CHAPTER 5: CONCRETE PLACEMENT AND CONSOLIDATION

Detailed planning and coordination are necessary to achieve successful concrete placement and avoid near- or long-term failure of aggregate material strength, durability, and safety. Chapter 5 sections include concrete delivery timing and necessary transportation; concrete mix continuity and common placement methods; and vital concrete inspections and tests.

5-1 Transportation

Section 5-1 details concrete transportation factors to consider, including:

1. Necessary equipment.
2. Delivery rate.
3. Mix consistency and uniformity.
4. Inspections and tests.

5-1.1 Equipment

The Standard Specifications (SS)[1] allows the Contractor to transport concrete by truck agitators or truck mixers. Section 90-1.01D, *Quality Control and Assurance,* establishes mixed concrete tests and criteria to assure the material is suitable for placement.

Concrete usually is delivered to the job site by truck transit mixers.

Methods of concrete transportation that are infrequently used, such as truck agitators, open-top vehicles, barges, etc., will not be discussed in this document. These methods are used in special cases and should be individually researched. Mobile mixers used for polyester concrete are addressed in SS 15-5.06, *Polyester Concrete Overlay*.

5-1.2 Delivery Rate

Since the rate of concrete delivery and placement affects the finishing operation, consider the following before placing concrete:

1. Total theoretical quantity (cubic yards) and expected delivery rate for the concrete placement.
2. Number of concrete pumps or concrete buckets and cranes.
3. Number and spacing of concrete trucks assigned to the concrete pour.
4. Method of concrete delivery at the concrete pump hopper.
5. Concrete pump capability to reach all areas of the pour, avoiding overhead hazards and suspended loads over traffic.

[1] 2010 SS 90-1.02G, *Mixing and Transporting Concrete.*

6. Possible need to relocate the concrete pump(s). Consider local traffic impacts affecting delivery rates (i.e., rush hour, local schools' start or end times, accidents, sporting events, etc.).

Once the concrete pour timing and estimated duration are determined, some issues to discuss with the Project Manager or Superintendent include:
1. Start time.
2. Adequate lighting.
3. Safety and traffic control.

Example:
Assume that the Contractor plans to place 600 cubic yards (CY) at 45 CY/hr. This means that the pour will take more than13 hours. If the pour starts at 7:00 a.m., the contractor will finish placement and strike off around 8:30 p.m. The Contractor tells the Engineer that he has asked for five trucks per hour, but could only secure four. However, the Contractor has been assured by the Supplier that four trucks will be more than enough since each truck carries 10 CY of concrete. During previous pours, the Engineer noticed that it took roughly five minutes to discharge a 10 CY truck, about 30 minutes each way to and from the plant, and 10 minutes to charge the mixer. Considering just the need to achieve a pour rate of 45 CY/hr, the Contractor needs 4.5 trucks/hr, or one truck about every 14 minutes. However, to maintain a steady rate of pour, consider the time cycle it takes a truck to complete a round trip, which is 75 minutes. Therefore, if the 75-minute cycle is divided by the 14-minute pour rate, the result is 75/14 = 5.4 trucks, or six trucks to assure an adequate amount of material. The Engineer must inform the Contractor that, according to the supplied figures, at least six trucks will be required to maintain a 45 CY/hr pour rate.

Additional consideration is also needed for lights at night and crews who can work a double shift.

The key to a successful pour is preparation that will result in a well-scheduled start and maintain a constant delivery rate.

Increased mechanization and decreased use of manual methods have allowed deck pours to proceed at a rate set by capacity of the finishing equipment and the rate of delivery—rarely by the crew's physical limitations. Therefore, pour rates can be reduced to mathematical calculations (with some allowances for mechanical malfunctions) and very little allowance for the "human factor."

Prior to the pour, mark 10-ft stations along the edge-of-deck handrails, and perform any necessary theoretical volume calculations. To verify and track the production rate during a deck pour, calculate the theoretical volume of concrete for a 10-ft section of deck, and then time its placement during the pour. This calculation should be done periodically during the pour to fine-tune the estimated time of completion and the actual quantity of concrete being used.

5-1.3 Mix Consistency and Uniformity

Standard Specifications[2] state that "Concrete must be thoroughly mixed, homogeneous, and free of lumps or evidence of undispersed cementitious material."

