Mixing, Handling, Placing and Compacting Concrete

Chapter 8

Introductory Notes

The production of high-quality concrete does not rest solely on proper proportioning. Lack of sufficient attention to mixing, handling, and placing can result in poor concrete from a well-designed mix.

Introductory Notes

The overall objective of the process is to ensure that the concrete within a structure is a **uniform blend** of the constituent materials in the **correct proportions** and thus conforms to the specifications.

Mixing Concrete

- The mixing operation consists essentially of rotation or stirring, the objective being to coat the surface of all the aggregate particles with cement paste, and to blend all the ingredients of concrete into a **uniform mass**.
- If concrete has been adequately mixed, then samples taken from different portions of a batch should have essentially the same strength, density, air content, slump, and coarse aggregate content, with some allowance for testing variability

Types of Concrete Mixers

1. Batch Mixer: in which one batch of concrete is mixed and discharged before any more materials are put into the mixer. There are different types of batch mixers.
    - Tilting drum mixer
    - A non-tilting drum mixer
    - horizontal shaft revolving blade or paddle type mixers

Types of Concrete Mixers

2. Continuous mixers: These are fed automatically by a continuous weigh-batching system. The mixer itself may be of drum-type or may be in the form of a screw moving in a stationary housing.

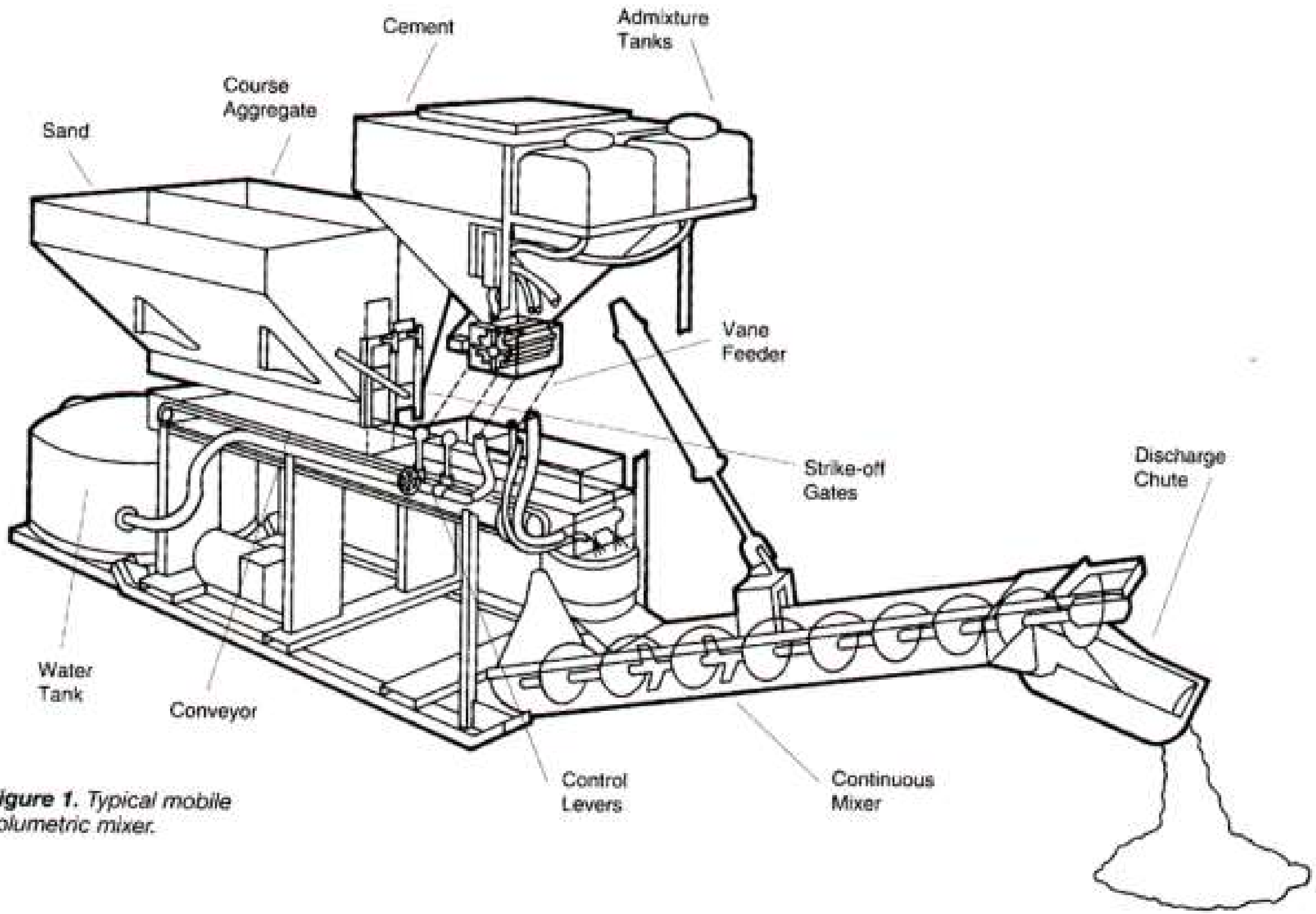


Figure 1. *Typical mobile volumetric mixer.*

Charging the Mixer

- There are no general rules on the order of feeding the ingredients into the mixer as this depends on the properties of the mixer and of the mix. Usually mixer can be charged according to the following sequence
  - It is desirable to add about 10% of the mixing water first
  - Add solid material, preferably uniformly and simultaneously with most of the water leaving about a final 10% to be added at the end.
- If water or cement is fed too fast or is too hot there is a danger of forming cement balls, sometimes as large as 75 in diameter.

Charging the Mixer

Charging Admixtures

- Addition of the admixture should be completed not later than one minute after addition of water to the cement has been completed or prior to the start of the last three-fourths of the mixing cycle.
- If retarding or water-reducing admixtures are used, they should be added in the same sequence each time. If not, significant variations in the time of initial setting and percentage of entrained air may result.
- If two or more admixtures are used in the same batch of concrete, they should be added separately to avoid any interaction

Mixing time

- <u>The optimum mixing time depends on:</u>
  - the type and characteristic of mixer,
  - the size of the charge, and
  - the nature of the constituent materials. For examples: Lean, dry, or harsh mixes require longer mixing time; Concretes made with angular aggregates need more mixing time than those made with rounded gravels.
- The mixing period should be measured from the time all cement and aggregates are in the mixer drum, provided all the water is added before one-fourth of the mixing time has elapsed.

