FOUNDATIONS
CONCRETE

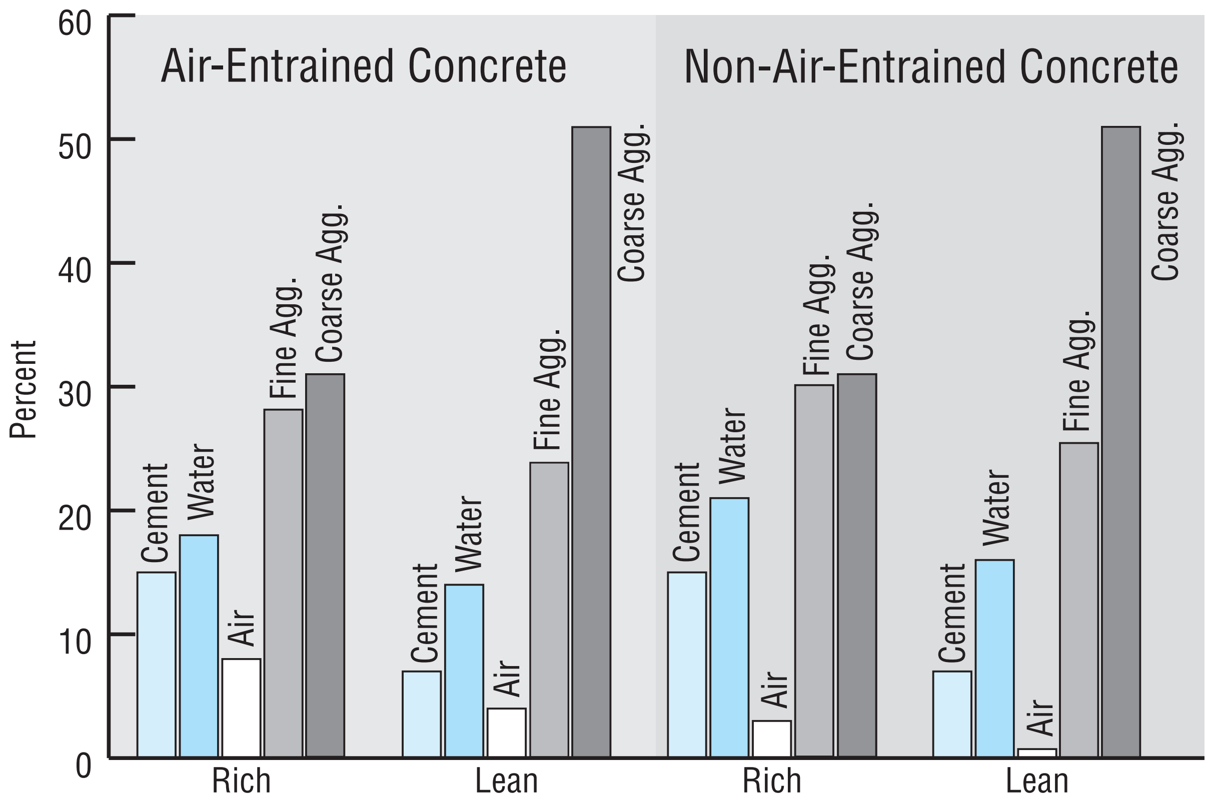
If you understand the fundamentals, you will be better able to keep costs down, improve the strength of your concrete, and minimize cracking.

Specifying Ready-Mix

SPECIFYING READY-MIX

Depending on the needs of the project, ready-mix suppliers can provide hundreds of different concrete mixes. In general, it's a good idea to tell your supplier what the concrete will be used for, and follow the supplier's recommendations for the appropriate mix. However, a builder should understand the way mix adjustments affect the concrete's properties.

FIGURE A: COMPONENTS OF CONCRETE



Percentages of cement, water, air, sand, and gravel in concrete mixes. Rich mixes contain higher percentages of cement. Air-entrainment introduces tiny air bubbles that allow the concrete to flow easier with less water, which makes for a stronger mix. The trapped bubbles also absorb minor expansion and contraction, allowing the concrete to better resist freeze/thaw damage.

At a minimum, concrete specifications will usually call out the compressive strength and water/cement ratio (**Figure B**), as well as the slump (**Figure E**). Concrete mixes can vary in the type and quantity of cement, the ratio of water to cement, the percentage of entrained air, and the size and grading of aggregates. You may also want to order concrete with various admixtures for special circumstances (see **Admixtures**, below).

Specifying Ready-Mix

FIGURE B: SELECTING RESIDENTIAL CONCRETE

Strucutral Element	Minimum Compressive Strength Required	Practical Water/ Cement Ratio
Foundations, basement walls, and slabs not exposed to weather	2,500 - 3,000 psi	.55
Foundations, basement walls, and slabs exposed to weather	3,500 psi	.45
Driveways, garage slabs, sidewalks, porches, patios, and steps exposed to weather	3,500 - 4,000 psi	.45

Cement Types

Figure C shows the five standard types of cement in use today.

FIGURE C: TYPES OF CEMENT

Type	Use
Type I, Type IA (air-entertaining)	Good for most residential work
Type II, Type IIA (air-entertaining)	Use where soils and ground water contain moderate sulfates that can attack concrete
Type III, Type IIIA (air-entertaining)	Use when freezing is a risk or to speed up setting and curing
Type IV	Only needed for massive industrial placements (special order)
Type V	Use in extreme sulfate exposure conditions

Concrete Types I, II, and III will meet most residential needs. For freeze-thaw durability, order air-entraining cement or an air-entraining admixture.

