510 Concrete Masonry

510.1 General
Instructions in this section apply to the proper control of procedures and operations used to produce concrete in its plastic state. These instructions are applicable to all grades and classes of concrete used in the construction of pavement, structures, and incidental items.

Placing, consolidating, finishing, curing, and protection of the mixed concrete are discussed elsewhere in this manual under the specific work items, such as pavement, structures, curb and gutter, etc.

Procedures for sampling and testing of the cement, aggregate, admixtures, and concrete are included in 800.

510.2 Stockpiling Aggregates
Concrete mix designs are based on uniformly graded aggregates containing the proper proportions of the various sizes from coarse to fine.

Segregation is the separation of the coarser and finer particles, where an excess of either one tends to accumulate over a particular area. Contamination is the presence in the aggregates of foreign materials that are unsuitable and detrimental in a concrete mix.

The following procedures should be followed in handling aggregates to reduce segregation and contamination to a minimum.

1. The site selected for stockpiling should be cleared and graded to a firm foundation. The area should be sloped to drain, preferably in a direction away from the side on which trucks or equipment will operate when building the stockpile. At no time during construction of the stockpile should this equipment be permitted to operate over soft or muddy ground when it tracks in muddy soil and contaminates the stockpile.

2. If lack of room does not permit the complete separation of the stockpiles, partitions or bulkheads are required between them to prevent intermingling of the fine aggregate and the several sizes of coarse aggregates.

3. Standard spec 501.3.3.1 requires coarse aggregate stockpiles to be constructed so that separation of the coarse and fine fractions is minimized. Significant segregation or variation in gradation will result when stockpiles are built cone-shaped or by dumping on a slope, so stockpiles should be constructed in layers. A judicious use of rubber-tire bulldozers or front-end loaders can be permitted if continued travel over the same area does not cause excessive breakage of the aggregates.

4. Uniformity of moisture content, particularly in sand, is essential in the production of a concrete mix of uniform consistency. Sand coming directly from the washing plant must be stockpiled for 12 hours before being used, to permit it to drain to a reasonably uniform moisture content. If conditions permit, the engineer may reduce this waiting period. When an excess of moisture collects in the bottom of the pile, sand from this location should not be used until a moisture determination has been made. A similar condition may exist in the bottom of the aggregate bins, particularly after a rain when material has not been used for some time. To avoid excessively wet initial batches, the first batch or two should be dumped back in the stockpile when operations are resumed.

510.3 Ready-Mixed Concrete
Standard spec 501.3.5.1 provides that ready-mixed concrete may be central-mixed concrete, transit-mixed concrete, or shrink-mixed concrete.

510.3.1 Central-Mixed Concrete
In the case of central-mixed concrete, the concrete is mixed in a stationary mixer located at the batching plant and the mixed concrete is transported to the job site. Stationary mixers may be of a comparatively large capacity, up to 10 cubic yards. For mixers having a rated capacity greater than 1 CY, the mixing time should be a minimum of 60 seconds, provided plant operations are reasonably stabilized and controlled, and apparent blending of materials during charging is achieved to the satisfaction of the engineer.

Should the stabilization, control, and blending not be accomplished the engineer may increase the mixing time to 75 seconds. The maximum mixing time should not exceed the minimum by more than 60 seconds. Exceptions to the minimum mixing time should be made only as allowed in standard spec 501.3.5.3.

Where central-mixed concrete is used, it is a requirement of the specifications that positive mechanical control of the mixing time be maintained by means of a timer and interlock, which prevents discharge of a batch before the required mixing period has been completed. Adequate provision for inspection control must also be maintained.

Proper blending of the materials being charged into the mixer is required. Standard spec 501.3.5.3 describes the sequence of charging the mixer to obtain the proper blending of the materials.

Stationary mixers operated by the contractor for producing central-mixed concrete should be checked for operating features that provide control of the mixing.
510.3.2 Transit-Mixed Concrete

Transit-mixed concrete is concrete completely mixed in a truck mixer. When transit-mixed concrete is used, truck mixers should be checked for mixing blade condition and assurance that there is no leakage from the water tank into the mixer.

Truck mixers are required by standard spec 501.3.5.3 to be equipped with an approved revolution counter. It should be read at the time of loading and marked on the load ticket for comparison with the revolution reading at time of discharge of the load.

Truck mixing must be done at the job site or the batching plant unless the truck is equipped with an accurate and dependable device to indicate and control the number of revolutions at mixing speed. This requirement is waived for truck mixers operating from plants erected for the sole purpose of supplying concrete to highway projects when the delivery time is so short the maximum 110 mixing revolutions cannot be exceeded. Truck mixers should be set at mixing speed when leaving the plant. Truck mixers are to be operated at agitating speed between the batching plant and the job site unless equipped with the above device.

When the mixing must be performed at either the job site or the batching plant, the plan selected must be by mutual agreement between the engineer and contractor (ready-mix dealer) based on consideration of all pertinent factors.

Generally, best control can probably be maintained by complete mixing at the batching plant, and this is recommended when an additional person can be made available to inspect the operation. When personnel consideration prevents adoption of this procedure, job site mixing may be resorted to.

