CONCRETE TECHNOLOGY MODULE

WEEK 1

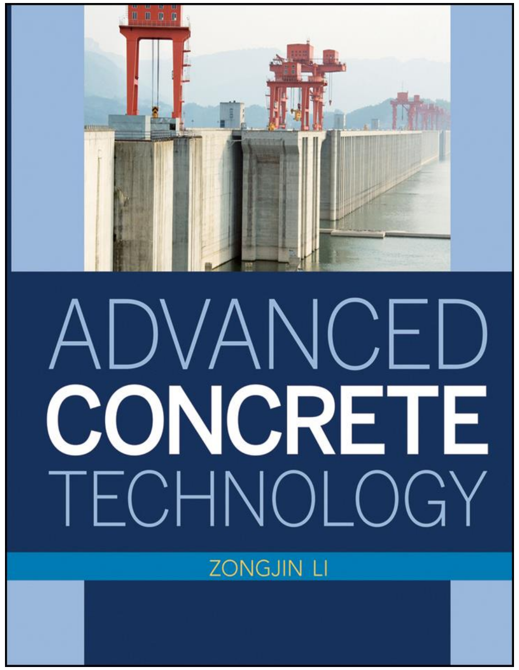
REFERENCES

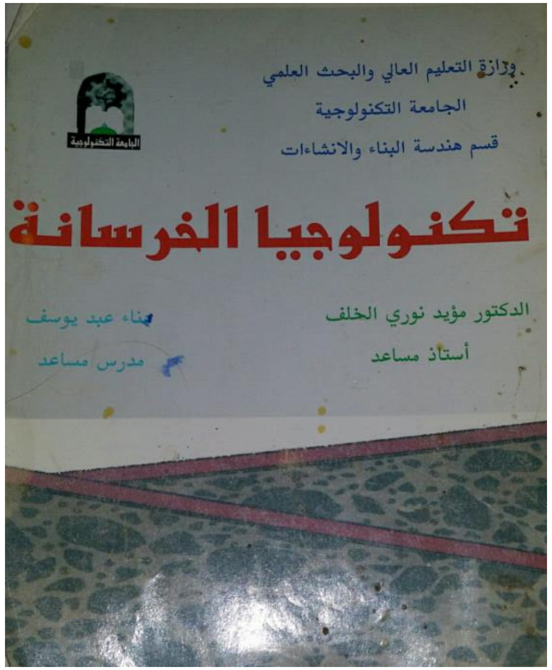
Main Reference

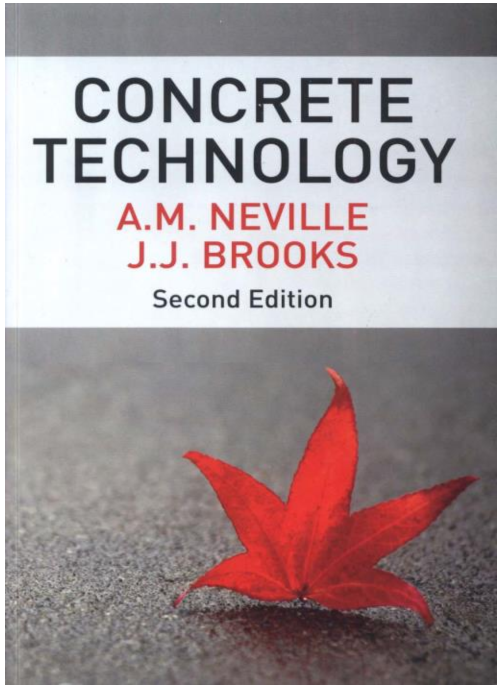
- Advanced concrete technology by Zongjin Li

Other references

- Concrete technology by Dr. Moaid Nory
- Concrete Technology -2dn Ed by A.M. NEVILLE







