Aggregates

Fine Aggregates

Coarse Aggregates

Aggregates

- **Freshly mixed normal weight concrete (2200 to 2400 kg/m3) can be produced using:**

  Natural gravel and sand are usually dug from a pit, river, lake, or seabed.

- **Crushed aggregate is produced by crushing quarry rock, boulders, cobbles, or large size gravel.**

- **Various light weight materials such as expanded shale, clay, slate, and slag are used as aggregates for producing lightweight concrete (1350 to 1850 kg/m^3).**

- **Other lightweight materials such as pumice, scoria, perlite, vermiculite, and diatomite are used to produce insulating lightweight concretes (250 to 1450 kg/m^3).**

- **Heavy weight aggregates such as barlite, magnetite and iron are used to produce heavy weight concrete and radiation-shielding concrete.**

Lightweight Aggregates

- Expanded clay (left)
- Expanded shale (right)

Constituents in Naturally Occurring Aggregates

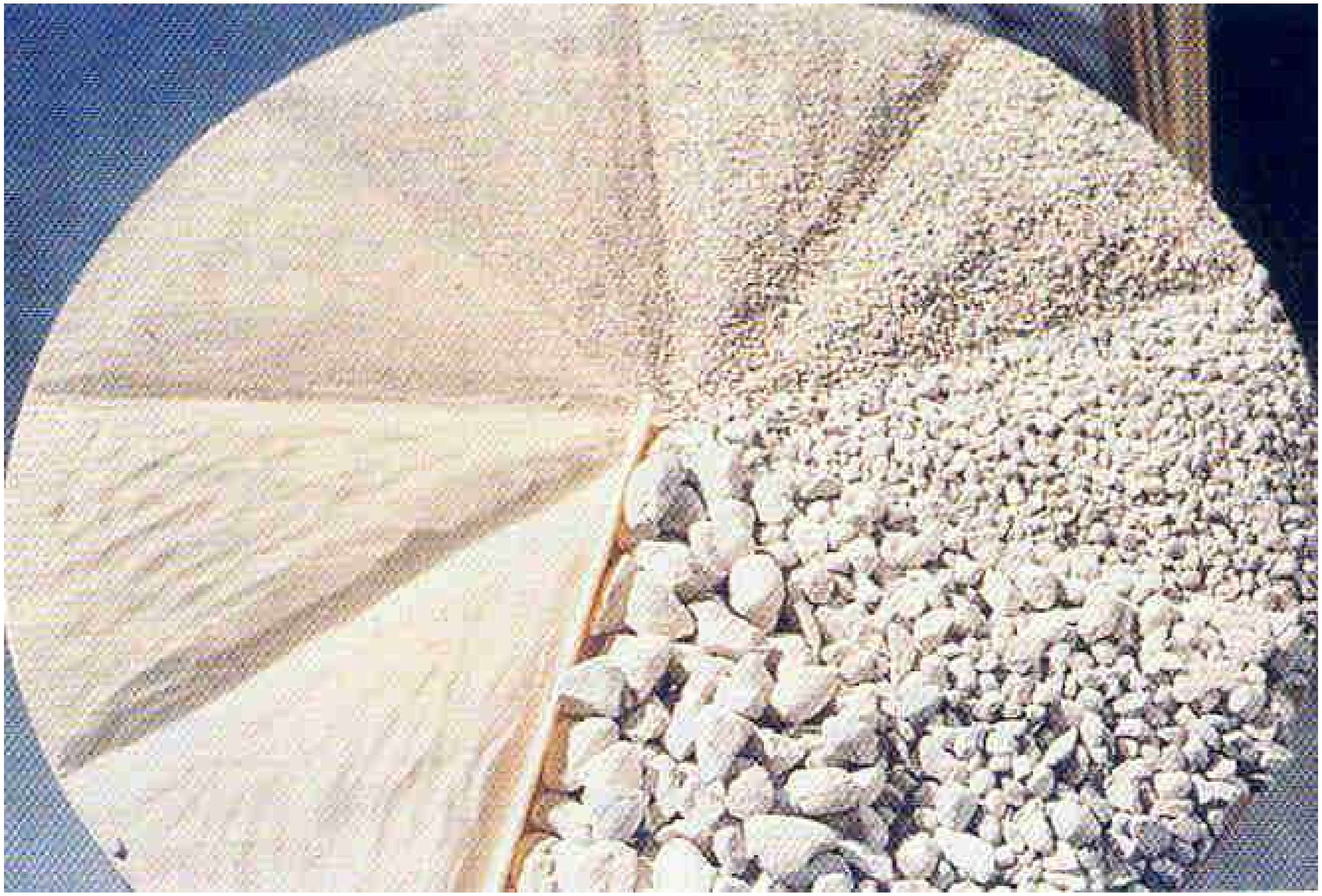
- Naturally occurring concrete aggregates are a mixture of rocks and minerals
  - Minerals
    - Silica (ex. Quartz)
    - Silicates (ex. Clay)
    - Carbonate (ex. Calcite, dolomite)
  - Igneous rocks
    - Granite
    - Basalt
  - Sedimentary rocks
    - Sandstone
    - Limestone
    - Shale
  - Metamorphic rocks
    - Marble
    - slate

