CONCRETE VIBRATOR HANDBOOK

Concrete consolidation theory

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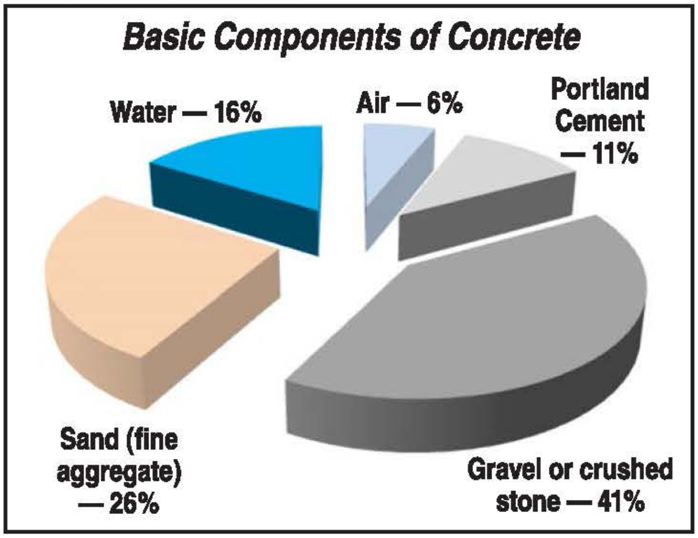
Concrete — A Trusted Material

Concrete is one of the world's most trusted building materials with a seemingly endless list of architectural and structural applications.

What is Concrete?



This is just one possible mix design. Beyond these basic components, other additives may be used.

Additives

Additives and other admixtures are often used to meet environmental and engineering requirements including:

- **Fly ash***
- **Accelerators**
- **Retardants**
- **Shake-on toppings and spray-on cures**

*Fly ash is a by-product of coal-fired electric generating plants. It improves the performance and quality of concrete. Fly ash affects the plastic properties of concrete by improving workability, reducing water demand, reducing segregation and bleeding, and lowering heat of hydration. Fly ash increases strength, reduces permeability, reduces corrosion of reinforcing steel, increases sulphate resistance, and reduces alkali-aggregate reaction. Fly ash reaches its maximum strength more slowly than concrete made with only Portland cement. The techniques for working with this type of concrete are standard for the industry.

Understanding Concrete Hydration

When cement is mixed with water a reaction occurs known as *hydration.*

Hydration converts the water-cement and aggregate suspension into a rigid porous material.

The nominal point of hydration at which this conversion occurs is called the *set point.*

The mass of water to cement in a given mixture is specified by the water to cement ratio (w/c).

- Ordinary concrete used in buildings uses cement paste with w/c 0.5.
- Newer high performance concretes often have w/c ratios of 0.3 or lower.

During the curing process the water is "consumed" through evaporation and chemical reaction. If evaporation is not controlled, defective concrete is created.

What happens when concrete reacts with water?

The various chemical and mineral phases within the cement powder hydrate at different rates, depending on their size and composition. They interact with one another to form various reaction products. Some products deposit on the remaining cement particle surfaces (surface products) while others form as crystals in the water-filled pore space between cement particles (pore products).

For simplicity, cement paste can be thought of as consisting of phases:

1) **Unreacted cement**
2) **Calcium-Silicate-Hydrate** (C-S-H)
3) **Pore products** (like CH = calcium hydroxide)
4) **Capillary pore space**

Calcium silicate hydrate (or C-S-H) is the main product of the hydration of Portland cement and is primarily responsible for the strength in cement based materials.

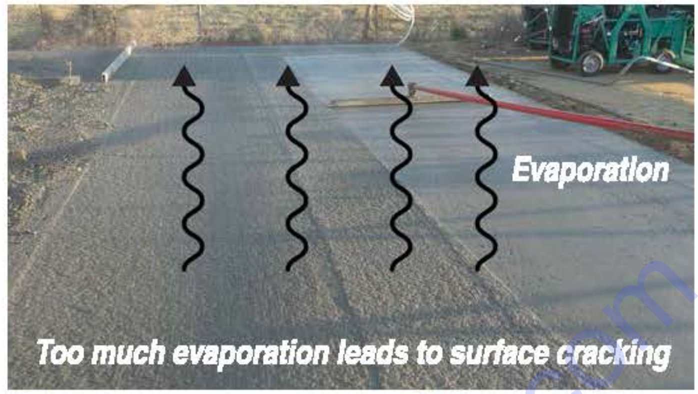
Understanding Water Vapor Transmission

- Microscopic capillary pores fill with water as concrete is being poured and placed.
- As concrete hardens, hydration consumes some of this water and surface moisture evaporates naturally via the sun and wind.
- After the capillaries dry out, water vapor will continue to diffuse from the soil through the concrete floor which is an open "sponge" for water vapor.
- Installing a **vapor barrier** prevents diffusion of moisture from the soil below through the concrete.
- Plastic sheeting is commonly used as an impermeable vapor barrier to prevent moisture in the soil from migrating through the concrete.

