

Section 90 Portland Cement Concrete

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4-9001 General

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This section covers portland cement concrete. The *Standard Specifications* designates concrete with the following descriptions:

- Class
- Cement content
- Compressive strength
- Minor concrete

This section does not cover specialty concrete such as polyester concrete and fast-setting hydraulic cement concrete. The resident engineer should contact the Division of Construction, the Office of Materials Engineering and Testing Services (METS), and the district materials engineer for guidance on specialty concrete.

For a complete discussion on various items using concrete, refer to Section 40, “Portland Cement Concrete Pavement,” Section 50, “Prestressing Concrete,” Section 51, “Concrete Structures,” Section 72, “Slope Protection,” and Section 73, “Concrete Curbs and Sidewalks,” among other sections of the *Standard Specifications*. Also refer to the corresponding Section 4-40, Section 4-51, Section 4-72, and Section 4-73 of the *Construction Manual* (manual). You can also obtain additional information on portland cement concrete from the Office of Structure Construction’s *Concrete Technology Manual* and the *Bridge Construction Records and Procedures Manual*.

4-9002 Before Work Begins

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The *Standard Specifications* requires the contractor to determine the mix proportions for all concrete except for pavement concrete. To determine the various types of concrete that will be required, review the contract provisions. Pay particular attention to concrete designations such as “class,” “cement content,” “compressive strength,” or “minor concrete.” Also, note the type of cement to be used and any special requirements for the aggregate and use of admixtures. Make a list of the various mix designs the contractor will need to submit and a note of the concrete that needs to be prequalified before use. For your review, encourage the contractor to submit the mix designs early in the project.

Review the mix designs for compliance with the special provisions, *Standard Specifications*, and contract plans, or forward the mix designs to the district materials unit for review. Before the contractor places any concrete, the district materials unit will need an approved copy of the mix design for unit’s plant inspectors. If the concrete is designated by compressive strength, obtain certified test data or trial batch test results in advance of the concrete’s use to avoid delays. Review the data and results for contract compliance.

Review the current certifications of Caltrans field staff who will perform the acceptance testing of the concrete. Staff must be certified in the following:

- California Test 125, “Sampling Highway Materials and Products Used in the Roadway Structural Section”
- California Test 518, “Unit Weight of Fresh Concrete”
- California Test 523, “Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading)”
- California Test 533, “Test for Ball Penetration in Fresh Portland Cement Concrete”
- California Test 540, “Making, Handling, and Storing Concrete Compressive Test Specimens in the Field”
- American Society for Testing and Materials (ASTM) C172, “Standard Practice for Sampling Freshly Mixed Concrete”

4-9002A Materials

Before work begins, do the following for materials:

- Verify the receipt and proper distribution of Form CEM-3101, “Notice of Materials to Be Used,” which lists concrete materials such as cement, fly ash, and aggregate.
- Cement is normally accepted on the basis of a Certificate of Compliance; therefore, initial samples are not taken. If special requirements exist for the cement or if it is obtained from an unusual source, consider initial testing. For more details about cement sampling and testing, see Chapter 6, “Sampling and Testing,” of this manual.
- In accord with the State Contract Act, verify that the aggregate source complies with the Surface Mining and Reclamation Act of 1975 (SMARA). Mining operations determined to be in compliance are listed on the AB 3098 SMARA Eligible List. This list can be obtained from the Division of Construction or at the Department of Conservation’s web site at:

http://www.consrv.ca.gov/OMR/ab_3098_list/index.htm

Also, see Section 7-103D (2), “Surface Mining and Reclamation Act,” to determine if the proposed materials site is exempt from SMARA.

- Verify with the district materials unit that current tests have been performed on aggregates as listed in Section 6-1, “Sample Types and Frequencies,” of this manual.
- You may omit initial sampling and testing if the specified aggregate is currently being used on another Caltrans contract with acceptable testing results. In the daily report, record any reasons for not taking initial samples.
- If current tests have not been performed, obtain initial samples of aggregate to be used and have them tested for all specified attributes. For reference, see the table in Section 6-1 of this manual. You can prevent unnecessary expense and delay if you send samples that can be made to conform to the specification grading. Indicate whether oversized material will be crushed or if any special blends are contemplated.

4-9002B Aggregate Gradings

From the contractor, obtain in writing the primary aggregate nominal sizes to be furnished. The Office of Structure Construction's *Concrete Technology Manual* has examples on how to check the contractor's proposed gradings. In addition, the Office of Structure Construction's web site has a spreadsheet available to assist in this review. When the requirement for furnishing the proposed gradation is unnecessary for the type or amount of concrete work, advise the contractor and note such a decision in the daily report.