Table 5.2. Characteristics and Tests of Aggregate

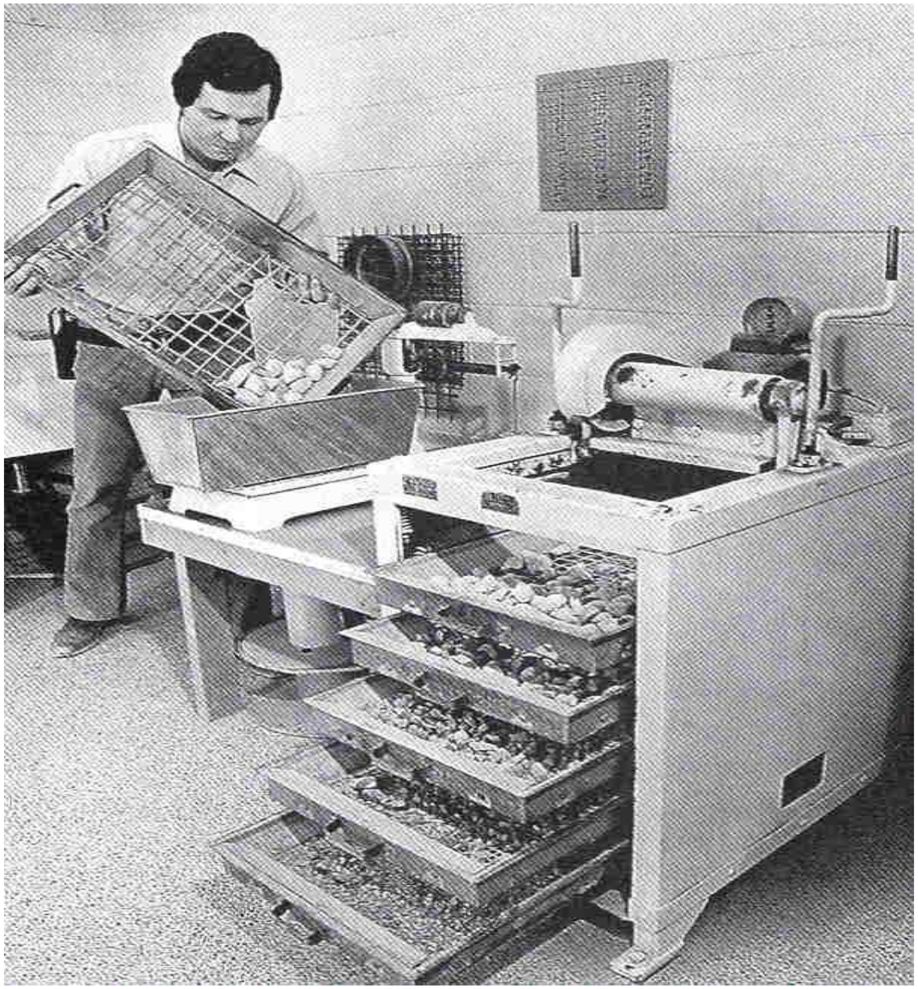
Characteristic	Significance	Test designation*	Requirement or item reported
Resistance to abrasion and degradation	Index of aggregate quality; wear resistance of floors and pavements	ASTM C 131 (AASHTO T 96) ASTM C 535 ASTM C 779	Maximum percentage of weight loss. Depth of wear and time
Resistance to freezing and thawing	Surface scaling, roughness, loss of section, and aesthetics	ASTM C 666 (AASHTO T 161) ASTM C 682 AASHTO T 103	Maximum number of cycles or period of frost immunity; durability factor
Resistance to disintegration by sulfates	Soundness against weathering action	ASTM C 88 (AASHTO T 104)	Weight loss, particles exhibiting distress
Particle shape and surface texture	Workability of fresh concrete	ASTM C 295 ASTM D 3398	Maximum percentage of flat and elongated particles
Grading	Workability of fresh concrete; economy	ASTM C 117 (AASHTO T 11) ASTM C 136 (AASHTO T 27)	Minimum and maximum percentage passing standard sieves
Fine aggregate degradation	Index of aggregate quality; Resistance to degradation during mixing	ASTM C 1137	Change in grading
Uncompacted void content of fine aggregate	Workability of fresh concrete	ASTM C 1252 (AASHTO T 304)	Uncompacted voids and specific gravity values
Bulk density (unit weight)	Mix design calculations; classification	ASTM C 29 (AASHTO T 19)	Compact weight and loose weight
Relative density (specific gravity)	Mix design calculations	ASTM C 127 (AASHTO T 85) fine aggregate ASTM C 128 (AASHTO T 84) coarse aggregate	—
Absorption and surface moisture	Control of concrete quality (water-cement ratio)	ASTM C 70 ASTM C 127 (AASHTO T 85) ASTM C 128 (AASHTO T 84) ASTM C 566 (AASHTO T 255)	—
Compressive and flexural strength	Acceptability of fine aggregate failing other tests	ASTM C 39 (AASHTO T 22) ASTM C 78 (AASHTO T 97)	Strength to exceed 95% of strength achieved with purified sand
Definitions of constituents	Clear understanding and communication	ASTM C 125 ASTM C 294	—
Aggregate constituents	Determine amount of deleterious and organic materials	ASTM C 40 (AASHTO T 21) ASTM C 87 (AASHTO T 71) ASTM C 117 (AASHTO T 11) ASTM C 123 (AASHTO T 113) ASTM C 142 (AASHTO T 112) ASTM C 295	Maximum percentage allowed of individual constituents
Resistance to alkali reactivity and volume change	Soundness against volume change	ASTM C 227 ASTM C 289 ASTM C 295 ASTM C 342 ASTM C 586 ASTM C 1260 (AASHTO T 303) ASTM C 1293	Maximum length change, constituents and amount of silica, and alkalinity

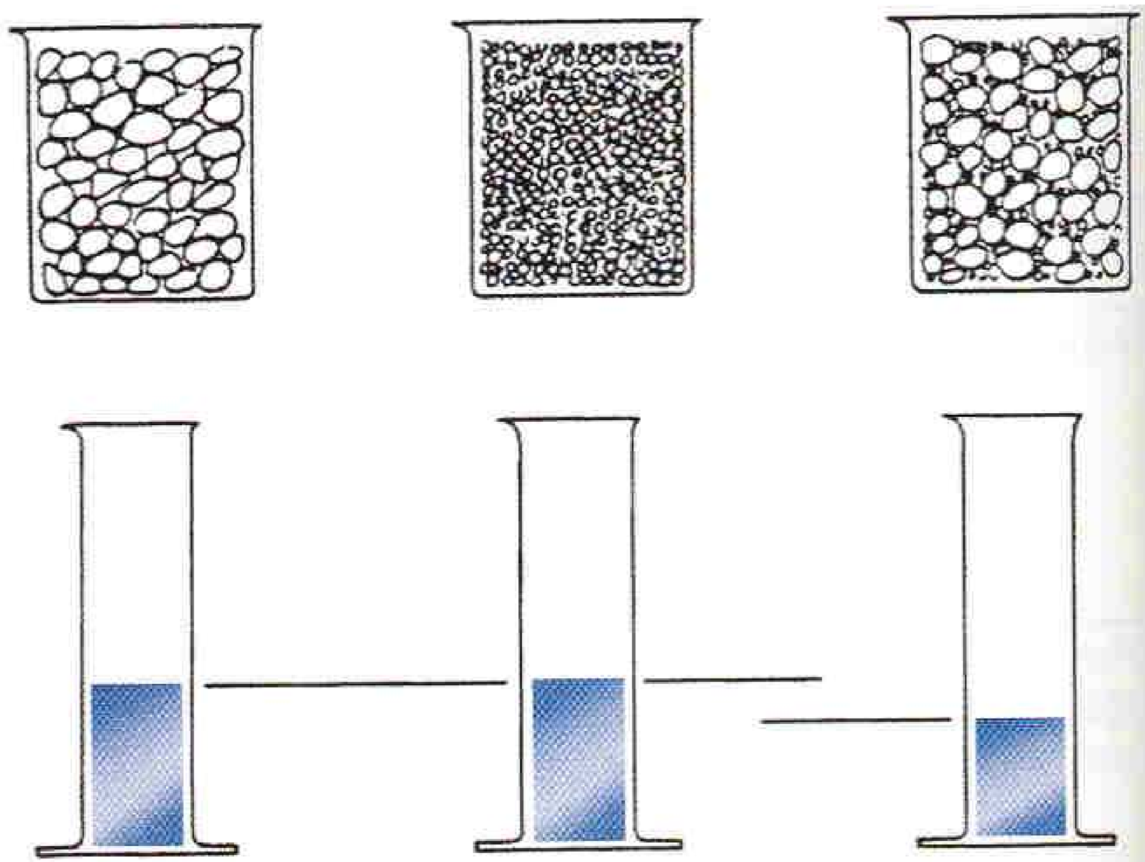
* The majority of the tests and characteristics listed are referenced in ASTM C 33 (AASHTO M 6/M 80). ACI 221R-96 presents additional test methods and properties of concrete influenced by aggregate characteristics.

