Concrete Vibration Handbook

MULTIQUIP

Concrete Vibration Handbook

Concrete is the combination of four basic components: water, cement, sand (small aggregate) and rock (large aggregate). When mixed together, hydration, or curing, occurs, where the cement paste acts as a glue binding all the surrounding aggregates.

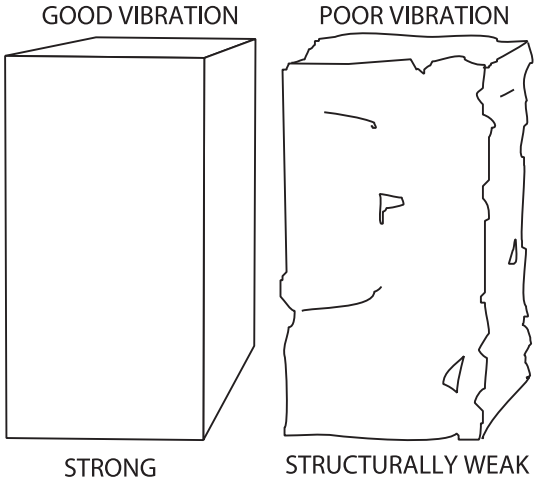
Cement

Pound-for-pound this is the most expensive ingredient in concrete. Several types of cement are available to meet different construction criteria.

Water content—curing

In order to begin the hydration process, water is needed to act as a catalyst. Water content will determine the strength, workability and placeability of the mix. An increase in water content will improve the concrete's workability but will decrease its ultimate strength and durability. For example, a standard mix with four gallons of water per bag of cement, or 0.36 W/C ratio (water-to-cement ratio), yields a compressive strength of about 6,300 lbs. Five gallons, or 0.44 W/C ratio, lowers it to about 5,100 lbs., a strength loss of 21%.

Proper curing is also important to the relative strength and durability of concrete. Several methods of curing are recommended by ACI (American Concrete Institute) in order to control the water retention of the slab. 28 days is considered the benchmark for ultimate concrete strength and represents 96% to 98% of the total strength over its lifetime. Improper curing will result in excess water loss, lower compressive strengths, shrinkage and cracking.



Aggregates

Aggregates consist of small particles, such as rocks and stones, which are divided into two grades, fine and coarse, and comprise the largest volume of concrete ingredients (typically 70%). The amount of cement used over a given area depends on aggregate size — the finer the aggregate, the larger the surface area. Also, the shape of the aggregate affects the amount of vibration required, since rough aggregate shapes hold more air than smooth.

Vibration (Consolidation)

Right after placement, concrete contains up to 20% entrapped air. The amount varies according to the type of mix and its slump, the placement method, form size, and the amount of reinforcing steel used. Concrete vibration can improve the compressive strength of the concrete by about 3% to 5% for each percent of air removed. Vibration consolidates concrete in two stages: first by moving the concrete particles, then by removing entrapped air.

Vibration settles the concrete by subjecting the individual particles to a rapid succession of impulses, causing differential motion (each particle moving independently of the other). The particles consolidate as trapped air are forced to the surface,

allowing the concrete to flow into corners, around rebar and flush against the form face. This eliminates voids (honeycombing) and brings paste to the surface to assist in finishing. Since concrete flows better with vibration, the mix can contain less water, thereby providing greater strength for the finished product.

Until both vibration stages are complete, the concrete isn't fully consolidated. If the vibrator is removed too soon, some of the smaller bubbles don't have enough time to move to the surface.

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.

