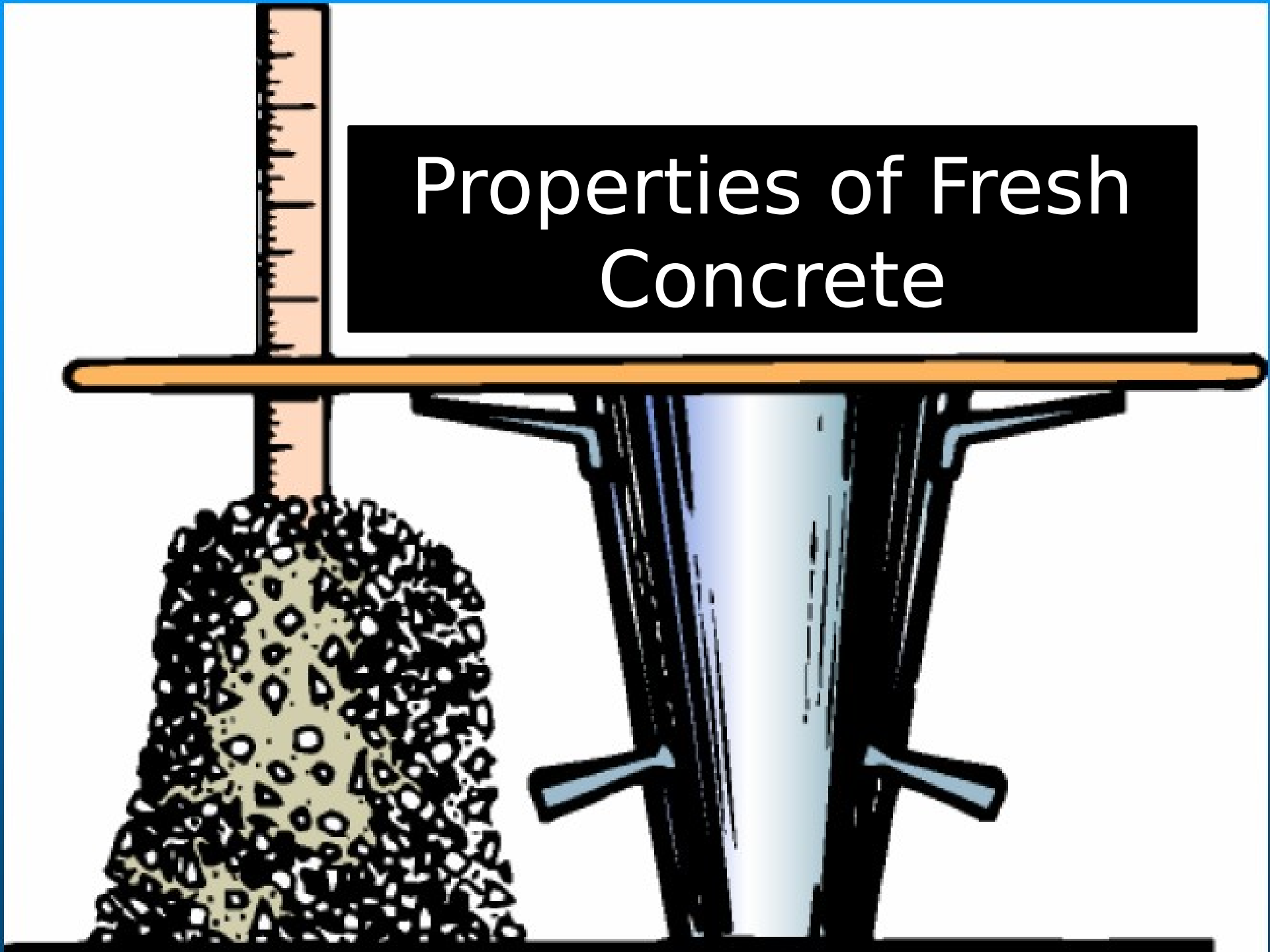
Properties of Fresh Concrete



Introduction

- Selection of proper materials and mixture proportions are important steps in producing a concrete meeting the requirements of strength and durability in a structural member.
- However, this goal will remain elusive if adequate attention is not paid to the processing operations to which concrete is subjected at early age.

Early age

- The term early age covers only an insignificant amount of time (e.g., first 2 days after production) in the total life of concrete but during this period numerous operations are performed such as mixing, transport to the job site, placement in the forms, consolidation, finishing, curing, and removal of formwork.
- The **first 48 hours are even** very important for the performance of the concrete structure → It **controls the long-term behavior**, influence f_c, E_c, creep, and durability.

What is concrete?

- Concrete, is a product or mass made by the use of a cementing medium.
- Generally, this medium is the product of reaction between hydraulic cement and water.
- Concrete is prepared by mixing cement (binder), sand (fine aggregate), gravel (coarse aggregate) and water with specific proportions.

HOW

- The hydrated cement composed of 4 major compounds namely, tri-calcium silicate (C_3S), di-calcium silicate (C_2S), tricalcium aluminate (C_3A) and tetracalcium aluminoferrite (C_4AF).
- The most important products of the hydration reaction are the calcium silicate hydrate ($C\text{-}S\text{-}H$) and the calcium hydroxide (CH).
- The hydration reactions of the major compounds can be written as below:

$$2C_3S + 6H \rightarrow C_3S_2H_3 + 3Ca(OH)_2$$

$$2C_2S + 4H \rightarrow C_3S_2H_3 + Ca(OH)_2$$

$$C_3A + 6H \rightarrow C_3AH_6$$

$$C_4AF + 2Ca(OH)_2 + 10H \rightarrow C_3AH_6 + C_3FH_6$$

Requirements of fresh concrete

1. It must be easily mixed and transported.
2. It must be uniform throughout a given batch, and between batches.
3. It must keep its fluidity during the transportation period.
4. It should have flow properties such that it is capable of completely filling the forms.
5. It must have the ability to be fully compacted without segregation.
6. It must set in a reasonable period of time.
7. It must be capable of being finished properly, either against the forms or by means of troweling or other surface treatment.