5-1.4 Inspection and Tests

Methods, frequency of sampling, and testing protocols for concrete are covered in Chapter 8, *Material Sampling and Testing, and* Chapter 9, *Job Control Sampling and Testing,* of the Concrete Technology Manual, as well as Web links to California Test Methods and ASTM test methods. Testing frequency is described in Chapter 6, *Sampling and Testing,* of the Construction Manual. Standard Specifications[3] state that uniformity of mixed concrete is checked by differences in penetration (*California Test 533*) and variations in the proportion of coarse aggregate (*California Test 529*). When the mix design specifies a penetration value, the difference in penetration of two samples from the same batch or truck must not exceed 0.5 in. When the mix design specifies a slump value, the variation in slump from samples of the same truck must not exceed the values set forth in the specifications.[4]

Table 5-1. All Concrete Tickets Should be Checked for Conformance

The weighmaster certificate must show: 1. Mix identification number. 2. Non-repeating load number. 3. Date and time the materials were batched. 4. Total quantity of water added to the load. 5. For transit-mixed concrete: the revolution counter reading at the time the truck mixer is charged with cement. 6. Actual scale weights in pounds for the ingredients batched. Do not substitute theoretical or target batch weights for actual scale weights.

It is absolutely essential for the first few loads to be checked and to verify that the approved mix is being delivered in conformance with the specifications.[5]

The Concrete Technology Manual (CTM) page 4-27, *Transporting Mixed Concrete,* outlines the procedure for checking load tickets. (Also see Table 5-1.1, *All Concrete Tickets Should be Checked for Conformance*).

[2] 2010 SS 90-1.02G(1), *Mixing and Transporting Concrete, General.*
[3] 2010 SS 90-1.01D(4), *Concrete Uniformity* or *2010* SS 90-1.02A, *Materials, General.*
[4] 2010 SS 90-1.02A, *Mixing and Transporting Concrete.*
[5] 2010 SS 90-101C(7), *Concrete Delivery of the Specifications.*

The Standard Specifications[6] state "Do not add water to the concrete in excess of that in the authorized mix design." Standard Specifications[7] also state that the amount of water used in concrete mixes must be regulated so that the penetration values of the concrete comply with *California Test 533* or the slump of the concrete as determined by ASTM Designation C143. Refer to the table in Standard Specifications Section 90-1.02G(6) for nominal range.

The Contractor designs and proposes the use of a concrete mix based on the desired mix workability, available local resources, and *Standard Specifications* and *Special Provisions* requirements. This mix may contain SCMs and/or chemical admixtures to enhance concrete performance, provided the admixtures are on the *Authorized Material List*[8] from Materials Engineering and Testing Services (METS). The Engineer reviews the proposed concrete mix designs and authorizes the mixes that comply with the specifications.

If water needs to be added, it should be added before the discharge of more than 1/4 cubic yard. Once discharge has begun, it is a challenge for the Contractor to add water and still meet the maximum water content allowed for the mixed design, since the volume of concrete left inside the truck cannot be accurately measured. The amount of added water should never exceed maximum water allowed for the mix design. It is a best practice to calculate the amount of free water allowed in advance of the pour to determine how much water can be added, if necessary.[9] After water is added, a minimum of 30 revolutions at mixing speed should be completed to assure the added water is thoroughly mixed and the concrete is homogeneous.

In the event of equipment failure or a concrete placement stoppage, consider the following:[10]

1. 90-minute rule. This can be shorter on a hot day.
2. Maximum 250 revolutions.
3. Concrete in the pipes of the concrete pump may have exceeded the 90-minute rule.

5-2 Conveyance and Placement

Section 5-2 details concrete conveyance and placement methods, including:

1. Equipment: Concrete buckets, Concrete pumps, and the advantages and disadvantages of each method.
2. Inspections and environmental compliance.

[6] 2010 SS 90-1.02G(3), *Transporting Mixed Concrete*.
[7] 2010 SS 90-1-02G(6), *Quantity of Water and Penetration or Slump*.
[8] http://www.dot.ca.gov/hq/esc/approved_products_list/index.html.
[9] *Concrete Technology Manual,* Chapter 3.
[10] Also refer to SS 90-1.02G(3), to fully understand how to administer and apply these rules.

5-2.1 Equipment

Contractors have tried several different methods of placing concrete during deck pours. Some of the successful methods to date are the use of buggies, conveyor belts, pumps, and buckets. Concrete buckets and pumps are the two most common methods used in the field.

5-2.1.1 Concrete Buckets

The term "concrete buckets" actually refers to the crane and bucket method of concrete placement (see Figure 5.2-1). Assume an average pour rate of 45 CY/hr when using one crane with two, 1 CY buckets. Two buckets are typically used for this method. While the crane is maneuvering and placing the first bucket, the second bucket is being filled. This ensures continuous placement of fresh concrete to the pour front.

Figure 5.2-1. Crane and Bucket Concrete Placement.

Advantages of using the crane and bucket method:

1. The crane can be used on other phases of work; therefore, pours do not require special equipment and setup.
2. The crane has a high degree of mobility, which allows concrete placement under difficult conditions.
3. A homogeneous mix is assured in most cases.
4. Cleanup is minimal.