Mixing of concrete in truck mixers, for either initial mixing or after adding extra water, must be at the mixing speed (drum revolutions per minute) recommended by the manufacturer as shown on an attached plate. In the case of complete mixing at the batching site, it is recommended the minimum 70 revolutions be accomplished, permitting an additional 40 revolutions to be used at the job site if additional water is required. For job site mixing, (or batch site mixing before uniform conditions have been established), a better procedure may be to mix for 50 revolutions, examine the mix, add water as necessary and mix an additional 20 revolutions. Any added water must be carefully measured and noted on the inspection ticket.

In any case, truck mixers or agitators delivering ready-mixed concrete must be operated at mixing or agitating speed until discharge of the batch.

510.3.3 Shrink-Mixed Concrete

This type of ready-mixed concrete has been partially mixed in a stationary mixer at the batch plant, with mixing completed in a truck mixer. Requirements discussed above for central-mixed and transit-mixed concrete apply.

510.3.4 Commercial Ready-Mix Plants

Commercial ready-mix plants are usually located in metropolitan or urban areas to supply concrete for general public use. They must meet all the requirements applicable to batch plants that supply concrete for state use, and all materials used must conform to WisDOT quality and gradation specifications.

510.3.5 On-Site Mixer (Concrete-Mobile)

Site-mixed concrete is used in present-day highway construction for Grade E overlays and can be used for items from other grades when permitted by the engineer. Standard spec 501.3.6 covers requirements for on-site mixers, including volumetric mixers.

Volumetric mixers are truck-mounted, mobile continuous concrete mixers which, when properly calibrated, will produce high-quality, uniform concrete masonry. The mixer has two aggregate bins, one for fine aggregates and one for Size No. 1 coarse aggregate, a cement bin, a water tank, and admixture dispensing equipment as needed. The sand and coarse aggregate should be as dry as possible. Excessive water carried in the fine or coarse aggregates will throw the proportioning of the ingredients out of balance.

Ingredient proportioning with the concrete mobile is based on the known unit dry weight of each ingredient. These weights are translated to the mix by volume-weight equivalent settings on specially prepared mix control setting charts. The charts are provided for the convenience of the operator and to enable delivery of the specified concrete without the necessity of making any calculations in the field.

Proportioning adjustment or mix controls (in the form of large dials with pointers, controlled by handwheels) are provided for both sand and coarse aggregate. With these controls, the operator may, in accordance with design formula specifications, change the proportions of both sand and coarse aggregate that are delivered into the mixer during each revolution of the cement feeder. Once they are properly set, the mix controls may
be locked to ensure constant and exact proportioning of the three dry ingredients (cement, sand, and coarse aggregate) to produce the desired mix.

Cement is fed into the charging end of the mixer by a positive rotary vane-type feeder at a constant rate directly proportional to the rotational speed of the shaft on which it operates. The accuracy of this feeder is the key to the entire proportioning operation.

Sand and coarse aggregate are ribbon-fed into the charging end of the mixer by a belt-type apron feeder system synchronized with the cement vane feeder to deliver a calibrated proportional amount of each type of aggregate during each rotation of the cement feeder. Because the cement and aggregate feeders are mechanically synchronized, the proportions of each of the dry ingredients are constant once the proportioning controls are set and locked.

A meter actuated by the cement feeder shaft enables the operator to easily check the number of accumulated revolutions of the cement feeder at any time during operation. This information enables a determination of the exact amount of concrete produced and delivered.

Water is fed into the charging end of the mixer under controlled pressure. A flow meter enables the operator to adjust the rate of flow, so it provides the exact amount of water needed to produce the concrete design specified by the engineer.

The mix setting charts include the proper settings for both the sand and coarse aggregate mix controls as well as for the rate of flow of the water, in liters per minute, to produce "design" concrete. Any variation from these settings will change the proportioning of ingredients and alter the predetermined concrete design.

The three major proportioning controls may be properly adjusted and locked within seconds. This makes it possible for the operator to deliver concrete of one design, stop production and change the control settings, then deliver concrete of an entirely different design at one call. The settings never should be changed while the concrete mobile is proportioning and mixing.

A possible exception to the above statement occurs when the inspector asks for more water for easier handling or more slump. This can be done by adjusting the water valve to increase the flow of water while the concrete mobile is in operation.

Determination of mix and admixture settings and the calibration of the mixer and admixture dispensing equipment must be in accordance with the manufacturer's manuals and charts.

510.4 Types of Batching Plants

Generally, batching plants for proportioning of aggregates for the mix consist of bins for immediate storage of each aggregate, hoppers for containing aggregates during weighing, and scales for weighing the aggregates. A separate and similar arrangement of bins, hoppers, and scales is provided for proportioning of cement.

There are various types of plants for batching concrete, from the simple manually controlled type to the complex fully automatic batchers that print a record of each batch. Batching plants may generally be classified as manual, semi-automatic, or automatic.

510.4.1 Manual Plants

As the term implies, in a manual plant the operator controls all the functions necessary to complete the weighing cycle. As the correct weights are dependent on the operator's skill and reliability, the plant inspector should be constantly alert to see that the correct amount of material goes into every batch.

510.4.2 Automatic and Semi-Automatic Plants

The mechanical operation of automatic and semi-automatic plants is similar. An automatic plant is considered as one where the complete batching cycle is set in motion by a single control button. A semi-automatic plant is governed by controls, which are actuated in a certain sequence to complete the batching cycle.