Aggregate

Sand and gravel are the strongest and cheapest ingredients in concrete. It is most economical to use aggregate that is large and well-graded (containing a good proportion of various sizes from large to small), because this reduces the required volume of cement paste. If reinforcing steel will be spaced close together, or if concrete must be pumped, maximum gravel sizes may have to be reduced.

Using more fine sand makes a concrete mix "creamier" and makes it easier to achieve a smooth finish; however, the mix will require more water, and therefore should have more cement added for adequate strength.

Water

Water used to mix concrete should be clean enough to drink. Adding water to a concrete mix can weaken concrete. Follow water/cement ratio guidelines below.

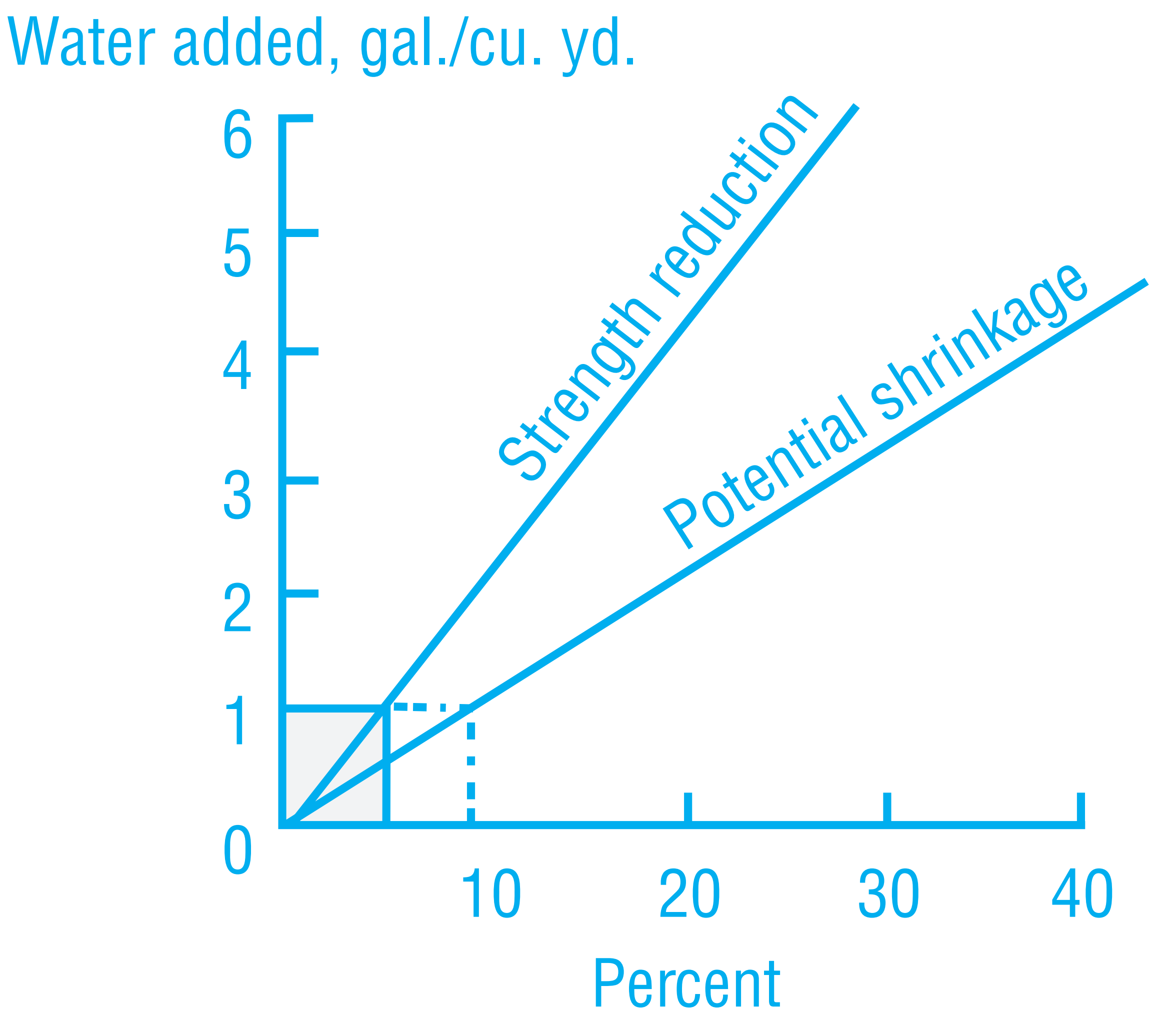
Water/Cement Ratio

The ratio of water to cement should be strictly controlled to ensure that the concrete reaches the specified strength (**Figure D**).

Specifying Ready-Mix

On site, add the minimum amount of water needed to make the concrete workable. More water makes the concrete easier to handle, but also makes it much weaker and more prone to shrinkage and cracking (**Figure D**).

FIGURE D: EFFECT OF ADDING WATER TO CONCRETE



The more water added to a concrete mix on site, the weaker it will become, and the more it will shrink and crack. Adding 2 gallons per yard will cut compressive strength by around 10% and will increase shrinkage by close to 20%.

Specifying Ready-Mix

FIGURE E: CONCRETE SLUMP

A slump test uses a standard cone — 12 in. high, 8 in. wide at the base, and 4 in. wide at the top. To perform the test, fill the cone in one-third lifts and "rod it" (churning by moving a piece of rebar up and down) 25 times between each lift. Remove the cone and measure the distance from the height of the cone to the height of the slumped concrete. Residential concrete should slump no more than 4 in.