Mixing time

- Many specifications require a minimum mixing time of one minute for the first **yd³** plus 15 seconds for every additional **yd³** unless mixer performance tests demonstrate that shorter periods are acceptable.

Recommended minimum mixing times

Capacity of mixer		Mixing time, min
m^3	yd^3	
0.8	up to 1	1
1.5	2	$1\frac{1}{4}$
2.3	3	$1\frac{1}{2}$
3.1	4	$1\frac{3}{4}$
3.8	5	2
4.6	6	$2\frac{1}{4}$
7.6	10	$3\frac{1}{4}$

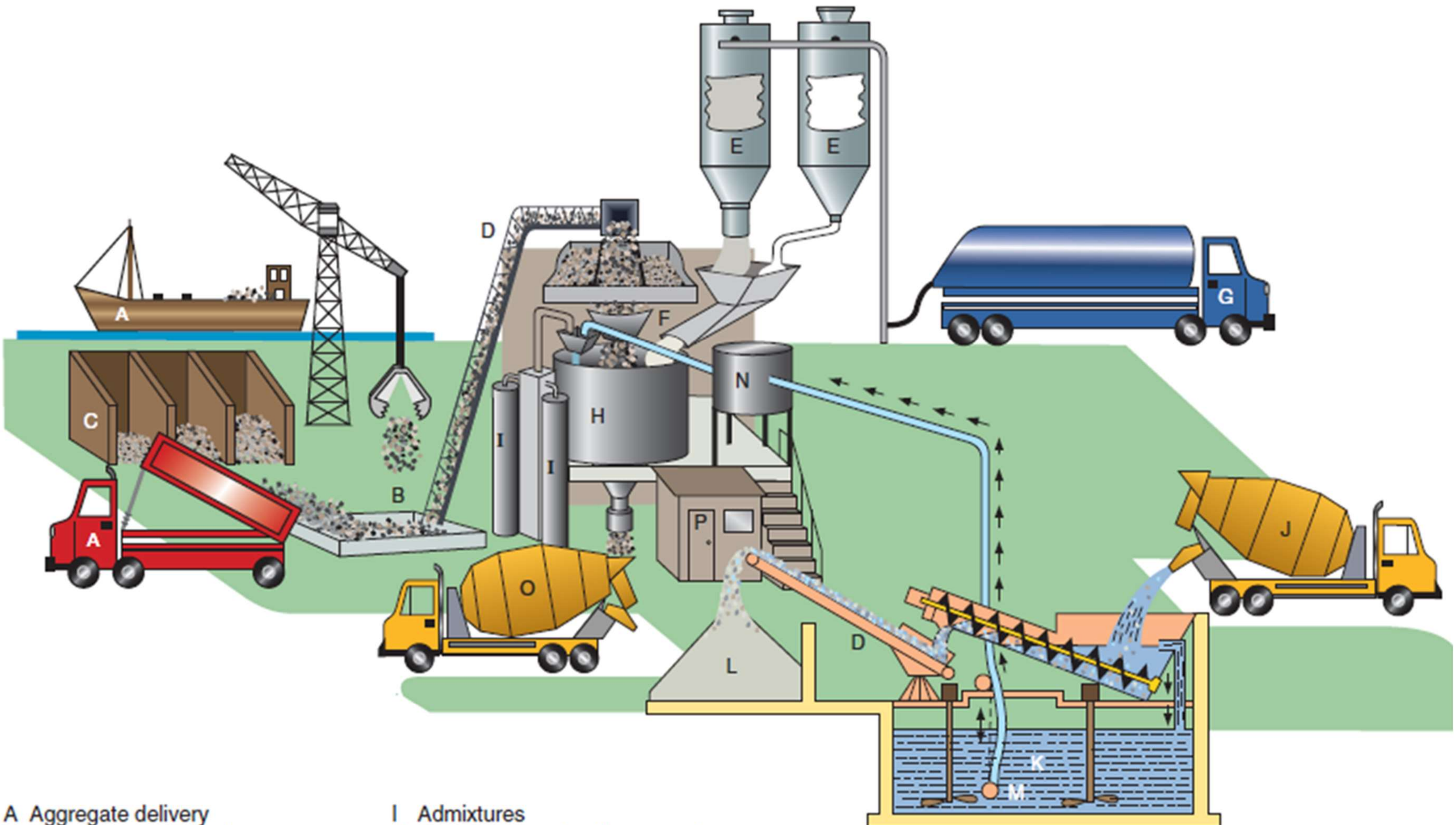
ACI 304R–00 and ASTM C 94–05.

Short and prolonged mixing times

- **Short mixing times.** Can result in non-homogenous mixtures, poor distribution of air voids (resulting in poor freeze-thaw resistance), poor strength gain, and early stiffening problems.

- **Prolonged mixing.** If mixing takes place over a long period, then:
  - Evaporation of water from the mix can occur, with a consequent decrease in workability and an increase in strength.
  - Grinding of the aggregate, particularly if soft, the grading thus becomes finer and the workability lower.
  - The friction effect also produces an increase in the temperature of the mix.
  - In the case of air-entrained concrete, prolonged mixing reduces the air content

Ready Mixed Concrete



A Aggregate delivery
B Aggregate receiving hopper
C Aggregate storage
D Conveyor belt
E Cementitious material storage
F Weigh hopper
G Cement delivery
H Mixer

I Admixtures
J Ready mix truck with returned concrete
K Recycled water
L Reclaimed aggregates
M Pump
N Water storage
O Concrete loaded in ready-mix truck
P Control room

Ready Mixed Concrete

- It is the concrete which is delivered for placing from a central plant instead of being batched and mixed on site. **This type of concrete offers numerous advantages** such as:

  a) close quality control of batching which reduces the variability of the desired properties of hardened concrete;

  b) use on congested sites or in highway construction where there is little space for a mixing plant and aggregate stockpiles;

  c) use of agitator trucks to ensure care in transportation, thus preventing segregation and maintaining workability;

  d) convenience when small quantities of concrete or intermittent placing is required.