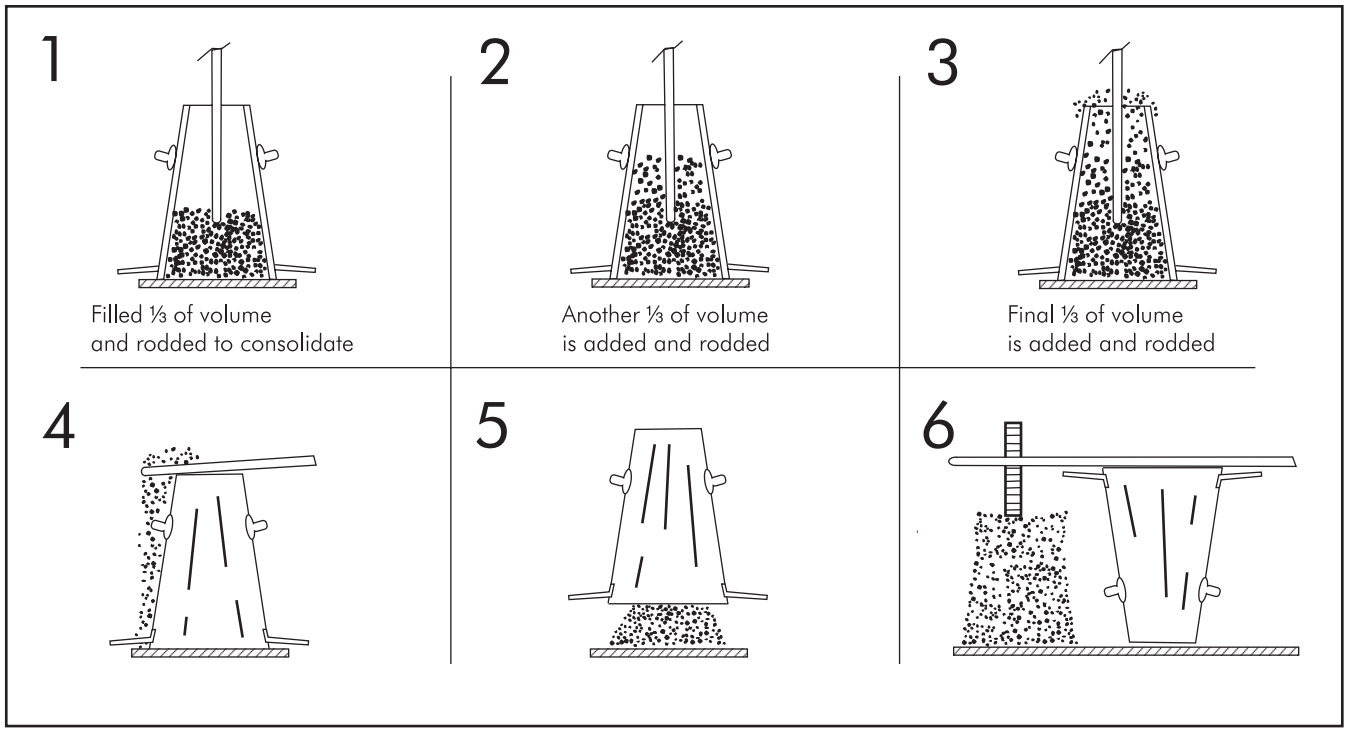
AMPLITUDE—a measurement of the outermost distance the vibrator head will move from its static axis; important with large aggregate mixes.

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 (Figure 5). A straight-edge is placed across the cone, extending over the concrete next to it, and the "slump" is measured after approximately 1½ minutes.

SLUMP TEST



RANGE OF CHARACTERISTICS, PERFORMANCE AND APPLICATION OF INTERNAL VIBRATIONS

1	2	3	4	5	6	7	8
COLUMN			Suggested value of		Approximate value of		
GROUP	Dia. of head in. (mm)	Recommended frequency, vibrations per min.	Average amplitude in. (mm)	Centrifugal force lbs. (kg)	Radius of action in. (cm)	Rate of concrete placement yds. per hr.	Application
1	¾-1½ (20-40)	9000-15,000	0.015-0.03 (0.4-0.8)	100-600 (45-272)	6-24 (15-61)	5-15	Plastic and flowing concrete in very thin members and confined places. May be used to supplement larger vibrators, especially in pre-stressed work where cables and ducts cause congestion in forms. Also used for fabricating laboratory test specimens.
2	1¼-2½ (30-60)	8500-12,500	0.02-0.04 (0.5-1.0)	300-1000 (136-453)	20-32 (51-81)	12-45	Plastic concrete in thin walls, columns, beams, pre-cast piles, thin slabs and along construction joints. May be used to supplement larger vibrators in confined areas.
3	2-3½ (50-90)	8000-12,000	0.025-0.05 (0.6-1.3)	700-2000 (317-907)	28-48 (71-122)	24-60	Stiff plastic concrete (less than 3 in. [80 mm] slump) in general construction such as walls, columns, beams, pre-stressed piles and heavy slabs. Auxiliary vibration adjacent to forms of mass concrete and pavements. May be gang-mounted to provide full-width internal vibration of pavement slabs.

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 small pours that require a minimal amount of vibration (i.e. thin slabs, narrow walls,

FLEX-SHAFT VIBRATOR

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 (⅞" to 2") can avoid hang-ups in the rebar (see table on page 3).

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

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.

HIGH-CYCLE VIBRATOR

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.

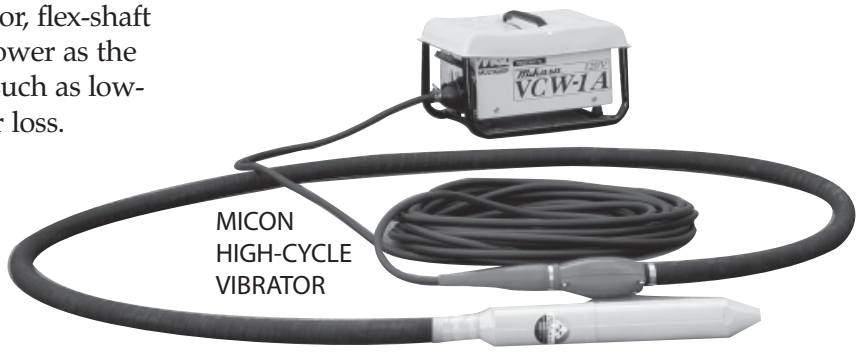
Micon high-cycle vibrator

Multiquip's microcomputer-controlled (Micon) fully-patented high-cycle vibrator is a major technological advancement allowing contractors to maximize their productivity. The Micon delivers the performance of a high-cycle vibrator while offering many exclusive features.