Properties at Early Ages

- Workability
- Slump Loss
- Segregation/Bleeding
- Plastic Shrinkage
- Time of Set
- Temperature

Workability

- Definition: Effort required to manipulate a concrete mixture with a minimum of segregation.
- It is not a fundamental property of concrete
- f(conditions, equipment, type of concrete, mix).
  - e.g., dry mix --> poor workability if pumped, but good workability when placed in a conveyor belt (mass concrete)

Workability

- Workability embodies certain characteristics of fresh concrete, such as consistency and cohesiveness.
- ***Consistency***, broadly speaking, is a measure of the wetness of the concrete mixture, which is commonly evaluated in terms of ***slump***.
- To obtain the specified slump, the mixture water requirement generally decreases as:

1. **The maximum size of a well-graded aggregate is increased;**
2. **The content of angular and rough-textured particles in the aggregate is reduced;**
3. **The amount of entrained air in the concrete mixture is increased; and**
4. **Coal fly ash is used as a partial replacement for a cement.**

Cohesiveness

- ***Cohesiveness*** is a measure of **compactibility** and **finishability**, which is generally evaluated by trowelability and visual judgment of resistance to segregation.
- In trial mixtures when **cohesiveness** is judged as poor, it can usually be improved by taking one or more of the following steps:
  - increase the sand/coarse aggregate ratio, partially replace the cement or sand with coal fly ash, and
  - increase the cement paste/aggregate ratio.

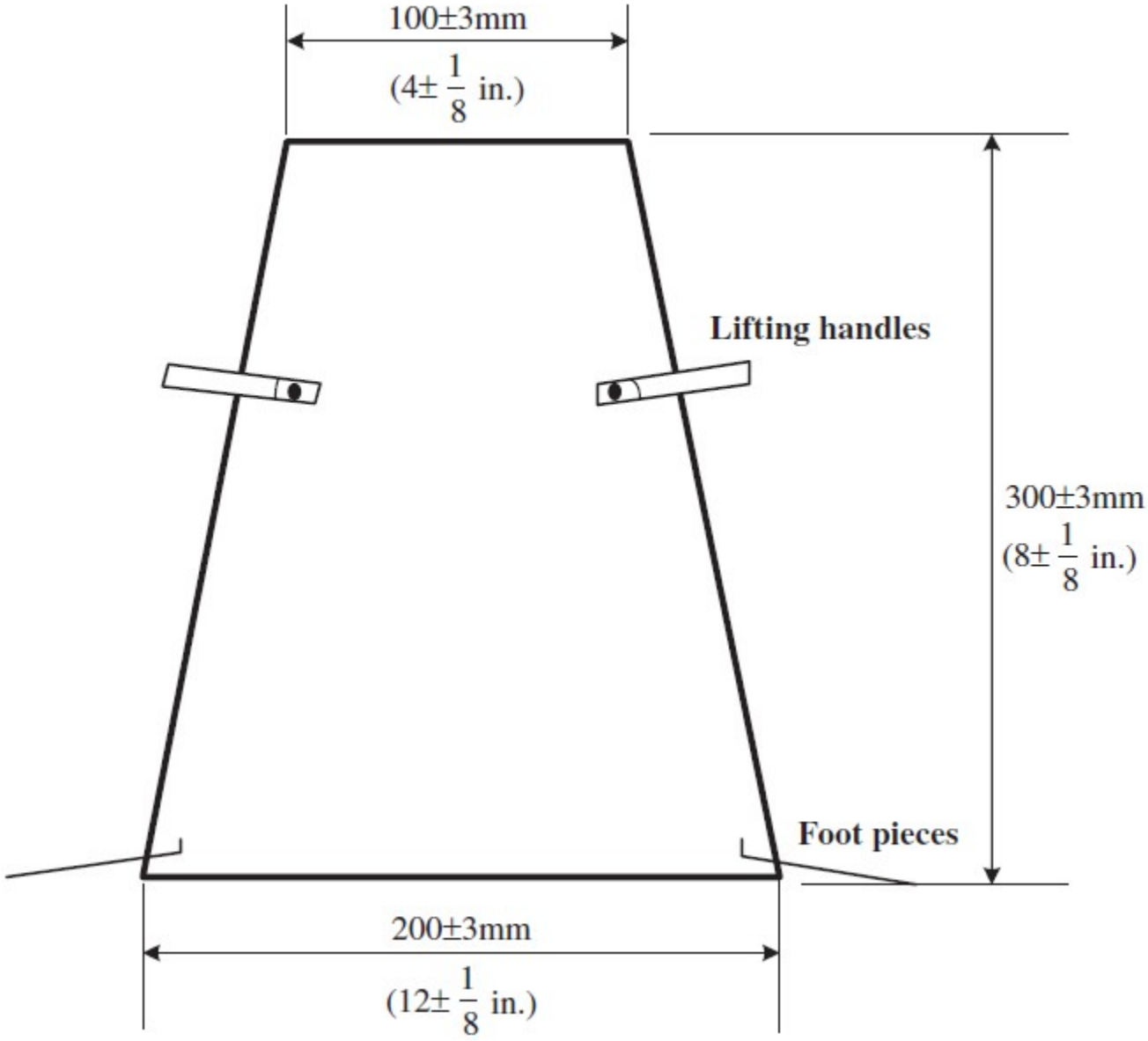
Cohesiveness …

- Due to its **lower density**, fly ash has the ability to increase the **cement mortar/aggregate** ratio by volume without an increase in the cement, water, or sand content of the mixture.
- There are no standard requirements for workability because they may vary from one job to another, depending on the type of construction and the equipment used to transport and consolidate concrete.

