

835 QMP - Concrete

835.1 Concrete Pavement and Concrete Structures

835.1.1 Quality Control Plan

The quality control plan must be produced and submitted according to the provision.

835.1.2 Contractor Concrete Mix Design

The contractor is responsible for providing the design of the concrete mixture for use on the project and for any necessary adjustments during production. A mix design may be a new design, or one used on a previous project. New mixtures are those that use different material sources or quantities than a previously used mix.

A PCC Technician II, hired or employed by the contractor, is required to develop and submit the mix design report to the engineer before the production of concrete for the project. The mix design must meet the conditions specified in the QMP provision. The report can include a number of different mix designs, but each mix design is required to have supporting laboratory or field test results. Multiple mix designs will enable using the most appropriate mix on a project, for given conditions. The contractor must complete department worksheet [WS5014](#), Concrete Mix Design, and submit to the engineer. The engineer's signature verifies that the engineer had an opportunity to review the mix design.

A mix design may be transferred from one project to another if the quality control and verification test results verify consistent, acceptable performance. To be used on a new project, a transferred mix should contain the same materials and proportions as that used on the previous project. The contractor should submit a written and signed request for transfer of a mix design. The written request must certify that the source and characteristics of the materials have not changed since the original mix design was issued. All supporting documentation should be included with the request. This includes a summary of the quality control and verification test results from the previous project(s).

With the initial use of a mixture in a production capacity, it is the contractor's responsibility to test the properties of the mixture in a trial batch before mass production. Trial mixtures must use the same materials proposed for the work. When necessary, minor adjustments may be made to a mix formula. The adjustments should be determined from the quality control test results. The adjusted mix formula must meet the conditions specified of the mix design in the QMP provision.

A copy of the mix design must be made available to all the interested project parties (i.e. engineer, contractor, QC Technician, QA Technician, and Independent Assurance Technician). For concrete structures, fly ash or slag is required to be used as a partial replacement for portland cement. Use the appropriate materials and proportions as specified in the provision. For concrete pavement, fly ash or slag may be used as a partial replacement for portland cement concrete. Use the appropriate materials and proportions as specified in the provision.

835.1.3 Concrete Plants

Plant start up includes calibration of the plant and testing equipment. Before production, the contractor should inspect the plant and test equipment. The engineer may choose to waive his inspection based on the results of the contractor's report.

In addition, the concrete producer is required to record the quantity of the materials used in each batch. The contractor is required to measure, monitor, and record the addition of materials to the mix after discharge from the plant.

835.1.4 Aggregate Sampling & Testing

Aggregate gradation sampling and testing must be performed according to the QMP provision.

835.1.4.1 Combined Gradation

A combined aggregate gradation analysis should only be conducted on samples collected during the production of concrete. This analysis is performed using the as-batched aggregate proportions for a production load of concrete. The batch proportions used for the analysis should be recorded from the plant at the time the aggregate samples are collected from the working faces of the stockpiles. After performing gradation testing for each aggregate sample, the combined aggregate gradation is calculated according to the form instructions. Record project data on department worksheet [WS3012](#), Combined Concrete Aggregate Gradation.

835.1.4.2 Specification Limits

Lower and upper (specification) limits for the combined gradation should be calculated as follows:

1. Determine the as-batched fractional portion of each aggregate gradation, by dividing the weight of the aggregate gradation by the weight of the total aggregate used in the batch.

2. For each gradation control sieve, multiply the upper and lower specification limits for each gradation by the fractional portion of that aggregate being used.
3. For each control sieve, add the resultant products, from step 2, for each aggregate's fractional upper specification limit and lower specification limit.

The specification part of the calculation sheet (lower part) will remain fixed unless a change is made in the aggregate proportioning. In which case, it will be necessary to re-calculate the specification limits.

835.1.4.3 Analysis of Combined Gradation Data

The data resulting from the combined gradation analysis is used by the QC personnel to evaluate the mixture quality and for control chart plotting. Analysis should be conducted as follows.

