

TECHNOTES

10333 N. Meridian St., Suite 272 | Indianapolis, IN 46290
317-571-9500 | 800-366-7731 | 317-571-0041 Fax | www.precast.org

Proper Vibration Techniques for Precast

Proper vibration of fresh concrete is an important process in order to ensure optimum strength, durability and appearance of quality precast products. Accepted practices in the precast industry are unique in some respects due to the industry's production environment. The following is a summary of some fundamental consolidation principles and recommended practices.

INTRODUCTION

Fresh concrete must be properly vibrated so that once hardened its strength and durability are fully realized. Studies have revealed a marked influence of reduced consolidation of fresh concrete on its ultimate compressive, tensile and flexural strength. For example, a 5 percent reduction in consolidation can result in a 30 percent reduction in compressive strength. Reduced density, due to under-consolidation, can result in increased permeability and consequently less resistance to deterioration. Other important characteristics such as rebar bond capacity and appearance are also affected. Over-consolidation is a lesser concern.

Newly placed concrete must be worked to eliminate voids, honeycombs and entrapped air, and to fully encase all rebar and other embedment. Vibration of fresh concrete reduces its internal shear strength and enables the concrete to temporarily liquefy, facilitating the consolidation process. Once the vibration stops, its liquid flow subsides. Adequate consolidation in congested areas due to blockouts and embedment warrants additional vibration efforts to ensure a quality product. Selecting the type of consolidation method is largely a matter of experience. Factors to consider include the product's configuration, mix design, size and rate of concrete placement, aggregate size, rebar configuration and desired finish.

TECHNIQUES

Vibration or compaction is the principal method of consolidation of concrete. Several methods of vibration are employed in the precast industry, including external and internal vibration, tamping, centrifugation, vacuums and pressure. An American Concrete Institute Committee on Consolidation of Concrete (ACI 309) has defined several of these methods in a manual of practice, a portion of which is included as Attachment A of this bulletin.

Vibrators, either internal or external, are usually characterized by their frequency and amplitude of vibration. Optimum frequencies and amplitudes will vary with mix design, form configurations and other factors. For example, lower water-cement ratios, greater cement content and greater angularity of coarse aggregate all require greater compactive efforts. Also, superplasticized concretes typically require 20 percent to 50 percent of the compactive effort of conventional concretes and can effectively employ smaller diameter internal vibrators.

The ideal vibrator is one in which the frequency and amplitude can be varied ranging from low-frequency, high-amplitude during initial consolidation to high-frequency, low-amplitude at final consolidation.

Fresh concrete should be vibrated until all voids and entrapped air pockets are released. The consolidation of the concrete will be evident when escaping air bubbles cease. Full consolidation can be judged by the formation of a mortar rich appearance on the concrete surface and, in cases, a noticeable difference in the sounds emanating from the vibrator. If a concrete is over-vibrated its surface will appear very wet and have a layer of mortar without coarse aggregate. When over-vibration is evident the slump rather than the amount of vibration should be reduced. Over-consolidation is normally not a significant concern. In fact, in cases where the appearance of the concrete surface is important, it is common to double the normal vibration time to ensure a smooth defect-free finished surface.

Re-vibration of concrete after initial consolidation is an accepted practice as necessary to weld successive lifts together. Fully tied rebar cages are urged to ensure that their positions are maintained during the consolidation effort and to reduce the potential for adverse vibrations that could compromise the concrete-rebar bond.

EXTERNAL VIBRATION/COMPACTION

Vibration tables, external form vibrators, drop tables and other specialized equipments are common in precast plants. Specialized equipment can provide product-specific benefits, offering more uniform control and greater overall economy. Vibration tables are unique to the precast industry. Vibration tables are rigid decks mounted on flexible supports which operate at 3,000 to 6,000 vibrations per minute (vpm).

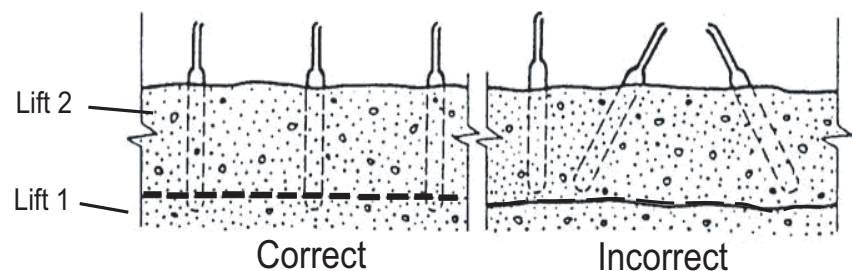
External form vibrators should be mounted just below poured concrete surfaces and have frequencies ranging from 2,000 vpm to 6,000 vpm. Precautions should be exercised to ensure that a pumping action is not created that could introduce air into the fresh concrete. Drop tables are also unique to the precast industry. This equipment employs a low-frequency, high-amplitude method of shock compaction. All consolidation equipment should be adequately secured and the formwork should be sufficiently sturdy to resist the repeated vibration and/or shock loads. Locking mechanisms are recommended on connectors as needed.

