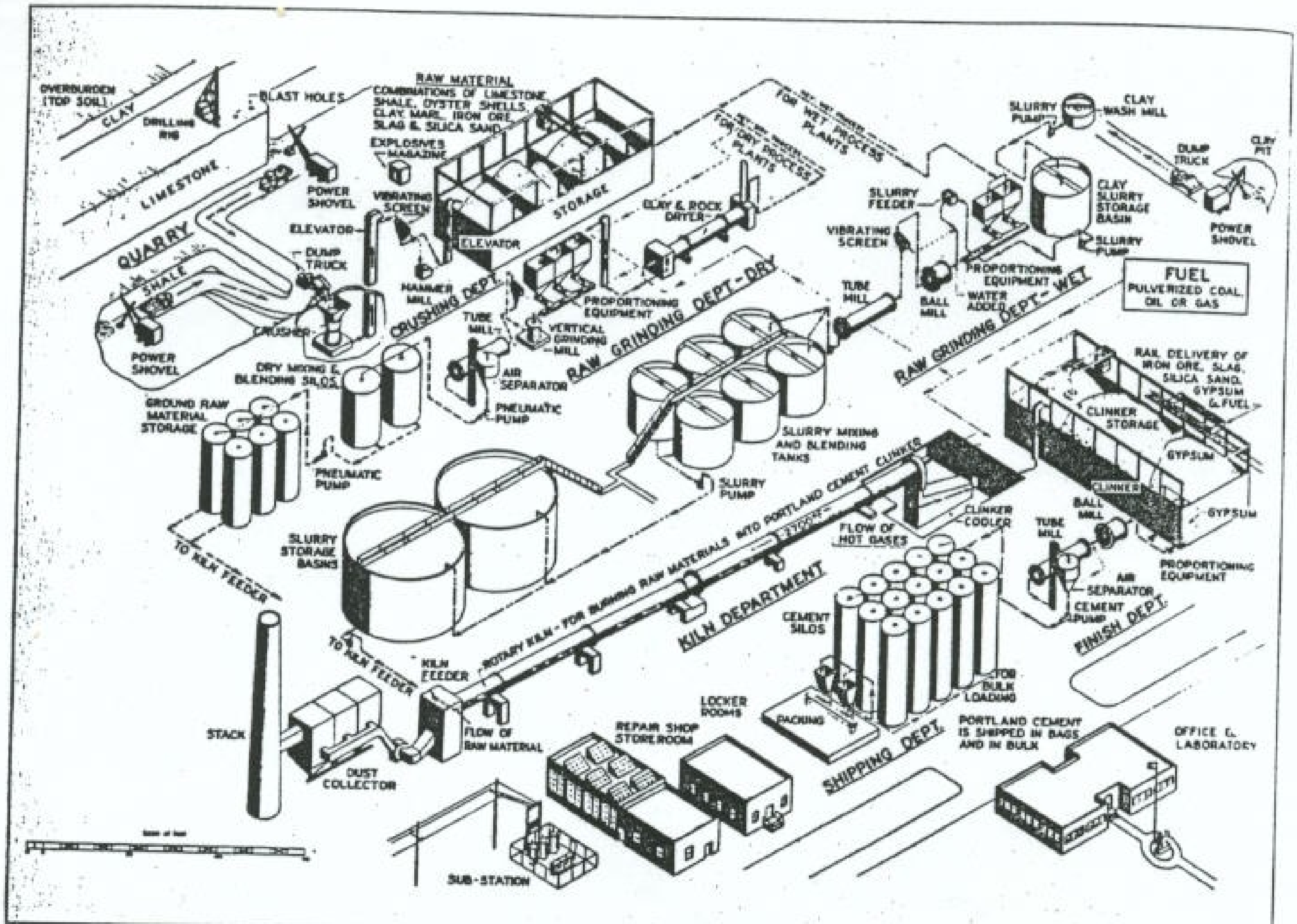


FIGURE 3.2-2 *Steps in the manufacture of portland cement, showing both dry and wet processes.* (Courtesy Portland Cement Association.)