Evaporation Control in Concrete

Concrete floors appear dry, hard, and water tight. In reality, they more closely resemble a solid, hard sponge.

- **Water vapor transmission** occurs as water rises through pores in the concrete floor by capillary action.
- Moisture in the concrete and sub-base rises as water vapor through a process called **diffusion.**
- Too much evaporation leads to surface cracking.



Tensile Strength

Tensile strength is used to estimate the load under which cracking will develop. This is due to its influence on the formation of cracks and its propagation to the tension side of reinforced concrete flexural member. This strength is of interest in designing of highway and airfield slabs as shear strength and resistance to cracking are critical.

The tensile strength of concrete is relatively low, about 10 to 15% of the compressive and could reach 20%. ASTM C1583 is the most common test established to test. Sample cores are extracted and tested by qualified labs using calibrated equipment as shown here. There are many factors that can influence the tensile strength of concrete, so test labs are furnished with the specified mix design and tests are conducted to confirm the intended strengths are achieved.

Compression Strength

The main measure of the structural quality of concrete is its compressive strength. Depending on the mix (especially the water-cement ratio) time and quality of the curing, compressive strength of concrete can be obtained up to 14,000 psi or more. Commercial production of concrete with ordinary aggregate is usually in the 3,000 to 12,000 psi range with the most common ranges for cast-in-place buildings from 3,000 to 6,000 psi. On the other hand, precast and pre-stressed applications often expect strengths of 4,000-8,000 psi.

Tests for this property are made on cylindrical specimens of height equal to twice the diameter, usually 6x12 in. Impervious molds of this shape

are filled with concrete during the operation of placement as specified by ASTM C172, "Standard Method of Sampling Fresh Concrete", and ASTM C31 "Standard Method for Making and Curing Concrete Test Specimens in The Field". The cylinders are moist-cured at about 70 degree F, generally for 28 days, and then tested in the laboratory at a specified rate of loading. The compressive strength obtained from such tests is known as the cylinder strength fc' and this term is used in design purposes.

Abrasion Resistance

Concrete abrasion resistance is markedly influenced by a number of factors including concrete strength, aggregate properties, surface finishing, and type of hardeners. A broom finish offers more skid resistance, however it will demonstrate wear much quicker than a steel troweled finish.

A large number of studies have indicated that concrete abrasion resistance is primarily dependent upon compressive strength of the concrete. Wear and tear on an industrial concrete floor's surface can have serious implications for the efficiency of the building. An uneven surface will make it more challenging for materials handling vehicles to operate, potentially increasing the wear to the vehicle itself. Abrasion resistance is tested with ASTM developed C779 test.

Vibration

One of the most important steps when pouring concrete is the consolidation or vibration of concrete. Consolidation of concrete is one of the important site operations that together enable the fresh concrete to reach its potential design strength, density and low permeability. Concrete shall be vibrated during placing so that:

- A monolithic mass is created between the ends of the member, planned joints or both;
- The formwork is completely filled to the intended level;
- The entrapped air is expelled;
- All reinforcement, tendons, ducts, anchorages and embedments are completely surrounded;
- The specified finish to the formed surfaces of the member is provided;
- The required properties of the concrete can be achieved.

In addition to expelling entrapped air, promotes a more even distribution of pores within the concrete, causing them to become discontinuous. The durability of the concrete is consequently improved except, perhaps, in freeze-thaw conditions, where excessive vibration can expel amounts of purposely-entrained air which is designed to increase the freeze-thaw resistance of hardened concrete.

The abrasion resistance of concrete surfaces is normally improved by adequate vibration. However, excessive vibration, or excessive working of the surface, can cause an excessive amount of mortar (and moisture) to collect on the surface, thereby reducing its potential abrasion resistance.

Lack of consolidation can cause voids, rock pockets, honeycombing, and poor bonding with the rebar. In extreme cases, improper consolidation can affect the structural integrity of the walls or columns. On the other hand, excessive vibration can create bulged walls and blowouts.

Concrete Vibration Terms

Following are terms used in the process of concrete vibration:

Centrifugal force — a measure of the ability to move the mix based on the speed of rotation and size of the eccentric rotor. The higher the force, the heavier the mix it can move.