Range of particle sizes found in aggregate for use in concrete

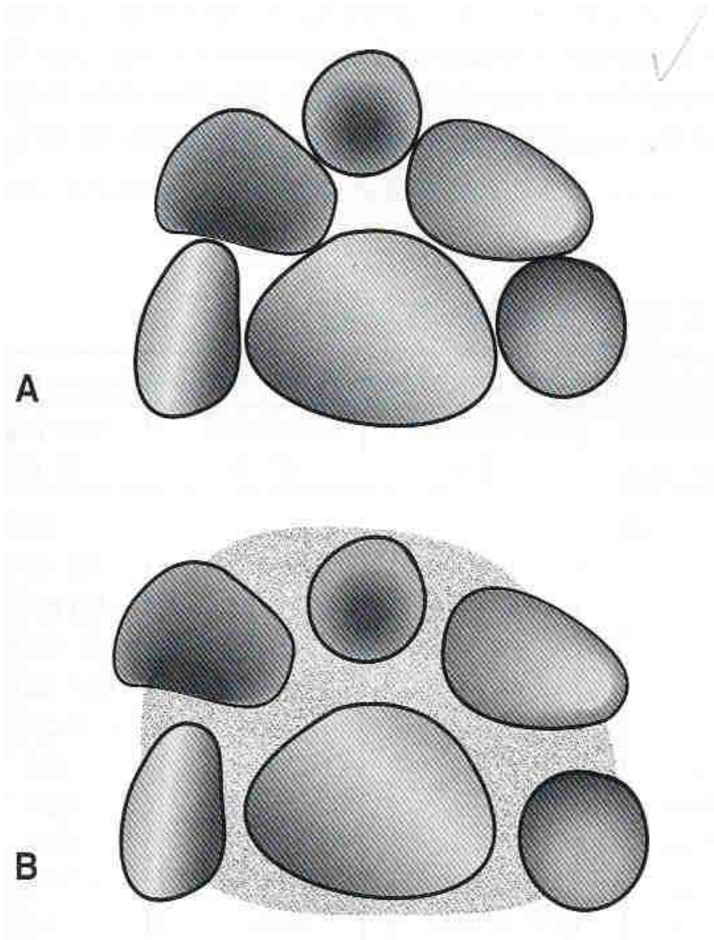


Making a sieve analysis test of coarse aggregate in a Lab





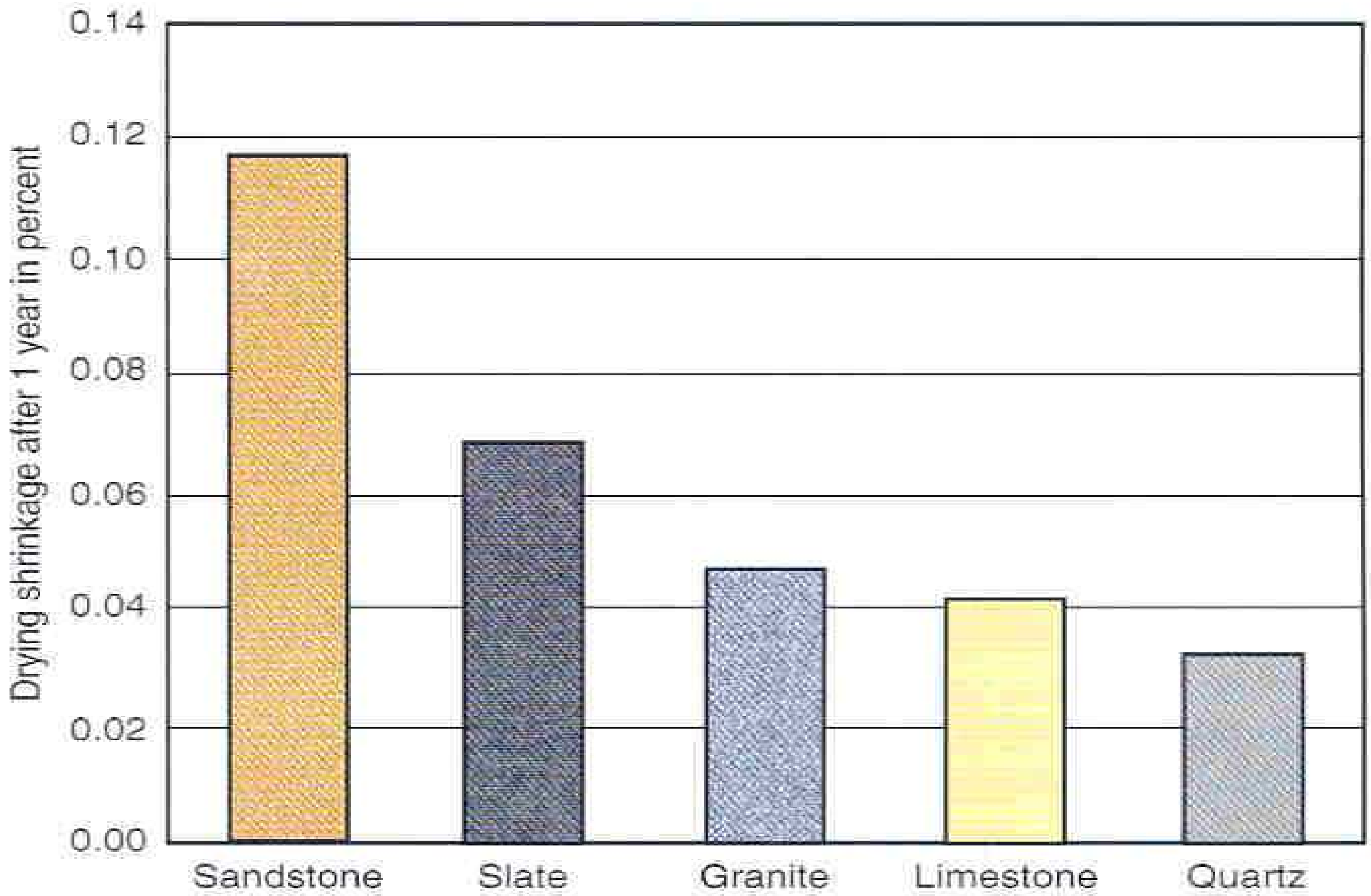
- Amount of cement paste required in concrete is greater than the volume of voids between the aggregates.