FIGURE 3.2-3
Portland Cement Types and Uses

ASTM C 150	Use	ASTM C 175
Type I	In general construction when special properties of other types are not required	Type IA*
Type II	In general construction where moderate heat of hydration is required	Type IIA*
Type III	When high early strength is required	Type IIIA*
Type IV	When low heat of hydration is required	
Type V	When high sulfate resistance is required	

Courtesy Portland Cement Association.
*Air-entraining portland cement.

where sulfate concentrations in the groundwater are higher than normal. Type II portland cement generates less heat of hydration and cures at a slower rate than Type I. This moderate heat of hydration reduces temperature rise, which is especially important when concrete is placed in warm weather in structures of considerable mass, such as in large piers or heavy retaining walls.

TYPE III, HIGH EARLY STRENGTH

Type III portland cement is used when high strengths are desired at a very early time, usually in a week or less. It is used when (1) early form removal is desirable; (2) the concrete must be put into service quickly; (3) the weather is cold, to reduce the period required for protection against low temperatures to control curing; and (4) high early strengths can be secured more satisfactorily or more economically than by using richer mixes of Type I portland cement.

TYPE IV, LOW-HEAT

Type IV is a special portland cement for use where the amount and rate of heat generated during hydration must be kept to a

Figure 3.5 Slump test.

TABLE 3.3 RECOMMENDED SLUMPS FOR VARIOUS TYPES OF CONSTRUCTION

Types of construction	Slump (in.) Maximum	Minimum
Footings, caissons, foundation walls, and substructure walls	3	1
Beams, columns, and walls	4	1
Pavements and slabs	3	1
Mass concrete	2	1

TABLE 3.4 APPROXIMATE MIXING WATER AND AIR CONTENT FOR TRIAL BATCHES

Range of Slump[a] (in.)	Approximate mixing water (lb/yd³ of concrete) for nominal maximum size of CA (in.): 3/8	1/2	3/4	1	1½	2	3	6
				Non-Air-Entrained Concrete				
1–2	350	335	315	300	275	260	240	210
3–4	385	365	340	325	300	285	265	230
6–7	410	385	360	340	315	300	285	–
Approximate air content (%)	3	2.5	2	1.5	1	0.5	0.3	0.2
				Air-Entrained Concrete				
1–2	305	295	280	270	250	240	225	200
3–4	340	325	305	295	275	265	250	220
6–7	365	345	325	310	290	280	270	–
Recommended Air content, (%)[b]	4.5–7.5	4.0–7.0	3.5–6.0	3.0–6.0	2.5–5.5	2.0–5.0	1.5–4.5	1.0–4.0

Source: ACI 211.1-91, Table 6.3.3. Reprinted with permission.

[a]Refer to Table 3.3.

[b]Refer to Table 3.5.

TABLE 3.5 TOTAL AIR CONTENT FOR FROST-RESISTANT CONCRETE

Normal maximum coarse aggregate size (in.)	Air content (%) Severe exposure	Moderate exposure
3/8	7½	6
1/2	7	5½
3/4	6	5
1	6	4½
1½	5½	4½
2	5	4
3	4½	3½

Source: ACI 318-89, Table 4.2.1, revised 1992. Reprinted with permission.

