S-1 (2461) STRUCTURAL CONCRETE – CONTRACTOR MIX DESIGN PILOT PROJECTS

NEW 01/28/2014

With the exception of Grades W and Y Precast and Prestressed concrete based upon intended use, delete MnDOT 2461, and replace with the following:

Revise all mix designations called out in the Contract in accordance with Table 2461-6 for the intended use.

2461.1 DESCRIPTION

This work consists of producing, providing, placing, curing, and protecting portland cement concrete for placement in structures, pavements and incidental construction.

2461.2 MATERIALS

A Cementitious Materials

Provide cementitious materials from certified sources listed on the Approved/Qualified Products list.

Use AASHTO Type III portland cement as allowed by the Contract or the Engineer for the specific application.

A.1 Portland Cement 3101

A.2 Ground Granulated Blast Furnace Slag 3102

A.3 Blended Hydraulic Cement 3103

A.4 Fly Ash 3115

B Fine Aggregate 3126

C Coarse Aggregate 3137

D Water 3906

E Concrete Admixtures 3113

For all Concrete Grades shown in Table 2461-8, use any of the following admixtures on the MnDOT Approved/Qualified Products list:

(1) Type A, Water Reducing Admixture
(2) Type B, Retarding Admixture
(3) Type D, Water Reducing and Retarding Admixture
(4) Type F, High Range Water Reducing Admixture
(5) Type G, High Range Water Reducing and Retarding Admixture
(6) Type S, Specific Performance Based Admixture

Use of any of the following MnDOT Approved/Qualified admixtures required approval of the Concrete Engineer unless otherwise allowed in the Contract.

(1) Type C, Accelerating Admixture
(2) Type E, Water Reducing and Accelerating Admixture

F Concrete Mix Designs

F.1 Classification of Concrete

The Department will classify concrete by type, grade, consistency, aggregate size, coarse aggregate class and supplementary cementitious material, if any, used as defined in Table 2461-1.

Table 2461-1
Mix Number Identification

First Digit	Second Digit	Third Digit	Fourth Digit	Fifth Digit	Sixth Digit	Additional Digits
Type Designation	Grade Designation	Maximum Slump	Coarse Aggregate Designation	Class of Coarse Aggregate	Supplementary Cementitious Material Designation	Additional Digits Allowed

F.1.a Type Designation

Provide Type 1 or Type 3 concrete in accordance with Table 2461-2:

Table 2461-2
Concrete Type Designation

Concrete Type	Target Air Content*, %
1	2.0
3	6.5 †

* For concrete mix design purposes only.
† Unless otherwise required by 2301 or elsewhere in the contract.

F.1.b Grade Designation

The Department will designate concrete grade in accordance with Table 2461-6 and Table 2461-7 using a letter to represent the following:

(1) Intended Use
(2) Maximum water/cement (w/c) ratio
(3) Minimum cementitious content
(4) Maximum Supplementary Cementitious Substitution (SCM)
(5) Minimum 28-day compressive strength, f'c
(6) Slump range
(7) Allowable admixtures
(8) Coarse Aggregate Quality in accordance with 3137

F.1.c Slump Designation

The Department will designate the upper limit of the slump range as defined by the Grade Designation in accordance with Table 2461-6.

F.1.d Coarse Aggregate (CA) Designation

Determine the coarse aggregate designation in accordance with Table 2461-3 based on the intended use and the gradation requirements in 3137, "Coarse Aggregate for Portland Cement Concrete."

Table 2461-3 Coarse Aggregate Designation for Concrete		
Designation	**MnDOT Coarse Aggregate Gradation Table 3137-4**	**ASTM C33 Gradation Table 3137-4REV**
0	Job Mix Formula (JMF)*	
1		#467
2		#67
3		#7
4		#89
5	CA-15	
6	CA-35	
7	CA-50	
8	CA-70	
9	CA-80	
*Job Mix Formula (JMF) is defined as the combined coarse and fine aggregate gradation		

F.1.e Class of Coarse Aggregate Designation

Identify class of coarse aggregate in accordance with Table 2461-4.

Table 2461-4 Class of Coarse Aggregate Designation for Concrete	
A	Class A Aggregate
B	Class B Aggregate
C	Class C Aggregate

F.1.f Supplementary Cementitious Material (SCM) Substitution Designation

Identify the type of supplementary cementitious material in the concrete mix in accordance with Table 2461-5.

Table 2461-5 Supplementary Cementitious Material Designation for Concrete	
Designation	**Type**
F	Fly Ash
S	Slag
M	Microsilica
T	Ternary (Blend of two supplementary cementitious material)

F.1.g Additional Concrete Mix Designation Digits

Any digits after the required digits in the concrete mix number are allowed.

F.2 Concrete Mix Design Requirements

The Department defines the concrete mix design requirements for Contractor Designed Mixes in accordance with Table 2461-6. The Department defines the concrete mix design requirements for High-Early concrete in accordance with Table 2461-7. The Department defines the concrete mix design requirements for MnDOT Designed Mixes in accordance with 2461.2.I.

Table 2461-6
Concrete Mix Design Requirements

Concrete Grade	Mix Number	Intended Use	Maximum w/c ratio †	Cementitious Content (lbs/cy)	Maximum %SCM (Fly Ash/ Slag/ Ternary)	Slump Range	Minimum Compressive Strength, f'c (28-day)	3137 Spec.
F	3F5#	**Flatwork** Sidewalk, curb and gutter, slope paving, median sidewalk, driveway entrances, ADA pedestrian sidewalk, exposed aggregate	0.45	530 – 750	25/30/0	2 - 5"	4000 psi	2D1
G	1G5#	**General** Footings	0.55	530 – 750	30/35/40	2 - 5"	4000 psi	2D1
	3G5#	**General (Non-Bridge)** Slope paving, walls, manholes and catch basins, fence posts, signal bases, light pole foundations, erosion control structures, box culverts, culvert headwalls, open flumes, base, formed non-bridge railings	0.45	530 – 750	30/35/40	2 - 5"	4000 psi	2D1
		General (Bridge) Bridge substructure, abutments, diaphragms, walls						
M	3M1#	**Slipform** Median barrier, non-bridge railing	0.42	530 – 750	30/35/0	½ - 1" ‡	4000 psi	2D1
	3M3#	**Slipform** Curb and Gutter	0.42	530 – 750	30/35/0	½ - 3" ‡	4000 psi	2D1
P	1P6#	**Non-Structural Concrete** Piling	0.60	420 – 750	40/40/40	3 - 6"	3000 psi	2D1
R	3R5#	**Concrete Pavement Rehabilitation** Full Depth Concrete Repairs	0.42	530 – 750	30/35/0	2 - 5"	3000 psi	2D3
S	3S1#	**Bridge Superstructure** Slipform bridge railing	0.42	530 – 750	30/35/40	½ - 1" ‡	4000 psi	2D2
	3S4#	**Bridge Superstructure*** Bridge decks	0.45	500 – 750	30/35/40	2 - 4"	4000 psi	2D2
	3S5#	**Miscellaneous Bridge*** Median barrier, posts, curbs, sidewalks, approach panels, formed bridge railings, end posts	0.45	530 - 750	30/35/40	2 - 5"	4000 psi	2D2

Designates the gradation for the 4th digit according to Table 2461-3
* These mix design requirements do not apply to high performance bridges and mass concrete
† The minimum water/cement (w/c) ratio is 0.30
‡ Adjust slump in accordance with 2461.3.G.6.a for slipform concrete placement.

Table 2461-7 High-Early (HE) Concrete Requirements ‡						
Mix Number	**Minimum Time to Opening**	**Maximum w/c ratio**	**Maximum Cementitious Content (lbs/cy) ‖**	**Slump Range**	**Minimum Strength †**	**Allowed Admixtures**
3F5#HE* 3G5#HE* 3M5#HE* 3R5#HE*	48 hrs	0.40	750	2 – 5”	3000 psi	Any

Designates the gradation range for the 4th digit according to Table 2461-3

* All HE concrete requires approval of the Engineer prior to incorporation into the work

‡ **The Department defines High-Early (HE) concrete as concrete designed to achieve the minimum strength to opening at 48 hours.**

‖ Supplementary Cementitious Materials allowed

† Requires control cylinders for determining strength; Use of the maturity method allowed in accordance with 2461.3.G.d

F.3 Contractor Designed

Design the concrete mix to an absolute volume of 27.00 cu. ft ± 0.10 cu. ft [1.000 cu. m ± 0.003 cu. m] for the following:

(1) Grades F, G, M, P, R and S concrete based upon the intended use in accordance with Table 2461-6.
(2) High-Early (HE) Strength concrete based upon the intended use in accordance with Table 2461-7.
(3) Grade A Concrete Pavement Mixes in accordance with 2301.
(4) Grade R Concrete Pavement Rehabilitation Mixes as modified in 2302.
(5) High Performance Bridge Concrete and Mass Concrete Mixes in accordance with the Special Provisions of the Contract.
(6) Cellular Concrete Grout in accordance with 2519, “Controlled Low Strength Material (CLSM)”.
(7) If the intended use is not included elsewhere in the Specification or Special Provisions, design the concrete mix in accordance with Table 2461-6 Mix Number 3G5#.

The Contractor assumes full responsibility for the mix design and performance of the concrete.

