

Concrete ingredients summary

Aggregates

- Potential aggregate sources are usually evaluated for **quality of the larger pieces**, the nature and **amount of fine material**, and the **gradation** of the aggregate.
- The extent and quality of rock in the quarry is usually investigated by **drilling cores** and performing trial blasts (or shots) to evaluate how the **rock breaks** and by **crushing** some materials in the laboratory to evaluate **grading**, **particle shape**, **soundness**, **durability**, and amount of fine material.

Aggregates

- Cores are examined **petrographically** for general quality, suitability for various uses, and amount of **deleterious materials**.
- Potential **sand** and **gravel pits** are evaluated by collecting samples and performing sieve analysis tests.
- The amount of large gravel and cobble sizes determines the need for **crushing**, while the amount of **fine material** determines the need for **washing**.

Aggregate Uses

- In Portland cement concrete, 60% to 75% of the volume and 79% to 85% of the weight are made up of aggregates.
- The aggregates act as a filler to reduce the amount of cement paste needed in the mix.
- In addition, aggregates have greater **volume stability** than the cement paste.
- Therefore, maximizing the amount of aggregate, to a certain extent, improves the **quality and economy of the mix.**

Soundness and Durability

- The ability of aggregate to withstand *weathering* is defined as soundness or durability.
- Aggregates used in various civil engineering applications must be sound and durable, particularly if the structure is subjected to severe climatic conditions.
- Water **freezing** in the voids of aggregates **generates stresses that can fracture** the stones.

Soundness ...

- The soundness test (*ASTM C88*) simulates weathering by soaking the aggregates in either a **sodium sulfate** or a **magnesium sulfate** solution.
- The test starts with an oven-dry sample separated into different sized fractions.
- The sample is subjected to typically 5 cycles of soaking in the sulfate for 16 hours, followed by drying.

Soundness ...

- Afterwards, the aggregates are washed and dried, each size is weighed, and the weighted average % loss for the entire sample is computed.
- This result is compared with allowable limits to determine whether the aggregate is acceptable.
- This is an empirical screening procedure for **new aggregate sources** when no service records are available.

Other tests

- **Toughness, Hardness, and Abrasion Resistance.**
- **Absorption**
- **Specific Gravity**
- **Bulk Unit Weight and Voids in Aggregate**
- **Strength and Modulus**
- **Gradation**

Mixing Water

- Any **potable water** is suitable for making concrete.
- However, some **non-potable** water may also be suitable.
- Frequently, material suppliers use unprocessed surface or well water if it can be obtained at **a lower cost than processed water**.
- However, impurities in the mixing water can affect concrete **set time, strength,** and long-term **durability**.

Acceptable Criteria

- The acceptance criteria for questionable water are specified in ASTM C94.
- After 7 days, the average compressive strength of **mortar cubes** made with the questionable water should not be **less than 90%** of the average strength of cubes made with **potable** or **distilled water** (ASTM C109).
- Also, the set time of cement paste made with the questionable water should, as measured using the Vicat apparatus (ASTM C191), not be **1 h less** than or **1½ h more than** the set time of paste made with potable or distilled water.

Acceptable ...

- Addition to the **compressive strength** and **set time**, there are **maximum chemical limits** that should not be exceeded in the mixing water.
- Several tests are available to evaluate the chemical impurities of questionable water.
- Over 100 different compounds and ions can exist in the mixing water and can affect concrete quality.

Chemical Limits for Wash Water Used as Mixing Water (ASTM C1602)

	Maximum Concentration Chemical (ppm)	ASTM Test Method
Chloride, as Cl		
Prestressed concrete or concrete in bridge decks	500	C114
Other reinforced concrete in moist environments or containing aluminum embedments or dissimilar metals or with stay-in-place galvanized metal forms	1000	C114
Sulfate, as SO ₄	3000	C114
Alkalis, as (Na ₂ O + 0.658 K ₂ O)	600	C114
Total Solids	50,000	C1603

