Concrete and Concrete Making Materials

1.1 Ingredients of Concrete

What is Concrete?

Concrete is a composite material made up of inert materials of varying sizes, which are bound together by a binding medium.

The strength of concrete is dependent on the strength of the aggregate paste bond.

Composition of Concrete

Concrete

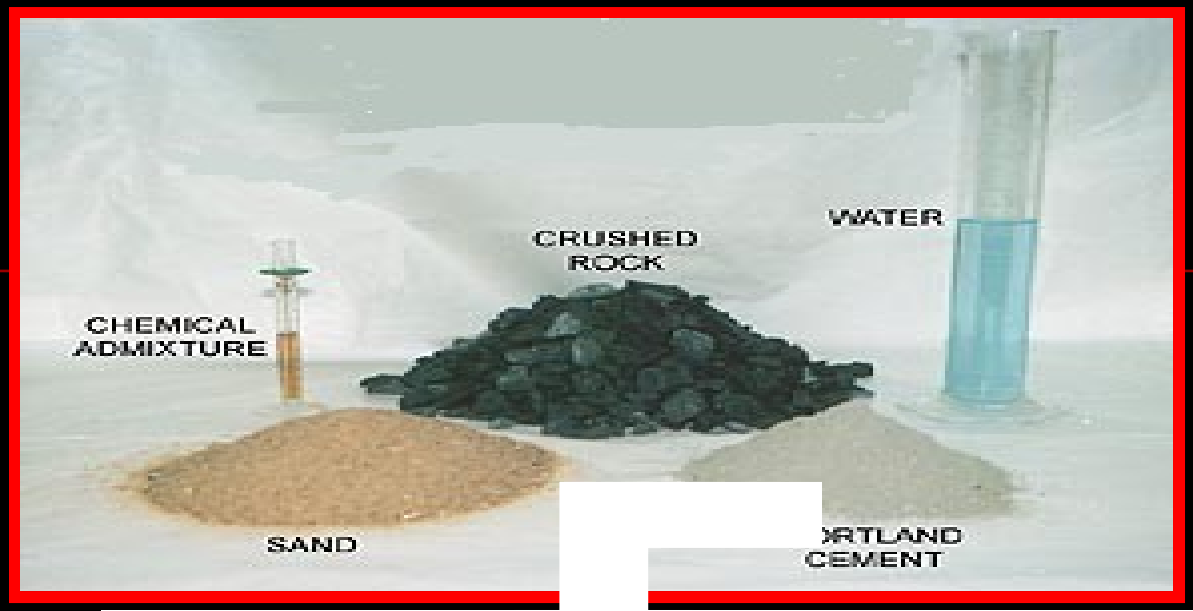
- Portland Cement
- *Water*
- *Air (entrapped or entrained)*

Paste

- Fine Aggregate (Sand)
- Coarse Aggregate (Gravel)

Aggregate

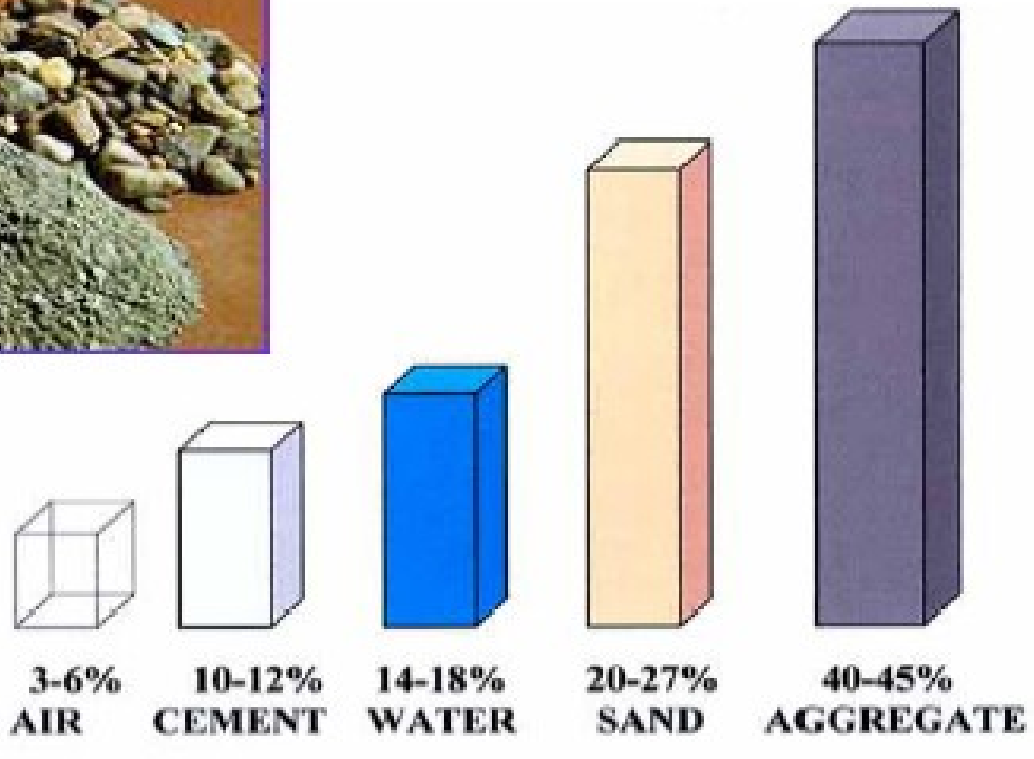
- Admixture (If required)


WATER
CRUSHED
ROCK
CHEMICAL
ADMIXTURE
SAND
ORTLAND
CEMENT



Composition of Concrete





Types and Uses of Concrete

Concrete is a very versatile material and can be made to satisfy a large variety of requirements.

1. **Plain (mass) concrete**
2. **No-fines concrete**
3. **Lightweight aggregate concrete**
4. **Aerated concrete**
5. **Reinforced concrete**

Advantages of Concrete

Good-quality concrete has many advantages:

- It is economical when ingredients are readily available.
- Its long life and relatively low maintenance requirements increase its economic benefits.

- It is not as likely to rot, corrode, or decay as other building materials.

- It has the ability to be molded or cast into almost any desired shape.

- It is a non-combustible material which makes it fire-safe and able withstand high temperatures.

- It is resistant to wind, water, rodents, and insects. Hence, concrete is often used for storm shelters.

- It has high compressive strength, resistance to weathering, impact and abrasion.

- Building of the molds and casting can occur on the work-site which reduces costs.

Disadvantages of Concrete

Some of disadvantages of concrete are:

- High cost of cement, steel and formwork (in developing countries).
- Difficult quality control on building sites, with the risk of cracking and gradual deterioration, if wrongly mixed, placed and insufficiently cured with water.

Disadvantages of Concrete

- In moist climates or coastal regions, corrosion of reinforcement (if insufficiently protected), leading to expansion cracks.
- Low tensile strength (but can be overcome with steel reinforcement).
- Demolishing concrete is difficult.

Ingredients of Concrete

- **Portland Cement**
- **Water**
- **Aggregates**
- **Admixtures (Additives)**

Portland Cement

- Dry power of very fine particles
- Forms a paste when mixed with water
- Chemical reaction –Hydration
- Paste coats all the aggregates together
- Hardens and forms solid mass

Usually, Portland cement is specified for general concrete construction work and should confirm to standard specifications. Various types of Portland cement as well as physical & chemical requirements were discussed in the previous course.

Water

Water serves two purposes in making concrete:

- It triggers the hydration of cement (only 1/3 of the water) and
- It makes the mix fluid and workable.

Surplus water = bad for strength, durability and permeability.

Clean water is important any impurities present will affect bond strength between the paste and aggregate.





Undesirable effects of impurities in mixing water:

Impurities in mixing water may cause any one or all of the following:

- ✓ Abnormal setting time
- ✓ Decreased strength
- ✓ Volume changes
- ✓ Efflorescence
- ✓ Corrosion of reinforcement

Some of the impurities in mixing water that cause undesirable effects in the final concrete:

1. Dissolved chemicals

- ✓ May either accelerate or retard the set and can substantially reduce the concrete strength.
- ✓ Can actively attack the cement-aggregate bond, leading to early disintegration of the concrete.

2. Seawater

- Seawater containing less than three percent salt is generally acceptable for plain concrete but not for reinforced concrete.

- The presence of salt can lead to corrosion of the reinforcing bars and a decrease in concrete strength by some 10-15%.

3. Algae

- Can cause a reduction in the strength of concrete by increasing the amount of air captured in the paste and
- Reduce the bond strength between the paste and the aggregate.

4. Sugar

If *sugar* is present in even small amounts, it can cause rapid setting and reduced concrete strength.

1.1.3 Aggregates



Quarry



Quarry



Aggregates

Aggregates are the filler materials which make up a large portion (roughly 65-80%) of the concrete volume. Considerable care should be taken to provide the best aggregates available.



Types of rock commonly used as aggregate

Sedimentary rock



Shale



Siltstone



Sandstone



Limestone

Igneous rock



Trap rock



Pegmat



Granite



Gabro

Metamorphic rock



Amphibolite



Gneiss



Slate



Marble

Classification of aggregates based on source_

Natural aggregates are taken from natural deposits without change in their nature during production, with the exception of crushing, sizing, grading, or during production. *In this group crushed stone, gravel, and sand are the most common.*

Manufactured aggregates include blast furnace slag and lightweight aggregates.

Recycled Aggregate – e.g. crushed concrete, clay bricks

Classification of aggregates based on size

- Fine aggregate: < 4.75 (No.4 sieve)
- Coarse aggregate: predominantly retained on the No.4 (4.75mm) sieve.





Classification based on Condit

- Crushed

From quarry - sharp, angular particles, rough surface, good bond strength, low workability

- Uncrushed

From river - round shapes, smooth surface, low bonding properties, high workability





Aggregate Terms and Types

The terms used to describe aggregates are many and varied. These descriptive terms are based on source, size, shape, type, use and other properties.

Some typical terms used in describing aggregates are:

1. **Fine aggregate**- aggregate particles passing the No. 4 (4.75mm) sieve and retained on the No. 200 (75µm) sieve.

2. **Coarse aggregate**- aggregate predominantly retained on the No.4 (4.75mm) sieve.

3. **Crushed gravel (gravel and sand)-** that has been put through a crusher either to break many of the rounded gravel particles to a smaller size or to produce rough surfaces.

4. **Crushed rock-** aggregate from the crushing of rock. All particles are angular, not rounded as in gravel.

5. **Screenings-** the chips and dust or powder that are produced in the crushing of rock for aggregates.

6. **All-in-aggregate-** aggregate composed of both fine and coarse aggregate.

7. **Concrete sand-** sand that has been washed (usually) to remove dust & fines.

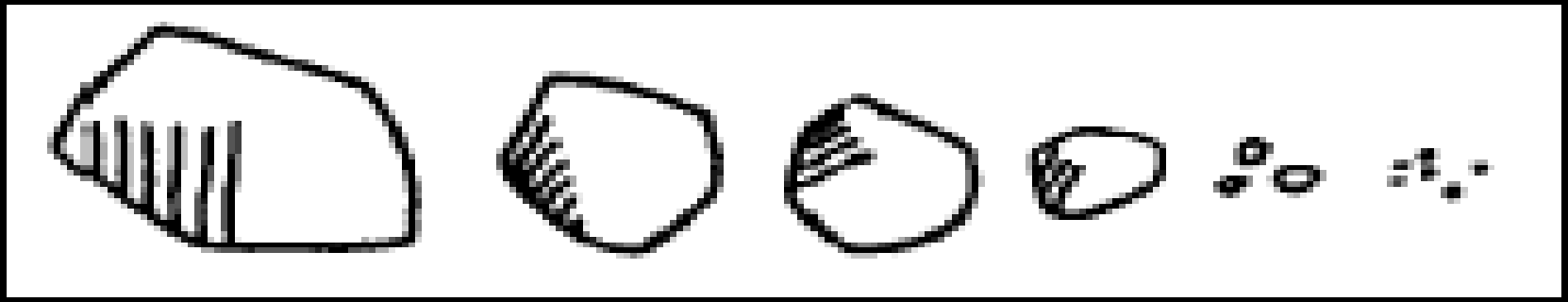
8. **Fines-** silty-clay or dust particles smaller than 75 micro m (No. 200 sieve) usually undesirable impurities in aggregates.

Properties of Aggregates

Important properties of aggregates include:

- Gradation (grain size distribution)
- Shape and surface texture
- Bulk unit weight
- Specific gravity (relative density)
- Absorption
- Hardness (resistance to abrasion or wear)
- Durability (resistance to weathering)
- Crushing strength
- Cleanliness (deleterious substances)
- Chemical stability

Gradation of Aggregates



Grading: is the distribution of particles of angular materials among various sizes



The gradation of aggregates influences:

- ✓ the amount of paste required
- ✓ the workability of the concrete
- ✓ the strength and
- ✓ water tightness of the finished product

In general, it is desirable that the size increase uniformly from fine sand to the maximum allowed for a given job.

Most specifications for concrete require a grain size distribution that will provide a dense and strong mixture.

Types of gradation

Aggregates may be:

- Dense
- Well graded
- Gap-graded
- Uniform
- Open-graded

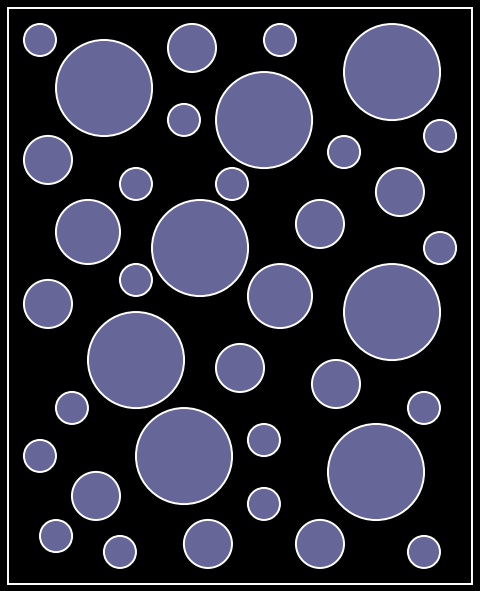
Well-graded

Poorly graded

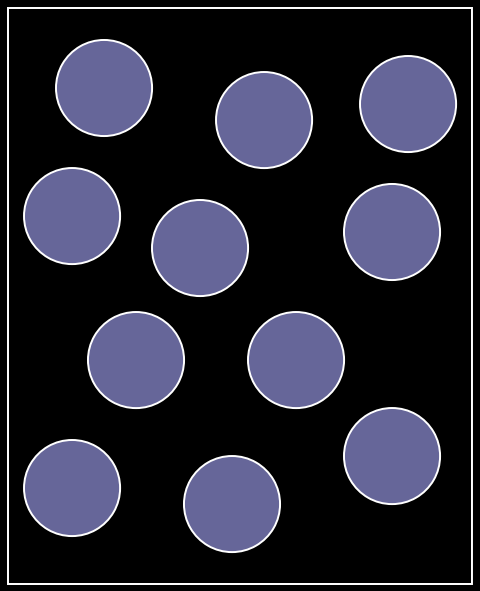
The terms “dense” and “well-graded” are essentially the same, as are “gap”, “uniform” and “open-graded”

Grading of aggregates

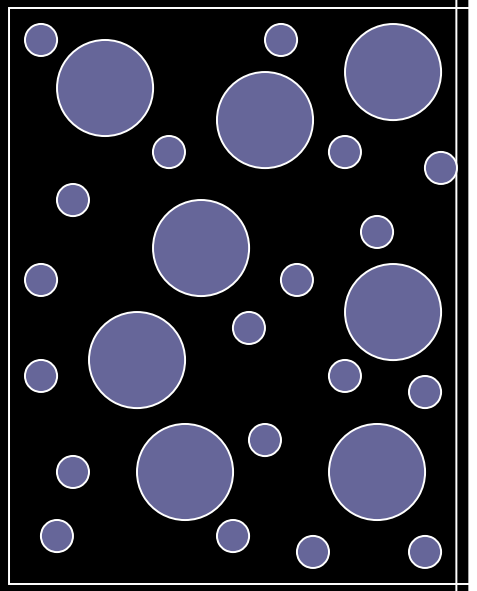
Well graded **Uniform graded** **Gap graded**



