Concrete Technology
Lecture 4

AGGREGATES

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Aggregates

- Aggregates are an important constituent in concrete. Aggregate are granular material, derived on the most part from the natural rocks, crushed stones, or natural gravels and sands.

- Aggregate generally occupy about 70% to 80% of the volume of concrete and can therefore be expected to have an important influence on strength, durability and even structural performance of concrete
- Aggregates give body to concrete, reduce shrinkage and effect economy

Aggregate Classification

- Classification based on unit weight
- Classification based on source
- Classification based on size
- Classification based on shape
- Classification based on texture

Classification based on unit weight

- Aggregates are classified as Light-weight, Heavy-weight and Normal-weight aggregate depending on weight and specific gravity.

AGGREGATE	SPECIFIC GRAVITY	UNIT WEIGHT (kN/m3)	BULK DENSITY (kN/m3)	EXAMPLE
normal-weight	2.5-2.7	23-26	15.20-16.80	Sand, Gravel, Crushed stone
heavy-weight	2.8-2.9	25-29	>20.80	Iron. Barite. Limonite etc
light-weight		12	<11.20	Shale. Clay. Slate. slag

Normal Aggregates vs Light weight Aggregates

Normal Aggregates (Gravel)

Light weight Aggregates (Shale)

Heavy Weight Aggregates

Barite Aggregates

Hematite Aggregates

Normal weight aggregate are further classified as

- **Natural Aggregates**
  - Sand, Gravel,
  - Crushed Rock such as Granite, Quartzite, Basalt, Sandstone
- **Artificial Aggregates**
  - Broken Brick,
  - Air-cooled Slag.
  - Sintered fly ash
  - Bloated clay

Natural Aggregates

Natural Gravel

Crushed Granite

Sand Stone Aggregates

Artificial Aggregates

Brick Chips

Air cooled Slag

Classification based on source

- All natural aggregates originate from bed rocks. There are three kinds of rocks namely *Igneous, Sedimentary, and Metamorphic* rocks.
- *Igneous* rocks are formed by cooling down of the magma or lava at surface of crest or beneath the crest. *Aggregates* from these rocks are hard, tough and dense. However, sometimes they tend to react with alkalis in cement. Trap, Basalt and Granite are some examples.
- *Sedimentary* rocks are originally formed below the sea bed by sedimentation. Some of these rocks yield flaky aggregates. Sedimentary rocks vary from soft to hard, porous to dense, and light to heavy. Examples are Limestone and Shale.
- *Metamorphic* rocks are either *Igneous* or *Sedimentary,* that are altered either by extreme heat or pressure below the earth's surface. Aggregates like quartzite and gneiss are considered of good quality.

Classification based on size

- **Coarse aggregate:**

Aggregate which retained on the No.4 (4.75mm) sieve. The function of the coarse aggregate is to act as the main load-bearing component of the concrete. Maximum size of coarse aggregate is up to 80mm.

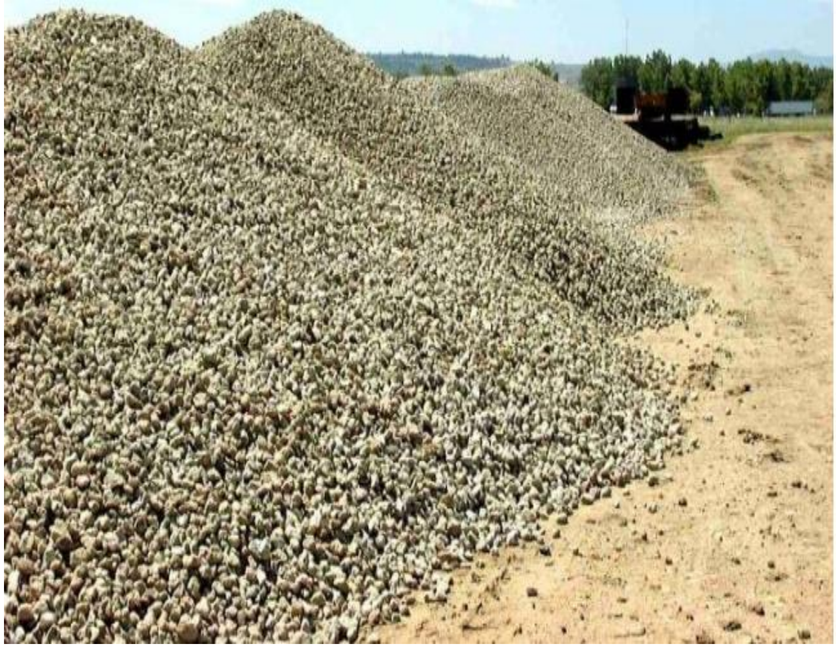
- **Fine aggregate:**

Aggregate passing No.4(4.75mm) sieve and predominately retained on the No.200 (75μ) sieve. The lower limit on sand particles is 0.06mm. The fine aggregate serve the purpose of filling all the open space in between the coarse particles.