Tests of workability

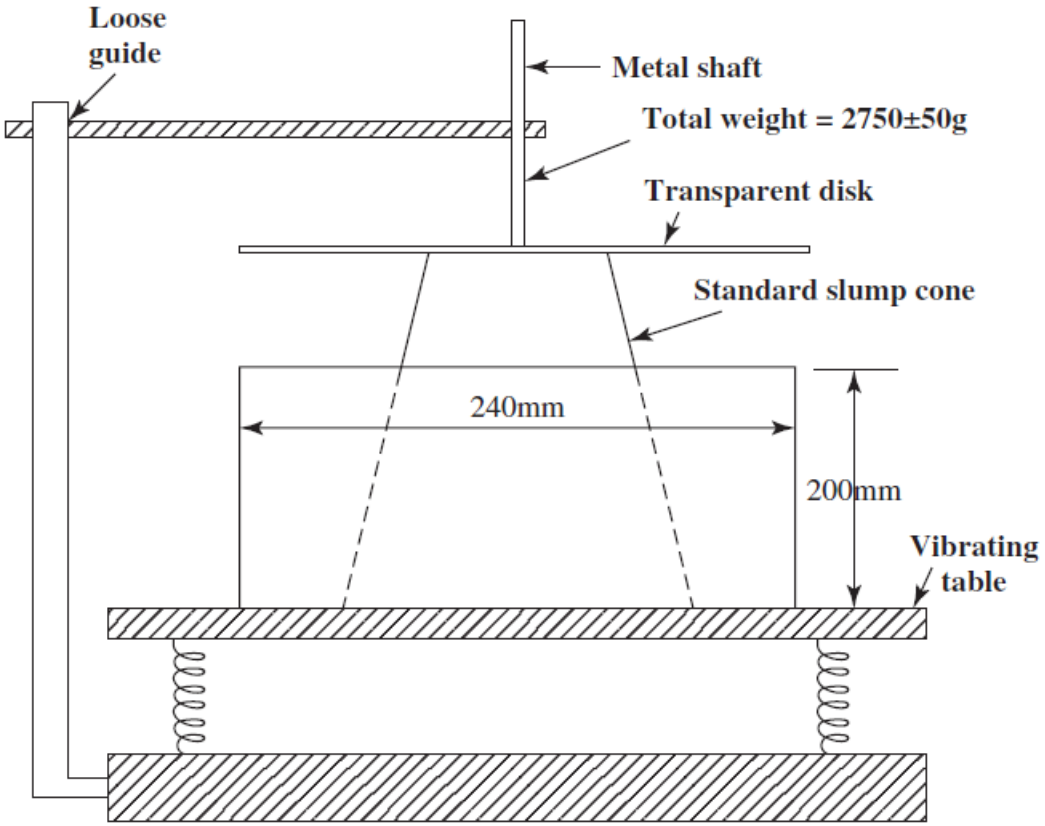
1. ***Slump test*** **-** most universally used test, which measures only the ***consistency*** of concrete.
2. ***Vebe test*** -more meaningful for mixtures with **low consistency.**
3. ***Compaction factor*****-**attempts to evaluate the compactibility characteristic of a concrete mixture.
4. ***Ball penetration test -*** related to the mechanical work.