Air Entrainment

Air entraining creates billions of microscopic air voids in hardened concrete, which serve to absorb the pressures caused by expanding ice or de-icing salts. Most ready-mix suppliers today add an air-entraining admixture to a standard cement mix.

Air entrainment is crucial for exposed concrete in cold climates, but it is recommended for almost all concrete, even in mild climates, because it reduces water demand, improves workability, reduces segregation of aggregate, and reduces bleeding of excess water. Recommended entrained-air percentages for different weather exposures are shown in **Figure F**. Refer to the map in **Figure G** for exposure regions throughout the continental United States.

Specifying Ready-Mix

FIGURE F: RECOMMENDED AIR ENTRAINMENT FOR RESIDENTIAL CONCRETE

Nominal Maximum Aggregate Size (in.)	Air Content (%)*		
	Severe Exposure	**Moderate Exposure**	**Mild Exposure**
3/8	7 1/2	6	4 1/2
1/2	7	5 1/2	4
3/4	6	5	3 1/2
1	6	4 1/2	3
1 1/2	5 1/2	4 1/2	2 1/2
2	5	4	2
3	4 1/2	3 1/2	1 1/2

*Air content is specified as a percentage by volume of concrete. For severe exposure conditions, air content of the mortar alone (cement paste and sand) should be about 9%. Lower air content percentages for concrete with large aggregate reflect the fact that less mortar is needed for mixes that contain large gravel.

These levels of air-entrainment shown for different climate exposures are minimums. Higher air amounts are permissible as long as the design strength is maintained. Refer to Figure G for exposure locations.

FIGURE G: WEATHER EXPOSURE REGIONS FOR RESIDENTIAL CONCRETE

"Severe" and "Moderate" exposures are determined based on the likelihood that de-icing salts will be used at a given location. Check local climate data because icing conditions may vary locally with altitude.

Specifying Ready-Mix

Admixtures

Finishing air-entrained concrete. A concrete finisher may wait for bleed water to evaporate before starting to trowel the surface, but when concrete is air-entrained, bleed water may not appear. Excess water should still be allowed to evaporate from beneath the surface for a time before troweling begins — otherwise, water may be trapped just below a hard surface skin and cause later scaling or flaking.

ADMIXTURES

Small amounts of specialty admixtures can be used to modify concrete properties as needed. Common admixtures are shown in **Figure H.** More detailed information on common admixtures used in residential concrete is given below:

FIGURE H: CONCRETE ADMIXTURES AND USES

Admixture	Common Active Ingredients	Use
Accelerator	Chloride: Calcium chloride Non-chloride: Triethanoline (TEA) Calcium formate, Calcium nitrate	To accelerate set and strength gain (primarily used in cold weather)
Retarder	Gypsum powder, Sugar*, Lignosulfonate, Hydroxycarbolic acid	To reduce setting time (primarily used in hot weather)
Water-reducer/plasticizer	Lignosulfonate, Hydroxycarbolic acid	To produce a more workable mix
Superplasticizer	Sulfonated melamine formaldehyde (SMF), Sulfonated naphthene formaldehyde (SNF), Modified lignosulfate (MLS)	To produce flowing plasticizer

* Large amounts of sugar will completely stop the setting reaction, so sugar is often used as a kill when a mixer breaks down and cannot be emptied.

Admixtures are chemical or mineral compounds used to alter the physical or chemical properties of concrete.

Accelerators

Accelerating admixtures are used when rapid strength gain is required, such as when the risk of freezing or tight schedules requires faster curing. Accelerators increase the heat of hydration, shorten the set time, and increase the early strength. However, they can decrease the long-term strength of the concrete. The additional heat of hydration may also contribute to increased thermal shrinkage cracking when the concrete cools.

Accelerators do not stop concrete from freezing; they only let the concrete quickly develop its air-entrainment, which gives water in concrete pores a place to go to relieve the pressure of expanding ice. When temperatures are cold, concrete may need to be protected from freezing with insulation or within a heated enclosure (see Cold-Weather Concrete).

Calcium Chloride

Calcium chloride is one of the most common accelerators. Chlorides can increase corrosion of reinforcing steel in concrete that's exposed to de-icing salts. (Non-chloride accelerators are available but seldom specified for residential work.) Calcium chloride can be added to the truck on-site, but it is better to have the ready-mix supplier add it at the plant. Accidentally varying the dose from one truck-load to the next can cause color variations in finished slabs.

Maximum Dose = 2% Calcium Chloride
(by weight of cement)*

*About two 50-lb. bags of calcium chloride per 10-yd. load

Water Reducers and Plasticizers
Water reducers are used to increase slumps and make concrete more workable without adding water. This makes placement easier without compromising strength. High-range water reducers, or superplasticizers, create flowable concrete that can be readily worked into forms and around rebar, and is easily consolidated.

Superplasticizers
These can be tricky to work with. The effect from a superplasticizer typically lasts only about 30 minutes and wears off rapidly. Adding water to restore slump when the superplasticizer wears off creates inconsistent quality within the batch and should be avoided. It is possible to combine a superplasticizer with a lower-range water reducer to provide a longer working life; if you anticipate delays on site, consult with your supplier.

Set Retarders
Concrete sets up rapidly in warm weather, and it may be difficult to finish the surface before the concrete becomes too hard. Set retarders slow the rate of hydration and allow a longer working time. However, set retarders do not prevent evaporation and slump loss, so concrete may still dry out rapidly and quality can suffer. Plastic shrinkage cracking, which occurs because concrete dries out before setting, may actually be worse if a set retarder is used.

PLACING CONCRETE
Concrete placement always happens under time pressure. Allow a half-hour to an hour per truckload of concrete — concrete is unusable after 90 minutes on the truck under normal conditions, and may go bad even faster in hot weather.