Coarse vs Fine aggregates

Fine Aggregates

Coarse Aggregates



Classification based on shape

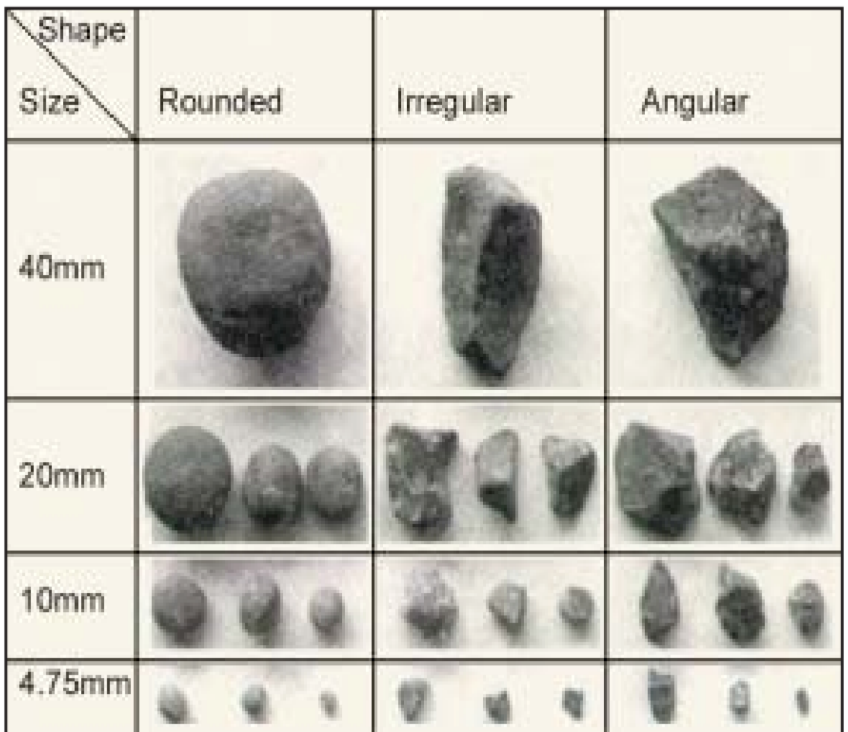
- The shape of aggregates is an important characteristic, since it affects the workability of concrete.

CLASSIFICATION	EXAMPLE
Rounded	River or seashore gravels
Irregular	Flint
Angular	Crushed Rocks
Flaky	Laminated rocks
Elongated	

Round (spherical) concrete aggregate.

Flaky concrete aggregate.

Crushed concrete aggregate.



Classification based on Shape (Cont'd)