- No equipment can measure consistency and cohesiveness at the same time



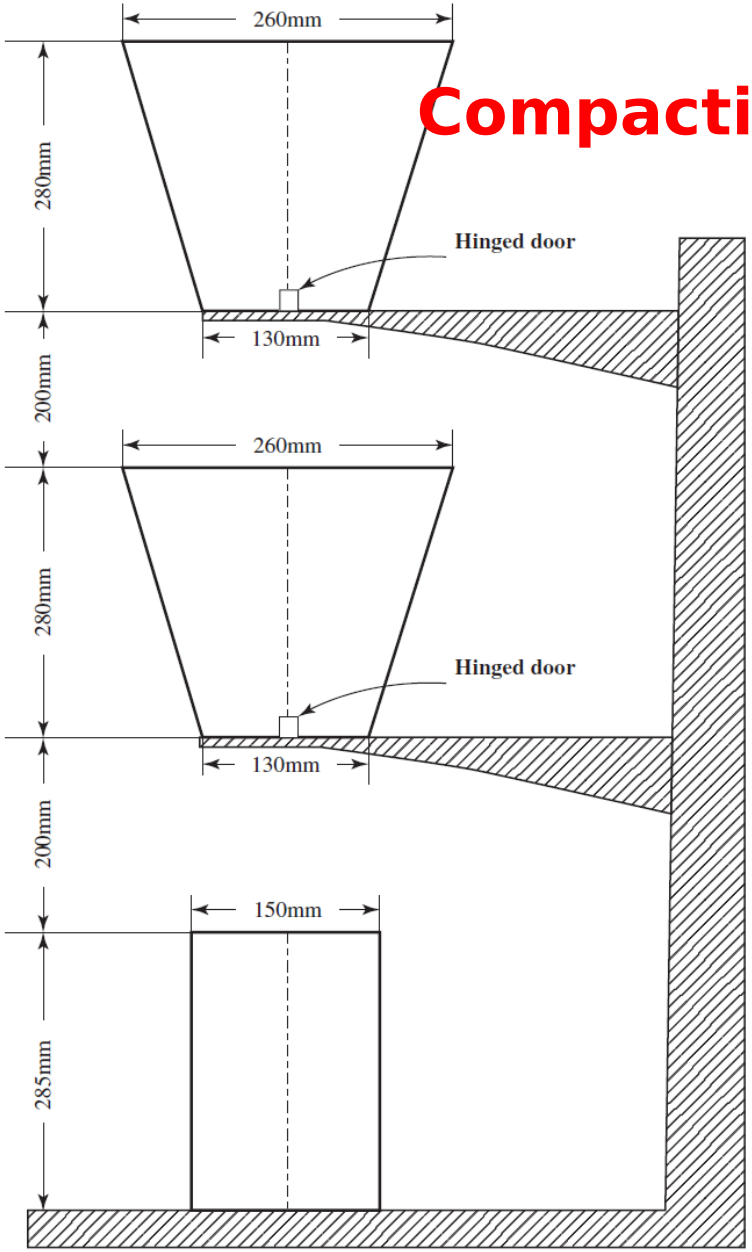
Truncated cone for the slump test



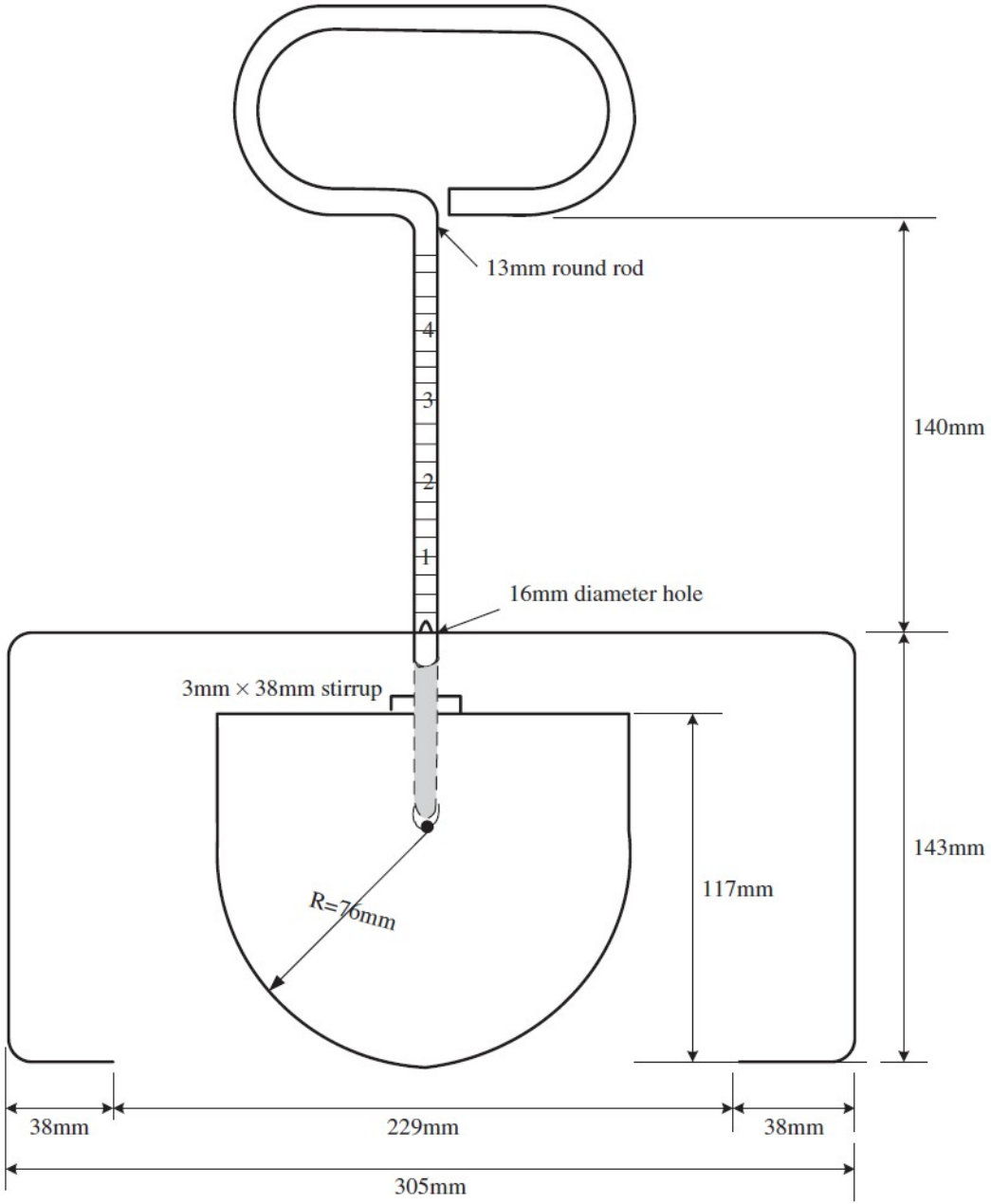


Vebe test setup

Compaction factor test apparatus



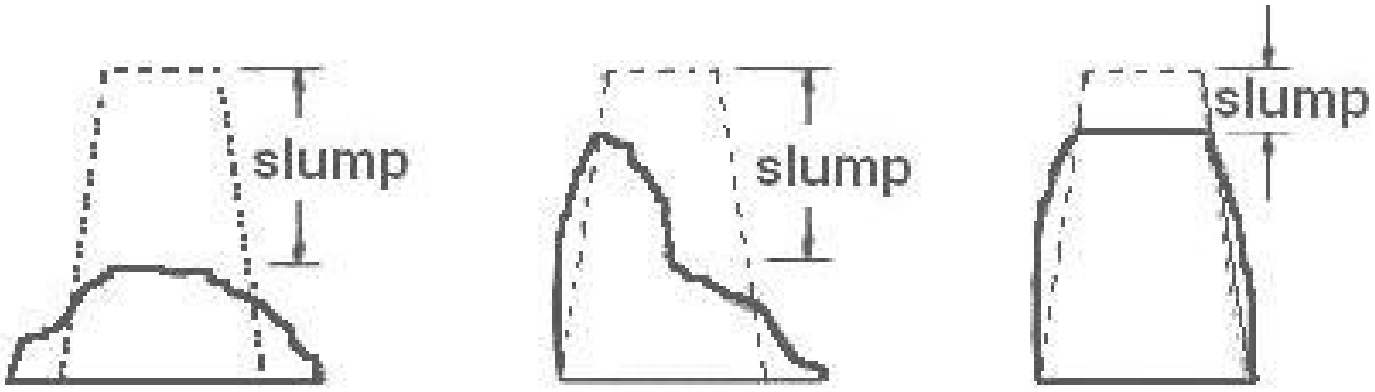








Ball penetration test setup



Collapse Shear True slump

Types of slump

Factors affecting workability

- **Water content :** water fills the spaces among the particles and “lubricates” the particles by a water film.
- Decreasing the water content will result in a low fluidity.
- If the water content is too small, the concrete will become too dry to mix and place.
- On contrary, too much water will reduce cohesiveness.

Factors …

- **Cement content:**
- For given *w/c ratio,* the larger the cement content, the higher the total water amount in the concrete; hence, the consistency of concrete will be enhanced.
  - Cement paste itself plays the roles of coating, filling, and lubrication for aggregate particles.
- In normal concrete, a considerably low cement content tends to produce a harsh mixture, with poor consistency and, subsequently, poor finishability.

Cement content …

- Increasing the fineness of the cement will decrease the fluidity of the concrete at a given *w/c ratio, but will increase the cohesiveness.*
- *Concretes containing a very high proportion* of cement or very fine cement show excellent cohesiveness but tend to be sticky

Factors …

- **Aggregate characteristics:** Aggregates can influence the workability of concrete through their need for surface coating and their friction and mobility during mixing, placing, and compaction.
- Maximum aggregate size, aggregate/cement ratio, fine aggregate/coarse aggregate ratio, and aggregate shape and texture are 4 aspects influencing the workability of concrete.

Aggregate characteristics ..

- For a given *w/c ratio,* as the maximum size of aggregate increases, the fluidity increases.
- In general, to get a similar consistency of concrete, more water is needed when crushed sand is used instead of natural sands.
- A higher aggregate/cement ratio implies more aggregates and less cement paste. Thus, the concrete consistency decreases with aggregate/cement ratio increase due to less cement paste being available for lubrication.

Aggregate characteristics ..

- Fine aggregate/coarse aggregate ratio also affects the cement paste requirement.