LECTURE CONTENTS

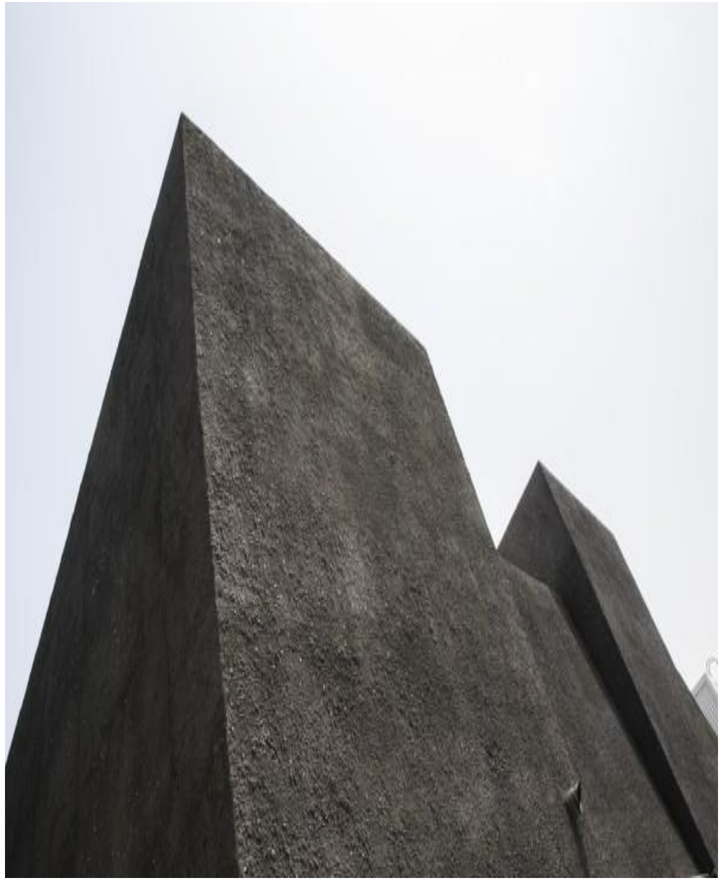
1. Concrete Definition and Historical Development
2. Concrete as a Structural Material
3. Characteristics of Concrete
4. Introduction to Concrete related Tests
5. Types of Concrete
6. Factors Influencing Concrete Properties

1. CONCRETE DEFINITION AND HISTORICAL DEVELOPMENT

Concrete is a manmade building material that looks like stone.

The word "concrete" is derived from the Latin concretus,

meaning "***to grow together.***"



It can be said that the concrete is a composite material that consists essentially of a binding medium in which are embedded particles or fragments of aggregates Limitations.

The simplest definition:

concrete = filler + binder

Depending on what kind of binder is used, concrete can be named in different ways:

- Nonhydraulic cement concrete: Typical examples
- of nonhydraulic cement are: gypsum and lime.

- Hydraulic cement concrete

- Examples of hydraulic cement include:

hydraulic lime, pozzolan cement, and Portland cement

- asphalt concrete

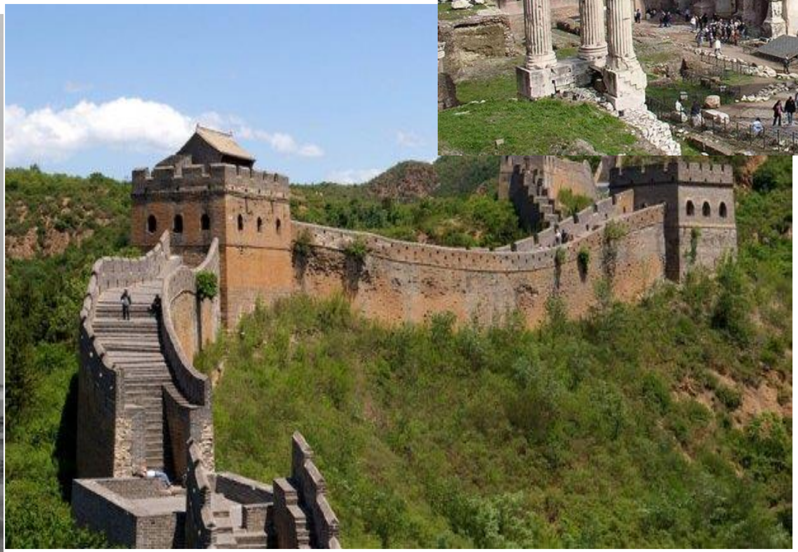
- polymer concrete

Nonhydraulic cement concretes are the oldest used in human history

The nonhydraulic cements used at that time were gypsum and lime

- The Romans made concrete by mixing small pieces of gravel and coarse sand mixed with hot lime and water, and sometimes even animal blood.
- Assyrians and Babylonians used clay as the bonding material.
- The Egyptians used gypsum mortar in construction
- The Chinese also used lime mortar to build the Great Wall in the Qin dynasty