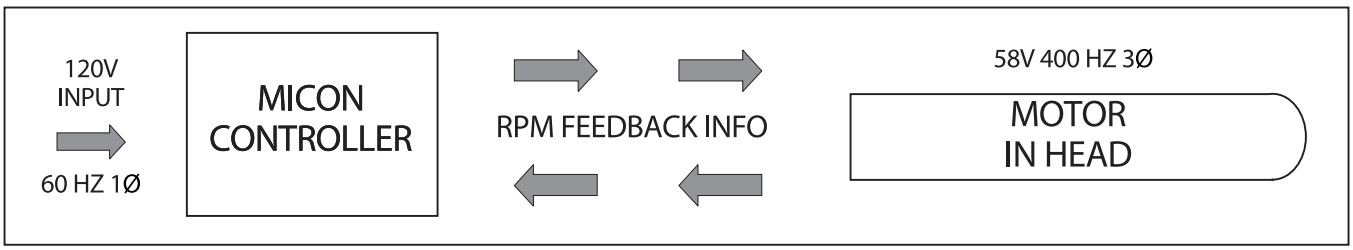
Why Micon high-cycle?

One advantage of the Micon is that it uses standard 60 Hz electrical current in place of the special 180 Hz generators that are required to power high-cycle vibrators. The Micon controller automatically converts the 120 volt, 60 Hz current into the 58 volt, 400 Hz current required by the motor.

A microcomputer located within the controller functions as the "brain" of the Micon, monitoring the vibrator's performance while submerged in concrete. This enables it to perform with



MICON HIGH-CYCLE VIBRATOR



unparalleled efficiency and achieve superior concrete consolidation regardless of the slump conditions. For example, a conventional vibrator placed in a stiff mix will experience a drop-off in frequency and RPMs. With the Micon, this loss is detected by the controller which signals the motor to increase its speed to compensate for the loss. Its capacity to maintain a frequency of up to 12,000 vpm makes it ideal for zero-slump conditions.

The controller also safeguards against common problems such as overheating, motor burnout and fluctuations in current. Built-in sensors constantly monitor the system, shutting down the motor at the first sign of a problem.

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.

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.

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.

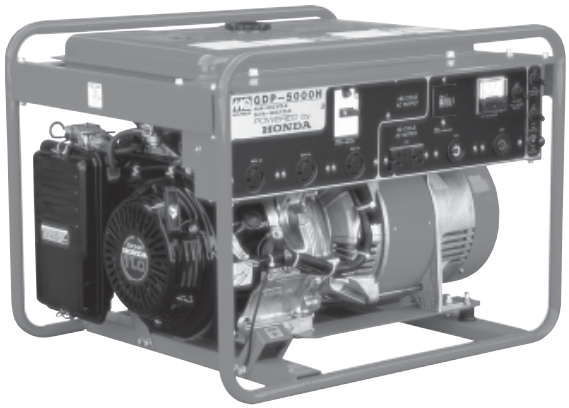
Multiquip's high-cycle vibrators are ideal for rental companies as they can handle a large range of concrete vibration applications and can be powered by the same generator used for standard AC tools. And they are built with large, heavy-duty permanently lubricated bearings to give maximum performance,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

Micon high-cycle vibrator systems are designed for continuous work with low- or zero-slump concrete. These units are also available with an extended rigid vibrator head that incorporates an extension pipe attached directly to the head. In certain situations where the handling hose on the vibrator is too flexible to position the vibrating head (in tight spots or against sloping form-faces), the head extension (5.8" in length) allows the operator to place the head in precise locations, assuring proper concrete consolidation. The Micon system gives the operator all the advantages of high-cycle vibrators plus additional performance and the ability to use a 120 volt,
60 Hz power supply.

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.



MULTIQUIP
60/180 HIGH-CYCLE GENERATOR
GDP-5000H

Vibrator selection

Stow Flex-Shaft Vibrators
1-, 2- & 3-HP electric motors
5.5-HP Honda gasoline engine
Flex shafts from 2ft. to 21ft.
Heads from ⅞" to 2⅝"

Mikasa Flex-Shaft Vibrators
2- & 3-HP electric motors
5.5-HP Honda
Flex shafts from 3ft. to 21ft.
Heads from ⅞" to 2⅜"

Mikasa High-Cycle Vibrators
2.0- & 4.5-amp motors
2" and 2⅜" heads
5kVA 180 Hz/4kW 60 Hz generator

Micon Micro-Computer-Controlled High-Cycle Vibrators
10- and 20-amp controllers
1.25" to 2.8" heads

Ask for our full-color "Concrete Vibrators" brochure showing our complete range of vibrator equipment

CV-219 (10/03) © COPYRIGHT 2003, MULTIQUIP INC.

MULTIQUIP INC.
PO BOX 6254, CARSON, CA 90749
310-537-3700 • 800-421-1244 • FAX: 310-537-3927
E-MAIL: mq@multiquip.com • www.multiquip.com