appendix) does not meet the requirements described in section 7 of this appendix. Resume production only after receiving a Notice to Resume Work (Form 1165) from the Engineer.

Figure 2: CF vs WF with Action Limits



6. Quality Control for Optimized Aggregate Gradation.

6.1 Quality Control Plan.

6.1.1 Elements of the Plan. The plan must address all elements that affect the quality of the aggregate, including but not limited to, the following:

6.1.1.1 Stockpile management (see subsection 3.2.2 of this appendix).

6.1.1.2 The frequency of sampling and testing including additional Production Gradation beyond the minimum required in subsection 5.1.1 of this appendix.

6.1.1.3 Corrective Actions.

6.1.1.3.1 Corrective actions to be taken when CF vs WF is outside of Action Limits Boundary.

6.1.1.3.2 Corrective actions to be taken when CF vs WF is outside of Operating Zone Boundary.

6.1.1.3.2 Corrective actions to be taken when an averaged gradation is non-compliant with section 7 of this appendix.

6.1.1.4 Methods for verifying Production Gradations.

6.2 Documentation. The Contractor must maintain records of all inspections and tests. The records must indicate the nature and number of observations made, the number and type of deficiencies found, the quantities represented by the test, and any corrective action taken. Copies must be submitted to the Engineer as work progresses.

6.2.1 A control chart and running tabulation of individual test results must be prepared for the following tests. These must be available to the Engineer at any time and submitted to the Engineer weekly in a format acceptable to the Engineer.

6.2.1.1 Gradations for both individual and combined aggregates.

6.2.1.2 Moisture content of aggregates.

6.2.1.3 Coarseness Factor.

6.2.1.4 Workability Factor.

6.2.2 Submit within 24 hours of sampling a copy of all documentation for each Production Gradation to the Engineer; including a copy of the respective Production Gradation Report (see subsection 5.1.2 of this appendix). Report coarse, intermediate, and fine aggregate proportions from each Production Gradation in relative percentage and resulting batch weights for each aggregate. Attach a copy of all respective concrete production batch tickets to the documentation for each Production Gradation.

6.3 Non-Compliant Materials. The Contractor must establish and maintain an effective and positive system for controlling non-compliant materials, including procedures for their identification, isolation and disposal. Reclaiming or reworking of non-complying materials must be in accordance with procedures acceptable to the Engineer.

All non-compliant materials and products must be separated and clearly identified to prevent use, shipment, and contamination with conforming materials.

The Contractor must take prompt action to correct and document conditions that have resulted, or could result, in the incorporation of non-compliant materials and update the Quality Control plan if necessary.

6.4 All sampling and testing performed under the Contractor's Quality Control Plan for optimized aggregate gradation must be performed by a Michigan Certified Aggregate Technician (MCAT). Each quality control person performing quality control sampling of aggregates on the project will be required to demonstrate to MCAT certified Department personnel proper sampling of course, intermediate and fine aggregate prior to batching concrete. The sampling will be done according to *MTM 107* using the mini-stockpile procedure.

7. Aggregate Physical Properties Reports.

7.1 Prior to the pre-production meeting, the Contractor must submit test reports from the aggregate producer verifying that the aggregates meet the physical requirements of this appendix. The reports must include, but are not limited to:

7.1.1 Coarse Aggregate:

- Freeze-thaw Report (MDOT report)
- Flat and Elongation Report (Aggregate Producer report)
- Mechanical Analysis (Aggregate Producer report)
  - Includes Gradation, Loss By Wash and Deleterious results.
  - Deleterious results will include at least the following: Soft Particles %, Chert Particles %, Sum of Soft and Chert %, sum of Coke and Coal %, and Clay-Ironstone %.

7.1.2 Intermediate Aggregate:

- Freeze-thaw Report (MDOT report)
- Mechanical Analysis (Aggregate Producer report)
  - Includes Gradation, Loss By Wash, and Deleterious results
  - Deleterious results include at least the following: Soft Particles %, Chert Particles %, Sum of Soft and Chert %, sum of Coke and Coal %, and Clay-Ironstone %.

7.1.3 Fine Aggregate:

- Organic Impurities results (Aggregate Producer report)
- Mechanical Analysis (Aggregate Producer report)
  - Includes Gradation, Loss By Wash, and Fineness Modulus

8. Acceptance.

8.1 Acceptance of the coarse, intermediate and fine aggregates will be conducted in accordance with the *Michigan Quality Assurance Procedures Manual*, except for the following:

8.1.1 The minimum sampling and testing frequency for each individual aggregate will be one per 5,000 tons (one per project for projects less than 5,000 tons).

8.1.2 Sampling for acceptance will be taken from aggregate stockpiles located at the concrete batching facility on a per project basis. Sampling will be taken using the mini-stockpile method in accordance with *MTM 107*.

8.1.3 The Department will perform a mechanical analysis for each individual aggregate in accordance with *MTM 108* and *MTM 109* utilizing the sieve nest listed in subsection 4.2.1 of this appendix.

8.1.3.1 The Department will verify the Loss by Wash of each aggregate based on the results included in the aggregate physical properties reports described in section 7 of this appendix.

8.1.3.2 The Department will verify the ability of the aggregates to be optimized. The mechanical analysis generated from the acceptance tests for each individual aggregate will be combined as described in subsection 4.4 of this appendix. The relative percentage for each classification of individual aggregate will be the actual relative percentages used during concrete production at the time the acceptance samples were obtained by the Department, as documented by the Contractor generated Production Gradation report. Acceptance will be based on the ability of the combined aggregate gradation to plot within the Operating Zone Boundary of the CF vs WF chart described in subsection 4.4.4.2 of this appendix.