The range of size are approximately in equal amounts



Most particles are of the same size



Most particles are of large or small size

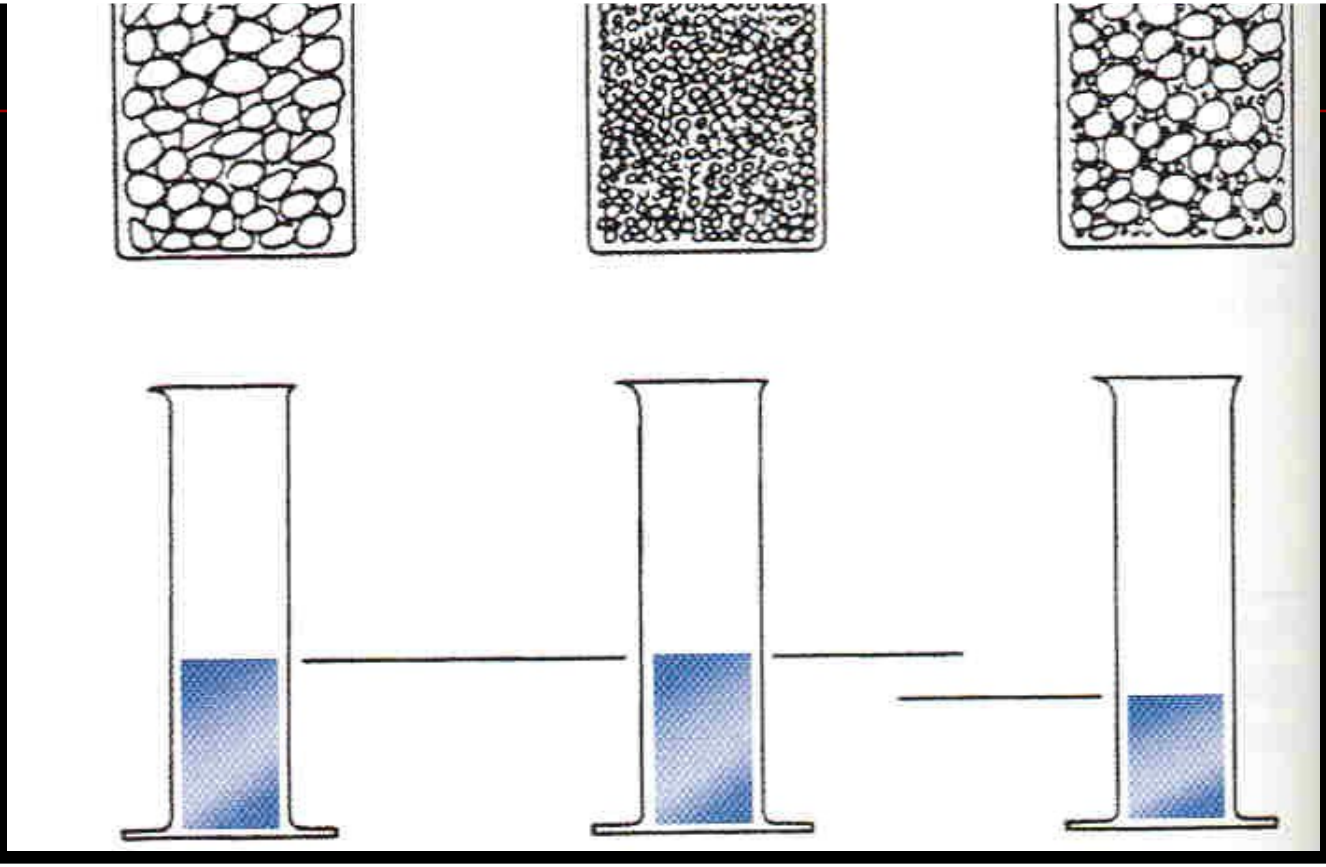
Well graded aggregates:

- Improve workability of the concrete and economy of the cement.

  (Such aggregate has a decreased amount of voids between the particles and consequently requires less cement paste).

- Produces a stronger concrete than a poorly graded one (less water is required to give suitable workability)

Proper selection of various sizes will be very effective in reducing the total volume of voids between aggregates



The cement paste requirement is related the void content of the combined aggregates.

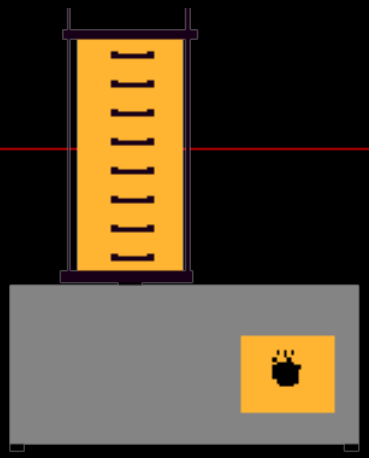
SIEVE ANALYSIS

The grading or particle size distribution of aggregate is det y sieve analysis.









Sieve Analysis



Sampling

Sample Reduction

Riffling or quartering are the two methods most often used to reduce a bulk sample to a representative size suitable for testing.

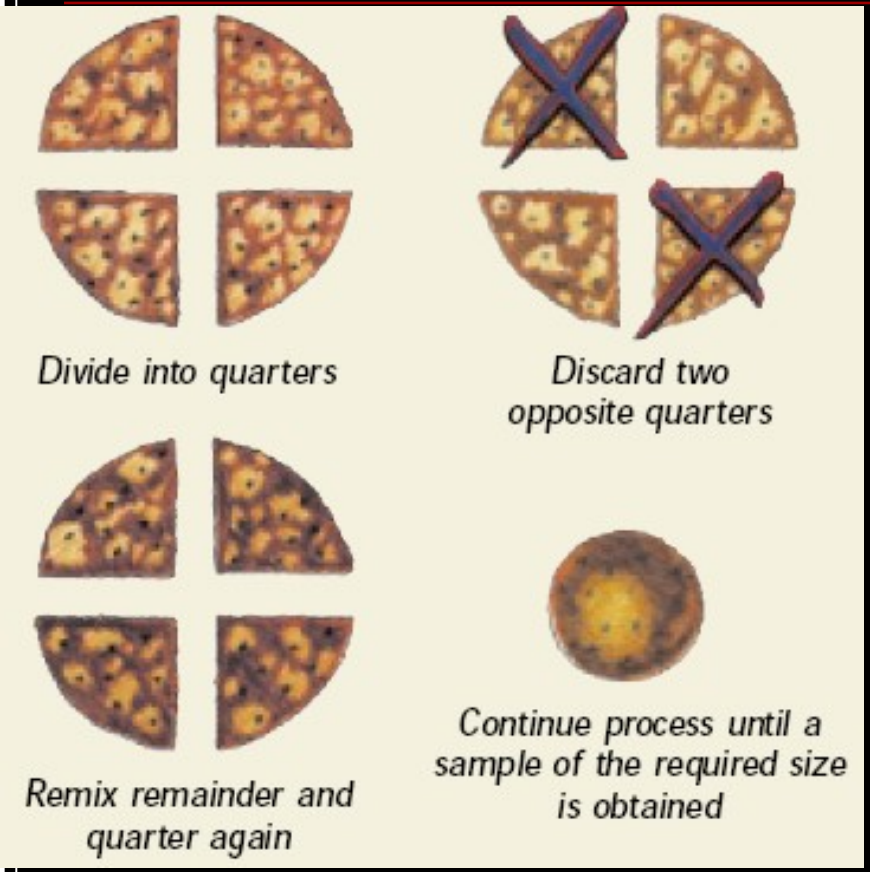
A Riffling, normally used for reducing material which is in a surface dry condition.

B Quartering can be used to reduce damp material down to a quantity which can be further prepared, e.g. by drying and then riffling.



Flatten the main sample

Quartering



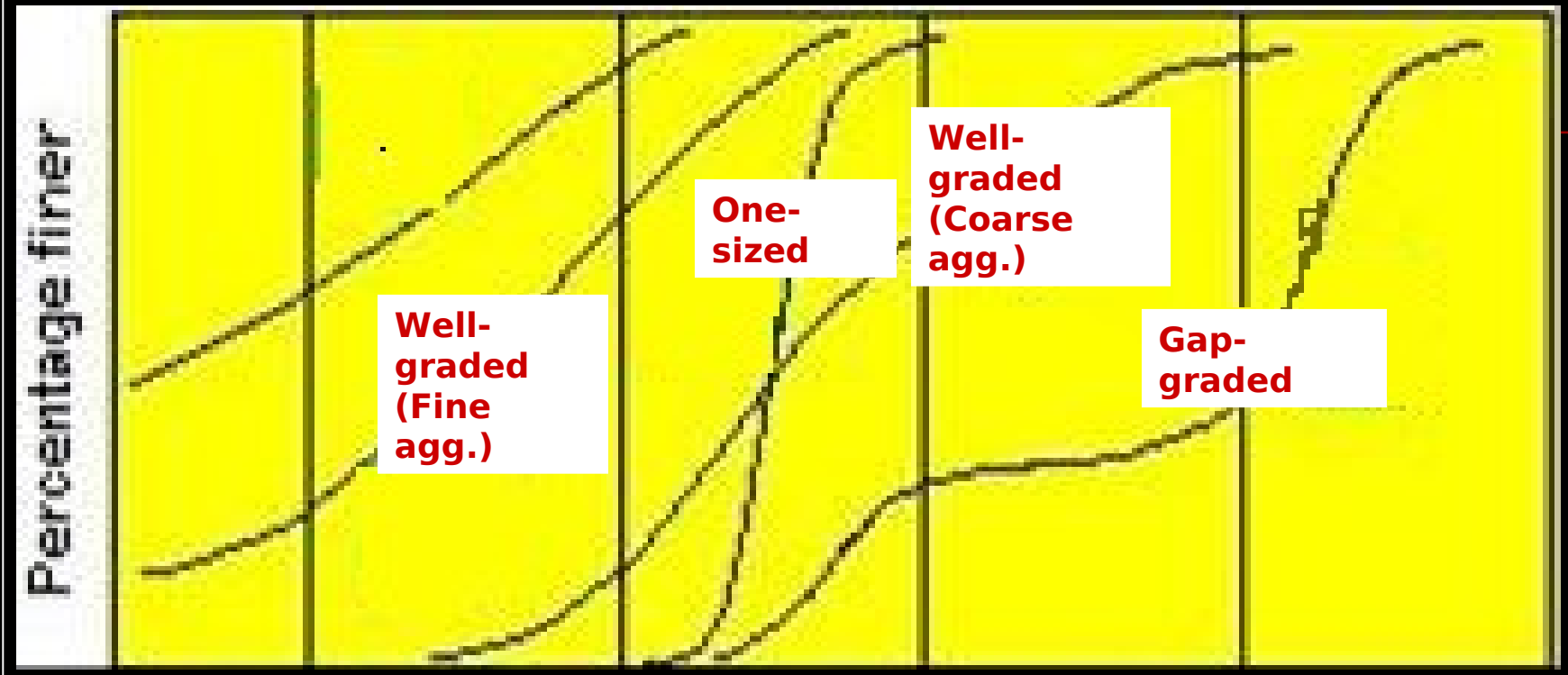
Riffling



Standard size and square openings

Sieve Designation	
Traditional	**Metric**
3”	75mm
2”	**50mm**
1 ½”	37.5mm
1”	**25mm**
¾”	19mm
½”	**12.5mm**
3/8”	9.5mm
No 4	4.75mm
No 8	2.36mm
No 16	1.18mm
No 30	600 micro m
No 50	300 micro m
No 100	150 micro m
No 200	75 micro m

7 standard sieves ranging from 150 µm to 9.5 mm (No. 100 to 3/8 in) for fine aggregates


Percentage finer
Well-graded (Fine agg.)
One-sized
Well-graded (Coarse agg.)
Gap-graded
Size (Log Scale)

Gradation Classifications

- **Well-graded:**

maximum density, high stability, low permeability

- **One-sized:**

particles same diameter, low stability, permeable

- **Gap-graded:**

Missing one or more sizes, stable, average permeability

- **Open-graded:**

Mostly large sizes, unstable, high permeability

Different standards and specifications specify grading limits for both fine and coarse aggregates.

There are several reasons for specifying grading limits and maximum aggregate size, they affect:

- Cement and water requirement
- Workability
- Economy
- Pumpability
- Relative aggregate proportions
- Shrinkage and durability of concrete

The following table shows the limits of ASTM C 33 with respect to fine aggregates, these limits are generally satisfactory for most concretes:

Sieve size		Percentage passing by mass
9.5 mm	(3/4 in)	100
4.75 mm	(No. 4)	95 to 100
2.36 mm	(No. 8)	80 to 100
1.18 mm	(No. 16)	50 to 85
600 µm	(No. 30)	25 to 60
300 µm	(No. 50)	5 to 30
150 µm	(No. 100)	0 to 10

Other requirements by ASTM C 33

- The fineness modulus (FM) must not be less than 2.3 nor more than 3.1
- The fine aggregate must not have more than 45% retained between two consecutive standard sieves.

Fineness Modulus (ASTM C 125)

- **The fineness modulus (FM) for both fine and coarse aggregates is obtained by adding the cumulative percentages by mass retained on each of a specified series of sieves and dividing the sum by 100.**
- **The FM is an index of the fineness of the aggregate. The higher the FM, the coarser the aggregate. FM of fine aggregate is useful in estimating proportions of fine and coarse aggregate in concrete mixtures.**

Coarse Aggregate Grading

- **ASTM C 33 permits a wide range in grading and variety of grading sizes**
- **Usually more water and cement is required for small-size aggregate than for large sizes, due to an increase in total aggregate surface area.**

- **Maximum size of aggregate**: the smallest sieve that all of a particular aggregate must pass through

- **Nominal maximum size of an aggregate**: the smallest sieve size through which the major portion of the aggregate must pass (90%-100%)

- **The maximum size of aggregate that must be used generally depends on the following:**
  - **Size and shape of the concrete member**
  - **The amount and distribution of reinforcing steel**
- **In general the maximum size of aggregate particles should not exceed:**
  - **1/5 of the narrowest dimension of a concrete member**
  - **3/4 the clear spacing between reinforcing bars and between the reinforcing bars and forms**
  - **1/3 the depth of slabs**

Special Use Gap-Graded aggregates

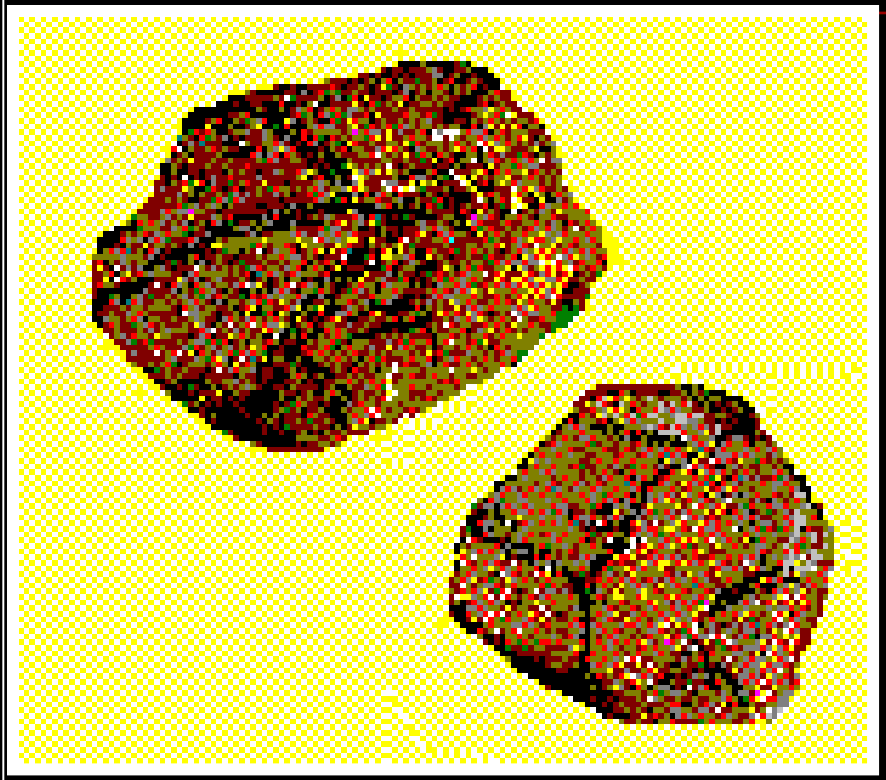
- When certain particle sizes are intentionally omitted. Ex., for an aggregate of 19 mm maximum size, the 4.75 mm to 9.5 mm particles can be omitted without making the concrete harsh subject to segregation. Gap-graded mixes are used in architectural concrete to obtain uniform textures in exposed –aggregate finishes.