Semi-automatic and automatic plants produce more uniform and more accurately proportioned concrete, when properly adjusted, than manual plants, so a full-time inspector is not required to observe the batching.

Standard spec 415.3.3 requires that semi-automatic or automatic batching plants must be used on projects having 15,000 SY or more of concrete pavement. A combination of semi-automatic or automatic batchers may be used; for example, a semi-automatic aggregate batcher and an automatic cement batcher or vice versa. Each system must meet the applicable interlock and other requirements.

Manual as well as semi-automatic and automatic plants can be used for projects having less than 15,000 SY of pavement or on projects involving concrete masonry for other purposes. When a contractor elects to operate a batch plant in the semi-automatic or automatic mode, when not required, the plant or operation must, nevertheless, meet the requirements for semi-automatic or automatic operation, as the case may be. A
contractor may, however, elect to operate a semi-automatic or automatic plant in the manual mode when the specifications do not require semi-automatic or automatic operation.

510.5 Ready-Mixed Concrete Plant Operation

510.5.1 Background

Batching is the first step in the physical production of concrete. It consists of the accurate measurement of the ingredients to form a production unit of concrete. Following batching, the material is thoroughly mixed until it is uniform, and all materials are evenly distributed.

The goal of batching and mixing is to produce a uniform concrete containing the required proportions of materials. The proportions of materials must be consistent in order to ensure this uniformity. Errors in the measurements of the ingredients during batching will cause variation in the workability, strength, and durability. The six requisites to batching and mixing are listed below:

- Materials must be homogeneous and non-segregated before and during production.
- The batching and mixing equipment must accurately handle material and must be capable of easily changing the quantities when required.
- The proper proportions of materials must be maintained from batch to batch.
- Materials must be introduced into the mixer in the proper sequence.
- Thorough mixing occurs when all aggregate particles have been completely coated with cement paste.
- The concrete discharged from batch to batch must be uniform and homogeneous.

510.5.2 Production Sequence

1. Batching

   1.1 Aggregates in the stockpiled size ranges are loaded onto conveyors and elevated to their separate bins. Conveyor belts should be positioned so the aggregates will drop into the bins without hitting the sidewalls. Aggregates can become undersized as a result of handling operations, thus altering the gradation. Aggregates should not fall from great heights because degradation, segregation, and loss of fines can occur. Bins should be kept nearly full to reduce breakage and segregation.

   1.2 Aggregates drop from their separate bins into their separate batchers where they are weighed and held before entering the mixing drum.

   1.3 Cement from its separate storage tank enters its own batcher where it is weighed and held before entering the mixing drum.

      The cement storage system should provide for dry storage, since even the moisture in the air can cause partial hydration of the cement. The silos should be weatherproof and vented to prevent moisture from accumulating. Interiors of bins should be smooth to allow for the free removal of cement. Each bin or silo is equipped with a gate and conveyor system. The conveying system should provide consistent flow of cement with precise cutoff. Bins or silos should be free of cracks to prevent leakage from the container.

      Cement silos should be emptied periodically, and an inspection made to ensure there is no build-up of cement. Drawing the silo empty once a month can prevent cement caking. Cement build-ups could break off and produce cement lumps in the finished concrete.

   1.4 Fly ash and ground granulated blast furnace slag, when used, are handled similarly to cement.

2. Mixing

   A mixing cycle consists of these four steps regardless of the type of mixer: charging time, mixing time, discharge time, and return time.

   2.1 Charging time begins when the batching is completed, and materials are entered into the drum. Charging continues until all solid materials are in the mixer and it is ready to start the mixing cycle.

      The charging of materials into the mixer is an important consideration. Loading must be done in a manner to prevent the packing of material in the head of the drum. A blend of water, cement, and aggregate from start to finish may cause problems such as head pack (sand and cement) and poor mixing.

      Refer to standard spec 501.3.5.3 for the charging sequence.

      In general, admixtures should be uniformly added with the water. In some instances, if the admixture is not working, it may be added after the water, in an attempt to solve the problem. When more than one admixture is used, separate discharge pipes should be provided for each. Care should be taken to keep admixtures from coming together before they enter the mixture.

      During charging, each batcher scale read-out system should be visually monitored to ensure it returns to zero after the material has been discharged from it. If it does not return to zero, this would indicate some material was left in the batcher and the resulting batches are light in that component.
2.2 Mixing time begins with the first mixing revolution of the drum. In a stationary-type of mixer this begins when the charging ends with all solid materials in the drum. The mixing time ends when the first mixed concrete is discharged from the mixer.

2.3 Discharge time is the time from when the first particle of concrete starts leaving the mixer until the mixer is empty.

2.4 The return time is the time from the instant the mixer is empty to when it is ready to be charged again. In a central mix operation this return time could be only a matter of seconds.

510.6 Plant Checkout

510.6.1 General
Before start of production operations, a thorough inspection of the concrete batching plant and mixing equipment should be made to determine the batching plant and mixing equipment conform to requirements of the specifications and are capable of producing the specified product. The inspection should be made as early as feasible in order to provide sufficient time for the contractor to complete any necessary alterations or corrections before start of production.