4-9002C Admixtures

Before work begins, do the following for admixtures:

- Admixtures must be of a type allowed by the *Standard Specifications* or special provisions. In addition, they must be on the approved list of admixtures maintained by METS. You can access this list through the Division of Engineering Services web site at:

http://www.dot.ca.gov/hq/esc/approved_products_list/.

Admixtures do not require initial tests if they are currently approved and a Certificate of Compliance is furnished.

- If you choose to test admixtures before using them, obtain samples of liquid admixtures and place them in clean liter cans or plastic bottles. Sample powdered admixtures in dry form (not after mixing with water on the job). Friction top cans or plastic bags similar to those used to sample cement are satisfactory.
- Send a completed Form TL-0101, "Sample Identification Card," with the sample. Include the manufacturer's lot number represented by the sample and the name of the product, including any prefix or suffix. Also, show the class of work for which the sample will be used, such as concrete pavement or prestressed concrete. The laboratory needs this information to determine the suitability and amount of admixture for use. For sampling admixtures, refer to California Test 125, "Sampling Highway Materials and Products Used in the Roadway Structural Sections."
- Air-entraining agents need not be sampled initially if the contractor presents evidence that the product meets specifications.
- Even when a contract specifically allows or requires admixtures, determine the rate of such use through consultation with METS for each specific product other than air-entraining agents.
- Section 100, "Concrete Materials and Mixing," of the *Bridge Construction Records and Procedures Manual* contains detailed information under Memo 100-4.0, "Admixtures for Portland Cement Concrete." Before making a final decision on the use of admixtures, review this data.

4-9002D Proportioning

The following is primarily a guide for the Caltrans plant inspector, but anyone who needs to verify that plant operations are contract compliant can also use this guide:

- Ensure that storage is as specified in the aggregate storage areas. When various sizes are to be stored separately, require physical separation, either by space between stockpiles or some type of wall that will provide positive separation. Pay particular attention to the method used to prevent contamination of the aggregate. In general, a hard surface, as specified in Section 90-5.01, "Storage of Aggregates," of the *Standard Specifications*, is required for storage of the aggregate stockpile.

- Determine whether the stockpiled aggregate is similar to material upon which the design was based.
- As a part of California Test 109, “Test for Weighing and Measuring Devices,” the district weights and measures coordinator will have completed a safety inspection of the plant facilities frequented by the Caltrans plant inspector for the plant in question. Review the sampling facilities to ensure they will deliver a sample in a safe manner that accurately represents the material. For sampling requirements, refer to California Test 125, “Sampling Highway Materials and Products Used in the Roadway Structural Sections.”
- Before use for Caltrans projects, the plant scales and meters must have a current Form CEM-4204, “California Test 109 Sticker.” The district weights and measures coordinator administers this test. Examine the plant to determine whether weighing equipment matches the testing results. Ensure that scales and meters have been sealed or tested as required. Request from the district weights and measures coordinator the material plant approval report. For additional details, see Section 3-903E, “Weighing and Metering Procedures,” of this manual.

The county sealer of weights and measures tests and seals weighing and metering devices at commercial plants. During the sealing of these plants, the county sealer does not test the interlocks. Therefore, even though the county sealer has sealed the scales and meters, the interlocks must be tested and approved as for noncommercial plants in accordance with California Test 109, “Test for Weighing and Measuring Devices.”

- Ensure that cement can be kept separate from the aggregate until discharged into the mixer.
- Ensure the plant or mixer has the specified automatic timing device. When automatic batching is used, the timing device must be interlocked with the mixer discharge mechanism as specified.
- Examine mixers to ensure that blades are not worn beyond specified tolerances. See that mixers are free of accumulations of hard concrete or mortar.
- Ensure truck mixers have the required metal plates containing the specified information. Also, check truck mixers to ensure they have the specified revolution counters.
- Ensure the contractor will not use equipment with aluminum or magnesium components if these components will contact plastic concrete.
- In addition to the above, check the following when the concrete to be produced is for portland cement concrete pavement:
 1. If specified, ensure the plant has a moisture meter. Be aware that any moisture determination is calculated “as a percent of the dry aggregate.” Commonly used moisture meters measure the total moisture in the material being tested. However, specifications for moisture content in the fine aggregate and batch proportion calculations are based on the free moisture rather than the total moisture content. Therefore, ensure the moisture meter is calibrated for the absorption of the aggregate upon which it is to be used.
 2. Ensure the system contains the specified proportioning interlocks. Determine whether the proportioning system is capable of full automatic operation.
 3. Determine whether the equipment is capable of accepting changes in proportions or sequence of weighing individual sizes without delay.