Shape and Surface Texture of Aggregates

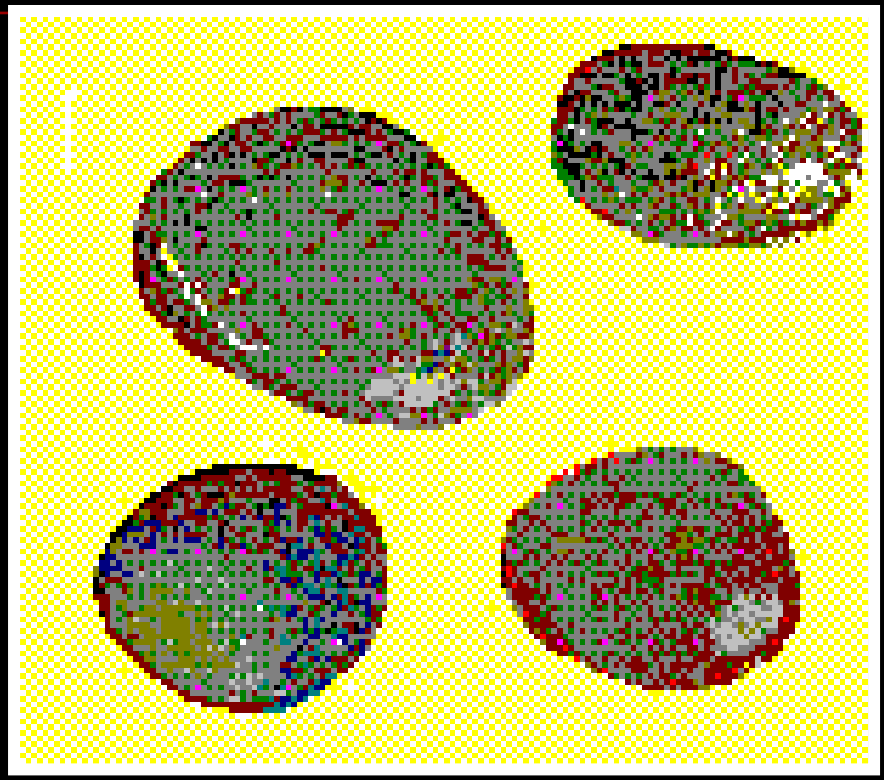




Aggregate Shapes

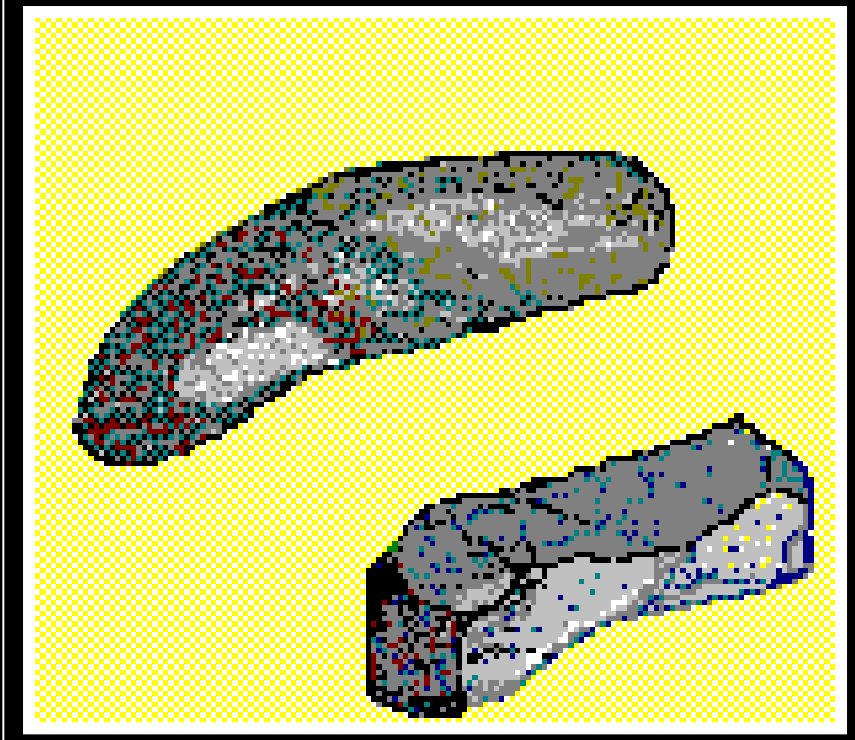


Rounded and angular



Rounded

Aggregate Shapes

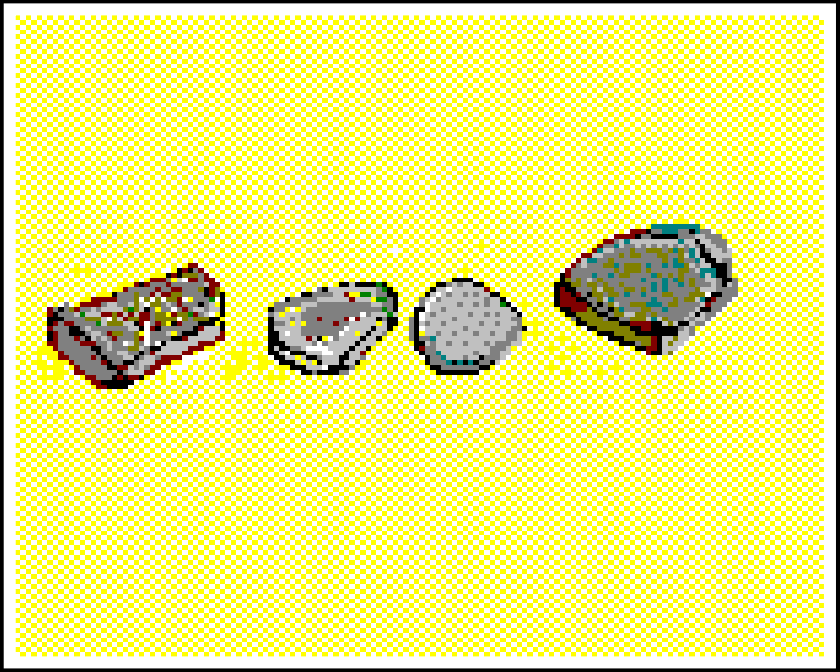


Elongated

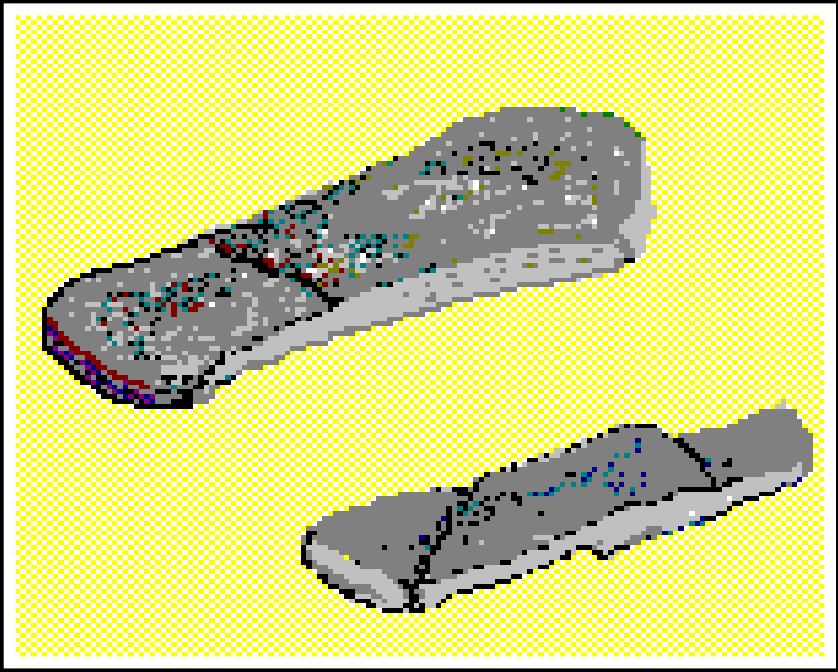


Angular

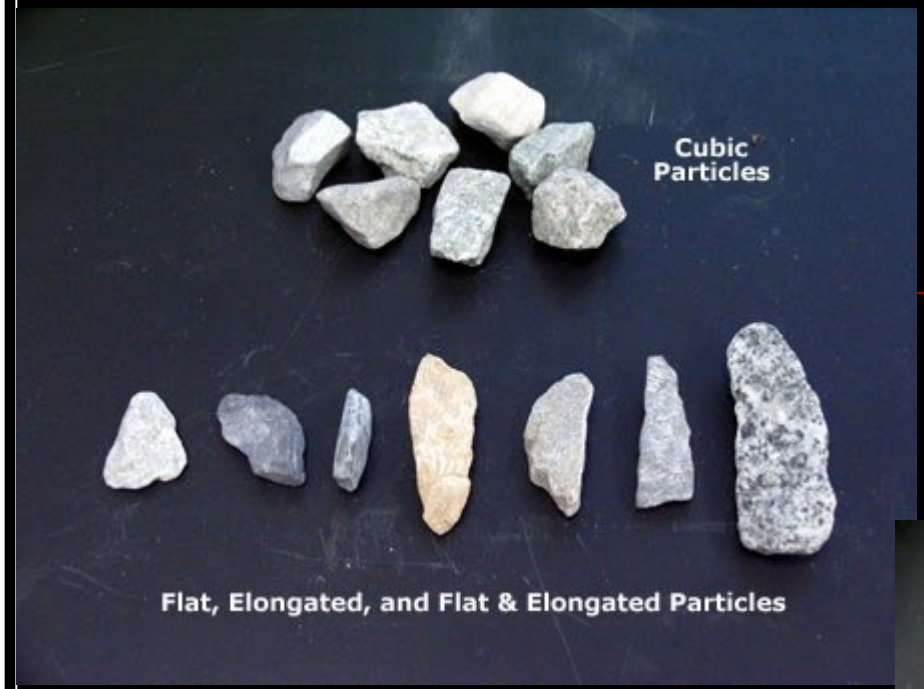
Aggregate Shapes

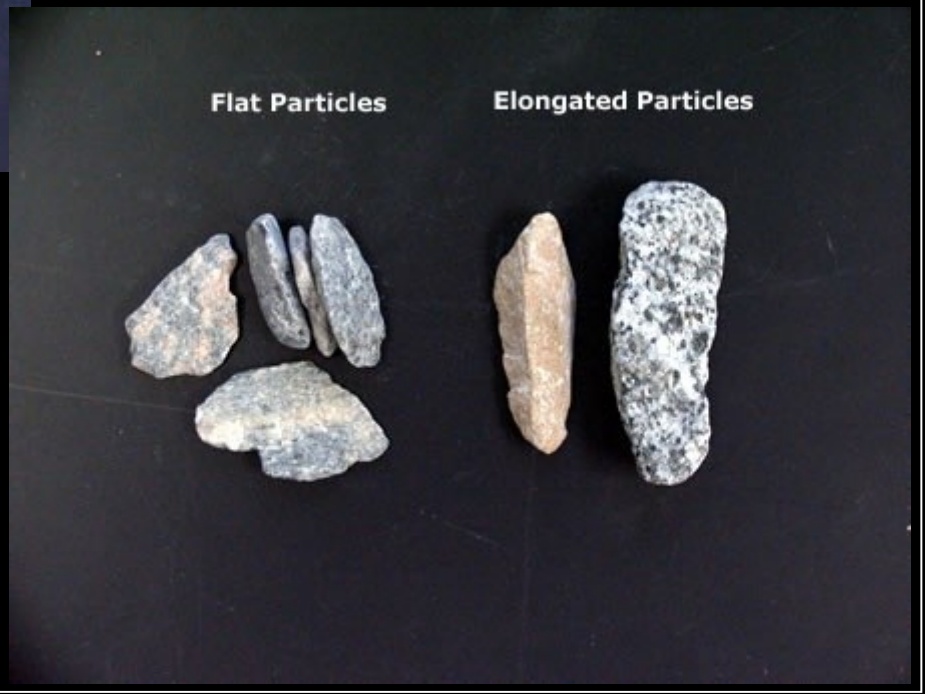


Flaky



Flaky and Elongated


Cubic Particles
Flat, Elongated, and Flat & Elongated Particles


Flat Particles
Elongated Particles

The particle shape and the surface texture of aggregates influence the properties of fresh concrete more than those of hardened concrete.

- ✓ Rough-textured, angular, and elongated particles require more water to produce workable concrete than smooth, rounded compact aggregate. Consequently, the cement content must also be increased to maintain the water-cement ratio.
- ✓ Flat, slivery pieces make concrete more difficult to finish

- ✓ **The increase in bond is important for selecting aggregates for concrete where strength at early age is important.**
- ✓ **Aggregate should be free of flat or elongated particles. Because they require an increase in mixing water and thus may affect the strength of concrete particularly in flexure.**
- ✓ **Generally, flat and elongated particles are avoided or are limited to about 15 percent by weight of the total aggregate.**

Bulk Unit Weight/Bulk Density

The bulk unit weight of an aggregate is the weight of the aggregate divided by the total volume occupied by it.

- The normal range of bulk unit weight for aggregates for normal-weight concrete is from 1200 to 1760 kg/m3.
- The range of aggregates that could be used in concrete are:

  Heavyweight, Lightweight, Normal Weight

Specific Gravity

- The specific gravity of an aggregate is another characteristic of the material which needs to be determined.
- Specific gravity is not a measure of aggregate quality but is used in making calculations related to mix design.
- The specific gravity of most normal weight aggregates will range from 2.4 to 2.9

Specific Gravity

Aggregate	Type	Specific Gravity
Granite	Normal weight	2.65
Gravel	Normal weight	2.70
Sand	Normal weight	2.60
	(For normal use)	
Pumice	Lightweight	0.75
Barite	Heavyweight	4.50
	(for special case e.g. heavy concrete, nuclear-	

Water Absorption

Aggregate have the ability to absorb water based on its porosity.

Thus, it may have internal moisture and external surface moisture.

Absorption of aggregate is important in concrete and asphalt concrete.

Over a 24-hr period light weight aggregates may absorb water in the amount of 5 to 20% of their own dry weight, depending on the type of aggregate and its pore structure .

A tendency of this sort must be taken into account when concrete is made with lightweight aggregate.

Moisture Content

Two types of moisture are recognized in aggregates:

- Absorbed moisture
- Surface moisture

Absorbed moisture is that which is taken in by the voids in aggregate particles and may not be apparent on the surface.

Surface moisture is that which clings to the surface of the particle.

Total moisture content

- The total amount of water present on the external and internal surfaces of aggregates.

  = Surface moisture + absorbed moisture

The moisture conditions of aggregates are designated as follows:

- ***Oven-Dry (OD)***: In this condition they are fully absorbent.
- ***Air-Dry (AD)***: Particles are dry at the surface but contain some interior moisture. They are therefore somewhat absorbent.
- ***Saturated Surface Dry (SSD)***: In this condition there is no water on the surface, but the particle contains all the interior moisture it will hold. It will neither absorb moisture from nor contribute moisture to the mix.
- ***Damp or Wet***: The particles contain an excess of moisture on the surface and will contribute moisture to a mix.

The ideal moisture ??????????

The moisture present in the aggregate affects the total water needed for the mix. The ideal moisture is "saturated surface dry" wherein all pores of the material are filled with water but no free moisture exists on the surface.

Bulking

- Surface moisture in fine aggregate is the cause of a phenomenon known as ***bulking of sand***.
- Surface moisture holds the particles apart, causing an increase in volume over the same amount of sand in a surface dry condition.
- The amount of bulking will depend on the fineness of the sand.

Strength and Durability of Aggregates

- One measure of the strength of an aggregate is its resistance to freeze-thaw and ability to withstand compressive stresses.
- Soluble, weak, or friable material must be avoided.

Cleanliness (Deleterious Substances)

The cleanliness of the aggregate affects the bond between the paste and the aggregate surface.

Deleterious (harmful substances) have the following effects on concrete:

- Weaken bondage between cement paste and aggregates
- Interfere with hydration
- Reduce of strength and durability
- Affect water tightness of the concrete
- Modify setting action and
- Cause efflorescence

Hardness of Aggregates

The hardness of aggregates is expressed in terms of their resistance to abrasion.

This characteristic is important if the aggregate is used in concrete intended for such purposes as heavy-duty floors.

A common method of making this test is *the Loss Angeles abrasion test.*



Loss Angeles abrasion test machine

Chemical Stability

- Aggregates need to be chemically stable so that they will neither react chemically with cement nor be affected chemically by outside influences.
- In some cases aggregates with certain chemical constituents react with alkalis in cement. This reaction may cause abnormal expansion and resultant cracking of concrete.

Alkali-aggregate reaction

- Certain forms of silica and siliceous material in aggregate (e.g. chert) interact with alkalis released during the hydration of Portland cement.
- This produces a gel like material which increases in volume in the presence of water causing expansion and cracking of concrete.

Effects of Alkali-silica reaction (ASR)



Crack



Popouts

HANDLING AND STOCKPILING OF AGGREGATES

The purpose of appropriate handling and stock piling of aggregates is to avoid breakage, segregation, contamination, and degradation.

Precautions:

- Storing on hard and dry ground or on platforms of planks, sheets, lean concrete
- Storing separately each aggregate size in compartments
- Avoiding segregation of aggregates resulting from free fall
- Damping consignments at different places.
- Proper collection and mixing of test batches is important to ensure that test samples accurately represent the aggregate in the entire stockpile.





1.1.4 Concrete A e







1. Definition

Admixtures are chemicals which are added to concrete at the mixing stage ***to modify*** some of the properties of the mix.

2. Uses of admixtures

- To increase workability without changing water content.
- To reduce water content without changing workability.
- To adjust setting time.
- To reduce segregation and/or bleeding.
- To improve Pumpability.
- To accelerate the rate of strength development at early ages.

3. Types of admixtures

Admixtures are classed according to function. There are five distinct classes of chemical admixtures:

1. Plasticizers (water-reducing agents)
2. Superplasticizers
3. Air entrainers
4. Accelerators
5. Retarders

3.1 Plasticizers

When added to a concrete mix, plasticizers (water-reducing agents) are absorbed on the surface of the binder particles, causing them to repel each other and deflocculate. This results in improved workability and provides a more even distribution of the binder particles through the mix.

Plasticizers Reduce the water requirement of a concrete mix for a given workability by about 10%.