Pumping Concrete
Pumping calls for a special mix, and usually requires a specialty pumping subcontractor. Coordination is important, so a pre-construction meeting of all the contractors involved is recommended.

Pouring Concrete
Place walls in lifts of 1- to 2-ft., working around the perimeter of the building. This lets lower lifts stiffen before the pour gets deep, reducing pressure on the forms.

Place slabs in bands 4- to 6-ft.-wide, and strike off as you go so you won't have to disturb concrete that has already begun to set.

Place concrete close to its final position. Don't puddle it in one place and drag it along — the farther the concrete is pulled, the more the gravel separates from the paste (segregates), causing honeycombing and weakening the structure.

Placing Concrete

Finishing Concrete

Curing Concrete

Do not drop the concrete more than 4 ft. Use a drop-chute with a 6-in.-diameter rubber or canvas hose to prevent segregation of aggregate.

Compact concrete as you place it by rodding, spading, or vibrating. This removes large air bubbles and prevents voids.

FINISHING CONCRETE

Strike off and bullfloat concrete as soon as it is placed, but wait for bleed water to evaporate before starting to trowel. Working concrete with water on the surface creates a weak layer and leads to dusting, crazing, and scaling. If concrete starts to set up before bleed water evaporates, sweep the bleed water off with a rubber hose or squeegee.

Edging is required to compact concrete near forms. Wait until bleed water evaporates to begin edging, but right after bullfloating, slip a mason's trowel down between the form and the concrete to cut the two apart in preparation for edging later.

Jointing. Joints can be made in the slab while it's still soft. The grooving tool must cut through the slab one-quarter its thickness to make the joint an effective control against shrinkage cracking (see Control Joints for Concrete Walls).

Floating drives aggregate just below the surface and removes surface imperfections. Floating should be done after edging and jointing, but before final troweling.

Troweling. Concrete is ready for hand-troweling when the weight of a worker makes a 1/4-in. heel-mark on the slab. For machine troweling (power-troweling), the concrete should be harder — a heel mark should be only 1/8-in.-deep.

Stripping forms. Allow concrete in forms to reach at least 500 psi compressive strength before stripping forms. This typically takes a day in mild weather, or three days in cold weather. Concrete suppliers can provide maturity curves that estimate the strength development of specific concrete mixes under specific field conditions — when in doubt, rely on the supplier's data.

CURING CONCRETE

Concrete hardens not by drying, but by hydration — a chemical reaction between cement and water. This reaction needs moisture and warmth. Curing is the technique of keeping the concrete moist and at the correct temperature (50°F to 90°F) for a period of at least three to seven days (the shorter period applies to concrete made with high-early-strength cement or with an accelerating admixture). If cured properly, concrete will be stronger, more abrasion-resistant, more durable, and less permeable.

Curing Problems

Drying out. If concrete dries out before curing is complete, hydration stops. Hardening will resume if the concrete becomes wet again, but in the field it is hard to resaturate concrete, so maintaining moisture for the maximum time is a better course.

Freezing. Concrete that freezes before reaching compressive strength of 500 psi may be ruined. If it freezes after reaching 500 psi, however, it will continue to harden when it warms up, as long as sufficient water is present. Again, maintaining good curing conditions for a few days is better than trying to reestablish them later.

Curing Concrete

Cold-Weather Concrete

Curing Conditions

Concrete is "comfortable" if people are comfortable. The best time to pour concrete work is when the weather is between 50°F and 70°F, humid, and not too sunny. In these conditions, little extra effort is required to cure concrete.

For walls in normal weather, leaving the forms in place will keep water trapped in the wall and allow curing to continue. The wall top should be kept wet with a soaker hose, or sealed with a spray-applied curing compound. If forms have to be stripped, spray the whole wall with curing compound or cover it with plastic sheeting (seal all seams and penetrations).

For slabs during mild weather, practical curing methods include ponding, sprinkling continuously, covering with plastic, covering with wet burlap, or sealing with a spray-applied curing compound. Each method has advantages and disadvantages (**Figure I**). Spraying on a curing compound has become the most popular method because the one-time step is quick, simple, and cheap; but the coatings may prevent the adhesion of tile or other floor coverings, and care must be taken to get full coverage.

FIGURE I: SLAB CURING TECHINQUES

Method	Advantages	Disadvantages	Comments
Cover with plastic sheeting	Low cost, easy to handle, effective, does not leave film on slab	May mottle slab surface; can be torn or disturbed	Use large pieces to minimize joints, seal carefully, inspect and maintain, save for reuse
Apply spray curing compound	Cheap, simple, does not require maintenance or monitoring	Coverage may be incomplete if not applied with carel film may prevent bonding of finish floor; may not work in cold weather	Select opaque disappearing brand to monitor coverage; consult with suppliers concerning floor bonding
Continuous sprinkling or cover with wet burlap	Highly effective if sprinkled continuously, or burlap kept wet is used	Requires monitoring; may create runoff	Use clean water, provide drainage, monitor and maintain
Ponding	Best results if maintained continuously for prescribed period	Complicated; required maintenance and monitoring; may cause runoff	May be practical for enclosed slabs (basements) and small areas

Special attention must be given to curing concrete slabs because their relatively large surface area gives up moisture and heat quickly. Proper curing keeps the moisture and temperature in the concrete as long as possible.

COLD-WEATHER CONCRETE

With concrete, cold weather refers to temperatures averaging lower than 40°F, or dropping below 50°F for more than half the day.