Categories Of Ready-mixed Concrete

- Central-mixed: mixing is done at a central plant and then the concrete is transported in an agitator truck.
- Shrink-mixed: concrete is partially mixed at the plant to shrink or reduce the overall volume, and mixing is completed in the truck mixer.
- Transit-mixed or truck-mixed: the materials are batched at a central plant but are mixed in the truck either in transit or immediately prior to discharging the concrete at the site this permits a longer haul and is less vulnerable in case of delay, but the truck capacity is smaller than that of the same truck which contains pre-mixed concrete.

Agitating and Mixing in truck-mixed concrete

- Agitating differs from mixing solely by the speed of rotation of the mixer, the agitating speed is between 2 and 6 rpm, while the mixing speed is between 4 to 16 rpm.
- ASTMC94 (AASHTOM157) require that when a truck mixer is used for complete mixing, 70 to 100 revolutions of the drum or blades at mixing speed are usually required to produce the uniformly mixed concrete. The homogeneity of concrete is maintained after mixing and during delivery by turning the drum at agitating speed.

Re-tempering (Remixing) Concrete

- Re-tempering means adding water to concrete to restore workability. This can be done providing the following conditions are met

  (1) maximum allowable water-cement ratio is not exceeded;

  (2) maximum allowable slump is not exceeded;

  (3) maximum allowable mixing and agitating time (or drum revolutions) are not exceeded; and

  (4) concrete is remixed for a minimum of 30 revolutions at mixing speed.

- If the condition not met, the adjustment of the mix can be done using admixtures such as water reducing admixture to increase slump, followed by sufficient mixing.

Handling Concrete

There are many methods of transporting concrete from the mixer to the site. certain circumstances must be taken into consideration:

- Delays. The transporting and handling equipment should reduce delays in concrete placement. Concrete shall be placed and compacted successfully within 90 minutes after mixing. To avoid Early Stiffening and Drying Out admixture can be used.
- Segregation. The method and equipment used to transport and handle the concrete must not result in segregation of the concrete materials.

Transporting and Handling Equipment

Pumped Concrete

- Concrete pump is one of the most used equipment in concrete transport. For example, the advanced mobile pump with hydraulic placing boom is probably the single most important innovation in concrete handling equipment.

- Recently, special high pressure pumps have delivered concrete to distances as great as 1400 m horizontally and 420 m vertically.

- The most important consequences of concrete pumping are The loss of slump caused by pressure forcing mix water into the aggregates and the reduction of the air content.

Requirement of Pumped concrete:

- The mix required to be pumped must not be harsh or sticky, nor too dry or too wet. A slump of between 40 and 100 mm is generally recommended for the mix.
- In particular, the percentage of fines is important since too little causes segregation and too much may cause blockage of the pipeline.
- The ratio of the maximum size of the coarse aggregate to the smallest inside pipe diameter should not exceed 0.33 for angular aggregates, or 0.40 for well-rounded gravel.
- The amount of coarse aggregate is usually reduced (by up to 10%) compared to mixes that are not pumped.
- Size gradation of both fine and coarse aggregate should be as close as possible to the middle range of the grading limits but continuity of aggregate grading is even more important.

Concrete Placing

- The main objective is to deposit the concrete as close as possible to its final position so that segregation is avoided and the concrete can be fully compacted

Preparation Before Placing

1. Planning
   - Check and insure that the works has been done according to the design drawings.
   - Ordering and scheduling materials and operations
   - Obtain available information about expected weather conditions and traffic flow.
   - List the necessary equipment and check their availability.

Preparation Before Placing

2. Formwork

- Forms should be properly aligned, clean, tight, adequately braced, and constructed of materials that will impart the desired off-the-form finish to hardened concrete
- The forms should be straight and free from warping and have sufficient strength to resist concrete pressure without deforming.
- Wood forms, unless oiled or otherwise treated with a form release agent, should be moistened before placing concrete, otherwise they will absorb water from the concrete and may swell

Good practice in concrete placing

- Concrete should be deposited continuously as near as possible to its final position.
- The concrete should not be dumped in large piles and moved horizontally into final position. These practices result in segregation because mortar tends to flow ahead of the coarser material.
- In general, concrete should be placed in walls, thick slabs, or foundations in layers of uniform thickness and thoroughly consolidated before the next layer is placed. In general, layers should be about 150 mm to 500 mm deep for reinforced members.
- The rate of placement should be rapid enough that previously placed concrete has not yet set when the next layer of concrete is placed upon it.

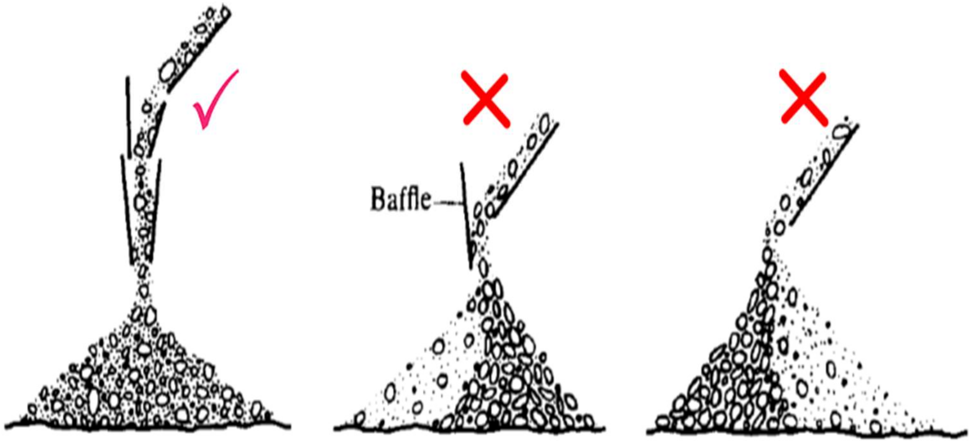
Good practice in concrete placing

- In monolithic placement of deep beams, walls, or columns, to avoid cracks between structural elements, concrete placement should pause (about 1 hr) to allow settlement of the deep element before concreting is continued. The delay should be short enough to allow the next layer of concrete to knit with the previous layer by vibration, thus pre-venting cold joints and honeycombing