- Concrete containing a plasticizer (water-reducing admixture) needs less water to reach a required slump than untreated concrete.
- The treated concrete can have a lower water-cement ratio. This usually indicates that a higher strength concrete can be produced without increasing the amount of cement.

Uses of plasticizers

- Increase the slump of concrete with a given water content.
- Reduce the water requirement of a concrete mix for a given workability by about 10%.
- The addition of a plasticizer makes it possible to achieve a given strength with a lower cement content.
- Improve pumpability.

Problems associated with plasticizers

- Some plasticizers contain chlorides which may increase the danger of corrosion of reinforcing steel.
- Where plasticizers are used to increase workability, the shrinkage and creep will invariably be increased.

3.2 Superplasticizers

Also known as or high-range water reducers (HRWR), reduce water content by 12 to 30 percent and can be added to concrete with a low-to-normal slump and water-cement ratio to make high-slump flowing concrete.

As a result of the slump loss, superplasticizers are usually added to concrete at the jobsite.

Uses of superplasticizers

- In areas of congested reinforcement.
- Where workable concrete that can be placed with little or no vibration or compaction.
- For high-strength concretes by decreasing the water: cement ratio as a result of reducing the water content by 12–30%.

Problems associated with superplasticizers

- The effect of a superplasticizer may disappear as soon as 30-60 minutes after mixing.
- They have a relatively high unit cost.
- Where superplasticizers are used to produce very high workability, the shrinkage and creep will be increased.

3.3 Air entrainers

An air-entraining agent introduces air in the form of minute bubbles distributed uniformly throughout the cement paste.

Uses of air-entertainers

- Where improved resistance of hardened concrete to damage from freezing and thawing is required.
- For improved workability, especially in harsh or lean mixes.
- To reduce bleeding and segregation, especially when a mix lacks fines.

Air entrainment may reduce the strength of concrete and overdosing can cause major loss of strength. As a rule-of-thumb, 1% air may cause a strength loss of 5%.

It is therefore important that mixes be specially designed for air entrainment and that the percentage of air entrained during construction must be monitored.

3.4 Accelerators

Accelerators :

- speed up the chemical reaction of the cement and water and so....
- accelerate the rate of setting and/or early gain in strength of concrete.

Uses of accelerators

- Where rapid setting and high early strengths are required.
- Where rapid turnover of moulds or formwork is required.
- Where concreting takes place under very cold conditions.

Problems associated with accelerators

- Certain accelerators may increase drying shrinkage, cracking and creep.
- Many chloride-based accelerators promote corrosion of reinforcing steel.
- Calcium chloride should not be used in reinforced concrete
- Overdosing with these materials can cause marked retardation.
- Accelerators work more effectively at lower ambient temperatures.

3.5 Retarders

These admixtures slow the chemical reaction of the cement and water leading to longer setting times and slower initial strength gain.

Uses of retarders

- When placing concrete in hot weather, particularly when the concrete is pumped.
- To prevent cold joints due to duration of placing.
- In concrete which has to be transported for a long time.

Problems associated with retarders

- If a mix is overdosed beyond the limit recommended by the supplier, retardation can last for days.
- Retarders often increase plastic shrinkage and plastic settlement cracking.
- Delayed addition of retarders can result in extended retardation.

Fresh Concrete









Gathering Ingredients

Proportioning

Mixing

Transporting

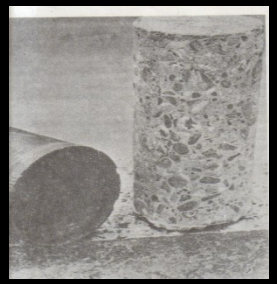
Placing Compaction & finishing

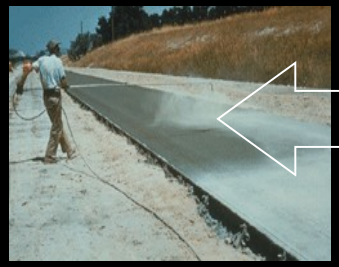






Hardened Concrete





Curing






WATER
CRUSHED
ROCK
CHEMICAL
ADMIXTURE
SAND
PORTLAND
CEMENT





Major properties of fresh concrete

Fresh concrete is also known as plastic concrete. The major Properties of concrete in its plastic state are:

- Workability
- Consistency
- Segregation
- Bleeding
- Stiffening and setting

1. Workability

Workability is ease of placing and resistance to segregation of concrete.

Workability means how easy it is to:

- PLACE
- HANDLE
- COMPACT and
- FINISH a concrete mix.

Concrete that is stiff or dry may be difficult to Handle, Place, Compact, and Finish will not be as strong or durable when finally hardened.

Factors that affect workability

- **Water content**
- **shape of aggregates**
- **Grading of Aggregates**
- **Size of Aggregates**
- **Surface Texture of Aggregates**
- **Admixtures**

Aggregate Properties

Water content

If water content is increased the coarse particles settle and bleeding occurs. Cement slurry can escape through joints of formworks.



Aggregate properties

- **shape of aggregates**
- **Grading of Aggregates**
- **Size of Aggregates**
- **Surface Texture of Aggregates**

Angular, flaky, and elongated aggregates reduce workability.

Nonabsorbent aggregates and optimum percentage of fine aggregate contributes to workability .

Admixtures

- Workability admixtures improve the workability of concrete
- Air entraining agents produce numerous air bubbles that act as rollers to decrease bleeding and segregation, and as a result increase workability.

2. Consistency

Consistency refers to ***ability to flow*** of concrete and **indicates wetness** of concrete, and thus workability.

Concrete could have:

- Dry
- Plastic: can be shaped into ball
- Semi-fluid: spreads out slowly and with out segregation of aggregate
- Fluid consistency: spreads out fast and results in segregation of aggregates

3. Segregation

Segregation is separation of coarse aggregates from the mass of concrete.

Segregation results from:

- Uncontrolled pumping or falling
- Placing under waters
- Placing concrete in heavily reinforced members

Precautions to control segregation



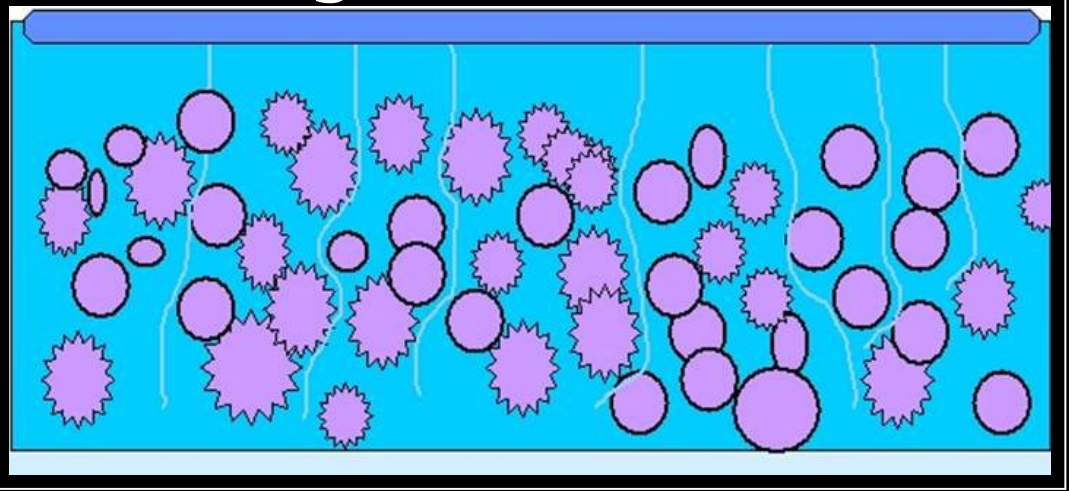
Placing concrete near its final position, instead of falling from greatest heights

Precautions to control segregation

- Careful handling, pacing, and consolidation of concrete
- Applying Admixtures : Plasticizer and air entraining admixture.

4. Bleeding

Bleeding is the appearance of water on concrete surface. As a consequence of bleeding, slum layer will be formed making concrete weak and porous.



Measures to minimize bleeding

- Using well graded and proportioned aggregates
- Increasing amount of cement
- Applying air entering agents
- Reducing amount of water

5. Stiffening and setting

Concrete is required to remain plastic for the time to be taken to transport, place, and consolidate it.

Temperature influences the stiffening of concrete. That is,

Low temperature⇒ delays

High temperature ⇒accelerates the stiffening of concrete.

MEASUREMENT OF WORKABILITY

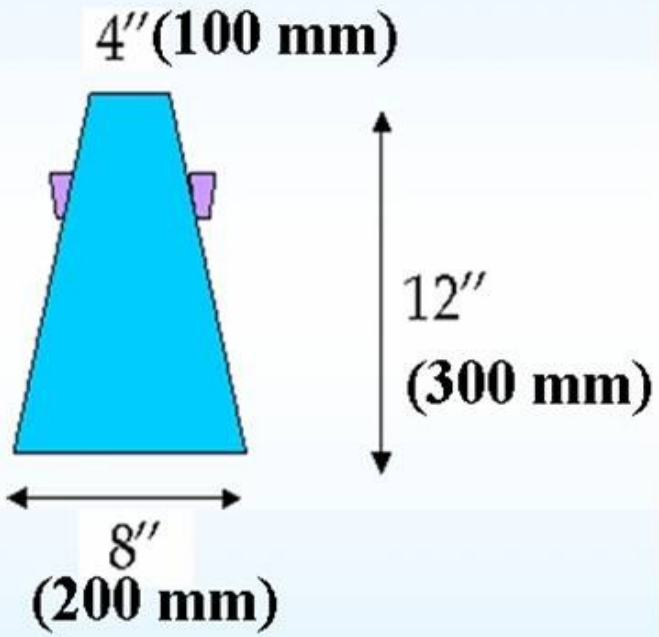
Some of the methods of measuring workability that is wetness or fluidity are:

- ✓ Slump test
- ✓ Compacting factor test

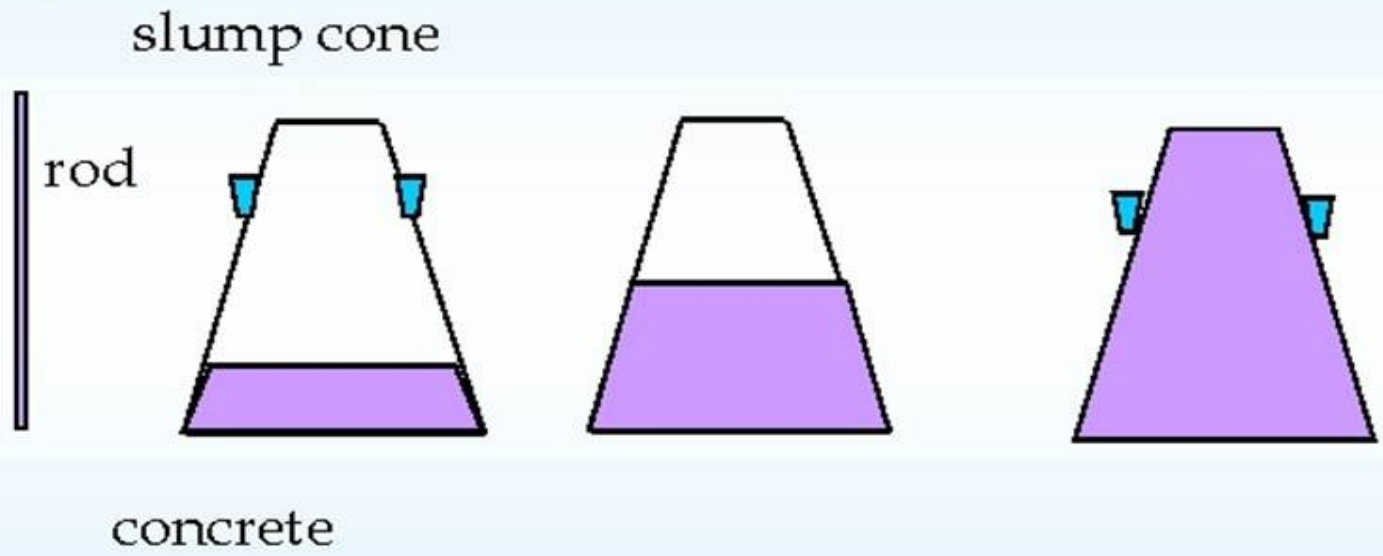
Slump Test

Slump is the subsidence of concrete cone after mold is lifted up.

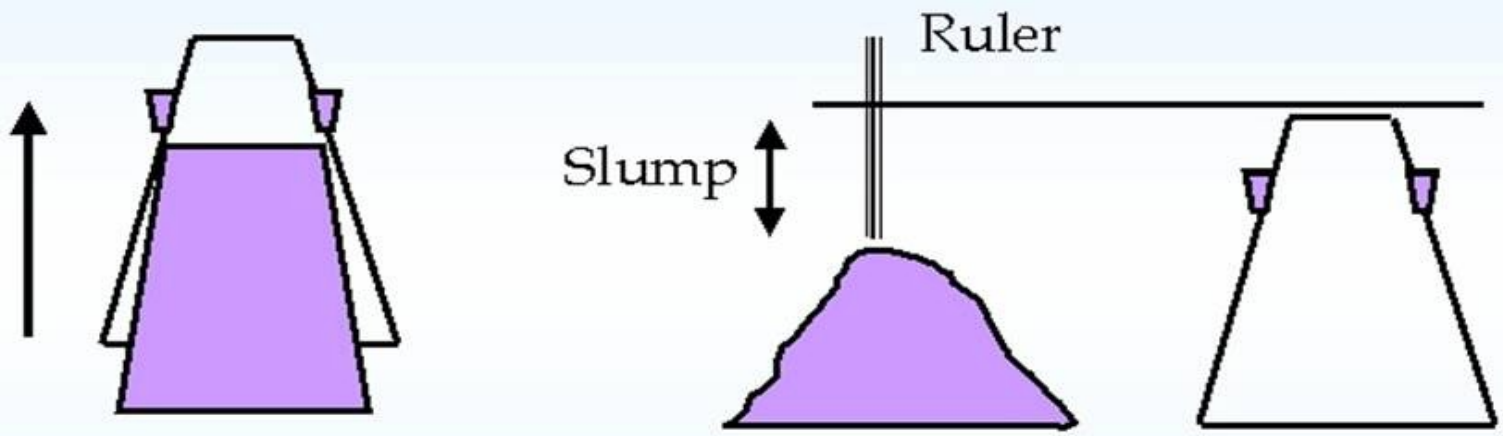
- Inverted cone
- fill it up with three layers of equal volume
- rod each layer 25 times
- scrape off the surface