Fine aggregate grading limits

Sieve size		Percent passing by mass	
9.5 mm	(⅜ 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	(AASHTO 10 to 30)
150 µm	(No. 100)	0 to 10	(AASHTO 2 to 10)

Type of aggregate and drying shrinkage

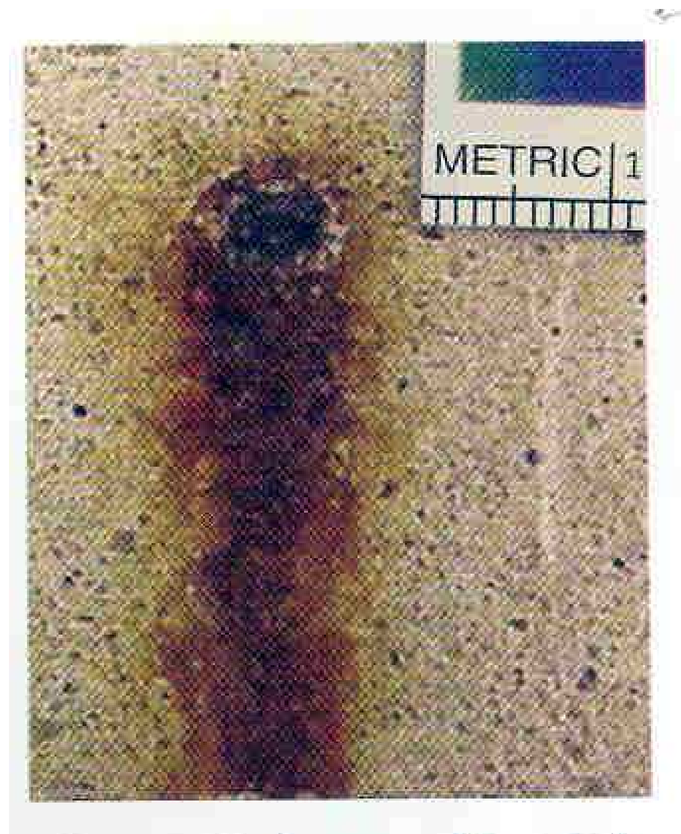


Harmful materials in aggregates

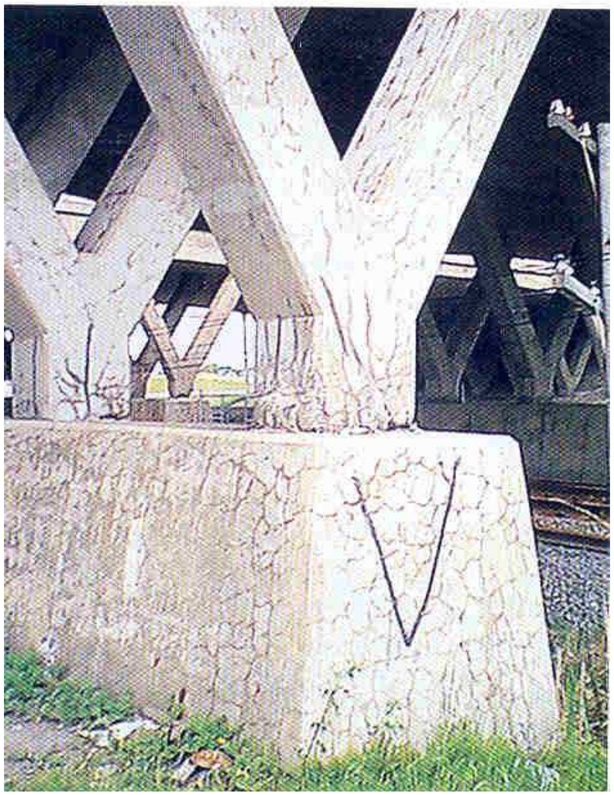
Table 5-6. Harmful Materials in Aggregates

