

# Concrete

# Solutions®

## Editor's Note

*We are pleased to send you a copy of our newsletter Concrete Solutions (which is a trademarked product of CalPortland Company). Concrete Solutions has been in circulation since 1994 in Washington and Oregon and is now being distributed throughout the entire CalPortland network in the Western U.S. and Canada. Concrete Solutions is intended to be a useful tool for the promotion of concrete as a preferred construction material. We encourage feedback therefore contact information can be found on page 3 of this newsletter. Concrete Solutions can also be downloaded on our website at [www.calportland.com](http://www.calportland.com)*

## Good Vibrations

There is nothing like a classic Beach Boys song to introduce this segment on the proper use of vibrators to consolidate concrete. While entrained air consists of microscopically small bubbles, entrapped air usually occupies about two percent of concrete volume. On your concrete project, entrapped air can be responsible for bugholes, voids, and poor encapsulation of the rebar. Poor consolidation can lead to reinforcement corrosion from increased chemical attack because of lower concrete density; this can lead to reduced service life of the structure; these problems can lead to increased costs, call backs, and a less than durable structure.

Proper vibration removes entrapped air and consolidates the mix, densifying it and insuring encapsulation of reinforcing steel and imbedded items. With proper vibration, compressive strength can increase, and cold joints and pour lines can be minimized, while segregation, voids and honeycombing are all decreased. Vibration can be used on flatwork, as well as vertical elements. Many contractors put the job of operating vibration equipment in the hands of the least experienced laborers. In reality, vibrating concrete should be done by finishers that are trained to get the proper results without incurring damage. Over vibration can result in a loss of entrained air, lowering freeze thaw durability. It can also lead to increased segregation, forms blowing out or bowing, discolorations, and numerous other unintended results.

### **Concrete Consolidation and Removal of Entrapped Air:**

To properly consolidate concrete takes a lot of work. Rodding it into forms and compacting concrete by hand requires energy that can be supplied by a vibrator. Vibrators can transfer a large amount of energy into the concrete very quickly. The energy a vibrator produces depends on the vibrator's frequency. A vibrator in fresh concrete alternately compresses and decompresses the surrounding concrete, with all the air bubbles contracting and expanding at the frequency of the vibrator. Fragile, elastic structures like air bubbles explode when they're forced to expand and contract at what is known as their resonant or natural frequency; and the larger the bubble, the lower its natural frequency. Similar to when concrete is placed by

pumping, larger bubbles are more likely to be lost during vibration.

### **Getting those Good Vibrations:**

Vibrator types vary from those mounted directly on forms, or permanent vibrators on slipform pavers and curb machines, to the most common hand-held immersion vibrators. Selecting the right method or the right vibrator depends on project requirements: what you are pouring, the rebar spacing, and if you can even get access with a hand held vibrator. The frequency that the vibrator is set at can have a big impact upon the effectiveness as well as the hardened air content. There have been cases where a paver mounted vibrator operating at too high a frequency caused the paste content to increase around the localized area of the vibrator. The surface then has longitudinal bands, or a visible "trail" where the pavement has reduced coarse aggregate due to excessive vibration.

Be sure to have a spare vibrator on the jobsite. With no spare, a failure or one stuck in a rebar cage can spell trouble. Watch the concrete to determine the vibrator's field of action. A big vibrator in a higher slump concrete will have a large field of action. The rule of thumb is that the field of action is 8 times the vibrator's head diameter. When vibrating a wall with a handheld vibrator, hold the vibrator vertically, being sure to penetrate the prior lift of concrete at least six inches. The vibrator should be run to start about 10 seconds and then removed steadily at a rate of about 15 seconds for a four foot lift or about 3 or 4 inches per second. The key is not to remove it faster than the entrapped air can escape. Space the insertions so the fields of action overlap. Look for the various

signs that indicate you are done vibrating. These include when the concrete surface takes sheen and you see that large air bubbles no longer escape. You may also hear the vibrator change pitch or tone and you feel a change in vibrator action.