- In 1756, John Smeaton was commissioned to rebuild the Eddystone Light house off the coast of Cornwall, England
- Smeaton used a mortar prepared from a hydraulic lime mixed with pozzolan imported from Italy
- James Parker of England filed a patent in 1796 for a natural hydraulic cement made by calcining nodules of impure limestone containing clay.
- Vicat of France produced artificial hydraulic lime by calcining synthetic mixtures of limestone and clay
- Portland cement was invented by Joseph Aspdin of England in **1824**.
- Portland cement was prepared by calcining finely ground limestone, mixing it with finely divided clay, and calcining the mixture again in a kiln until the CO2 was driven off. This mixture was then finely ground and used as cement.
- Isaac Johnson who first burned the raw materials to the clinkering temperature in 1845 to produce modern Portland cement

Aggregates are another main ingredient of concrete, and which include sand, crushed stone, clay, gravel, slag, and shale.

- First generation of concrete = Plain concrete made of Portland cement and aggregate

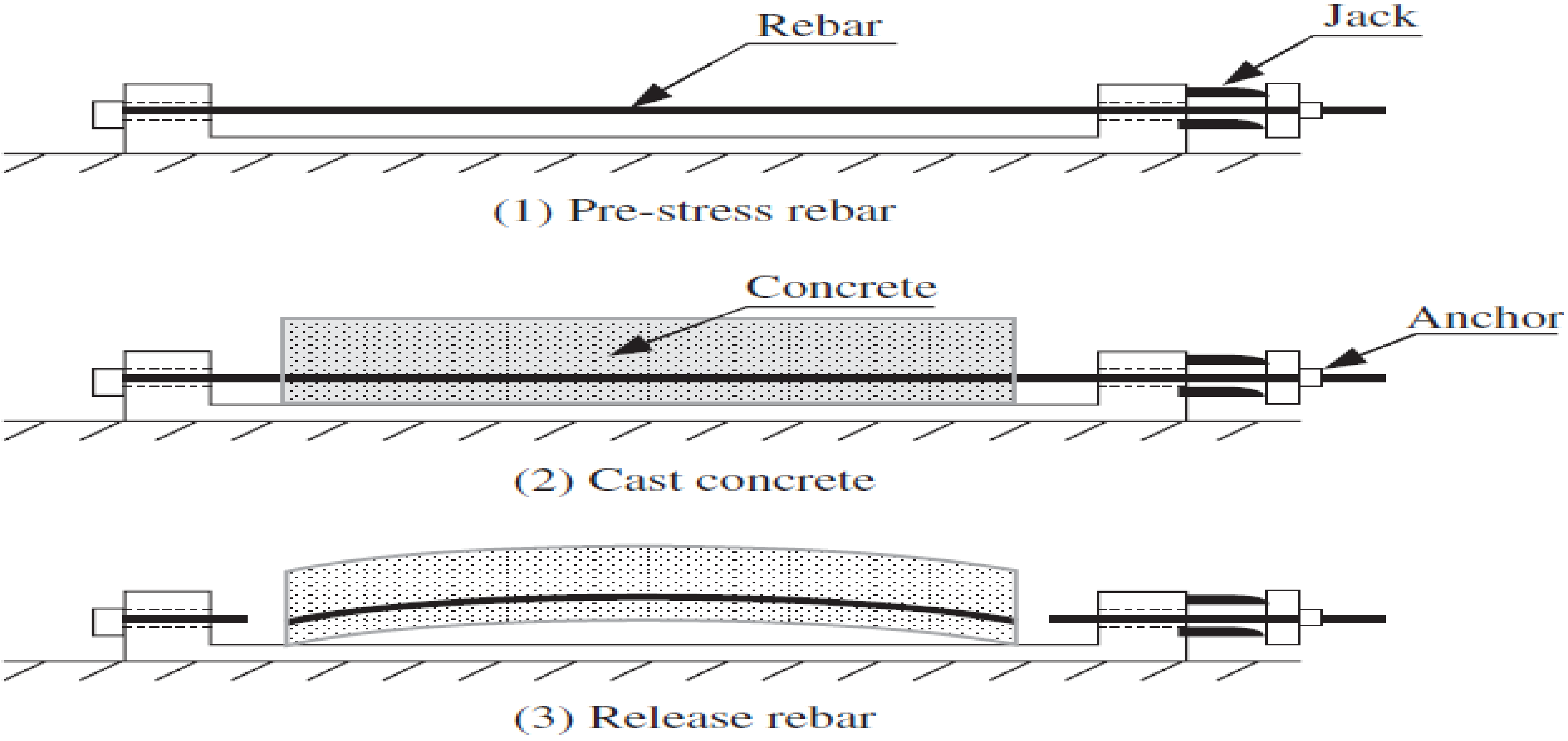
Joseph Aspdin 1824

- Second generation of concrete = steel bar-reinforced concrete

Invented by Joseph Monier on 16 July 1867

- **Third generation of concrete = Prestressed concrete**

first patented by a San Francisco engineer P. H. Jackson in 1886.



- As a structural material, the compressive strength at an age of 28 days is the main design index for concrete.
- There are several reasons for choosing compressive strength as the representative index.
- **First**, concrete is used in a structure mainly to resist the compression force.
- **Second**, the measurement of compressive strength is relatively easier.
- **Finally**, it is thought that other properties of concrete can be related to its compressive strength through the microstructure.
- As early as 1918, it was found that the compressive strength of a concrete was inversely proportional to the water-to-cement ratio.
- Since the 1960s, the development of high-strength concrete has made significant progress due to two main factors: **the invention of water-reducing admixtures** and **the incorporation of mineral admixtures**, such as silica fume, fly ash, and slag.
- Concrete produced after the 1980s usually contains a sufficient amount of fly ash, slag, or silica fume as well as many different chemical admixtures
- such concretes are referred to as **contemporary concretes.**

Contemporary concretes

Ultra-high-performance concrete (UHPC)

It is defined as a concrete that can meet special performance and uniformity requirements, which cannot always be achieved routinely by using only conventional materials and normal mixing, placing or curing practices.