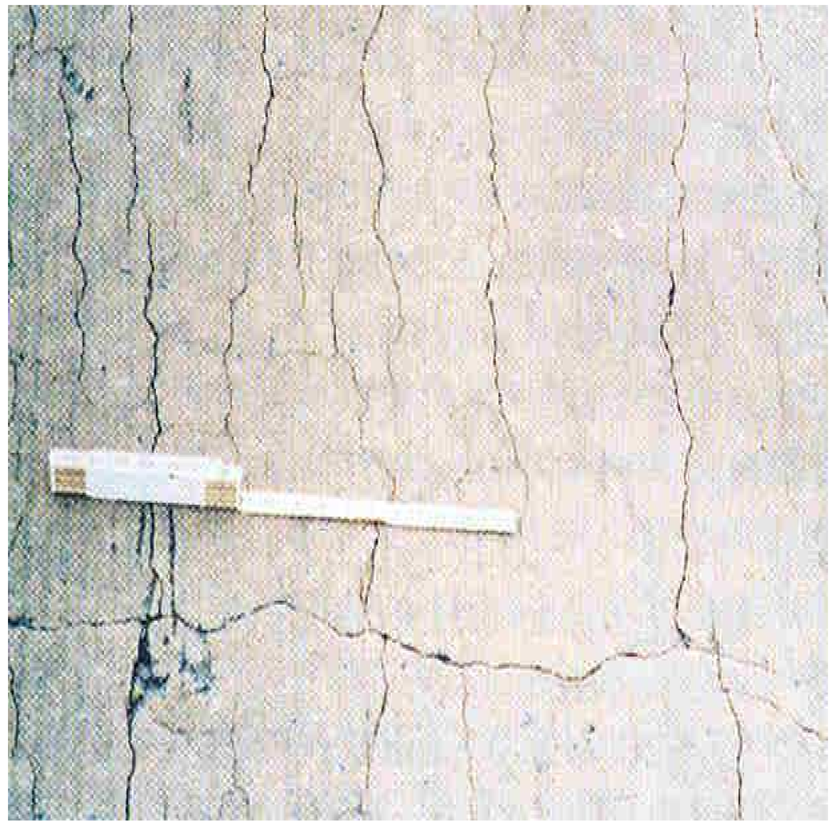
Substances	Effect on concrete	Test designation
Organic impurities	Affects setting and hardening, may cause deterioration	ASTM C 40 (AASHTO T 21) ASTM C 87 (AASHTO T 71)
Materials finer than the 75 µm (No. 200) sieve	Affects bond, increases water requirement	ASTM C 117 (AASHTO T 11)
Coal, lignite, or other lightweight materials	Affects durability, may cause stains and popouts	ASTM C 123 (AASHTO T 113)
Soft particles	Affects durability	
Clay lumps and friable particles	Affects work-ability and durability, may cause popouts	ASTM C 142 (AASHTO T 112)
Chert of less than 2.40 relative density	Affects durability, may cause popouts	ASTM C 123 (AASHTO T 113) ASTM C 295
Alkali-reactive aggregates	Causes abnormal expansion, map cracking, and popouts	ASTM C 227 ASTM C 289 ASTM C 295 ASTM C 342 ASTM C 586 ASTM C 1260 (AASHTO T 303) ASTM C 1293

- Aggregates can occasionally contain particles of iron oxide and iron sulfide that result in stains on exposed concrete surface.