The Concrete Engineer will:

(1) Provide specific gravity and absorption data using oven dry (OD) weights for mix design calculations.
(2) Review the mix design submittal and approve the materials and mix design for compliance with the Specifications.
(3) Allow a maximum of 6 mix designs per concrete grade for a given combination of aggregates

The Engineer determines final acceptance of the concrete for payment based on satisfactory field placement and performance.

F.3.a Contractor Submittal Requirements

At least 21 calendar days before initial placement of the concrete, submit a Contractor Mix Design Submittal package to the Concrete Engineer for approval. The Contractor Mix Design Submittal package is available from the MnDOT Concrete Engineering Website.

Mix Design Submittal requirements are defined as Level 1 and Level 2 Mixes in accordance with Table 2461-8.

Table 2461-8
Mix Design Submittal Requirements

	SCM Substitution Limits	Fine Aggregate Limit	Gradation Requirements	Preliminary Test Data Requirements	Submittal Package
Level 1 Mixes	Fly Ash: 0 – 15% Slag: 0 – 35%	40 – 45% of total aggregate by volume	3126 and 3137	None	Contractor Mix Design
Level 2 Mixes	Fly Ash: > 15% Ternary: Any	None	Use Either: • 3126 and 3137 • Job Mix Formula (JMF)	2461.2.F.3.a	Use Either: • Contractor Mix Design • Contractor Mix Design (JMF)

F.3.a Preliminary Test Data Requirements for Level 2 Mixes

For Level 2 Mixes, the Concrete Engineer requires the Contractor to submit documentation based upon either by a suitable experience record or by conventional trial mixtures. The strength test records will include air content, slump and concrete temperature data. The Contractor Mix Design Submittal Package includes a *Test Data* spreadsheet for submittal of the required test data.

The Concrete Engineer considers the following Preliminary Test Data acceptable to use when determining the Mix Design Proportions:

(1) Where a concrete production facility has test records for the specified grade or within 1000 psi of that specified for the proposed work,
(2) Test results represent materials and proportions, quality control procedures, and conditions similar to those expected for the proposed work.
(3) At least 30 consecutive tests or two groups of consecutive tests totaling at least 30 tests within the previous 18 months; in no case less than 10 test results representing a time period of at least 45 days
(4) Test results representing SCM contents at the proposed mix design proportions
(5) If the Contractor does not have test data as required in (1) through (4) above, establish concrete proportions from trial mixtures, utilizing an AMRL accredited laboratory in accordance with the following:
    a. Use combination of materials similar to those for proposed work;
    b. Use proportions and consistencies required for proposed work using at least three different w/c ratios or cementitious materials content that will produce a range of strengths encompassing the required average strength *(f'cr)*;
    c. Design trial mixtures to produce slump within ± 0.75 in. of maximum permitted;
    d. For air-entrained concrete, design trial mixtures to produce air content within ± 0.5 percent of maximum allowable air content;
    e. For each w/c ratio or cementitious materials content, make and cure at least three test cylinders for 28-day breaks in accordance with ASTM C 192.
    f. Plot a curve of the cylinder test results at 28-days age showing the relationship between w/c ratio or cementitious materials content and compressive strength
    g. Use maximum w/c ratio or minimum cementitious materials content shown by the curve to produce the average strength required (f'cr).

When selecting a suitable concrete mixture, determine the following using the *Test Data* spreadsheet:

(1) Determine the Standard Deviation (S).
(2) Determine the Required Average Strength (f'cr)

The required average strength (f'c ≤ 5000 psi) is the larger value computed from the equations below:

f'cr = f'c +1.34S
f'cr = f'c +2.33S – 500 ..... if f'c>5000 psi, use f'cr = 0.90f'c + 2.33S

where S = Standard Deviation

(3) Select the Mix Design Proportions required to produce f'cr.

G Mix Design Adjustments

The Department will allow mix design adjustments based upon the criteria as defined in Table 2461-9:

Table 2461-9
Mix Design Adjustments Requirements

	Type of Change or Adjustment	Mix Design Approval Resubmittal Requirements
Level 1 Mixes	• Cementitious Sources • Admixture Sources • Admixture Dosage Rate	No resubmittal required
	• Aggregate Sources • ≤ 10% in any aggregate proportion	Resubmittal of Mix Design
Level 2 Mixes	• Admixture Dosage Rate	No resubmittal required
	• Aggregate Source, no change in Aggregate Class • Cement or SCM sources • ≤ 5% in any cementitious or SCM proportion* • ≤ 10% in Aggregate Proportions	Resubmittal of Mix Design
	• Aggregate source and Class of Coarse Aggregate • > 5% in any cementitious or SCM proportion • > 10% Aggregate Proportions • Admixture Sources	Resubmittal in accordance with 2461.2.F.3.a

* Only one (1) increase in cementitious or SCM allowed per mix design, next adjustment require resubmittals in accordance with 2461.2.F.3.a

H MnDOT Review for Continual Acceptance of Contractor Mix Designs

In November of each calendar year, the MnDOT Concrete Engineering Unit will review all test results relating to each individual Contractor approved mix design.

Provided the requirements are met, the Contractor will have that mix design available for use during the next calendar year. MnDOT will review the following test results for continual acceptance:

(1) Compressive Strength at 28 days
(2) Monthly Aggregate Quality Testing

I Department Designed

The Department will provide the mix proportions for the following concrete mixes:

(1) 1X62 for use in Cofferdam Seals in Table 2461-10.
(2) Grout (Riprap) in Table 2461-11.
(3) 3U17A for use in Low Slump Concrete Overlays on the back of the Form 21412, "Weekly Report of Low Slump Concrete".
(4) Lean Mix Backfill – mix design proportions in 2520.
(5) Bagged Portland Cement Concrete Patching Mix Grade 3U18 – mix design proportions in 3105.

I.1 Concrete Yield

The Department defines concrete yield as the ratio of the volume of mixed concrete, less accountable waste, to the planned volume of the work constructed. The Department will not assume responsibility for the yield from a given volume of mixed concrete.

Table 2461-10
Concrete Mix Design Requirements for Cofferdam Seals 1X62

Mix Number	Maximum w/c ratio	Water Content (pounds)	Cement Content (pounds)	Fly Ash (pounds)	Fine Aggregate Content (pounds)	Coarse Aggregate Calculation (pounds)	%Air Content	Slump Range	Minimum 28-day Strength	3137 Spec.
1X62	0.43	314	730	0	1265	627 x Specific Gravity	3	3 - 6"	5400	2D1
1X62F	0.43	314	584	146	1265	617 x Specific Gravity	3	3 - 6"	5400	2D1

Table 2461-11
Concrete Mix Design Requirements for Grout Mixes

Grout Mix Number*	Maximum w/c ratio	Water Content (pounds)	Cement Content (pounds)	Fine Aggregate Calculation † (pounds)	%Air Content	Maximum Slump	Minimum 28-day Strength
1CGROUT	0.64	379	596	1082 x Specific Gravity	3%	As needed	3000
3CGROUT	0.55	379	691	933 x Specific Gravity	10%	As needed	3000
1AGROUT	0.50	379	758	1031 x Specific Gravity	3%	As needed	4000
3AGROUT	0.44	379	865	878 x Specific Gravity	10%	As needed	4000
3WGROUT	0.36	379	1072	812 x Specific Gravity	10%	As needed	5000

***** Do not provide grout containing coarse aggregate.
† If the plans do not specify grout mix, provide 3A GROUT.

2461.3 CONSTRUCTION REQUIREMENTS

A Batching Equipment

A.1 Mixer Requirements

Provide stationary mixers or truck mixers.

A.2 General Condition

Maintain mixers as necessary to detect changes in condition due to accumulations of hardened concrete or mortar and examine to detect wear of blades.

Replace or recondition pickup and throwover blades in mixers with a rated capacity less than 14 cu. ft [0.40 cu. m] showing a blade wear loss of greater than ½ in [13 mm], and pickup and throwover blades in mixers of greater capacity, showing a blade wear loss of no greater than ¾ in [19 mm] from the original factory dimensions.

A.3 Manufacturer's Rating Plate

Provide mixers that include the manufacturer's rating plate, showing the following information:

(1) Serial number of the unit,
(2) Mixing speed of the drum or paddles, and
(3) Maximum capacity in terms of volume of mixed concrete.

A.4 Drum Speed for Stationary Mixers

Operate the drum speed in the mixer as specified by the manufacturer or as directed by the Engineer.

A.5 Auxiliary Equipment Requirements

Provide mixers equipped with the following:

(1) Timing device,
(2) Discharge locking device,
(3) Water measuring device that operates mechanically and automatically during each batching cycle, and
(4) A graduated adjustable indicator device to represent the volume of discharge in increments no greater than ¼ gal [1 L] in full view.

A.6 Mixer Capacity

Do not exceed the manufacturer's rated capacity of the mixer when mixing a single batch of concrete.

Batch concrete in volumes the mixer can accommodate without spilling, leaking, or segregating during the charging, mixing, or discharging operations. Provide mixers with a capacity of at least 1 sack [0.25 cu. m].

A.7 Mixing Time

The Department defines the mixing time as the time period beginning when the cement and aggregates enter the mixer drum and ending when the discharge begins.

Refer to the manufacturer's recommended minimum mixing time for single drum and dual drum mixers. In the absence of manufacturer's recommendation, the Engineer will designate the minimum mixing time. The minimum mixing time for any concrete batch is 60 s. The Contractor may reduce the manufacturer's recommended minimum mixing time or the Engineer designated mixing time if the Contractor obtains uniform mixing in accordance with 2461.3.E, "Mixing Requirements," and as approved by the Engineer, in conjunction with the Concrete Engineer.