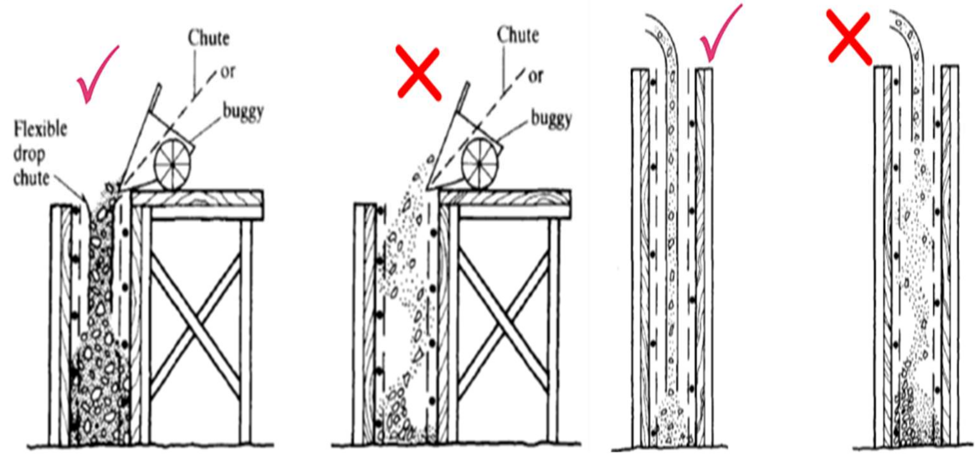
- Collision between concrete and formwork or reinforcement should be avoided. For deep sections, a long down pipe ensures accuracy of location of the concrete and minimum segregation.

- Concrete should be placed in a vertical plane. When placing in horizontal or sloping forms, the concrete should be placed vertically against, and not away from, the previously placed concrete. For slopes greater than 10°, a slip-form screed should be used

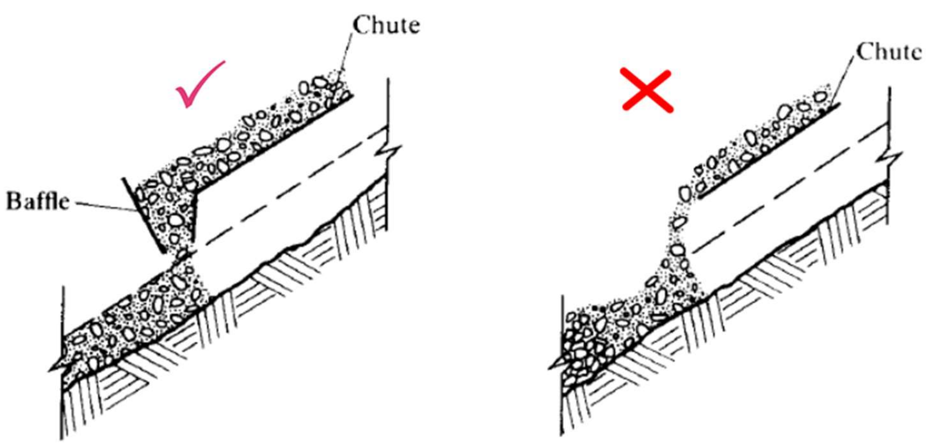
Good practice in concrete placing



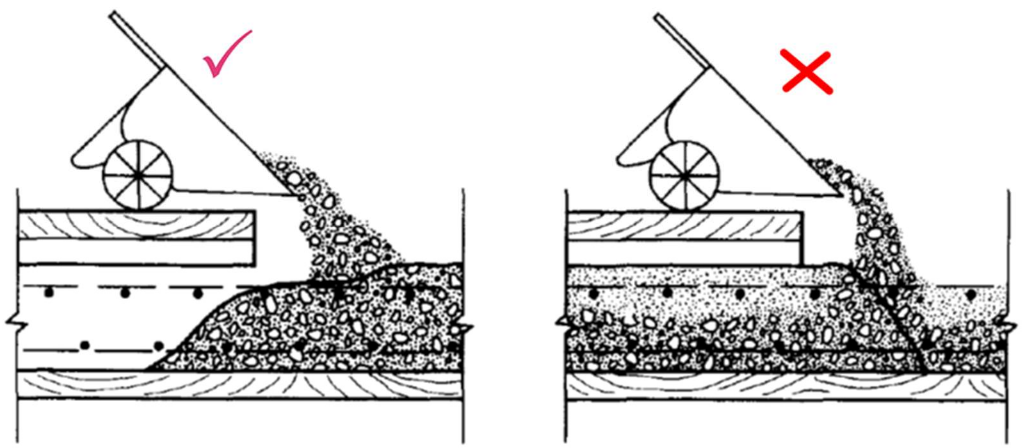
Control of segregation at the end of concrete chutes