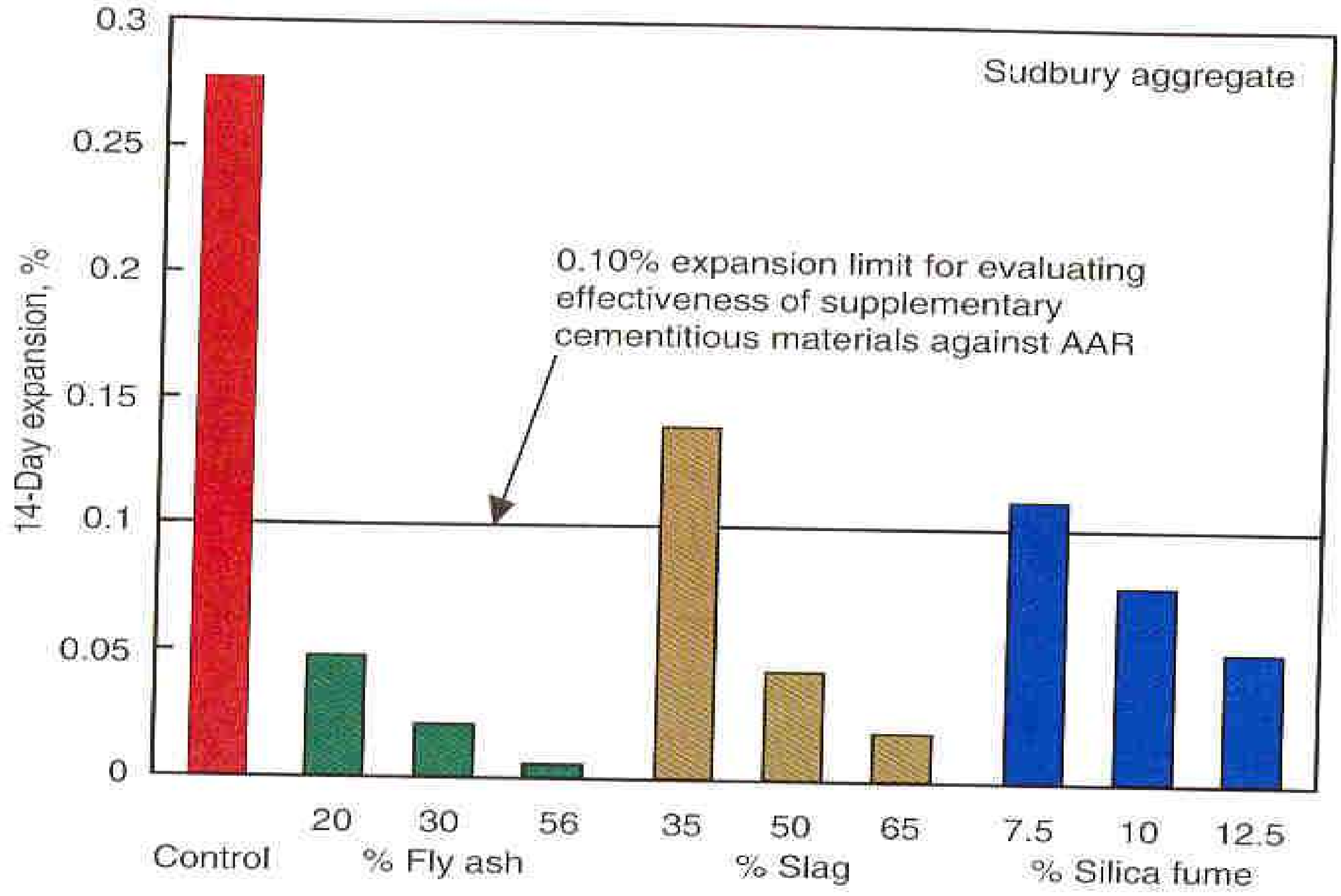


Cracking of concrete from alkali silica reactivity

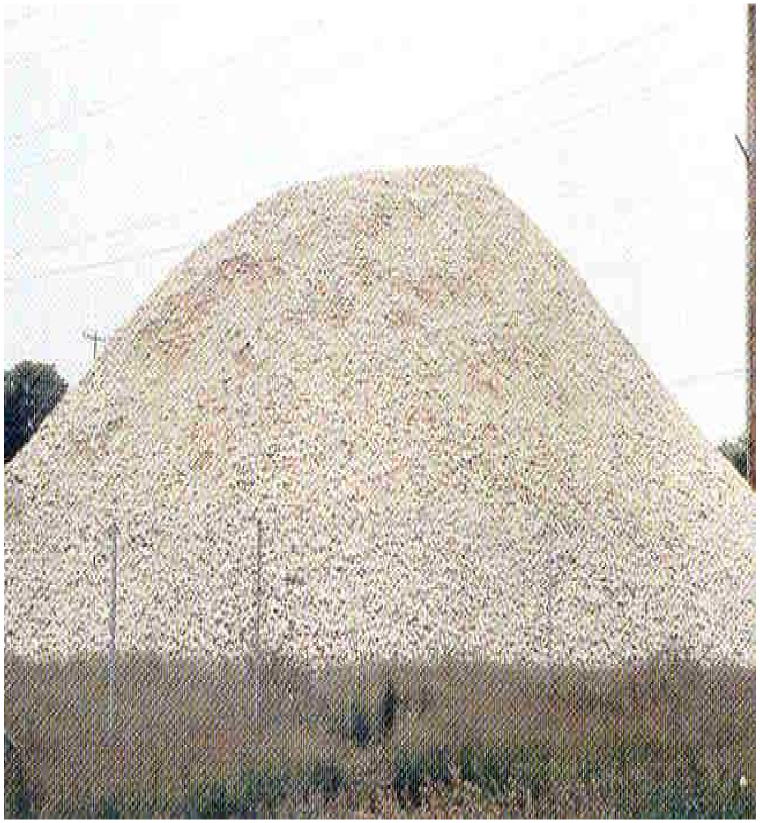




Influence of Adding mineral admixture on alkali-silica reactivity (ASR)



Heavily reinforced concrete is crushed with a beam-crusher



Recycled-concrete aggregate

Tests on Aggregates

Grading

- **Grading is the distribution of particles among various sizes. Grading is usually expressed in terms of cumulative percentage passing each sieve.**

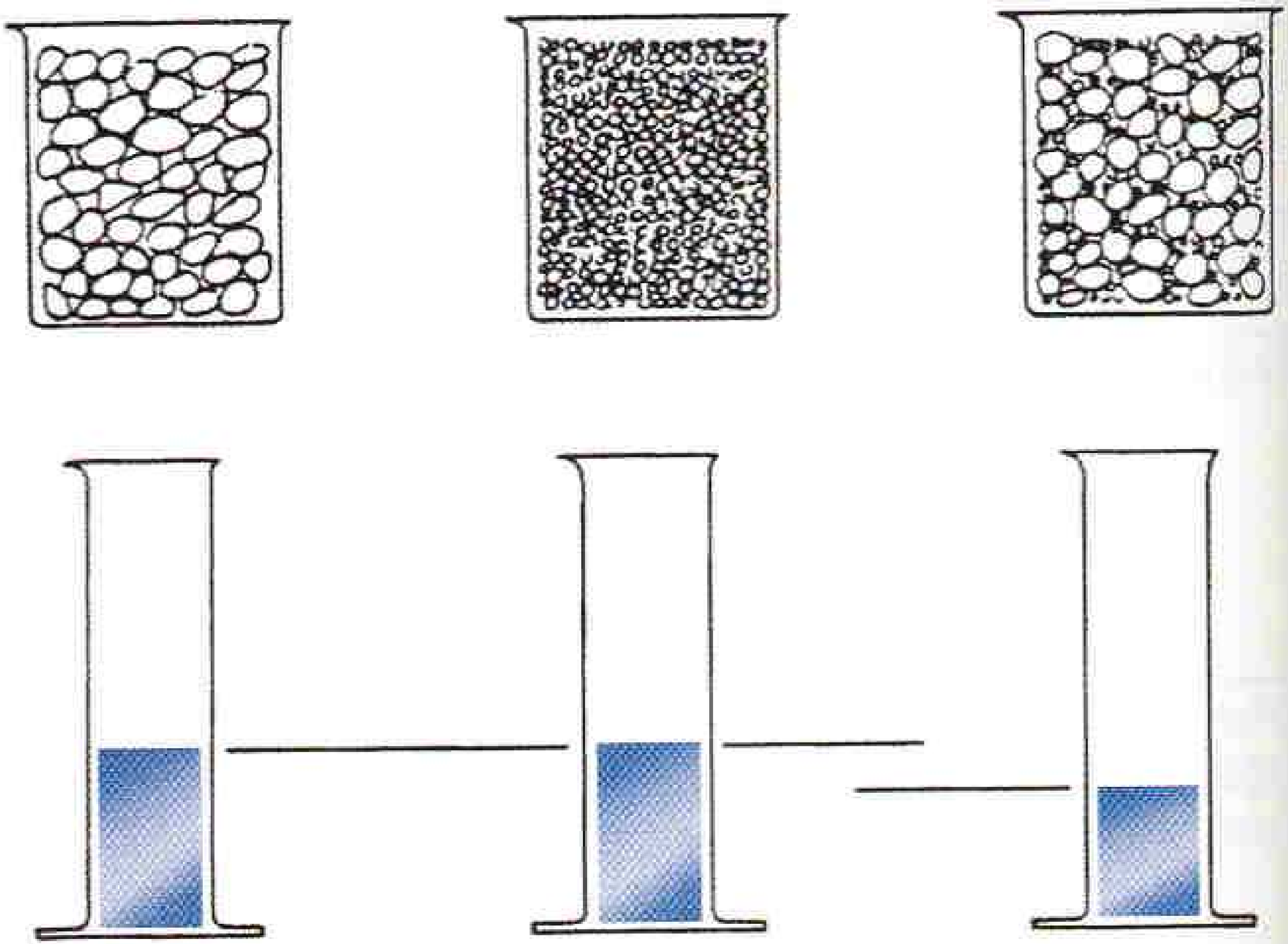
Different standards and specifications specify grading limits for both fine and coarse aggregates. There are several reasons for specifying grading limits and maximum aggregate size, they affect:

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

- **Aggregates that do not have deficiency or excess of any size and give smooth grading curve will produce the most satisfactory results.**
- **The aggregate particle size is determined by using wire-mesh sieves with square openings:**
- **7 standard sieves ranging from 150 µm to 9.5 mm (No. 100 to 3/8 in) for fine aggregates**
- **13 standard sieves ranging from 1.18 mm to 100 mm (0.046 in. to 4 in) for coarse aggregates**

- **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.**

- **Production of satisfactory; economical concrete requires aggregates of low void content, but not the lowest.**



Fine Aggregate Grading

- **Wide range in fine aggregate gradation is permitted by ASTM C 33. The most desirable fine-aggregate gradation depends on the type of work, the richness of the mixture, and the maximum size of coarse aggregate.**

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 fine aggregate must not have more than 45% retained between two consecutive standard sieves.