4-9002E Curing Concrete

Review the various methods of curing concrete contained in Section 90-7, “Curing Concrete,” in the *Standard Specifications*, and discuss with the contractor the proposed methods. Before concrete work begins, ensure the contractor has the required curing materials on-site. Such materials include rugs, a water supply, or a properly inspected curing compound.

The curing compound must be of the type specified by the special provisions, *Standard Specifications*, or both. Before the compound’s use, ensure METS inspects and releases the curing compound. If more than one year has passed since the METS inspection, ensure that before use the curing compound is sampled and tested again.

4-9002F Compressive Strength

When concrete is designated by compressive strength, the contractor must prequalify the concrete before its use as a compressive strength concrete. For additional details, see both Section 6-305D (2), “Trial Batches,” of this manual and also the *Bridge Construction Records and Procedures Manual*.

4-9002G Minor Concrete

When minor concrete is to be used, obtain from the contractor the proposed combined aggregate grading. In general, for minor concrete, you may approve any gradation that produces concrete that meets all other specified qualities.

4-9002H Design of Mix

Concrete mixes should be designed with proportions that will produce concrete with the following qualities:

- The stiffest consistency (lowest penetration) that can be placed efficiently
- Adequate mortar content to provide the required finish
- The lowest water demand consistent with the aggregate specified

4-9002H (1) Selecting Proportions

The following are guidelines to design a workable mix of concrete:

4-9002H (1a) Cement Content

For concrete designated by class, the cement content is fixed, and the design must be based on the specified amount. For concrete designated by cement content, determine whether the amount of cement applies to the source the contractor selected, and base the design on a cement content that will produce the quality the designer anticipated. For more details about concrete used for pavement, see Section 4-40, “Portland Cement Concrete Pavement,” of this manual.

4-9002H (1b) Water Content

The quantity of water per unit of concrete required to produce a mix of the desired consistency is influenced by the maximum size, particle shape, and grading of the aggregate and by the admixtures used. The quantity of water remains relatively unaffected by the quantity of cement.

The quantities of water shown in the Table 4-90.1, “Estimate of Free Water Content for Initial Design” should apply with sufficient accuracy for preliminary estimates or proportions. The values are near the maximal, which should be expected for fairly well shaped but angular aggregate graded within the limits

of the specification. Without specific knowledge to the contrary for the materials being considered, use the data in the table to determine the free water content of the initial mix designs.

The following table shows estimated free water content for different ranges of consistency (penetration) and maximum aggregate size. The free water content for crushed aggregate can be estimated at the upper limit of the listed water contents and rounded aggregates can be estimated at the lower limit of free water content. Additional cementitious material must be ordered, if the free water content exceeds the amount specified in Section 90-6.06 of the *Standard Specifications*. Notify the contractor of any ordered increase in the cementitious material. If the contractor elects to use a water-reducing agent, ensure that the proposed admixture is on METS' list of approved brands. Testing of the mix design must include the proposed admixtures to ensure that the desired concrete properties, such as strength, and air content are attained.

Table 4-90.1 Estimate of Free Water Content for Initial Design

Penetration (mm)	Free Water, (kg/m ³)		
	Max. Size Aggregate 25 mm	Max. Size Aggregate 37.5 mm	Max. Size Aggregate 63 mm
12.5 mm to 25 mm 37 mm to 50 mm 75 mm to 90 mm	180 to 190 190 to 200 210 to 220	160 to 170 170 to 185 185 to 195	140 to 155 160 to 170 165 to 180
Approximate amount of entrapped air in nonair-entrained concrete, percent	2	1	0.4

If the contractor elects to use a water-reducing agent, the admixture must be tested to ensure that it meets the criteria specified for drying shrinkage and strength. See Section 4-9002C, "Admixtures," earlier in this section.

4-9002H (1c) Combined Grading of Aggregate

In considering the use of 37.5 mm maximum size aggregate, the recommended procedure in selecting the fine aggregate content is to start with the median value of the percent passing the 4.75 mm sieve (38 percent) and then adjust this value in accordance with the following criteria:

If the fine aggregate is close to the fine side of the specification limits for the various sieve sizes, use two percentage points less fine aggregate in the mix.