If there is evidence of inadequately mixed concrete (unmixed or partially mixed materials) during concrete placement, the Engineer may direct an increase in the mixing time.

A.8 Turbine Type Mixers

Provide turbine type mixers meeting the applicable requirements for conventional type mixers (2461.3.A.1 through 2461.3.A.7) and in accordance with this subsection (2461.3.A.8). Maintain the mixer drum in a cylindrical shape within ¾ in [19 mm] from the original factory dimensions at any point. Maintain the mixer discharge gate in a mortar tight condition in the closed position. Replace or recondition mixer paddles showing a wear loss greater than ½ in [13 mm] from the original factory dimensions.

Add the mixing water to the batch materials in a manner that distributes the water to the inner or central areas of the drum. Start the flow of water before introducing the solid batch materials into the mixer drum.

During mixing, operate the paddles at a speed between 20 revolutions and 30 revolutions per minute. After adding the batch materials to the drum, mix the concrete for an additional 60 s.

A.9 Horizontal Axial-Revolving Blade Type Mixers

Provide horizontal axial-revolving blade type mixers in accordance with the applicable requirements for conventional type mixers (2461.3.A.1 through 2461.3.A.7) and in accordance with this subsection (2461.3.A.9).

Charge the water, aggregates, and cement in the sequence approved by the Engineer. Test the concrete uniformity as directed by the Engineer. The Engineer will use concrete uniformity tests to determine the minimum mixing time.

B Transportation Units

B.1 General Requirements

Equip transportation units intended for both mixing and agitating with watertight revolving drums mounted and powered and fitted with properly designed mixing blades in accordance with 2461.3.A.1 through 2461.3.A.7. Provide units capable of combining all the ingredients into a homogeneous mixture and designed to provide two drum speeds, one for mixing and the other for agitating. Provide units capable of delivering the concrete without segregation or loss of any of the batch materials.

Equip the mixer drum with a working counting device to record the number of revolutions.

Equip dump trucks and agitator trucks with vibrators to aid in discharge, are mortar tight, capable of complete discharge of the concrete and in accordance with 2301.3.F.

B.2 Capacity of Transportation Units

Refer to the truck mixer manufacturer's certification plate attached to the unit for the maximum capacity of the unit. If the unit will not satisfactorily mix the maximum volume shown, reduce the batch volume to allow proper mixing or discontinue use of the mixing unit as directed by the Engineer until the problem is corrected.

C Handling and Storing Materials

C.1 Batch Material Requirements

Do not change the source, kind or gradation of batch materials after the start of concrete production for the work unless otherwise approved by the Engineer. If the Engineer approves use of different material, completely exhaust the supply on hand before changing to the different material.

If delivering freshly washed aggregates to the batching plant, drain the aggregates for at least 12 h before using in the batching operation. If draining freshly washed aggregates at the site of the batching plant, completely separate the drained material from the undrained materials, and provide for the disposal of water that accumulates from the drainage of materials.

Provide smooth, firm, and well-drained stockpile sites cleared of vegetable and extraneous matter. Where the natural foundation is unsatisfactory, as determined by the Engineer, construct the stockpiles on suitable platforms. Construct suitable bulkheads or partitions to separate different kinds of aggregate, gradation, or water content.

Construct stockpiles by methods that hold segregation and degradation to a minimum. If the Engineer sees segregation or degradation, the Engineer may designate that pile as unacceptable for use.

Do not use aggregates used to construct runways for loading or hauling equipment in concrete batches.

Use of aggregates from the bottom 1 ft [0.3 m] of a stockpile placed on an unprepared surface in concrete batches is allowed only under the Engineer's direct supervision and if the material meets all

requirements of 3126, “Fine Aggregate for Portland Cement Concrete,” and 3137, “Coarse Aggregate for Portland Cement Concrete.”

Provide aggregates in accordance with the specified gradation requirements.

The Engineer will consider aggregates unacceptable if the variation in moisture content carried by any of the aggregates causes a marked variation in the consistency of successive batches of the mixed concrete, and will suspend operations until corrected.

C.2 Concrete Temperature Control

Produce concrete at temperatures from 50 °F to 90 °F [10 °C to 30 °C] and maintain temperatures until deposited in the work.

If necessary to maintain placement temperature, uniformly heat or cool the water, aggregates, or both, before introduction into the mixer. Control the temperature of the mixing water during heating or cooling.

Use aggregate at temperatures from 32 °F to 130 °F [0 °C to 55 °C]. Do not allow cementitious material to contact other batch material when the aggregate temperature exceeds 130 °F [55 °C].

Do not heat the cement, add salt, or add chemical admixtures to the concrete mix to prevent freezing.

Use a heating system to heat batch materials as approved by the Engineer. Do not use steam jets to spot heat the material as the work progresses.

Do not place mixer heaters intended for heating the batch materials in the mixer drum.

D Batching Requirements

Calibrate weighing equipment in accordance with 1901, “Measurement of Quantities.” Inspect and calibrate the scales in accordance with the Concrete Manual.

D.1 Batching by Weight

D.1.a Proportioning Methods

Proportion concrete batch materials by weight in a central plant or by volume as directed by the Engineer, in conjunction with the Concrete Engineer.

D.1.b Weighing Equipment and Tolerances

Weigh or measure concrete mixture ingredients using load cells or meters for ready-mix and paving concrete to within the targeted batch weight in accordance with the following:

(1) Water – 1 percent,
(2) Cement – 1 percent,
(3) Other cementitious materials – 3 percent,
(4) Aggregates – 2 percent, and
(5) Admixtures – 3 percent.

D.1.c Batching of Mixing Water

Measure the mixing water on scales or water metering devices containing the following:

(1) A discharge indicator capable of being set to within 1 gal [5 L] of a predetermined quantity,
(2) A positive automatic shutoff valve, and
(3) An approved inspection seal on the scale or water metering device dating the time of the previous calibration and adjustment

An authorized service agency will calibrate the water meter every 6 months and make adjustments as necessary before use meeting the requirements of the weighing procedure in the Concrete Manual.

Check the water meter for accuracy at least once each month as the work progresses.

D.1.d Batching of Cementitious Materials

Weigh the cementitious material independently of the aggregates in separate compartments or on separate scales.

If the Contractor weighs the cement first and then separately records the weights of each individual cementitious material, the Contractor may weigh the cementitious materials cumulatively as approved by the Engineer, in conjunction with the Concrete Engineer.

D.1.e Batching of Aggregates

If the Contractor records each individual fraction weight of aggregates separately, the Contractor may weigh aggregates cumulatively as approved by the Engineer, in conjunction with the Concrete Engineer.

D.1.f Admixture Proportioning

If using two or more admixtures in a single concrete batch, add each admixture separately to prevent interaction of the different admixtures before mixing with other batch materials. Agitate admixtures to ensure homogeneous concentrations in accordance with the manufacturers recommendations.

Incorporate admixtures to the batch mix in liquid form. Maintain admixture solutions at a uniform concentration at all times. Use the solution concentration and proportions designated by the manufacturer.

If using a mechanical dispenser for proportioning Class I or Class II admixtures, provide a site gauge or meter. Have the admixture manufacturer check admixture dispensers yearly to determine accuracy and ensure unobstructed flow.

When incorporating admixtures into the concrete:

(1) Use admixture dosage rates recommended by the manufacturer;
(2) Add all admixtures at the plant;
(3) Provide admixture additions at the job site that are the same products as originally incorporated into the mix; and
(4) Use calcium chloride in concrete as approved by the Concrete Engineer. Do not use calcium chloride in units containing prestressing steel or in bridge superstructure concrete.

D.2 Batching by Volume

Proportion concrete for bridge deck overlays by volume or as required by the contract.

If the Contractor calibrates the mixer for the specific batch materials in use, the Contractor may proportion concrete on other items of work by volume as approved by the Engineer in writing.

The Engineer will approve all methods and equipment used in volumetric proportioning.

Determine all material proportions and calibration settings on the basis of 100 lb [100 kg] of cementitious material.

Provide and use only sacked cement in the original mill containers unless the Contractor calibrates the mixer for the specific materials in use. Do not use fractional sacks.

Increase the cementitious content by 10 percent in the computation of volume proportions unless the Contractor calibrates the mixer for the specific materials in use.

E Mixing Requirements

The Engineer may check the water measuring equipment for accuracy before mixing operations begin and at any other time the Engineer considers necessary.

Mix concrete by one of the following methods:

(1) A central plant (stationary plant),
(2) Entirely or in part in truck mixers, or
(3) At the construction site.

Do not allow the mixing batch to merge or intermix with the subsequent dry batch during mixing.

Discharge water remaining in the drums before batching.

Mix concrete to provide a mixture that is homogeneous and uniform in color. The Engineer will reject concrete batches that show a marked variation in consistency or evidence of improper mixing as unacceptable work in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

After completely mixing the concrete, either in a central plant mixer or truck mixer, continuously agitate while in transit to the point of placement until the concrete is discharged from the unit, unless otherwise allowed by the Engineer, in conjunction with the Concrete Engineer.

If the mixing does not appear uniform, perform slump tests at the 15 percentage point and the 85 percentage points during unloading. If the results show a slump variation greater than 1½ in [38 mm], stop work and correct the mixing unit.