First, complete [WS3012](#) and determine the specification limits, by summarizing the principle gradations and performing the indicated calculations for the percent total retained and percent between sieves.

The Aggregate Gradation Chart is used as a visual of where the combined gradation lies within the specification limits. If any blend changes are made the control chart running average values will start over.

The provision requires the contractor to notify the engineer of adjustments made in the batching process. While movement within the specification envelope will be allowed to benefit the contractor's use of aggregate, any blend change resulting in a combined gradation outside the established envelope will constitute a significant adjustment to the mixture design. These adjustments will require approval of the engineer and re-establishment of the specification limits, following the previously outlined procedures.

The gradation summary table and the aggregate gradation chart are intended to help the contractor make quality control decisions.

835.1.4.4 Aggregate Moisture and P200 Testing

During concrete production for pavement and structures, P200 tests are required. In addition, moisture content tests and Water cementitious ratio (W/Cm) calculations are required for class I structures concrete. Use department worksheet [WS3010](#) "Worksheet for Calculating: Aggregate Moisture Content, Combined % Passing #200 Sieve, and Water/Cementitious Ratio" to calculate moisture content and combined P200. The quantities used must reflect a specific batch of concrete (not mix design quantities); therefore, as aggregate samples are collected the technician must also obtain current batch quantities.

835.1.5 Concrete Testing

835.1.5.1 Materials Reporting System

The contractor submits mix information and test results for concrete pavement and concrete structures using the department's Materials Reporting System (MRS) software available on the department's web site at:

<http://www.atwoodsystems.com/>

835.1.5.2 Water Cementitious Ratio

Water cementitious ratio (W/Cm) is an indicator of concrete quality. High water contents result in lower strength. W/Cm below 0.42 is desirable.

The W/Cm is calculated according to the formula below. Quantities used must reflect target batch weights for production concrete; therefore, when an individual aggregate moisture content changes significantly, the technician must also obtain current target batch quantities and adjust the target batch weights to maintain the design W/Cm. If using mobile transit mixer trucks, be sure that the technician includes the water added on-site to the mix drum.

$$\text{Water Cementitious Ratio} = \frac{\text{Weight of Net Water}}{\text{Weight of Total Cementitious Material}}$$

$$W/Cm = \frac{MW + \sum AFM}{C + ASH + SLAG}$$

Where:

$$\sum AFM = AFM_1 + AFM_2 + AFM_3 + \dots + AFM_n$$

AFM = the weight of free moisture contributed by each aggregate

W/Cm = ratio of water to cementitious material

MW = the weight of mix water added to the batch

C = weight of cement
ASH = weight of fly ash
SLAG = weight of slag

**For the weight of free moisture
contributed by each aggregate,
AFM:**

$$AFM = W_{\text{Batch}} \frac{TM - AC}{1 + TM}$$

Where:

WBatch = the batch weight of the aggregate at field moisture;
TM = percent of total moisture of the aggregate expressed as a decimal fraction based on oven dry weight;
AC = percent absorption of the aggregate expressed as a decimal fraction based on oven dry weight.

In order to make this information useful to the batch operator, timely results are necessary. Work should begin immediately after the samples are collected and results should be shared as soon as they are available.

835.1.5.3 Concrete Pavement Lots & Sublots

The contractor must define lot and subplot locations before placing any QMP concrete. Lots and sublots may contain concrete placed on more than one day of paving. A mainline subplot is 1000 lane feet in size. Therefore, depending on the paving operation, a subplot will be 500 linear feet for 2 lanes being paved simultaneously, or 1000 linear feet if the paving operation is one lane wide. For non-mainline surfaces a subplot is a maximum of 250 cubic yards.

Lots will consist of a maximum of 8 sublots and contain material from a single mix design. If a lot contains less than 4 sublots, there is not enough information to establish a meaningful percent within limits (PWL) statistic, and therefore there is no opportunity for the contractor to earn a strength incentive for that lot.

835.1.5.4 Concrete Structures Lots & Sublot

The contractor must define all lots on the project before placing any QMP concrete. The contractor may need to adjust the planned lot sizes and locations to match the actual construction operations. These adjustments are allowable if they do not introduce bias.