If the fine aggregate is close to the coarse side of the specification limits for the various sieve sizes, use two percentage points more fine aggregate in the mix. This was done in the following Example 4-90.1, "Sieve Analysis and Combined Grading for Portland Cement Concrete, 37.5 mm Maximum."



If the maximum size of aggregate is 63 mm, use two percentage points less fine aggregate.

If the coarse aggregate is largely crushed or is naturally very angular in shape, use two percentage points more fine aggregate.

If the cement content is 350 kg or more per cubic meter, use two percentage points less fine aggregate.

These recommended adjustments may be compensating or cumulative adjustments.

To select the percentage of aggregate of 25 mm x 4.75 mm primary size, start with the percentage of aggregate necessary to meet approximately the middle of the specifications for the 19 mm sieve (60 percent). The percentage of fine aggregate is then subtracted ($60 - 40 = 20$), giving a figure of 20 percent for the 25 mm x 4.75 mm aggregate. The remainder of the mix is made up of 37.5 mm x 19 mm aggregate ($100 - 60 = 40$).

If the maximum aggregate size is 63 mm, determine the percentages of both primary coarse aggregate sizes, computing the percentage of aggregate necessary to meet approximately the middle of the specification limits on the 37.5 mm sieve. Make up the remainder of the mix with 63 mm x 37.5 mm aggregate.

Check the grading of the combined mix against the specification limits for the various intermediate screens. Also analyze the grading of the combined mix based on experience and judgment.

You may tabulate the gradations to be used as shown in columns (b), (d), and (f) in Example 4-90.1, "Sieve Analysis and Combined Grading for Portland Cement Concrete, 37.5 mm Maximum" in these instructions.

4-9002H (2) *Computations for Mix Design*

In designing a concrete mix, you need an understanding of the effect of varying amounts of water from various sources to do the calculations. To aid in this understanding, we have provided the following definitions:

- *Batched Water:* The water added by a batcher to a concrete or mortar mixture before or during the initial stages of mixing.
- *Free Water:* The total water in the concrete mixture minus the water absorbed by the aggregate in reaching a saturated, surface-dry condition. Also referred to as "mixing water," this water is considered in the computation of the net water to cement ratio.
- *Free or Surface Moisture:* Free moisture retained on the surface of the aggregate particles and considered to be part of the mixing water in concrete, as distinguished from absorbed moisture. This moisture is water on the aggregate over and above that required to produce a saturated, surface-dry condition.

- *Saturated, Surface-Dry (SSD)*: The condition of an aggregate particle when all permeable voids are filled with water and no water exists on the exposed surfaces of the aggregate (total absorption).
- *Percent Moisture*: The amount of moisture expressed as a percent of the dry weight of the aggregate.
- *Percent Absorption*: The amount of moisture required to produce a saturated, surface-dry condition in the aggregate (all permeable voids filled with water) expressed as a percent of the dry weight.

Example 4-90.1 Sieve Analysis and Combined Grading for Portland Cement Concrete, 37.5 mm Maximum

Given the following gradations and preliminary data:

Sieve Size (a)	37.5 mm x 19 mm (b)	Portion of Combined 40% (c)	25 mm x 4.75 mm (d)	Portion of Combined 20% (e)	Fine (f)	Portion of Combined 40% (g)	Combined Mix (h)	Specification. (i)
50 mm	100	40	100	20	100	40	100	100
37.5 mm	95	38	100	20	100	40	98	90-100
25 mm	8	3	99	20	100	40	63	50-86
19 mm	3	1	95	19	100	40	60	45-75
9.5 mm	0	0	8	2	100	40	42	38-55
4.75 mm	-	-	3	1	95	38	39	30-45
2.36 mm	-	-	0	0	75	30	30	23-38
1.18 mm	-	-	-	-	50	20	20	17-33
600 μ m	-	-	-	-	27	11	11	10-22
300 μ m	-	-	-	-	12	5	5	4-10
150 μ m	-	-	-	-	5	2	2	1-6
75 μ m	-	-	-	-	2	1	1	0-3

4-9002H (2a) Preliminary Data and Source

The following known information is used in this section’s example calculations.