Slump Test



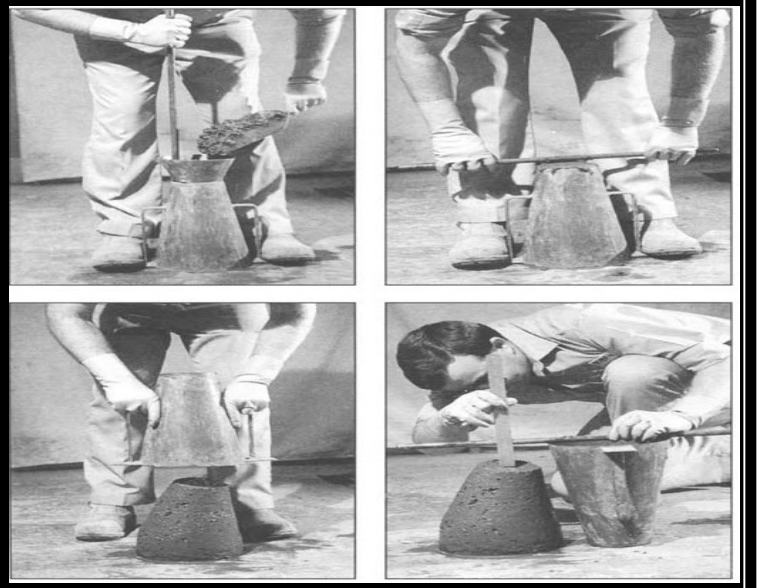
Slump test



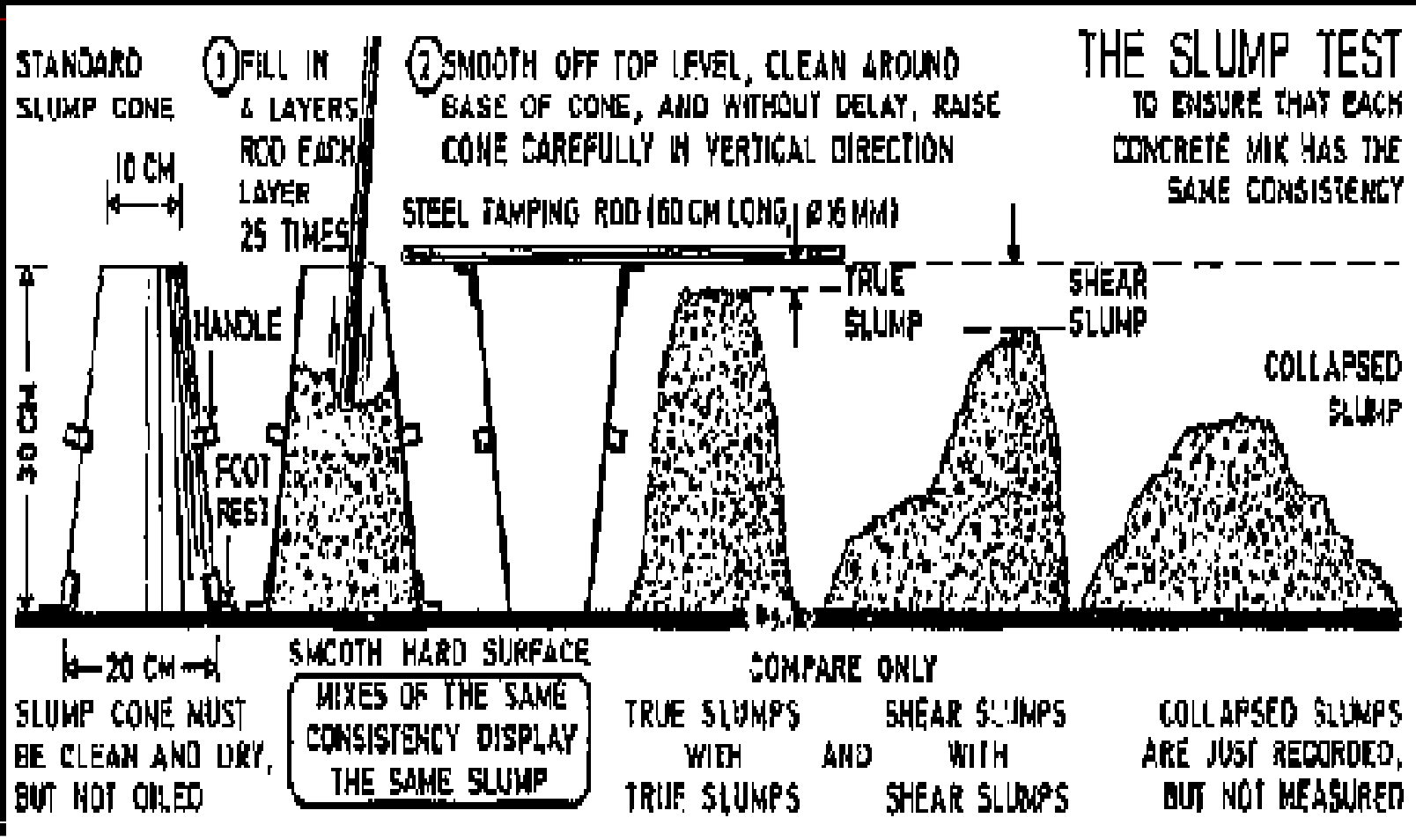








Types of slump



Types of slump (results of slump)

- **True Slump** - Has even subsidence
- **Shear Slump** - Half of the cone slides, difficult to measure, and results from harsh mixes deficient in fine aggregates.
- **Collapse Slump** - difficult to measure, results from very wet mixes.

Slump test results

Slump (mm)	Degree of workability (Suitability)
0-25	Very low (Massive sections, little reinforcement)
25-50	Low (little reinforcement)
50-100	Medium (Beam, columns)
100-175	High (For heavily reinforced sections

Limitations of slump test

- Not applicable for aggregates size greater than 40 mm .
- Applicable to plastic mixes only
- Not applicable to harsh and wet mixes

Compacting Factor Test

Drier mixes do not give slump. Therefore, compaction factor test should be done to determine degree of compaction (compacting factor) by falling the mix through successive hoppers with standard height using a compaction factor test apparatus.



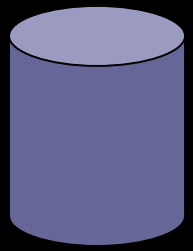
Compaction factor test apparatus

Compaction factor

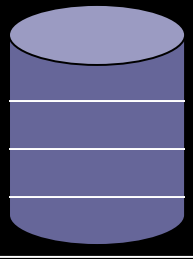
$$= \frac{\text{weight of partially compacted concrete}}{\text{weight of fully compacted concrete}}$$

(compacted in 4 layers, 25 x tempering each layer)

e.g.



weight of concrete partially compacted = 11.02 kg



weight of concrete fully compacted = 12.04 kg

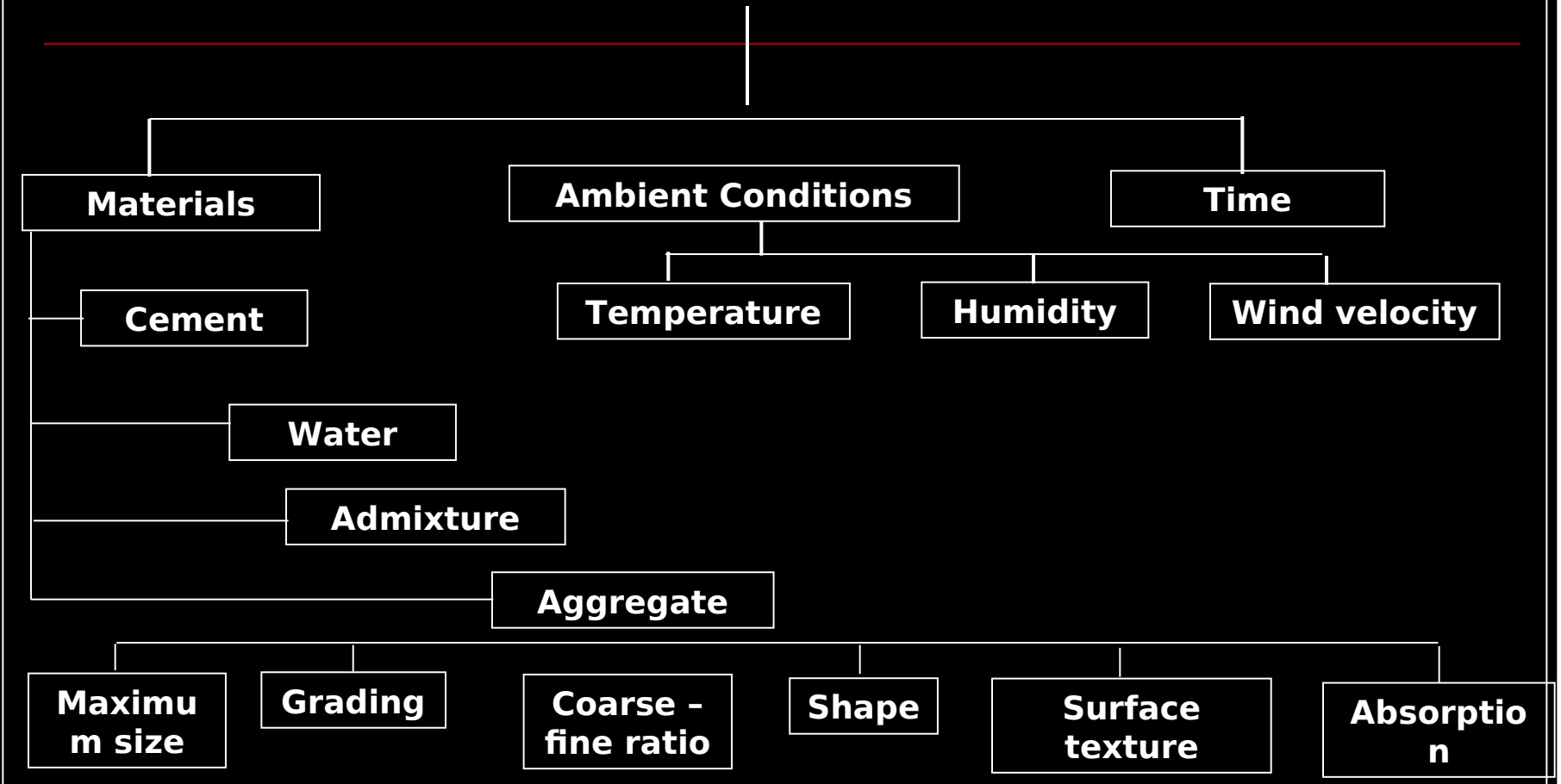
Compaction factor = 11.02 kg / 12.04 kg

= 0.915

Compacting factor values

- For compacting factor values between 0.75-0.80, compacting concrete by hand is not permissible.
- For Compacting Values less than 0.75, pressure should be exerted into concrete to vibrate.
- Compacting factor test is suitable for both dry and wet mixes, since it gives constant results.

Factors affecting workability



1.2 MIXING OF CONCRETE



Purpose of mixing

The purpose of concrete mixing is to provide a ***uniformly blended product*** of cement, water, and aggregates.

Basic requirement of mixing is to produce concrete of uniform consistency from beginning to end.

Mixing time 2 to 3 minutes

Methods of mixing

Two basic methods of mixing concrete;

i. Hand (Manual) mixing
ii. Machine mixing

Methods for mixing concrete

Machine
ing



Drum mixe

Manually







Readymixed

Hand Mixing

Adopted for small works and quantity of concrete used is small

Procedure:

a. Sand + cement ⇒ dry mix

b. Spread the sand -cement mix on a flat platform

c. Spread the measured quantity of coarse aggregate on the cement-sand mix

d. Mix the cement + sand + c.agg. At least three times by shoveling from center to the side and then back to the center and again to the side

e. Make a hallow in the middle of the mixed pile and pour slowly into it half to three-quarter of the total quantity of water required

f. Add the remainder of the water slowly, turning the mixture over and again until the color and consistency are uniform throughout the pile

Note: 1. Time of mixing should not exceed 3 minutes

2. Mixing platform is cleaned at the end of the days work, so that it is ready for use the next day

Machine mixing

- Used in case of a large quantity of concrete is to be produced
- Concrete can be produced at a faster rate at a lesser cost and of better quality

Note

- Care for mixer is very important!
  1. Wash the mixer every day preferably with a hose
  2. Hammering or hitting of the loading skip in order to accelerate the discharge of adhering sand and cement should not be permitted
  3. When the mixer is installed at one place for a loner periods, it should be ensured that wheels and axle of the mixer do not get buried under accumulating materials
  4. Before closing down a shift or day’s work, the interiors of the drum and blades are flushed clean
  5. General upkeep and maintenance of the mixer engine be attended everyday, i.e., fuel, water, lubricant, etc.

Transporting Concrete

1. Pans
   - When quantity is small
   - When access to work is restricted
   - Method is tedious, slow and costly



2. Wheel barrows

Moderate distance and medium quantities



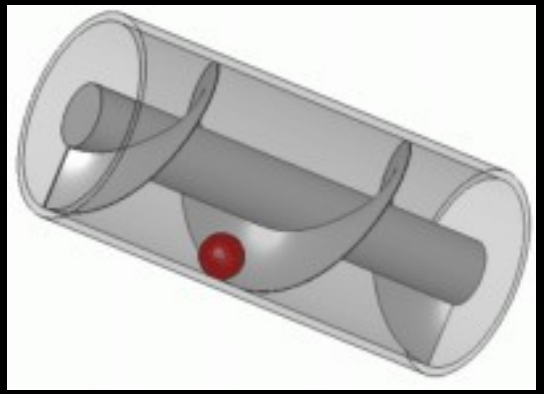
Wheelbarrow

Transporting Concrete

3. Truck mixer

- When place of deposit of concrete is at a very long distance from the mixer such that the concrete cannot be transported and placed in the forms within 30 minutes
- Happens in case of ready-mixed concrete
- Drum containing the concrete rotates continuously to prevent the concrete from being **stiff** and to prevent **segregation**


11:35 AM



4. Belt conveyors

- When the concrete is to be transported continuously and to a higher level
- Installed in an inclined position
- Concrete should be **stiff** consistency having a slump not more than 50 mm

5. Chutes

- When concrete is to be placed below ground level, the mixer may be placed on an upper level and concrete discharged to the lower level through a chute of corrugated i



Chute



7. Pumps

- When large quantity of concrete is to be transported continuously to congested sites where mixing plant can not be installed

- To a ma 0 m horizontally ar ally



Methods for transporting
te



Wheelbarrow



oncrete buggy



Chute



Bucket

Large & massive construction. Handled by crane)



(through pipe)

Placing of concrete

- Concrete should be placed and compacted before setting commences

- Method of placing should be in such a way as to prevent **segregation** (should n dropped from a height n an about 1m)









An elevation column of h=3.71m is being casted with out a window at h=1.50m (one of the reasons for segregation).



Good construction methodology, in casting columns from convenient height by providing a window.

Formwork

Material

i. Timber ⇒ Most commonly used

ii. Plywood ⇒ Bounded with water proof synthetic resin adhesives

iii. Hard board ⇒ Manufactured from wood fibers, usually impregnated with drying oils and factory applied plastic coatings

iv. Metal forms ⇒ very common nowadays







worn-out timber formwork







Formwork?.....What formwork!

Compaction of Concrete



When first placed in the form, normal concrete excluding those with very low or very high slumps will contain between 5% and 20% by volume of entrapped air.

Compaction is the process which expels entrapped air from freshly placed concrete and packs the aggregate particles together so as to increase the density of concrete.

What is compaction?

Compaction is the process which expels entrapped air from freshly placed concrete and packs the aggregate particles together so as to increase the density of concrete.

When first placed in the form, normal concrete excluding those with very low or very high slumps will contain between 5% and 20% by volume of entrapped air.

Proper compaction:

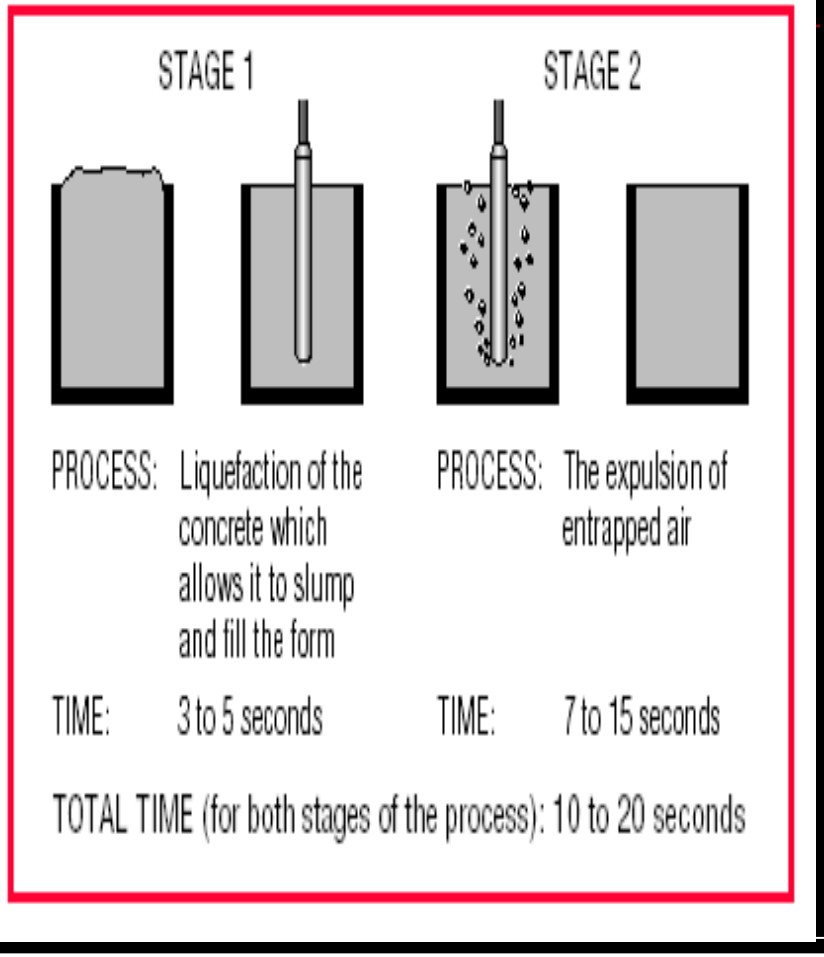
- Increase significantly the ultimate strength of concrete and
- Enhances the bond with reinforcement.
- Increases the abrasion resistance and general durability of the concrete,
- Decreases the permeability and helps to minimize its shrinkage-and-creep characteristics.
- Also ensures that the formwork is completely filled – i.e. there are no pockets of honeycombed material – and that the required finish is obtained on vertical surfaces.

Stages of Compaction

Compaction of concrete is a two-stage process.