Placing concrete in a deep wall
a good rule for drop height is 0.9 to 1.5m



Placing concrete from buggies



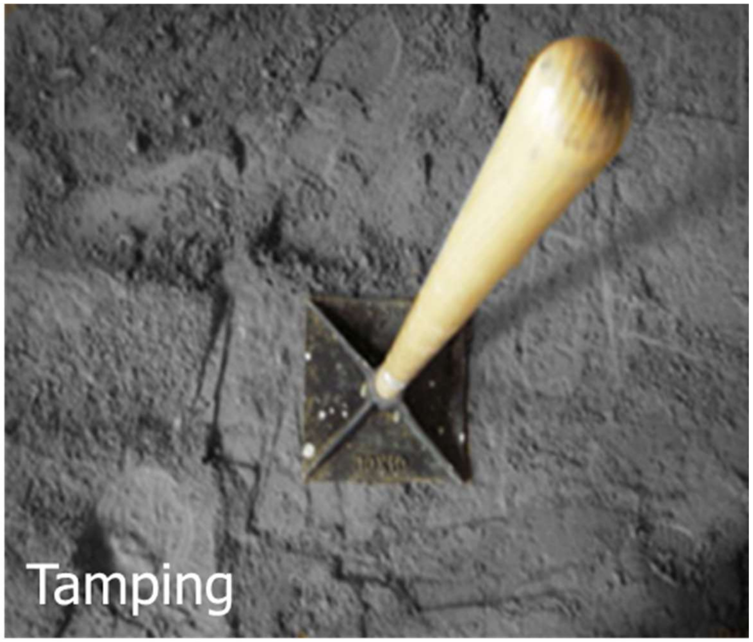
Placing concrete on a sloping surface

Compacting Concrete

- Compacting or Consolidation is the process of compacting fresh concrete to mold it within the forms and around embedded items and reinforcement to eliminate entrapped air so that the hardened concrete has a minimum voids, and, consequently, strong, and durable with low permeability.
- Consolidation can be accomplished by hand or by mechanical methods. The method chosen usually depends on
  - The consistency of the mixture
  - The placing conditions, such as complexity of the formwork and amount and spacing of reinforcement.
- Generally, mechanical methods using either internal or external vibration are preferred. However both methods can produce good quality concrete. Likewise, both methods can produce poor concrete

Hand compaction methods

The various methods of hand compaction include Rodding, Ramming and Tamping



Compaction by Mechanical Method - Vibrators

- Conceptually, when concrete is vibrated, the internal friction between the aggregate particles is temporarily disrupted and the concrete behaves like a liquid; it settles in the forms under the action of gravity and the large entrapped air voids rise more easily to the surface. Internal friction is reestablished as soon as vibration stops.
- Essentially, there are three basic methods of compacting concrete by vibration, they are Internal vibrators, External vibrators and vibrating tables.
- Vibrators, whether internal or external, are usually characterized by their frequency and amplitude of vibration.

Compaction by Mechanical Method - Vibrators

- The main advantages of using vibrators in compaction are:
  I. Making possible the use of low slump stiff mixes for production of high quality concrete.
  II. Essential in heavily reinforced members.
  III. Necessary if the available aggregates are of such poor shape and texture which would produce a concrete of poor workability unless large amount of water and cement is used.

Internal vibrators

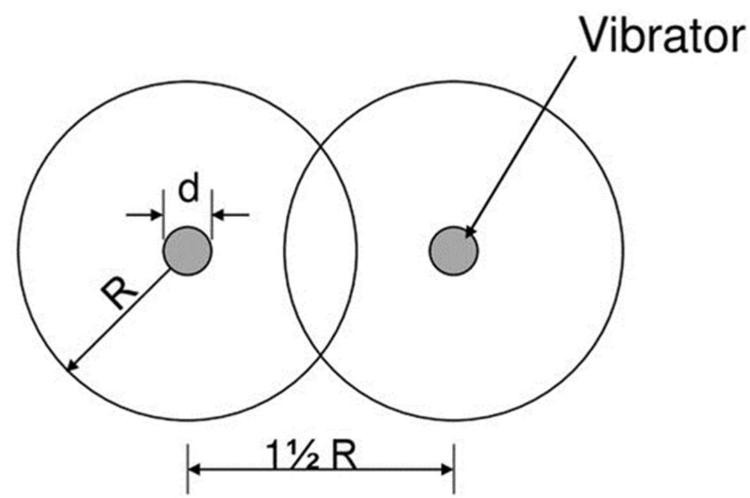
- Internal or immersion-type vibrators, often called spud or poker or Needle vibrators (see figure), are commonly used to consolidate concrete in walls, columns, beams, and slabs.

- Poker consist of a vibrating head (usually cylindrical with a diameter ranging from 20 to 180 mm) connected to a driving motor by a flexible shaft. Inside the head, an eccentric weight connected to the shaft rotates at high speed, causing the head to revolve in a circular orbit.

Performance of internal vibrator.

- The performance of internal vibrator is affected by
  - Dimensions of the vibrator head.
  - Frequency and amplitude of the vibrator
  - Workability of the mixture.
  - The effective radius of action of a vibrator (R)

- The effective radius of action of a vibrator (R) is the distance over which concrete is fully consolidated at one time and it increases with increasing diameter of the vibrator. (see the table at the next page)



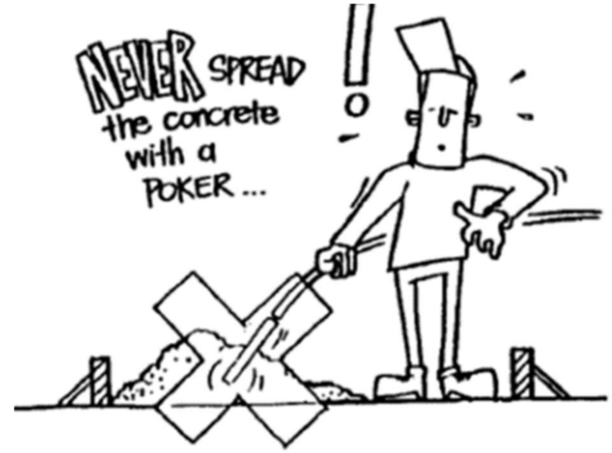
Selection of internal vibrators

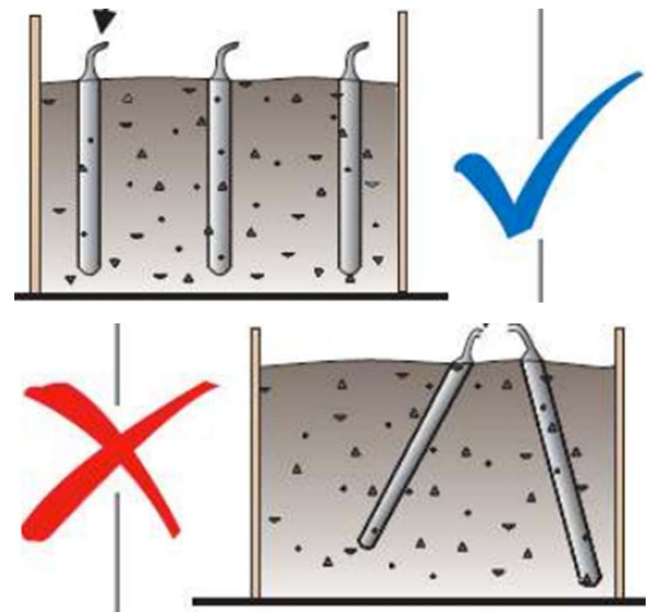
Range of Characteristics, Performance, and Applications of Internal Vibrators