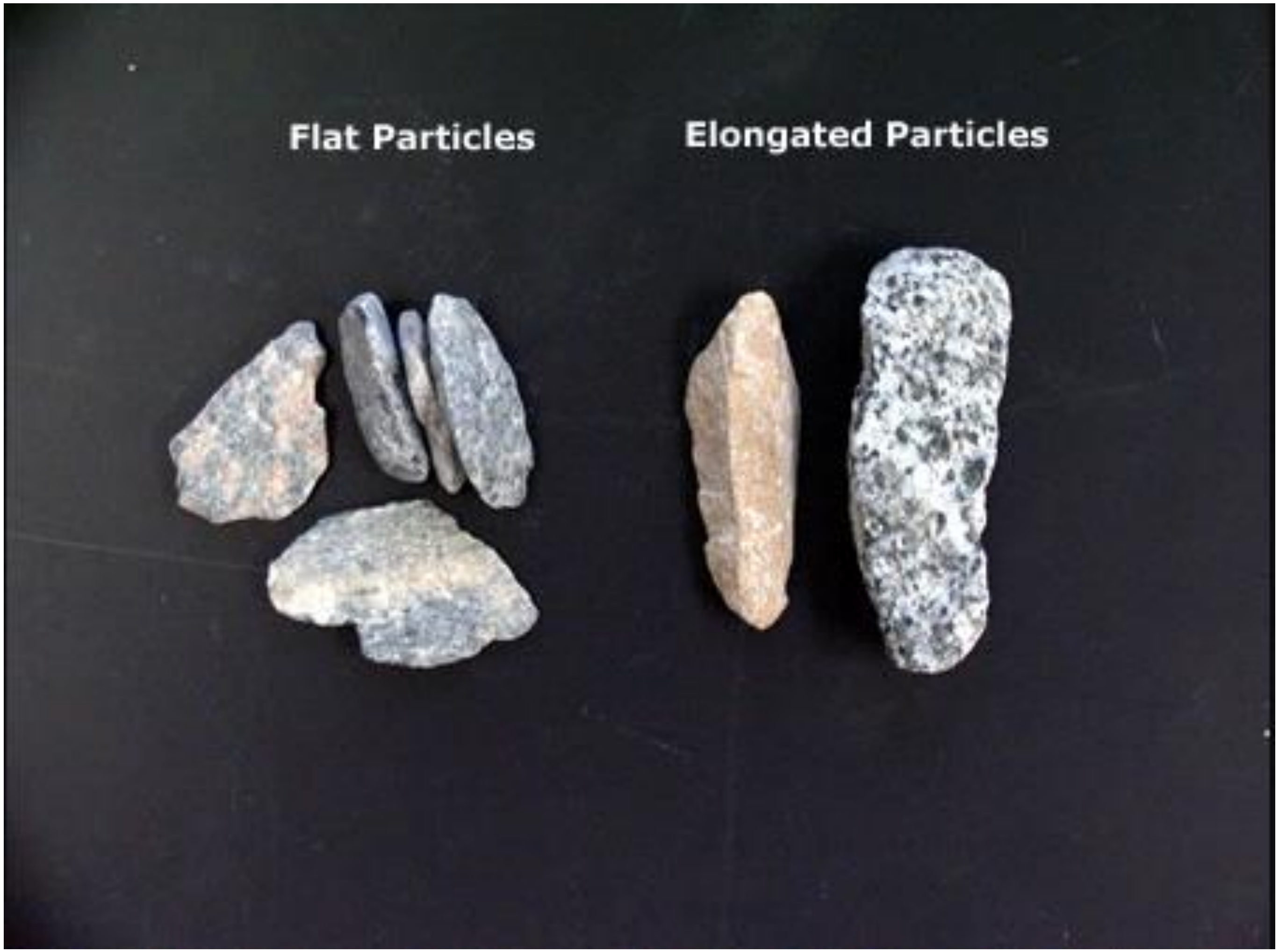
- From the standpoint of economy in cement requirement for a given water/cement ratio, rounded aggregates are preferable to angular aggregates. On the other hand, the additional cement required for angular aggregate is offset to some extent by the higher strengths and sometimes by greater durability as a result of the interlocking texture of the hardened concrete and higher bond characteristic between aggregate and cement paste.
- Flat particles in concrete aggregates will have particularly objectionable influence on the workability, cement requirement, strength and durability. In general, flaky aggregate in excess of 10 to 15% of the mass of C.A makes very poor concrete.

Rounded vs Angular Aggregates

Rounded Aggregate

Angular Aggregate

Flaky vs. Elongated Aggregates



Classification based on texture

- Surface texture is a measure of the smoothness and roughness of aggregate. The grouping of aggregate is broad and is based on visual examination of the specimen.

CLASSIFICATION	EXAMPLES
Glassy	Black flint
Smooth	Gravel, Marble
Granular	Sandstone
Rough	Basalt
Crystalline	Granite
Honeycombed & Porous	Brick, slag