Produce concrete in such quantity and at such a rate as proper placement and finishing will permit. Do not re-temper partially set concrete.

Do not hand mix concrete.

E.1 Mixing In Truck Mixer

Charge the materials into the truck mixer drum by introducing sufficient water before adding solid materials. Perform charging operations without losing materials.

Leave the truck mixer at the plant site for a minimum of 5 min or 50 revolutions during the mixing period. Transport the concrete at agitating speed to the point of placement.

F Certified Ready-Mix Concrete

F.1 Definitions

The Department defines ready-mix concrete as one of the following:

(1) Central-mixed concrete proportioned and mixed in a stationary plant and hauled to the point of placement in revolving drum agitator trucks or a truck mixer, or
(2) Truck-mixed concrete proportioned in a stationary plant and fully mixed in truck mixers.

Table 2461-12 defines commonly used certified ready-mix terms.

Table 2461-12 Certified Ready-Mix Terminology	
Term	Definition
Mix design water	The maximum allowable water content for 1 cu. yd [1 cu. m] of concrete in accordance with Mn/DOT Form TP 02406, *Estimated Composition of Concrete Mixes*.
Total moisture factor	Factor used to determine total amount of water carried by a given wet aggregate.
Absorption factor	Factor used to determine the water contained within the pores of the aggregate and is held within the particles by capillary force.
Free moisture	The water that is carried on the surface of the aggregate that becomes part of the total water.
Batch water	Water actually batched into the truck by the batcher.
Total water	Batch water added to free moisture. Total water may also include the water used in diluting admixture solutions.
Temper water	Water added in mixer to adjust slump.
Total actual water	The water in the concrete mixture at the time of placement from any source other than the amount absorbed by the aggregate. It includes all batch water placed in the mixer, free moisture on the aggregate and any water added to the ready mix truck prior to placement.
Ready-Mix Producer or "Producer"	Party that is producing the concrete for the Contract. It is understood that the Ready-Mix Producer is the agent of the Contractor.
Water/Cement (w/c) Ratio	W/C ratio is defined as the ratio of the total water weight to the total cementitious weight, which includes cement and supplementary cementitious materials.

F.2 General Requirements

Supply ready-mix concrete in accordance with 2461.3.F.3, "Certified Ready-Mix Plant Program."

The Engineer will reject ready-mix concrete delivered to the work site that does not meet the specified requirements for delivery time, consistency, quality, air content, or other properties as unacceptable work in accordance with 1512, "Unacceptable and Unauthorized Work."

Provide batches for a delivered load of concrete in sizes of at least 1 cu. yd [1 cu. m].

F.3 Certified Ready-Mix Plant Program

Provide ready-mix concrete produced by a certified ready-mix plant. Perform quality control of concrete production under a certification program for ready-mix concrete plants.

Complete all concrete plant documentation utilizing the Concrete Ready-mix Plant QC Workbook available from the MnDOT Concrete Engineering website. Electronically submit the QC Workbook to the Engineer by the Tuesday immediately following the previous week's production.

F.3.a Plant Certification

Before concrete production each season, ensure the producer performs the following:

(1) Performs an on-site inspection at the concrete plant with the Engineer and completes a Mn/DOT Form 2163, *Concrete Plant Contact Report*.

(2) Signs the report certifying compliance with the Certified Ready Mix requirements and continual maintenance of the plant. The Engineer will also sign Mn/DOT Form 2163, *Concrete Plant Contact Report*.

(3) Provides continuous access on-site to the MnDOT Concrete Manual available from MnDOT's website.

(4) Supply the Certified Ready-Mix Plant with a working email address.
(5) Keeps plant reports, charts, and supporting documentation on file at the plant site for 5 calendar years
(6) Provides electronic scales for weighing all materials.

F.3.b Sampling and Testing

Provide a Mn/DOT Certified Concrete Plant Level 2 Technician to oversee testing and plant operations and to remain on-site during concrete production or have cellular phone availability.

Provide facilities in accordance with 1604, "Plant Inspection – Commercial Facility," for the use of the plant technician in performing tests.

Ensure the producer provides technicians with certification at least meeting Mn/DOT Concrete Plant Level 1 to perform all of the duties in accordance with the Concrete Manual. The Engineer will provide technicians with certification at least meeting Mn/DOT Concrete Plant Level 1 to perform all of the duties in accordance with the Concrete Manual.

Ensure the producer performs testing in accordance with the Concrete Manual and determines testing rates meeting the requirements of the Schedule of Materials Control. The Engineer performs testing in accordance with the Concrete Manual and determines testing rates meeting the requirements of the Schedule of Materials Control.

Take samples randomly using ASTM D 3665, Section 5.

Perform testing at the certified ready-mix plant site. Perform additional testing as directed by the Engineer. The Engineer may oversee the quality control sampling process.

Provide equipment and perform calibrations meeting the requirements of the following:

(1) AASHTO T 27, "Sieve Analysis of Fine and Coarse Aggregates,"
(2) AASHTO T 255, "Total Moisture Content of Aggregate by Drying,"
(3) AASHTO M 92, "Wire-cloth Sieves for Testing Purpose," and
(4) AASHTO M 231, "Weighing Devices Used in the Testing of Materials."

F.3.c Gradations

Determine the gradation of the fine aggregates and the coarse aggregates as required by the contract. Use mechanical shakers for sieve analysis of fine and coarse aggregates.

Identify quality control companion samples with the following information:

(1) Date,
(2) Test number,
(3) Time,
(4) Type of material,
(5) Plant, and
(6) Sampling location.

Document gradation results on Mn/DOT Form 2449, *Weekly Concrete Aggregate Report*.

Chart all producer gradation results and Department verification gradation results of the coarse aggregate and the No. 8 [2.36 mm], No. 30 [600 µm], and No. 50 [300 µm] sieves of the fine aggregate.

The producer may request a reduction in testing rates as approved by the Engineer, in conjunction with the Concrete Engineer.

If the gradation tests on split samples from quality control or verification samples result in a variation between the producer and the Department greater than that set forth in Table 2461-13, the parties

shall follow the procedures for test result dispute resolution available from the Mn/DOT Concrete Engineering website.

Table 2461-13 Allowable Variations on Percent Passing Sieves	
Sieve Size	**Allowed Percentage**
2 in – ⅜ in [50 mm – 9.5 mm]	± 6
No. 4 – No. 30 [4.75 mm – 600 µm]	± 4
No. 50 [300 µm]	± 3
No. 100 [150 µm]	± 2
No. 200 [75 µm]	± 0.6

F.3.c.(1) Non-conforming Material

Only place concrete meeting the gradation requirements in the work. If the Contractor inadvertently places concrete not meeting the gradation requirements into the work, the Engineer will not accept nonconforming concrete at the contract unit price.

For concrete not meeting the required gradation, the Engineer will make determinations regarding the disposition, payment, or removal. The Department will adjust the contract unit price for the concrete contract item in accordance with Table 2461-14 and Table 2461-15. When there is not a separate *Structural Concrete* contract unit price for an item of work or the concrete is a minor component of the contract unit price, the Department will reduce payment based on a concrete price of $100.00 per cu. yd [$130.00 per cu. m] or the Contractor-provided invoice amount for the concrete in question, whichever is less.

Table 2461-14 Grades A, F, G, M, P, S, X, U for Individual Aggregate Fractions Fine and Coarse Aggregate Specification Sieves other than Fine Aggregate No. 200 [75 µm]	
Outside of Specification, %	**Adjusted Contract Unit Price**
≤ 3	The Department will pay 98 percent of the relevant contract unit price for concrete placed as approved by the Engineer.
4 – 6	The Department will pay 95 percent of the relevant contract unit price for concrete placed as approved by the Engineer.
7 – 10	The Department will pay 90 percent of the relevant contract unit price for concrete placed as approved by the Engineer.
> 10	The Department will pay 75 percent of the relevant contract unit price for concrete placed as approved by the Engineer.

Table 2461-15 Grades A, F, G, M, P, S, X, U for No. 200 [75 µm] Sieve of Fine Aggregate	
Outside of Specification, %	**Adjusted Contract Unit Price**
< 0.3	The Department will pay 98 percent of the relevant contract unit price for concrete placed as approved by the Engineer.
0.4 – 0.6	The Department will pay 95 percent of the relevant contract unit price for concrete placed as approved by the Engineer.
0.7 – 1.0	The Department will pay 90 percent of the relevant contract unit price for concrete placed as approved by the Engineer.
> 1.0	The Department will pay for 75 percent of the relevant contract unit price for concrete placed as approved by the Engineer.

If failure occurs on the fine aggregate No. 200 [75 µm] sieve and on other sieves concurrently, the Department will only reduce the price based on the larger percentage deduction.

The Engineer, in conjunction with the Concrete Engineer, will determine adjusted contract unit prices for coarse aggregate quality failures in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

F.3.d Moisture Content

Ensure the Producer performs the following:

(1) Determines the moisture content using the oven-dry method in all fractions of the aggregate.
(2) Documents moisture tests on Mn/DOT Form 2152, *Concrete Batching Report*.

In addition to the oven-dry moisture test, the producer may obtain the moisture content in the fine aggregate using a moisture probe.

To obtain approval for the use of a moisture probe, ensure the producer calibrates the moisture probe before each construction season meeting the requirements of the Concrete Manual. Ensure the producer verifies both the probe moisture content and the oven-dry verification moisture test and records in the Producer plant diary.