self-compacting concrete (SCC)

Initially developed by Professor Okamura and his students in Japan in the late 1980s

Ultra-high-strength (performance) concrete (UHSC)

200 mpa +

footbridge built in Sherbrooke, Canada

2.CONCRETE AS A STRUCTURAL MATERIAL

At this stage, if not specified, the term concrete usually refers to Portland cement concrete. For this kind of concrete, the compositions can be listed as follows:

Portland cement
+ water (& admixtures) → cement paste
+ fine aggregate → mortar
+ coarse aggregate → concrete

Admixtures are almost always used in modern practice and essential component of contemporary concrete.

Admixtures are defined as materials other than aggregate (fine and coarse), water, and cement that are added into a concrete batch immediately before or during mixing. **Its benefits include:**

For instance, chemical admixtures can modify the setting and hardening characteristics of cement paste by influencing the rate of cement hydration.

Water-reducing admixtures can plasticize fresh concrete mixtures by reducing surface tension of the water.

Air-entraining admixtures can improve the durability of concrete, and

Mineral admixtures such as pozzolans (materials containing reactive silica) can reduce thermal cracking.

Concrete is **the most widely used construction material in the world**, and its popularity can be attributed to two aspects.

First, concrete is used for many different structures, such as dams, pavements, building frames, or bridges, much more than any other construction material.

Second, the amount of concrete used is much more than any other material.

Its worldwide production exceeds that of steel by a factor of 10 in tonnage and by more than a factor of 30 in volume.

As of now, the annual world consumption of concrete has reached a value such that if concrete were edible, every person on earth would have 2000 kg per year to "eat." You may wonder why concrete has become so popular.

- In a **concrete structure**, there are two commonly used structural materials:
  - concrete and steel.
- A structural material is a material that carries not only its self-weight, but also the load passing from other members.

- Steel is manufactured under carefully controlled conditions, always in a highly sophisticated plant; the properties of every type of steel are determined in a laboratory and described in a **manufacturer's certificate.**
- However, the quality of concrete is hardly guaranteed because of many other factors, such as aggregates, mixing procedures, and skills of the operators of concrete production, placement, and consolidation.