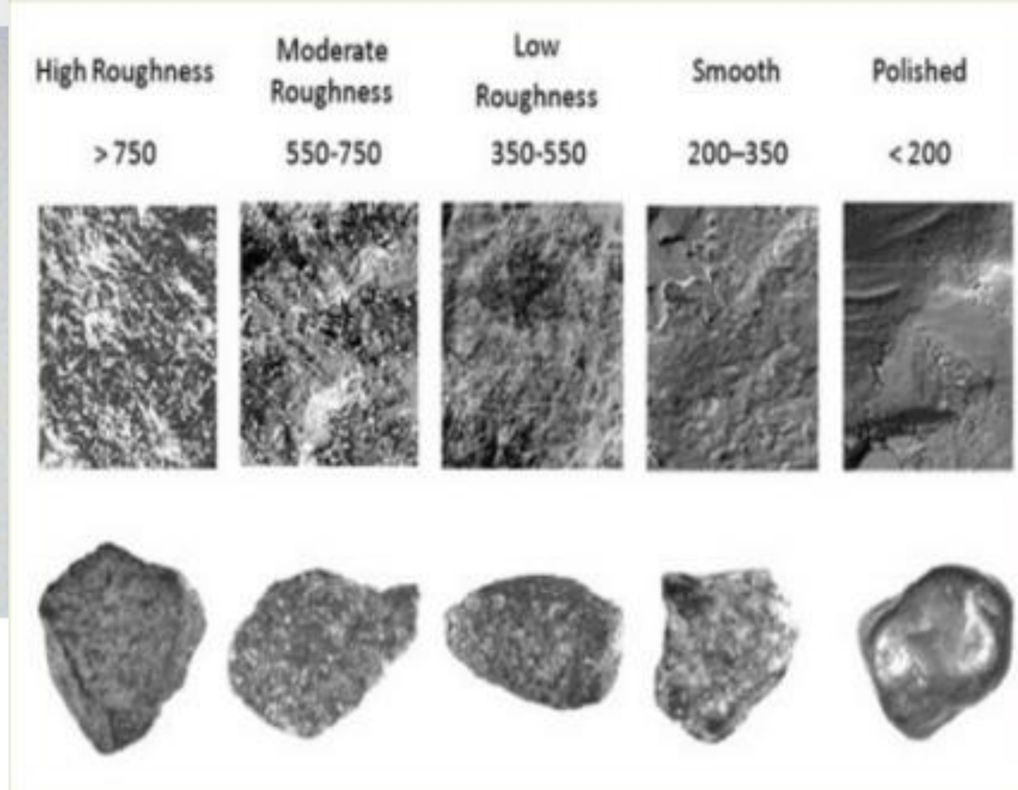
Classification based on texture

- Surface texture depends upon the hardness, grain size, and pore characterizes of the parent rock.
- Hard, dense and fine grained rocks usually have smooth surface.
- Surface texture influence the water requirement for the mixture.
- Rough surface provides more contact area for cement paste and hence a stronger bond but require more paste. Therefor the final concrete is less dense.
- Smooth surface provide thin cement paste layer resulting in dense packing.

Smooth vs. Rough Texture Aggregates

SMOOTH

ROUGH



Mechanical Properties of Aggregates

- Bond
- Strength
- Toughness
- Hardness

Bond

- Both the shape and the surface texture of aggregate influence considerably the strength of concrete
- Rougher texture results in a greater adhesion or bond between the particles and the cement matrix compared to smooth texture.
- Likewise, the larger surface area of a more angular aggregate provides a greater bond compared to rounded aggregates
- The determination of the quality of bond is rather difficult and no accepted test exists.

Strength

- The compressive strength of concrete cannot significantly exceed that of the *major* part of the aggregate contained therein.
- The required information about the aggregate particles has to be obtained from indirect tests: crushing strength of prepared rock samples, crushing value of bulk aggregate, and performance of aggregate in concrete.
- The *aggregate crushing value* (ACV) test is prescribed by BS 812-110: 1990 and BS EN 1097-2: 1998, and is a useful guide when dealing with aggregates of unknown performance
- The aggregate crushing value gives a relative measure of resistance of an aggregate to crushing under a gradually applied compressive load

Toughness

- Toughness can be defined as the resistance of aggregate to failure by impact, and it is usual to determine the *aggregate impact value* of bulk aggregate and is measured by Impact value test
- The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact.
- The impact value is some times used as an alternative to its crushing value.

Hardness

- Hardness, or resistance to wear, is an important property of concrete used in roads and in floor surfaces subjected to heavy traffic.
- It is measured by aggregate abrasion value test
- The aggregate abrasion value gives a relative measure of resistance of an aggregate to wear when it is rotated in a cylinder along with some abrasive charge
- Los Angeles Abrasion Test.

Physical Properties

- Bulk Density
- Specific Gravity
- Porosity and Absorption
- Moisture Content
- Bulking of Aggregates
- Soundness

Bulk Density

- The bulk density or unit w eight of an aggregate gives valuable information regarding the shape and grading of the aggregate.
- The bulk density of aggregate is measured by filling a container of known volume in a standard manner and weighing it.
- Bulk density shows how densely the aggregate is packed when filled in a standard manner.
- The bulk density depends on the particle size distribution and shape of the particles.
- The higher the bulk density, the lower is the void content to be filled by sand and cement.
- The sample which gives the minimum voids or the one which gives maximum bulk density is taken as the right sample of aggregate for making economical mix.

Specific Gravity

- Specific gravity is defined as the ratio of the density of a material to the density of distilled water at a stated temperature; hence, specific gravity is dimensionless
- Specific gravity of aggregates is made use of in design calculations of concrete mixes.
- Similarly, specific gravity of aggregate is required to be considered when we deal with light weight and heavy weight concrete. Average specific gravity of the rocks vary from 2.6 to 2.8.