- With an increase of the fine aggregate/coarse aggregate ratio the consistency of concrete decreases and the cohesiveness improves.
- Increasing the **fine aggregate/coarse aggregate ratio is the most effective** measure to increase the **cohesiveness** of concrete.

Factors …

- **Admixtures:** Both chemical and mineral admixtures can influence the workability of concrete.
- **Temperature and time:** A high temperature reduces the workability and increases the slump loss because the hydration rate is higher and the loss of water is faster at a higher temperature.
  - In practice, when the ambient conditions are unusual, it is best to perform actual site tests to determine the workability of the mix.

Air content of freshly mixed concrete

- The most common method of measuring the air content of freshly mixed concrete is the "**pressure method**" **(*ASTM* C231).**
- In this method, pressure is applied to a concrete sample placed into an air meter and the reduction in volume observed on a gage calibrated in terms of % air.
- The observed amount of air includes both the purposely entrained air as well as the entrapped air (about 1% by volume of concrete).

Causes of Slump Loss

1. Use of an abnormal setting cement
2. unusual long time for mixing, transporting or finishing
3. High temperature due to excessive heat of hydration.

Example:

- Type II cement (low in C3A ~6%)
- T= 70 F

Initial Slump	30 min	60 min	2h
5 in	4 3/8	3 1/8	1 1/2

Type I cement (10% C3A)

Initial Slump	30 min	60 min	2h
5 in	3 1/4	2 1/4	1

Increasing the water content

	Initial	30 min	60 min	2h
Type II	7 1/2	7	5 1/2	2
Type I	7 1/2	4 3/4	3 1/4	1 1/2

so, adding more water does not solve the problem

Batching, Mixing, and Transport

- Batching is the process of measuring and introducing into the mixer the ingredients for a batch of concrete.
- Most specifications require that *batching* of concrete ingredients be carried out by mass rather than by volume.
- This is because *bulking of damp sand* causes inaccuracies in measurement.

Batching …

- Water and liquid admixtures can be batched accurately either by volume or weight.
- In many countries most concrete today is batched and mixed by ready-mixed concrete plants, where the batching is generally automatic or semi-automatic rather than manual.
- *Transportation of the ready-mixed* concrete to a job site should be done as quickly as possible to minimize stiffening to the point that, after the placement, full consolidation and proper finishing become difficult.