Group	Diameter of head, mm (in.)	Recommended frequency, vibrations per minute**	Suggested values of: Eccentric moment, mm-kg in.-lb (10^{-3})	Suggested values of: Average amplitude, mm (in.)	Suggested values of: Centrifugal force, kg (lb)	Approximate values of: Radius of action,† mm (in.)	Approximate values of: Rate of concrete placement, m^3/h (yd^3/h)‡	Application
1	20-40 (¾-1½)	9000-15,000	3.5-12 (0.03-0.10)	0.4-0.8 (0.015-0.03)	45-180 (100-400)	80-150 (3-6)	0.8-4 (1-5)	Plastic and flowing concrete in very thin members and confined places. May be used to supplement larger vibrators, especially in prestressed work where cables and ducts cause congestion in forms. Also used for fabricating laboratory test specimens.
2	30-60 (1¼-2½)	8500-12,500	9-29 (0.08-0.25)	0.5-1.0 (0.02-0.04)	140-400 (300-900)	130-250 (5-10)	2.3-8 (3-10)	Plastic concrete in thin walls, columns, beams, precast piles, thin slabs, and along construction joints. May be used to supplement larger vibrators in confined areas.
3	50-90 (2-3½)	8000-12,000	23-81 (0.20-0.70)	0.6-1.3 (0.025-0.05)	320-900 (700-2000)	180-360 (7-14)	4.6-15 (6-20)	Stiff plastic concrete (less than 80-mm [3-in.] slump) in general construction such as walls, columns, beams, prestressed 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.
4	80-150 (3-6)	7000-10,500	8-290 (0.70-2.5)	0.8-1.5 (0.03-0.06)	680-1800 (1500-4000)	300-510 (12-20)	11-31 (15-40)	Mass and structural concrete up to 50-mm (2-in.) slump deposited in quantities up to 3 m^3 (4 yd^3) in relatively open forms of heavy construction (powerhouses, heavy bridge piers, and foundations). Also used for auxiliary vibration in dam construction near forms and around embedded items and reinforcing steel.
5	130-150 (5-6)	5500-8500	260-400 (2.25-3.50)	1.0-2.0 (0.04-0.08)	1100-2700 (2500-6000)	400-610 (16-24)	19-38 (25-50)	Mass concrete in gravity dams, large piers, massive walls, etc. Two or more vibrators will be required to operate simultaneously to mix and consolidate quantities of concrete of 3 m^3 (4 yd^3) or more deposited at one time into the form.

Proper use of internal vibrators

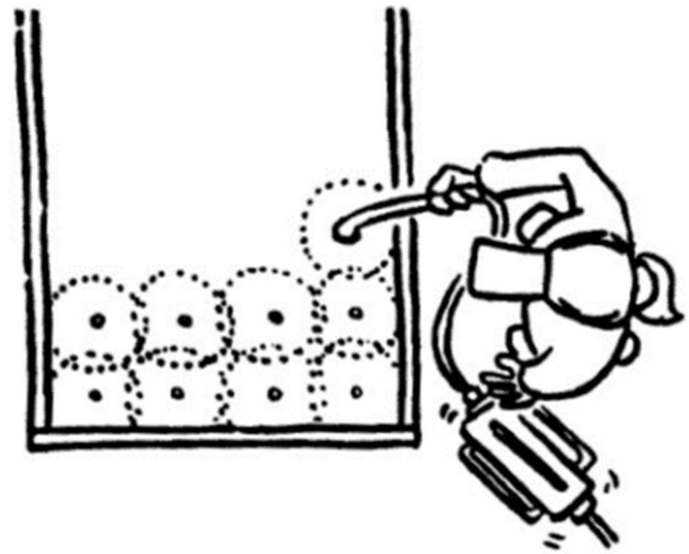
- Vibrators should not be used to move concrete horizontally since this can causes segregation.
- The vibrator should be lowered vertically into the concrete at regularly spaced intervals and allowed to descend by gravity.
- The vibrator should be held stationary until adequate consolidation is attained and then slowly withdrawn to allow the concrete to close in around the vibrator head as it is removed