The results of the inspection should be reported. One copy of the report should be kept available for review in the engineer's office. If any items listed are found to be not in accordance with the specifications, the corrective measures taken should be indicated on the report. Additional inspections should be made during production to ensure that proper operating conditions are maintained.

510.6.2 Testing Scales
All scales used for weighing of aggregates or cement must be tested before start of proportioning operations and checked as often thereafter during the progress of the work as is necessary for assurance of their continued operation within the degree of accuracy required. Scales should be checked and tested in accordance with requirements stated in 813.

High production plants may require more frequent scale checks than usual. The engineer should determine the frequency of scale tests on the basis of the particular plant operation.

An "over or under" indicator is required on beam scales, which indicates when the required load in the weigh hopper is being approached or if there is a deficiency or excess in the amount of material in the hopper. The beam poises should be checked frequently to see that they are fastened securely in their correct position. Accumulation of material in the hopper or on any part of the scale mechanism should not be permitted. When dial scales are used, markers must be attached to the dial rim to mark the proper weights for each aggregate. Scales should be accurate to within 0.4% of the net load in the hopper. The weigh beams or dial should be graduated to permit settings to be made within this tolerance. Some plants may be equipped with digital scales, which provide a continuous numerical read-out.

510.6.3 Aggregate Bin Checks
Batching bins provide intermediate storage for the aggregates to be used in the batch. They are divided into compartments for the separation of the different sizes or kinds of aggregates. Each compartment has a discharge gate by which the required amount of each aggregate is metered into the weigh hoppers.

The separating partitions should extend above the top of the bin a sufficient distance to prevent the intermingling of the aggregates when they are heaped.

Batch bins should be erected on firm foundations to preclude uneven settlement after they are loaded. The accuracy of a scale depends on its operation in a true horizontal position. The bins should, therefore, be checked for level after a short period of operation and at frequent intervals thereafter.

Before batching operations are started, the bins should be loaded to their capacity for a minimum of five hours before testing the scales to allow for settlement and adjustment to working conditions, as required in standard spec 501.3.4.5.

510.6.4 Posting Batch Weights
After the mix proportions have been computed and the moisture determination has been made, the weights of each kind of material per batch should be posted on the scale in full view of the scale operator and the weigh inspector. Any subsequent change should be posted promptly so that at no time should there be any question as to the weight of material to be batched.

510.6.5 Tolerance and Interlock Checks
An automation and interlock checkout of the plant should be performed as early as feasible to allow sufficient time for the contractor to make any necessary repairs or adjustments. The contractor should furnish trained personnel to perform the automation and interlock tests, and to check the tolerance settings. Most operators
do not like to perform tolerance checkouts; however, most plants are operated with either no tolerances or very large tolerances, so a checkout should be required.

Before performing the initial tolerance check, the batching scales should be checked. The entire plant should be inspected, and the operation of all interlocks, except interlocks having specified tolerances, should be checked.

The engineer or plant inspector should observe the checkout and verify and record the results. A report of results obtained should be recorded each time an automation and interlock checkout is performed. The record should be retained with the project records and be available for inspection.

In addition to the initial check-out performed before the start of plant operations, a subsequent tolerance and interlock test should be made during the first week of operation and at least weekly thereafter. Checkouts and tolerance tests should also be performed whenever equipment malfunctions indicate a need.

**Standard spec 501.3.4.5.4** requires that in automatic plants the batcher charging mechanism must be interlocked, (1) against opening until the batcher is entirely discharged and the scale is balanced with 0.3% of the scale capacity, and (2) against opening when the batcher discharge gate is open. They also require that the batcher discharge must be interlocked, (1) against opening when the batcher charging mechanism is open, and (2) against opening if the batch is either over or under weight by more than 1.5% of the specified batch weight in individual batchers, (1.0% for cement) or 1.5% of the specified intermediate and final cumulative batch weights in cumulative batchers. The batcher discharge of semi-automatic plants must be interlocked against opening if the batch in the hopper is either overweight or underweight by more than 1.5% of the specified intermediate and final cumulative batch weights in cumulative batchers.

Tolerance and interlock checks should be performed in accordance with manufacturer's instructions or the following procedure. A complete tolerance and interlock checkout may not be necessary at commercial ready-mix plants; however, the inspector should be assured the interlocks are operating satisfactorily.

**Standard spec 501.3.4.5.4** and **standard spec 501.3.4.6** do not require automatic or semi-automatic concrete batch plants to be equipped with a dial puller or device to apply pressure on a scale lever to simulate weights and facilitate tolerance checks. This equipment is desirable; however, the tolerance checks can be accomplished by loading the batchers with material in the required amounts.

**Typical batch computations for individual and accumulative batchers are shown in Example 1. The calculation of the zero tolerance assumes that a cumulative batcher is being used, the capacity of the aggregate scale is 30,000 lbs., and the capacity of the cement scale is 5,000 lbs.**

**Example 1**

Assume one batch is composed of 1 CY of Grade A mix having 565 lb. of cement and 3,120 lb. aggregate total, 40% of which is fine aggregate (1,248 lb.) and 60% of which is coarse aggregate (1,872 lb.). The coarse aggregate is 40% No. 1 stone (750 lb.) and 60% No. 2 stone (1,122 lb.). Six batches (6 CY) are being individually and cumulatively weighed.