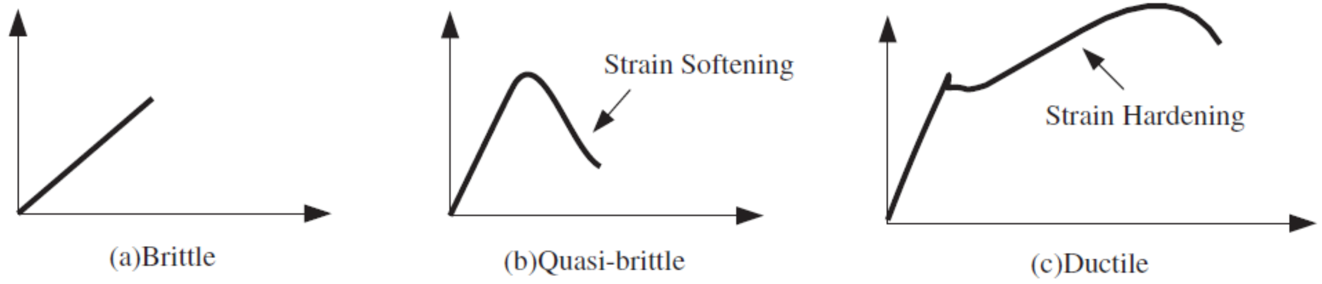
3. CHARACTERISTICS OF CONCRETE

Advantages of concrete

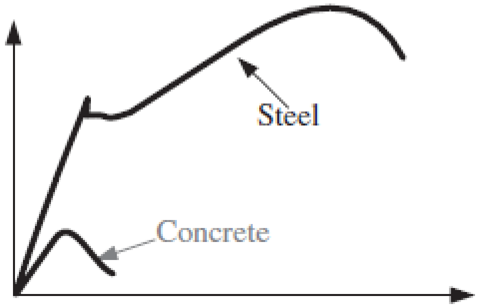
- Economical:
- Ambient temperature-hardened material
- Ability to be cast
- Energy efficient
- Excellent resistance to water
- High-temperature resistance
- Ability to consume waste
- Ability to work with reinforcing steel
- Less maintenance required

Limitations

- *Quasi-brittle failure mode*



- Low tensile strength



- Low toughness (ductility):
- Low specific strength (strength/density ratio):
- Formwork is needed:
- Long curing time
- Working with cracks

TYPES OF CONCRETE

1.Classification in accordance with unit weight

According to the unit weight of concretes, they can be classified into four categories:

Ultra-lightweight concrete: used to build up non-structural members

Lightweight concrete: used to build up both non-structural and structural members

Normal-weight concrete: used to build up most of the structural members

Heavyweight concrete: used to build up special type of members, such as radiation proofing

Classification	Unit Weight (Kg/m^3)
Ultra-lightweight concrete	<1200
Lightweight concrete	$1200 < UW < 1800$
Normal-weight concrete	~ 2400
Heavyweight concrete	>3200

Lightweight concrete:

- Structural lightweight concrete is defined as a concrete having compressive strength in excess 17 MPa up to 60 Mpa with a bulk density less than 1950 kg/m3.
- To make lightweight concrete, light weight aggregate has to be used, such as expanded shale, clay or some kind of slate



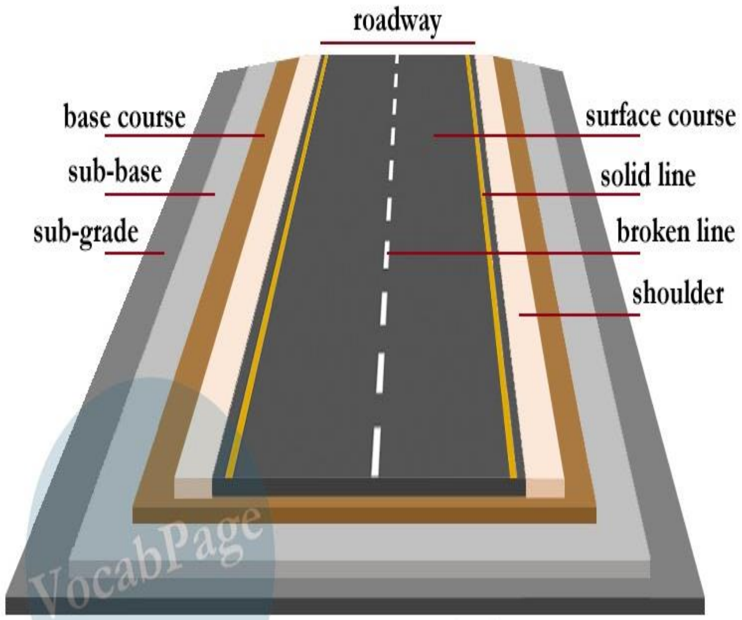
- Structural lightweight concrete has shown enhanced durability in chemical resistance, frost resistance, fire resistance, and permeability reduction.
- The improved fire resistance of structural lightweight concrete can be attributed to a **lower expansion coefficient and a lower reduction of strength at elevated temperatures.**