### **Bye, Bye Bug Holes:**

As more specifiers use structural concrete elements in finished construction, surface quality becomes critical. Bug holes can be minimized by a careful selection of materials and quality workmanship that includes good consolidation. One of the most influential causes of bug holes is improper vibration. Mix design can also be considered a significant contributor to bug hole formation. Mix designs vary widely in their use of aggregate type, size, and grading and their use of admixtures and air-entrainment. A sticky or stiff mixture that does not respond to consolidation can be directly linked to increased surface void formation. For many projects, a superplasticized mix may go a long way towards minimizing vibration requirements. Mixes placed at an eight inch slump require 50% of the vibration that a mix placed at a four inch slump would require. This reduces the risk of over vibration having negative effect on the entrained air void structure. Primarily in the precast industry, self-consolidating concrete (SCC) is becoming increasingly popular to improve surface quality.

Overall, the best defense against bug holes is a good offense. On critical projects a series of mock ups can identify the best mixes, form releases and vibrator settings, frequencies, and techniques that will be required to produce the desired finish.

### **Vibrating Concrete in ICF Walls:**

Being made up of polystyrene, walls built with insulating concrete forms are not quite as robust as conventional wall forms, so contractors were afraid to use vibrators. In the early days of ICF construction, walls were vibrated by pounding on the outside of the forms, or using a reciprocating saw or orbital sander.

Because ICF walls are not stripped, issues with improper consolidation could go undetected, leading to structural problems; in some cases, poor consolidation required structures to be torn down and rebuilt. Eventually, the Portland Cement Association (PCA) did a study on the effectiveness of these "external" vibration techniques. They found that many contractors simply were trying to place concrete too dry and external vibration was substandard, scoring slightly better with mixes placed at a higher slump, but not nearly as well as when vibrated. The bottom line was: "Internal vibration was found to provide adequate consolidation for concrete with a slump of 6 inches or greater."

ICF walls are not mass concrete so proper size and vibrator frequency is important. Our ICF technical staff recommends the use of a pencil head (3/4 inch) with a high frequency for six and eight inch ICF forms. We generally place ICF mixes at a six to seven inch slump, and the pencil head has a good area of influence with a mix that flows. We also use a fourteen foot "whip", or flex shaft, so we can reach down in taller walls. With ICFs, the areas that need the most strength, such as lintels and corners, will carry the most rebar, and need the most vibration, and hence, the most bracing. Since ICF forms vary considerably, check with the manufacturer for vibration and consolidation recommendations.

### **Vibration, Consolidation, Success:**

When architects and engineers design concrete structures, not only are they counting on the ready mix producer to supply mixes that meet strength specifications, but many times, they assume those mixes will have adequate rheology and workability. They are also depending on the contractor to properly place and cure these mixes. A large part of placement involves consolidation, and proper vibration techniques are essential. By following the guidelines regarding vibration, contractors can achieve the dense consolidation they need to encapsulate the rebar for

structural soundness and produce quality surfaces that show up when the forms are removed.

## **Catching Air ...**

Concrete that will be exposed to freeze thaw conditions needs to be air entrained. Air does not prevent concrete from freezing, but protects it from the effects of freezing. When the temperature drops below freezing, the water turns to ice. Ice occupies 9 percent more volume than water. The expanding ice forces the water through the capillaries as it freezes. Properly entrained air creates many tiny voids in the concrete, providing a place for internal pressure to be relieved when frost expands water particles. This improves durability by reducing stresses associated with freezing water particles in pores. Without air, exterior flatwork spalls from frost damage within the cement paste. Not developed until the 1930's, air entrainment could be characterized as one of the great advances in concrete technology. Although air is measured while concrete is in the plastic state, it can also be measured after the concrete has hardened.

### **Tiny Bubbles:**

Entrained air consists of microscopically small bubbles, uniformly distributed throughout the concrete mix, having diameters greater than 10 micrometers (0.0004 in.) and less than 1 mm (0.04 in.). The uniform spacing of the bubbles reduces the distance water would have to travel before entering an air void, thereby reducing the pressure from frost, increasing durability. Once the concrete has set, the casts of the original air bubbles are left behind in the hardened concrete as voids. This is commonly referred to as the "air-void system" in hardened concrete. Although air-entrained concrete can be