<table>
<thead>
<tr>
<th>Weight (lbs.)</th>
<th>Total Weight (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total aggregate</td>
<td>= 3,120 x 6 = 18,720</td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>= 1,248 x 6 = 7,488</td>
</tr>
<tr>
<td>No. 1 stone</td>
<td>= 750 x 6 = 4,500</td>
</tr>
<tr>
<td>No. 2 stone</td>
<td>= 1,122 x 6 = 6,732</td>
</tr>
<tr>
<td>Cement</td>
<td>= 565 x 6 = 3,390</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weight (lbs.)</th>
<th>Total Weight (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero return tolerance (aggregate scale)</td>
<td>= 30,000 x 0.003 = ± 90</td>
</tr>
<tr>
<td>Total aggregate tolerance</td>
<td>= 18,720 x 0.015 = ± 281</td>
</tr>
<tr>
<td>Fine aggregate tolerance</td>
<td>= 7,488 x 0.015 = ± 112</td>
</tr>
<tr>
<td>No. 1 stone tolerance</td>
<td>= 4,500 x 0.015 = ± 68</td>
</tr>
<tr>
<td>No. 2 stone tolerance</td>
<td>= 6,732 x 0.015 = ± 101</td>
</tr>
<tr>
<td>Zero return tolerance (cement scale)</td>
<td>= 5,000 x 0.003 = ± 15</td>
</tr>
<tr>
<td>Cement tolerance</td>
<td>= 3,390 x 0.01 = ± 34</td>
</tr>
<tr>
<td></td>
<td>Weight (lbs.)</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Fine agg. (bin 1)</td>
<td>7,488</td>
</tr>
<tr>
<td>No. 1 (bin 2)</td>
<td>4,500</td>
</tr>
<tr>
<td>No. 2. (bin 3)</td>
<td>6,732</td>
</tr>
<tr>
<td>Cement</td>
<td>3,390</td>
</tr>
</tbody>
</table>

Before performing the initial tolerance check, the plant scales should be checked as provided in procedure 813. The entire plant should be inspected and the operation of all interlocks, except interlocks having specified tolerances, should be checked.

Some plants provide for setting tolerances by dials; others may be computer programmed or use other methods. When plants do not have the capability to accept tolerance adjustments throughout the full range of batch sizes to be used, the tolerance for the smallest size batch being regularly produced should be used. Production of occasional fractional batches at the end of a pour may be visually inspected for compliance.

Automatic plants should be provided with controls to stop the cycle in the overweight check position and the underweight check position to permit checking of the tolerances. One common method of providing for checking of tolerances is by equipping the controls with Stop-over and Stop-under switches. The following checkout procedure assumes the plant is equipped in this manner and the tolerances are set by the use of dials. Although each manufacturer and plant may have unique features, a satisfactory tolerance check can generally be made using the following procedure.

1. The initial tolerance check is the test of the zero return or tolerance for the tare weight of the aggregate hopper. Standard spec 501.3.4.5.4 provides that the batcher inlet must be interlocked against opening until the batcher is completely discharged and the scales balanced within 0.3% of the scale capacity. In the foregoing example, the allowable tolerance is computed as 68 lbs.

Place both the Stop-over and Stop-under switches in the stop position and turn the plant to automatic. The plant should not batch out any material. Move the pointer (dial scale) or poise (beam scale) until the over-light on the panel comes on, the weight at which the light comes on is the actual zero tolerance, unless the weight indicated is greater than 68 lbs. If the indicated weight is greater than 68 lbs., hold the scale at 68 lbs. and turn the zero-tolerance dial until the light goes out. This should set the tolerance at exactly 68 lbs.

2. Turn the Stop-over switch to run, leaving the Stop-under switch in the stop position. This permits the plant to advance to the first weighing cycle (Bin 1). The underweight tolerance may now be checked by moving the scale pointer or poise until the underweight light for Bin 1 comes on. If the indicated weight is less than 7,387 lbs., the tolerance can be set by holding the scale at 7,387 lbs. (or more) and turning the Under tolerance dial for Bin 1 until the underweight light goes out.

3. Turn the Stop-over switch to stop and the Stop-under switch to run. Move the scale pointer or poise until the overweight light for Bin 1 comes on. If the weight at which the light comes on is greater than 7,613 lbs. the tolerance must be adjusted by holding the scale at 7,613 lbs. and turning the dial until the over light goes out.

4. Turn the Stop-over switch to run and the stop-under switch to stop thus cycling the plant to the next weighing cycle (Bin 2). Repeat the procedures outlined in Steps 2 and 3 for the remaining aggregate bins, using the applicable bin weights.

5. The procedures outlined in Steps 1, 2 and 3 should be repeated for the cement batcher using +/-1% as the over-under tolerance.

Standard spec 501.3.4.5.4 requires the audible signal to sound if a batch is discharged containing components outside the specified tolerances. Many plants, however, may have the audible signal device wired so that it is activated whenever any component outside the specified tolerance is discharged into the batcher. The operation of the horn for most plants wired in this manner can be checked during the tolerance check, since the horn should sound any time the over or under lights are on.