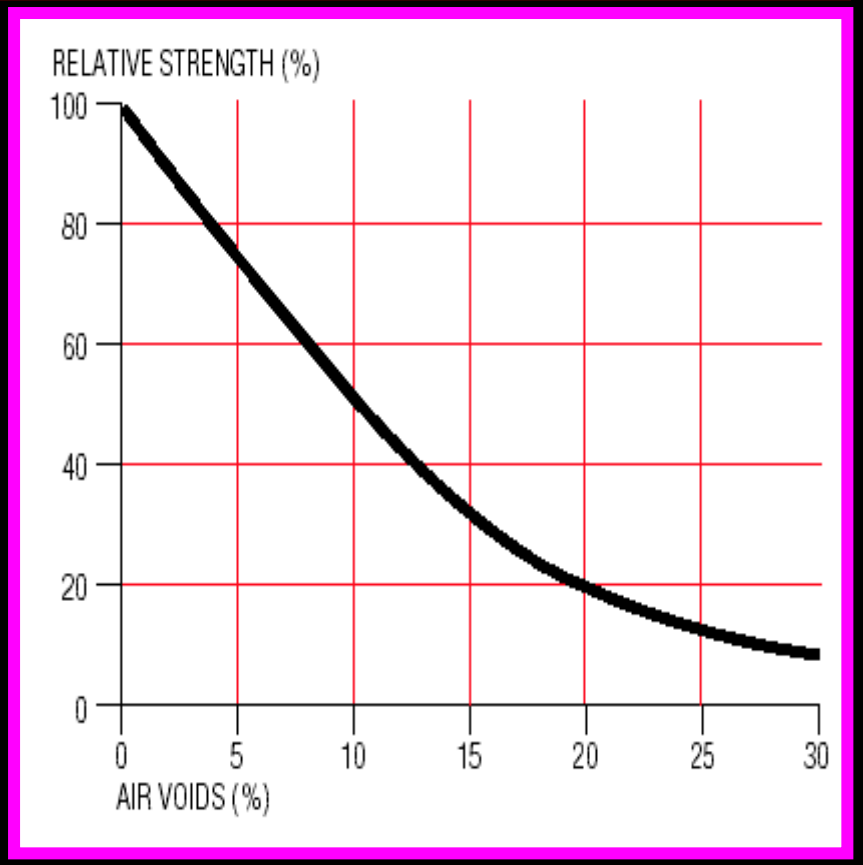
First the aggregate particles are set in motion and slump to fill the form giving a level top surface.

In the second stage, entrapped air is expelled.



Effect of compaction on hardened concrete

As may be seen from the figure the effect of compaction on compressive strength is dramatic. For example, the strength of concrete containing 10% of entrapped air may be as little as 50% that of the concrete when fully compacted.



Loss of strength through incomplete compaction

Methods of compaction

i. Hand compaction (Tamping)

ii. Vibrators

- Internal vibrators
- Form vibrators
- Surface vibrators

Types of vibrators

1. Immersion Vibrator

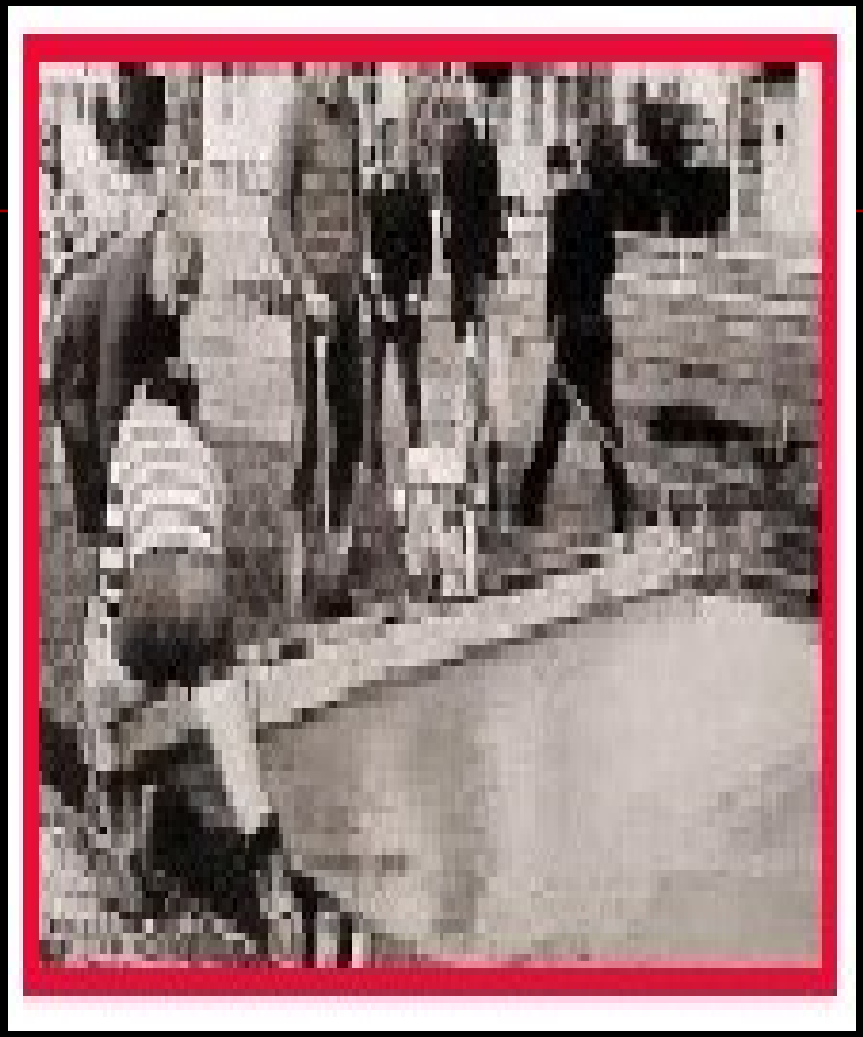
Immersion vibrators consist essentially of a tubular housing which contains a rotating eccentric weight. The out-of-balance rotating weight causes the casing to vibrate and, when immersed in concrete, the concrete itself. Depending on the diameter of the casing, and on the frequency and the amplitude of the vibration, an immersion vibrator may have a radius of action between 100 and 600 mm.



Immersion Vibrator

2. **Surface Vibrators**

Surface vibrators are applied to the top surface of concrete and act downwards from there. They are very useful for compacting slabs, industrial floors, road pavements, and similar flat surfaces. They also aid in leveling and finishing the surface.



Surface Vibrator

Finishing concrete

Concrete that will be visible, such as slabs like driveways, highways, or patios, often needs finishing. Concrete slabs can be finished in many ways, depending on the intended service use.



Finishing concrete

Options include various colors and textures, such as exposed aggregate or a patterned-stamped surface. Some surfaces may require only strike off and screeding to proper contour and elevation, while for other surfaces a broomed, floated, or troweled finish may be specified.

In slab construction, screeding or strike off is the process of cutting off excess concrete to bring the top surface of the slab to proper grade. A straight edge is moved across the concrete with a sawing motion and advanced forward a short distance with each movement.

Curing Concrete

Curing is the process which controls the loss of moisture from concrete either after it has been placed in position (or during the manufacture of concrete products), thereby providing time for the hydration of the cement to occur.

Since the hydration of cement does take time – days, and even weeks rather than hours – curing must be undertaken for a reasonable period of time if the concrete is to achieve its potential strength and durability.

Methods of curing

i. Shading concrete
ii. Covering concrete surfaces
iii. Sprinkling water
iv. Ponding method
v. Membrane curing
vi. Steam curing

Duration of curing

Concrete shall be covered and kept constantly wet for seven days from the date of placing



Sprinkling water



Polyethylene sheets



Straw or hay

1.3 HARDENED CONCRETE

Definition

Hardened concrete is a concrete which developed the required strength and changed to solid state.

Properties of Hardened concrete

The properties of Hardened concrete are properties which change contentiously with time. In its hardened state the various properties which need consideration are

1. Strength
2. Permeability
3. Durability
4. Dimensional Change (elasticity shrinkage, thermal expansion, creep)
5. Fire Resistance

Strength

Significance :- The strength of concrete is the most important property as far as structural designs are concerned.

Nature and Kind :- Strength of concrete is defined the ability to resist force which might cause rupture by the following kinds of stresses.

- Compressive stress
- Tensile stress
- Flexural stress
- Shear stress

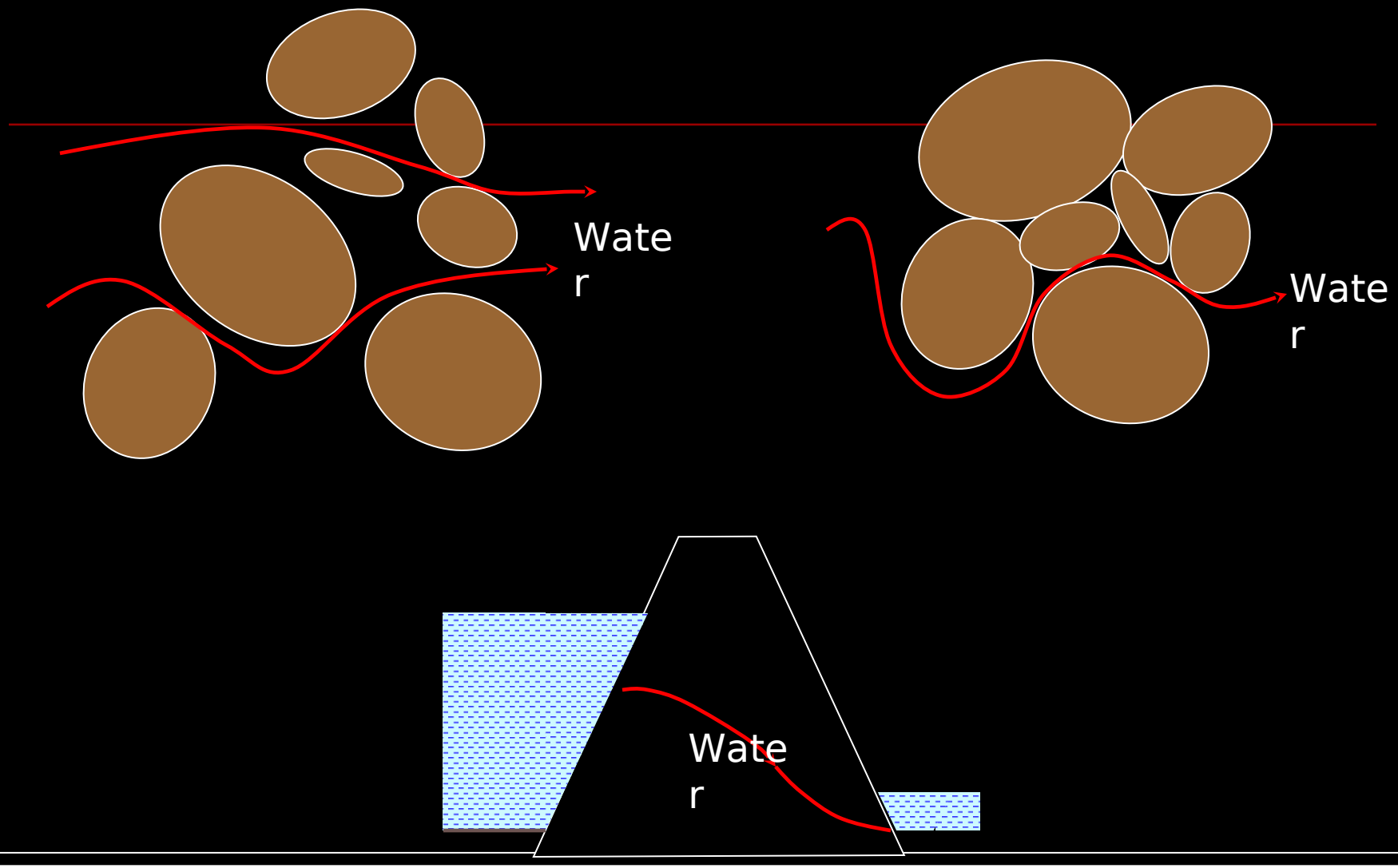
Permeability

The passage of water through the body of concrete is known as *Permeability*

- Impermeability of concrete is of more importance than strength for hydraulic structure

Permeability test can also used for

1. determining the leakage through the walls of a hydraulic structure
2. comparing the efficiency of water proofing agents


Wate
r
Wate
r
Wate
r

Durability

Property of concrete to withstand factors, which reduces the life of concrete by their disintegrating effects.

Mechanisms that affect durability

i. Freeze-thaw damage (physical effects, weathering).

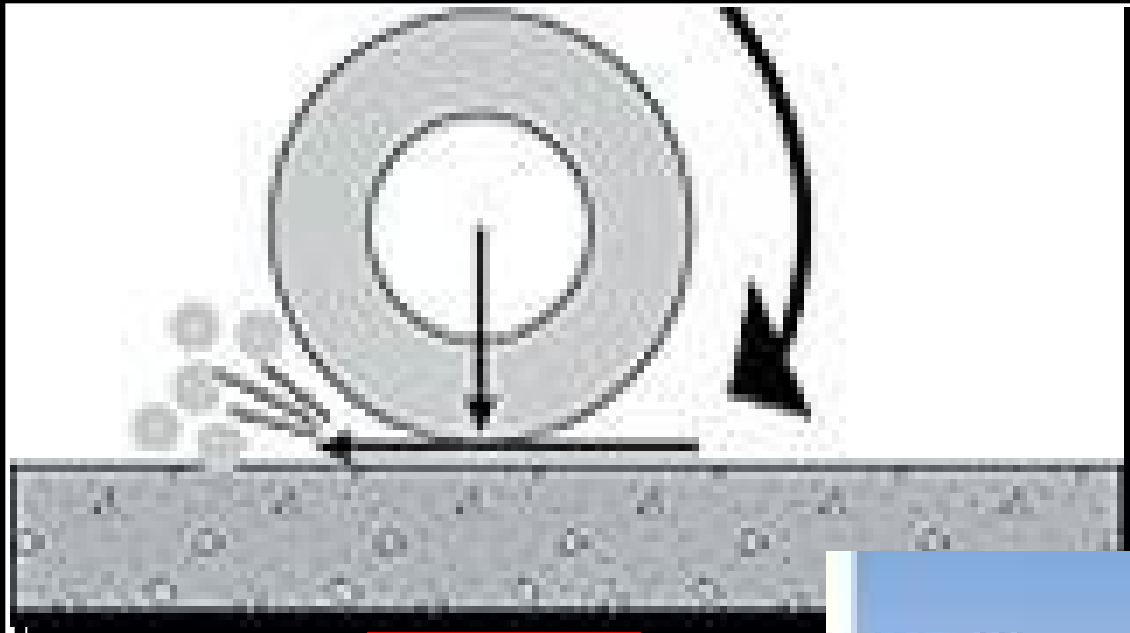
ii. Alkali-aggregate reactions (chemical effects).

iii. Sulfate attack (chemical effects).

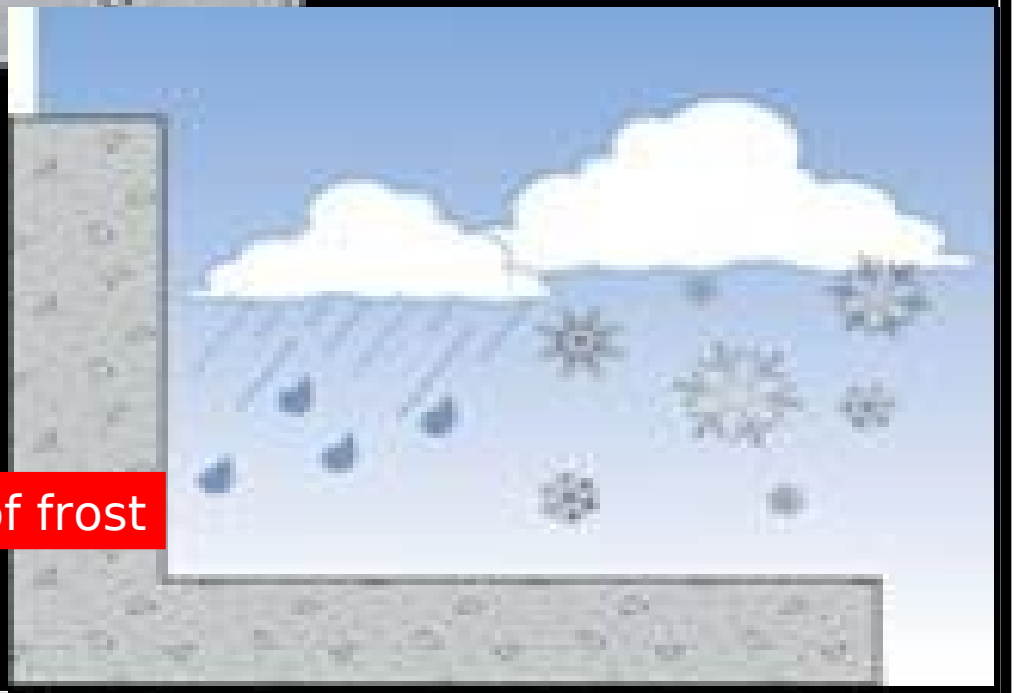
iv. Corrosion of reinforcing steel embedded in concrete

v. Abrasion (physical effects).

vi. Mechanical loads (physical effects).



Abrassion



action of frost

Dimensional Change

The dimensional Changes of concrete mainly depend upon

(a) Elasticity

(b) Shrinkage

(c) Thermal expansion

(d) creep

Fire Resistance

When concrete is subjected to high temperature, aggregates and steel go on expanding. This causes concrete to crack and crumble.