Centrally mixed concrete in a ready-mixed concrete plant



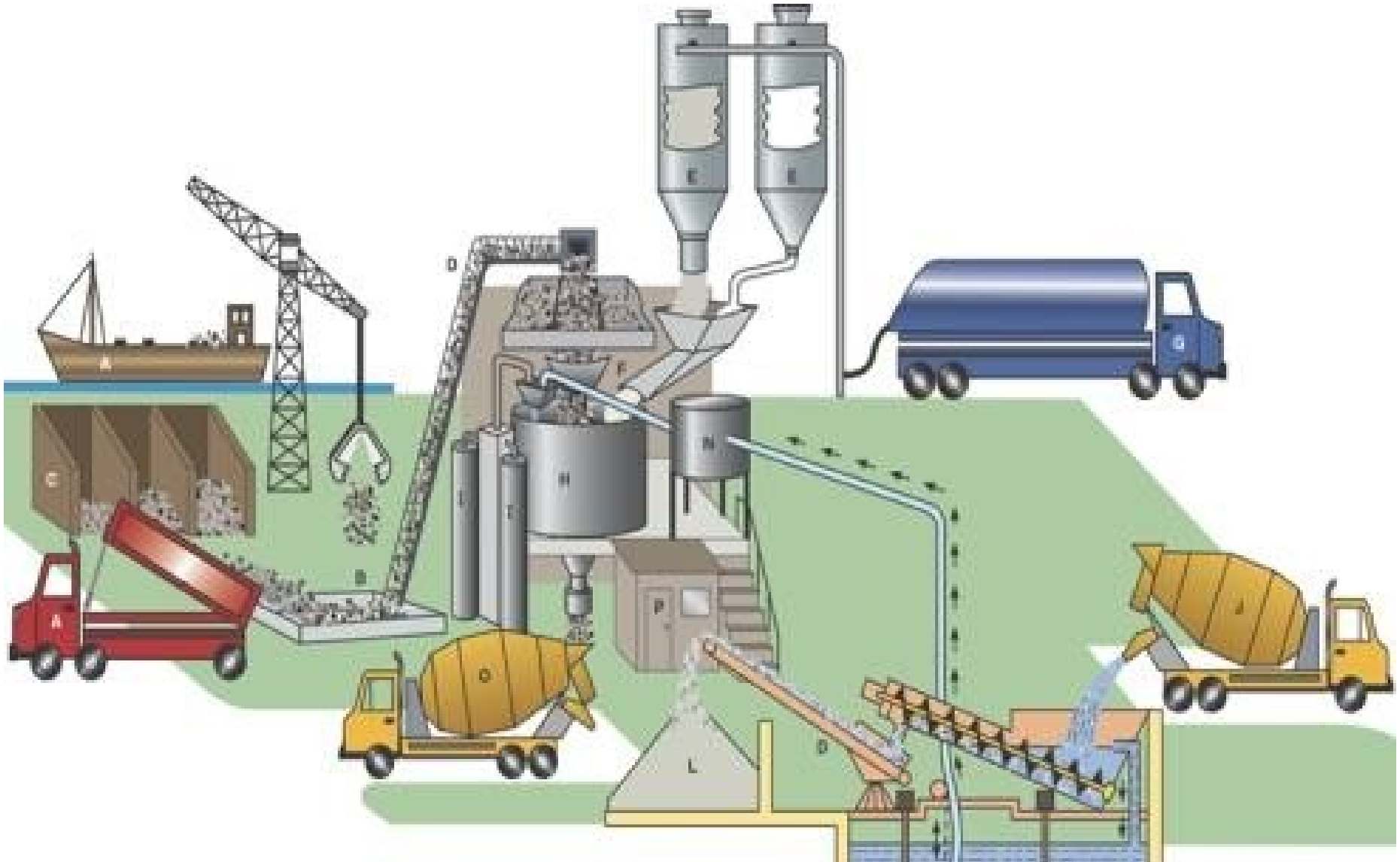
Transportation

- When concrete is kept in a slow state of agitation or is mixed periodically, it undergoes some slump loss with time but, normally this does not present a serious problem for the placement and consolidation of freshly made concrete within 90 min.
- Special attention must be paid to possible delays in transporting and placing concrete under hot and dry weather conditions.

Equipments

- Truck Agitator
- Truck mixer
- Nonagitating Truck
- Mobile continuous mixer
- Crane & Buckets
- Barrows and buggies
- chutes

- Belt conveyors
- Tremies
- Screw spreaders
- Pneumatic guns
- Concrete Pumps
- Dropchutes