TABLE 3.6 MAXIMUM PERMISSIBLE WATER/CEMENTITIOUS MATERIALS RATIOS BY WEIGHT FOR TRIAL BATCHES

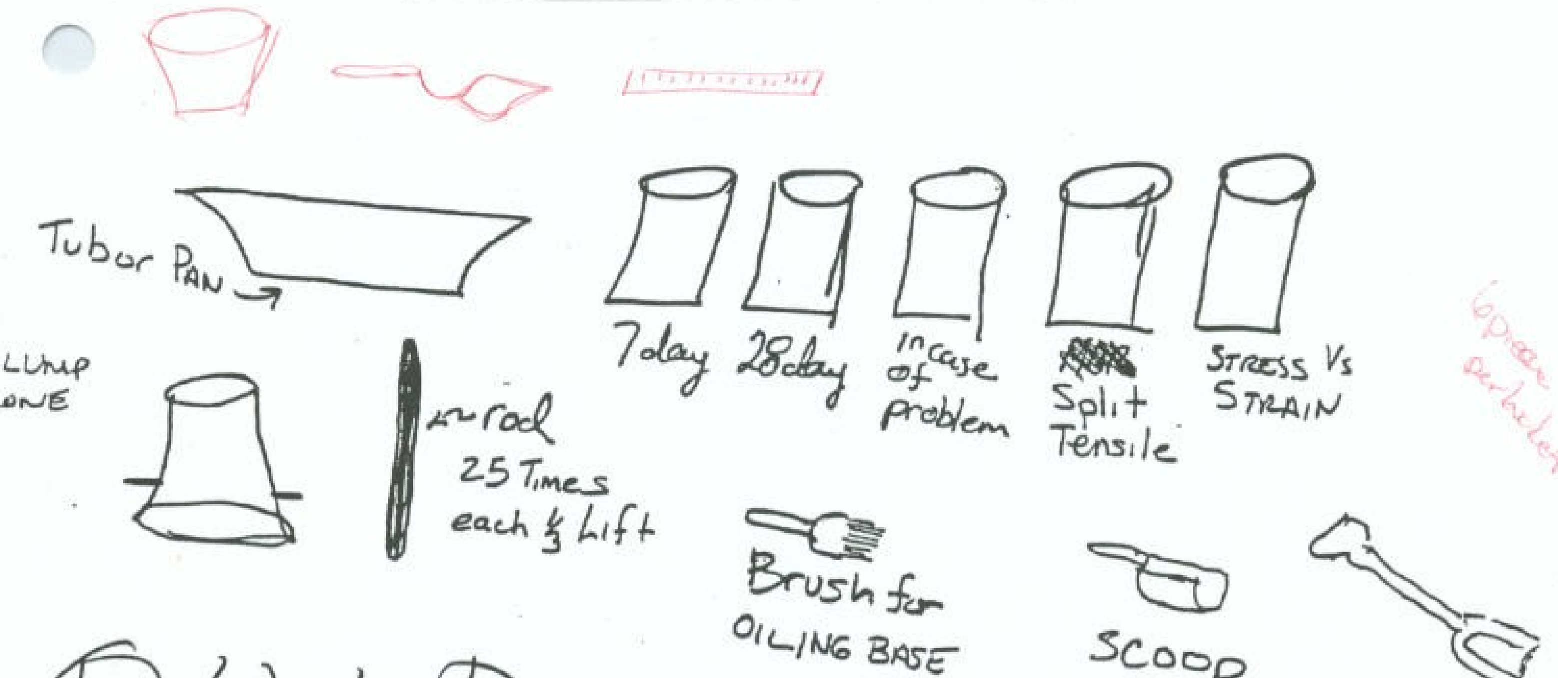
Specified compressive strength f'_c (psi)	Absolute water/cementitious materials ratio by weight: Non-air-entrained concrete	Air entrained concrete
2500	0.67	0.54
3000	0.58	0.46
3500	0.51	0.40
4000	0.44	0.35
4500	0.38	–
–	–	–

Source: ACI 318-89: Table 5.4, revised 1992. Reprinted with permission.

TABLE 3.9 VOLUME OF COARSE AGGREGATE PER UNIT VOLUME OF CONCRETE BASED ON WORKABILITY REQUIREMENTS

Nominal maximum coarse aggregate size (in.)	Volume of dry-rodded coarse aggregate per unit volume of concrete for fineness modulus of sand: 2.4	2.6	2.8	3.0
3/8	0.5	0.48	0.46	0.44
1/2	0.59	0.57	0.55	0.53
3/4	0.66	0.64	0.62	0.60
–	–	–	–	–
1½	0.75	0.73	0.71	0.69
2	0.78	0.76	0.74	0.72
3	0.82	0.80	0.78	0.76
6	0.87	0.85	0.83	0.81