Factors affecting properties of hardened concrete

- Water cement ratio
- Cement content
- Temperature
- Age
- Aggregates properties
- Curing
- Frost
- Entrained Air

Corrosion of Reinforced Concrete





Reinforced Concrete Corrosion



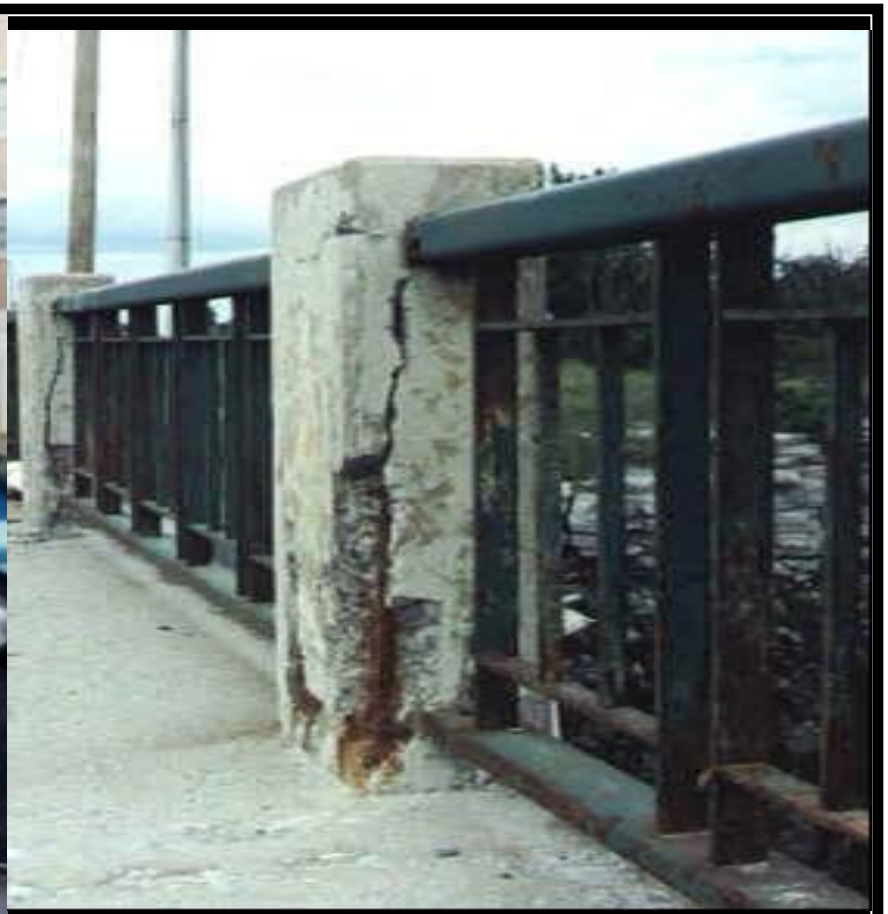










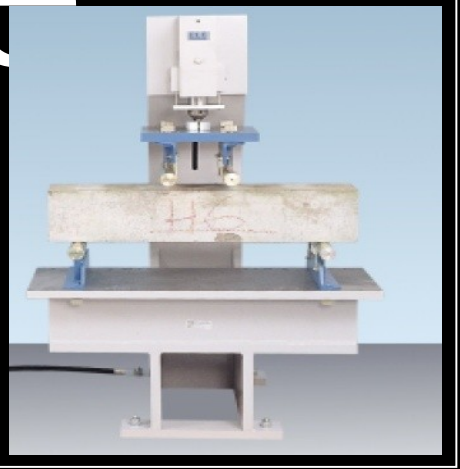






Testes for Hardened Concrete





There are three basic categories of concrete testing ,
Namely :-

1. Quality control
2. Compliance test
3. Secondary test

for hardened concrete ,we mainly use the secondary test type.

Secondary test

↓ ↓

Distractive test | None distractive

Distractive Tests

- Cube/cylinder compressive strength test
- Flexure test
- Concrete Core Test

Cube/cylinder compressive strength test









2.2 GRADES OF CONCRETE

(1) Concrete is graded in terms of its characteristic compressive cube strength. The grade of concrete to be used in design depends on the classification of the concrete work and the intended use.

(2) Table 2.1 gives the permissible grades of concrete for the two classes of concrete works.

(3) The numbers in the grade designation denote the specified characteristic compressive strength in MPa.

Table 2.1 Grades of Concrete

Class	Permissible Grades of Concrete							
I	C5	C15	C20	C25	C30	C40	C50	C60
II	C5	C15	C20					

Grade C5 shall be used only as lean concrete

Table 2.2 Conversion Factors for Strength

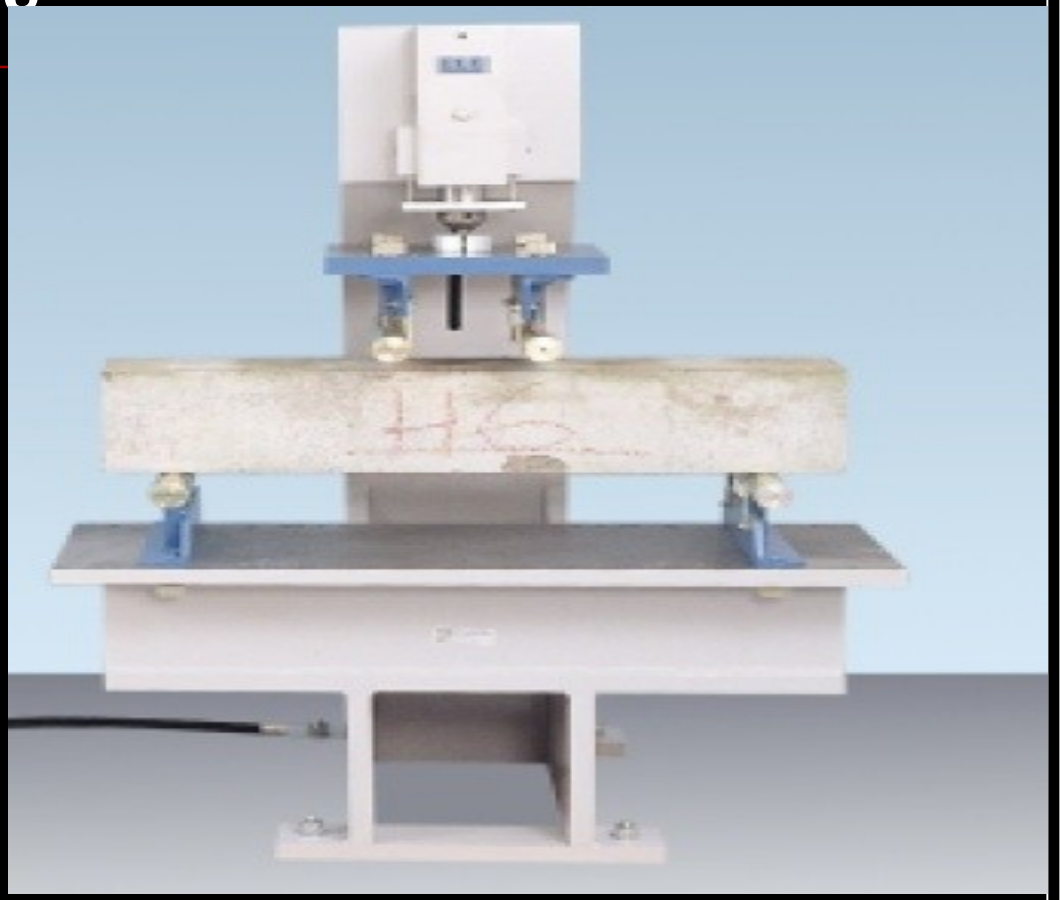
Size and Type of Test Specimen	Conversion Factor
Cube (200 mm)	1.05
Cylinder (150 mm diameter 300 mm height)	1.25

Table 2.3 Grades of Concrete and Characteristic Cylinder Compressive Strength f_{ck}

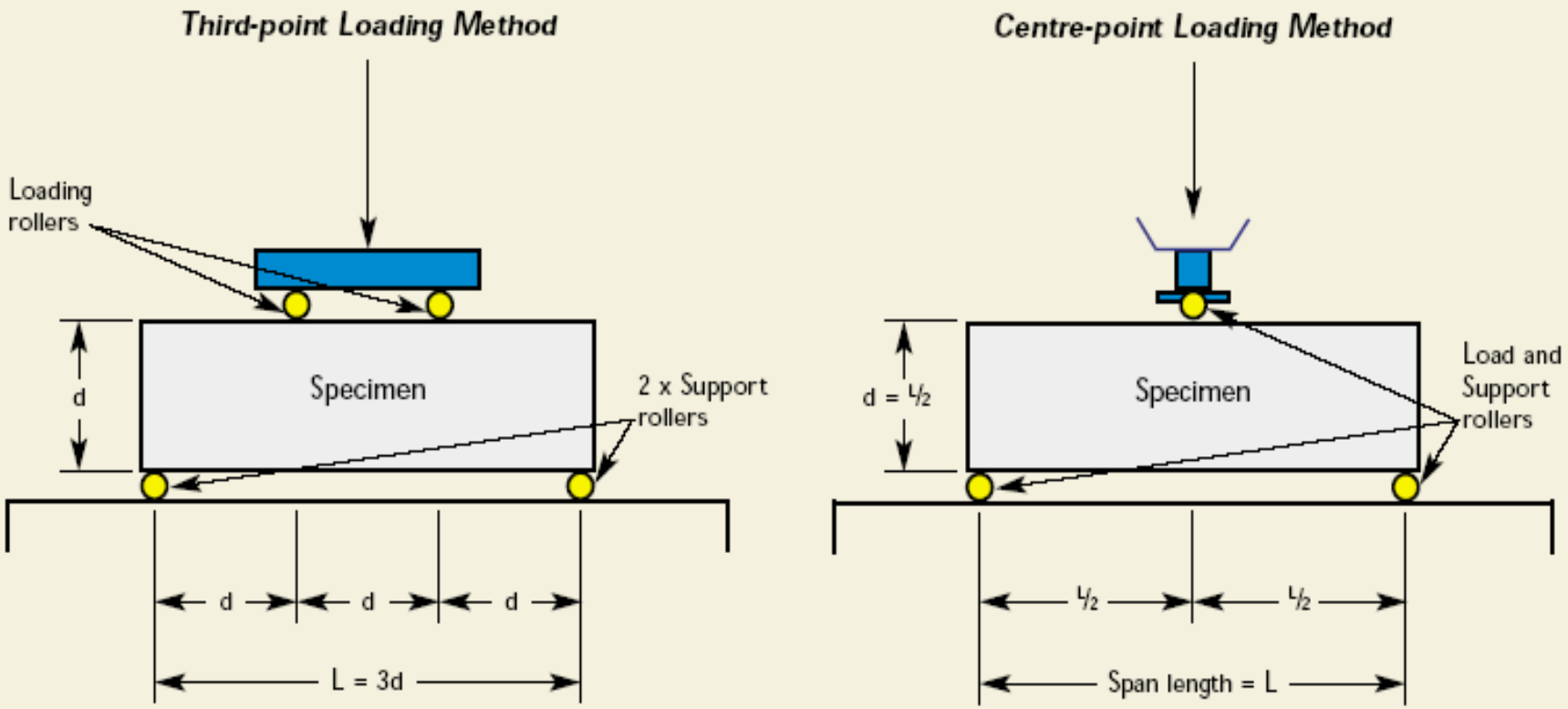
Grades of Concrete	C15	C20	C25	C30	C40	C50	C60
f_{ck}	12	16	20	24	32	40	48

Flexure test





Principles of Flexural Testing



d = Nominal cross-section of the beam

Concrete Core Test

The examination of compressive strength testing of core drilled from hardened concrete enable the visual inspection of interior region of the structural member along with the estimation of actual concrete strength.

- ***Location***

  The choice of location is governed primarily by the basic purpose of the testing

  Normally the core should be taken at the point where minimum strength and maximum stress coincide

- ***Size***

  For compression testing the standards require that the core diameter be at least three times the nominal maximum size of aggregate

- ***Drilling***

  The cores are usually cut by means of portable equipment having rotary cutting tool with diamond bits, and water supply to lubricate the cutter

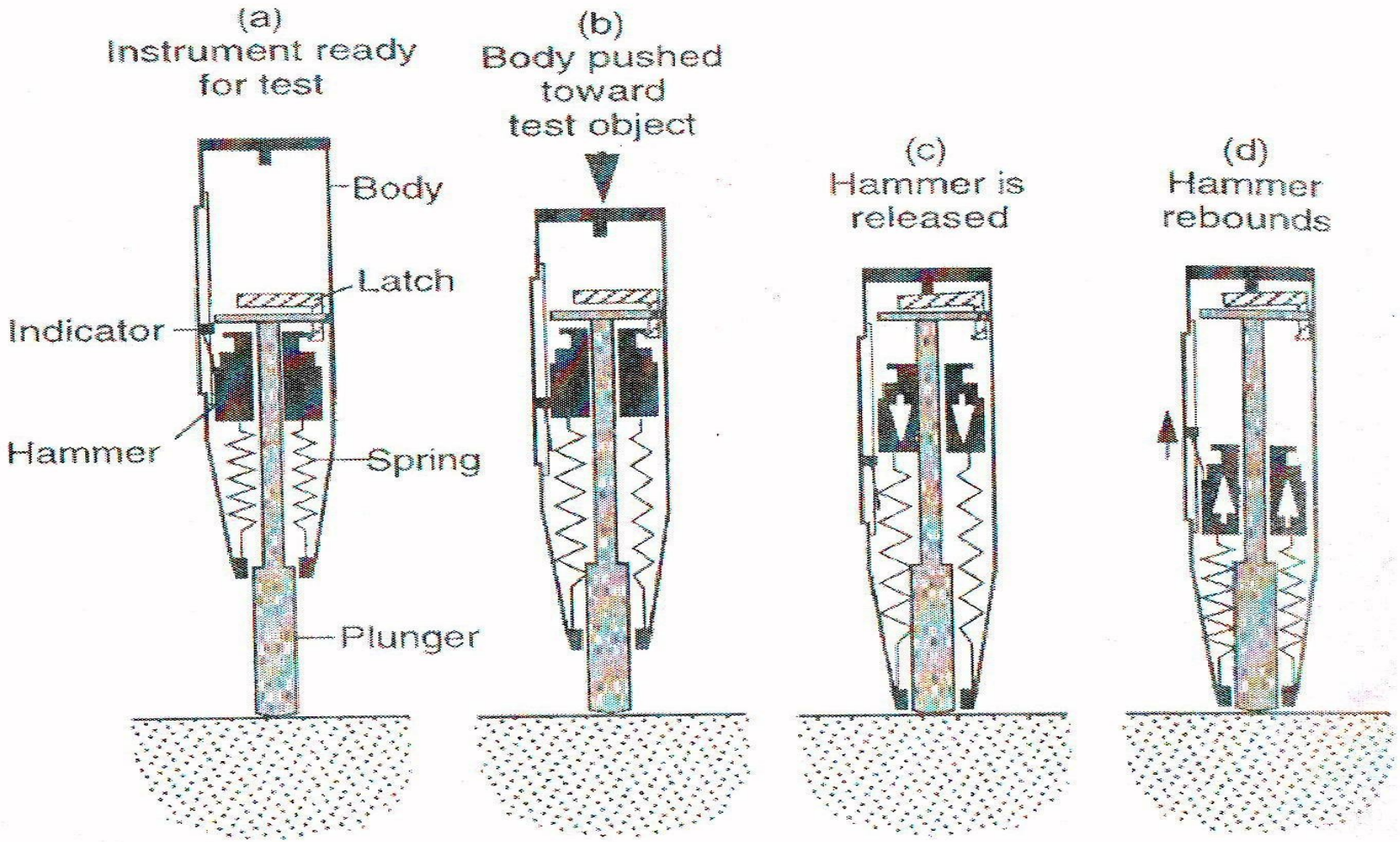
None Distractive test

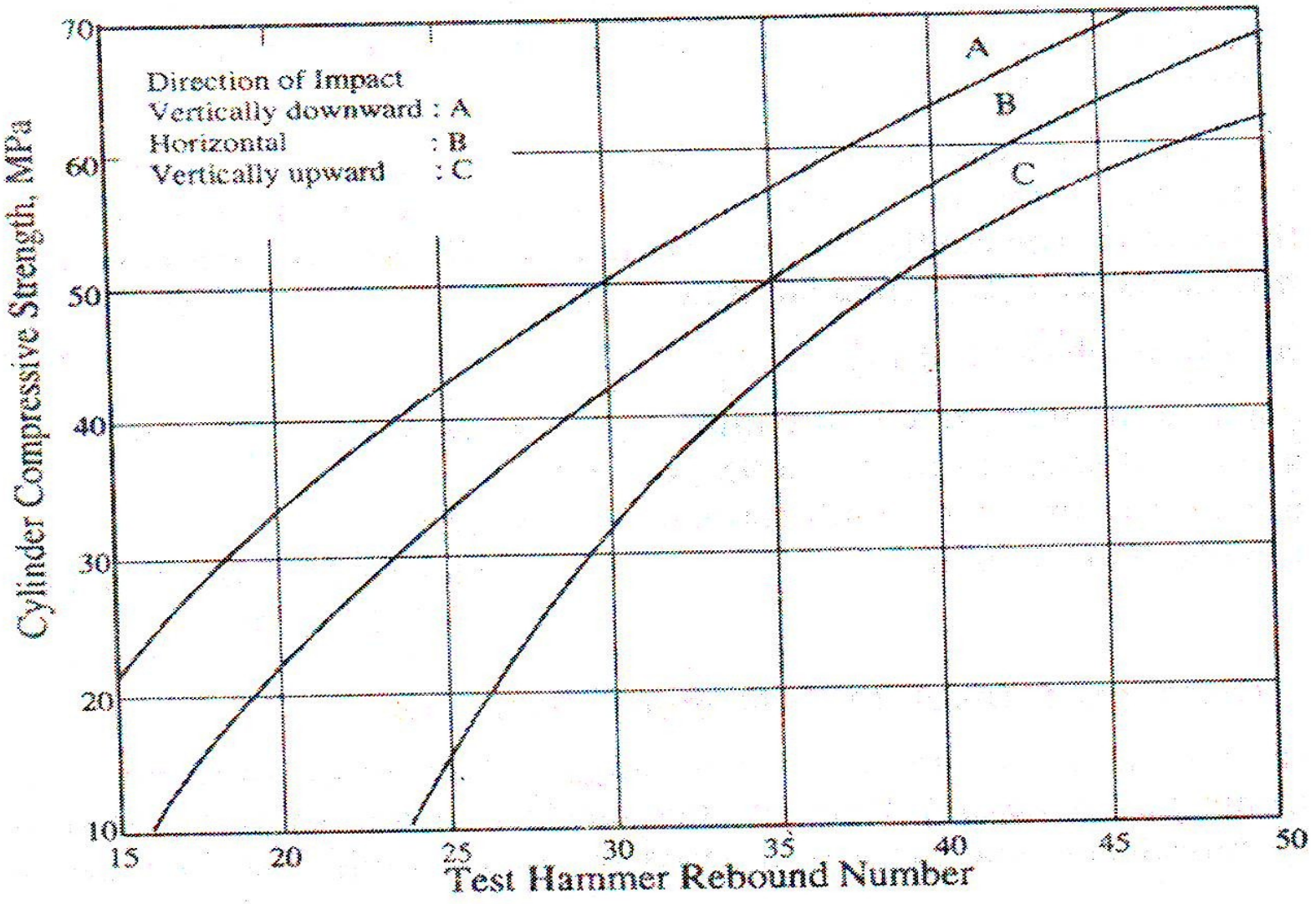
- Rebound hammer test
- Ultrasonic test
- Probe penetration test
- Pullout test