To test audible devices wired to the discharge of the batch, it will be necessary to simulate or produce a batch having components outside of the tolerances and discharge it manually and then check the horn operation when the batch is discharged.

The interlock requirements for cement batchers are similar to the interlock requirements for aggregate batchers for both automatic and semi-automatic plants specified in standard spec 501.3.4.5.4, except that the tolerance for the batcher discharge is reduced to 1%. Instructions for interlock and tolerance checks are as described above.
510.6.6 Cement, Fly Ash, and Slag Handling

Cement having a temperature in excess of 165°F when delivered to the mixer should not be used until it has cooled. Cement must be weighed in its own separate hoppers and scales. They may be either of the beam digital or dial type and are subject to the same general requirements for aggregate scales. Due to the sensitivity of cement to moisture and to losses sustained in strong winds, storage bins and hoppers for cement are completely enclosed, and reliance must be placed entirely on the scales to determine if the weigh hoppers are completely full or empty.

Standard spec 501.3.3.3 requires facilities for storing, handling, transporting, and conveying fly ash or slag to be equal to those used for the cement. Frequent balancing of the scales at zero reading for all types of plants is required as a check on whether cement is accumulating in the weigh hopper to add to the tare weight.

A check should be made on the adequacy of the venting system used in cement bins and hoppers to relieve the air pressure built up when cement is unloaded from truck transports by compressed air. Unless properly relieved, these pressures may build up to the point where a sudden surge of cement into the weigh hopper may trip the weighing mechanism prematurely or may cause false scale readings. This condition is usually accompanied by the erratic action of the weigh indicator on a beam scale or the needle of a dial scale. As a check, the cement should not be discharged from the weigh hopper until the air pressure has been relieved and the indicator or dial needle registers a constant weight. Where necessary, corrections should be made by equipping the hopper and the bin with larger vents, which should be checked periodically thereafter for accumulations of cement.

When fly ash or slag is batched together with the Portland cement, the cement must be weighed into the batcher first and the fly ash or slag added to the cumulative weight. When separate batching equipment is used to add the fly ash or slag it must meet the same requirements as the cement batching equipment.

Refer to the procedure used to sample incoming shipments of cement. Fly ash is to be sampled and tested in accordance with standard spec 501.2.6. Slag is to be sampled and tested in accordance with standard spec 501.2.7.

510.7 Control of Concrete Mix

510.7.1 Water-Cement Ratio

510.7.1.1 Background

A concrete mix is designed to provide a workable mix with the maximum possible strength gain. Standard spec 501.3.2.2 provides a percentage range for each size of aggregate in order to permit adjustment within the specified limits when necessary to provide workability. Workability of the mix is especially necessary in concrete for pavements and bridge decks to produce a good riding surface.

No single factor affects the durability of concrete as much as the relationship between the quantity of water contained in the mix and its cement content. It is frequently referred to as the water-cement ratio.

Approximately 1 gallon of water per 30 pounds of cement is required to effect hydration. Concrete with this water-cement ratio is unworkable, and additional water is required to promote workability. Additional water, however, dilutes the cement paste that bonds the aggregate, and the concrete strength is decreased.

Only under extreme conditions is the maximum amount of mix water required. If the mix is harsh and difficult to finish, addition of water as a corrective measure is seldom the answer and may aggravate the condition. Many factors enter into the conditions affecting the workability of the mix. Lack of sufficient mortar to properly fill the voids and provide a slight excess to facilitate finishing is a condition frequently encountered.

510.7.1.2 Slump

The water-cement ratio is directly related to the consistency of the mixed concrete. For the purpose of providing a term that is convenient for the measurement, the consistency of the concrete is expressed as the slump of the concrete. Mixed concrete is composed of required proportions of aggregates, cement, minimum water content to produce a mix of a consistency that has workability suitable for its intended use, and an entrained air content within the specified range. The mix should have a slump within the slump range provided in the standard specifications for concrete for that particular use.

At the start of concrete production operations and until uniformity in desired consistency has been established, slump tests should be performed as frequently as necessary, in conjunction with operational adjustments, to establish uniformity of production well within the specification limits.

Generally, when uniform production prevails, except for very small pours a minimum of two slump tests per day should be made. However, observation should be maintained for indications of deviation from desired consistency. If deviation occurs, additional tests and necessary adjustments should be made to rectify the
condition. Vigilance in this respect is especially required with reference to transit-mixed concrete where conditions may vary from unit to unit.

The slump ranges provided in the standard specifications relate to the consistency of the concrete as it is deposited in its approximate final location. When the site of the deposit is removed from the truck mixers, such as when the concrete is moved from the mixer to its final location by conveyor belt, slump tests may be run at the mixer for informational purposes to assist the contractor in determining what the slump of the concrete at the mixer should be in order for the slump to be within specification tolerances at the point of deposit.

Although upon specific approval by the engineer the standard specifications permit incorporation of measured quantities of wash water in batches, this approval may be withdrawn at any time that uniformity in slump is not maintained as a result of this practice.

510.7.2 Air-Entrainment

It is the requirement that all concrete used in the work, except for pre-stressed concrete I-type girders, must be air-entrained, and that air-entrained concrete must meet the requirements of the standard specifications.