Mixing Procedure



(1a) Wet Down Pan, etc

(1) Oil The Base Of Each Cylinder

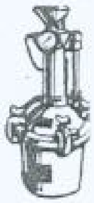
(2) Weigh Out The Amount Needed Of Sand, Gravel, Cement + Water

(3) Mix Ingredients Inside The Tub As Required
(Note: Add Gravel Last Since It Is Difficult To Mix This Add't'l Weight)
(6000 psi Group Should Request An Admixture For Workability)

(4) Concrete Should Be added into each mold rodding 25 times each ⅓ Lift, and leveled off with a Trowel

(5) Place Molds into Curing Storage Room

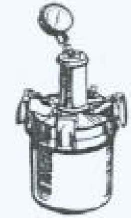
15 whack with hammer to knock out air



Air Content — Pressure Method (Type A) "Acme" Meter

ASTM C 231-89ª: Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

1. This test method is not for concrete with lightweight or porous aggregate.
2. Determine aggregate correction factor (see ASTM C 231, paragraph 6). Remix the sample and wet the meter.
3. Wet the equipment, then remove excess moisture.
4. Fill the bowl in three equal layers, uniformly rodding each layer 25 times and penetrating 1 in. (25 mm) into the previous layer. Rap the sides smartly 10 to 15 times with a standard mallet after rodding each layer. There should be no substantial excess or shortage of concrete after consolidation; an excess of 1/8 in. (3 mm) is optimum.
5. Strike off with a metal strike-off bar. Clean the contact surfaces and dampen the rubber seal on the cover. Clamp on the cover.
6. Pour water into the fill tube until the level reaches about halfway the 4% mark on the glass standpipe gauge (water column).
7. Rotate the meter on its base at a 30° angle several times, tapping the cover with a mallet. Then fill the column until water discharges from top valve. Tap the sides with a mallet.
8. Bring the water level to the initial fill line above zero by opening the lower drain valve. Close the top vents of the column and the top valve on the fill tube.
9. Pump the pressure to slightly above the desired test pressure and tap the meter sides with a mallet. Zero pressure at the required level.
10. The level on the water column is the air content less the aggregate correction factor.
11. Gradually release pressure through the top vent of the water column and tap the meter sides lightly for about one minute.
12. The level of the gauge should be at zero. (For other kinds of Type A meters, fill to zero mark, then note final water level after pressure is removed. The difference between these two levels is subtracted from the level observed at required pressure.)



Air Content — Pressure Method (Type B)

ASTM C 231-89ª: Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

1. This test method is not for concrete with lightweight or porous aggregate.
2. Determine aggregate correction factor (see ASTM C 231, paragraph 5). Remix the sample and wet the meter.
3. Wet the equipment, then remove excess moisture.
4. Fill the bowl in three equal layers, uniformly rodding each layer 25 times and penetrating 1 in. (25 mm) into the previous layer. Rap the sides smartly 10 to 15 times with a standard mallet after rodding each layer. There should be no substantial excess or shortage of concrete after consolidation; an excess of 1/8 in. (3 mm) is optimum.
5. Strike off with a metal strike-off bar. Clean the contact surfaces and dampen the rubber seal on the cover.
6. Open both petcocks and clamp on the cover.
7. Close the main air valve between the air chamber and the measuring bowl.
8. Syringe water through one petcock until water comes out the other petcock.
9. Jar the meter gently until no air bubbles come out.
10. Close the air bleeder valve and pump the pressure up to the initial pressure line (usually 2 to 3% depending on calibration).
11. Allow a few seconds for compressed air to cool, then zero the meter at this line by pumping or bleeding while tapping the gauge lightly.
12. Close both petcocks on the holes through the cover.
13. Open the main air valve. Sharply rap the base and lightly tap the gauge.
14. Read the air content on the gauge and subtract the aggregate correction factor.
15. Release the pressure by opening both petcocks.

(These steps apply to the Pressure Meter. The White Meter version varies slightly from these procedures; see instructions that come with the unit.)

CODE

3.3 — Aggregates

3.3.1 — Concrete aggregates shall conform to one of the following specifications:

(a) "Specification for Concrete Aggregates" (ASTM C 33).

