CONCRETE

Constituents of concrete (Cement and aggregate): Proportioning of concrete, water-cement ratio, Fresh concrete, Hardened concrete, Quality control (Sampling, Acceptance, etc.), Transportation and placing, Testing of concrete (including NDT), Admixtures (Chemical, mineral), Concrete and environment.

CONSTITUENTS OF CONCRETE (CEMENT AND AGGREGATE)

Concrete is a mixture of

- Cement (11%),
- Fine aggregates (26%),
- Coarse aggregates (41%)
- water (16%)
- air (6%).

Cement	-- Powder
Cement + Water	-- Cement Paste
Cement Paste + Fine Aggregate (FA)	-- Mortar
Mortar + Coarse Aggregate (CA)	-- Concrete

Portland cement, water, sand, and coarse aggregate are proportioned and mixed to produce concrete suited to the particular job for which it is intended.

Concrete a composite man-made material is the most widely used building material in the construction industry.

It consists of a rationally chosen mixture of binding material such as lime or cement, well graded fine and coarse aggregates, water and admixtures (to produce concrete with special properties).

In a concrete mix, cement and water form a paste or matrix which in addition to filling the voids of the fine aggregate, coats the surface of fine and coarse aggregates and binds them together.

The matrix is usually 22-34% of the total volume.

Freshly mixed concrete before set is known as wet or green concrete whereas after setting and hardening it is known as set or hardened concrete.

PROPORTIONING OF CONCRETE

Process of selection of relative proportions of cement, sand, coarse aggregate and water, so as to obtain a concrete of desired quality is known as the proportioning concrete.

It is observed that if a vessel, as shown in figure below is taken and filled with stones, of equal size, the voids to the extent of about 45 % are formed.

This result is independent of the size of the stones. It is interesting to note that if sand is taken in place of stones, the same result will be obtained.

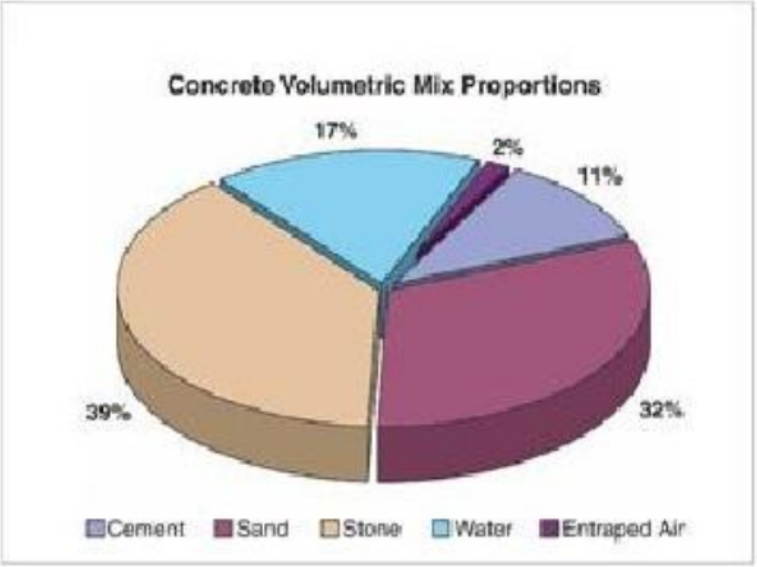
The result can be verified by pouring water in the vessel till it is full. The volume of water added in the vessel represents the amount of voids.

The theory of formation of concrete is based on this phenomenon of formation of voids, when coarse aggregate is placed, such as voids are formed.

When fine aggregate i.e., sand is added it occupies these voids.

Further, when finely powdered cement is added, it occupies the voids of sand particles.

Finally, when water is added, it occupies very fine voids between the cement particles.



Proportioning of Concrete

In general, the proportions of coarse aggregate, fine aggregate, cement and water should be such that the resulting concrete has the following properties.

- When concrete is fresh, it should have enough workability so that it can be placed in the formwork economically.
- The concrete must possess maximum density or in other words, it should be the strongest and most watertight.
- The cost of materials and labour required to form the concrete should be minimum.

Methods of proportioning concrete

- Arbitrary method
- Fineness modulus method
- Minimum voids method
- Maximum density method
- Water-cement ratio method

Principles of Proportioning:

The fundamental object in proportioning concrete or mortar mixes is the production of a durable material of requisite strength, water tightness, and other essential properties at minimum cost.

To achieve these objectives, careful attention must be given to the selection of cement, aggregate, and water to the following considerations:

The mix must be workable so that it can be placed and finished without undue labour.

Since cement is the most costly ingredient in the mix, the proportion used should be as small as is consistent with the attainment of desired properties. Within wide limits, experiments have shown:

(a) The strength and degree of water tightness of mixes, having like constituent materials, density, and workability, increase with the cement content.

(b) With the cement content, materials, and workability all constant, the strength and degree of water tightness increase with the density of the mix.