The contractor must define lots that do not exceed 500 CY of material from a single mix design. Each lot must be divided into sublots that do not exceed 50 CY. If a lot contains less than 4 sublots, there is not enough information to establish a meaningful percent within limits (PWL) statistic, and therefore there is no opportunity for the contractor to earn a strength incentive for that lot.

The contractor should try to create lots that logically correspond to their construction operations.

Encourage the contractor to define smaller lots if the work is spread out over time or if a number of smaller individual components are being constructed. Within each lot, the contractor should try to designate sublots that are all about the same size. Each subplot, however, is weighted by its volume for pay determination.

Contractors will usually prefer to do the minimum required testing. Remind the contractor that under a statistical specification, it may be in their interest to define their lots and sublots rationally to reduce potential variability.

Examples:

1. A series of bridge footings is poured in a day. These footings contain 40 CY of material. For this pour, the contractor may want to create one subplot to represent the concrete that is placed on that day.
2. A 700 CY deck is planned. This pour requires at least two lots. The contractor may want to divide the pour into two lots of 350 CY each and subdivide each lot into 7 sublots of 50 CY each.
3. A small project contains two 35 CY abutments and an 80 CY deck. Since the total quantity of concrete under the Concrete Masonry Bridges bid item for the project is 150 CY, "small quantity" provisions apply.

Here the contractor is instructed in the special provision to divide the project into at least 3 approximately uniformly sized sublots.

If the contractor wants the benefit of a full statistical analysis and a possible strength incentive, they must create 4 or more sublots. In this example, it may make sense to define two 35 CY sublots for the abutment work and two 40 CY sublots for the deck.

835.1.5.5 Slump

Slump test results must be documented with appropriate sample identification information on a copy of the Air Content Control Chart.

835.1.5.6 Temperature

High concrete temperatures result in fast hydration of the concrete and can result in shrinkage cracking and low strengths. Temperature data must be recorded on a copy of the Air Content Control Chart.

835.1.5.7 Air Content

The contractor plots air content data using the department's MRS software.

835.1.5.8 Compressive Strength

The contractor QC staff is responsible for fabrication, curing, and strength testing for standard-cured cylinders required under the QMP. These cylinders are independent of the field-cured opening strength cylinders that the contractor casts and breaks to determine when to remove forms, falsework, or open to service.

835.1.5.9 Fabricating & Curing Cylinders

The contractor QC staff fabricates, cures, and tests cylinders to determine the 28-day compressive strength for each subplot. A set of three 6X12 inch QC cylinders is required. The contractor selects 2 of the 3 QC cylinders at random and breaks them. If the breaking strengths are close to the same, the average strength of those 2 cylinders defines the subplot strength. If the 2 breaking strengths are significantly different, the contractor breaks the third QC cylinder and determines the subplot strength as the average of the 2 highest strength cylinders.

The contractor records cylinder fabrication data using the department's MRS software.

Care should be taken during casting, curing, transporting, and breaking cylinders to avoid anything that might bias the strength results. If vibrating cylinders, the technician should take particular care to avoid over-vibration that can cause segregation and lower strength. Although poor technique generally gives inconsistent and lower compressive strengths, which will hurt the contractor, some irregularities may benefit the contractor.

All HTCP certified technicians are trained to follow the same standard procedures. The department's independent assurance staff is charged with monitoring all project testing, whether by the contractor, the department, or a consultant, to make sure that those standard procedures are followed.

835.1.5.9.1 Strength Test Results

The 28-day strength is the benchmark strength the department uses for design, to measure the concrete quality, and to determine incentive/disincentive pay adjustment. The average strength of the 2 QMP cylinders from each subplot defines the 28-day compressive strength for that subplot.