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





Versatile power buggy can move all types of concrete over short distances



Screw Spreaders



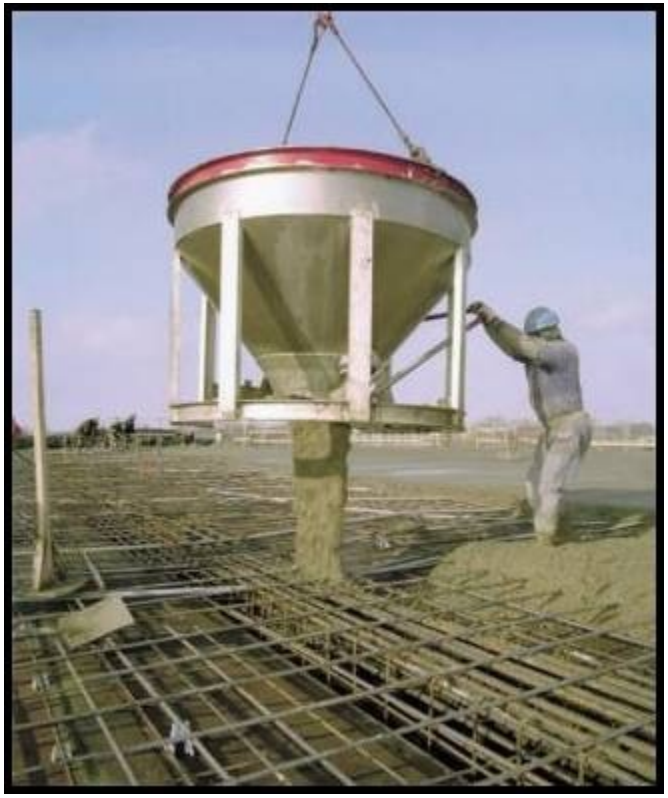


The conveyor belt is an efficient, portable method of handling concrete

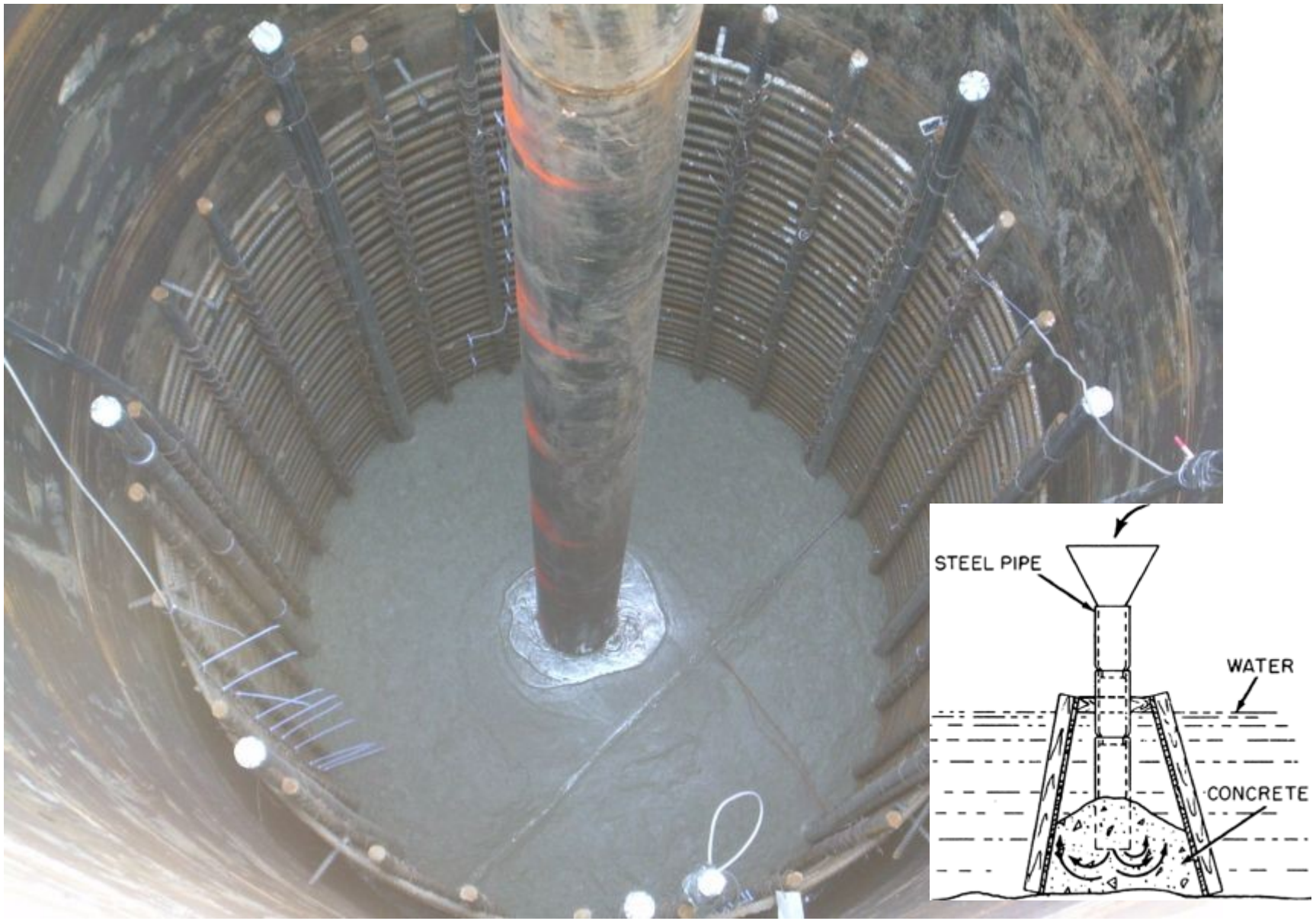


A pump boom mounted on a mast and located near the center of a structure can frequently reach all points of placement. It is especially applicable to tall buildings where tower cranes cannot be tied up with placing concrete. Concrete is supplied to the boom through a pipeline from a ground-level pump. Concrete can be pumped hundreds of meters vertically with these pumping





Concrete is easily lifted to its final location by bucket and crane.



Concrete being placed by **tremie** inside the shaft.

Placing, Compacting, and Finishing

- After arrival at the job site, the ready-mixed concrete should be placed as near as possible to its final position.
- Belt conveyers, truck-mounted chutes, and mobile-boom pumps are among the most commonly used today for *concrete placement.*
- *To minimize segregation, concrete should not be moved* over too long a distance during the placement into forms.

Consolidation or compaction

- *Vibration, whether internal or external, is the most widely used method for* compacting concrete.
- The internal friction between the coarse aggregate particles is greatly reduced on vibration; consequently, the mixture behaves like a liquid and begins to flow into the empty space.
- Several specialty types of vibrators are used in the production of precast concrete.
  - These include *external vibrators, vibrating tables, surface vibrators, electric hammers,* and *vibratory rollers (Neville, 1996).*

Consolidation …

- One purpose of using internal vibrators is to force entrapped air out of the concrete by plunging the vibrator **rapidly into the mixture and removing it slowly with an up-and down motion**.
- The rapid penetration forces the concrete upward and outward, thereby helping the air to escape.
- Nowadays, the newly developed self-compacting concrete can reach a dense structure by its self-weight without any vibration.