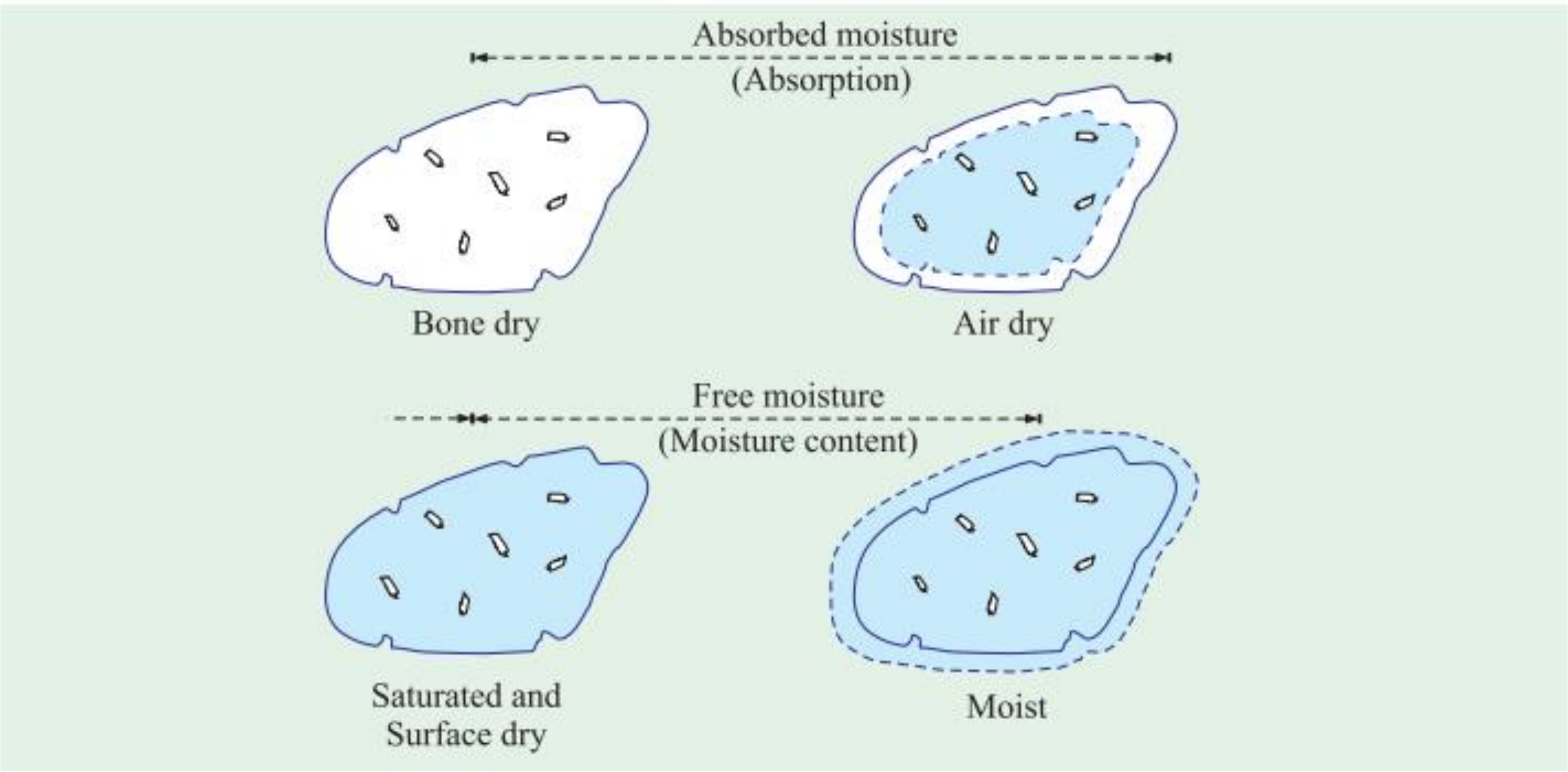
Porosity and Absorption

- Some of the aggregates are porous and absorptive. Porosity and absorption of aggregate will affect the water/cement ratio and hence the workability of concrete as well as the bond between it and cement paste.
- The porosity of aggregate will also affect the durability of concrete when the concrete is subjected to freezing and thawing
- The porosity of normal rocks vary from 0 to 50%.
- The water absorption of aggregate is determined by measuring the increase in weight of an oven dry sample when immersed in water for 24 hours.
- The ratio of the increase in weight to the weight of the dry sample expressed as percentage is know n as absorption of aggregate

Moisture Content

- *Moisture content* as the water in excess of the saturated and surface-dry condition.
- Thus, the total water content of a moist aggregate is equal to the sum of absorption and moisture content
- Aggregate exposed to rain collects a considerable amount of moisture on the surface of the particles, and, except at the surface of the stockpile, keeps this moisture over long periods
- In concrete, the water absorbed by aggregate in time interval equal to the final setting is of importance which is 10 to 30 minutes rather than 24 hours.
- This is particularly true of fine aggregate, and the moisture content must be allowed for in the calculation of batch quantities and of the total water requirement of the mix
- Can be determined by ***buoyancy meter test***