Summary of Effects of Water Impurities on Concrete Quality

Impurity	Effect
Alkali Carbonate and Bicarbonate	Can retard or accelerate strength test setting and 28-day strength when total dissolved salts exceed 1000 ppm. Can also aggravate alkali-aggregate reaction.
Chloride	Corrosion of reinforcing steel is primary concern. Chloride can enter the mix through admixtures, aggregates, cement, and mixing water, so limits are expressed in terms of total free chloride ions. ACI limits water-soluble ion content based on the type of reinforcement: Prestressed concrete 0.06% Reinforced concrete exposed to chloride in service 0.15% Reinforced concrete protected from moisture 1.00% Other reinforced concrete 0.30%
Sulfate	Can cause expansive reaction and deterioration.
Other Salts	Not harmful when concentrations limited to Calcium Bicarbonate 400 ppm Magnesium Bicarbonate 400 ppm Magnesium Sulfate 25,000 ppm Magnesium Chloride 40,000 ppm Iron Salts 40,000 ppm Sodium Sulfide 100 ppm
Sea Water	Do not use for reinforced concrete. Can accelerate strength gain but reduces ultimate strength. Can aggravate alkali reactions.
Acid Water	Limit concentrations of hydrochloric, sulfuric, and other inorganic acids to less than 10,000 ppm.
Alkaline Water	Possible increase in alkali-aggregate reactivity. Sodium hydroxide may introduce quick set at concentrations higher than 0.5%. Strength may be lowered. Potassium hydroxide in concentrations over 1.2% may reduce 28-day strength of some cements.
Sanitary Sewage Water	Dilute to reduce organic matter to less than 20 ppm.
Sugar	Concentrations over 500 ppm can retard setting time and alter strength development. Sucrose in the range of 0.03 to approximately 0.15% usually retards setting. Concentrations over 0.25% by weight of cement can accelerate strength gain, but substantially reduce 28-day strength.
Oils	Mineral oil (petroleum) in excess of 2.5% by weight of mix may reduce strength by 20%.
Algae	Can reduce hydration and entrain air. Do not use water containing algae.

Admixtures for Concrete

- Admixtures are ingredients other than Portland cement, water, and aggregates that may be added to concrete **to impart a specific quality to either the plastic** (fresh) mix or the **hardened concrete**.
- Some admixtures are charged into the mix as solutions.
 - In such cases the liquid should be considered part of the mixing water.
- If admixtures cannot be added in solution, they are either weighed or measured by volume as recommended by the manufacturer.

General classifications

- Admixtures are classified by the following chemical and functional physical characteristics:
 1. Air entrainers
 2. Water reducers
 3. Retarders
 4. Hydration controller admixtures
 5. Accelerators
 6. **Specialty admixtures**
 7. Supplementary Cementitious Materials

Specialty Admixtures

Several admixtures are available to improve concrete quality in particular ways.

It needs to study their application in detail, as well as their cost, before using them.

Examples of specialty admixtures include:

- workability agents
- corrosion inhibitors
- damp-proofing agents
- permeability-reducing agents
- fungicidal, germicidal, and insecticidal admixtures
- pumping aids
- bonding agents
- grouting agents
- gas-forming agents
- coloring agents
- shrinkage reducing

Supplementary Cementitious Materials

- These materials are cementitious, they can be used in addition to or as a partial replacement for Portland cement.
- These supplementary cementitious materials include fly ash, ground granulated blast furnace slag, silica fume, and natural Pozzolans.

Class Exercises

1. In order to evaluate the suitability of non-potable water available at the job site for mixing concrete, 6 standard mortar cubes were made using that water and 6 others using potable water. The cubes were tested for compressive strength after 7 days of curing and produced the following loads to failure (in Newtons).
 - a. Based on these results only, would you accept that water for mixing concrete according to ASTM C94?
 - b. According to ASTM C94, are there other tests to be performed to evaluate the suitability of that water?

Cubes Made with Non-potable Water	Cubes Made with Potable Water
72061	79178
64633	73529
70371	74819
62987	79712
71616	69793
70593	83716
63965	74374

2. Two batches of cement mortar with properties as shown below. If mortar cubes are made from these batches, which batch do you expect to have larger compressive strength? Why?

Batch Number	Water-Cement Ratio	Superplasticizer Content
1	0.5	0
2	0.5	39 mL/m ³

Answers

- 1.
- a.
- Average strength using non-potable water
= 27 N/mm²
- Average strength using potable water
= 31 N/mm²
Percent difference = $(31-27) \times 100 / 31$
= 11% > 10%



Therefore, **do not accept the water!**

- b. The set time measured by the Vicat test should not change significantly

- 2.
- The two batches are expected to have about the same compressive strength since they have the same w/c ratio.