produced through the use of air-entraining cement, the most common method to add air is by dosing air-entraining admixtures when the concrete is batched at the plant. Air-entraining agents stabilize air bubbles in concrete by reducing the surface tension at the air-water interface. The shearing action of the mixer and aggregates divides air into fine bubbles surrounded by a stabilizing agent. It is critical that sufficient mixing time be allowed for the air bubbles to be generated and stabilized. This is another reason for the minimum revolutions to be put on a mix before it leaves the plant. Trial batches or prior experience with the mix and job equipment is necessary to determine the proper dosage and minimum mixing time. The amount of entrained air is usually between 5 percent and 8 percent of the volume of the concrete, but may be varied as required by special conditions. When tested, even non-air entrained concrete will show about two percent air. This is not entrained air, but entrapped air. Entrapped air is not micro air that is well distributed through the mix, but consists of larger air voids, the type that is removed by proper vibration at placement.

### Sampling and Testing for Air:

The sample size for air content testing of fresh concrete should be a minimum of a cubic foot. The sample should not be taken from the very first or last portion of the load. To keep consistency on larger pours, air should be sampled every one hundred yards or at least once per day. The common method of measuring air content in fresh concrete is the pressure method, using an air pot. This method is based on the principle that the only significantly compressible ingredient of fresh concrete is the air. Pressure meters should not be used for concrete made with lightweight aggregates or aggregates of high porosity. In these instances the volumetric air meter should be used. The volumetric method for determination of air content relies on simple displacement of air with water in a vessel of pre-calibrated volume.

### The Right Percentage of Air:

Specifications often stipulate air entrainment, but since it is impossible to measure entrained air separately from the entrapped air in freshly mixed concrete, a total air content percentage is usually specified. Hitting the right percentage of air can be tricky business. Since the surface tension of bubbles is affected by everything from the type of admixture to chemical variations in the aggregate to how each truck mixer works, there is no way to hit an exact percentage every time. Although the normal industry standard is six percent air content, most specifications carry a leeway of plus or minus one to one and a half percent. If the truck arrives at the jobsite and the percentage of air is low, what do you do? Usually on tested jobs, QC can add air on site, so the load meets specifications. If the air is a little high, putting mixing revolutions on the truck can sometimes lower the air content. Too much air is an impediment to concrete strength. Since the use of air entrainment in high-strength concrete reduces the compressive strength by about 5 percent or about 500 psi for each one percent increase in air content, it is desirable to minimize the air content to maximize strength. The loss in strength is offset by the benefits entrained air provides. Beyond freeze-thaw protection, these include: saturated and improved salt scaling resistance, increased workability, reduced water demand, decreased segregation and bleeding, and reduced permeability and increased resistance to sulfate attack. The influence of air entrainment on the workability may be explained by the entrained air bubbles acting as particles, over which the aggregate can slide.

### Issues with Air:

If you are using color hardeners and dry shake colors you should cut the air back to four percent, because you can experience blistering at six percent air; this is caused when the color hardeners are finished into the surface where air can be trapped. You also need to be careful with carbon black, or lamp black, (Davis Color #8084) color. Carbon black is not compatible with most air-

entraining admixtures. Black iron oxide (Davis Color # 860) is what you must use with air entrained concrete. In mixtures containing fly ashes, the amount of air-entraining agent required to produce a given percentage of entrained air is higher. Temperature can also have a significant effect on air entrainment. Air entrainment varies inversely with temperature. The same mix will entrain more air at 50° F than at 100°F. It is important to check the air content of fresh concrete regularly for control purposes. Air content should be tested not only at the mixer but also at the point of discharge into the forms, because of losses of air content due to handling and placement. When placing concrete by pump, bucket, or conveyor, air will be lost.

### Air: A Significant Part of Durability:

Durable, freeze resistant concrete is the goal. Properly entrained air is part of the way to get there. Understanding what is going on with air contents and why you need them is the first step towards success with air entrained concrete mixes. As a ready mix producer, it is our goal to provide this built in air void system, while maximizing the strength of your mixes. Despite the hundred of variables that affect air contents, we are constantly monitoring this aspect of concrete to continue to provide you with the quality you expect.

## Concrete Solutions®

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**NEIL'S TIPS**

**Protect Air Content When Finishing Air Entrained Concrete**

Since air entrainment is specified in exterior concrete that is exposed to freeze thaw cycles, it is usually finished with a bull float and freso and given a broom finish. Broom finishes give exterior flatwork the best slip resistance and avoid serious problems which can happen when air entrained concrete is finished with a hard trowel.