(c) For usual methods of placement, the strength and degree of water tightness of well cured concrete and mortar are greatest when the mix is plastic (has a slump of approximately 50 mm). Drier mixes, although frequently as strong, are likely to be porous unless compacted by pneumatic rammers or electrically driven vibrators. Increasing the water content beyond that required for plasticity causes the strength to decrease rapidly.

(d) Concrete with 4–7 per cent, by volume, entrained air made by using an air entraining cement or by adding air-entraining admixtures is more resistant to freezing and thawing action and also to scaling due to the use of salt for ice removal than concrete made with regular cement and without air-entraining admixtures. In addition to the above, the following statements appear to be justified by the results of experience and tests.

(e) To proportion concrete for the maximum resistance to fire, a porous noncombustible aggregate of high specific heat together with cement sufficient to provide the requisite strength should be thoroughly mixed and placed with as little ramming as possible to produce a porous concrete.

(f) In proportioning concrete or mortar which is to be subjected to freezing temperatures shortly after placement, a minimum amount of water and quick setting cement should be used.

(g) Concrete for road construction should be made from a carefully graded, hard tough aggregate bound together with as small a proportion of rich mortar as is consistent with the required workability, strength, and imperviousness. In locations where resistance to freezing and thawing is required, the concrete should have 3–6 per cent of entrained air. The principal methods used in scientific proportioning of mixes are based upon relationships between properties and ratio of cement to voids in the mix, or on the relationship between properties and the ratio of water to cement in the mix.

WATER-CEMENT RATIO

The water in concrete has to perform the following **two** functions:

- The water enters into chemical action with cement and this action causes the setting and hardening of concrete.
- The water lubricates the aggregates and it facilitates the passage of cement through

voids of aggregates. This means that water makes the concrete workable.

The ratio of the amount of water to the amount of cement by weight is termed as the water-cement ratio and the strength and quality of concrete primarily depend upon this ratio.

The quantity of water is usually expressed in litres per bag of cement and hence the water-cement ratio reduces to the quantity of water required in litres per kg of cement as one litre of water weighs one kg.

For instance, if water required for 1 bag of cement in 30 litres, the water-cement ratio is equal to 30/50 = 0.60.

Net water – cement ratio by weight	Probable cube crushing strength in N/mm ^{2}	
	7 Days	28 Days
0.4	35	47
0.5	25	37
0.6	18	28
0.8	10.5	17.5

FRESH CONCRETE

Properties of Fresh Concrete (Properties at Early Ages)

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

Workability:

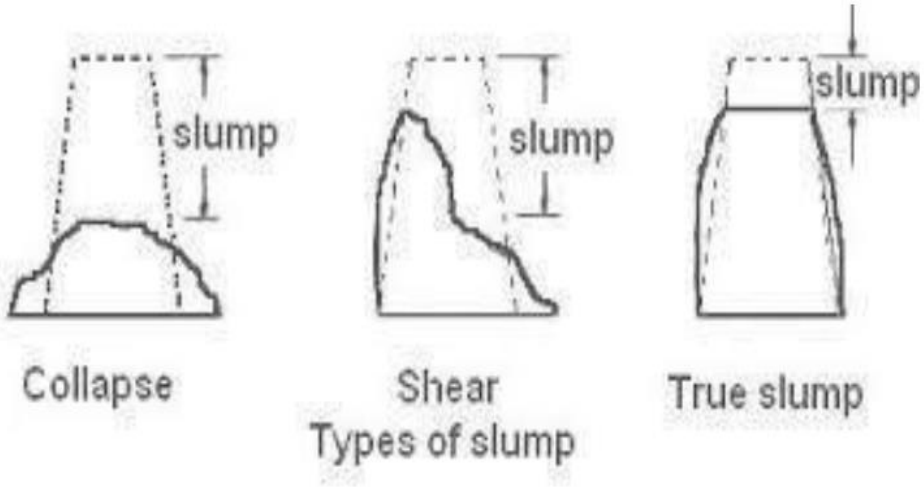
Definition: Effort required manipulating a concrete mixture with a minimum of segregation. It is not a fundamental property of concrete.

I) **consistency** (slump) -- easy to flow

II) **Cohesiveness** --tendency to bleed and segregate

Slump Test:

Slump test is a test conducting before concrete to be used for casting. The purpose of slump test is to determine the water content in concrete and its workability



Recommended Slumps of Concrete

Sl.No.	Type of concrete	Slump
1	Concrete for road construction	20 – 40 mm
2	Concrete for tops of curbs, parapets, piers, Slabs and walls that are horizontal	40 – 50 mm
3	Normal R.C.C Work	80 – 150mm
4	Mass concrete	25 – 50 mm
5	Concrete to be vibrated	10 – 25 mm

Slump Test

Degree of workability	Slump (mm)	Compacting Factor	Use for which concrete is suitable
Very low	0 - 25	0.78	Very dry mixes; used in road making. Roads vibrated by power operated machines
Low	25 - 50	0.85	Low workability mixes; used for foundations with light reinforcement. Roads vibrated by hand operated Machines
Medium	50 - 100	0.92	Medium workability mixes; manually compacted flat slabs using crushed aggregates. Normal reinforced concrete manually compacted and heavily reinforced sections with vibrations
High	100 - 175	0.95	High workability concrete; for sections with congested reinforcement. Not normally suitable for vibration

>Table : Workability, Slump and Compacting Factor of concrete with 19 or 38 mm (3/4 or 1½ in) maximum size of aggregate.