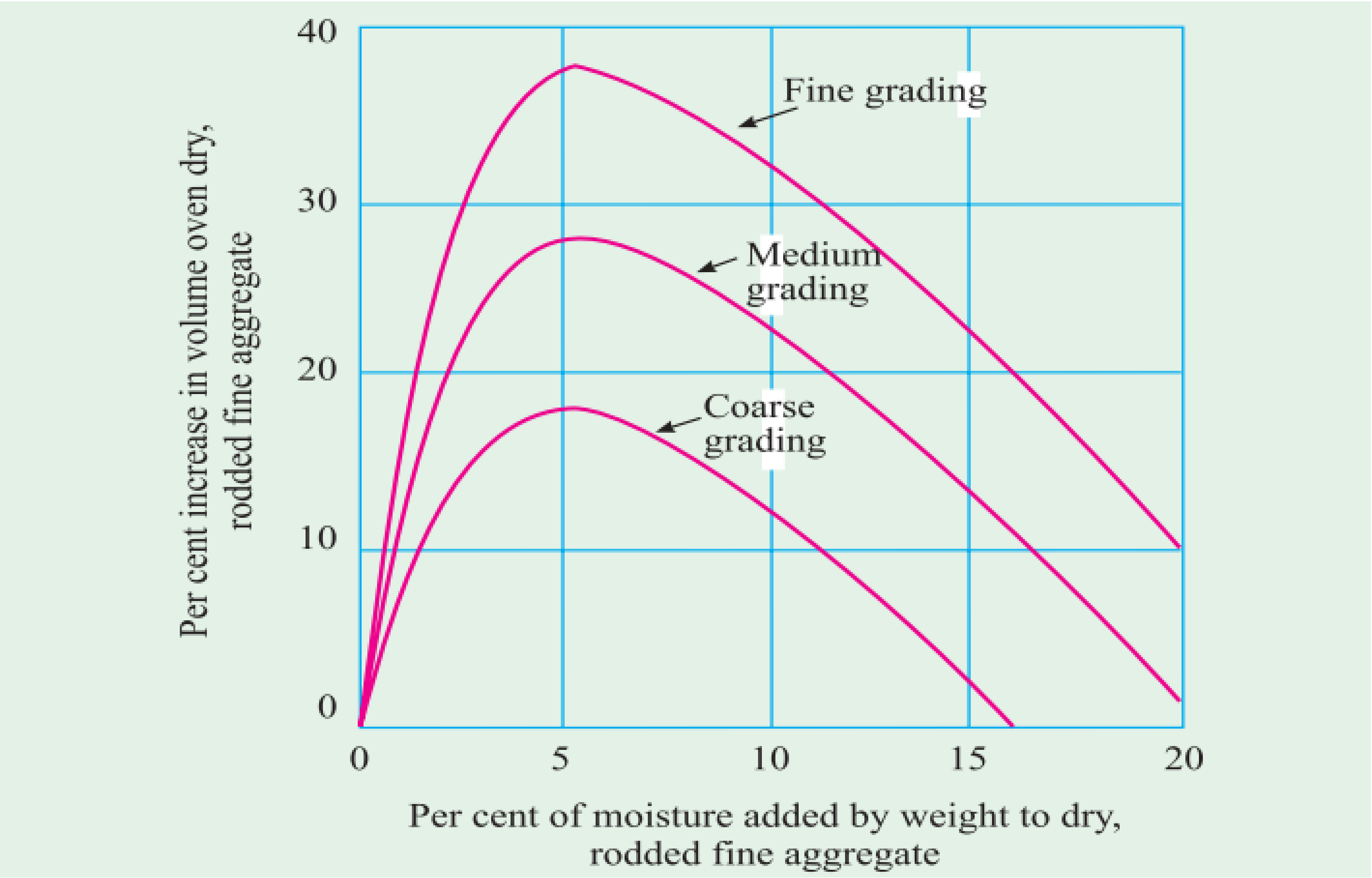
Diagrammatic representation of moisture in aggregates



Bulking of Aggregates

- The free moisture content in fine aggregate results in bulking of volume i.e. increase in the volume of a given mass of fine aggregates caused by the films of water pushing the aggregate particles apart
- Due to the bulking, fine aggregate shows completely unrealistic volume. Therefore, it is absolutely necessary that consideration must be given to the effect of bulking in proportioning the concrete by volume.
- It will also affect the yield of concrete for a given cement content.

Plot between volume change and moisture content of aggregates



Soundness

- Soundness refers to the ability of aggregate to resist excessive changes in volume as a result of changes in physical conditions.
- These physical conditions that affect the soundness of aggregate are the freezing the thawing, variation in temperature, alternate wetting and drying under normal conditions and wetting and drying in salt water.
- Aggregates which are porous, weak and containing any undesirable deleterious matter undergo excessive volume change when subjected to the above conditions.
- Aggregates which undergo more than the specified amount of volume change is said to be unsound aggregates.
- If concrete is liable to be exposed to the action of frost, the coarse and fine aggregate which are going to be used should be subjected to soundness test.

Unsoundness due to impurities

- Sometimes aggregates fail to maintain their integrity owing to the non-durable impurities.
- Shale and other particles of low density are considered unsound and so are soft inclusions such as clay lumps, wood and coal as they lead to scaling.
- Mica, gypsum and other sulphates and sulphides should also be avoided.