Reasons why the Contractor will use the crane and bucket method:

1. Smaller pour.
2. Contractor owns the crane and bucket equipment.
3. Provides for a slower, more controlled pour rate.

Disadvantages of using the crane and bucket method:

1. There may be areas outside of the crane's radii that do not encompass the pour front.
2. Safety problems from swinging booms may occur during high pour rates that require use of additional cranes.
3. Overhead wires and loads over traffic are a serious hazard.
4. Impact due to concrete dropping from a high bucket can cause forms to fail.

When the crane and bucket method is used, take care to position the bucket on a sheet of plywood to catch spills as it is being filled with concrete, and to keep the bottom of the bucket frame and boot out of the dirt.

5-2.1.2 Concrete Pump

Concrete pumps are the most popular and reliable method for placing deck concrete. Truck-mounted pumps are more versatile and have higher pour rates than previously used methods. Present day pumps can be expected to deliver up to 100 CY/hr without major breakdowns or malfunctions.

Reasons why Contractors use the concrete pump method:

1. Delivery of a constant rate of concrete during the pour.
2. A concrete pump can reach farther than a crane.
3. Pumps are less labor-intensive since the machine does the pumping work.

Cranes with buckets and other previously used methods of conveyance generally are limited to receiving ready-mix concrete in one or two locations; by comparison pumps are mobile and can quickly change locations. A concrete pump has the ability to place concrete in difficult-to-reach locations (see Figure 5.2-2). This is very important for keeping a fresh pour front for deck concrete placement. A concrete pump has advantages in areas where overhead space is congested with utility lines or other obstructions because it requires less headroom. Pumps also offer a less disruptive, ominous presence and, in general, are less hazardous than cranes since there is no need for crew to take evasive maneuvers to avoid swinging buckets.

Figure 5.2-2 Concrete Pump.

Note: Whether using crane and buckets or a concrete pump, remember that no suspended loads are permitted to pass over public traffic. (A concrete pump boom is considered to be a suspended load.) Additionally, ensure that all pump hose and pipe sections are properly clamped together with collars, and that the locking safety devices for the collars are being used.

5-2.2 Inspection

Forms and surfaces that will come in contact with fresh concrete must be wet. Water ponding is prohibited. Maintain uniform consistency of concrete and a uniform pour front parallel to the finishing machine. The concrete must be adequately consolidated but not overly vibrated. Continuously check reinforcing steel clearances. Any displaced steel must be repositioned, blocked, and tied. Broken dobies also must be replaced. Check the position of waterstops, deck drains, manholes, conduit, prestressing hardware and accessories; reposition any that have been displaced.

5-2.2.1 Storm Water Pollution Prevention Plan (SWPPP)

Caltrans is a committed steward of the environment. Project permits must be followed so that Caltrans can keep commitments made to other agencies. All concrete placement methods must comply with the approved Water Pollution Control Program (WPCP) and/or SWPPP. Transit trucks and concrete pumps must use approved and designated washout pits. Spills must be cleaned promptly.

5-3 Vibration

Section 5-3 details proper mix and placement of concrete that will be settled using vibration as a method of consolidation after the pour, and to avoid air and rock pockets.

Standard Specifications[11] states that concrete shall be placed and consolidated …"using methods that (1) Do not cause segregation of the aggregate and (2) Produce dense, homogeneous concrete w without voids or rock pockets." It also requires the Contractor to consolidate all concrete by means of high frequency internal vibrators within 15 minutes after it is deposited in the forms. The importance of proper vibration cannot be overstated (see Figure 5.3-1).

Figure 5.3-1. Vibrating Concrete.

Prior to vibration, concrete presents a dry, irregular surface. By contrast, vibrated concrete appears moist once the fine aggregates rise and the large aggregates settle.

The Operator's technique should vary with the depths and complexity of each section. In deep sections where it is possible to get full penetration of the vibrator, it is imperative for the vibrator operator to hit the concrete approximately every 2 ft and make sure that the head of the vibrator enters almost vertically. In thin deck sections it still is imperative for the Operator to hit the concrete approximately every 2 ft, but it is not as important to enter the concrete vertically.[12]

The vibrator should not be dragged horizontally over the top of the concrete surface, nor should the vibrator be allowed to run continuously while the operator is not providing his or her full attention. If this occurs, the fine and large aggregates will not settle properly, and the deck cross section no longer will be homogeneous. Material in this condition leads to added maintenance and costs over the life of the deck.

[11] 2010 SS 51-1.03D(1), *Placing Concrete, General.*
[12] Concrete Technology Manual, Chapter 5, p. 45, *Concrete Construction, Consolidating Concrete.*

Special care must be taken when vibrating areas where there is a high concentration of reinforcing steel.

Note: If the concrete is poured in lifts (columns, girders, stems, etc.), it is important to make sure that the vibrator penetrates deep into the previous lift to ensure that there will be no exposed construction joints, cold joints, or rock pockets.

Additional information about concrete placement and consolidation can be found in Chapter 5 of the *Concrete Technology Manual*.