When placing concrete in cold weather, take these precautions:

Thaw forms and subgrade. Never place concrete on frozen ground or in icy or frosty forms. Ice and frost-swelled soil can fill the space meant to contain concrete, leaving future voids. Concrete may freeze instead of hardening, and could be damaged or weakened. Frost heave of soil after concrete is placed also may damage footings, walls, or slabs.

Cold-Weather Concrete

To thaw ground and forms, cover them with straw or blankets, or build a heated enclosure. Make sure exhaust from heaters goes outside the enclosure; otherwise workers may be poisoned from carbon monoxide. Carbon dioxide in exhaust can also damage concrete surfaces.

Adjust mix for rapid strength gain. Follow the supplier's recommendations for an appropriate mix for the placement and end-use weather conditions. To generate extra heat and speed up strength gain, options include adding extra cement to the mix, using Type III cement, or using an accelerating admixture (in very cold weather, all three strategies may be combined). General recommendations for cold-weather mixes and curing protection are shown in **Figure J**.

FIGURE J: COLD-WEATHER GUIDELINES FOR CONCRETE WALLS AND FOOTINGS

Type I Cement	Type III Cement
Predicted low temperature prior to concrete reaching 500-psi compressive strength:	Predicted low temperature prior to concrete reaching 500-ps compressive strength:
32°F to 20°F	**32°F to 20°F**
Min. 470 lb. cement/yd. (5-sack mix) Temperature of concrete: Min. of 60°F Max. 6-in. slump 1% Calcium Chloride or equivalent accelerator No protection required	Min. 470 lb. cement/yd. (5-sack mix) Temperature of concrete: Min. of 60°F Max. 6-in. slump No accelerator No protection required
19°F to 10°F	**19°F to 10°F**
Min. 517 lb. cement/yd. (5 1/2-sack mix) Temperature of concrete: Min. of 60°F Max. 6-in. slump 2% Calcium Chloride or equivalent accelerator No protection required	Min. 517 lb. cement/yd. (5 1/2-sack mix) Temperature of concrete: Min. of 60°F Max. 6-in. slump 1% Calcium Chloride or equivalent accelerator
9°F to 0°F	**9°F to 0°F**
Min. 564 lb. cement/yd. (6-sack mix) Temperature of concrete: Min. of 60°F Max. 6-in. slump 2% Calcium Chloride or equivalent accelerator Cover top of wall with 6-ft.-wide insulated blanket	Min. 564 lb. cement/yd. (6-sack mix) Temperature of concrete: Min. of 60°F Max. 6-in. slump 2% Calcium Chloride or equivalent accelerator No protection required
Below 0°F	**Below 0°F**
Min. 564 lb. cement/yd. (6-sack mix) Temperature of concrete: Min. of 60°F Max. 6-in. slump 2% Calcium Chloride or equivalent accelerator Cover entire wall with an insulated blanket or cover and provide auxiliary heat	Min. 564 lb. cement/yd. (6-sack mix) Temperature of concrete: Min. of 60°F Max. 6-in. slump 2% Calcium Chloride or equivalent accelerator Cover top of wall with 6-ft.-wide insulated blanket

For each type of cement used, follow these mix and protection guidelines to prevent freezing of plain, unreinforced concrete. Note: These recommendations are designed to prevent freezing damage to green concrete, but may not provide ideal curing conditions.

Check concrete temperature. Concrete coming down the chute should be at 60°F. Make your supplier aware of your expectations and be ready to reject loads that are cooler than 55°F.

Protect subgrade from freezing before and after pour. Even after concrete is cured, frost heaves in soil can crack structures. To prevent this, insulate slabs, footings, and walls, cap foundation quickly, backfill as soon as possible, and heat structure.

Cold-Weather Concrete

Cold-Weather Finishing

In cold weather, set times are delayed (**Figure K**) so schedule the pour early in the day. In cold temperatures (below 40°F), don't be surprised if finishing has to be done at night, long after regular quitting time. Bleed water may not evaporate; be ready to squeegee it off the slab. Slabs cool rapidly, so be ready to protect the slab with insulating blankets and straw as soon as finish troweling is complete.

FIGURE K: CONCRETE TEMPERATURE VS. SET TIME

Concrete Temperature (F°)	Set Time (hrs.)
70	6
60	8
50	11
40	14
30	19

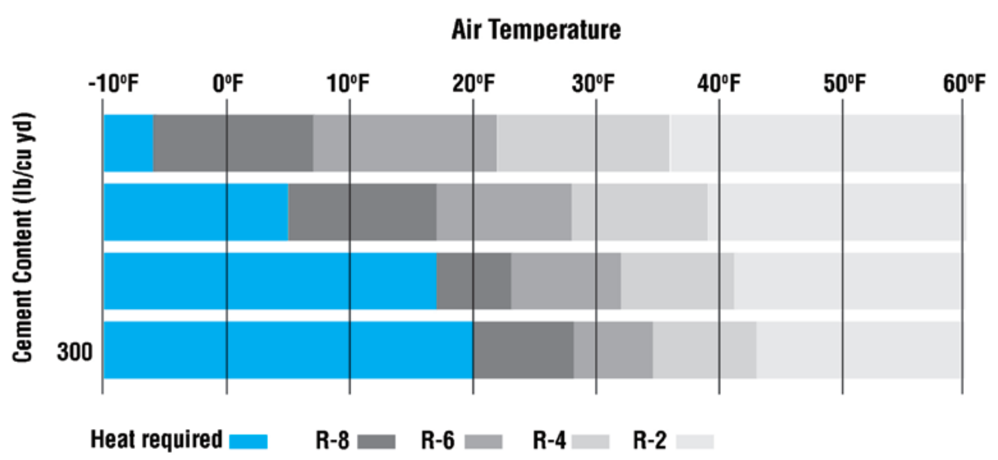
Set time (the time it takes for concrete to harden enough so that finishing can begin) increases by a third for every 10°F drop in concrete temperature.