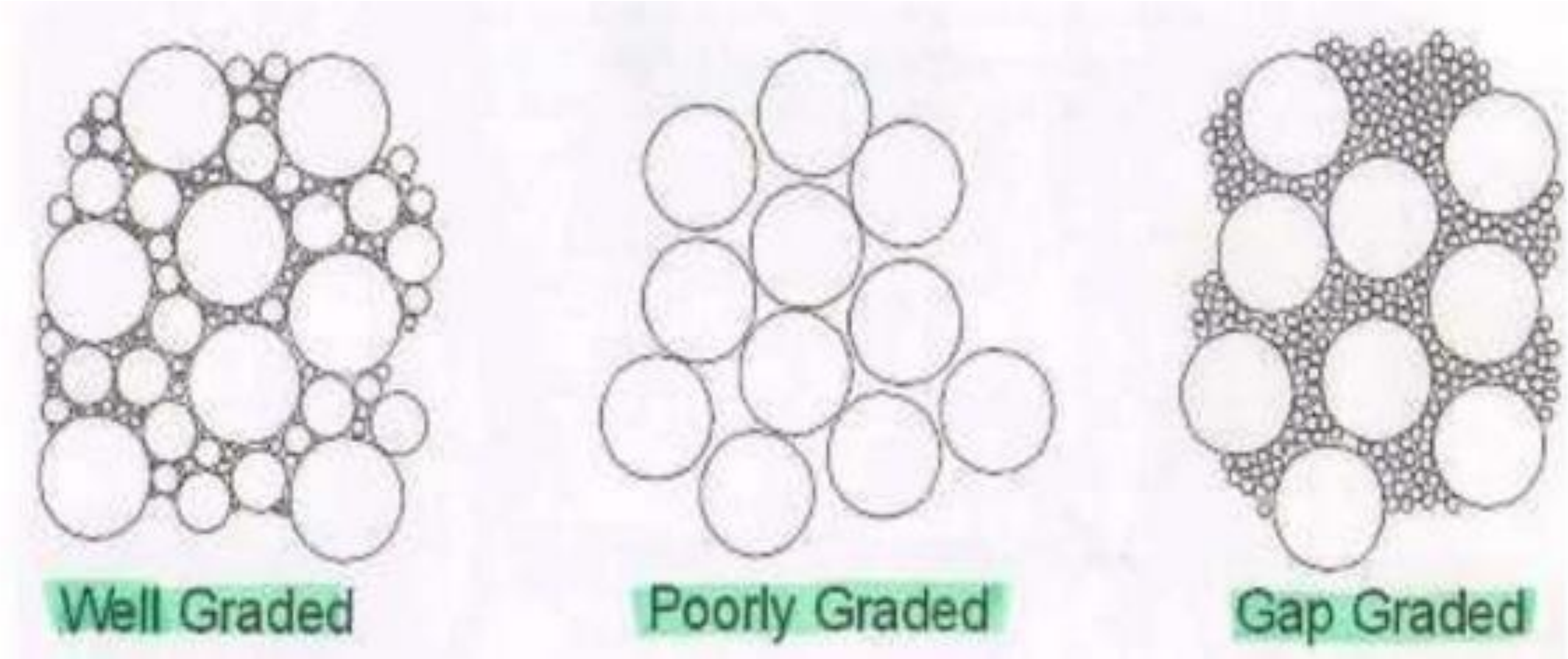
Gradation

- Aggregates in concrete are of various uses, this particle size distribution in concrete is termed as "Gradation"
- The particle size distribution is determined by sieve analysis
- Proper gradation is one of the most important factors in producing workable concrete.