(b) "Specification for Lightweight Aggregates for Structural Concrete" (ASTM C 330).

Exception: Aggregates which have been shown by special test or actual service to produce concrete of adequate strength and durability and approved by the building official.

3.3.2 — Nominal maximum size of coarse aggregate shall be not larger than:

(a) $^1/_5$ the narrowest dimension between sides of forms, nor

(b) $^1/_3$ the depth of slabs, nor

(c) $^3/_4$ the minimum clear spacing between individual reinforcing bars or wires, bundles of bars, or prestressing tendons or ducts.

These limitations shall not apply if, in the judgment of the engineer, workability and methods of consolidation are such that concrete can be placed without honeycomb or voids.

3.4 — Water

3.4.1 — Water used in mixing concrete shall be clean and free from injurious amounts of oils, acids, alkalis, salts, organic materials, or other substances deleterious to concrete or reinforcement.

COMMENTARY

R3.3 — Aggregates

R3.3.1 — It is recognized that aggregates conforming to the ASTM specifications are not always economically available and that, in some instances, noncomplying materials have a long history of satisfactory performance. Such nonconforming materials are permitted with special approval when acceptable evidence of satisfactory performance is provided. It should be noted, however, that satisfactory performance in the past does not guarantee good performance under other conditions and in other localities. Whenever possible, aggregates conforming to the designated specifications should be used.

R3.3.2 — The size limitations on aggregates are provided to ensure proper encasement of reinforcement and to minimize honeycomb. Note that the limitations on maximum size of the aggregate may be waived if, in the judgment of the engineer, the workability and methods of consolidation of the concrete are such that the concrete can be placed without honeycomb or voids. In this instance, the engineer must decide whether or not the limitations on maximum size of aggregate may be waived.

R3.4 — Water

R3.4.1 — Almost any natural water that is drinkable (potable) and has no pronounced taste or odor is satisfactory as mixing water for making concrete. Impurities in mixing water, when excessive, may affect not only setting time, concrete strength, and volume stability (length change), but may also cause efflorescence or corrosion of reinforcement. Where possible, water with high concentrations of dissolved solids should be avoided.

Salts, or other deleterious substances contributed from the aggregate or admixtures are additive to the amount which might be contained in the mixing water. These additional amounts must be considered in evaluating the acceptability of the total impurities that may be deleterious to concrete or steel.

Test CON-1: Slump Test of Portland Cement Concrete

Purpose: To determine the slump of plastic concrete.

Related standards: ASTM C143, C172.

Equipment: Slump mold, tamping rod (⅝-in. diameter), pan, scale, shovel, hand scoop.

Sample: Minimum 0.3 ft^3 of plastic concrete.

Procedure:

1. Start the test within 5 min. after obtaining the final portion of the composite sample.
2. Dampen the mold and place it on a flat moist pan.
3. Hold the mold firmly in place during filling (by the operator standing on the two foot pieces).
4. Fill the mold in three layers, each approximately one-third the volume of the mold.
5. Rod each layer with 25 strokes of the tamping rod. In filling and rodding the top layer, heap the concrete above the mold before rodding is started.
6. Strike off the surface by screeding and a rolling motion of the tamping rod.
7. Remove the mold immediately by raising it in a vertical direction. (The entire test, from the start of the filling through removal of the mold, should be completed within 2½ min..)
8. Place the empty mold (upside down) adjacent to the concrete sample and measure the vertical difference between the top of the mold and the displaced original center of the top surface of the specimen. This is slump.

Report: Record the slump in inches to the nearest ¼ in.

with caution, since specific effects that will result from their use seldom can be predicted accurately. In addition, two or more admixtures should not be used in the same concrete mix, unless their combined effect is well known and will not produce an undesirable condition.

ASTM Standard C 494 classifies some chemical admixtures by function, as follows:

- Type A: Water-reducing
- Type B: Retarding
- Type C: Accelerating
- Type D: Water-reducing and retarding
- Type E: Water-reducing and accelerating
- Type F: High-range water-reducing
- Type G: High-range water-reducing and retarding

Of these, the most frequently used are air-entraining agents, water-reducing agents, retarders, and accelerators.