Cold-Weather Curing

Ponding and sprinkling are impractical in freezing weather. Use curing compounds or plastic sheeting to hold moisture in fresh concrete. Provide enough insulation to keep concrete temperature above 50°F for at least three days (seven days is preferable). See **Figure L** for the insulation level needed to maintain adequate warmth and **Figure M** for insulation materials to meet R-value requirements.

After curing, exposed slabs need to dry thoroughly before they can withstand winter freezing. For that reason, pouring slabs in late fall is risky in colder regions.

FIGURE L: INSULATION REQUIRED TO KEEP CONCRETE AT 55 ° F



A temperature drop greater than 50°F over 24 hours risks thermal shrinkage cracking. Insulation thrown over poured concrete, however, will trap the heat of hydration and allow the concrete to cool slowly. As outside air temperature drops, it may become harder to keep concrete at the correct temperature using insulation alone. Below a certain point for any given mix, provide a heated enclosure to prevent damage to the concrete from freezing.

Cold-Weather Concrete

Hot-Weather Concrete

FIGURE M: R-VALUES OF COMMON MATERIAL

Material	R-Value
1/2-in. plywood	0.5
1-in. straw	2.0
1-in. mineral fiber blanket	3.0
1-in. expanded polyurethane	6.0

HOT-WEATHER CONCRETE

Rapid evaporation causes most of the hot-weather problems for concrete. If sweat is evaporating quickly off workers, chances are that moisture is evaporating quickly from the concrete as well. Take these precautions:

- **Wet forms and subgrade.** Use a spray hose or sprinkler to dampen work area before beginning. Soak area well, but do not create standing water. Soaking the subgrade the night before the pour may be most practical.
- **Chill the mix.** You can order concrete made with chilled water or even shaved ice. Some suppliers can refrigerate their aggregate also. Concrete should not be hotter than 60°F coming off the truck.
- **Provide shade and wind protection.** Sun screens, movable awnings, and wind barriers can reduce evaporation rates.
- **Fog the work.** Rent a fogging sprayer to elevate the humidity around the slab.
- **Retemper with care.** It's okay to replace water lost to evaporation, but not to add water to a partially hy-drated load. In practice, add no more than a gallon or two per yard. Add this at the beginning, not midway through the load.
- **Adjust schedule.** Start work at sunup and finish before noon, or work in late evening.
- **Adjust manpower.** Have extra help ready to place and finish concrete quickly. If your normal crew is four people, add a fifth or sixth person.
- **Schedule work in stages.** Don't pour too far ahead of yourself — place small sections of slab that you can finish with the available labor.

Hot-Weather Finishing

Start to trowel as soon as bleed water has evaporated. Do not trowel water back into slab or sprinkle water onto slab (this causes crazing and flaking). However, if concrete begins to harden before water has evaporated, drag the water off with a hose or squeegee.

Hot-Weather Curing

For walls, apply curing compound to wall top right away, and to wall sides as soon as forms are stripped, or cover completely with plastic. Seal all plastic seams and penetrations, and ensure complete coverage with curing compound.

For slabs, start curing (cover with plastic or ponded water, spray on curing compound, or begin sprinkling) as soon as troweling is complete. Concrete must not be allowed to dry out.

Do not cover with black plastic, which absorbs solar heat and can cause too-rapid hydration or drying. Clear plastic is better, and reflective white plastic is best.

REBAR SIZES

Rebar comes in a range of diameters, numbered 3 through 11. The numbers denote the diameter of the bar in 1/8-in. increments. Thus, #3 bar is 3/8 in. in diameter, #4 bar is 4/8 (or 1/2) in., #5 bar is 5/8 in., and so on. The size most commonly used in residential construction is #4, though #5 and #6 bar are used often in hillside construction and tall concrete walls in seismic zones. Walkways, pool decks, steps, and simple landings often use #3 bar.

REBAR GRADES

Rebar is graded in primary classifications, commonly known as grade 40 and grade 60. Grade 40 is more malleable and easier to bend. Grade 60 is stiffer and does not bend as easily. Typically, Grade 40 is found in #3 and #4 bar, and Grade 60 in #5 and larger.

SIZING AND SPACING IN WALLS

Figure N shows proper reinforcement size and spacing for standard 8-in.-thick concrete and masonry walls at various heights. "Standard" construction implies work on well-drained sites with stable soils and the use of granular backfills and perimeter drains.

Sizing and Spacing in Walls

FIGURE N: FOUNDATION WALL REINFORCEMENTS FOR WELL-DRAINED SITES (8-IN. WALL THICKNESS)

