QUALITY ASSURANCE *for* AGGREGATES

Aggregates influence the properties of concrete/mortar such as water requirement, cohesiveness and workability of the concrete in plastic stage, while they influence strength, density, durability, permeability, surface finish and colour in hardened stage.

Aggregates are generally classified into two categories viz. *natural and manufactured/processed*.
Geologically aggregates may be obtained from basalt, granite, limestone, quartzite, gabbro or schist rock etc. Main resources are igneous (granite or basalt) or sedimentary (limestone) rock. Generally all are suitable for concrete depending on their degree of weathering density and shape.

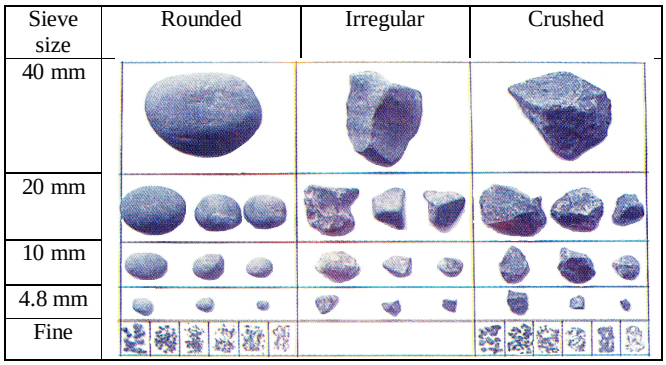
➢ **Choice of aggregates** depends on several factors. The first and the most important factor is availability.

S.N.	Factors	Influence on concrete property
1	Specific gravity/porosity	Strength/absorption
2	Chemical stability	Durability
3	Surface texture	Bond grip
4	Shape	Water demand (strength)
5	Gradation or particle size distribution	Water demand (strength) cohesion, bleeding and segregation
6	Maximum size	Strength and water demand
7	Deleterious material	Water demand (strength), bond, cohesion and durability

➢ **Surface texture of aggregate** influences the bond between the aggregate and cement. Smooth surface such as that found on gravels will have a poor bond. Crushed aggregates have a rough texture and give a good mechanical bond with cement. However, gravel or rounded aggregates have been used for high strength concrete without any serious problems of poor bond. If the gravel is clean, and well washed the changes of the poor bond is considerably reduced.

➢ **Shape of aggregate** can be broadly classified as follows in order of desirability like *Rounded, Irregular rounded, Cubical, Flaky angular, Elongated, Flaky elongated*.

- ***Rounded shape*** has minimum surface area for the same mass than other shapes therefore it requires minimum cement paste for bonding as compared to other shapes. Hence, for a given aggregate-cement ratio in a concrete mix, workability will be higher, if *rounded* aggregates are used as compared to others.



- ***Flaky aggregate*** are the aggregates whose least dimension is less than 3/5th of its mean dimension i.e. the mean dimension of an aggregate passing through 40 mm sieve and retained on 20 mm sieve is 40+20/2 = 30 mm. Now if the least dimension is less than18 mm (3/5 x 30 = 18 mm) then the aggregate is flaky.
- ***Elongated aggregates*** are the aggregates whose length is 1.8 times of its mean dimension. If the mean dimension as shown above is say 30 mm then for a length above 54 mm (1.8x30mm) the aggregates will be classified as elongated.
  Concrete produced using flaky and elongated aggregates will be prone to segregation, poor surface finish, high cement and sand demand. Generally rounded, irregular rounded and cubical shapes are preferred in concrete mixes.

➢ **Size of aggregates:** The nominal maximum size of coarse aggregate should be as large as possible within the limits specified, but in no case greater than 1/4th of the min. thickness of the member.

For most works, 20 mm aggregate is suitable. 40 mm and 10 mm size should be used for work specified. Plums above 160 mm should be used, when specifically permitted in plain concrete with a max limit of 20% by volume and should not be closer than 150 mm from the surface. For heavily RCC members like ribs of main beams, the nominal maximum size of the aggregate should usually be restricted to 5 mm less than the minimum clear distance between the main bars or 5 mm less than the minimum cover to the reinforcement whichever is smaller.