835.1.5.9.2 Pay Adjustment for Strength

The department determines a pay adjustment for 28-day compressive strength. For lots with less than 4 sublots, each subplot is evaluated individually. For lots with 4 or more sublots a statistical analysis is done to determine a lot-by-lot pay adjustment. After verifying the contractor's data, the department calculates pay adjustments using the department's MRS software. The contractor must submit the required strength test information electronically using the MRS software available at:

<http://www.atwoodsystems.com/>

The department administers incentives and disincentives under different items. The unit for both items is dollars. The engineer should always use these items for pay adjustment. On smaller jobs, there may be a single pay adjustment done for the entire project. On larger projects pay adjustments may be issued with progress payments.

The incentive items are included in the contract schedule of items as predetermined prices fixed at bidding. The fixed costs for the items are estimated at 60% of the maximum available incentives for the project. These items allow the engineer to pay incentives without a construction change order. Because a contractor can earn 0% to 100% of the maximum strength incentives attainable for the project and the contract bid items were at 60% of the maximum attainable, a project can result in more or less pay for the compressive strength incentives.

The disincentive items are administrative items included in the Field Manager reference files to allow the engineer to assess disincentives but require the addition of the administrative items by change order.

835.1.5.9.3 Pay Adjustment for Small Lots (less than 4 sublots)

The contractor is free to establish lots with less than 4 sublots. With 4 sublots a statistical analysis is still meaningful, but with less than 4 sublots it is of questionable value. The department calculates the pay adjustment for a lot with less than 4 sublots by treating each subplot individually. Sublots with average subplot strength greater than or equal to the specification limit receive no adjustment. Sublots with an average subplot strength less than the specification limit receive a disincentive.

835.1.5.9.4 Statistical Pay Adjustment (4 or more sublots)

The department calculates the pay adjustment for a lot with 4 or more sublots using a percent within limits analysis (PWL) based on lot statistics, the lot mean strength, and the lot sample standard deviation.

Only those lots with a standard deviation below a specified threshold are eligible for incentive payment. The lower quality index, how many standard deviations the lot mean is above the specification limit, is calculated and used to determine the PWL for a given sample size. The resultant PWL is applied to a pay equation to determine the appropriate pay adjustment for the lot.

The basis for the analysis is the subplot average strength, the average of 2 QC cylinders for each subplot. Weighted lot statistics are developed from the set of subplot average strengths as follows:

LOT MEAN:

Where:

$$X = \frac{C_1 w_1 + C_2 w_2 + C_3 w_3 + \dots + C_n w_n}{W}$$

X = lot mean

C = subplot average strength for each subplot

w = subplot weighting factor (subplot size)

W = Sum of weighting factors (lot size)

LOT STANDARD DEVIATION:

$$S_n = \sqrt{\frac{(C_1 - X)^2 w_1 + (C_2 - X)^2 w_2 + \dots + (C_n - X)^2 w_n}{(n - 1)W \div n}}$$

Where:

Sn = lot standard deviation

C = subplot average strength for each subplot

X = lot mean

w = subplot weighting factor (subplot size)

W = Sum of weighting factors (lot size)

n = number of sublots in lot

LOWER QUALITY INDEX:

$$Q_L = \frac{X - L}{S_n}$$

Where:

QL = lower quality index

X = lot mean

L = specification limit

Sn = lot standard deviation

835.1.5.9.5 Additional Payment Considerations

Special circumstances may require the engineer to modify the pay adjustment using the MRS software.

Material that is represented by out-of-spec test results is not eligible for incentive payment. The engineer must deduct the appropriate amount from the lot pay adjustment that the MRS calculates. Testing frequencies for those other properties (aggregate gradation, P200, air content, slump, and concrete temperature) may not correspond to the strength sublots. The engineer should note what additional adjustments were made and how the quantity was determined using the MRS software "redlining tools."

835.1.6 Department Testing

Verification and independent assurance sampling and testing will be performed by the department or a department representative as described in the provision. Sampling and testing will be performed by an HTCP certified technician.

835.1.6.1 Verification Testing

Verification testing is performed by a department representative on samples collected independently of the contractor's samples according to the provision. Testing of the material is conducted in a separate laboratory and with separate equipment from the contractor's tests. The fabrication, curing, and strength testing of QV cylinders will follow the same procedures specified for QC cylinders.