<ul style="list-style-type: none"> • 350 kg/m³ cementitious material, 25 percent of which is fly ash [262 kg – cement, 88 kg – fly ash] (<i>Standard Specifications</i>) • Specific gravity of cement = 3.15 (<i>known</i>) • Specific gravity of fly ash = 2.33 (<i>known</i>) • 40 percent fine aggregate* • 20 percent 25 mm x 4.75 mm aggregate* • 40 percent 37.5 mm x 19 mm aggregate • Nominal penetration – 50 mm* • 180 kg/m³ water * • 1 percent entrapped air* <p>*From Section 4-9002H, “Design of Mix.”</p>	<table> <thead> <tr> <th></th> <th>SSD Specific Gravity</th> <th>Percent Absorbed Moisture</th> </tr> </thead> <tbody> <tr> <td>Fine aggregate (from lab)</td> <td>2.64</td> <td>2.1</td> </tr> <tr> <td>25 mm x 4.75 mm (from lab)</td> <td>2.68</td> <td>1.1</td> </tr> <tr> <td>37.5 mm x 19 mm (from lab)</td> <td>2.65</td> <td>0.9</td> </tr> </tbody> </table>		SSD Specific Gravity	Percent Absorbed Moisture	Fine aggregate (from lab)	2.64	2.1	25 mm x 4.75 mm (from lab)	2.68	1.1	37.5 mm x 19 mm (from lab)	2.65	0.9
	SSD Specific Gravity	Percent Absorbed Moisture											
Fine aggregate (from lab)	2.64	2.1											
25 mm x 4.75 mm (from lab)	2.68	1.1											
37.5 mm x 19 mm (from lab)	2.65	0.9											

4-9002H (2b) Absolute Volumes

Determine the absolute volume of aggregate required per cubic meter of concrete mix. This is to be done by calculating the volume remaining when the absolute volume of cement, fly ash, water, and entrapped air (not entrained air) is subtracted from a cubic meter.



The absolute volume of a material is related to its weight and specific gravity as follows: (For aggregate, specific gravity is based on a saturated, surface-dry condition of the particles.)

$$\text{Absolute volume in m}^3 = \frac{\text{weight, kg}}{\text{SSD, specific gravity} * 1000} \quad (1)$$

and

$$\text{Weight in kg.} = \text{Absolute volume in m}^3 \times \text{SSD specific gravity} \times 1000 \quad (2)$$

Computation of the absolute volume of aggregate based on the proportions given in “Design of Mix,” above, is as follows:

Absolute volume cement =	$\frac{262}{3.15 * 1000} = 0.08m^3$
Absolute volume fly ash =	$\frac{88}{2.33 * 1000} = 0.04m^3$
Absolute volume water =	$\frac{180}{1.00 * 1000} = 0.18m^3$
Absolute volume air =	$1 \text{ percent} = 0.01 m^3$
	Total = 0.31 m³

Subtract the absolute volume of the cement, fly ash, water, and air in the mix from 1 cubic meter; this calculation will give you the K factor.

	$1 m^3 - 0.31 m^3$	$= 0.69 m^3$
Aggregate =	$0.40 \times 0.69 m^3$	$= 0.28 m^3$ (use 0.27 m ³)
25 mm x 4.75 mm =	$0.20 \times 0.69 m^3$	$= 0.14 m^3$
37.5 mm x 19 mm =	$0.40 \times 0.69 m^3$	$= 0.28 m^3$

Volume check:

Cement	0.08
Fly ash	0.04
Water	0.18
Air	0.01
37.5 mm	0.27
25 mm	0.14
Sand	<u>0.28</u>
	1.00

4-9002H (2c) Quantities Per Cubic Meter

Compute the weights of the various aggregate sizes on the basis of a saturated, surface-dry condition.

This computation is illustrated by continuing the example as follows:

Weight of cement	= 262 kg/ m ³
Weight of fly ash	= 88 kg/ m ³
Weight of water (total free water)	= 180 kg/ m ³
Weight of SSD fine aggregate: 0.27 x 2.64 X 1000 (Equation 2)	= 713 kg/ m ³
Weight of SSD 25 mm x 4.75 mm: 0.14 x 2.68 x 1000 (Equation 2)	= 375 kg/ m ³
Weight of SSD 37.5 mm x 19 mm 0.28 x 2.65 x 1000	= <u>742 kg/ m³</u>
Total	= <u>2,360 kg/ m³</u>

4-9002H (2d) Batch Weights Per Cubic Meter

The above design for a cubic meter of concrete is based on aggregate in an SSD condition. As used on the job, aggregate usually contains free moisture in excess of the moisture absorbed. In determining the quantities of aggregate to be placed in the mixer, make allowances for this free moisture.