INTERNAL VIBRATION

The primary factors that influence the effectiveness of internal vibrators are the vibrator's head diameter, frequency and amplitude. Head diameter for range from 0.75 inches to a 7-inch diameter and are available in varied shapes. However, larger-diameter heads are usually not employed in the precast industry. Internal vibrator frequencies range from 4,000 vpm to 15,000 vpm and many have variable frequencies and amplitudes to accommodate a wide range of use.

Internal vibrators should be vertically dropped into the concrete, allowed to vibrate in place (5-15 seconds for wet mixes or up to 2-3 minutes for stiff mixes) and then removed. The withdrawal should be at a somewhat quicker rate than its placement. Vibrators should not be used to transport concrete laterally. An internal vibrator should slightly penetrate into the previous lift to ensure an adequate bond, as noted in Figure 1.

Care should be taken to avoid touching or damaging the formwork. An excerpt of recommendations from ACI 309 concerning the range of characteristics, performance and applications of internal vibrators is included as Attachment B of this bulletin.



SERVICE AND USE

A comprehensive preventative maintenance program is urged for all consolidation equipment. Equipment should be frequently cleaned, inspected and serviced, including in-service verifications to ensure continued reliable performance. Because of the importance of adequate consolidation, stocking of reserve vibrators and spare parts is encouraged.

CONCLUSION

Forty years ago, the use of vibration to consolidate concrete had been cited as the greatest advance in the art of concrete placement since the invention of the mixer. That advance and continued improvements of consolidation equipment has made the use of stiffer mixes possible resulting in an appreciably higher quality concrete.

REFERENCES

ACI 309, Standard Practice for Consolidation of Concrete

Attachment A

Consolidation Methods for Precast Concrete Products (ACI 309)

Product	Mix Classification	Forming Material	Conveying and Placement Method	Consolidation Method
Concrete pipe	a to d	Steel	Pumping or bucket (thin layers)	Tamping; internal or external vibration; centrifugation
Concrete piles and poles	c,d	Steel	Pumping or conveyed by mixer trucks	Centrifugation; internal or external high frequency, low amplitude vibration; roller packed
Concrete block	b	Steel	Machine hopper	Low frequency, high amplitude vibration plus pressure
Slab and beam sections	b,c	Steel	Traveling hopper, mixer trucks, belt conveyors	External vibration with or without roller compactions; internal vibration with surface vibration screed
Wall panels	a to c	Reinforced concrete, steel or wood	Buckets and belt conveyors (continuous ribbon feed)	Tampers; internal and external vibration

Notes:

- Very stiff mixes, with water-cement ratios of 0.30 by weight or less
- Stiff mixes having a water-cement ratio exceeding 0.30 but with less than 1-inch slump
- Uniformly gap-graded mixes with slump in the 1-inch to 4-inch range
- Mixes with more than 4-inch slump, which flow readily and segregate if mechanical vibration is applied

Attachment B

Range of Characteristics, Performance and Applications of Internal Vibrators Consolidation Methods (ACI 309)

Diameter of head (inches)	Recommended frequency (vpm) [1]	Suggested Value of			Approximate Value of		Application
		Eccentric moment (#) [2]	Average amplitude (inches) [2,3]	Centrifugal force (#) [2]	Radius of action [4,6]	Rate of concrete placement (cy,hr,vib) [5,6]	
0.75 inch to 1.5 inches	10,000-15,000	0.03-0.1	0.015-0.03	100-400	3-6	1-5	Plastic and flowing concrete in very thin members and confined spaces
1.25 inch to 2.5 inches	9,000-13,500	0.08-0.25	0.02-0.04	300-900	5-10	3-10	Plastic concrete in thin walls, columns, beams, precast piles, thin slabs and along construction joints

Notes:

- While vibrator is in concrete
- See ACI 309
- Operating in air
- Distance over which concrete is fully consolidated
- Assumes insertion spacing is 1.5 times the radius of action, and that the vibrator operated two-thirds of the time the concrete is being placed
- These ranges reflect not only the capability of the vibrator but also differences in the workability of the mix, degree of de-aeration desired, and other conditions experienced in construction