Although a range of air content is stated in the standard specifications, this does not mean that the air content of the concrete for a given pour may fluctuate, among the various batches, within the specified range limits, but that the specific air content selected for the concrete pour must be stable within that percentage range and preferably should be close to the center of the range. Once the air content for a given pour has been established, it should remain reasonably constant throughout the pour.

In some instances, it has been noted the added air-entraining agent does not increase the air content to that desired, even when relatively large quantities of it are added. This may be due to the incompatibility of the added admixture with that originally mixed with the cement, or to other factors. A complete record should be made of all such instances that occur, including name of additive, amount added, and results.

The air content of mixed concrete is measured by tests included in 800. At the start of concrete production operations and until uniformity in desired air content has been established, tests for air content should be performed as frequently as necessary, in conjunction with adjustment of quantities of added air-entraining admixture, to establish the required air content uniformly in the produced concrete. Generally, when uniform production prevails and except for very small pours, a minimum of two tests per day should be made. However, observations should be maintained for indications of deviation from selected air content and, if this occurs, additional tests and adjustments of quantity of added admixture should be made.

Set retarding admixtures are capable of changing the air content. When it is proposed to use one with air-entraining cement, it is advisable to test a preliminary batch to determine whether there is a risk of producing concrete with air content above or below the specification limit.

510.7.3 Admixtures

510.7.3.1 Approved Admixtures

The admixtures on the approved list have been given conditional approval based on provided and derived information that indicates essential compliance with applicable specifications. Only air-entraining agents, water reducer-set retarding agents, and normal water reducing agents shown on the APL may be used in WisDOT work.

The set retarding and water reducing admixtures are capable of having a significant effect on the entrained air and slump of the mix. Care must be exercised to make sure the resulting entrained air and consistency are within the specified requirements.

The department assumes no responsibility for the performance of any admixture; the responsibility must be that of the contractor. The engineer reserves the right to rescind or restrict approval of any admixture, which in the engineer's judgment does not produce the desired results.

Care must be used to ensure each admixture's addition rate is carefully controlled, the admixture is properly added to the concrete mixtures, and when two admixtures are used, they are totally compatible. Admixtures are usually added with the water. If an admixture does not appear to be working, it may be added to the mix after the water is introduced, as a possible solution to the problem.

510.7.3.2 Air-Entraining Admixtures

The addition rates must be in accordance with the manufacturer's recommendations, adjusted as needed to produce specified and desired entrained air contents.
Many of the air-entraining admixtures are available in various strengths or concentrations. When there is a change in strength or concentration, it will be necessary to make an adjustment in the addition rate to compensate for the change.

510.7.3.3 Set Retarding Admixtures
Set retarders may be specified under certain circumstances. Any of the approved products listed on the approved products list APL as a Set Retarder, Type D, may be used. The addition rates must follow manufacturer recommendations. They may have to be adjusted, based upon the manufacturer's data and recommendations concerning relationships between mix and air temperature, amount of cement, setting time, results of field tests, and observations of preliminary batches of concrete.

510.7.3.4 Water-Reducing Admixtures
When concrete grades requiring a water-reducing admixture are used in the work, the required water-reducing admixture may be either an approved water-reducing admixture, Type A, or an approved set-retarding admixture, Type D, since both fulfill the requirements for water-reducing admixtures. When either is used as a water-reducer the addition rate must follow manufacturer recommendations.

Type A and Type D admixtures should never both be added to the same batch of concrete.

510.7.3.5 Storage
Containers for admixtures should be plainly identified, and the solutions should be protected from contamination, dilution, evaporation, and freezing. If need be, storage tanks should be agitated during batching to prevent settlement of the solutions.

510.7.3.6 Dispensing Equipment
Admixtures are commonly provided in liquid form and may be dispensed into the mixer by weight or volume. Dispensers should be large enough to measure a full batch of admixture for each batch of concrete. The volumetric container system is considered the most reliable and is the most common method. This type should have either a sight glass or a transparent container and be located so the plant operator and inspector can visually check to see the container fills to the desired volume and totally discharges for each batch.

Standard spec 501.3.4.7 requires admixture dispensing systems to be interlocked with the batching process for semi-automatic and automatic batching plants and for on-site mixers of 0.8 cubic yards or more.

Dispensing by means of a graduated jar or beaker, or a graduated glass tube filled and emptied by manually operated valves, should not be approved.

The dispensing equipment must be flushed with water occasionally to minimize the possibility of material accumulation, which will impair the equipment performance or dispense erroneous quantities.

510.8 Production
510.8.1 Computation of Batch Quantities
Standard spec 501.3.5.3 and standard spec 501.3.6.2 state the maximum allowable batch size in stationary mixers, truck mixers, and on-site batch mixers, respectively, and specify that the volume must be computed on the basis of the "nominal" cubic yard of concrete. The "nominal" cubic yard of concrete contains, in addition to the prescribed quantities of aggregates and cement, the "design" quantity of water and a 6.0% air content. The "nominal" cubic yard is based on field conditions, and generally the amount of air and water actually used will reasonably agree with those in the "nominal" cubic yard.

510.8.2 Batch Records and Cement Usage Check
It is important that the inspector keep an accurate record of the number of batches weighed out each day. It is of immediate value in the computation of the daily yield or spread, and later as a permanent record of the amount of material incorporated in the work.