3.2.4.1

Water-Reducing Admixtures

Water-reducing admixtures, such as hydroxylated carboxylic acid, should be used in almost all concrete. They permit the use of a lower water content and improve workability. They also increase the efficiency of the portland cement in a mix, which lowers the cost of the concrete relative to its performance.

High-range water-reducing admixtures (*super plasticizers*) are used mostly in concrete that is to be pumped. They produce a mix that flows easily with no increase in its water content.

3.2.4.2

Retarders

Admixtures that have a retarding effect on the set of portland cement are used in concrete to overcome the accelerating effect that temperature has on setting during hot weather and in large masses of concrete and to delay the early stiffening of concrete placed under difficult conditions. Retarder solutions are sometimes applied directly to the surface of concrete to retard the set of a surface layer of mortar so it can be readily removed by brushing, thus exposing the aggregate and producing textured surface effects.

Because most retarders also act as water reducers, they are frequently called *water-reducing retarders*. Retarders may also entrain some air in concrete. Many chemicals are mentioned in current literature as having a retarding influence on the normal setting time of portland cement. Some of these chemicals have been found variable in action, retarding the set of certain portland cements and accelerating the set of others. Unless experience with a retarder has determined the extent of its effect on the setting time and other properties of a concrete, its use as an admixture should not be attempted without technical advice or advance experimentation with the portland cement and other concreting materials involved to determine its effects on the properties of the concrete.

3.2.4.3

Accelerators

Accelerators increase the rate of early strength development in concrete to (1) reduce the waiting time before finishing operations can be started; (2) permit earlier removal of forms and screeds; (3) reduce the required period for curing in certain types of work; (4) advance the time when a structure can be placed in service; (5) partially compensate for the slow gain in strength of a concrete even with proper protection during cold weather; and (6) reduce the period of protection required for initial and final set in making emergency repairs and other work.

Under most conditions, commonly used accelerators cause an increase in the drying shrinkage of concrete. In many cases, it must be decided whether to use an admixture, increase the portland cement content, use a portland cement with high early strength, provide greater protection or longer curing period, or use a combination of these.

Calcium chloride is used to accelerate the time of set and to increase the rate of strength gain. It should meet the requirements of ASTM Standard D 98. The amount used should not exceed 2% by weight of the portland cement used. Greater amounts may cause rapid stiffening, increase drying shrinkage, and corrode reinforcement. Calcium chloride should always be added in solution as part of the mixing water to ensure uniform distribution. If it is added in dry form, all the dry particles may not dissolve completely during mixing. Undissolved lumps can cause popouts or dark spots in hardened concrete. Calcium chloride should never be used as an antifreeze. To lower the freezing point of concrete appreciably would require using so much calcium chloride that the concrete would be ruined. Instead, protective measures should be taken to prevent the concrete from freezing (see Section 3.8.3.1).

Using calcium chloride or admixtures that contain soluble chlorides is not recommended under the following conditions: (1) in prestressed concrete, because of possible corrosion hazards; (2) in concrete containing embedded aluminum, such as conduit, because serious corrosion can result, especially if the aluminum is in contact with embedded steel and the concrete is in a humid environment; (3) in concrete exposed to soils or water containing sulfates; (4) in floor slabs intended to receive dryshake metallic finishes; or (5) in hot weather generally.

3.2.4.4

Air-Entraining Agents

Air-entrained concrete can be made either with admixtures added to the mix or with air-entraining portland cement as listed in ASTM Standard C 150, which already contains the admixtures. Air-entraining admixtures produce many microscopic stable air bubbles in concrete. These materials should conform with the requirements of ASTM Standard C 260, which includes specifications and methods of testing. These admixtures will, at little or no additional cost, improve the workability and durability of concrete and produce a hardened concrete that is resistant to severe frost action and the effects of applications of salt for snow and ice removal. Common air-entrainment admixtures include wood resin, sulfonated hydrocarbons, and fatty resinous acids. Because careful control is essential in producing air-entrained concrete, its use should be restricted to plant or transit-mixed batches.