CONCRETE TECHNOLOGY MODULE
SEMESTER 1 – LECTURE 10

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SEMESTER 1 OUTLINE

Item	Subject	Item	
1	**Introduction: Cement and Aggregate**		
2	**Manufacturing of concrete** - Mixing - Transportation - Placing and compaction - Curing - Finishing	4	**Strength of Concrete** - Compressive strength - Tensile strength - Modulus of rupture - Bond strength with steel reinforcement - Factors affecting concrete strength - Factor affecting concrete test
3	**Properties of Fresh Concrete** - Workability and Consistency - Segregation and Bleeding - Pressure on form work - Stripping of form	5	**Deformation of Concrete** - Creep - Shrinkage - Modulus of elasticity and Poisson's ratio

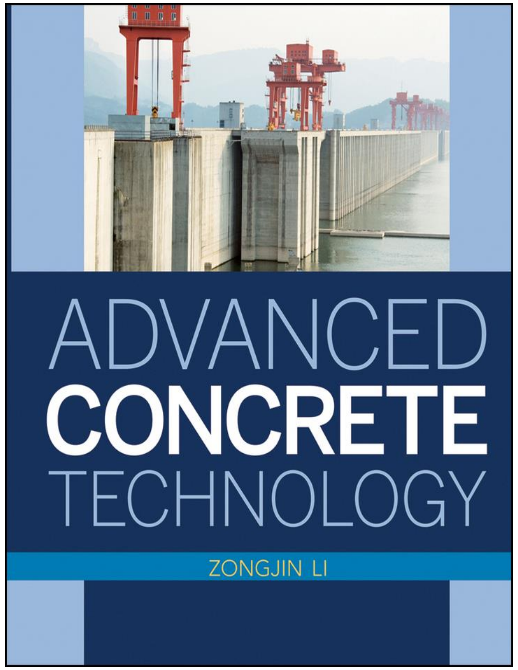
REFERENCES

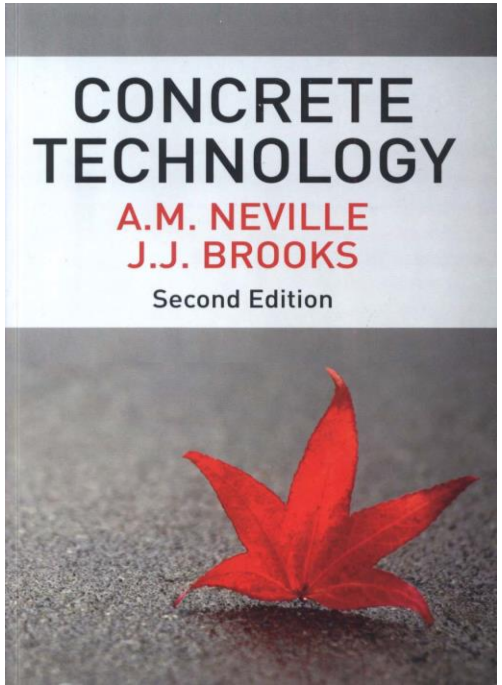
Main Reference

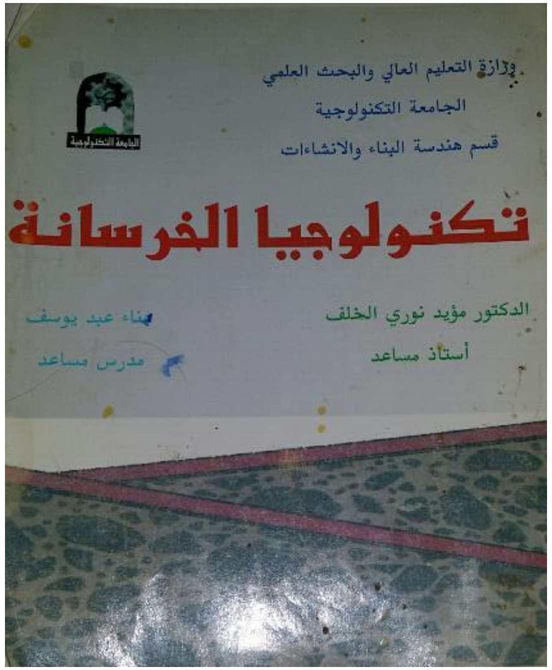
- Advanced concrete technology by Zongjin Li