835.1.6.2 Independent Assurance Review

Independent assurance reviews are conducted by a department representative according to the provision and the department's Independent Assurance Program. These reviews are made of the contractor's quality control and the department's verification sampling and testing equipment and personnel.

835.2 Ancillary Concrete

835.2.1 Acceptance by Certification

According to the provision, certain ancillary concrete items can be accepted based on a contractor's certificate of compliance. Not all ancillary concrete items can be accepted with this method. An example certificate of compliance is shown in figure 835-1.

835.2.2 Concrete Mix Design

The contractor may elect to use a concrete mix from standard spec 501 or, where one of the grade A mixes is allowed under [standard spec 501.3.1](#), an approved QMP mix design for concrete pavement or structural concrete from the current contract may be used.

835.2.3 QC Documentation

Document all observations, inspection records, mix adjustments, cylinder identification, and test results daily for the engineer using department worksheet [WS5013](#) "Ancillary Concrete Daily Test Report". Submit original testing records to the engineer in a neat and orderly manner within 10 days after completing concrete production.

835.2.4 Sampling Frequency

Randomly choose sample locations using the procedures described in [830](#). Tests must be performed at the following frequencies:

1. A minimum of one slump and air test per 100 cubic yards per mix grade and placement method.
2. A minimum of one set of cylinders per 200 cubic yards per mix grade and placement method.
3. For deck overlays, one set of tests and one set of cylinders per 50 cubic yards.
4. For concrete base and base patching, one set of tests and one set of cylinders per 250 cubic yards.

835.2.5 Compressive Strength

The contractor QC staff is responsible for casting, field curing, and breaking cylinders for each sample location.

835.2.6 Air Content

The air content data must be plotted on a copy of [WS5013](#).

835.2.7 Temperature

The recording of concrete temperature during the fabrication of strength cylinders will provide the contractor information that may be useful on future projects. High concrete temperatures result in fast hydration of the concrete, thus reducing the time before sawing must occur. If the hydration process is too fast, it can result in shrinkage cracking and low strength. The temperature data should be plotted on a copy of the [WS5013](#).

FIGURE 835-1 Example Certificate of Compliance for Ancillary Concrete

(use company letterhead here)

Ready Mixed Concrete Producer Name _____

Ready Mixed Concrete Producer Location _____

This letter is to certify that the above ready-mixed concrete plant is supplying concrete in compliance with WisDOT specifications for project # (xxxx-xx-xx) and the ancillary concrete items listed below.

Ancillary Concrete Items (example: 504.0900 Concrete Masonry Endwalls)	
Item No.	Description

Signed: _____

Name: _____

Position: _____
(example: Plant Manager, QC Manager)

Phone: _____

E-mail: _____

Fax: _____

Date: _____

835.2.8 Slump

A certified PCC technician I or IA should measure slump according to AASHTO T119. Do not use cut-off components of a metal roll-up tape. The measuring device must start at "zero" inches. The contractor need not test slump for slip-formed concrete unless the engineer requests. Provide material conforming to [standard spec 501.3.7.1](#). Slump should be recorded on a copy of the [WS5013](#).

835.2.9 Aggregate Gradation Sampling and Testing

Aggregate gradations must be performed according to the provision and using AASHTO T11 and T27.

835.2.10 Department Testing

Verification and independent assurance sampling and testing are performed by the department or a department representative as described in the provision. Sampling and testing must be performed by an HTCP certified technician.

835.2.10.1 Verification Testing

Verification testing is performed by a department representative on samples collected independently of the contractor's samples according to the provision. Testing of the material is conducted in a separate laboratory and with separate equipment from the contractor's tests. The fabrication, curing, and strength testing of QV cylinders will follow the same procedures specified for QC cylinders.

835.2.10.2 Independent Assurance Review

Independent assurance reviews are conducted by a department representative according to the provision and the department's Independent Assurance Program. These reviews are made of the contractor's quality control and the department's verification sampling and testing equipment and personnel.

835.2.11 Dispute Resolution

Dispute resolution is conducted according to the provision.