F.3.e Plant Diaries

Provide daily plant diaries in accordance with the Concrete Manual using an approved form from the Mn/DOT's Concrete Engineering website.

F.3.f Batch Weight Verification

The Engineer will observe the batching process to verify weights shown on the Certificate of Compliance.

The Engineer will observe the actual water batched during each collection of verification gradations in accordance with the following:

(1) Watching the ready-mix truck reverse the drum after washing,
(2) Verifying use of the current moisture test,
(3) Verifying that any additional water added to adjust the slump is recorded, and
(4) Validating water weights on the load batched and comparing the total water with the design water.

The Engineer will document the actual water batched on Mn/DOT Form 24143, *Weekly Certified Ready-Mix Plant Report* and submit a copy to the Engineer to provide to the Concrete Engineer.

The Engineer will provide plant diaries in accordance with the Concrete Manual.

F.3.g Certificate of Compliance

Provide a computerized Certificate of Compliance with each truckload of ready-mixed concrete at the time of delivery. The Department defines computerized to mean a document that records mix design quantities from load cells and meters.

If the computer that generates the Certificate of Compliance malfunctions, the Engineer may allow the Contractor to finish any pours in progress if the producer issues a handwritten Mn/DOT Form 0042, *Certificate of Compliance* with each load. Do not allow the producer to begin new pours without a working computerized Certificate of Compliance.

Provide a computerized Certificate of Compliance from the producer for each item of information, including the following:

(1) Name of the ready-mix concrete plant.
(2) Name of the Contractor.
(3) Date.
(4) State Project Number (SP) or (SAP).
(5) Bridge Number (if applicable).
(6) Time concrete was batched.
(7) Truck number.
(8) Quantity of concrete in this load.
(9) Running total of each type of concrete, each day for each project.
(10) Type of concrete (Mn/DOT Mix Designation Number).
(11) Cementitious materials using Mn/DOT Standard Abbreviations.
(12) Admixtures using Mn/DOT Standard Abbreviations.
(13) Aggregate sources using 5 digit State Pit Numbers.
(14) Admixture quantity in fluid ounces per 100 lb [milliliters per kilogram] or ounces per cubic yard [milliliters per cubic meter].
(15) Batch information for materials using Mn/DOT standardized labels to represent each column in Table 2461-16. Present the information in the order listed across the page (a through k) or print the information using two lines provided that the materials are identified in each line of information.

Table 2461-16 Standardized Certificate of Compliance Labels			
	Formula Letter	Formula	Standard Label
a	Ingredients (aggregate, cementitious, water, admixtures)	—	Ingredient
b	Product Source (Mn/DOT Standard Abbreviation)	—	Source
c	Total Moisture Factor (in decimals to 3 places)	—	MCFac
d	Absorption Factor (in decimals to 3 places)	—	AbsFac
e	Mn/DOT mix design oven dry (OD) weights, *lb/cu. yd [kg/cu. m]*	—	OD
f	Absorbed moisture in the aggregates, *lb/cu. yd [kg/cu. m]*	(e × d)	Abs
g	Saturated surface dry (SSD) weights for aggregates, *lb/cu. yd [kg/cu. m]*)	(e + f)	SSD
h	Free moisture, *lb/cu. yd [kg/cu. m]*	(c - d) × e	Free Mst
i	Target weights for one cubic yard [cubic meter] of concrete, *lb/cu. yd [kg/cu. m]*	(g + h)	CY Targ [CM Targ]
j	Target batch weights, *lb [kg]*	(cu. yd × i) [cu. m × i]	Target
k	Actual batch weights, *lb [kg]*	—	Actual
NOTE: Actual cubic yards [cubic meters] batched may vary due to differences in air content, weight tolerances, specific gravities of aggregates, and other variables.			

(16) Total Water (Batch Water + Free Moisture) in pounds [kilograms].

(17) Water available to add [(Mix Design Water) × (Target CY (CM)) – Total water] in gallons [liters].

(18) Space to note the water adjustment information, including:

(18.1) Water in gallons [liters] added to truck at plant (filled in by producer, enter zero if no water is added).

(18.2) Water in gallons [liters] added to truck at the jobsite (filled in by producer or Engineer, enter zero if no water is added), and

(18.3) Total actual water in pounds [kilogram] (Total Water from Certificate of Compliance plus any additions).

(19) The following information printed with enough room beside each item to allow the Engineer to record the test results:

(19.1) Air content,

(19.2) Air temperature,

(19.3) Concrete temperature,

(19.4) Slump,

(19.5) Cylinder number,

(19.6) Location or part of structure,

(19.7) Time discharge, and

(19.8) Signature of Inspector.

(20) Location for the signature of the Mn/DOT Certified Plant 1 Technician representing the producer. The technician will review the first Certificate of Compliance for each mix type, each day, for accuracy and hand sign the Certificate of Compliance at a location designated for signature signifying agreement to the terms of this policy and to certify that the materials itemized in the shipment comply requirements of the contract.

F.3.h Decertification

If the Contractor provides concrete from a plant that cannot produce concrete, fails to perform testing, fails to report accurate results, or fails to complete the required documentation, the Engineer may reject the concrete as unacceptable in accordance with 1503, “Conformity with Contract Documents,” and 1512, “Unacceptable and Unauthorized Work.”

The Concrete Engineer, with coordination from the Engineer, may decertify the plant and halt production of concrete if the producer performs the following:

(1) Procedural changes made after the completion of the Concrete Plant Contact Report and after starting the work that cause non-compliance with the program,
(2) Continually produces concrete in non-compliance with this section,
(3) Completely disregards the requirements of this section, and
(4) Submits fraudulent test reports.

If decertifying the plant, the Concrete Engineer may perform the following:

(1) Revoke plant certification.
(2) Revoke technician certification for individuals involved,
(3) Revoke bidding privileges as determined by the Construction Engineer, and
(4) Criminal prosecution for fraud as determined by the Attorney General.

G Concrete Placement

Do not produce concrete earlier than 60 min before the National Weather Service official sunrise, unless the Engineer approves otherwise.

Place concrete after the Engineer inspects and approves the foundation preparations, forms and falsework erection, placement of reinforcement steel, materials, equipment condition, and cold weather protection.

Do not place concrete if portions of the base, subbase, or subgrade layer are frozen, or if the excessive moisture levels make the grade unstable. Maintain the surface temperature above freezing for forms, steel, and adjacent concrete that will come in contact with the poured concrete before concrete placement.

Protect the concrete from freezing.

Protect the concrete against damage from construction operations or traffic.

Assume full responsibility for the acceptable production, placement, finishing, and curing of all concrete under the conditions prevailing, regardless of the restrictions imposed. Provide any artificial lighting, rain or cold weather protection necessary at no additional cost to the Department. The Engineer may subject any defects in concrete or concrete surfaces resulting from weather conditions, inadequate lighting, or other causes to 1503, “Conformity with Contract Documents,” and 1512, “Unacceptable and Unauthorized Work.”

G.1 Notice of Inspection

Notify the Engineer at least 24 h before beginning concrete production to allow the Engineer time to provide inspection forces needed for the work and to approve preparations for concrete placement. If the Contractor fails to provide 24 h notice, the Engineer may delay concrete placement in accordance with 1503, “Conformity with Contract Documents” and 1512, “Unacceptable and Unauthorized Work.”

If the producer needs to change plants during placement, notify the Engineer and obtain approval before changing the plant.

G.2 Placement Temperatures

Do not place concrete when the air temperature at the point of placement is below 36 °F [2 °C] or is expected to fall below 36 °F [2 °C] within the following 24 h period unless approved cold-weather provisions are in-place. Discontinue concrete placement if the air temperature falls below 36 °F [2 °C].

Maintain concrete at a temperature from 50 °F to 90 °F [10 °C to 30 °C] until placement.

G.3 Delivery Requirements

Place concrete into the work in accordance with the following:

(1) Type 1 Concrete—within 90 min of batching, and

(2) Type 3 Concrete—within 90 minutes of batching when all admixtures are added at the plant at the manufacturer's recommended dosage rates listed on the Approved Products list. If the haul time does not facilitate mixing and placing the concrete within 90 minutes, test the concrete in accordance with 2461.3.G.a.

The Contractor may transport Type 3 concrete in non-agitating equipment if the concrete is discharged within 45 min of batching.

Batch time starts when the batch plant or the transit mix truck adds the cement to the other batch materials.

G.3.a Delivery Time Beyond 90 Minutes

If the haul time does not facilitate mixing and placing the concrete within 90 minutes, perform the following procedures for pre-qualifying a concrete mix to extend the delivery time to 120 minutes. Extending the delivery time beyond 120 minutes will require additional testing at 30 minute intervals up to the maximum desired delivery time as directed by the Concrete Engineer.

(1) Contact the Concrete Engineer to determine if Laboratory and Field Trial Batching are required for your specific project prior to bidding.