Amplitude — a measurement of the outermost distance the vibrator head will move from its static axis; important with large aggregate mixes.

Frequency — measured by vibrations per minute, or VPM, the speed at which the vibrator head moves within the confines of its amplitude. High VPM vibrators (up to 12,000 VPM) will primarily affect fine particles. This is ideal because the majority of the trapped air occurs around these particles. High VPM gives the cement paste the opportunity to coat these fine particles after the air is removed, thus helping to unify the mass. Frequency liquefies or moves the concrete mix. The greater the VPM, the greater the ability to liquefy stiff mixes.

Concrete slump

Depending on the structure's specifications, the concrete used for floors, walls, columns, etc., may need a specific consistency. On most jobs, samples of the concrete used on the pour are taken from the redi-mix truck and tested to determine that the concrete has been mixed to the required specifications. One of these tests is known as the "slump test." Several samples are taken from the same batch of mix at regular intervals during the pour. The concrete is placed in a cone-shaped form and rodded to settle the contents (see Slump Test below). The cone is removed and placed next to the concrete shaped by the cone. A straight-edge is placed across the cone, extending over the concrete next to it, and the "slump" is measured after approximately 1½ minutes. The slump equals the distance the concrete drops after sitting for this period of time.

The greater the drop, the higher the slump and the wetter the mix. Low slump (0-2") is considered a "stiff" mix. These mixes need the most help in consolidation. 2" to 4" is considered to be a low/medium slump; a 4" to 6" slump is a soft or wet mix and is probably the most widely used; over 6" is considered a flowing mix. These slump designations are approximations, generally accepted as "rule of thumb," and necessary to match the appropriate vibrator to the application.

Concrete Vibrators

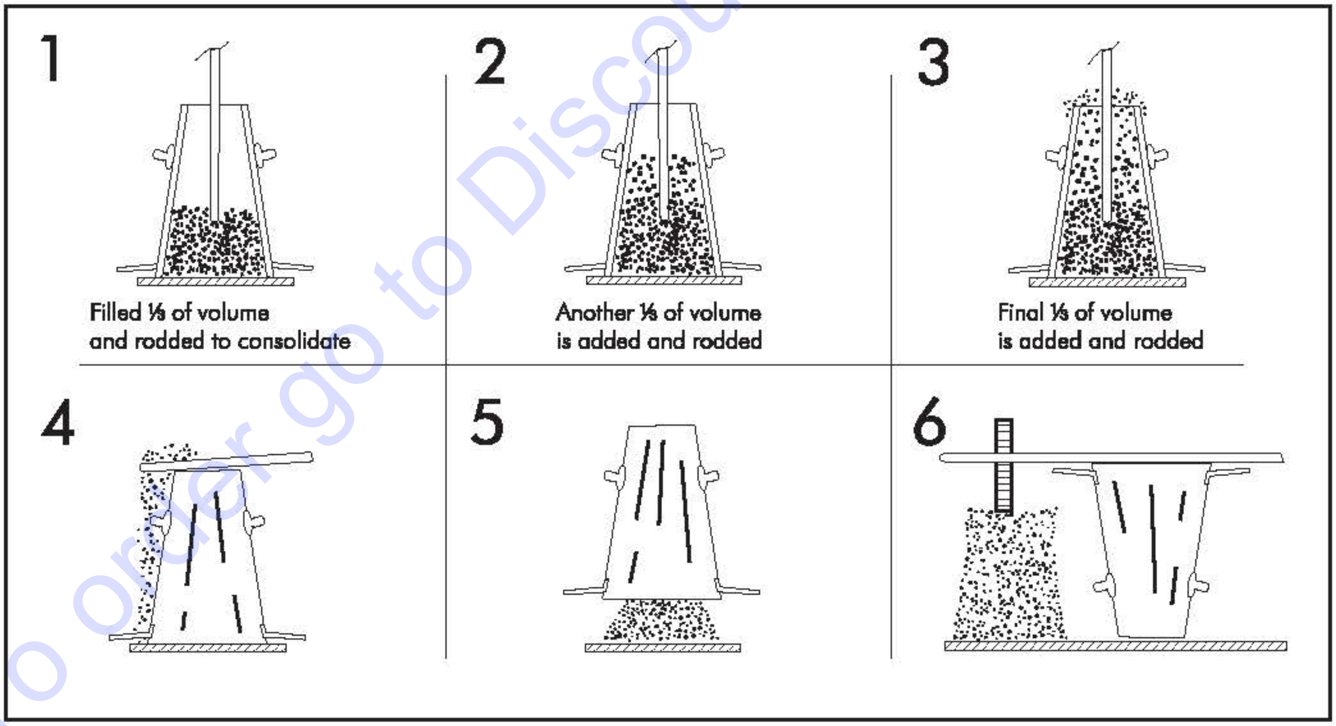
Concrete vibrators are divided into two major categories: *external* and *internal*.