➢ **Aggregates Quality** should consist of naturally occurring (crushed or uncrushed) stones, gravel and sand or combination thereof. They should be hard, strong, dense, durable, clear and free from veins and adherent coating, and free from injurious amounts of disintegrated pieces, alkali, vegetable matter and other deleterious substances. As for as possible, flaky, scoriaceous and elongated pieces, pieces are avoided.
Visual inspection of gravel and natural sand is necessary for presence of clay lumps, clay coating, silt, grading and shape, while for crushed aggregates and sand inspection is necessary for stone dust, flaky shape and grading. If clay dust silt or mud is present and not removed/reduce through washing, it may produce lower strength concrete.

The maximum quantity of deleterious materials in the **coarse and fine aggregates** (crushed or natural) should not exceed the limits as specified in the table—

S.N	Deleterious substance	Fine Aggr. % by weight Max.		Coarse Aggr. % by weight Max.	
		Uncrus-hed	Crus-hed	Uncrus-hed	Crush-ed
i)	Coal and lignite	1.00	1.00	1.00	1.00
ii)	Clay lumps	1.00	1.00	1.00	1.00
iii)	Materials finer than 75µ IS Sieve	3.00	15.00	3.00	3.00
iv)	Soft fragments	-	-	3.00	-
v)	Shale	1.00	-	-	-
vi)	Total of %age of all deleterious materials (except mica) i/c S.N. (i) to (v) for col. 3, 5 & 6 and S.N. (i) to (ii) for col. 4 only.	5.00	2.00	5.00	5.00

The presence of mica should be investigate in fine aggregate and should also make suitable allowances for the possible reduction in the strength of concrete or mortar. The aggregate should not contain harmful organic impurities, excess to the limit specified.

- **Aggregate crushing value** gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. The aggregate crushing value should not exceed 45% for aggregate used for concrete other than for wearing surfaces, and 30 % for concrete for wearing surfaces, such as runways, roads for pavements.
- **Aggregate impact value** gives a relative measure of the resistance of an aggregate to sudden shock or impact, As an alternative to crushing value, the aggregate impact value should not exceed 45% by weight for aggregates used for concrete other than for wearing surfaces and 30% by weight for concrete for wearing surfaces, such as runways, roads for pavements.
- **Specific gravity**, a low specified gravity indicates to high porosity, which results in poor durability and low strength. The concrete density is greatly depending on the specific gravity. A porous nature (i.e. those which increase in weight exceeding 10% of dry weight after immersion for 24 hours) should not be permitted, unless specified. The range of specific gravity for aggregates should be between 2.4 and 2.9.

- **Soundness of aggregate** -for concrete liable to be exposed the action of frost, coarse and fine aggregates should pass a sodium or magnesium sulphate accelerated soundness test.

➢ **Grading of aggregates:** Grading of aggregates is an important aspect as they can influence the various properties of concrete such as cohesion, water demand, workability and strength. Aggregates should be well graded and consistent in their grading. Fine aggregates are the aggregates, most of which passes through 4.75 mm IS sieve and contained only so much coarser material, which is permitted as per specification. Coarse Aggregates are the aggregates, most of which retained on 4.75 mm IS sieve and contained only so much finer material, which is permitted for the various types described in the specification. Cyclopean aggregates or cobbles are of size 75 mm to 150 mm.

I.S. Sieve Designation	%age passing for graded aggregate of nominal size			
	40 mm	20 mm	16 mm	12.5 mm
80 mm	100	-	-	-
63 mm	-	-	-	-
40 mm	95 to 100	100	-	-
20 mm	30 to 70	95 to 100	100	100
16 mm	-	-	90 to 100	-
12.5 mm	-	-	-	90 to 100
10 mm	10 to 35	25 to 55	30 to 70	40 to 85
4.75 mm	0 to 5	0 to 10	0 to 10	0 to 10
2.36 mm	-	-	-	-

- **Sand or fine aggregate:** The sand should consist of natural sand, crushed stone sand or crushed gravel sand, or a combination of any these. The sand should be hard, durable, chemically inert, clean and free from adherent coatings organic matter and harmful impurities e.g. iron pyrites, alkalis, salts, laminated or other materials in such form or in such quantities as to affect adversely the hardening, the strength, the durability or the appearance of the mortar. The sand is graded into four zones as per table given below:

IS Sieve	Equivalent BS sieve	Percentage passing for			
		Zone 1	Zone 2	Zone 3	Zone 4
10 mm	3/8 -in	100	100	100	100
4.75 mm	3/16 - in	90-100	90-100	90-100	95-100
2.36 mm	No.7	60-95	75-100	85-100	95-100
1.18 mm	No.14	30-70	55-90	75-100	90-100
600 micron	No.25	15-34	35-59	60-79	80-100
300 micron	No.52	5-20	8-30	12-40	15-50
150 micron	No.100	0-10	0-10	0-10	0-15

- A close look at the various ranges for each sieve size shows that zone 1 sand is the coarsest and zone 4 sand is finest whereas sand in zones 2 and 3 are moderate.
- Fine aggregate conforming to grading zone 4 should *not be used in reinforced concrete*.
- When the grading falls outside the percentage limits prescribed for the sieves other than 600 micron and 300 micron (IS) Sieves by not more than 5%, it should be re-graded as falling within this zone. The portion of the aggregate below 600 micron size are finer fines and they greatly influence the cohesiveness, water demand, workability and permeability as their specific surface per unit volume is much greater than other aggregate sizes.
- If a particular sieve size is not present in aggregates they are called gap graded. Sand, which has gap grading, is generally not preferred to the sand, which is uniformly graded. Gap grading can create deficiency in cohesiveness, permeability and surface finish.

➢ Other impurities

- **Organic matters** in fine aggregates (sand) are usually found due to presence of vegetable matter. Even vary small fraction of organic matter will delay or prevent the hardening of concrete.
- **Chlorides,** if present in fine aggregates will not be harmful to concrete or mortar but will be harmful to the reinforcement or other steel embedments in concrete will accelerate rusting. Chlorides may also be present in cement, water and concrete additives.
  The total chloride content for long span bridges and prestressed structures should be limited to 0.10% by weight of cement and for reinforced concrete structures it should be limited to 0.15% by weight of cement.
- **Alkali reactivity:** If the aggregates proposed are alkali reactive then the presence of alkali oxides (Nao+0.658 K_2O) in cement have to be carefully examined. Alkali oxides in cement should not be beyond permissible limits i.e. more than 1 %, which may cause cracking and disintegration of concrete in longer term.

➢ **Storage of aggregate** is an important aspect to avoid aggregates gets contaminated with dust, mud and soil. Aggregates must be stored on hard surface so that they do not get mixed with soft materials at the base. If hard surface is not available, a 100 mm thick plain concrete layer should be provided at the base before unloading the aggregates. Coarse and fine aggregate should be batched separately.

The dust coated crushed aggregates may tend to accumulate towards the bottom of the heap especially during the rainy season. It is therefore suggested that the bottom most layers in an aggregate stockpile should not be used unless it is cleaned and washed thoroughly.

Generally workers feel comfortable to relax on the sand stacks, hence care should be taken to see that the stack is not contaminated with waste paper, cigarette butts, tea leaves sugar etc.

➢ Precautions in extreme weather

- **Cold weather:** In extreme winter (below zero^0 C) it is essential to cover the stockpiles with proper covers to prevent *snow and ice* from contaminating it. If stock piles are kept exposed the aggregates will stick to each other bound by ice and will not flow into the mixer skip easily from the batching plant bin.
  As a matter of precautions, it is also essential that no snow or ice should be present within the concrete at the time of placing. Hence, if aggregates are kept covered it will not only help in smoother concreting operation but will also prevent quality problems.
- **Warm weather:** In warm weather, it is preferable to spray cold water on the stack and cool the aggregates before mixing it with other materials. In large or massive pours chilling of aggregates may also be necessary. In warm weather it is necessary to spray water on aggregates to avoid rapid drop in workability due to absorption of water by hot dry aggregates.

➢ Field Tests for Aggregate

a) Surface moisture content, absorption and porosity: The surface moisture in the aggregate, influences the water cement ratio, strength and durability of the mix. To determine the surface moisture of moist or wet aggregate, method is as follows-

Frying pan method: The following apparatus are required: A frying pan or metal tray, gas stove or an electric hair dryer, a metal or glass stirring rod and scales to measures.