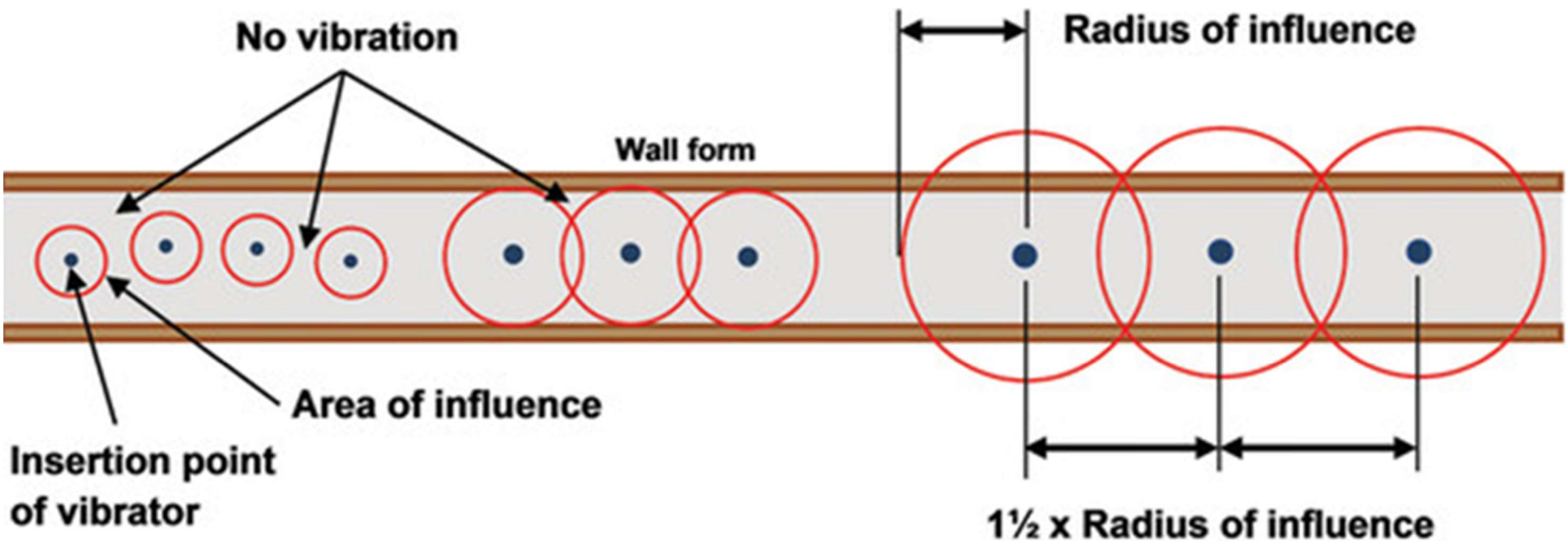




Proper use of internal vibrators

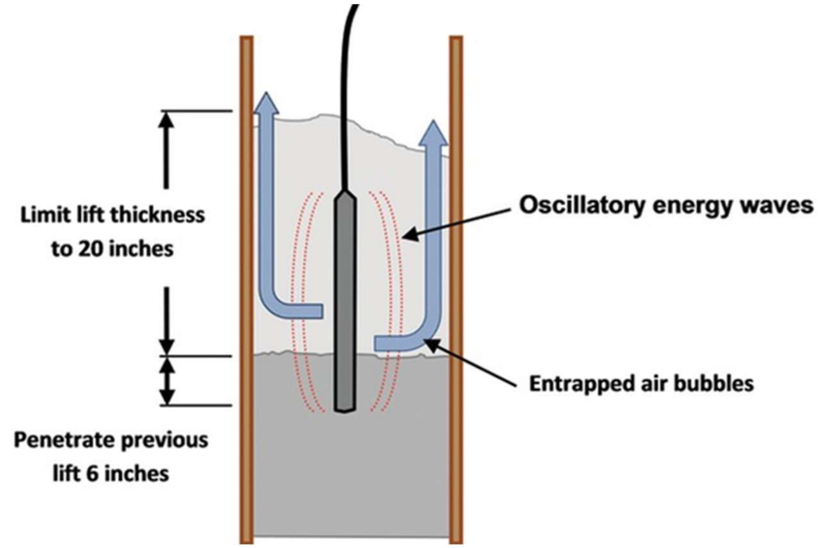
- The distance between insertions should be about 1 ½ times the effective radius so that the area visibly affected by the vibrator overlaps the adjacent previously vibrated area by a few centimeters.



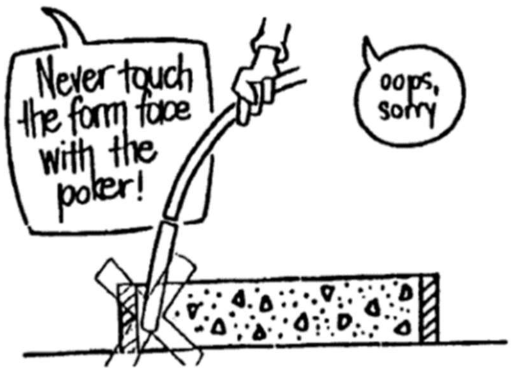


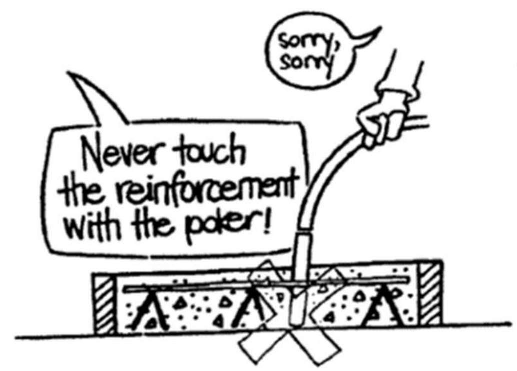
Proper use of internal vibrators

- The vibrators should penetrate to the bottom of the layer being placed and at least 150 mm (6 in.) into any previously placed layer. In this manner, monolithic concrete is obtained, thus avoiding a plane of weakness at the junction of the two layers, possible settlement cracks, and the internal effects of bleeding.



- Internal vibrators should not touch the reinforcing bars or the forms





Proper use of internal vibrators

Completion of vibration

- The length of time that a vibrator should be left in the concrete will depend on the workability of the concrete, the power of the vibrator, and the nature of the section being consolidated.
- An insertion time of 5 to 15 seconds will usually provide adequate consolidation. However adequacy of internal vibration can be judged by experience and by changes in the surface appearance of the concrete.
- Changes to watch for are the embedment of large aggregate particles, general batch leveling, the appearance of a thin film of mortar on the top surface, and the cessation of large bubbles of entrapped air escaping at the surface.
- Allowing a vibrator to remain immersed in concrete after paste accumulates over the head can result in non uniformity.

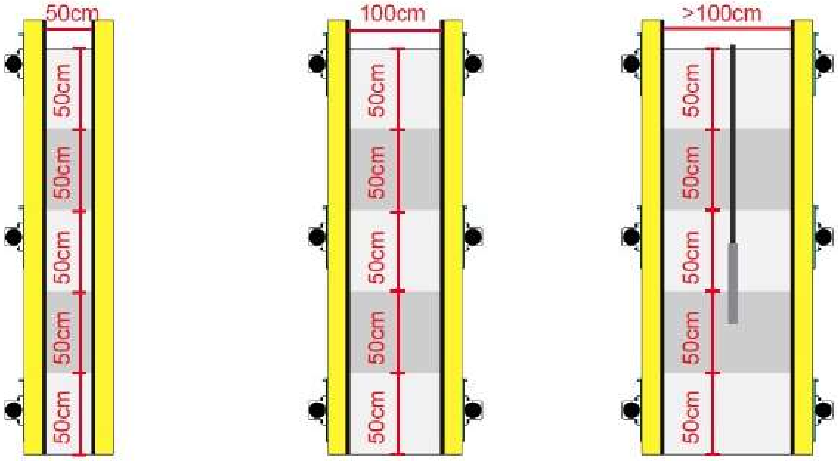
Proper use of internal vibrators

- For vibrated concrete, the formwork shall be strong, and the joints of the formwork shall be made and maintained tight and close enough to prevent the squeezing out of grout or sucking in of air during vibration. normally gaps larger than 1.5 mm between the boards should not be permitted.