Heavyweight concrete

- Heavyweight concrete is used to build some special structures, such as laboratories, hospital examination rooms, and nuclear plant, where radioactive protection is needed to minimize its influence on people's health.
- It is made from **MagnaDense** (aggregates)

2. Classification in Accordance with Compressive Strength

Classification	Compressive Strength (MPa)
Low-strength concrete	<20
Moderate-strength concrete	20–50
High-strength concrete	50–150
Ultra-high-strength concrete	>150



3. Classification in accordance with additives

Classification	Additives
MDF	Polymers
Fiber-reinforced concrete	Different fibers
DSP concrete	Large amount silica fume
Polymer concrete	Polymers

- Densified with Small Particles (DSP) has incorporated a large amount of silica fume, a mineral admixture with very small particles. DSP has excellent abrasion resistance and is mainly used to produce machine tools and industrial molds.

- Fiber Reinforced Concrete

(MDF) = Macro Defect free

3. FACTORS INFLUENCING CONCRETE PROPERTIES

1. *w/c* ratio (or *w/b* or *w/p* ratio)

concrete compressive strength has been known since the early 1900s (Abrams, 1927), leading to Abrams's law:

$$f_c = \frac{A}{B^{1.5(w/c)}} \tag{1-7}$$

where f_c is the compressive strength, A is an empirical constant (usually 97 MPa or 14,000 psi), and B is a constant that depends mostly on the cement properties (usually 4). It can be seen from the formula that the higher the w/c ratio, the lower the compressive strength. Another form to show the influence of the w/c ratio to compressive strength of a concrete can be written as

$$f_c = Af_{ce}\left(\frac{c}{w} - B\right) \tag{1-8}$$

where f_c is the compressive strength, A and B are empirical constants that depend on the aggregate, and f_{ce} is the compressive strength of a specified cement at 28 days. c/w is the reverse of w/c.

2 Cement content

- Cement paste has three functions in concrete: **binding, coating, and lubricating.**
- The cement content influences concrete workability in the fresh stage, heat release rate in the fast hydration stage, and volume stabilities in the hardened stage.
- The range of the amount of cement content in mass concrete is 160–200 kg/m3, in normal strength concrete it is less than 400 kg/m3, and in high strength concrete it is 400–600 kg/m3.

3 Aggregate

- **(a)** *Maximum aggregate size*:
- For normal-strength concrete, at the same w/c ratio and with the same cement content**, the larger the maximum sizes, the better the workability**; at the same workability, the larger the maximum sizes, **the higher the strength**.
- However, a larger aggregate size has some **drawbacks**. **First,** a larger aggregate size may make the concrete appear nonhomogeneous. **Second,** a larger aggregate size may lead to a large interface that can influence the concrete transport properties and the mechanical properties.
- Generally, the maximum size of coarse aggregate should be the largest that is economically available and consistent with the dimensions of the structure.
- In choosing the maximum aggregate size, the structural member size and spacing of reinforcing steel in a member have to be taken into consideration.
- In no event should the maximum size exceed **one-fifth of the narrowest dimension in the sizes of the forms, one-third of the depth of slabs**, or **three-quarters of the minimum clear spacing between reinforcing bars.**

- (b) ***Aggregate grading***

  - Aggregate grading refers to the size distribution of the aggregate.
  - The grading mainly influences the space filling or particle packing. The classical idea of particle packing is based on the **Apollonian (order) concept**, in which the smaller particles fit into the interstices left by the large particles.
  - Well-defined grading with an ideal size distribution of aggregate will decrease the **voids** in the concrete and hence the cement content.
  - As the price of the aggregate is usually only one-tenth that of cement, well-defined grading not only will lead to a **better compressive strength and low permeability**, but also is more economical at lower cost.