- The fineness modulus (FM) must not be less than 2.3 nor more than 3.1

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

- **Usually more water and cement is required for small-size aggregate than for large sizes, due to an increase in total aggregate surface area.**
- **The optimum maximum size of coarse aggregate for higher strength depends on:**
  - **Relative strength of the cement paste**
  - **Cement-aggregate bond**
  - **Strength of the aggregate particles**

- **<u>Maximum size of aggregate</u>: the smallest sieve that all of a particular aggregate must pass through.**

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

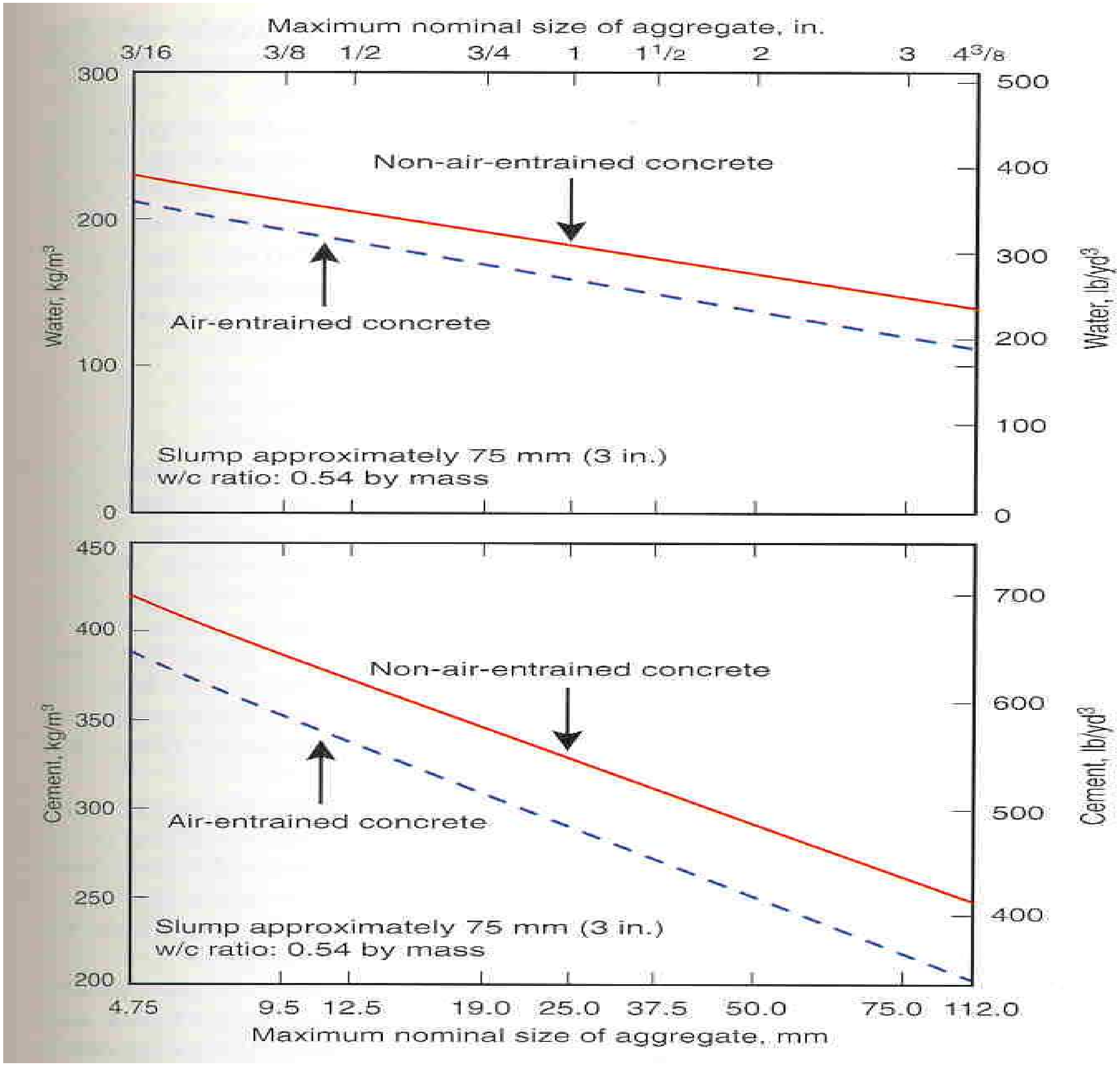
- **Example: Aggregate size number 7 has a maximum size of 19 mm, and a nominal maximum size of 12.5 mm.**

Examples for determining Max and nominal Max size of aggregate

Size number	37.7 mm (1 ½ in)	25 mm (1 in)	19 mm (3/4 in)	12.5 mm (1/2 in)	9.5 mm (3/8 in)
57	100	95 to 100	xxxx	25 to 60	xxxxx
6	xxxx	100	90 to 100	20 to 55	0 to 15
67	xxxx	100	90 to 100	xxxx	25 to 55
7	xxxx	xxxx	100	90 to 100	40 to 70
8	xxxx	xxxx	xxxxx	100	85 to 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**



Maximum nominal size of aggregate, in.
3/16
3/8
1/2
3/4
1
1 1/2
2
3
4 3/8
300
200
100
0
Water, kg/m3
500
400
300
200
100
0
Water, lb/yd3
Non-air-entrained concrete
Air-entrained concrete
Slump approximately 75 mm (3 in.)
w/c ratio: 0.54 by mass
450
400
350
300
250
200
Cement, kg/m3
700
600
500
400
Cement, lb/yd3
Non-air-entrained concrete
Air-entrained concrete
Slump approximately 75 mm (3 in.)
w/c ratio: 0.54 by mass
4.75
9.5
12.5
19.0
25.0
37.5
50.0
75.0
112.0
Maximum nominal size of aggregate, mm

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.