Other references

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







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3.1.2 Measurement of workability

The most widely used test, which mainly measures the consistency of concrete, is called the **slump test.**

For the same purpose, the second test in order of importance is the ***Vebe test***, which is more meaningful for mixtures with low consistency.

The third test is the **compacting factor test**, which attempts to evaluate the compactability characteristic of a concrete mixture.

The fourth test method is the **ball penetration test** that is somewhat related to the mechanical work.

3.1.2.1 Slump test

- **If slumping occurs evenly all around, it is regarded as a true slump.**
- **If one-half of the cone slides down along an inclined plane, it is regarded as shear slump.**
- **Shear slump is caused by insufficient cohesiveness and the concrete proportions should be adjusted.**
- Mixes of very stiff consistency have zero slump, so that in the rather dry range no slump can be detected between mixes of different workability.
- There is no problem with rich mixes, their slumps are sensitive to variations in workability;
- however, in a lean mix with a tendency to harshness, a true slump can be easily changed to the shear type, or even collapse with a nonuniform distribution of aggregates, especially coarse aggregates, and widely different values of slump can be obtained in different samples from the same mix.
- **Thus, the slump test is unreliable for lean mixes.**



3.1.2.2 Vebe test

The time required for the concrete cone to shorten and change from the conical to a cylindrical shape, until the disk on the top is completely covered with concrete, is the index of workability and is reported as the number of Vebe seconds.

The Vebe test is a good laboratory test, particularly for very dry mixes. This is in contrast to the compacting factor test where error may be introduced by the tendency of some dry mixes to stick in the hoppers.

The Vebe test also has the additional advantage that the treatment of concrete during the test is comparatively closely related to the method of placing in practice.

Moreover, the cohesiveness of concrete can be easily distinguished by Vebe test through the observation of distribution of the coarse aggregate after vibration.

3.1.2.3 Compaction factor

To perform an experiment, the upper hopper is first fully filled with fresh concrete.

Then the hinged door is slid open and hence the concrete will fall into the lower hopper by gravity.

Next, the hinged door of the power hopper is slid open and the concrete free falls into the 150 × 300mm cylindrical mold.

After the excessive concrete is struck off on the top of the mold, the weight of the cylinder is measured and noted as *Mp*, representing a partially compacted cylinder mass.

Another cylinder is made with same concrete by three layers with 25 times rodding on each layer and striking off any excessive concrete.

The weight of the cylinder is measured as *Mf*, representing the fully compacted cylinder mass. The compaction factor is defined as

$$\text{compaction factor} = \frac{M_p}{M_f}$$

Usually, the range of compaction factor is from 0.78 to 0.95 and concrete with high fluidity has a higher compaction factor.

3.1.2.4 Ball penetration test

When taking measurements, the box is placed on the top of the concrete to be tested with the surface of the hammer touching the concrete.

When the pin is removed, the hammer will sink into the fresh concrete by its own weight.

The depth of the hammer penetration can be read from the ruler and is used as an index of workability.

A concrete with higher consistency leads to a deeper ball penetration. Since the measurement is related to the work done by the hammer penetration, ball penetration measurement is close to the definition of workability given by Mindess et al. (2003).

The penetration test is usually very quick and can be done on site, right in the formwork, provided it is wide enough. The ratio of slump value to penetration depth is from 1.3 to 2.0.