- For coarse aggregate 2 kg sample is adequate and for fine aggregate 0.5 kg sample is adequate.
- The wet/moist sample is then weighed *wet weight (W)* accurately.
- Heated very gently on the frying pan or metal plate and stirred with a glass or metallic rod to maintain uniform distribution of heat, until the sheen disappears from the surface. The fine aggregates become surface dry when it just starts showing free flowing characteristics.
- The aggregates is then cooled and reweighed. The *surface dry aggregate weight (W_{sd})* is noted. The surface moisture is then calculated as follows-

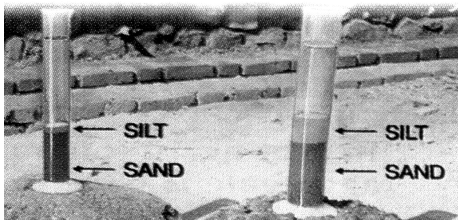
  Surface moisture = $W-W_{sd}/W_{sd}$ x 100%

- *Overheating must be avoided, as it will not give the correct surface moisture*.
- If heating is continued either on the fry pan or in the oven till the aggregate is *bone dry* aggregate weight is then noted *(W_{bd})* after continuous heating. The absorption (absorbed water content) is then calculated as follows-

  Absorption = $W_{sd} - W_{bd}/ W_{bd}$ X100%

  Similarly, if the dry aggregates are received on site and absorption capacity is to be determined then the aggregates are first soaked in water and then the above methods are deployed to determine the absorption capacity of aggregates.

(b) Silt test for sand: The permissible silt content in sand (fine aggregate) is specified in the Bureau of Indian Standards by weight. However, this method can only be used for natural sand, it should not be used for crushed rock sand.



The apparatus required for this test is only 250 ml glass measuring cylinder. The silt content determination by volume is done in the following manner:

- The glass cylinder is filled with salt-water solution (concentration of the solution will teaspoon full of common salt for every 570 ml) upto 50 ml mark.
- Add sand until the level of the sand is upto 100 ml mark.
- Add further salt-water solution till 150 ml mark is reached.
- Place the palm on the mouth of the glass cylinder and shake it vigorously.
- Place the cylinder on hard levelled surface and tap it all round so that sand is levelled.
- Wait for three hours for silt to settle on top of sand.
- Measure the thickness of the silt layer and the height of the sand. The silt content can be calculated as follows:

$$\textbf{Silt (\%) by volume} = \frac{\textbf{Thickness of silt layer}}{\textbf{Height of sand + Silt}} \times 100\ \%$$

If silt content by weight exceeds 3% then washing of sand is necessary. After conducting few tests, a co-relation can be developed for silt layer thicknesses at various intervals of time. The silt content at 10 minutes can be fixed as inspection criteria.

c) Bulkage of sand: When sand is damp, the water coating on the surface of each sand particle causes separation of particles from one another due to surface tension. This causes sand to bulk. Bulked sand occupies more volume and hence if volumetric measuring is done while proportioning it, bulkage correction is necessary.

The bulkage test is done as follows:

- The sand is filled, in loose condition in a box of measured height (H cm).
- The box is then flooded with water and rodding is done to make the sand settle and consolidate. Care should be taken that sand does not overflow during the flooding and compaction.
- The sand is then levelled in the box and the drop in height is measured (h cm).
- Bulkage is calculated as: **Bulkage % = h/H x 100%**

Dry sand occupies the same volume as fully saturated sand. The bulkage will vary from load to load and day to day depending on the fineness of sand and its surface moisture content. It is there-fore, very essential to make bulkage corrections by checking the actual bulkage of sand proposed to be used by volumetric batching for mortar or concrete.

Moisture contents %age by wt.	Bulking % by volume
2	15
3	20
4	25
5	30

Sieve Analysis

This test is done initially for concrete mix design and later conducted periodically for mix proportion adjustments if it is suspected that the grading of aggregates has changed considerably. The sample taken for sand is 0.5 kg. The Fineness Modulus is cumulative percentage retained on each of sieves stated divided by 100. The value of FM for : Very Fine – Below 2.2, Fine – Between 2.2 to 2.6, Medium - Between 2.6 to 2.9, Coarse - Between 2.9 to 3.2, Very Coarse – Above 3.2. Only sand between FM 2.6 to 2.9 is considered suitable for nominal mix proportion.

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for

AGGREGATES

CAMTECH/C/2006/QA–AGG/1.0

October - 2006

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