Hard troweling air entrained concrete can have a number of negative effects. First off, the repeated passes of the steel trowels result in a burnished finish, which indicates densification of the surface paste. This can be a good thing in an

interior warehouse slab that will take heavy traffic. In exterior flatwork however, the densified surface has had the air pushed out of it, effectively eliminating the air content, thus increasing the probability of freeze-thaw damage and deicer-scaling damage. Second, hard troweling air entrained concrete can push the air downward, leading to voids just below the surface mortar. This can result in varying degrees of delamination, where segments of the top surface "pop off" or may even delaminate in entire sections. Without air in the surface paste, both scaling and delaminations can cause loss of the surface mortar, opening up the concrete to the very elements that air entrainment is designed to protect against.

In special situations such as a freezer slab, where a hard trowel finish is required in a freeze thaw environment, our recommendation is

to specify a non-air mix with the largest rock size possible, higher cement contents with fly ash, and a Shrinkage Reducing Admixture to minimize cracking. The use of a low w/c ratio mix will minimize the water that can cause freeze damage. To assure this water is used in the hydration process, be sure to properly cure these slabs for 28 days (if practical) prior to taking them below freezing. For the most part, freezer slabs tend to undergo only a few cycles per year, and it has been our experience following these guidelines presents fewer problems than putting a hard trowel finish on an air-entrained mix. If a hard trowel finish is specified for a freezer floor that will endure numerous cycles, our Caltite admixture negates the need for air entrainment entirely, solving this problem.

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**TONY'S TIPS**

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Hard troweling air entrained concrete can have a number of negative effects. First off, the repeated passes of the steel trowels result in a burnished finish, which indicates densification of the surface paste. This can be a good thing in an

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to specify a non-air mix with the largest rock size possible, higher cement contents with fly ash, and a Shrinkage Reducing Admixture to minimize cracking. The use of a low w/c ratio mix will minimize the water that can cause freeze damage. To assure this water is used in the hydration process, be sure to properly cure these slabs for 28 days (if practical) prior to taking them below freezing. For the most part, freezer slabs tend to undergo only a few cycles per year, and it has been our experience following these guidelines presents fewer problems than putting a hard trowel finish on an air-entrained mix. If a hard trowel finish is specified for a freezer floor that will endure numerous cycles, our Caltite admixture negates the need for air entrainment entirely, solving this problem.

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**TOM'S TIPS**

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Since air entrainment is specified in exterior concrete that is exposed to freeze thaw cycles, it is usually finished with a bull float and fresno and given a broom finish. Broom finishes give exterior flatwork the best slip resistance and avoid serious problems which can happen when air entrained concrete is finished with a hard trowel.

Hard troweling air entrained concrete can have a number of negative effects. First off, the repeated passes of the steel trowels result in a burnished finish, which indicates densification of the surface paste. This can be a good thing in an

interior warehouse slab that will take heavy traffic. In exterior flatwork however, the densified surface has had the air pushed out of it, effectively eliminating the air content, thus increasing the probability of freeze-thaw damage and deicer-scaling damage. Second, hard troweling air entrained concrete can push the air downward, leading to voids just below the surface mortar. This can result in varying degrees of delamination, where segments of the top surface "pop off" or may even delaminate in entire sections. Without air in the surface paste, both scaling and delaminations can cause loss of the surface mortar, opening up the concrete to the very elements that air entrainment is designed to protect against.

In special situations such as a freezer slab, where a hard trowel finish is required in a freeze thaw environment, our recommendation is

to specify a non-air mix with the largest rock size possible, higher cement contents with fly ash, and a Shrinkage Reducing Admixture to minimize cracking. The use of a low w/c ratio mix will minimize the water that can cause freeze damage. To assure this water is used in the hydration process, be sure to properly cure these slabs for 28 days (if practical) prior to taking them below freezing. For the most part, freezer slabs tend to undergo only a few cycles per year, and it has been our experience following these guidelines presents fewer problems than putting a hard trowel finish on an air-entrained mix. If a hard trowel finish is specified for a freezer floor that will endure numerous cycles, our Caltite admixture negates the need for air entrainment entirely, solving this problem.

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