3.1.3 Factors affecting workability

3.1.3.1 Water content

- Water content is regarded as the most important factor influencing the workability of concrete.
- After adding water to a concrete mix, the water is absorbed on the surface of the particles of the cement and aggregates.
- Additional water fills the spaces among the particles and “lubricates” the particles by a water film.
- **Decreasing the water content will result in a low fluidity.**
- If the water content is too small, the concrete will become too dry to mix and place.
- Increasing the amount of water will increase the amount of water for lubrication and hence improve the fluidity and make it easy to be compacted.
- **However, too much water will reduce cohesiveness.**
- This not only leads to **segregation and bleeding**, but also **reduces the concrete strength.**
- The water content in a concrete is determined by w/c or w/b and cement or binder content.

3.1.3.2 Cement content

Cement content influences the workability of concrete in two ways:

First, for given *w/c* ratio, the larger the cement content, the higher the total water amount in the concrete; hence, the consistency of concrete will be enhanced.

Second, cement paste itself plays the roles of coating, filling, and lubrication for aggregate particles.

- In normal concrete, a considerably low cement content tends to produce a harsh mixture, with poor consistency and, subsequently, poor finishability.
- High cement content implies that more lubricant is available for consistency improvement.
- **Finally, with an increase of the cement content at a low *w/c* ratio, both consistency and cohesiveness can be improved.**
- **Under the same *w/c* ratio, the higher the cement content, the better the workability.**
- **Increasing the fineness of the cement particles will decrease the fluidity of the concrete at a given *w/c* ratio, but will increase the cohesiveness.**
- **Concretes containing a very high proportion of cement or very fine cement show excellent cohesiveness but tend to be sticky.**

3.1.3.3 Aggregate characteristics

Aggregates can influence the workability of concrete through their need for surface coating and their friction and mobility during mixing, placing, and compaction.

Maximum aggregate size, aggregate/cement ratio, fine aggregate/coarse aggregate ratio, and aggregate shape and texture are four aspects influencing the workability of concrete.

The particle size of coarse aggregates influences the paste requirement for coating through the surface area.

The larger aggregates have smaller surface area than smaller aggregates with the same volume.

Subsequently, the amount of the paste available for lubrication is increased for concrete with large aggregates, and **consistency is improved**.

Hence, for a given *w/c* ratio, as the maximum size of aggregate increases, the fluidity increases.

Moreover, **very fine sands or angular sands** will require more paste for a given consistency; alternatively, **they will produce harsh and unworkable mixtures** at water contents that might have been adequate with coarser or well-rounded particles.

In general, to get a similar consistency of concrete, **more water is needed when crushed sand is used instead of natural sands.**

The aggregate/cement ratio influences the paste requirement.

A higher aggregate/cement ratio implies more aggregates and less cement paste.

Thus, the concrete consistency decreases with aggregate/cement ratio increase due to less cement paste being available for lubrication.

Fine aggregate/coarse aggregate ratio also affects the cement paste requirement.

With an increase of the fine aggregate/coarse aggregate ratio, concrete contains more fine aggregates and less coarse aggregates. Thus, the total surface area of the aggregates increases, which leads to a higher demand on the cement paste for surface coating.

As a result, the consistency of concrete decreases and the cohesiveness improves.

Increasing the fine aggregate/coarse aggregate ratio is the most effective measure to increase the cohesiveness of concrete.

The shape and texture of aggregate particles can affect the workability of concrete through the influence on paste requirement, particle moving friction, and moving ability.

Cubical, irregular, granular, and rough aggregates require more coating cement paste and have higher friction than spherical, glassy, and smooth aggregates.

As a general rule, the more spherical the particles, the more workable is the concrete.

3.1.3.4 Admixtures

Both chemical and mineral admixtures can influence the workability of concrete.

For instance, an air-entraining agent increases the paste volume and improves the consistency of concrete for a given water content through the entrained air.

The entrained air also increases cohesiveness by reducing bleeding and segregation.

Improvement in consistency and cohesiveness by air entrainment is more pronounced in harsh and unworkable mixtures, such as in mass concrete, which has low cement content.

Water-reducing admixtures can improve the fluidity of concrete due to the dispersing effect on cement particles and the releasing of entrapped water by cement clusters.