(2) Provide a contractor mix design in accordance with 2461.2.F.3 for each combination of materials;

(3) Laboratory trial batching on the proposed mix includes the following testing requirements:
   (a) Perform all laboratory trial batching at an AMRL accredited laboratory;
   (b) Perform all plastic concrete testing after adding all admixtures to the concrete mixture;
   (c) Perform slump, air content, unit weight, and temperature testing immediately after batching, at 90 minutes, and at 120 minutes;
   (d) Fabricate concrete cylinders for compressive strength at 90 minutes and at 120 minutes (sets of 3) and cylinders for hardened air content testing at 90 minutes and at 120 minutes (sets of 5);
   (e) Test the cylinders for compressive strength at 28 days;
   (f) Determine the hardened air content (ASTM C457) at a minimum of 7 days. The Contractor is required to test 2 samples representing 90 minutes and 2 samples representing 120 minutes and provide MnDOT with the other 6 samples for testing at their discretion. Retain any hardened concrete test specimens for a minimum of 90 days for MnDOT to examine at their discretion;
   (g) Ensure the admixture manufacturer's technical representative is present during the trial batching;
   (h) Contact the MnDOT Concrete Engineering Unit a minimum of 2 days before mixing. This same 2 day notification is required before any physical testing on hardened concrete samples; and
   (i) Once accepted by the Concrete Engineer, the Department will consider the laboratory trial batching acceptable for use for 5 years, unless it is determined the material sources have changed significantly since the initial laboratory testing and acceptance. The Engineer will require field trial batching on all projects.

(4) Field trial batching on the proposed mix for each specific project shall include batching in the presence of the Engineer and the following:
   (a) Provide a QC Plan for extending the delivery time beyond 90 minutes;
   (b) Perform all plastic concrete testing with a MnDOT Certified Field 1 Technician or ACI Certified Field Level 1 Technician. Test all hardened concrete samples at an AMRL accredited laboratory.
   (c) Batch a minimum 5 cu. yd (4 cu. m) of concrete utilizing the same methods intended for use when supplying concrete placed into the permanent work;
   (d) Maintain the ready mix truck in transit; by either driving around the yard or on the roadway; and maintain the drum speed at 5 to 7 revolutions per minute for the entire 120 minutes;

(e) Perform all plastic concrete testing after adding admixtures to the concrete mixture;
(f) Perform slump, air content, unit weight, and temperature testing at 90 minutes and 120 minutes;
(g) Fabricate concrete cylinders for compressive strength at 90 minutes and 120 minutes (sets of 3) and cylinders for hardened air content testing at 90 minutes and 120 minutes (sets of 2);
(h) Test the cylinders for compressive strength at a minimum of 7 days;
(i) Determine the hardened air content (ASTM C457) at a minimum of 7 days. The Contractor is required to test 1 sample representing 90 minutes and 1 sample representing 120 minutes and provide MnDOT with the other 2 samples for testing at their discretion. Retain any hardened concrete test specimens for a minimum of 90 days for MnDOT to examine at their discretion;
(j) Incorporate the trial batch concrete into other work with the approval of the Engineer; and
(k) The Contractor must demonstrate to the Engineer the ability to properly mix, control, and place the concrete.

(5) The Concrete Engineer will review the trial batch results, including the certificates of compliance, and all related concrete testing for compliance with the QC Plan and the Contract. Final approval of the mixture is based on satisfactory field placement and performance.

G.4 Field Adjustments

For all grades of concrete, do not add additional mixing water unless the Certificate of Compliance states there is water available to add or once the concrete has attained an age 60 min from the initial batch time stated on the Certificate of Compliance.

For all grades of concrete with slumps of greater than 1 inch (25 mm) do not make water adjustments after discharging approximately 1 cubic yard (**1 m^3**).

For slip-form concrete median barrier and railing mixes with slumps of 1 inch (25 mm) or less, the Engineer will allow water adjustments as necessary to facilitate placement not to exceed the available amount of water to add stated on the Certificate of Compliance.

The Engineer will test the concrete for compliance with 2461.3.G.6, “Consistency,” and 2461.3.G.7, “Air Content,” in accordance with the following:

(1) If the first test taken by the Engineer passes, the Engineer will continue verification testing in accordance with the Schedule of Materials Control.
(2) If the test taken by the Engineer fails, make adjustments and perform any quality control testing before the Engineer performs a final test. Acceptance or rejection of the truck is based on the Engineer’s final test result.
(3) The Engineer will test up to two additional trucks in accordance with items (1) and (2) above, and
(4) If the concrete does not meet the specification after those three trucks, the Engineer will reduce their verification testing rate to once per truck for acceptance for the remainder of the pour.

For Department designed concrete mixtures 3U17 and 3U18, allow mix to hydrate 5 minutes before slump test to assure all cement is saturated.

Mix the load a minimum of 5 minutes or 50 revolutions at mixing speed after addition of any admixture.

G.5 Test Methods and Specimens

Perform sampling and testing in accordance with the Concrete Manual and determine testing rates meeting the requirements of the Schedule of Materials Control. When required by the Engineer, record

field measurements, including strength specimen identifications on MnDOT Form 2448, *Weekly Concrete Report*, to provide to the Engineer. The Engineer performs sampling and testing in accordance with the Concrete Manual and determines testing rates meeting the requirements of the Schedule of Materials Control and records field measurements, including strength specimen identifications on MnDOT Form 2448, *Weekly Concrete Report*, to provide to the Engineer.

Take samples randomly using ASTM D3665, Section 5.

The Engineer will furnish molds based on the maximum size aggregate for the test specimens in accordance with the following:

(1) 4 in × 8 in [100 mm × 200 mm] cylinder molds,
(2) 6 in × 12 in [150 in × 300 mm] cylinder molds for maximum aggregate sizes greater than 1¼ in [31.5 mm], and
(3) 6 in × 6 in × 20 in [150 in × 150 in × 500 mm] beam molds and use other beam mold sizes as approved by the Engineer

G.5.a Standard (28-day) Strength Cylinders

The Department will perform the following for standard strength cylinders:

(1) Cast cylinders (sets of 3) for testing at 28 days in accordance with the Schedule of Materials Control, **for the purposes of the pilot project, cast one (1) additional cylinder for testing at seven (7) days.**
(2) Mark cylinders for identification of the represented unit or section of concrete in accordance with the following: (1.1, 1.2, 1.3, 1.4/ 2.1, 2.2, 2.3, 2.4/ 3.1, 3.2, etc.). The Engineer will break the fourth cylinder in the numbering sequence (X**.**4) at 7 days. In order to differentiate between portions of a project, prefixes before the numbering sequence are allowed.
(3) Cure the cylinders meeting the requirements of the 2461.3.G.5.b and the Concrete Manual.
(4) Complete the MnDOT Concrete Cylinder Identification Card including the corresponding test results for air content, slump, concrete, and air temperature.

G.5.b Curing and Transporting Standard (28-day) Strength Cylinders

Provide moist curing environments of adequate size and number for initial and final curing in accordance with ASTM C31 and in accordance with 2031.3.C, "Special Requirements."

The Concrete Engineer defines the **initial curing period** as immediately after molding and finishing for a period of up to 48 hours in a temperature range from 60 °F to 80 °F [16 °C and 27 °C]."

After the initial curing period, the Engineer will both transport and further cure the test specimens in the provided curing tanks. The Engineer will deliver the test specimens to the laboratory for compressive strength testing.

Provide curing tanks of adequate size and number for curing all of the concrete test specimens in accordance with 2031.3.C, "Special Requirements." Maintain the water in the curing tanks to a water temperature of 60 °F to 80 °F [16 °C and 27 °C]. When cured in the laboratory, maintain the cylinders at a temperature of 73.5 °F ± 3.5 °F [23.0°C ± 2.0°C].

G.5.c Control Strength Cylinders

The Engineer will use control cylinders to determine when the sequence of construction operations is dependent upon the rate of concrete strength development. The Engineer will cast control cylinders to determine when the concrete attains the required strength for all desired control limitations. The Contractor is responsible for any additional control cylinders beyond the requirements of 2461.3.G.5.c (1).

The Engineer will perform the following for control strength cylinders:

(1) Cast up to three (3) control cylinders per structure.

(2) Mark control cylinders for identification of the represented unit or section of concrete in accordance with 2461.3.G.5.a(2). Mark Control Cylinders with the letter C after the numbering sequence (X.5C)

(3) Cure the cylinders in the same location and under the same conditions as the concrete structure or unit involved meeting the requirements of the Concrete Manual,

(3.1) For High-Early (HE) Concrete as defined in Table 2461-7 or UHE concrete as defined in 2302, the Engineer will allow the Contractor to store control cylinders in an insulated storage compartment, provided the Contractor monitors both the temperature inside the insulated storage compartment and in-place concrete to ensure the curing conditions replicate the in-place concrete temperature. The Contractor will provide the insulated storage compartment and any materials needed to monitor all temperatures.

(4) Complete the MnDOT Concrete Cylinder Identification Card including the corresponding test results for air content, slump, concrete, and air temperature.

During the Departments normal laboratory operating hours, the Engineer will perform compressive strength testing on the control cylinders. If Project scheduling requires testing outside of the Departments' laboratories normal operating hours or the Department's nearest laboratory is greater than 30 miles from the project; Provide certified and calibrated hydraulic cylinder-testing machine within 30 miles of the project and at a location approved by the Engineer. Test the control cylinders in the presence of the Engineer in accordance with ASTM C39.

The Engineer will allow the Contractor to submit a strength-maturity relationship curve for use in lieu of control cylinders in accordance with 2461.3.G.5.e.

G.5.d Strength Specimens for Concrete Paving

Use flexural beams to determine strength or provide cylinders as allowed by the contract or approved by the Engineer.

Cast standard beams or cylinders for testing at 28-days.

Cast a sufficient number of control beams or cylinders to determine when the concrete attains the required strength for all desired control limitations.

Cure the standard beams or cylinders meeting the requirements of the Concrete Manual.