The free moisture in the aggregate is considered part of the mixing water and, therefore, must be subtracted from the specified amount to be used in the mixture. Increase the weights of aggregate to compensate for the moisture they contain. (Reverse this procedure if the aggregate as used is less than the SSD.)

You can determine the amount of moisture in aggregate by drying representative samples and weighing the samples both before and after drying. If dried to a constant weight (oven-dry condition), you will determine the total moisture. To obtain the free moisture present, make allowances for the absorbed water.

To determine this total moisture in aggregate, you can use many methods. The aggregate can be dried in an oven or in a pan over a hot plate or open fire. If facilities are available, you can use California Test 223, "Surface Moisture in Concrete Aggregates by the Displacement Method (Field Method)," to determine free moisture directly.

Assume, for the example, the *total* moisture in the aggregate is 10.1 percent in the fine aggregate, 3.1 percent in the 25 mm x 4.75 mm aggregate, and 1.9 percent in the 37.5 mm x 19 mm aggregate. Determine the *free* moisture as follows:

Percent free moisture in fine aggregate	= 10.1 %
minus 2.1	= 8.0 %
Percent free moisture in 25 mm x 4.75 mm aggregate	= 3.1 %
minus 1.1	= 2.0 %
Percent free moisture in 37.5 mm x 19 mm aggregate	= 1.9 %
minus 0.9	= 1.0 %

The adjustment in the mix design to compensate for this moisture can now be made as follows:

Kg free moisture in fine aggregate =	$\frac{0.08 * 713}{1.021} = 56 \text{ kg} / \text{m}^3$
Kg free moisture in 25 mm x 4.75 mm aggregate =	$\frac{0.02 * 375}{1.011} = 7 \text{ kg} / \text{m}^3$
Kg free moisture in 37.5 mm x 19 mm aggregate =	$\frac{0.01 * 742}{1.009} = 7 \text{ kg} / \text{m}^3$
Total free moisture from aggregate	$= 70 \text{ kg} / \text{m}^3$

Batch weights for a one cubic meter mix as follows:

Cement	$= 262 \text{ kg} / \text{m}^3$
Fly ash	$= 88 \text{ kg} / \text{m}^3$
Fine aggregate (713+56)	$= 769 \text{ kg} / \text{m}^3$
25 mm x 4.75 mm aggregate (375+7)	$= 382 \text{ kg} / \text{m}^3$
37.5 mm x 19 mm aggregate (742+7)	$= 749 \text{ kg} / \text{m}^3$
Batched water at mixer (180-70)	$= 110 \text{ kg} / \text{m}^3$

4-9002H (2e) Scale Weights for Batching Plants

Multiply the values obtained for the one cubic meter mix as determined above in “Batch Weights Per Cubic Meter” by the number of cubic meters in the batch.

4-9002H (3) Reproportioning for Air Entrainment

When entrained air is introduced into a concrete mixture, the increased volume of air must be compensated for by a reduction in the amount of water and sand.

If the percentage of entrapped air is higher than the example of 1 percent, then go back to “Absolute Volumes,” under the heading “Computations for Design,” and reevaluate the volume proportions.

4-9002H (4) Adjustment of Initial Mix Design

You may adjust the initial mix design after it is used in the field to maintain the specified cement content, improve workability, and stay within the specified penetration and water limits.

You must also make adjustments if California Test 518, “Unit Weight of Fresh Concrete,” indicates that the proportions used in the initial design do not produce a cubic meter of plastic concrete. Keep the actual cement content within prescribed limits (as determined by California Test 518) by making adjustments in batch weights as necessary.

4-9003
During the Course
of Work

4-9003 During the Course of Work

During the work, the resident engineer must do the following:

- Sample the concrete within the requirements and frequencies of Section 90, “Portland Cement Concrete,” of the *Standard Specifications* and Chapter 6, “Sampling and Testing,” of this manual.
- Make appropriate arrangements for plant inspection.
- Review placement, protection, curing, and staging. Also review concrete washout procedures as they apply to the water pollution control plan.