Similarly, when the water content of concrete mixtures is held constant, **the addition of water-reducing admixtures (pla**sticizer) will increase the consistency.

Different mineral admixtures have different effects on workability, **although they all tend to improve the cohesiveness of concrete.**

Fly ash, when used as a partial replacement for cement, generally increases the consistency at a given water content due to the spherical shape and glassy surface.

When **silica fume** is used to replace part of the cement, it tends to reduce the amount of water used for lubrication, due to its very large surface area and hence the need for a water film coating.

3.1.3.5 Temperature and time

Freshly mixed concrete stiffens with time due to evaporation of the mixing water, particularly when the concrete is directly exposed to sun or wind, absorption by the aggregate, and consumption in the formation of hydration products.

The stiffening of concrete is effectively measured by a loss of workability with time, known as slump loss, which varies with richness of the mix, type of cement, temperature of the concrete, and initial workability.

A high temperature reduces the workability and increases the slump loss because the hydration rate is higher and the loss of water is faster at a higher temperature.

In practice, when the ambient conditions are unusual, it is best to perform actual site tests to determine the workability of the mix.

3.1.4 Segregation and bleeding

3.1.4.1 Segregation

In discussing the workability of concrete, it has been pointed out that **cohesiveness is an important characteristic of the workability.**

A proper cohesiveness can ensure concrete to hold all the ingredients in a homogeneous way without any concentration of a single component, and even after the full compaction is achieved.

An obvious separation of different constituents in concrete is called segregation, as shown in Figure 3-6.