The daily batch record also enables the calculation of the daily and accumulated cement used. As often as feasible in conjunction with the contractor's operations, the cement storage bins and hopper should be completely emptied. Checks on cement usage at the one-quarter point of production, one-half point, three-quarters point, and the end of concrete production are recommended.

On projects where a secondary storage bin or "pig" is used, a check may be made without emptying the silo or bin supplying the batcher by making the check when this silo or bin is full and the secondary storage bin is empty. To obtain this condition it will be necessary to unload the secondary bin at a rate that will ensure the supply silo is full at the time the secondary bin becomes empty. This allows a check to be made on the total amount received or the theoretical amount used. If this method is not feasible, it is permissible to allow a
partial load in the overhead bin, provided this amount can be estimated with accuracy. The above record can be kept in a daily Portland cement inventory, which can be found in the department’s pantry software.

510.8.3 Batch Delivery

Batch delivery time is the elapsed time starting with addition of water to the cement or addition of cement to the aggregates and ending with the complete discharge of the concrete from the transporting vehicle. Delivery times for ready-mixed concrete are specified in standard spec 501.3.5.2.

The specifications permit the delivery of ready-mixed and central-mixed concrete in non-agitating, smooth, mortar-tight metal bodies. Trucks equipped with ordinary dump boxes are often used. End gates should be checked for tight fit to prevent mortar leakage and to ensure secure locking of the gate. Watertight covers are necessary when rainy conditions occur. The truck boxes must be cleaned of any retained concrete immediately after delivery to prevent build-up of hardened concrete. Delivery must be accomplished within 30 minutes of mixing. Free water should not be evident on the surface of the batch at the time of delivery. The concrete must be free from excessive segregation and slump tests taken from the batch cannot vary by more than 2 inches.

510.8.4 Ready-Mix Concrete Delivery and Inspection Tickets

510.8.4.1 Concrete from Noncommercial Plants

Standard spec 501.3.5.4 provides that ready-mixed concrete used in concrete pavement and associated items may be accepted without an inspection ticket when such concrete is mixed in plants erected specifically for such purpose. The inspection ticket requirement may also be waived for minor amounts of ready-mixed concrete used in incidental items.

Random checks of haul time of individual loads should be made. A record of departure times must be maintained at the plant by the contractor.

Information and facts relating to the waiver of ticket requirements for both concrete pavement and incidental items should be entered in the project records.

510.8.4.2 Concrete from Commercial Plants

When concrete is ordered from a commercial ready-mix plant, the plant inspector should have the following information, especially when inspecting more than one project:

- Project ID number
- Name of inspector
- Mix design number
- Slump required
- Location of pour
- Number of cubic yards required
- Time of pour
- Intended use of concrete
- Special instructions on temperature and admixtures

Inspection tickets furnished by the contractor containing the same information may be used in lieu of the form when signed or initiated by WisDOT or consultant personnel.

If any difficulty occurs on the job with the mix, such as undesirable air content, slump or temperature, the plant inspector should be notified immediately so the problem can be corrected. Observation of these properties at the plant in the case of transit mix is sometimes difficult.

510.9 Sampling and Testing Concrete


Test cylinders may also be made for the purpose of determining when concrete pavement may be opened to traffic or when falsework may be removed. Standard spec 415.3.17 provides that concrete pavement may be opened to traffic when the tests of at least two cylinders show a compressive strength of at least 3,000 psi (urban cross section) or 3,500 psi (rural cross section), provided that neither cylinder has a compressive strength of less than 2,700 psi or 3,150, respectively. The cylinders should be placed adjacent to the pavement and cured under conditions similar to those prevailing for the pavement they represent.
510.9.1 Strength Requirements for the Removal of Falsework Based on Test Cylinder Breaks

The cylinders should be cured under conditions that are not more favorable than the most unfavorable conditions for the portions of the concrete that the cylinders represent.

If job control cylinders for opening to traffic or for form or falsework removal are lost or damaged, the engineer may allow the use of alternate non-destructive testing methods to evaluate the concrete and expedite the progress of the project. The Windsor Probe testing system or the Concrete Rebound Test Hammer (a.k.a. "swiss hammer") are acceptable methods for non-destructive strength evaluation for this purpose.

510.10 Inspection Summary

The following summary of major areas of inspection in concrete placement will ensure a high-quality product. Review of this information with the contractor is advised.

- The concrete plant must have the capacity to produce concrete to adequately keep the job site operation moving.
- Aggregate sampling and testing should be completed as stockpiles are produced to ensure uniformly graded stockpiles.
- Commercial ready-mix plants must designate an adequate number of trucks to ensure a regular hauling cycle.
- Quality truck mixers must be used and inspected for specification compliance, including condition of fins.
- Mix water at the plant should be adjusted so no water is required at the job site.
- Concrete delivery must be a continuous regular hauling cycle to avoid stops and starts in placing operations.
- When transit-mixed concrete is used, stationary mixing at mixing revolutions rated on truck must be inspected.
- Consistent uniform slump from load to load without excessive deviation is important. The contractor must hold slump to the standard spec range for the application for which the concrete is to be used.
- There should be strict control of slump and entrained-air by test at the work site.