Rebound hammer test

- Is a test developed for testing concrete based on rebound principle .
- when concrete is struck by hammer , the degree of rebound is the indicator of the hardness of the concrete .
- In 1948, Ernest Schmidt, a Swiss engineer, developed a device for testing concrete based on the rebound principle .




(a)
Instrument ready
for test
Body
Latch
Indicator
Hammer
Spring
Plunger
(b)
Body pushed
toward
test object
(c)
Hammer is
released
(d)
Hammer
rebounds


Direction of Impact
Vertically downward : A
Horizontal : B
Vertically upward : C
A
B
C
Cylinder Compressive Strength, MPa
70
60
50
40
30
20
10
15
20
25
30
35
40
45
50
Test Hammer Rebound Number





Ultrasonic test

The ultrasonic pulse velocity (UPV) method basically involves measurement of the velocity of electronic pulses passing through the concrete .

Pulse velocity	**Condition**
Above 4570	Excellent
3660 to 4570	Generally Good
3050 to 3660	questionable
2130 to 3050	Generally poor
Below 2130	Very poor

Classification of concrete condition based on pulse velocity.


2296
PUNDIT
plus
ULTRASOUND
COUPLANT

Factors which should be considered in conducting (UPV) test

- Moisture content – an increase moisture content
  - increases the pulse velocity
- presence of reinforcement oriented parallel to
  - the pulse - propagation direction the pulse may
  - propagate through the bars and result is
  - apparent pulse velocity that is higher than that
  - propagate through the concrete.
- presence of cracks and voids – these can
  - increase the length of the travel path and result
  - in longer travel time

Probe penetration test

Probe penetration method involves a gun to drive a hardened steel rod , or probe into a concrete. Measuring the exposed level of rod can be used to estimate compressive strength .

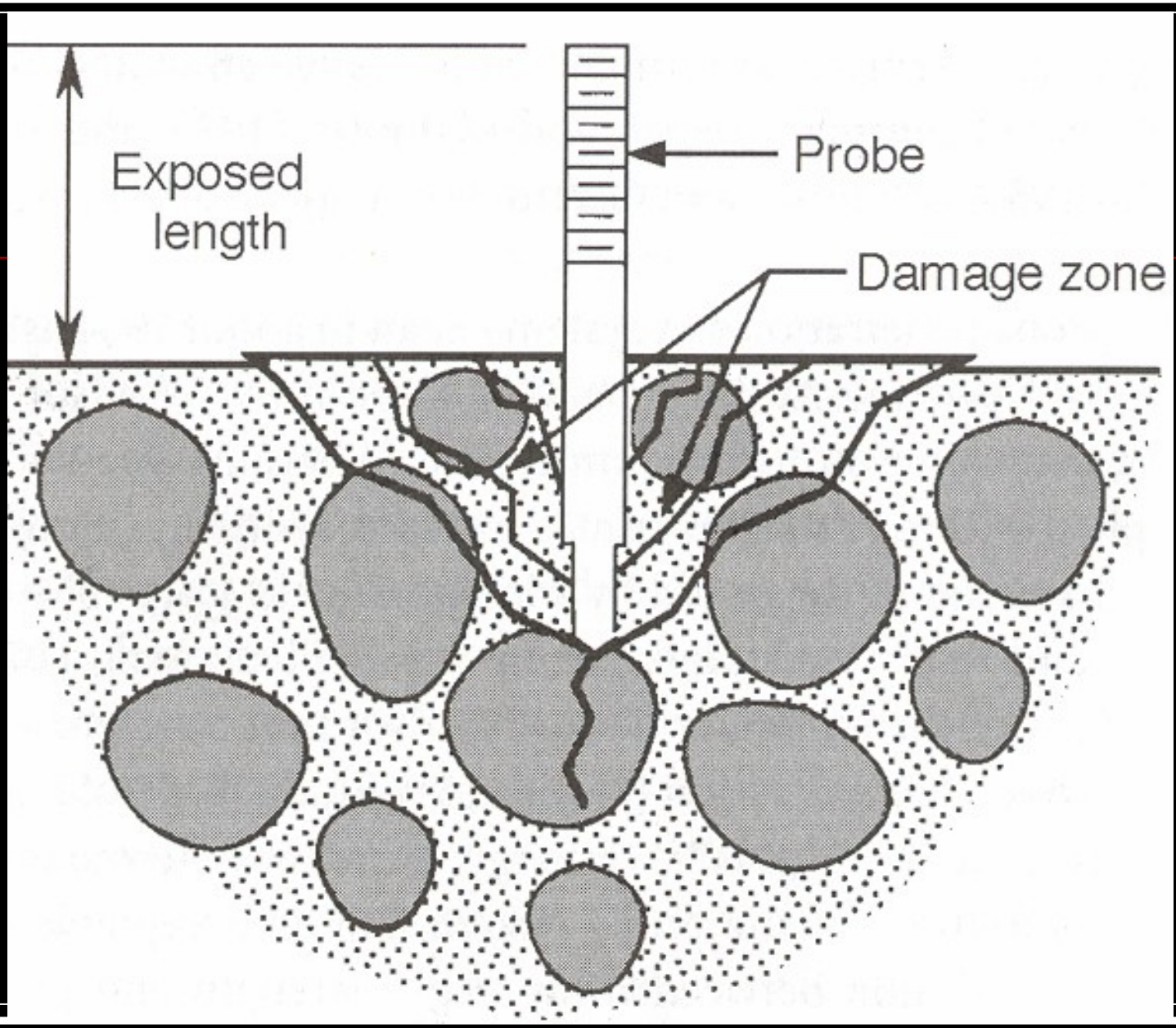


Figure Schematic of conical failure zone during probe penetration test.

Pullout test

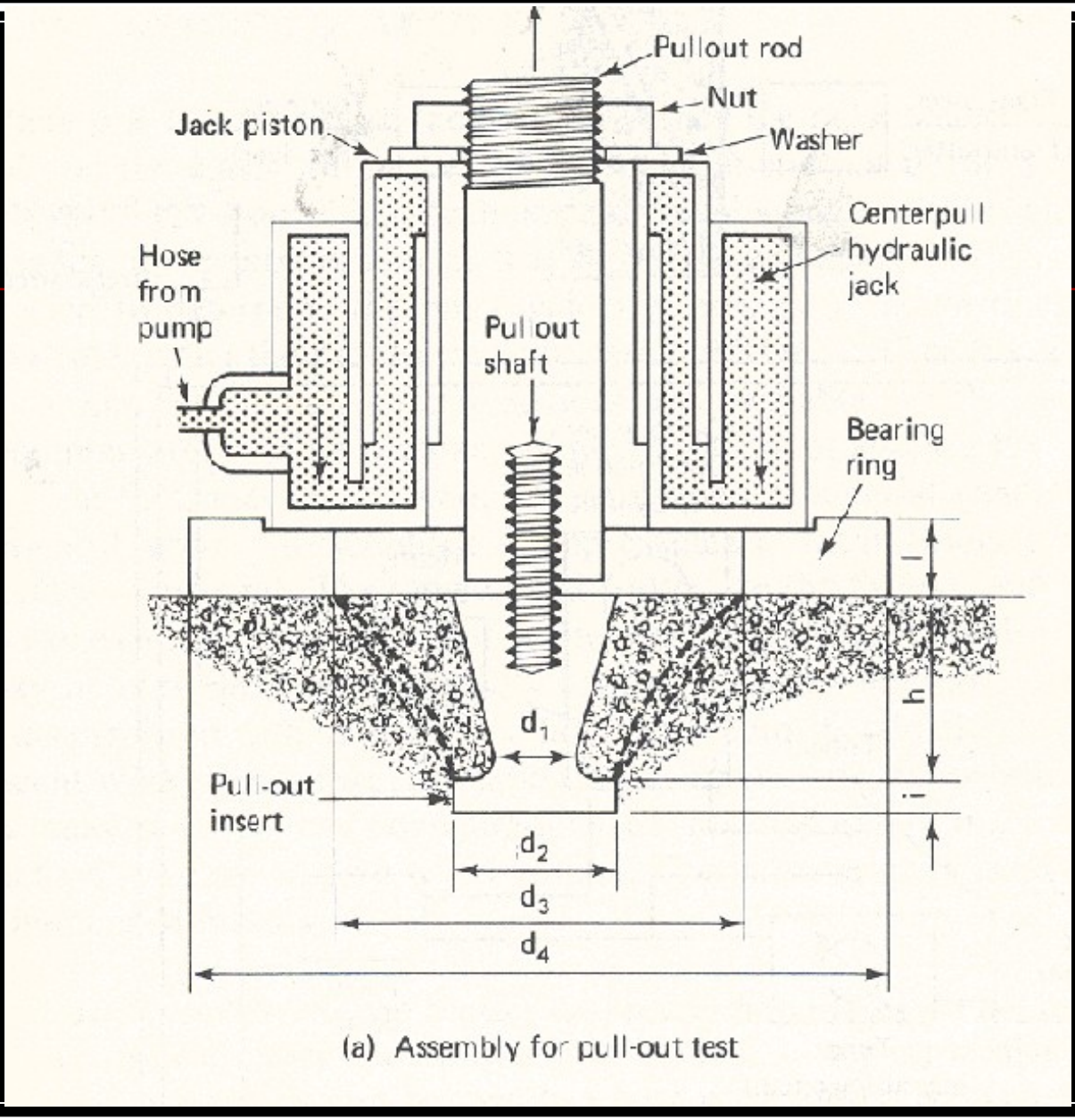
- A pullout test involve the determination of the force required to pull out a steel inserted in a concrete which is embedded during casting .
- Assuming that the failure is a frustum the pullout strength can be calculated by :-

$$F_p = F/A$$

Where F is the force on the ram at failure

A is area of frustum

- These provides the measure of the shear strength of the concrete which can be correlated with the compressive strength .



(a) Assembly for pull-out test

Pull-out test: (a) Assembly for pull-out test

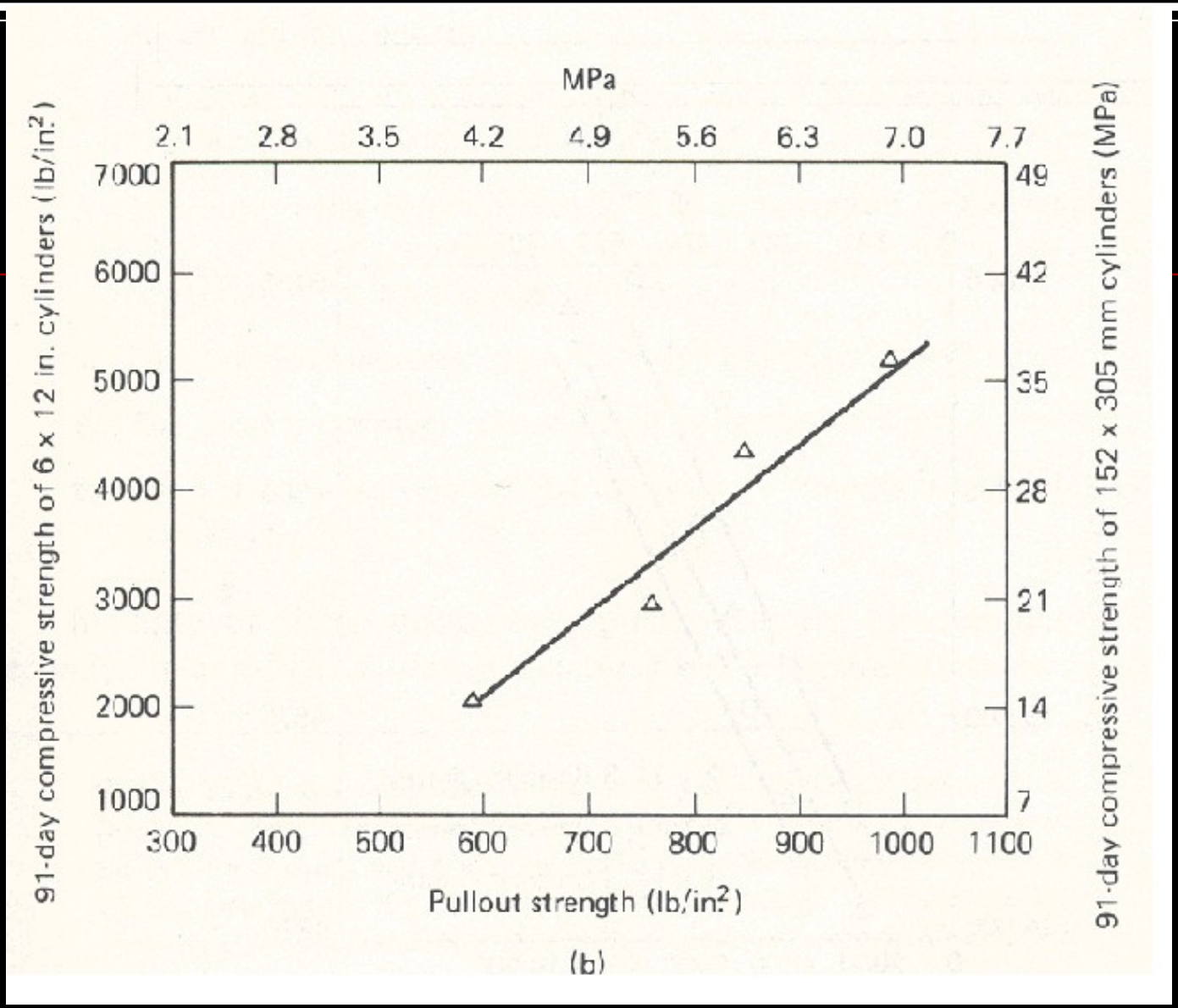


Figure (B) correlation b/n pull-out strength and compressive strength (91-day test results)

Other tests

- Relative Newly Developed Methods
  - X-ray And Gamma Radiography
  - Neutron Moisture Gauges
  - Magnetic Cover Meters
  - Electrical Methods
  - Microwave Absorption, And
  - Acoustic Emissions Techniques.

VOLUME OF FRESH CONCRETE

$$V = V_a + V_w + V_c + V_{fa} + V_{ca}$$

VOLUME OF FRESH CONCRETE

The volume of the fresh concrete is equal to the sum of the absolute volumes of its components, including the naturally entrapped or purposely entrained air.

$$V = V_a + V_w + V_c + V_{fa} + V_{ca}$$

$$V = V_a + V_w + V_c + V_{fa} + V_{ca}$$

Where:

- V_a = Volume of the air
- V_w = volume of the water
- V_c= absolute volume of the cement
- V_{fa} = absolute volume of the fine aggregate
- V_{ca} = absolute volume of the coarse aggregate