External vibrators are attached directly to the concrete form, thereby vibrating the concrete through the form.

Internal vibrators utilize a vibrating head that is placed directly into the concrete mix. Internal vibrators fall into two major categories: flex-shaft and high-cycle.

Flex-shaft vibrators consist of a universal motor connected to a flexible shaft casing with a wire core and a head on the other end of the shaft. The motor turns the shaft, which turns the head. Flex-shaft vibrators have specific applications, such as

SLUMP TEST



Flex-shaft vibrator

small pours that require a minimal amount of vibration (i.e. thin slabs, narrow walls, bases and small footings). In these cases, flex-shaft vibrators are usually sufficient. In pours with heavy rebar concentration, flex shafts can be used since small diameter heads (7/8" to 2") can avoid hang-ups in the rebar.

Stiff concrete cannot be used in this situation; concrete slumps of 3" or more are commonly vibrated with the flex shaft.

High-cycle vibrator

High-cycle vibrators are so-named because of the electrical requirement of 180 Hz (cycles per second) indicating that the alternating current reverses direction 180 times per second. (Not to be confused with the vpm rating of vibrators also known as "high-cycle"or "high-frequency.") This allows the use of an induction motor, which can provide plenty of power in a smaller package than universal motors. With this small packaged motor, the eccentric rotor can be directly coupled to the motor that is enclosed in the head, eliminating the need for a flexible shaft. (The long handling hose between the motor/head and the power source contains electrical wires only.) This allows the high-cycle to be used on 1" to 3" slump concrete, especially in production situations.

Why high-cycle vibrators?

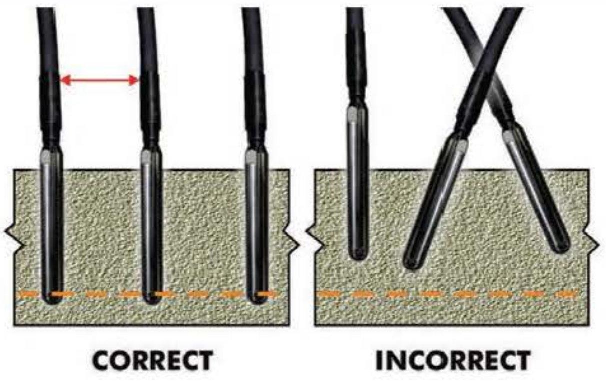
Due to the nature of the universal motor, flex-shaft vibrator motors will continually lose power as the load increases. The stronger the load (such as low-slump concrete), the greater the power loss. The principle advantage is that the 180-cycle induction motor used in high-cycle vibrators will lose only about 5% of its VPM under load. Additionally, the flexible shaft will create friction loss with each bend, further slowing the effective VPM at the head. The difference is performance in low- to medium-slump concrete. A high-cycle vibrator will run at approximately 10,800 VPM even in low slump (concrete moves best at 10,000 to 11,500 VPM). In a stiff mix, a flex shaft will operate around 9,000 VPM or lower, causing the operator to leave the vibrator in the concrete longer. In addition, the high cycle creates more centrifugal force and has a longer head, subjecting more of the mix to vibration. These factors allow the operator to vibrate a greater cubic yardage of mix.