4-9003A Proportioning and Mixing Operations

This section is primarily a guide for the Caltrans plant inspector, but can be used by anyone who may need to verify that plant operations comply with the contract. During proportioning and mixing operations, do the following:

- Obtain and ensure that the Certificate of Compliance for cement is signed as specified. Sample the cement in accordance with the details in Chapter 6, “Sampling and Testing,” of this manual.
- Observe the cement storage facilities to ensure the cement is protected from moisture.
- Obtain samples of the aggregate in accordance with California Test 125, “Sampling Highway Materials and Products Used in the Roadway Structural Sections,” and test them for the specified properties in accordance with the frequencies shown in Section 6-1, “Sample Types and Frequencies,” of this manual. For the surface moisture content of fine aggregate, vary the testing frequency depending on the uniformity of supply. A change of 1 percent in the moisture content of sand, if not compensated, may change the penetration of concrete as much as 19 mm and the compressive strength as much as 2 Mpa. You can use California Test 223, “Surface Moisture in Concrete Aggregates by the Displacement Method (Field Method),” or the oven-dry method, in which case you must consider an adjustment for absorption.

Compare the test results with the data upon which the design was based, and order necessary corrective action. When class or cement content designates the concrete, adjust the design to compensate for any significant differences within the nominal sizes the contractor proposed. When the concrete is designated by compressive strength, order immediate corrective action for any significant deviations in production operations from those used during the production of trial batches.

- Observe the addition of admixtures to ensure they are the agreed-upon products and are dispensed in the specified manner.
- For air-entraining agents, obtain a Certificate of Compliance, when required, for each shipment.



- During proportioning and mixing of materials, ensure the following occur in the quantities and by the methods specified:
 1. At least twice during each shift, ensure scales are balanced at zero load and inspect them for signs of sluggishness, inaccuracy, or damage. Should an apparent problem with the weighing or measurement systems exist, contact the district weights and measures coordinator for the method of correcting the problem. Also, check for sticking materials that do not discharge.
 2. Batch controllers that have the ability to provide for an estimate of returned concrete, for rebatching; must have that feature disabled. Check that delivery trucks are completely empty prior to loading. Ready-mix trucks can be verified to be empty by spinning the mixing drum in reverse immediately prior to loading.
 3. Check that the entry of water into the mixer is timed to ensure that some water is introduced in advance of aggregate and cement. Also, check that all water has been introduced by the end of the first one-fourth of the specified mixing time. Finally, see that no leakage exists that would affect the proper water content.
 4. Check the batch size to ensure it does not exceed the specified capacity or the limit to which the scales were tested during California Test 109, “Test for Weighing and Measuring Devices.”
 5. Check the mixer operation to ensure that the automatic timing device is interlocked as specified and that the mixing time is as specified.
 6. Observe the hand-mixing of concrete to ensure it is being mixed in the specified manner.
- For concrete used in pavement, or when required for other types of concrete, ensure that automatic devices perform the proportioning operation as specified. Require the plant operator to demonstrate the function of interlock devices. Limit this check of proportioning interlock tolerances to a visual witnessing of the maximum tolerance settings in the batch computer.
- Perform California Test 518, “Unit Weight of Fresh Concrete,” to verify the unit weight, volume, and cement content of concrete in accordance with the frequencies shown in Section 6-1, “Sample Types and Frequencies,” of this manual. Advise the contractor of any changes to be made when the test results do not confirm the correctness of the proportions being used.

Whenever California Test 518 is performed, the data for batch weights must be the *actual* weights as observed for the batch to be tested. Actual batch weights are available from the delivery ticket. It is not sufficiently accurate to use the ordered batch weights.

When the unit weight or cement factor varies considerably for no apparent reason, check the accuracy of the scales. For a quick method, weigh a loaded and unloaded truck on platform scales. With this method, you can also detect erratic weighing because of binding scales.

- When air-entraining agents are used, perform California Test 504, “Determining Air Content of Freshly Mixed Concrete by the Pressure Method” to determine the air content of concrete in accordance with the frequencies shown in Section 6-1 of this manual. For air content of more than 4 percent, ensure that the cement is added as specified.

- To determine the consistency of the concrete, perform California Test 533, “Method of Test for Ball Penetration in Fresh Portland Cement Concrete.” When specified values are exceeded, order adjustments in the mixture.

Also, use the results of California Test 533, and California Test 529, “Proportions of Coarse Aggregate in Fresh Concrete,” to determine the uniformity of concrete. When differences exceed specified values, require the contractor to improve the mixing operation.

- Periodically check the recording of data on tickets for truck mixers or agitators to ensure that the required information is being entered.
- Periodically determine the concrete’s temperature to ensure it falls within the specified values.
- Obtain samples of the completed concrete mixture and perform tests in accordance with Section 6-1, “Sample Types and Frequencies,” of this manual.