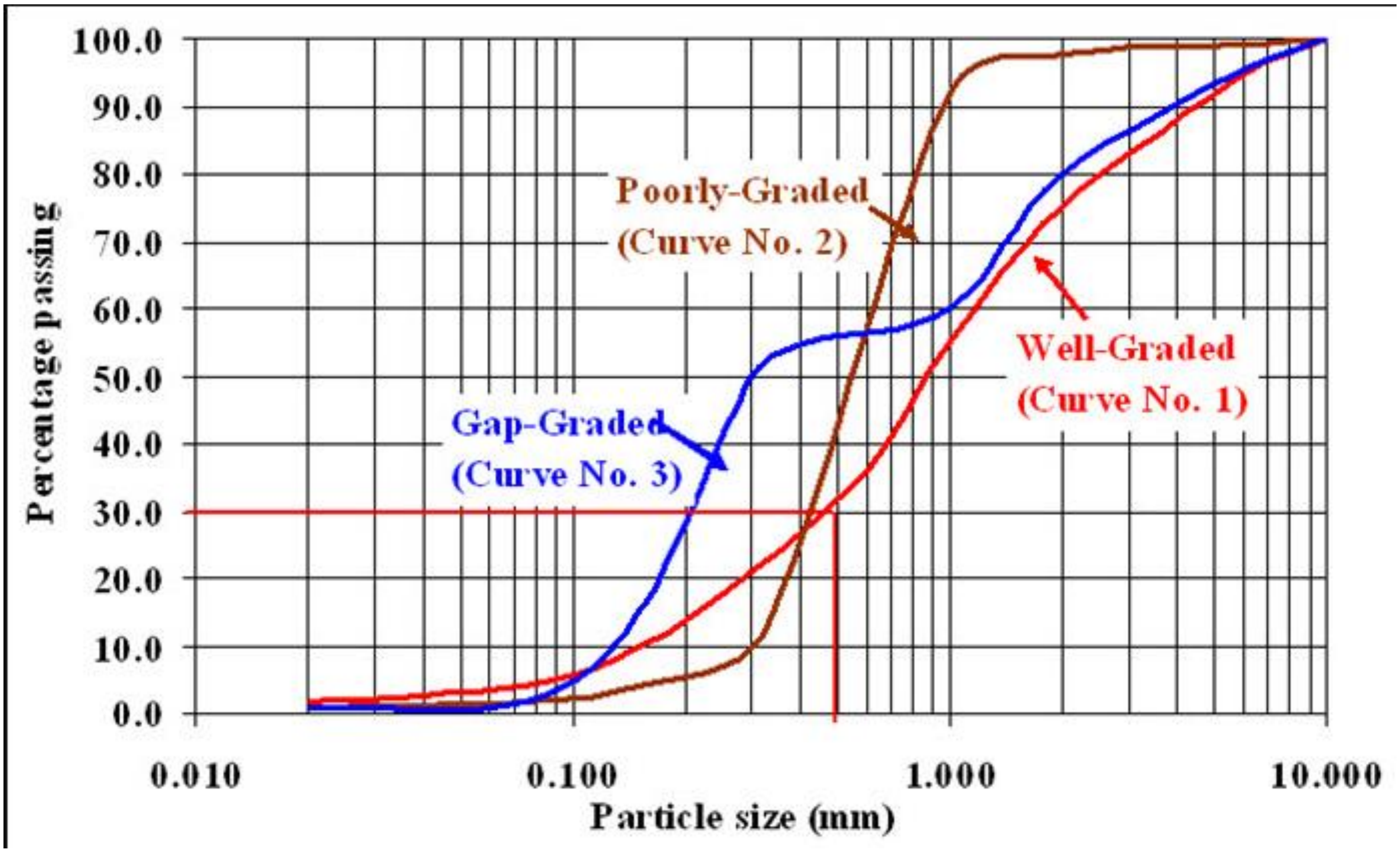
Gradation (Cont'd)

- There are 3 main types
  - **Well Graded:** Well graded aggregate has a gradation of particle size that fairly evenly spans the size from the finest to the coarsest which means particles are densly packed together leaving little or no voids. Represented by S shape in gradation curve
  - **Poorly Graded:** Contains particle distribution of similar sizes which means particles pack together leaving large voids in concrete mass. Represented by Steep curve
  - **Gap Graded:** Aggregates consist of particles in which some intermediate size particles are missing. Characterized by a gradation curve with hump in between

Figure Showing Gradation of Aggregates



Gradation Curves



Quality of Water

- The quality of the water is important because impurities in it may interfere with the *setting* of the cement, may adversely affect the *strength* of the concrete or cause *staining* of its surface, and may also lead to *corrosion* of the reinforcement. For these reasons, the suitability of water for mixing and curing purposes should be considered. Clear distinction must be made between the effects of *mixing* water and the *attack* on hardened concrete by aggressive waters because some of the latter type may be harmless or even beneficial when used in mixing.

Mixing Water

- In many specifications, the quality of water is covered by a clause saying that water should be fit for drinking
- Such water very rarely contains dissolved solids in excess of 2000 parts per million (ppm), and as a rule less than 1000 ppm
- The criterion of potability of water is not absolute: drinking water may be unsuitable as mixing water when the water has a high concentration of sodium or potassium and there is a danger of alkali-aggregate reaction

Limits of Impurities in Mixing Water in mg/l

Impurity	BS 3148: 1980	BS EN 1008: 2002	ASTM C 1602/C 1602M–06
Chloride ion:			
prestressed concrete		500	500*
reinforced concrete	500	1000	1000
plain concrete		4500	—
Sulfate	1000 (SO_3)	2000 (SO_3)	3000 (SO_4)
Alkali	1000	1500	600

Curing Water

- Any water suitable for mixing, or even slightly inferior in quality, is acceptable for curing. However, it is essential that curing water be free from substances that attack hardened concrete. For example, concrete is attacked by water containing free CO,. Flowing pure water, formed by melting ice or by condensation, and containing little $C0_2$, dissolves $Ca(OH)_2$ and causes surface erosion

THE END