Consolidation …

- *Internal or immersion-type vibrators,* also called spud or poker vibrators, are commonly used for compacting concrete in beams, columns, walls, and slabs.
- *External or form vibrators* can be securely clamped to the outside of the forms.
  - They are commonly used for compacting thin or heavily reinforced concrete members.
- vibration of a member congested with reinforcement helps to remove air and water that may be entrapped underneath the reinforcing bars thus **improving the bond between the bars and concrete.**

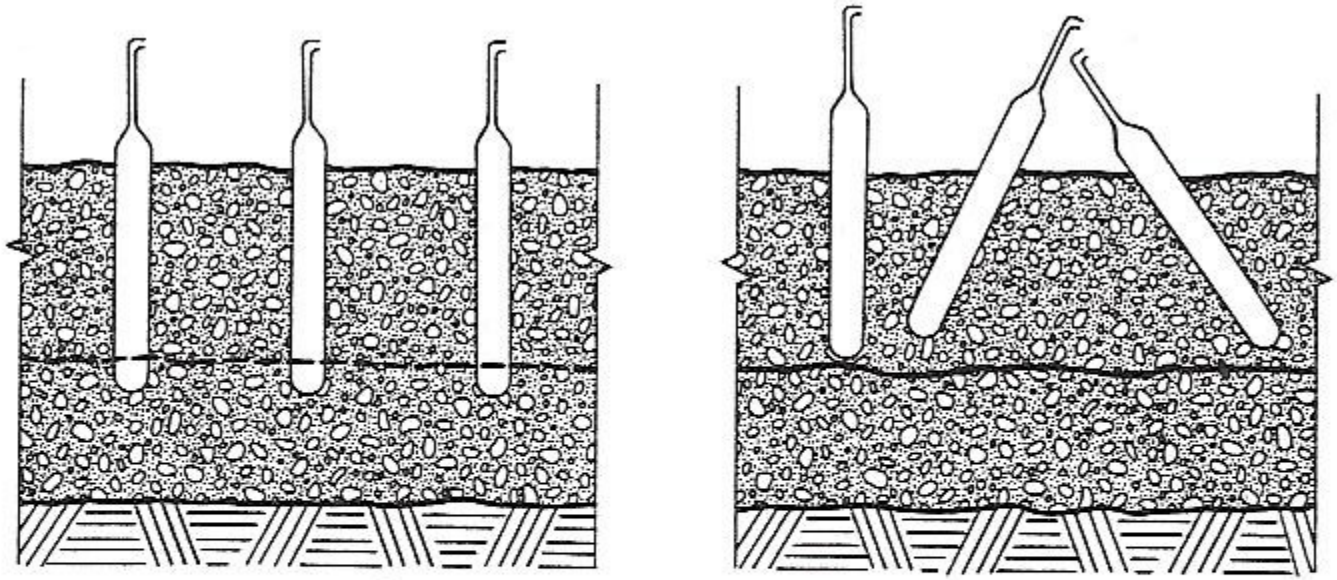


Fig. 7.11: Placing of poker vibrators
(Based on *ACI Manual of Concrete Practice.*)

Segregation of a reinforced concrete column





Segregation due to over-vibration



Fig. 3: Segregation in over-vibrated concrete. The cylinder on the left was vibrated longer

Concrete Curing

- The two *objectives of curing* are:
  1. To prevent the loss of moisture and
  2. To **control the temperature of concrete** for a period sufficient to achieve a desired strength level.
- When the ambient temperature is sufficiently well above freezing, the curing of pavements and slabs can be accomplished by ponding or immersion; other structures can be cured by spraying or fogging, or moisture-retaining coverings saturated with water.

Concrete Curing ...

- These methods afford some **cooling through evaporation**, which is beneficial in hot-weather concreting.
- Another group of methods are based on prevention of moisture loss from concrete by sealing the surface through the application of ***waterproof curing paper***, ***polyethylene sheets***, or ***membrane-forming curing compounds***.
- The use of curing compounds is preferred for speedy construction.

Concrete Curing …

- When the ambient temperature is low, concrete must be protected from freezing with the help of insulating blankets.
- In cold weather, the rate of strength gain can be accelerated by curing concrete with live steam, heating coils, or electrically heated forms or pads.
- The choice of the specific curing method or combination of methods depends on the **availability of curing materials**, **size and shape of the structure** and economics.

Spraying or Fogging

- A system of nozzles or sprayers can be used to provide continuous spraying or fogging.
- This method requires a large amount of water and could be **expensive**.
- It is most suitable in **high temperature** and **low humidity environments**.

Wet Coverings

- Moisture-retaining fabric coverings saturated with water, such as **burlap**, **cotton mats**, and **rugs** are used in many applications.
- The fabric can be kept wet, either by periodic watering or covering the fabric with **polyethylene film** to retain moisture.
- On small jobs, wet coverings of earth, sand, saw dust, hay, or straw can be used.



Burla



Polyethylene film



Hays



Fogging









Curing period

- For Portland cement concrete, a minimum period of 7 days of moist curing is generally recommended.
- If curing is carried out at a higher temperature, the hydration products form faster, but they do not form uniformly.
  - As a result, the long-term strength is reduced.

Formwork removal

- Generally the last operation carried out during the “early-age” period of concrete.
- The operation has economic implication because, on the one hand, early removal of formwork keeps the construction cost low, while on the other hand, concrete structures have failed when forms were stripped before concrete had attained sufficient strength.
- Formwork should not be removed until the concrete is strong enough to carry the stresses from both the dead load and the imposed construction load.

Discussion topics

- Can you describe the terms of workability, consistency, cohesiveness, segregation, and bleeding of freshly concrete?
- What are the methods to evaluate the workability of fresh concrete? What are their suitability and limitations?
- Discuss the factors affecting consistency of concrete.
- Discuss the factors affecting cohesion of concrete.
- Why does workability decrease with time? Discuss the role of water in fresh concrete.
- Discuss the commonly used methods of curing and their suitability.
- Discuss the effects of curing in ensuring concrete quality.