Analyze the test results continuously and remain alert to any changes in the concrete’s uniformity or consistency. When test results so indicate, order corrections in the production operation or provide the contractor with revisions in the mix design, or do both. Reject (based on penetration) excessively wet batches discharged from mixers and not used in the work. Prohibit indiscriminate additions of water to the mixer solely to increase the flow of already workable concrete.

Record all tests and keep them in the project files. When a specific form is not used for recording test results, such as California Test 533, record the results in the daily report.

4-9003B Mixing and Transporting

During the work, do the following:

- Ensure concrete is transported in accordance with the applicable specifications.
- Ensure the proper mix design is being batched and arrives at the job site. The concrete must arrive with a load ticket that contains the specified information and a Certificate of Compliance for the cement and all mineral admixtures. The weight certificate must also show the actual scale masses (kilograms) for the ingredients batched. Prohibit theoretical or target batch masses as substitutes for actual scale masses. Check the load tickets, and verify that the specified information is actually on the ticket.
- As the concrete is placed, ensure that it is homogeneous and thoroughly mixed and that no lumps or evidence of undispersed cement exists.
- Check truck agitators to determine whether they are being operated at the speed designated by the manufacturer.
- Ensure that bodies on nonagitator hauling equipment do not leak and can self-clean during discharge.
- Ensure that concrete hauled in open-top vehicles is protected (covered) as specified.
- Verify the consistency of the concrete through California Test 533. Record the results on the daily report. If the concrete exceeds the nominal or maximum penetration allowed by the *Standard Specifications*, take appropriate action.

- Additional mix water, when necessary, can be added when the resident engineer or assistant resident engineers authorize. When additional mixing water is authorized, ensure it is mixed as specified. Make corrections in the proportioning if it is necessary to continuously order water at the discharge point.
- Measure the temperature of the concrete periodically. You can obtain the temperature of the fresh concrete from a sample withdrawn from the mixer just before discharge or from within the forms during or immediately after discharge from the mixer.
- When concrete is being hauled in truck mixers or agitators, ensure the discharge is completed within one and one-half hours or 250 revolutions as specified. If the concrete's temperature is 30° C or above, determine the time (less than one and one-half hours) that will be allowed. Advise the contractor accordingly.
- For proper mixing, verify that the concrete delivered in truck mixers or agitators has received the minimum number of revolutions recommended by the manufacturer. However, a minimum of 70 revolutions is a good rule of thumb.
- The temperature requirements for specialty concrete will vary. Refer to the special provisions.
- When nonagitating equipment is used, ensure the discharge is completed within one hour as specified. If the concrete's temperature is 30° C or above, or under other conditions contributing to quick stiffening of the concrete, ensure the discharge is completed within 45 minutes as specified.
- In the daily report, note the concrete's temperature and decisions relating to that measurement.
- For transit-mixed concrete, you cannot determine directly from the revolution counter the requirements for minimum and maximum revolutions of mixing at the mixing speed. However, in many instances, a simple calculation based on the total number of mixing revolutions and the hauling time will verify compliance with the specifications. If, because of the circumstances of long hauls or other reasons, such a calculation is not possible, you can ask the supplier for the schedule of time the drum will be operated at mixing speed. At the end of that time, the operator can reduce drum speed to agitating range. The number of revolutions at mixing speed is not considered to be as important as the total number of revolutions of mixing. However, at very low rpm's of the mixer and at the minimum number of revolutions, it is possible that inadequate mixing will result.
- Sample concrete and fabricate test cylinders in accordance with Section 6-1, "Sample Types and Frequencies," in this manual.
- Do not allow trucks to exceed the weight limits, especially for bridges, given in Section 7-1.02, "Load Limitations," of the *Standard Specifications*.

4-9003C Curing Concrete

Ensure the contractor applies the proper cure method in accordance with the specifications. Periodically check that the contractor is maintaining the cure through the curing period.

4-9003D Protecting Concrete

Anticipate adverse weather conditions, and discuss options with the contractor. Require the contractor to submit a written plan on methods to protect the concrete if adverse weather sets in.

Concrete needs time to attain sufficient strength to carry loads. Do not allow anyone to drive or place equipment or loads on the pavement when those loads are greater than those allowed by the contract.

4-9004 Measurement and Payment

Measurement and payment must comply with the applicable sections of this manual and the special provisions, *Standard Specifications*, and *Bridge Construction Records and Procedures Manual*.

Review and document the results of acceptance testing in accordance with Chapter 6, "Sampling and Testing," of this manual. Take appropriate remedial action or deductions for failing results on acceptance tests.