Cure the control beams or cylinders in the same location and under the same conditions as the concrete structure or unit involved meeting the requirements of the Concrete Manual.

The Engineer will test the flexural beams and record the results on Mn/DOT Form 2162, *Concrete Test Beam Data*.

If using cylinders, the Engineer will submit cylinders, field testing information and a completed identification card to the Department's Laboratory.

G.5.e Placeholder for Concrete Maturity Spec

For the PILOT projects in 2014, MnDOT will review cylinder strength results and evaluate low strengths as follows:

G.5.f Acceptance of Concrete Compressive Strength

The Concrete Engineer defines a **strength test** as the average (28-day) strength of three (3) cylinders fabricated from a single sample of concrete and cured in accordance with the MnDOT Concrete Manual.

The Engineer will consider concrete acceptable in accordance with Table 2461-17 provided **both** conditions are met for a required f'c.

Table 2461-17 Acceptance Criteria for Standard 28-day Cylinders Concrete Grades F, G, M, P, and S		
	No strength test less than:	**Moving average of 3 consecutive strength tests***
f'c ≤ 5000 psi	< f'c – 500 psi	≥ f'c
f'c > 5000 psi	< 0.90 * f'c	≥ f'c
*If a project does not establish a moving average of 3 consecutive strength tests, use either the single strength test or the average of 2 strength tests to determine acceptance.		

If the moving average of three (3) consecutive strength tests falls below 87.5% of f'c, the Concrete Engineer will require immediate adjustment of the Concrete Mix Design in question or use of an alternate approved Concrete Mix Design in accordance with Table 2461-6.

If any strength test falls below the criteria established in Table 2461-17, the Engineer, in conjunction with the Concrete Engineer, will determine the following:

(1) If investigation is required;
(2) If the concrete has attained critical load-carrying capacity;
(3) Monetary adjustments in accordance with Table 2461-19.

The investigation may consist of, but is not limited to reviewing the following:

(1) Sampling and testing plastic concrete,
(2) Handling of cylinders,
(3) Cylinder curing procedures,
(4) Compressive strength testing procedures,
(5) Certificate of Compliances

If the Engineer, in conjunction with the Concrete Engineer, determines the concrete in question is acceptable to remain in place with no additional testing; the Engineer will determine if a price adjustment is required in accordance with Table 2461-19.

If the Engineer, in conjunction with the Concrete Engineer, determines the concrete in question is not acceptable:

(1) The Engineer and Contractor will mutually agree on an Independent Third Party to core and test the concrete in question in accordance with ASTM C42.
(2) The Engineer will identify a minimum of three (3) locations for the Independent Third Party to core. The Independent Third Party will take one (1) core at each location.
(3) The Contractor is responsible for ensuring the core holes are repaired.
(4) The Engineer will require the Contractor to complete all coring within 14 days of notification of the low strength concrete.

The Engineer, in conjunction with the Concrete Engineer, will review the core test results and evaluate in accordance with Table 2461-18, providing all other concrete tests meet requirements.

Table 2461-18 Evaluation of Core Test Results			
Core (average of 3 cores) Test Results:	**Engineer considers concrete:**	**Cost of Coring and Testing:**	**Resolution:**
≥ 85% of f'c	Acceptable to remain in place	Engineer Responsibility	No monetary adjustment and consider any additional actions in accordance with Table 2461-19.
< 85% of f'c	Unacceptable	Contractor Responsibility	Remove and replace concrete in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work," as directed by the Engineer. If the Engineer, in conjunction with the Concrete Engineer, determines the concrete can remain in place, the Engineer may not pay for the concrete or will pay at an adjusted Contract Unit Price and consider any additional actions in accordance with Table 2461-19.

G.5.g Non-Conforming Material

If the Contractor inadvertently places concrete not meeting the strength requirements in accordance with Table 2461-17 into the work, the Engineer will not accept nonconforming concrete at the contract unit price.

For concrete not meeting the moving average of three (3) consecutive strength tests, the Engineer will make determinations regarding the disposition, payment, or removal. The Department will adjust the contract unit price for the contract item of the concrete in accordance with Tables 2461-19 based upon cylinder strength test results.

Table 2461-19 Concrete Grades F, G(Non-Bridge), M, and P**	
Moving average of 3 consecutive strength tests	**Adjusted Contract Unit Price**
> 93.0% of f'c	The Department will pay 87.5 percent of the relevant contract unit price for materials placed as approved by the Engineer.
≥ 87.5% and ≤ 93.0% of f'c	The Department will pay 75 percent of the relevant contract unit price for materials placed as approved by the Engineer.
< 87.5% of f'c	Remove and replace concrete in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work," as directed by the Engineer. If the Engineer, in conjunction with the Concrete Engineer, determines the concrete can remain in place, the Engineer will not pay for the concrete.
When there is not a separate contract unit price for *Structural Concrete* for an item of work or the concrete is a minor component of the contract unit price, the Department will reduce payment based on a concrete price of $100.00 per cu. yd [$130.00 per cu. m] or the Contractor-provided invoice amount for the concrete in question, whichever is less.	

****The Engineer, in conjunction with the Concrete Engineer, will determine adjusted contract unit prices for Concrete Grade G(Bridge) and Grade S strength failures in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."**

G.6 Consistency

The Engineer will test the concrete for consistency using the slump test during the progress of the work. The Department may reject concrete batches with consistencies outside the slump range limits stated in Table 2461-6, Table 2461-7, Table 2461-10 and Table 2461-11.

If any test shows the slump outside of the slump range requirements, the Engineer will reject the concrete represented by that test. In order to bring the mixture back into the slump range requirements, the Engineer will allow adjustments to the concrete in accordance with 2461.3.G.3, "Delivery Requirements" and 2461.3.G.4, "Field Adjustments.

Adjust the slump not to exceed the slump range allowed to optimize both placement and finishing. Contact the Engineer if encountering unusual placement conditions that render the maximum slump unsuitable.

G.6.a Concrete Placed by the Slip-Form Method

Place concrete that does not slough and is adequately consolidated at a slump value that optimizes placement for the designated mixture and in accordance with 2461.3.G.4.

G.6.b Non-Conforming Material

Place concrete meeting the slump range requirements. If the Contractor inadvertently places concrete not meeting the slump requirements into the work, the Engineer will not accept non-conforming concrete at the contract unit price.

For concrete not meeting the required slump, the Engineer will make determinations regarding the disposition, payment, or removal. The Department will adjust the contract unit price for the contract item of the concrete in accordance with Tables 2461-20, 2461-21, 2461-22 and 2461-23.

Table 2461-20
Concrete Grades F, G, M, P, R, S(Non-Bridge Deck)*

Outside of Slump Range	Adjusted Contract Unit Price
Below slump range*	No deduction for materials placed as approved by the Engineer.
≤ 1½ in [40 mm] above slump range	The Department will pay 75 percent of the relevant contract unit price for materials placed as approved by the Engineer.
1¾ in [45 mm] – 2¼ in [55 mm] above slump range	The Department will pay 50 percent of the relevant contract unit price for materials placed as approved by the Engineer.
> 2¼ in [55 mm] above slump range	The Department will pay 25 percent of the relevant contract unit price for materials placed as approved by the Engineer

* If the Contractor places piling or footing concrete below the slump range, the Department will deduct $100 per cu. yd [$130 per cu. m] or the Contractor-provided invoice amount to the relevant contract unit price of the concrete represented by the slump test, whichever is less. The Department will not reduce contract unit price for low slump concrete placed with the slip-form method as approved by the Engineer.

Table 2461-21
Bridge Deck Concrete, Grade S

Outside of Slump Range	Adjusted Contract Unit Price
Below slump range	No deduction for materials placed as approved by the Engineer.
≤ 1½ in [40 mm] above slump range	The Department will pay 75 percent of the relevant contract unit price for materials placed as approved by the Engineer.
> 1½ in [40 mm] above slump range	The Department will pay 25 percent of the relevant contract unit price for materials placed as approved by the Engineer.

Table 2461-22 Low Slump Bridge Deck Concrete, 3U17A From ½ in to 1 in [12 mm to 25 mm]	
Outside of Slump Range	**Adjusted Contract Unit Price**
Below slump range	No deduction for materials placed as approved by the Engineer.
≤ ½ in [12 mm] above slump range	The Department will pay 50 percent of the relevant contract unit price for materials placed as approved by the Engineer.
> ½ in – ¾ in [12 mm – 20 mm] above slump range	The Department will not pay for concrete placed but will allow the concrete to remain in place as approved by the Engineer.
> ¾ in [20 mm] above slump range	The Department will not pay for concrete. Provide additional testing as directed by the Engineer to determine if the concrete can remain in place or is subject to removal and replacement.

Table 2461-23 Low Slump Concrete — Patching From ½ in to 1 in [12 mm to 25 mm]	
Outside of Slump Range	**Adjusted Contract Unit Price**
Below slump range	No deduction for materials placed as approved by the Engineer
≤ ½ in [12 mm] above slump range	The Department will pay 75 percent of the relevant contract unit price for materials placed as approved by the Engineer.
≥ ¾ in [20 mm] above slump range	The Department will pay 25 percent of the relevant contract unit price for materials placed as approved by the Engineer.

When there is not a separate contract unit price for *Structural Concrete* for an item of work or the concrete is a minor component of the contract unit price, the Department will reduce payment based on a concrete price of $100.00 per cu. yd [$130.00 per cu. m] or the Contractor-provided invoice amount for the concrete in question, whichever is less.