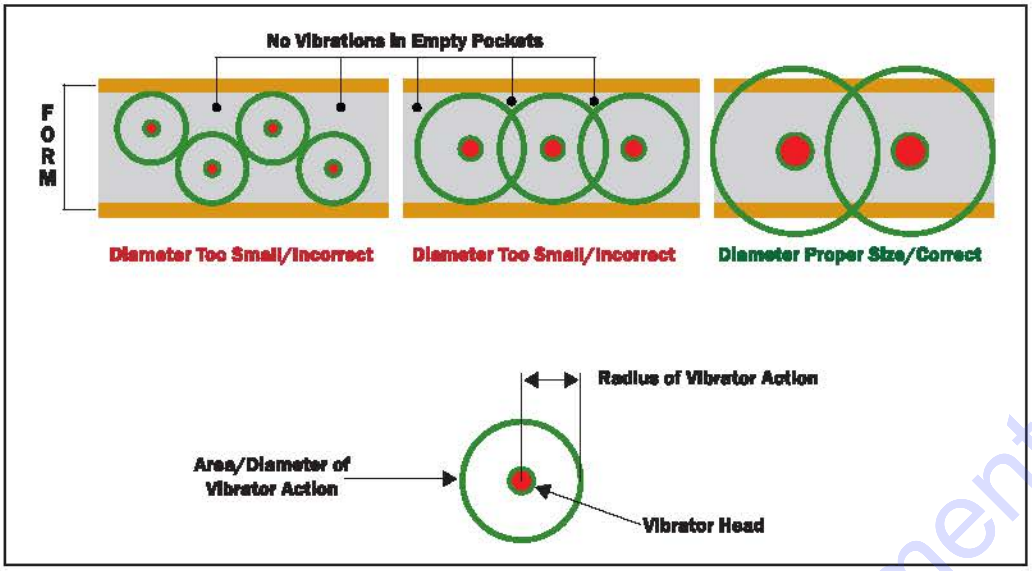
Applications for high-cycle vibrators include any work requiring low- to medium-slump concrete, including dams, large retaining walls, slab pours on high-rise buildings and parking lots, tilt-up walls, and other types of standard construction work.

External vibrators

External vibrators attach directly to the form wall and consolidate without actually touching the concrete (hence, "external"). External vibration is preferred in situations where columns or heavy concentrations of rebar could result in the tangling of an internal head. External vibrators are useful for precast production work, as they can be permanently placed and thereby save on labor.

The correct spacing between head insertions is 1½ times the radius of vibrator action.





Selling high-cycle vibrators

When high-cycle concrete vibrator technology first became available, the new vibrators required generators designed specifically for that purpose (240 volt, 3 phase, 180 Hz) with some auxiliary 115 volt DC power. These single-purpose high-cycle generators were large, heavy and expensive; their use was strictly limited to high-cycle applications.

In the past, high-cycle vibrator sales were minimal because of the restrictive power supply requirements. Nevertheless, contractors preferred to use high-cycle for the following reasons:

- **Less maintenance than flex-shaft units.**
- **Higher and more consistent centrifugal force** (and area of compaction) than flex-shaft.
- **Eliminates problem** of a motor dropping into the concrete mix or mix getting into the motor.
- **Nominal RPM loss** under load.
- **Higher productivity rates** than flex shaft.
- **Greater ability to handle stiff mixes** and high- production work.

GDP5HA 60/180 cycle generator

The introduction of Multiquip's GDP series 60/180 cycle generators allows the contractor to use one machine for both general 60 Hz applications and high-cycle power (180 Hz). Multiquip's 60/180 cycle generators are unique in that they are lighter, far less expensive and offer more standard features—at a lower list price—than other brands.

Multiquip's high-cycle vibrators are ideal for rental companies as they can handle a large range of concrete vibration applications and can be powered by the same generator used for standard AC tools. And they are built with large, heavy-duty permanently lubricated bearings to give maximum performance, durability and long life.

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When selling concrete vibrators, eliminate the possibility of over-equipping or under-equipping customers by utilizing the above information to determine specific job applications. Required data includes the dimensions of the form, form material, concrete slump, the extent of rebar concentration, the number of pours needed and available power supply at the jobsite.

Vibration procedures

- **Before using a vibrator,** check for proper operation and VPMs using a simple hand tachometer (wire-type.)
- **It is good practice** always to have a spare vibrator on the job.
- **Concrete in walls and columns** are placed in lifts of various depths, usually 12" to 24". Vibrate the first lift with the head all the way to the bottom of the form as the vibration force extends laterally from the head, not below the tip of the head. The vibrator must always be used vertically.
- **Place the vibrator into the highest levels of concrete first,** and when a fairly even surface is obtained, insert it at regular intervals (1½ times the radius of influence) for consolidation.
- **Observe the vibration action** on the surface to calculate the radius, and place accordingly to create an overlap; it is better to err on the side of more overlap than not enough.
- **Vibrate with the head totally submerged** in the concrete, maintaining consistency of spacing and vibration time.
- **Keep the vibrator stationary for 5 to 15 seconds** depending on the mix and the force of the vibrator. Less time will not allow for proper consolidation or entrapped air to escape; too much can cause segregation, sand streaks and/or loss of entrained air. The surface should be covered with a thin sheet of paste (mortar) and air bubbles should no longer rise to the surface.
- **Pull the vibrator slowly out of the mix** so concrete can fill in behind the head. When placing the next lift, insert the vibrator at least 6" into the previous lift to stitch the layers together—this eliminates cold joints.
- **Never use vibrators to spread concrete** and always stay 2" away from form faces and bottom slabs.

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