Particle Shape and Surface Texture

- **The shape and surface texture affect the properties of fresh concrete more than the properties of hardened concrete.**
- **Rough-texture, and angular particles require more water to produce workable concrete than do smooth, rounded and compact particles. For both crushed or noncrushed aggregate, proper gradation gives the same strength for the same cement factor.**

- Bond between cement paste and a given aggregate generally increases the particles surfaces change from smooth and rounded to rough and angular. 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.

Bulk Density (ASTM C 29)

- Defined as the weight of the aggregate particles that would fill a unit volume. The term *bulk* is used since the volume is occupied by both the aggregates and voids. The typical bulk density used in making normal concrete ranges from 1200 to 1750 kg/m^3.

- The void contents range between 30% to 45% for coarse aggregate and 40% to 50% for fine aggregate. Void content increases with angularity and decreases with well graded aggregate.

Relative Density (Specific Gravity)

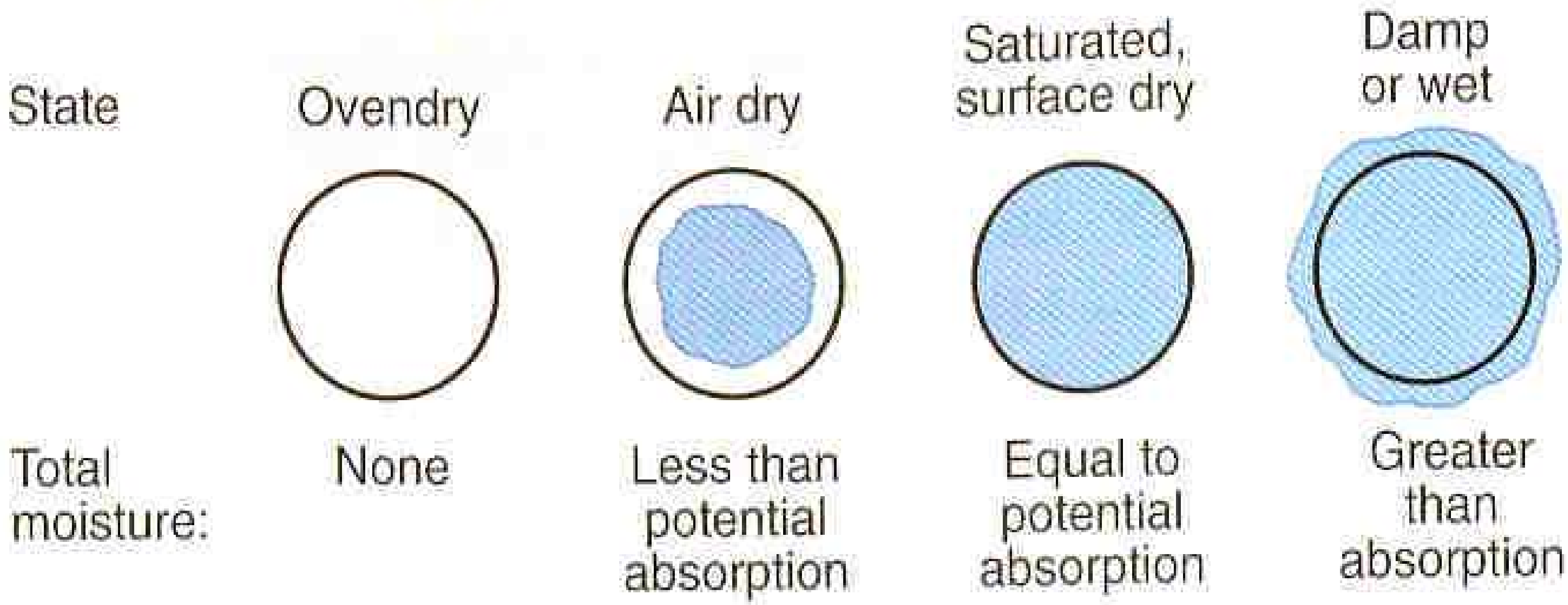
- **The relative density of an aggregate (ASTM C 127 and C 128) is defined as the ratio of its mass to the mass of an equal volume of water. It is used in certain computations for mixture proportioning and control. Most natural aggregates have relative densities between 2.4 and 2.9 (2400 and 2900 kg/ m^3).**

- **The density of aggregate used in mixture proportioning computations (not including the voids between particles) is determined by multiplying the relative density of the aggregate times the density of water (1000 kg/m^3).**

Absorption and Surface Moisture

- **The absorption and surface moisture of aggregates should be determined using ASTM C 70, C127, C128, and C 566 so that the total water content of the concrete can be controlled and the batch weights determined. The moisture conditions of aggregates are:**
- **Oven dry**
- **Air dry**
- **Saturated surface dry (SSD)**
- **Damp or wet**

Moisture conditions of aggregate



Wetting and Drying

- **Alternate wetting and drying can develop severe strain in some aggregates, and with certain types of aggregate this can cause a permanent increase in volume of concrete and eventual breakdown. Also, moisture swelling of clay and shales can cause popouts in concrete.**

Abrasion and Skid Resistance (ASTM C 131)

- **Abrasion resistance of an aggregate is used as a general index of its quality. This characteristic is important when concrete is going to be subjected to abrasion, as in heavy duty floors or pavements.**

- **Low abrasion resistance may increase the quantity of fines in the concrete during mixing; and hence increases the water requirement and require an adjustment in w/c ratio.**

- **Los Angeles abrasion test as per ASTM C 131 is the most common test for abrasion test.**

Strength

- **Generally, strength of aggregate does not influence the strength of conventional concrete as much as the strength of the paste and the paste-aggregate strength. However, aggregate strength becomes important in high strength concrete.**

- **Aggregate tensile strengths range between 2 to 15 MPa, and compressive strengths range between 65 to 270 MPa.**

Resistance to Acid and other Corrosive Substances

- **Acid solutions (pH less than 6.0) attack the calcium compounds of the cement paste, the rate of attack depends on the acidity of the solution. Siliceous aggregates may not be attacked by acidic solutions, however, calcareous aggregates often reacts with acids resulting in reduction of the solution acidity.**

- **Other gases and salts may attack and disintegrate concrete. Therefore, concrete structures subjected to harsh conditions should be protected and aggressive agents should be prevented from coming into contact with the concrete by using protective coatings.**

Fire Resistance and Thermal Properties

- **The fire resistance and thermal properties of concrete depend on the mineral constituents of the aggregates. Lightweight aggregates are more fire resistance than normal weight aggregates due to their insulation properties.**

- **Concrete containing calcareous coarse aggregates performs better under fire exposure than siliceous aggregate (granite or quartz).**