Maximum Wall Height (ft.)	Maximum Unbalanced Backfill Height [5] (ft.)	Minimum Vertical Reinforcement Size and Spacing[1][2] for 8-in. Nominal Wall Thickness[3] — Soil Classes[4]: GW, GP, SW and SP soils	GM, GC, SM, SM-SC and ML soils	SC, MH, ML-CL and inorganic CL soils
6	5	#4 at 48" o.c.	#4 at 48" o.c.	#4 at 48" o.c.
	6	#4 at 48" o.c.	#4 at 40" o.c.	#5 at 48" o.c.
7	4	#4 at 48" o.c.	#4 at 48" o.c.	#4 at 48" o.c.
	5	#4 at 48" o.c.	#4 at 48" o.c.	#4 at 40" o.c.
	6	#4 at 48" o.c.	#5 at 48" o.c.	#5 at 40" o.c.
	7	#4 at 40" o.c.	#5 at 40" o.c.	#6 at 48" o.c.
8	5	#4 at 48" o.c.	#4 at 48" o.c.	#4 at 40" o.c.
	6	#4 at 48" o.c.	#5 at 48" o.c.	#5 at 40" o.c.
	7	#5 at 48" o.c.	#6 at 48" o.c.	#6 at 40" o.c.
	8	#5 at 40" o.c.	#6 at 40" o.c.	#6 at 24" o.c.
9	5	#4 at 48" o.c.	#4 at 48" o.c.	#5 at 48" o.c.
	6	#4 at 48" o.c.	#5 at 48" o.c.	#6 at 48" o.c.
	7	#5 at 48" o.c.	#6 at 48" o.c.	#6 at 32" o.c.
	8	#5 at 40" o.c.	#6 at 32" o.c.	#6 at 24" o.c.
	9	#6 at 40" o.c.	#6 at 24" o.c.	#6 at 16" o.c.

(1) Alternative reinforcing bar sizes and spacings having an equivalent cross-sectional area of reinforcement per lineal foot of wall are permitted by code, provided the spacing of the reinforcement does not exceed 72 in.

(2) Use minimum Grade 60 rebar. The distance from the face of the soil side of the wall to the center of vertical reinforcement must be at least 5 in.

(3) For masonry walls, use Type M or S mortar and lay masonry in a running bond. See Concrete Block.

(4) Soil classes refer to symbols explained in **Figure: Properties of Soils According to the Unified Soil Classification System** in Soil Types.

(5) Unbalanced backfill height is the difference in height of the exterior and interior finish ground levels. Where an interior concrete slab is provided, the unbalanced backfill height is measured from the exterior finish ground level to the top of the interior concrete slab.

Reinforcement for Seismic Forces

In seismic zones, code requires extra reinforcement. For foundations supporting more than 4 ft. of unbalanced fill, follow the schedules shown in **Figure O** and **Figure P**. For best results, err on the side of placing more rebar, and always backfill the foundation with a free-draining granular soil to reduce lateral forces (see **Backfill**).

Sizing and Spacing in Walls

FIGURE O: FOUNDATION WALL REINFORCEMENT FOR SEISMIC ZONES (12-IN. WALL THICKNESS)

Maximum Wall Height (ft.)	Maximum Unbalanced Backfill Height [5] (ft.)	Minimum Vertical Reinforcement Size and Spacing[1][2] for 12-in. Nominal Wall Thickness[3]		
		Soil Classes[4]		
		GW, GP, SW and SP soils	GM, GC, SM, SM-SC and ML soils	SC, MH, ML-CL and inorganic CL soils
7	4	#4 at 72" o.c.	#4 at 72" o.c.	#4 at 72" o.c.
	5	#4 at 72" o.c.	#4 at 72" o.c.	#4 at 72" o.c.
	6	#4 at 72" o.c.	#4 at 64" o.c.	#4 at 48" o.c.
	7	#4 at 72" o.c.	#4 at 48" o.c.	#5 at 56" o.c.
8	5	#4 at 72" o.c.	#4 at 72" o.c.	#4 at 72" o.c.
	6	#4 at 72" o.c.	#4 at 56" o.c.	#5 at 72" o.c.
	7	#4 at 64" o.c.	#5 at 64" o.c.	#4 at 32" o.c.
	8	#4 at 48" o.c.	#4 at 32" o.c.	#5 at 40" o.c.
9	5	#4 at 72" o.c.	#4 at 72" o.c.	#4 at 72" o.c.
	6	#4 at 72" o.c.	#4 at 56" o.c.	#5 at 64" o.c.
	7	#4 at 56" o.c.	#4 at 40" o.c.	#6 at 64" o.c.
	8	#4 at 64" o.c.	#6 at 64" o.c.	#6 at 48" o.c.
	9	#5 at 56" o.c.	#7 at 72" o.c.	#6 at 40" o.c.

(1) Alternative reinforcing bar sizes and spacings having an equivalent cross-sectional area of reinforcement per lineal foot of wall are permitted by code, provided the spacing of the reinforcement does not exceed 72 in.

(2) Use minimum Grade 60 rebar. The distance from the face of the soil side of the wall to the center of vertical reinforcement must be at least 8.75 in.

(3) For masonry walls, use Type M or S mortar and lay masonry in a running bond. See Concrete Block.

(4) Soil classes refer to symbols explained in **Figure: Properties of Soils According to the Unified Soil Classification System** in Soil Types.

(5) Unbalanced backfill height is the difference in height of the exterior and interior finish ground levels. Where an interior concrete slab is provided, the unbalanced backfill height is measured from the exterior finish ground level to the top of the interior concrete slab.