G.7 Air Content

Maintain the air content of Type 3 general concrete at the specified target of 6.5 percent (+2.0 percent and -1.5 percent) of the measured volume of the plastic concrete in accordance with 1503, "Conformity with Contract Documents."

Measure the air content at the point of placement but before consolidation.

Make any adjustments immediately to maintain the desired air content.

G.7.a Non-Conforming Material

Place Type 3 concrete meeting the air content requirements. If the Contractor inadvertently places Type 3 concrete not meeting the air content requirements into the work, the Engineer will not accept non-conforming concrete at the contract unit price.

For concrete not meeting the required air content, the Engineer will make determinations regarding the disposition, payment, or removal. The Department will adjust the contract unit price for the contract item of the concrete in accordance with Table 2461-24.

Table 2461-24 General Concrete (Target Air Content 6.5%), Grades A, F, G, M, P, R, and S	
Air Content, %	**Adjusted Contract Unit Price**
> 10.0	The Engineer, in conjunction with the Concrete Engineer will determine the concrete suitability for the intended use in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work,"
>8.5 – 10.0	The Department will pay 75 percent of the Contract unit price for the concrete represented for material placed as approved by the Engineer.
5.0 – 8.5	The Department will pay 100 percent of the contract unit price for the concrete represented, for material placed as approved by the Engineer.
>4.0 – <5.0	The Department will pay 75 percent of the contract unit price for the concrete represented for material placed as approved by the Engineer.
>3.5 – 4.0	The Department will pay 25 percent of the contract unit price for the concrete represented and placed as approved by the Engineer. If the Engineer, in conjunction with the Concrete Engineer, determines the surface is exposed to freeze-thaw cycling, coat the concrete with an approved epoxy penetrant sealer from the Approved/Qualified Products List.
≤ 3.5	Remove and replace concrete in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work," as directed by the Engineer. If the Engineer, in conjunction with the Concrete Engineer, determines the concrete can remain in place, the Engineer will not pay for the concrete and if the Engineer determines the surface is exposed to salt-brine freeze-thaw cycling, coat with an approved epoxy penetrant sealer from the Approved/Qualified Products List.

When there is not a separate contract unit price for *Structural Concrete* for an item of work or the concrete is a minor component of the contract unit price, the Department will reduce payment based on a concrete price of $100.00 per cu. yd [$130.00 per cu. m] or the Contractor-provided invoice amount for the concrete in question, whichever is less.

G.8 Allowable Testing Tolerances

Allowable tolerances are based on the results from two different testers and two different pieces of equipment from the same sample. Perform the test within the allowable tolerances in accordance with Table 2461-25.

Table 2461-25 Allowable Testing Tolerances	
Test	**Allowable Tolerance**
Air content, % volume of concrete	1.0
Average slump:	
≤ 4 in [100 mm]	1.0 in [25 mm]
4 in – 6 in [100 mm – 150 mm]	1.5 in [38 mm]
≥ 6 in [150 mm]	2.0 in [50 mm]
Unit weight, per cu. ft [cu. m], calculated to an air-free basis	1.0 lb/cu. ft [16 kg/cu. m]
Compressive strength 3,000 psi – 8,000 psi [20.6 MPa – 55.2 MPa], average of 3 tests	500 psi [3.4 MPa]

2461.4 METHOD OF MEASUREMENT

The Engineer will measure fresh concrete produced as required by the contract by the theoretical volume.

The Engineer will deduct accountable waste from the concrete measurement.

The Engineer will measure concrete mixtures on the basis of the dimensions of the structure shown on the plans. If the plans do not include a contract item for concrete used in miscellaneous items, include the cost of the concrete with the relevant contract items.

2461.5 BASIS OF PAYMENT

The Department will include the cost of the Certified Ready-Mix Plant Program with other relevant contract items.

The contract cubic yard [cubic meter] price for *Concrete, Mix No.* ___ includes the cost of production, placement, finishing, curing, and protection of concrete.

The Department will pay for structural concrete on the basis of the following schedule:

Item No.:	Item:	Unit:
2461.501	Concrete, Mix No.___	cubic yard [cubic meter]

S-2 (3137) COURSE AGGREGATE FOR PORTLAND CEMENT CONCRETE PILOT PROJECTS

MnDOT 3137 is hereby modified as follows:

S-2.1 MnDOT 3137 shall be modified to include Table 3137-4REV immediately following Table 3137-4:

Table 3137-4REV
Coarse Aggregate Designation for Concrete,
percent by weight passing square opening sieves

	Coarse Aggregate Designation			
	4	**6**	**7**	**8**
Sieve Sizes	**ASTM #467**	**ASTM #67***	**ASTM #7***	**ASTM #89**
2 in [50 mm]	100	-	-	-
1½ in [37.5 mm]	95 – 100	-	-	-
1 in [25.0 mm]	-	100	-	-
¾ in [19.0 mm]	35 – 70	90 – 100	100	-
½ in [12.5 mm]	-	-	90 – 100	100
⅜ in [9.5 mm]	10 – 30	20 – 55	40 – 70	90 – 100
No.4 [4.75 mm]	0 – 5	0 – 10	0 – 15	20 – 55
No.8 [2.36 mm]	-	-	-	5 – 30
No.16 [1.18 mm]	-	-	-	0 – 10
No.50 [300 µm]	-	-	-	0 - 5
*ASTM #67 and ASTM #7 Gradations are MnDOT Modified.				

S-3 REVISED SCHEDULE OF MATERIALS CONTROL FOR CONCRETE FIELD TESTING FOR CONTRACTOR MIX DESIGNS -– PILOT

Delete the Concrete Field Testing Tables for General Concrete and Bridge Concrete from the Standard Schedule of Materials Control and replace with the following tables:

Concrete Field Testing –General Concrete Grades F, G(Non-Bridge), M, P, and R					
Pay Item No.	Test Type	**Spec. No.**	**Contractor Testing**	**Agency Testing**	**Form No.**
2302 2452 2461 2506 2511 2514 2520 2521 2531 2533 2545 2550 2554 2557 2564 2565	Air Content for Type 3 Concrete (Verification) (5-694.541)	2461		1 per 100 yd^3 (m^3) Test first load each day per mix Test when adjustments are made to the mix.	2448 Weekly Concrete Report
	Slump (Verification) (5-694.531)	2461		Test first load each day per mix, then test as necessary to verify passing slump No slump testing required for slipform placement	
	Air and Concrete Temperature (5-694.550)	2461	Record temperature each time air content, slump, or strength test specimen is performed/fabricated.	Record temperature each time air content, slump, or strength test specimen is performed/fabricated.	
	Compressive Strength (Verification) (5-694.511)	2461	Any additional control cylinders are the responsibility of the Contractor. MnDOT standard cylinder mold size is 4 x 8 inch (100 x 200 mm). If aggregate has a maximum size greater than 1-1/4 inch (31.5 mm), use 6 x 12 inch (150 x 300 mm) molds.	1 set of 4 cylinders per 300 yd^3 (m^3) MnDOT will break 1 cylinder at 7-days MnDOT will break 3 cylinders at 28-days MnDOT will cast up to three (3) control cylinders. MnDOT standard cylinder mold size is 4 x 8 inch (100 x 200 mm). If aggregate has a maximum size greater than 1-1/4 inch (31.5 mm), use 6 x 12 inch (150 x 300 mm) molds for the 28-day strengths.	2409 ID Card Concrete Test Cylinder When submitting samples, record all field test results and Batch Ticket Number on the Cylinder ID Card.

Concrete Field Testing – Bridge Concrete Grade G(Bridge), S					
Pay Item No.	**Test Type**	**Spec. No.**	**Contractor Testing**	**Agency Testing**	**Form No.**
2401 2406 2411 2461	Air Content for Type 3 Concrete (Verification) (5-694.541)	2461		1 per 100 yd^3 (m^3) Test first load each day per mix Test when adjustments are made to the mix.	2448 Weekly Concrete Report
	Slump (Verification) (5-694.531)	2461		1 per 100 yd^3 (m^3) Test first load each day per mix Test as necessary to verify passing slump No slump testing required for slipform placement	
	Air and Concrete Temperature (5-694.550)	2461	Record temperature each time air content, slump, or strength test specimen is performed/fabricated.	Record temperature each time air content, slump, or strength test specimen is performed/fabricated.	
	Compressive Strength (Verification) (5-694.511)	2461	Any additional control cylinders are the responsibility of the Contractor. MnDOT standard cylinder mold size is 4 x 8 inch (100 x 200 mm). If aggregate has a maximum size greater than 1-1/4 inch (31.5 mm), use 6 x 12 inch (150 x 300 mm) molds.	1 set of 4 cylinders for 100 yd^3 (m^3), then 1 set of 4 cylinders per 300 yd^3 (m^3) thereafter MnDOT will break 1 cylinder at 7-days MnDOT will break 3 cylinders at 28-days MnDOT will cast up to three (3) control cylinders. MnDOT standard cylinder mold size is 4 x 8 inch (100 x 200 mm). If aggregate has a maximum size greater than 1-1/4 inch (31.5 mm), use 1 set of 2 (6 x 12 inch (150 x 300 mm) molds) in lieu of the 1 set of 3 - 4 x 8 cylinders for the 28-day strengths.	2409 ID Card Concrete Test Cylinder When submitting samples, record all field test results and Batch Ticket Number on the Cylinder ID Card.