Advantages of slump test:

- It grants the facility to easily detect the difference in water content of successive batches of concrete of the same identical mix.
- Apparatus is cheap, portable and convenient to be used at site.

Limitations of slump test:

- No direct relationship between the workability and the value of slump.
- Not suitable for a concrete in which maximum size of the aggregate exceeds 40mm.
- A chance of many shapes of slump to occur and it is difficult to decide which the correct value.
- Slump occurs only in case of plastic mixes. It does not occur in case of dry mixes.

Consistency:

Consistency or fluidity of concrete is an important component of workability and refers in a way to the wetness of the concrete.

If a mix is too wet, segregation may occur with resulting honeycomb, excessive bleeding, and sand streaking on the formed surfaces.

On the other hand, if a mix is too dry it may be difficult to place and compact and segregation may occur because of lack of cohesiveness and plasticity of the paste.

HARDENED CONCRETE

Properties of Hardened Concrete

The principal properties of hardened concrete which are of practical importance can be listed as:

- Strength
- Permeability & durability
- Shrinkage & creep deformations
- Response to temperature variations

Of these compressive strength is the most important property of concrete. Because Of the abovementioned hardened properties compressive strength is one of the most important property that is often required, simply because;

- Concrete is used for compressive loads
- Compressive strength is easily obtained
- It is a good measure of all the other properties.

Compressive Strength is determined by loading properly prepared and cured cubic, cylindrical or prismatic specimens under compression.

• Cubic: 15x15x15 cm

Cubic specimens are crushed after rotating those 90° to decrease the amount of friction caused by the rough finishing.

• Cylinder: h/D=2 with h=15

To decrease the amount of friction, capping of the rough casting surface is performed.

Quality Control (Sampling, Acceptance, Etc.)

General

Provide qualified personnel and sufficient equipment meeting the requirements listed in the Department's Construction Manual to conduct quality control testing which conforms with the Sampling and Testing Frequency Chart for Portland Cement Concrete Pavement for Quality Control/Quality Assurance Projects

Calibrate and correlate the testing equipment with prescribed procedures and conduct tests in conformance with specified testing procedures as listed in the Department's Construction Manual.

Quality Control Plan

Prepare a Quality Control Plan detailing the type and frequency of inspection, sampling and testing deemed necessary to measure and control the various properties of materials and construction governed by the Specifications. As a minimum, detail sampling location and techniques, and test frequency to be utilized in the sampling and testing plan. The Department may utilize quality control sampling and testing performed by the Contractor for acceptance. Submit the Quality Control Plan to the Engineer in writing a minimum of 30 days before work begins.

Elements of the Plan.

- Mix Designs
- Aggregate Production
- Quality of Components
- Stockpile Management
- Proportioning, including added water
- Mixing and transportation, including time from batching to completion of delivery
- Initial mix properties, including temperature, air content, and consistency

- Placement and consolidation, including a schedule for calibrating and checking vibrators
- Concrete yield versus Plan quantity records
- Compressive strength
- Finishing and curing

Personnel Requirements:

Detail in the Plan:

- The frequency of sampling and testing, coordination of activities, corrective actions to be taken, and documentation.
- How the duties and responsibilities are to be accomplished and documented, and whether more than one Certified Technician is required.
- The criteria utilized by the Technician to correct or reject unsatisfactory materials.Certified Technicians required duties.
- Perform and utilize quality control tests and other quality control practices to assure that delivered materials and proportioning meet the requirements of the mix designs, including temperature, slump, air content, and strength. Be available on the project site whenever concrete is being produced for use on or being placed on the project site.
- Periodically inspect all equipment utilized in transporting, proportioning, mixing, placing, consolidating, finishing, and curing to assure it is operating properly and that placement, consolidation, finishing, and curing conform to the mix design and other Contract requirements

Documentation

Maintain adequate records of all inspections and tests. Indicate the nature and number of observations made, the number and type of deficiencies found, the quantities approved and rejected, and the nature of corrective action taken as appropriate in the records.

The Contractor's documentation procedures will be subject to approval of the Engineer before the start of the work and to compliance checks during the progress of the work.

Charts and Forms.

Keep all conforming and non-conforming inspections and test results complete and available at all times to the Engineer during the performance of the work.

Provide forms on a computer-acceptable medium where required. Document batch tickets and gradation data in accordance with Department requirements.

Chart test data for portland cement concrete, including gradation, in accordance with the applicable requirements.

The Contractor may use other types of control charts as deemed appropriate. It is normally expected that testing and charting will be completed within 24 hours after sampling.

All charts and records documenting the Contractor's quality control inspections and tests become property of the Department upon completion of the work.