External Vibration

- External vibrators can be form vibrators, vibrating tables, or surface vibrators such as vibratory screeds, plate vibrators, vibratory roller screeds, or vibratory hand floats or trowels.

Arrangement of form vibrator



Form vibrator

vibratory screed

Form vibrators

- Form vibrators is rigidly clamped to the formwork which rests on an elastic support. As a result, a considerable proportion of the work done is used in vibrating the formwork, which has to be strong and tight so as to prevent distortion and leakage of grout.
- Form vibrators are useful for consolidating concrete in members that are very thin or congested with reinforcement, stiff mixtures where internal vibrators cannot be used, and to supplement internal vibration.
- When form vibrator is used, the concrete has to be placed in layers of suitable depth as air cannot be expelled through too great a depth of concrete, and the position of the vibrator may have to be changed as concreting progresses.

Vibrating tables

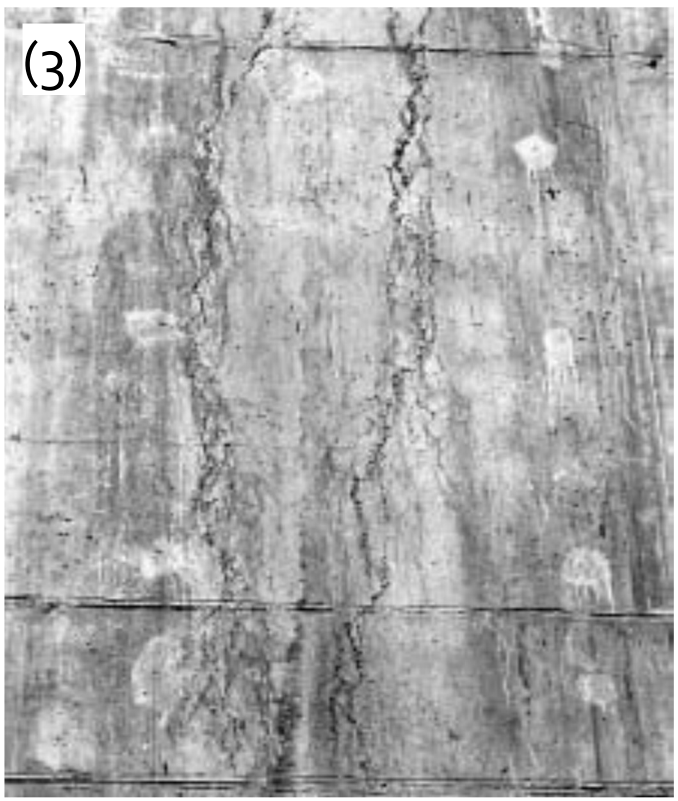
- Usually used in pre-cast concrete plants and laboratories.
- Usually equipped with controls so that the frequency and amplitude can be varied according to the size of the element to be cast and the consistency of the concrete.

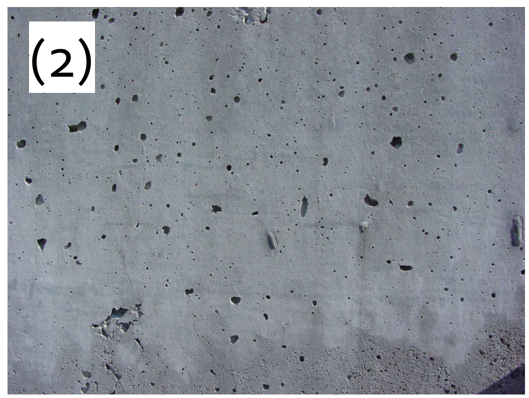
Consequences of Improper Vibration

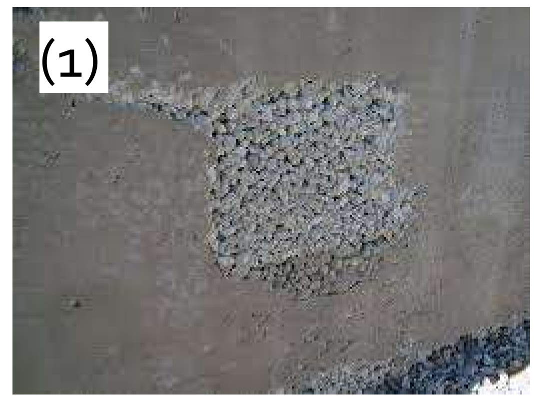
Under-vibration consequences

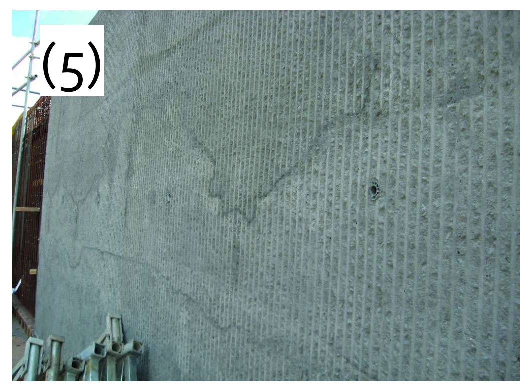
Following are some of the worst defects caused by under vibration:

(1) honeycomb; (2) excessive amount of entrapped air voids, often called bugholes; (3) sand streaks; (4) cold joints; (5) placement lines; and (6) subsidence cracking.









Consequences of Improper Vibration

Over-vibration consequences

Defects from over-vibration include:

(a) segregation as vibration and gravity causes heavier aggregates to settle while lighter aggregates rise; (b) sand streaks; (c) loss of entrained air in air-entrained concrete; (d) excessive form deflections or form damage; and (e) form failure