- **(c) *Aggregate shape and texture***
- *The aggregate shape and texture can influence the workability, bonding, and compressive strength of concrete.*
- *At the same w/c ratio and with the same cement content, aggregates with angular shape and rough surface texture result in lower workability, but lead to a better bond and better mechanical properties.*
- *On the other hand, aggregates with spherical shape and smooth surface texture result in higher workability, but lead to a lower bond and lower mechanical properties.*

- **(d) *Sand/coarse aggregate ratio***

The fine/coarse aggregate ratio will influence the packing of concrete.

It also influences the workability of concrete in the fresh stage.

Increase of the sand to coarse aggregate ratio can lead to an increase of cohesiveness, but reduces the consistency.

Of all the measures for improving the **cohesiveness** of concrete, increasing the sand/coarse aggregate ratio has been proven to be the most effective one.

- (e) ***Aggregate/cement ratio***

- The aggregate/cement ratio has an effect on the concrete cost, workability, mechanical properties, and volume stability.
- Due to the price difference between the aggregate and cement, increasing the aggregate/cement ratio will decrease the **cost of concrete.**
- From a **workability** point of view, an increase of the aggregate to cement ratio results in a lower consistency because of less cement paste for lubrication.
- As for **mechanical properties**, increase of the aggregate/cement ratio can lead to a high stiffness and compressive strength if proper compaction can be guaranteed.
- Increasing the aggregate/cement ratio will definitely improve concrete's dimension stability due to reduction of shrinkage and **creep.**

4 Admixtures

- The concrete properties, both in fresh and hardened states, can be modified or improved by admixtures.
- For instance, concrete **workability** can be affected by **air entraining agents**, water reducers, and fly ash.
- Concrete **strength** can be improved by silica fume.

5 Mixing procedures

Mixing procedures refer to the sequence of putting raw materials into a mixer and the mixing time required for each step.

Mixing procedures directly influence the workability of fresh concrete and indirectly influence some mature properties of concrete.

The following mixing procedure can be used to obtain a very good workability with a good coating on the coarse aggregate to protect alkali aggregate reaction.

Step 1: Coarse aggregate + 50% water + 50% cement: mixing for 30 sec to 1 min.

Step 2: Adding 50% cement + 25% water + superplasticizer + fine aggregate: mixing for 2 min.

Step 3: Adding 25% water: mixing for 3 min.

6 Curing

- Curing is defined as the measures for taking care of fresh concrete right after casting.
- The main principle of curing is to keep favourable moist conditions under a suitable temperature range during the fast hydration process for concrete.
- It is a very important stage for the development of concrete strength and in controlling early volume changes.
- Fresh concrete requires considerable care, just like a baby.
- Careful curing will ensure that the concrete is hydrated properly, with good microstructure, proper strength, and good volume stability.
- On the other hand, careless curing always leads to improper hydration with defects in the microstructure, insufficient strength, and unstable dimensions.
- One of the common phenomena of careless curing is plastic shrinkage, which usually leads to an early age crack that provides a path for harmful ions and agents to get into the concrete body easily and causes durability problems.
- Curing is a simple measure to achieve a good quality of concrete. However, it is often ignored on construction sites.

Some methods could be helpful in curing:

(a) Moisten the subgrade and forms

(b) Moisten the aggregate

(c) Erect windbreaks and sunshades

(d) Cool the aggregate and mixing water

(e) Fog spray

(f) Cover

(g) High temperature (70–80°C) steam curing

(h) Use shrinkage compensating concrete

(i) Curing Compounds

DISCUSSION TOPICS

- Why is concrete so popular?
- What are the weaknesses of concrete?
- What are the factors influencing concrete properties?
- Give some examples for concrete applications.
- When you do a structural design, which failure mode should be applied?
- How would you like to improve concrete workability (fluidity or cohesiveness)?
- How can you enhance concrete compressive strength?


Thank you for your attention!