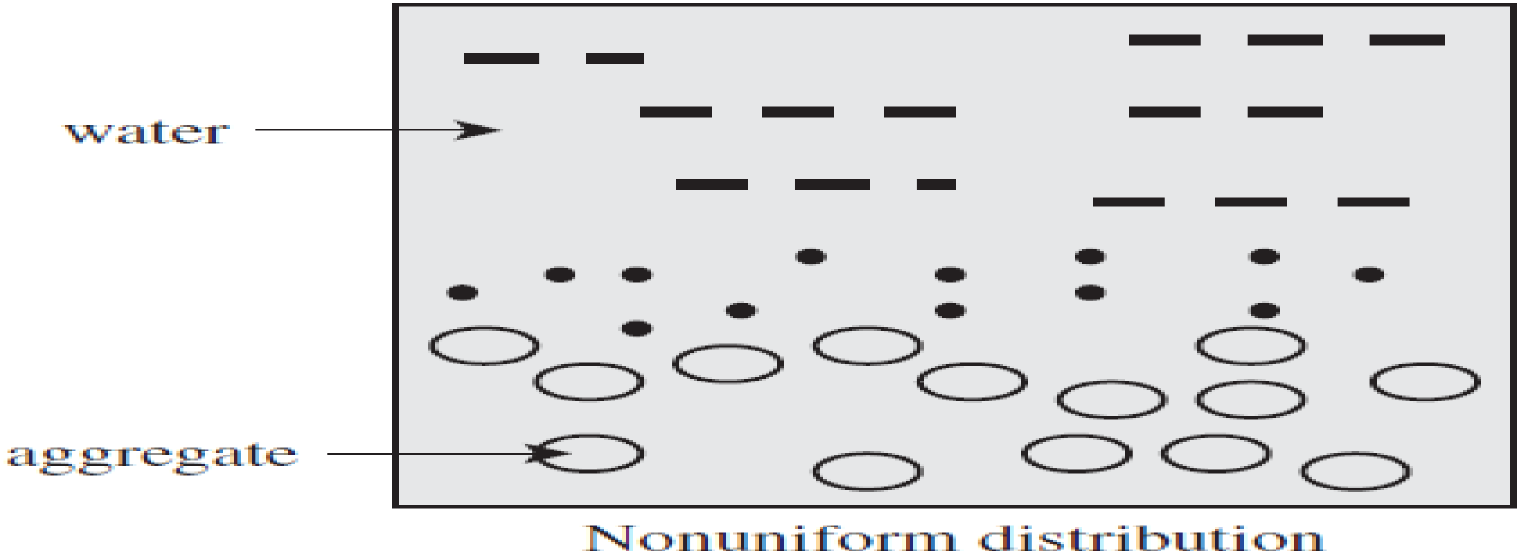
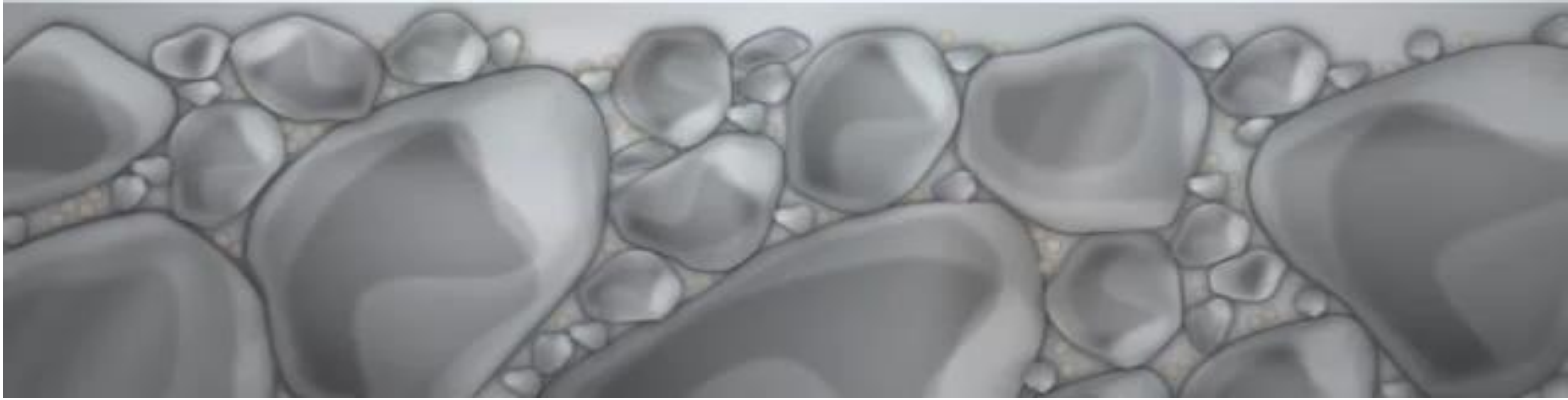


Figure 3-6 Segregation of concrete mixture

Thus, segregation can be defined as concentration of individual constituents of a heterogeneous (nonuniform) mixture so that their distribution is no longer uniform.

In the case of concrete, it is the differences in the size and weight of particles (and sometimes in the specific gravity of the mix constituents) **that are the primary causes of segregation, but the extent can be controlled by the concrete proportion, choice of suitable grading, and care in handling.**



3.1.4.2 Bleeding

Bleeding is a form of local concentration of water in some special positions in concrete, usually the bottom of the coarse aggregates, the bottom of the reinforcement, and the top surface of the concrete member, as shown in Figure 3-7.