Sizing and Spacing in Walls

Placing Foundation Rebar

FIGURE P: FOUNDATION WALL THICKNESS FOR SEISMIC ZONES (10-IN. WALL THICKNESS)

Maximum Wall Height (ft.)	Maximum Unbalanced Backfill Height [5] (ft.)	Minimum Vertical Reinforcement Size and Spacing[1][2] for 10-in. Nominal Wall Thickness[3] — Soil Classes[4]: GW, GP, SW and SP soils	GM, GC, SM, SM-SC and ML soils	SC, MH, ML-CL and inorganic CL soils
7	4	#4 at 56" o.c.	#4 at 56" o.c.	#4 at 56" o.c.
	5	#4 at 56" o.c.	#4 at 56" o.c.	#4 at 56" o.c.
	6	#4 at 56" o.c.	#4 at 48" o.c.	#4 at 40" o.c.
	7	#4 at 56" o.c.	#5 at 56" o.c.	#5 at 40" o.c.
8	5	#4 at 56" o.c.	#4 at 56" o.c.	#4 at 48" o.c.
	6	#4 at 56" o.c.	#4 at 48" o.c.	#5 at 56" o.c.
	7	#4 at 48" o.c.	#4 at 32" o.c.	#6 at 56" o.c.
	8	#5 at 56" o.c.	#5 at 40" o.c.	#7 at 56" o.c.
9	5	#4 at 56" o.c.	#4 at 56" o.c.	#4 at 48" o.c.
	6	#4 at 56" o.c.	#4 at 40" o.c.	#4 at 32" o.c.
	7	#4 at 56" o.c.	#5 at 48" o.c.	#6 at 48" o.c.
	8	#4 at 32" o.c.	#6 at 48" o.c.	#4 at 16" o.c.
	9	#5 at 40" o.c.	#6 at 40" o.c.	#7 at 40" o.c.

(1) Alternative reinforcing bar sizes and spacings having an equivalent cross-sectional area of reinforcement per lineal foot of wall are permitted by code, provided the spacing of the reinforcement does not exceed 72 in.

(2) Use minimum Grade 60 rebar. The distance from the face of the soil side of the wall to the center of vertical reinforcement must be at least 6.75 in.

(3) For masonry walls, use Type M or S mortar and lay masonry in a running bond. See Concrete Block.

(4) Soil classes refer to symbols explained in **Figure: Properties of Soils According to the Unified Soil Classification System** in Soil Types.

(5) Unbalanced backfill height is the difference in height of the exterior and interior finish ground levels. Where an interior concrete slab is provided, the unbalanced backfill height is measured from the exterior finish ground level to the top of the interior concrete slab.

Reinforcement for Wet Sites

On sites with high seasonal water tables that will exert increased hydrostatic pressure on foundations, all codes require engineering.

PLACING FOUNDATION REBAR

Rebar should always be placed near the tension side of the concrete.

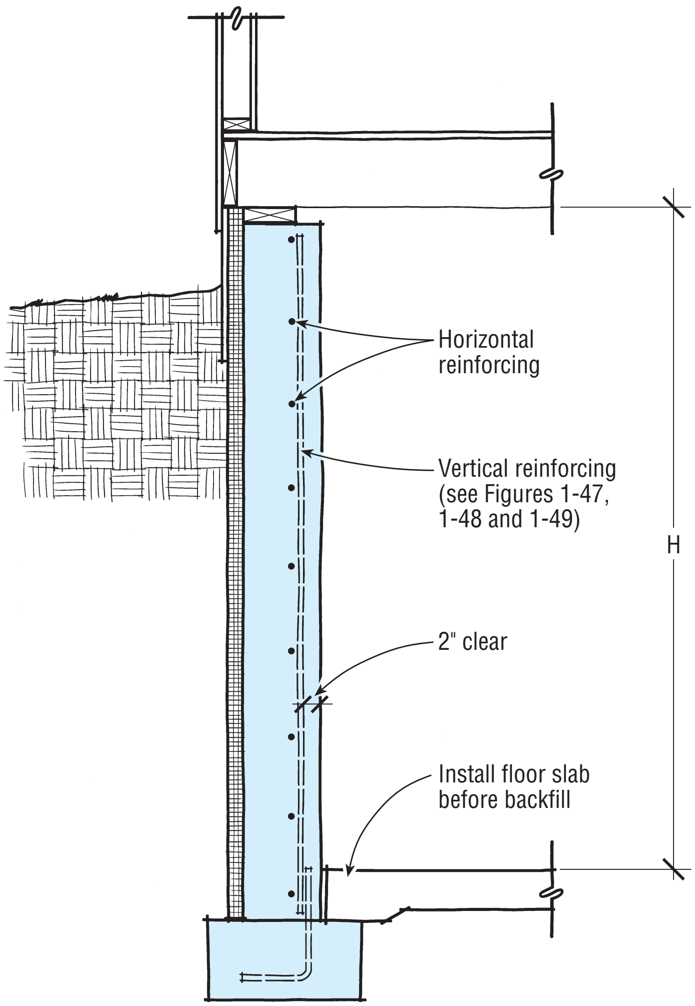
In a full-height foundation wall, which is held in place by floor framing at the top and by the footing at the bottom, the tension side is toward the inside (**Figure Q**, below, and **Figure: Reinforcing Block Walls** in Reinforcing Block Walls).

Placing Foundation Rebar

In a free-standing retaining wall or a half-height foundation wall, the tension would be on the side nearest the ground load (see Stepped Foundation Walls).

Horizontal rebar is most effective along the top and bottom of the foundation elevation.

FIGURE Q: REBAR FOR POURED FOUNDATION WALLS



Place rebar towards the tension side of a concrete foundation wall that is pinned in place by floor framing and a basement slab. If the concrete wall is thicker than 10 in., a second layer of reinforcing, placed near the outside face, is recommended.

Concrete Coverage Over Rebar

To prevent corrosion, rebar must be covered with concrete:

- In pads and footings: 3-in. minimum coverage
- In walls and slabs, #6 or larger requires 2-in. minimum coverage; #5 or smaller needs 11/2-in. minimum coverage

Splicing Rebar

Tie all rebar with wire at splices. Overlap splices by 24 bar diameters (12-in. overlap for #4 bar, 15-in. overlapfor #5 bar, 18-in. overlap for #6 bar), or as specified by an engineer.