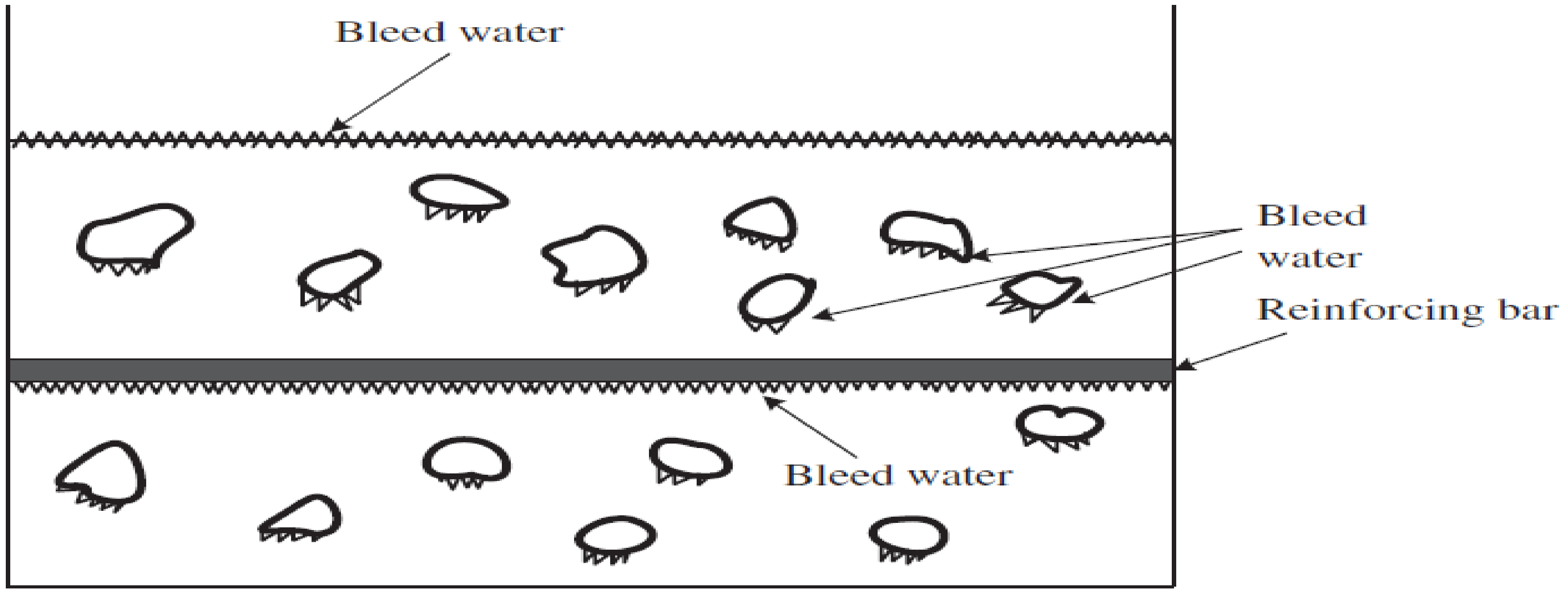


Figure 3-7 Bleeding phenomenon

During placing and compaction, some of water in the mix tends to rise to the surface of freshly placed concrete.

This is caused by the inability of the solid constituents of the mix to hold all the mixing water when they settle downward due to the lighter density of water.

Bleeding can be expressed quantitatively as the total settlement (reduction in height) per unit height of concrete, and bleeding capacity as the amount (in volume or weight) of water that rises to the surface of freshly placed concrete.

As a result of bleeding, an interface between aggregates and bulk cement paste is formed, and the top of every lift (layer of concrete placed) may become too wet.

If the water is trapped by the superimposed concrete, a porous and weak layer of nondurable concrete may result.

If the bleeding water is remixed during the finishing process of the surface, a weak wearing surface can be formed.

This can be avoided by delaying the finishing operations until the bleeding water has evaporated, and also by the use of wood floats and avoidance of overworking the surface.

On the other hand, if evaporation of water from the surface of the concrete is faster than the bleeding rate, plastic shrinkage cracking may be generated.

3.1.5 Slump loss

- Slump loss can be defined as the loss of consistency in fresh concrete with elapsed time.

- Slump loss is a normal phenomenon in all concretes because it results from gradual stiffening and setting of hydrated cement paste, which is associated with the formation of hydration products such as ettringite and calcium silicate hydrate.

- **Slump loss occurs when the free water from a concrete mixture is removed by hydration reactions, by absorption on the surface of hydration products, and by evaporation.**

- Slump loss should be controlled to an acceptable value, especially for concrete transported with a long delivery time, to ensure that it is still placeable and compactable when shipped to the construction site.

- **Slump loss can be minimized by using a setting retarder.**


Thank you for
your
attention!